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The Design and Implementation of Manufacturing Infrastructures

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Abstract

This work addresses the problem of difficulties in the implementation of Computer Aided Production Management systems, and presents a methodology for their implementation which significantly improves on current practice. The methodology provides a structured approach which leads the company through a series of strategic business decisions which establish the context within which the solution must operate. The work focusses attention upon the design of the whole system with respect to the relationship between computerised functions and the infrastructure of human elements which facilitate and govern the system's operation. A model of the tasks involved in production management is presented. The model is used to structure decisions relating to the design of the infrastructure.

The research work described proceeded in two distinct stages. In the first stage the author participated with other researchers who jointly developed the framework of the process methodology for CAPM implementation. This stage provides the context for the development of the task model approach to the design of the system, which represents the author's individual contribution (see section 1.8).

The task model can be used as a tool to identify the options available for the way each task within production management may be executed, giving the user a basis for the design of a particular system while not advocating any particular solution. By the use of this approach the user is encouraged to consider the options available, and to adopt an integrated approach which looks at all areas of production management, not only those for which there is a pressing problem or a tempting solution.

This work results in a contribution to the development of the process methodology, the development of a tool in the CAPM task model and a review of the factors involved in the design of a system including both human and computerised elements.

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Contents

Chapter 1. Introduction

The work reported in this document was carried out as part of a government sponsored initiative to improve the success of UK industry with Computer Aided Production Management (CAPM).

1.1. Background - CAPM Initiative

The CAPM research initiative from which this work stems originated from the study by Waterlow and Monniot[1]. Their work was initiated by the joint SERC/DTI Advanced Manufacturing Technology Committee which required a basis for research, education and awareness training to improve the use and development of CAPM in UK industry. The report led to the ACME CAPM Initiative.

> "It [the Initiative] was established in 1986 because of widespread concern that UK industries, particularly smaller companies, were not making the most efficient use of CAPM. Significant gains in industrial manufacturing performance could be made with low capital investment, if this problem was addressed and the results efficiently transferred to the users." [2]

A series of awards totalling £3m were granted to universities and polytechnics to support research to produce

> "user-led implementation methodologies for the audit, selection, design, implementation and operation of manufacturing systems in order to provide better manufacturing control".

Information and control are of crucial importance to manufacturing. Whilst CAPM has some of the features of other computer applications in the provision of records and reports etc, its scheduling and controlling functions extend its influence beyond the reach of many other applications into the control of day to day operations. By controlling the flow of work in a factory, regulating stock and inventory levels and assuring on-time delivery performance CAPM plays a vital role in the success of a manufacturing business. CAPM improvements directly affect the performance of the manufacturing company, and are therefore of significant importance to the manufacturing base of the UK economy.

The CAPM Initiative was set up to instigate, coordinate and focus academic research in the field in a directed effort to make an impact on the problem. The initiative was divided into sectors covering large companies, small companies, "make to order" companies and the electronics industry. The sectors consisted of several projects each looking at particular aspects such as the design, selection, organisation, implementation, control (etc.) of CAPM systems.

The close monitoring and supervision of the ACME CAPM initiative provides a structure which facilitates the cross-fertilisation and coordination of the research and ensures its relevance to the needs of UK industry.

The electronics sector was assigned the largest single project with broad terms of reference and a large research team with a wide range of skills. The aim of this project was to produce a methodology which would embrace all aspects of CAPM system implementation with respect to the particular characteristics of the electronics industry. This thesis relates to work done as part of this project.

1.2. CAPM Project

The research work which forms the basis of this document was carried out as part of a research project established under the CAPM Initiative and jointly led by Professor D R Hughes of the Department of Computing, Polytechnic South West* and Professor J S Smith and Professor D R Tranfield, Directors of the Change Management Research Unit, Sheffield Business School, entitled "The development of a user-led methodology for the implementation of integrated manufacturing systems within the electronics sector".

The project's aim was to develop a methodology for the implementation of CAPM systems which would avoid many of the pitfalls experienced by previous implementors. These pitfalls could largely be seen to represent a lack of fit of the system to the situation, manifested in poor definition of requirements, inadequate flexibility and adaptability, integration difficulties and project management problems.

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* Polytechnic South West was established on April 1st 1989 by the amalgamation of Plymouth Polytechnic, Rolle College of Education, Exeter College of Art and Design and Seale-Hayne College.

1.3. What is CAPM?

For the purpose of the Initiative, CAPM was regarded as

> "the use of computer based information to support production management functions and to coordinate flows of orders, materials and finished goods" [3].

The earlier report by Waterlow and Monniot (ibid) suggested that CAPM encompassed all computer aids supplied to the production manager.

For the purposes of this research, the two descriptions above are accepted. However they do not describe the constituent elements of CAPM. In a business where the production manager is supplied with computer aids, production management is achieved by the performance of certain functions by the computer and certain functions by people. These activities are all controlled by the policies, procedures and practices of the company, which cause or permit activities to be performed in certain ways. In order to look at the whole problem of production management, including Computer Aided Production Management, all these elements must be considered. The term "CAPM" is used here to describe the system which manages and controls the production function in the achievement of its targets, which consists of computer systems and manual tasks operating in accordance with certain policies, procedures and practices.

Many manufacturing companies have difficulties in managing production when growth or diversification increases the complexity of their activities. As the number of customers and the volume of production increase, the number of different jobs in progress on the shop floor at any time can multiply to a stage at which it becomes impractical to keep control of all the items using manual methods such as progress charts, and beyond the capabilities of shop floor controllers, expeditors, and chasers. As production becomes more out-of-control, CAPM solutions begin to appear more attractive. Thus CAPM implementation is often concomitant to business growth.

Waterlow and Monniot (ibid) observed from their study that

> "the trigger which prompted most first time users to examine the use of CAPM was shortage of administrative resources - rarely strategic issues."

CAPM is therefore seen as a solution to the problem of increasingly complex operating requirements which cannot be satisfied by manual systems. However, the outcome is not always as intended. Stock-outs, excess stock levels, late orders and customer dissatisfaction have been cited both as reasons for implementing CAPM and, unfortunately, as reasons for implementing new CAPM systems where existing ones had failed.

For a variety of reasons, failure rather than success is the outcome of many CAPM projects[4], and many companies continue to resist the temptation to computerise production management because of their fears of the possible outcome. Many companies also feel that CAPM is not suitable for their company because of the widely held belief that their business and all their problems are unique.

1.3.1. Infrastructure

CAPM systems are seen as one element of the "infrastructure" of systems which support and control manufacturing activities. The context within which CAPM systems operate is seen as vital to their successful exploitation. The term "infrastructure" will be defined further in Chapter 4.

1.4. CAPM Failures

The most obvious way to improve the success rate of CAPM implementation was to understand the reasons for failure and to develop ways of avoiding such failures in future implementations.

As the work focussed upon the implementation process, especially the organisational aspects of fitting the system to the company's strategy, failure would be regarded as any circumstance in which an element of the CAPM system had to be significantly altered or abandoned after implementation, or where the implementation did not go ahead as planned. This would include the failure of the software involved in the system, although no such failures came to light.

It should be noted that this view of failure condemns the CAPM system which fails as a result of changed demands being made of it. This is felt to be justified since it indicates the failure of one of a company's main functional areas to respond to the nature of the changing business, and the assumption is made that CAPM systems should be able to cope with the level of change in the business. Such failure would only be acceptable if the company's express strategy was to implement disposable, cheap system elements which could be removed and replaced when necessary. No such strategy has been encountered.

The CAPM implementation failures which were observed fell into four categories:

- the CAPM requirements were not defined correctly;

- the CAPM requirements were defined correctly but the wrong system was implemented;

- the CAPM requirements were initially defined correctly, but these subsequently changed;

- The implementation was badly managed.[5]

Of these causes of failure, the first and second could be dealt with by an approach which ensured a more rigorous procedure for the analysis of requirements and the assessment of candidate systems in the light of the requirements. Similarly, the poor management of the implementation process could presumably be tackled by ensuring that elements such as timetabling, consultation, training, etc, were dealt with in a more structured, professional manner. There is therefore a need for guidance in the analysis of requirements and in the management of the project.

However, it was difficult to see how any amount of care and professionalism would answer the problem of changing requirements. It was felt that this could only be addressed by equipping the CAPM system to deal with the range of possibilities which may ensue over the lifetime of the system. This required both a resilience in the system to deal with change, and an understanding of the changes likely in the business. This in turn meant that understanding the business context in which the system would operate would be a key to the success of the system.

It was also noted that changes to the operation of a CAPM system are felt by the people closely connected with the system through changes in their work, and that the response of the operators of the system is an important criterion of success, since they inevitably control the way the system will function. It is therefore convenient to regard the people closely involved with the system as being elements of a socio-technical system, which should be designed not only from a technical viewpoint. This concept will be elaborated in Chapter 8.

The research aim of improving the implementation of whole systems, giving attention to a broad set of contextual elements, should lead to the development of resilient solutions which are not prone to failure when circumstances change.

The development of computer systems which are in themselves more resilient and adaptable to change, such as fourth generation languages (4GLs) and artificial intelligence (AI) applications, is a valid and important area for study, but one which is beyond the scope of this research. The view has been taken in this work that the development of the mixed human/computer system in its context will remain relevant even to applications of the most flexible computer systems.

1.5. Implementation.

CAPM systems are complex systems consisting of both computerised and non-computerised elements. Their operation is very closely linked to the company's performance. Because of the significance and complexity of CAPM systems, their introduction is much more significant than the "installation" of a new piece of equipment. Rather, it should be seen as the "implementation" of a strategy for the control of manufacturing within the company.

This perspective has important implications. The implementation of a control strategy necessitates the examination of strategic issues within the business, not just the selection of a tool to fit a simple short-term requirement. Particularly important is the integration of the CAPM strategy with the company's plans relating to product types, rate of change of products, mix and volume, and nature of manufacturing processes. Simplification on the shop floor related to quality improvements or a Just-In-Time philosophy has important effects on the ability of the CAPM system to continue to perform. Certain computer packages only provide limited facilities for adaptation, and changes may be beyond the scope of the package, leading to manual "workaround" arrangements.

An implementation project must therefore deal with:

- the design, specification and selection of the elements of a suitable system in the light of the company's business strategies,

- the way in which the system's users are (or are not) involved,

- the way the system operates and

- the way the system interfaces with other systems and working procedures within the company.

This strategic approach leads to the possibility of re-evaluating manufacturing control systems, which at present are often computerised "as is" without any review of the way the company needs to work in order to achieve its strategic aims. Thus the tendency to computerise chaos is avoided - the solution may not involve computers at all. Researchers involved in the implementation of FMS have noted that

> "in many instances a major element of the increases in productive efficiency derives not merely from the new technology but also from changes in working practices and attitudes" [6].

1.6. The user-led approach

A theme of the CAPM initiative which was echoed in the project was the need for the development of "user-led" methodologies. The term "user-led" was used to denote an approach in which the user, either the company or individual users within the company, would set the agenda for the CAPM implementation, would specify the goals for CAPM in their organisation and would ensure that the solution would fit into the strategies of the business. This would ensure their full participation in the project, which had already been identified as an ingredient vital to success[7].

The user-led approach has been put forward as one solution to the problem of vendor-defined solutions which are seen as one cause of the high failure rate in CAPM[8]. The user-led approach was also believed to be the only one which could cater for an industry sector which is fast changing, since it forces the user to articulate a business strategy with which the company can move forward and explicitly ties the CAPM solution to the forward strategy rather than to the current exigencies. The methodology must therefore address the problem of change in manufacturing, which is a characteristic of the electronics industry already beginning to be felt in other industry sectors.

This approach ensured from the outset that the project would produce a methodology geared to the needs of users and avoiding some of the pitfalls of those used by vendor-based implementors. Vendors tend to specify their own systems, and consultancy companies often have arrangements with particular vendors. These arrangements can lead to the company trying to fit itself to the way of operating which is engendered by a particular software product. This may or may not be beneficial to the company, and in either case it may generate friction.

In contrast, a user-led methodology would require the user to determine which were the important issues in the business and, beginning from these issues, to determine the solutions in a structured manner.
A proprietary CAPM package would not necessarily form part of the solution; the approach recognises that the solution to production management problems may well lie outside the sphere of the CAPM systems themselves.

The extreme user-led approach may be seen in the companies who have been led to develop their own systems software. This arises from the view within certain companies that the CAPM problem is so central to the operation of the business that it must not be entrusted to outsiders such as software vendors, who have neither the specific experience and understanding of the business nor the personal commitment to ensure success. However, with a few notable exceptions, the development of robust and practical software is beyond the expertise of most manufacturing companies, and this approach almost inevitably leads to significant problems of growth and integration.

The home-grown solution is also prone to the problem that the staff involved in development may move on, making further development in the face of changing circumstances more difficult.

The methodology must therefore provide the user with enough knowledge and a rigorous approach to ensure that decisions about CAPM are not made naively, removing the need to trust the key decisions to software vendors.

Er points out that with participative approaches

> "there is a danger that the user will exercise his/her control to influence the information system under development. .... Users may play politics so as to achieve personal political gains, which may not serve the best interests of the corporation" [9].

A solution is to make use of the "sponsor" and "facilitator" roles as described by Hirschheim[10]. The sponsor would be a senior member of the company who would advocate and encourage the process, while the facilitator role would be suited to an outside agent with a detailed understanding of the use of the methodology.

The facilitator role, unlike that of a consultant, is to support the activities of the users whilst not advocating any particular solution. The facilitator is a guide, not a leader or a "doer". The facilitator may require considerable interpersonal skills to avoid conflicts.

1.7. Process methodology

Implementation must involve a wide range of skills. Different kinds of expertise are called for to design computer systems, to select systems, to establish strategy for manufacturing and to achieve user commitment to the solution, etc. Many elements must be coordinated to achieve successful implementation.

The present work is primarily concerned with ways of making CAPM systems operate better by developing a closer degree of fit with the company's strategy, methods and organisation, in order to achieve successful implementation. This work is not concerned with the details of particular configurations of software or the advantages of various products, although these often form the basis of production management strategy.

The methodology-based approach provides a way of dealing with the large number of issues that arise. It avoids the traps which have caught previous implementors and makes available techniques which have been found to be successful. The methodology is in itself a device for encapsulating the experience of each implementation.

The greatest problem of an approach which comes into a company from outside is the extent to which it can deal with the specific problems of the particular company. CAPM systems must be matched to a wide variety of different situations, and while the differences are often much smaller than individual companies will accept, a good degree of tailoring may be required to increase the fit of any software package into a typical company[11]. The only common element between all companies implementing CAPM is that they all wish to improve their CAPM systems and are considering a change in the systems they use.

CAPM implementation success must therefore come from developing not the solutions - panaceas are unlikely to be effective - but the process by which the company itself develops the solution to its problems. The approach which forms the basis of this work is one which concentrates on the development of a structured, methodical approach to the CAPM question during which various activities are specified in order to build up the information required for decision making. The process therefore ensures that the right questions are asked and provides tools and techniques to help at various stages of the analysis. The process ensures that important issues are dealt with and that the required information relating to the business context of CAPM is articulated.

1.8. Relationship of this thesis to the CAPM Project

The contribution of this thesis to the project is in the area of the management and infrastructural issues relating to CAPM. It aims to provide new ways of increasing the fit and effectiveness of CAPM systems by providing a basis for tailoring the policies, procedures and practices which constitute the structural and cultural context within which CAPM systems are operated.

Other issues were concentrated upon by other members of the research team. Technical aspects of the specification and design of the CAPM systems themselves were the subject of the work of Weston[12].

Since the CAPM project was focussed upon the electronics industry, the research began by concentrating upon electronics companies. Other manufacturing companies were included later in the work.

1.9. Aims of the Research

Production managers tend to be largely unaware of the complexities of CAPM implementation until they gain first-hand experience. CAPM implementations are not usually frequent within a particular company. Thus CAPM implementation is for many companies an immensely educative process, and an expensive one. It can prove expensive in wasted time, scarce skills and money, which can far outweigh the cost of the system itself. The aim of the implementor should be to implement successfully a CAPM solution which will meet the changing demands of the business over a period of time, that is, an effective, resilient solution. The aim of this research was to support this activity by providing guidance on the way a resilient CAPM system should best be implemented. This involves both structuring the activities of the implementors to ensure that the implementation process is executed efficiently and successfully, and guiding the implementor's decisions within the process by making available lessons learned from previous implementations.

The particular focus of this work is the integration of the human and computerised elements within the system, to take full advantage of the benefits of flexibility and adaptability which lead to successful CAPM systems.

1.10. Structure of this thesis

Chapter 1 has established the orientation of the research to develop an alternative to vendor-based methods for the implementation of CAPM systems. The concepts underlying the work include the user-led approach and the incorporation of CAPM into business strategy through the process methodology, with an emphasis upon simplification and resilience. CAPM is seen as being related to the manufacturing context as part of the company's "infrastructure".

Chapter 2 describes the methodology used for the research.

Chapter 3 addresses the question of flexibility in manufacturing, which was found to constitute a major problem for CAPM implementations.

In Chapter 4 the flexibility problem is explained with respect to the infrastructure of the manufacturing company. The concept of "infrastructure" is explored and the relationship of CAPM to the infrastructure is described.

Chapter 5 looks at the need for the early stages of the CAPM methodology to help the company to establish the infrastructural context for CAPM.

Chapter 6 describes the experimental trial of the first stages of the methodology in a manufacturing company. The experience gained confirmed the importance of establishing the strategic context before proceeding with CAPM implementation.

Chapter 7 returns to the detail of the CAPM solution, examining the flexibility of various types of CAPM system available and concluding that the performance of the infrastructure as a whole is largely dependent upon the way people work within the system.

Chapter 8 examines the contributions of earlier researchers on the types of CAPM systems appropriate for various circumstances and on the role of humans in the system.

Chapter 9 looks at the development of a tool for designing the infrastructure based upon the various tasks which constitute the management of a manufacturing company. The task model can be used to structure decisions on the role of computers and humans in the system, ensuring that the human and computerised tasks can be fully integrated to meet the requirements established in the earlier stages of the methodology.

Chapter 10 concludes the work by evaluating the progress made and suggesting some ways in which the work may be developed in the future.

Summary

The implementation of CAPM is a complex process which has often been reported to end in failure.

This work provides an original approach to the problem by

- forming part of a means for matching the CAPM system to the strategies and characteristics of the business to increase its likelihood of meeting changes in the business;

- providing the users themselves with the means of developing the appropriate CAPM solution, via a methodical user-led process;

- providing detailed guidance on the tasks involved in CAPM and the way these should be carried out;

- providing guidance on the roles of humans and computers in the system, considering where appropriate the need for flexibility of operation.

The next chapter describes the methodology used to examine the CAPM problem.

Chapter 2. Research Methodology

In any research, the answers obtained depend upon the questions that are asked. If the answers are to be useful it is important to ask the right questions. In other words, the choice of research methodology constrains the information obtained and the outcome of the research.

The view underlying this work is a practical or engineering orientation which attempts to address, understand and solve a problem which is seen to exist. The emphasis is on "making things work better", rather than developing the understanding of phenomena. It aims to develop techniques of analysis and intervention which can be used in an immediately practical way to produce the required outcomes. The research takes a "systems view" of the manufacturing business[13]. The emphasis is placed less on "Have we learnt anything?" than on "Does it work?" [14].

It was important to structure the research around the experiences of the CAPM implementors who "own" the problem in question. The research must therefore be grounded in experience rather than conjecture, and the approach must allow the work to develop as indicated by the findings. No attempt was made to explain CAPM implementation experiences through existing theories of management or behaviour; rather, the work is an attempt to deal with the situations which arise.

The task model, which will be described in Chapter 9, arose from observation of actual companies. This may be regarded as a "Grounded Theory" approach[15].

The CAPM implementation problem is complex and does not lend itself to being understood on the basis of a few key facts, so the approach of determining answers to key questions, such as by using questionnaires, was not considered appropriate. Instead, an "Action Research" approach was used which allowed the methodology to be continuously developed as experience and opinions were gained.

2.1. What to study

To improve the process of implementing CAPM systems, the work would require a basis in an understanding of the operation of CAPM and the experiences of implementors themselves. From the implementors, it would be hoped to elicit information on the methods used to specify their CAPM requirements, the approach taken to manage the project, and their experience of the outcome of the process with emphasis on the problems which may have been encountered. The views of users would also be important, since user-acceptance is seen as important to the success of an implementation. In this sense the company as a whole (besides the individuals in the company) could be seen as a user whose needs must be met by the system. Since the research would be based upon the understanding of a CAPM system as including both human and computer elements, the decision to automate certain tasks for whatever reasons would be of interest.

The view of CAPM as a system comprising human and computer elements, with the purpose of supporting and enabling manufacturing functions gives a perspective which allows the consideration of the system as a whole, whose performance characteristics can be altered by changing the characteristics of the system. Thus certain tasks may be computerised or not according to reasoning based upon the performance of the system as a whole. The optimisation of the performance of an element within the system is of importance only when it can be seen to improve the system as a whole.

2.2. Data collection method

Clearly, in the development of an element of a user-led methodology, the major source of information would be the implementors and users themselves. From these, the details of their experiences of CAPM implementation, especially their difficulties and failures, would be elicited. Other sources would be used including the literature and the views of academics and CAPM system consultants and vendors.

The main tools for data collection were literature surveys and interviews. The solutions which were developed to deal with the problems found were tested as prototypes, and then further refined.

2.2.1. Literature survey

Before consulting the professionals in the field, the literature would be examined to provide an introduction to recent developments.

Literature searches were used both to provide a theoretical background to the work and to provide more cases to add to the material from the companies visited. Extensive use was made of the on-line databases of abstracts made available through the Polytechnic's library service, especially the ABI-Inform and Compendex databases. Initial broad searches were conducted in the areas of:

Advanced Manufacturing Technology	Methodologies
Computer Integrated Manufacturing	MRP
Computerisation	Participation
Decision making	Production Control
Electronics	Production Management
Flexibility	Production Management Activities
Implementation	Responsibilities
Integration	Roles
Just In Time	Systems Design
Kanban	Tasks
Manufacturing	User-led
Manufacturing Systems	

It became clear that the literature in the area of production management and management in general was split into two broad areas between which the CAPM problem falls. Production literature tends to look at the relative advantages of the prevailing styles of production management, such as Just-In-Time, Total Quality Management, MRP etc. and focusses on the experiences of various companies with different control policies. Whilst literature of this type gives a useful background, it often falls short of providing experience which can be applied elsewhere. Management literature in general tends to focus upon the effects of different styles of management on the management theory concerns such as centralisation/decentralisation, leadership and motivation, conflict etc. The problem of designing a system made up of computer and human elements designed to perform the various functions of production management has received little attention in recent years, although the problem has been addressed at a more general level, for example [16]. Even in the area of (computer) systems analysis the integration of human elements tends to be neglected, for example [17]. Those writers who concentrate on these issues will be referred to later in this thesis.

2.2.2. Information from CAPM users

Information was collected from a range of companies of different types within the electronics sector, including companies at all stages of the CAPM implementation process from those beginning to consider CAPM to those with experience of several implementations and failures.

Case study information was also made available to the author by other members of the project team.

2.2.2.1. Depth versus coverage

Two main alternative approaches to data collection were possible. Either a small number of implementations could be studied in depth, or a larger number could be considered in less detail. It was felt that a study looking at implementation of such complex systems would require considerable detail to allow a useful understanding of the factors involved. However the methodology to be developed would need to be applicable in a general sense, so it was important to look at a range of instances in order to be able to draw out common themes. There was felt to be a danger in looking at too few cases in that the methodology arising from these experiences could only address the comparatively small range of problems encountered, whilst the complexity of CAPM suggests that a wide range of different experiences would be likely.

A certain breadth was felt to be necessary in order to come to some general understanding of implementation experiences.

A balance between depth and range of coverage was attempted by obtaining as much information as possible from implementors within the case companies. This was regarded as being second-best to being present during the implementations, since it would make available the implementor's experience to the extent that it could be drawn out by interview and discussion. Whilst some information would no doubt be lost, this approach permitted the number of cases under study to be increased while reducing the time required. Thus an interview-based approach was developed.

2.2.2.2. Interviews

The interviews were conducted at the factories concerned and ranged in length from half a day to several days. In several cases it was necessary to re-visit companies in order to discuss their experiences further or to interview different individuals. It was found to be particularly important to interview the person who had the day to day responsibility for the CAPM implementation, not necessarily the project leader or manager. By meeting the right individuals, a rich picture of the company's experience could be formed.

Interviews were structured to ensure coverage of all the relevant areas. The structure identified the areas of interest but served more as an agenda for discussion than as a questionnaire. By following a structure the interview could be conducted by two researchers with the advantage that one could pick up the thread of the interview to allow the other to reflect or to take notes. The structure was continually revised as the data collection exercise proceeded and further areas of interest were identified.

The important areas of the interview structure were:

- Company history and situation - products, markets, technology, structure, previous CAPM experience;

- Company approach to implementation - the story of what happened including the justification and objectives for the project;

- Success or failure of the implementation as perceived by the interviewee;

- Lessons learned about implementation.

2.2.2.3. Confidentiality

Most of the companies who took part in this research did so only on the strict understanding that their commercial confidentiality would be honoured. Companies will therefore be referred to only as "Company A" etc.

2.3. What would be developed from the findings?

The aim of the research stage was to determine what the CAPM problem is, or why systems fail, and how implementors can be helped to do better in the future. It was felt that failures of implementations (rather than failures of the CAPM products themselves) would provide useful guidance for future implementations.

Failure resulting from neglecting to find certain information, such as in the specification of CAPM requirements, could be addressed by a methodology including activities aimed at securing that information. Failure resulting from not managing the project well could be addressed by providing a structure to guide the implementors' activities.

The result which would be developed from the findings would be the outline of a structured approach to CAPM, a methodology. The methodology would provide a framework or programme for activities supported by the tools and techniques found by users to be useful, together with those drawn from the literature or created by the researcher which would help deal with implementation problems.

As the project continued, findings from the preceding work began to suggest ways of developing a methodology. As these ideas developed they were continually presented to implementors, consultants, users and other academics who could add their experience to test validity and to stimulate further contributions to help the project forward. Thus the methodology was developed on the basis of the research findings with a high degree of involvement of professionals in the area. This ensured that the findings were grounded in practical experience and would be valid to the people who would be expected to make use of them.

2.4. Testing the results

Whilst the methodology being developed was based upon findings from research and the contribution from experienced practitioners in the area, which would certainly appear at face value to work, it must be tested by users in the field before it could be claimed to have empirical validity, or true usefulness.

The ultimate demonstration of the success of the work would be the proof that the work had led to the implementation of successful systems which had had the required flexibility and responsiveness to withstand the test of time in real companies. However such a longitudinal test was beyond the scope of the project because of the time which would be required (and the difficulty of determining a suitable target lifetime) and because of the lack of a control experiment for comparison.

A more practical test, considering the engineering approach of the work, was to ensure that the methodology could be applied.
A prerequisite for the success of the systems developed by the methodology was the applicability of the methodology itself. If it was not found to be workable in practice, the elegance and sophistication of the solutions which may hypothetically have been generated would be without value. Thus despite the need for better CAPM solutions to be implemented, the focus was placed on improving the implementation process. This would be expected to lead to better solutions and would also have the advantage of making the process available to the company as a tool for repeated analysis and adjustment, in addition to an implemented solution. Elements of the process could be used as necessary to deal with changes and developments in the business. Thus the methodology would transfer additional benefits to the company in the form of knowledge and experience of applying various tools and techniques.

It was therefore hoped that the methodology could be tested by real life use during the latter stages of the research if a suitable company could be found. The experience from the "road test" would be expected to add to the detail of the methodology (as "action research") and to validate the principles developed. This test would assess the suitability of the process of the methodology.

The main means of evaluating the work would be the views of users and others in the field. Since no methodology had previously been developed to guide the activities of CAPM implementors the usefulness of a well-structured approach was guaranteed. The correctness of the methodology, in terms of the appropriateness and completeness of its content could only be assessed by independent comment.

A suitable company was found for the road test. The results of this exercise are described in Chapter 6.

A further validation exercise was carried out to have the research findings examined by a group of practitioners and academics who could reasonably be expected to be independent of the taken for granted assumptions of the research team and those connected with the work. This test would evaluate the content of the methodology.

Summary

The research methodology took an engineering approach in the focus upon the development of a practical tool based on a sound theoretical perspective. The work would be based upon user experience in order to be useful to users in real-life situations.

Emphasis would be placed upon the development of the implementation process rather than upon the solutions implemented, so that the process would be independent of the needs of any particular company at any particular time. This approach allows the process to be widely used and for the companies concerned elements of the process can be used to continually re-assess requirements as they develop over time.

The research orientation thus dictated that the outcome of the research would be a tool for deriving a resilient CAPM solution, rather than focussing upon the value of any particular CAPM configuration or system type. This is believed to be an original approach which would have wide applicability.

Experience gained in the prototyping exercises on the methodology and on the task model shows the success of the material developed. These stages will be described in later chapters.

Chapter 3. The need for flexibility in manufacturing

Flexibility is a theme of much recent literature and is often assumed to be a requirement of manufacturing systems. However, this represents a distinct change from the mass production norm established by Ford in the early part of the twentieth century which was still prevalent in the era of mass-produced consumer goods in the 1950s and 1960s[18]. If flexibility has become a requirement of manufacturing industry in recent years, it must be fully understood and closely defined so that the means to provide the required flexibility can be made available.

3.1. Change in the nature of competition

Increasing pressures are forcing many companies to rethink the basic assumptions and values of their businesses. The mass production of large numbers of identical items was an approach based upon the economies of scale which applied when supplying during periods of high demand, when products could easily be sold, manufacturing industry was less developed and competition was weak.

Increasing international competition has given customers more choice and has led to the need for companies to compete on the other attributes of their products, such as quality, functionality and style, rather than on price alone.

3.1.1. Performance measures

In these new competitive circumstances, the traditional measures of performance such as standard hours recovery and labour productivity are being questioned and rejected. They become less relevant as labour costs make up a decreasing proportion of the total costs incurred in manufacturing, and cost itself is no longer the only critical factor but one of a series of factors which contribute to business competitiveness[19].

As Abernathy observed in his study of the USA motor industry to 1973,

> "Development in productivity continues until the industry reaches stagnation" [20].

Productivity objectives can lead to the entrenchment of the company within a narrow product range, in which competitive advantage can only come from high volumes and reduced cost, in a marketplace where price - and therefore the value of business in the market - is diminishing.

It is not necessarily therefore a wise strategy for a manufacturing business to concentrate upon the increase in productivity and the reduction of cost. Growing customisation and oversupply suggests the benefits of

> ".... a mixed production system of making a large variety of products in small lots .... the one-of-a-kind production system in which products are made to the specifications of individual customers, without lowering production efficiency." [21]

Besides cost, emphasis is being placed upon factors such as quality, lead time, time to market and delivery. The ability to respond quickly to changes in supply and demand is also becoming important, since it is becoming increasingly difficult to foresee changes in the marketplace[22].

3.1.2. A new manufacturing problem?

These changes in competitive forces are presenting companies with difficulties with which they are not entirely equipped to cope. The high rate of change called for in the parameters of manufacturing - products, processes, quantities - has changed the nature of the production management problem. Economies of scale are being replaced by economies of scope[23]. Managers and management teams whose training, experience and organisation are geared up to the consistent output of a known range of products - the maintenance of a manufacturing status quo - are finding themselves in a rapidly changing world. In this new manufacturing arena the maintenance of the existing order is less relevant than the development of techniques for coping with rapid and unpredictable change whilst still producing economic and better quality products on time. It could be argued that this marks the change to a new post-Ford technological paradigm as described by Dosi[24].

The traditional problem-solving approach of production engineering is built on the assumption that problems in production must be solved as they arise, and that increased productivity (meaning labour productivity) is the key to the well-being of the business. This assumption is a legacy from the influences of Taylor[25] and Gilbreth[26] upon the evolution of management in the USA and Europe during the twentieth century. "Scientific Management", the development of methods of working designed to produce the maximum output from the human resource, aimed to increase labour productivity and thus the efficiency of labour-intensive production. (See also [27].)

Skinner[28] points out that the productivity approach is a short-sighted one which prevents the company from using manufacturing as a strategic resource. It sees manufacturing as a cost centre which by implication must be restricted in terms of expenditure, rather than a resource which could provide a competitive edge for the business by responding to demands from the marketplace such as for quality, reliable delivery, short lead times, etc. Attention is focussed instead on short-term cost objectives, under the assumption that the manufacturing activity concerned will remain necessary.

It is also suggested by Skinner (ibid) that the loss of productivity in the short term which would be caused by the introduction of new process technology has contributed to its slow adoption, which has therefore left companies without a key strategic competitive resource. CAPM has been reported to suffer from this slow adoption.

> "Many companies who have introduced computer systems have done so because they have come up against the inevitability of the decision when faced with growing problems." [29]

Thus manufacturing should be recognised as a profit centre rather than as a cost centre, and should be the object of forward-looking development to enhance its capability for satisfying the changing demands of the market, in all performance measures including cost.

This argument leads the company to consider the investment of both money and effort in manufacturing, to develop competitive advantage.

3.2. Manufacturing Improvement

Many intertwining and inter-related techniques are involved in the improvement of manufacturing operations. Rapid switching from one product to another makes demands on the company's production technology and must be within the scope of the CAPM system in use, if the CAPM system is not to be amended. The cost of such changeovers is magnified if large amounts of stock are present in the system, which must wait until they again become "live" and risk obsolescence, besides being an unnecessary use of working capital. Generally, therefore, the minimum work in progress is desired. The reduction of stocks reduces the slack built into the manufacturing system to cope with faulty components, so quality becomes critical to the continuity of production, not just to customer satisfaction.

There are many logical routes linking the various aspects of manufacturing improvement. For instance, a desired reduction in inventory leads to the need for better quality and the development of small lot size techniques in production technology and production control. A desired improvement in quality pushes towards improved technology and the reduction of lot sizes. The reduction of lot sizes makes demands upon manufacturing technology for quicker changeovers of equipment, with the knowledge that the first product from the new set up will be correct - hence the need for effective methods of assuring quality.

These shop-floor improvements are also linked with improvements necessitated in other areas. For instance, satisfying customer demands for small quantities of different items brings a need for the rapid processing of orders, designs, tooling, works instructions and materials. These will be dealt with in Chapter 4.

Whichever logical route appears appropriate, manufacturing improvement tends to require the economic production of higher quality products in smaller lots and time scales with consequently increased numbers of changes of product type. Sometimes the changes required are between alternatives already available in the company's capabilities, other demands may require the company to do something new, to extend its capabilities. In the more fast moving markets, including electronics, the pressures for these changes have been very severe over the past few years. Changes required to the product often lead to changes in the processes surrounding the product: manufacturing processes, control, design, purchasing, etc. Coping with unpredictable requirements - uncertainty - is a characteristic of the electronics industry.

Kooy examines the pressures put on manufacturers by the technology and by the market as experienced by Philips, observing that the market pressure can be traced back to the first oil crisis in the early seventies. The perceived change from a seller's to a buyer's market increased product diversity, reduced the production quantities of items from millions to hundreds of thousands and reduced product life cycles from four or five years to around two years. The effects of these changes were to increase competition, quality requirements, rate of innovation, and integration and miniaturisation of the product which call for a well planned industrial strategy comprising

> "integral approach,
> reduction of complexity,
> flexible organisation and
> advanced technology" [30].

The change to a buyer's market has led to the requirement for manufacturers to respond to the demands of the market more than before, since the increased competition amongst sellers means that only those who meet the market's demands closely are able to sell. This has increased the need for manufacturers to respond to the needs of the market, or to risk losing business to their more flexible competitors. However it is clearly uneconomical for a manufacturer to aim to satisfy too wide a range of demands for diverse products. A degree of specialisation or focussing has therefore been put forward as a vital element of manufacturing strategy[31], but this must be balanced against the need for a flexible response to market demand.

The company must carefully weigh the advantages of flexibility and standardisation for its desired competitive position.

3.3. The nature of flexibility

"Flexibility" is a loose term which can be used and interpreted in many different ways. To the production foreman, flexibility might mean the ability to move operators to different jobs. To the production engineer, it may mean the capability of a machine to perform several different operations on a workpiece. To the lexicographer, it may mean "ability to bend" [32]. The common feature of these interpretations is the notion that something flexible can accommodate change by adaptation.

The definition of flexibility as "adaptability to change" is a useful one for CAPM. The need for flexibility and the definition of the term have been considered by many writers, notably the following.

3.3.1. Slack's concept of Range and Response flexibility

Slack makes a very useful contribution to the field of flexibility by identifying that

> "Flexibility has three dimensions - the range of states a system can adopt, the cost of moving from one state to another, and the time which is necessary to move from one state to another" [33].

These three categories are reduced to two distinct and independent dimensions in a later paper[34] which groups together cost and time as

> "the 'friction' elements of flexibility which constrain the [rate of] response of the system"

thus leaving

> "Range flexibility, the total envelope of capability or range of states which the production system or resource is capable of achieving"

and

> "Response flexibility, the ease (in terms of cost, time, or both) with which changes can be made within the flexibility envelope."

To apply these dimensions to a company's products, for instance, high range flexibility would indicate that the company was able to produce a large number of different items. High response flexibility would mean that the company was able to switch easily from one product to another.

These two measures are not dependent upon each other, and can be measured quite separately. In terms of changing demand, high range flexibility increases the likelihood of the company being able to satisfy the new demand, since the new requirement is more likely to fit within its capabilities. However this says nothing about the practicality of meeting the demand, which is only expressed by the response flexibility of the company to make the change to satisfy the new requirement in a reasonable length of time and at a cost at which production can still be profitable.

The "envelope" of range which Slack mentions is a concept which can be used to help managers formulate strategy by expressing the limits of their required flexibility. The envelope can also be used to specify the expected limits of response.

These dimensions are dimensions of flexibility itself, rather than of the flexibility of any element of a manufacturing system, each of which has its own range and response characteristics.

3.3.2. Other writers on flexibility

Dooner[35] refers to these dimensions, together with broadly similar ones developed by Mandelbaum[36] (action flexibility, state flexibility) and Zelenovic[37] (application flexibility, adaptation flexibility) and observes

> "one might argue that there are as many aspects to flexibility as there are [production system] design variables and operational parameters".

This is corroborated by Kumar[38] who cites several other researchers who emphasise different types of flexibility and instead pursues a mathematical approach.

While "flexibility" can be interpreted in different ways according to context, for the purposes of this work a definition based upon "adaptation to change" will be used together with Slack's dimensions of "range" and "response".

3.4. Flexibility requirements

Having established that flexibility is necessary, the next obvious step is to decide how much flexibility can be afforded by the company in question, in order to make a trade-off between the advantages accruing to the company from a flexible response and the costs of providing that flexibility. Clearly, machines, computers and people which have extended capabilities are more expensive than their less functional alternatives, and overspecification of requirements is an unnecessary waste. Using the limited view of the future which is available to them, managers must assess the most appropriate level of flexibility for their situation. This can be facilitated by taking a strategic view of future business directions and dictating the company's own future as far as it is able, as will be described in Chapter 5. The "envelope" of future requirements as described by Slack can then be defined, which helps the manager to assess the range flexibility required.

An approach which tends to be overlooked, however, is the strategic reduction in the amount of flexibility required. This simplification approach is the basis of the manufacturing techniques attributed to Japan. Strategic decisions restrict the amount of flexing required by modularising products and restricting customisation, whilst simplification on the shop floor provides rapid response from low-technology engineering improvements and method study[39].

3.5. Cost of inflexibility

As has been pointed out by Slack, the lack of flexibility of a system can be seen as friction which hinders change. In addition to the possible business lost by slow response to customer demands, the "stiffness" of the system causes costs. Burbidge[40] states that

> "the main types of costs which are reduced by an increase in flexibility are:
>
> 1. Obsolescence of plant and tooling.
> 2. Materials obsolescence, or the obsolescence of raw materials, parts, work in progress and finished products.
> 3. Losses due to changes in the Load/capacity balance.
> 4. The costs of planning and introducing product changes.
>
> .... the first .... is mainly dependent on the design of the technological, product design and production planning systems. The second .... depends mainly on the way in which the Production Control and Purchasing systems are designed. Losses due to changes in the Load/capacity balance are usually due to wasted capacity and depend again on the design of the Production Control System. .... The costs of planning and introducing product changes will depend mainly on the design of the organisational system, but will be affected also by the design of all the other sub-systems."

In order to minimise these costs, therefore, attention must be focussed upon the production control system (CAPM), the purchasing system and the organisational and other sub-systems making up the complete manufacturing system of the company. These various elements must form a coherent and cohesive system which can operate smoothly, since one of its objectives is to respond quickly to changing demands. This level of integration can only be achieved by formulating an improvement strategy for the manufacturing system as a whole, based upon the business strategy of the company.

Summary

Increased manufacturing competition has led to a change in the dimensions of competitiveness, placing increased emphasis on factors such as quality, lead time and delivery performance. Manufacturing companies must begin to compete by developing the means to address these factors, using manufacturing capabilities - not just cost - to gain a competitive advantage. One aspect of the manufacturing improvement which is required is the development of the correct amount of flexibility to suit the market. Since the CAPM system is concerned with the control of the flow of work and the achievement of delivery performance it is essential to develop the CAPM system as part of a strategy to provide the flexibility required in the business.

Chapter 4. The role of the infrastructure in the manufacturing system

In order to ensure the integration of complex manufacturing functions a coordinated plan or strategy is required. This must establish the aims of the business and provide all areas with a set of objectives which can contribute to the overall objectives of the business. To achieve successful coordination, the strategic aims of the business must be examined, validated and communicated. A methodology for the improvement of manufacturing functions must begin by considering the company's business strategy, and forming a suitable manufacturing strategy. Neither CAPM nor any other component of the manufacturing system must be considered in isolation.

4.1. Manufacturing system

An examination of the problems in manufacturing and their solution must be set within an understanding of the way the manufacturing system operates. A systems approach leads to the definition of the system under examination, so that analysis can concentrate on internal consistency and its boundaries or interfaces with other systems.

The view has been put forward[41,42] that the flexibility of the manufacturing system is to a large extent governed by the network of systems which supports the actual manufacturing activity. Therefore to produce a manufacturing system capable of responding to a given set of requirements, it will be necessary to consider not just the arrangements made on the shop floor but also the support systems.

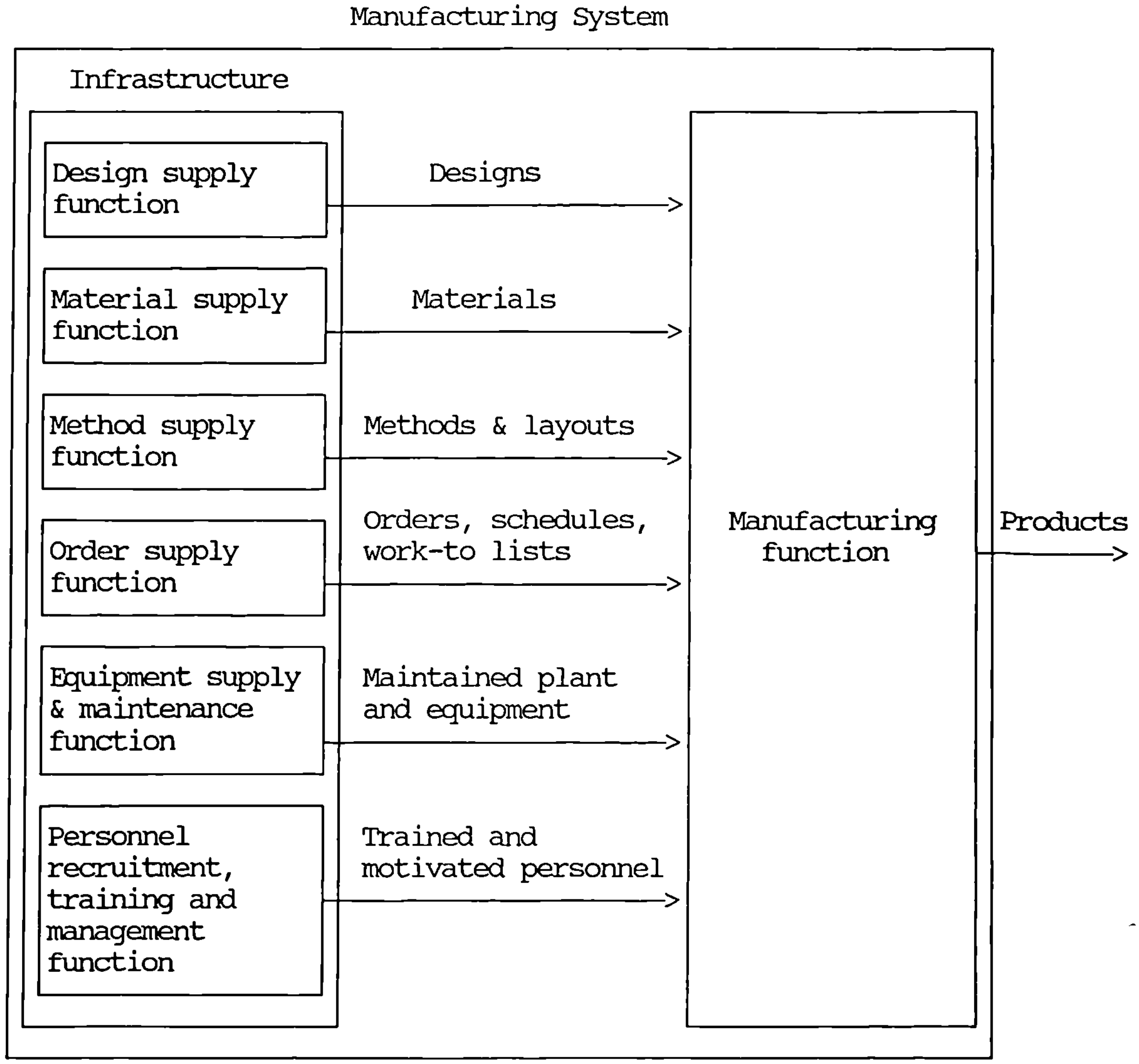
Parnaby[43] defines a manufacturing system as

> "An integrated combination of processes, machine systems, people, organisational structures, information flows, control systems and computers whose purpose is to achieve economic product manufacture and internationally competitive performance. ...."

A useful extension of this definition is to consider the functions performed by the sub-systems which make up the manufacturing system, since concepts such as "information flows" and "control systems" are difficult to compare as units of analysis.

This functional analysis has been presented by the author[44,45] and results in the schematic structure shown in Fig.1. This analysis shows the manufacturing function, which is the sum of all direct manufacturing activities, together with the six functions which support and control manufacturing activities. These six functions can be thought of as the "infrastructure" of the manufacturing system. Since these functions provide manufacturing with all the resources and information required for manufacturing to continue, the performance of the manufacturing system as a whole could be restrained by the lack of performance of any of the system elements. Thus the performance of the infrastructure is an important strategic consideration.

Fig.1. Schematic diagram of manufacturing system showing infrastructure sub-systems



4.2. The infrastructure

A dictionary[46] defines "infrastructure" as

"basic necessities on which more complex activities depend".

Since different activities require different "basic necessities", the infrastructure also determines the range of activities which can be carried out.

In the context of a manufacturing company the infrastructure consists of the supporting functions which allow manufacturing activities to take place. In order to follow through the analogy this must include the provision of all the "basic necessities" of manufacturing, such as the machines, plant and equipment together with the administrative and production control systems of the company.

The infrastructure can be regarded as the internal environment within which manufacturing must operate, and which supports manufacturing operations.

Hill defines the infrastructure as the

> "controls, procedures, systems and communications combined with the attitudes, experience and skill of the people involved" [47],

while Skinner refers to the

> "policies, procedures and organization by which manufacturing accomplishes its work, specifically production and inventory control systems, cost and quality control systems, work force management policies and organizational structure" [48].

Meredith describes the infrastructure as

> "the network of non-physical support systems that enable the technical structure to operate" [49].

The view of infrastructure adopted in this work is described below.

4.2.1. Definition of "Infrastructure"

For the purposes of this work, the production management infrastructure of a manufacturing company is defined as "the network of support services and systems which provide the necessary resources and information to allow manufacturing activities to continue".

4.3. Components of the infrastructure

The components of the infrastructure as shown in Fig.1 are the design supply function, the material supply function, the methods supply function, the order supply function, the equipment supply and maintenance function and the personnel recruitment, training and management function. All the functions must work together in an integrated, coordinated fashion to facilitate the fulfillment of manufacturing objectives, so their design must be undertaken in a coordinated, systematic manner. Skinner concludes that

> "Elements of the infrastructure must be mutually and internally consistent.
>
> "Everything counts, since one overlooked element may ruin the total.
>
> "Manufacturing decisions must span the infrastructure; changes can no longer be made piecemeal if they are to be successful." [50]

This entreaty makes enormous demands upon the management team who have the difficult task of overseeing the design and development of systems with many elements and complex interactions. However, systems theory allows the systems to be viewed separately as long as their interactions and performance parameters are carefully matched.

4.3.1. The design supply function

Flexibility of the design function relates particularly to the rate at which new designs can be provided. Company A, a manufacturer of domestic electronic goods, found that increased flexibility and Just-In-Time manufacturing on the shop floor together with a continuous improvement policy created a demand for thousands of design modifications per year. The existing procedure became overloaded, and the company is now considering ways of improving this function.

Company B, a computer manufacturer, also found that increasing numbers of design changes were required, and was able to implement a computer-based design change management system to facilitate the passing of information between departments and to monitor the progress of all change requests.

4.3.2. The material supply function

Materials can be a severe limiting factor to flexibility. Company B finds that long procurement times, such as three months to purchase an "ASIC" chip from Japan, are a limit to the company's responsiveness. This has also caused quality and inventory problems due to circuit boards being assembled as components become available rather than in line with the customer order schedule.

In the electronics industry the total manufacturing lead times and therefore the responsiveness to customer demands depend to a large extent on the procurement lead time, since the actual manufacturing lead time is often relatively short. In Company C, a manufacturer of defence-related products, steps are being taken to improve the time taken to issue purchase orders and to improve supplier relationships in order to become more responsive.

Company D, a components manufacturer, has improved its ordering process so that all purchasing is dealt with by one manager and a typist, who also have other responsibilities. This appears to provide the appropriate level of flexibility for this business.

4.3.3. The methods supply function

Company E, a subcontract assembler, has no area with specific responsibility for method engineering, since the business is built around one specific method only and all products are processed through the same route. This company has decided to have no flexibility of methods. If this technology becomes obsolete, the company will face difficulties in responding quickly.

Company F, a component manufacturer, requires little methods flexibility to meet day to day changes, which tend to be of mix only. However it has assembled a highly skilled team for the development of new process equipment to create a specific market advantage.

In some companies, for example company D, methods work is carried out by the design department.

4.3.4. The order supply function

Most of the companies investigated are conscious of the importance of processing orders quickly. For example, companies D and F both allow major customers to enter orders by data transfer direct into the orders database. Some other companies were considering this possibility.

Company G manufactures tailor-made electronic equipment. Customers ordering from this company are able to speak direct to a design engineer who can quickly tailor the design as required, provide a price and pass the order immediately to manufacturing.

4.3.5. The equipment supply and maintenance function

The companies investigated had made little attempt to develop flexibility in the area of tool and equipment provision, relying generally on external equipment manufacturers, tool manufacturers and maintenance contractors. However this must limit the responsiveness of the companies to changes requiring new processes or tooling. The case for tool management is presented by Carrie and Bititci[51].

4.3.6. The personnel recruitment, training and management function

Flexible personnel approaches have been implemented by almost all the companies. This generally involves operators moving between different operations.

Company F has attempted to de-skill all direct operations and to employ operators on short term contracts to provide numerical flexibility.

Company E contracts out some operations and employs outworkers on a subcontract basis.

Personnel flexibility is treated by Gustavsen[52] and Atkinson[53].

4.4. Focus of this work

The focus of this work is upon the improvement of CAPM implementation. In the model of the infrastructure, as described in section 4.3, CAPM forms the order supply function, which deals with the data controlling the flow of work.

Each of the infrastructure sub-systems must be configured to meet the objectives of the manufacturing business, so that the manufacturing system can operate as an integrated whole. Performance of the manufacturing system is limited by the performance of any of the sub-systems. This is the context in which CAPM systems must operate.

Summary

The manufacturing system of a company is made up of various sub-systems. Manufacturing operations are facilitated and controlled by the six sub-systems which form the infrastructure. These systems supply designs, materials, methods information, orders, equipment and personnel. Manufacturing performance is constrained by the performance of the infrastructure.

CAPM is a sub-system of the manufacturing infrastructure. As one of the functions which determine manufacturing performance, CAPM must be designed to suit the company's business strategy. Success of the manufacturing system, however, depends not only on CAPM but also on the other infrastructure sub-systems.

Chapter 5. The need for a methodology to determine the context for CAPM

Computer systems for CAPM represent considerable investments. Implementors face problems of justification in a manufacturing business environment which is often far from certain. Some guidance on how to approach the problem is required.

5.1. A strategic approach

Traditional approaches to justification include the payback period method, the return-on-investment method and the discounted cash flow approach[54]. Under these approaches a machine or system may be purchased to address a particular problem which is perceived by the production personnel concerned, providing they can demonstrate to the financial administrators that the requirement is likely to persist and that the purchase will cover its costs. This may mean demonstrating that it will continue to be useful for a certain period, such as two or five years.

There is a prevailing yet indistinct feeling amongst manufacturing managers that investments in "New Technology" (machines and data processing equipment involving computers) must be approached in a different way to other purchases.[55]

5.1.1. The justification of investments

The difficulty of justifying investments in technology arises from the combination of on one hand a financial strategy which insists on guaranteed benefits and on the other hand a short-term manufacturing requirement, since manufacturing managers are unlikely to be able to forecast the future with any degree of certainty.

This tends to result in a struggle to justify investments based on uncertain information and a hope that an investment in technology will prove flexible enough to meet whatever future demands may arise.

These solutions are based upon today's requirements. They are single point solutions good for only the current situation. In order to ensure a resilient solution it is necessary to develop solutions capable of accommodating future requirements.

5.1.2. An uncertain future?

Whilst it is never easy to forecast the future, the firm does control its own destiny to the extent that it can choose whether to operate in a particular market area, which can be delineated in terms of products, customers, location, etc.

The company may decide that its business is the manufacture of devices of a certain type or operating principle, whose functionality lies between certain upper and lower limits, which is suitable for a certain specified range of applications and which is aimed at a certain range of customers. Whilst the company must always re-assess and adjust these choices and develop day to day plans to meet the demands thus arising, the choice of operating area for the company serves to provide some boundaries within which guidelines can be developed for the future. The concept of an envelope of performance capability as described in Chapter 3 can be used to specify required performance for each level of the manufacturing hierarchy from business strategy to CAPM requirements.

Within certain practical limits, the company can attempt to influence its own future. The company can set itself guidelines which can be used to structure investment in resources. Without at least this level of certainty, the company's resources including technology can not be exploited to the full. By such an approach, the single point solution to today's problem can be replaced by a strategic long-term solution which will have a more lasting effect.

The methodology which is the required outcome of the research as described in Chapter 1 must guide the implementor in the development of a strategic long-term CAPM solution.

5.2. Strategies and tactics for manufacturing

Manufacturing companies have tended to develop into hierarchical organisation structures consisting of specialised departments. In this form of organisation, departments deal with problems that arise in their defined area of competence. Thus a design is created and corrected, amended and modified by the design department; production processes are dealt with by the production engineering department (which may be subdivided into areas such as process planning, work study, estimating) etc. Thus the organisation's structure provides a framework within which the appropriate specialist area can be called upon to deal with any required task. The structure of the organisation determines which tactical response will be made to a problem falling into any area.

Unfortunately there are some problems which refuse to fall into the jurisdiction of any one functional area. It is not unusual for problems to be tossed back and forth between areas, each pointing out the aspects of the problem believed to fall in the other area. Such transactions are common at the interface between design and manufacturing[56]. Even when the area of responsibility is clear, the expertise to solve the problem may not lie within that area. Most importantly, this departmentalisation tends to overlook the advantages which may come from encouraging the departments to work together[57,58]. When time is short and new problems arise, the structural determination of responses may be too unresponsive to operate successfully.
A different strategy is required.

The difference between strategy and tactics is that tactics provide responses to disturbances, or ways of fighting battles, whilst a strategic approach identifies which war is to be fought and what resources need to be made available to succeed. To relate this analogy back to manufacturing, a strategy for a fast moving industry sector such as electronics is likely to be based upon flexibility and speed of response and will dictate policies for all areas of the business which contribute to this strategy. In other circumstances strategies may be chosen which relate to the importance of other factors such as product cost or market share.

Different strategies mean different configurations of the business. In order to create a competitive advantage, therefore, a strategy must be formed which will provide a basis for equipping the company to fight a particular war.

What is needed is more than well-known tactical responses giving short-term solutions to problems. The company must determine which problems it will address and how it will equip itself to deal with them as they arise, even though the precise nature of each problem cannot be foreseen. The extent of the strategic choice must reach all aspects of the organisation; structure, technology, control systems, personnel, markets, etc. A strategy which can be justified sets a framework within which equipment purchases and other initiatives can be evaluated.[59]

5.3. Characterisation of the manufacturing problem

The design of manufacturing systems must be undertaken in a pragmatic way in which the details of the particular business are taken into consideration. In order to use such an approach it is necessary to define a set of dimensions which can be used to characterise the particular situation in which a manufacturing system must operate and the demands which will be made of the system in terms of what it must produce and to what variations it must be able to respond.

Dimensions which can be used to describe the manufacturing situation include

- type of flow (built in one place, moved round job shop, moved along flow line, issued from a machine)

- lot size (one-off, small batch, large batch, continuous)

- volume of production (one-offs, short runs, long runs)

- production frequency of different products (runners, repeaters, strangers)

- mode of production (make to order, make to forecast, make to stock)

- mode of inventory management (re-order point, two-bin, kanban, MRP)

- Shop floor layout (ad-hoc arrangement, machine grouping by type, grouping into GT cells, process flow layout, flow line, process plant)

One way to introduce a CAPM system, for instance, is to regard some or all of these parameters as given, and design a system to suit. Different circumstances make widely different demands upon the CAPM system, and require different solutions. For instance, the mode of production may determine the scheduling algorithm to be used. Forecasting or stockholding may be required to reconcile short delivery times with long manufacturing or procurement lead times. Data volumes may be small or large. Some solutions must operate within existing data processing environments which may exclude certain software packages.

However, the application of this approach to CAPM, a sub-system of the manufacturing system, may give a sub-optimal result since design is based upon a restricted number of factors and any element of the system could be optimised for a possibly non-optimum arrangement of the other parts of the system. It is also possible for any of these factors to change, leading to inappropriateness of the CAPM solution, or for the current way of working to be at odds with the company's desired competitive position. For these reasons, in looking at the total system and in particular the infrastructure, analysis must start at a level above the current manufacturing arrangements and consider their redesign within the framework of an overall business strategy.

5.4. A hierarchical approach

As was established in Chapter 4, a strategic approach is required which sees the manufacturing company as a system which is structured and operated to meet a defined set of objectives. As the CAPM system is only one part of this whole system, it must be seen as a sub-system which operates to fulfil a series of manufacturing objectives which are themselves a sub-set of the overall objectives for the business. The CAPM system can be seen as supporting the manufacturing operations within the company. Similarly, the manufacturing operations as a whole can be seen as supporting the strategic business level objectives of the company. These objectives may in turn be a sub-set of objectives defined by a parent company.

In order to ensure that all areas of the business can be integrated into a well structured whole, the context surrounding each system must be considered. The CAPM systems must fit the requirements of the manufacturing strategy, which must in turn fit the objectives established to fit the business into its market context. The highest level of fit must be examined first, in order to provide the framework for the lower levels beneath. This entails the consideration of many factors which may be beyond the knowledge or responsibility of any individual. It is not a sufficient solution to advocate a hierarchical, strategic approach - success in practice will require more guidance. Thus, a guiding methodology is required.

The methodology developed to address this process consists of a series of activities undertaken by members of the company concerned. The activities are undertaken under the guidance of a facilitator who helps the users through the process. Activities include workshop meetings, preparatory work ("pre-work"), and the creation of milestone documents to set down results at each stage. The workbook[60] provides background information on the techniques and proformas to structure responses.

The methodology is based upon the user-led concept and intended to be practical for companies of all sizes to use. It structures a series of tasks and pre-works which should take only a few weeks to complete, so that the time required is not prohibitive for small companies.

The following sections briefly summarise the key stages of the methodology. Further description can be found in [61]; more detail can be found in the workbook.

5.5. Strategic Analysis

Strategic Analysis considers the establishment of the business context of the firm in which the CAPM solution must operate. This involves establishing or re-establishing the mission of the company and its orientation with respect to products and markets. This stage identifies the objectives of the company and defines the operational performance envelope for the company. The range and response dimensions are expressed in terms of the product range that the manufacturing function must deliver, together with likely volume, performance, delivery and cost requirements necessary for the company to compete in its chosen markets.

5.5.1. Corporate Mission Workshop

This meeting is used to define a common understanding amongst the company's top management team of the principal aims of the business, and should confirm the company's Mission Statement.

5.5.2. Strategic Audit

This stage audits the company's position with respect to stakeholders and products.

Stakeholder Analysis[62] examines the influences on the company of major interest groups. A stakeholder is an individual or a body which has influence over and an interest in the company. Stakeholders can include customers, suppliers, employees, shareholders, governments, etc.

Boston Consultancy Group (BCG) Analysis[63] examines the composition of the company's current product portfolio according to their financial viability as shown in Fig.2.

Fig.2. Boston Consultancy Group Grid

Market Growth Rate			
	High	?	Rising Star
	Low	Dog	Cow
		Low	High
		Market Share Cash Generation	

A further stage, BCGII Analysis is a development of BCG Analysis which examines the company's product portfolio and suggests appropriate competitive strategies for each product family.

5.5.3. Price of Non-Competitiveness (PONCII) Analysis

This stage is developed from the concepts of "order qualifying criteria" and "order winning criteria" put forward by Hill.

> ".... manufacturing .... must provide the qualifying criteria in order to get into or stay in the market-place. But those will not win orders. .... Once the qualifying criteria have been achieved, manufacturing then has to turn its attention to the ways in which orders are won and to ideally provide these better than anyone else." [64]

The qualification to enter a particular market is related to the Price Of Non-Conformance to market requirements and is the basis for PONC analysis[65]. This is the cost of not providing the basic requirements of the market. From this idea has been developed PONCII analysis which is based upon the costs of becoming competitive in the market, or the Price Of Non Competitiveness. The analysis aims to estimate the value of the business which could be gained by taking various steps to increase competitiveness.

The output from the Strategic Analysis stage is a set of required competitive objectives for each product family and an estimate of the value to the business of achieving those objectives.

5.6. Manufacturing Analysis

Before considering the specifics of the CAPM implementation it is important to ensure that the current manufacturing facilities are configured in such a way as to fulfil the strategic requirements established in the foregoing analysis. This means ensuring that the company can perform at all positions within the operational performance envelope.

At this stage the company should consider the possible redesign of its manufacturing facilities. The most common approaches to the configuration of machining and assembly operations are the formation of groups or cells on the Group Technology principle for batch production, and the development of flow lines for continuous or very large batch production. The theme of simplification is key.

The common element in either approach is the rejection of the traditional job-shop configuration based upon grouping operations by process type (process organisation) in favour of grouping based upon products (product organisation). This leads to significant advantages, most importantly the reduction of lead time and work in progress, and therefore in flexibility[66,67,68,69].

5.6.1. Manufacturing Audit

This activity examines the company's current manufacturing resources, as a basis for the following workshop. This includes a Manufacturing Audit report outlining the current type and state of control systems, machines and other facilities available for manufacturing.

5.6.2. Manufacturing Analysis Workshop

This workshop examines the company's manufacturing resources in the light of the competitive objectives. Various tools are used for this analysis, including Resource Impact Analysis, which looks at the effects of various resources on the competitive objectives. The output from this stage is a set of action objectives for each manufacturing resource, which sets targets for work to reconfigure resources where necessary. These objectives provide a description of the future manufacturing configuration, and a rough-cut control strategy for each product family, which will be considered in more detail at a later stage.

5.7. CAPM Requirements

Having established the business context and the configuration of the manufacturing facilities, attention can be focussed upon the control systems which will operate the facilities. The nature of the control strategy employed will depend both upon the configuration of the manufacturing facilities and upon the rough-cut control strategy. Thus a different control strategy would be formulated for a company continuously producing products from a flow line from that required for a company producing a wide range of goods in a job-shop type configuration. Similarly, a different control strategy would be formulated for a company delivering products to individual orders from that required in a make-to-stock business.

These requirements must be examined in detail before a system can be designed. This will be considered in Chapter 7.

Summary

Investments which are to provide a lasting return must not be based entirely upon today's requirements but upon future requirements. The future requirements can be addressed by considering the company's business strategy.

Manufacturing systems can be designed according to the different characteristics of the business. However, the design or specification of a CAPM system - one element of the infrastructure - must be considered as part of the development of a strategy for the manufacturing system as a whole. A hierarchical methodology is required, which will enable the implementor to establish the context for CAPM by considering business strategy, manufacturing strategy and CAPM requirements before focussing on CAPM solutions.

Chapter 6. Experience gained using the methodology to determine the strategic business context for CAPM in a company

The preceding chapters have described the need for CAPM to be implemented as part of a strategy to allow the manufacturing company to increase its competitiveness. The process of determining the context for CAPM in order to allow CAPM to contribute to manufacturing competitiveness has been outlined.

At the stage in the research when some confidence in the stages of the process outlined above had been gained, the possibility of testing the methodology in a company arose. This chapter describes the experience gained in this trial.

6.1. Background

The company is a manufacturer of cast and machined products. Rapid growth had led to problems of production control, and the company was considering the purchase of a CAPM package. The research team was asked to recommend a suitable product.

An initial survey examined the company's data processing facilities, which were found to be very limited. Subsequent discussions with the company led to the possibility of using the process methodology to help develop a fuller understanding of the CAPM requirement from an analysis of the business and manufacturing contexts in which the CAPM system would operate. The company's managers were enthusiastic and prepared to give time to the process in the hope of gaining additional benefits.

6.2. Strategic Analysis

6.2.1. Corporate Mission Workshop

The process began by initiating a discussion among the senior management and directors of the company concerning the corporate mission. A rapid consensus was reached with growth as a central focus, to achieve the mission of becoming the largest supplier of its products in Europe. This discussion occupied a period of approximately 1½ hours and produced a "first attempt" company mission. During the discussion it became clear that the corporate mission would have to be revised following a deeper analysis of potential products and manufacturing capability. Nevertheless, this workshop gave a starting point around which top team members were able to begin their debate.

6.2.2. Strategic Audit

This activity began with a top team workshop that outlined the importance of the concept of stakeholders. The analysis which took place simplified the concept of stakeholders into three categories; suppliers, customers and competitors. The top team were then asked to consider all product families against these key stakeholders. The team began by defining fifteen product families and assessing the importance and dynamism of the key stakeholders against each.

The analysis identified the key customers, suppliers and competitors, the basis for their power over the company, the relative strength of their influence and whether the basis of that power was changing.

The next stage of the process involved undertaking a BCG analysis. Each product family was analysed in turn for its market growth and market share. Because of the nature of the business it was felt necessary to split the analysis into UK and overseas markets. This analysis identified a number of important products that were "cash cows", yet were threatened by key competitors. It highlighted products that were "dogs" and acting as a cash drain. A combination of stakeholder analysis and BCG analysis was used to identify opportunities for new products particularly in the "question mark" and "rising star" quadrants. It transpired that many of the UK "cash cows" were "question marks" in the overseas markets and represented areas for possible expansion.

The BCGII analysis stage of the process methodology looked at each product family in turn in order to identify the barriers to entry in the market and the opportunities for differentiation. This was a particularly useful activity because by identifying the specific quadrant occupied by each product family the research team were able to provide some immediate feedback on the suggested competitive strategy for that product family.

These insights, together with the following PONCII investigation, provided management with material for use in developing and refining the corporate mission and for objectively planning their business strategy.

6.2.3. PONCII analysis

This analysis brought out two conflicting views. The marketing director expressed his views on the extra business that the company could win if it were more competitive than its chief rival on its key order winning criterion for a particular product family. However, the manufacturing view was expressed that considerable cross subsidisation was taking place, which distorted the marketing department's view of product cost. This was because all overheads were apportioned across the whole product range. In fact all of the pattern making and casting costs should, it was argued, be apportioned only to cast products. This issue could not be resolved in the workshop and was identified as a major work item to be dealt with before the next stage of the process. Clearly the profit or loss being made by a product must be determined before decisions on future actions could be made. A guide on cost auditing was subsequently added to the methodology.

During this activity it became clear that the company was competitive on some product families whilst others presented both considerable opportunities and threats. This phase highlighted the potential for growth of certain product families and the means by which growth could be achieved.

6.2.4. Issues arising from the strategic analysis phase.

From the first stage of the process, the following points became clear.

The process cannot be expected to operate sequentially. Some aspects of the analysis, such as the mission statement, are always likely to need revision after gathering and analysing information. The process should be regarded as iterative in nature.

Facilitators using the methodology should beware of relying too heavily on perceptions rather than the facts of the company situation. By using the methodology in this limited way a totally false impression of the state of the company could develop. For example, this company had very little accurate costing data, but a variety of opinions. Without this data being available the company could easily have developed a strategy focused on loss-making products.

The facilitator approach was found to work well. The management team accepted the requirement to work in a "project group" and to openly discuss their views.

Much of the process of this stage was educative for the company. By encouraging team building and providing specific roles and actions for team members the methodology helped generate shared goals and values with a common understanding of the situation. This develops a sound basis for the implementation of change.

6.3. Manufacturing analysis

The Manufacturing Audit stage follows on from the work done in the Strategic Analysis stage.

6.3.1. Manufacturing Audit

The pre-requisite for the Manufacturing Analysis Workshop is the Manufacturing Audit. The aim of this stage is to provide the participants in the workshop with a common understanding of the current state of manufacturing resources, with a view to adjusting the resources to meet the competitive objectives.

This work was assigned to the Works Manager as the person responsible for manufacturing resources within the company.

In order to facilitate the Manufacturing Audit an extract from the workbook describing the pre-work required was provided, and a member of the research team discussed the work with the manager before it was begun. The manager saw the usefulness of this piece of work in terms of providing some common understanding for members of his staff in different departments and on different sites.

6.3.2. Manufacturing Analysis Workshop

The workshop aims to generate a set of proposed solutions to satisfy the Competitive Objectives established for each product family during the Strategic Analysis phase.

The following people were invited to the workshop:

Managing Director
Works Manager
Manager of Stores
Manager of Despatch
Production Controller
Pattern Shop Manager
Foundry Manager
Two Foremen
Chief Design Engineer

Buyer

Order Processing Clerk

Members of Research Team.

As this meeting was the first involvement of many company members in the process, it began with an introduction to the process by the research team. The Managing Director then outlined the output of the Strategic Analysis phase, the Competitive Objectives.

The Works Manager made a verbal presentation of the Manufacturing Audit information described above. Further points were raised by the team members. The point raised generally referred to existing problems:

- Realistic completion dates for orders could not be provided.

- Order processing took up much of the available time before delivery dates.

- Many orders (50%) were passed to the drawing office with incomplete information preventing the drawing being made. Much time was lost in checking with sales and the customer.

- Many job cards reached the foundry with incomplete information necessitating checking.

- Sales issued quotations even when unaware whether patterns were available, thus giving unrealistic delivery promises to customers.

- Sales should make more effort to sell from the standard range, which may save 5-6 weeks in pattern making time and cost. Differential costing and lead time could be used to encourage customers to buy standards.

- One-off sales could be diverted to dealers, thus smoothing demand.

- Sales may demand that a job be broken down in the machine shop or pattern shop to fit in a rush order.

- Both the foundry and machine shop kept unofficial stocks "under the bench" to cushion against rush orders.

The points raised highlighted these difficulties:

- There was a boundary of poor understanding between the Sales and Manufacturing functions, which resulted in an adversarial relationship in which Sales appeared to hold the upper hand.

- The company contained many unresolved problems which preoccupied the staff members to the extent that reflection and creative thinking were almost impossible.

- All the points raised related to the poor state of production management in the company, none of which would have been resolved by the imposition of a CAPM package.

It is impossible to overstate the importance of these difficulties to the company. It was clear that these matters must be dealt with as a pre-requisite to any significant improvement in the company. For the Process Methodology, it was learned that a forum for the airing of grievances is vital before progress can be achieved. Even if the points raised were irrelevant to the issues at hand, (which they were not) the individuals concerned perceived them to be of importance and could not have been expected to maintain their enthusiasm if their first contributions were ignored.

6.3.3. Follow-up meeting

In order to take positive action on the points raised at this meeting, a further meeting was arranged to include a representative from Sales together with the Managing Director and Works manager.

The problems of fluctuating load were explained using a simple diagram on the flip chart. The result was that Sales defended itself against some criticisms whilst agreeing that there was a problem of obtaining information about Manufacturing. The points raised were:

- Sales would like to see an indication of current manufacturing capacity to help give realistic promises to customers.

- Sales would welcome a checklist to ensure orders were complete. A suitable checklist was produced.

- Sales had recently begun checking whether patterns exist before issuing promises to customers.

- Sales received no feedback from manufacturing to indicate the likely lead time for manufacturing any given product.

6.3.4. Experience gained during Manufacturing Analysis

People may need to express their anxieties before creative discussion can take place. It was felt that the company could not begin to move forward in any integrated, strategic activity without dealing with the grievances of employees which, although sometimes apparently trivial, created an uncooperative atmosphere, even in a small company where all output relied on informal relationships.

The facilitator was not immediately accepted by the larger workshop group. One member, who may have been speaking for a silent majority, expressed the view that the company was too busy to spend time on an academic exercise, and that the important thing was to keep the factory running. However, as some problems in the business were presented and discussed and the group began to understand the process, this view dissolved and a very positive attitude developed. The same individual apologised afterwards for having appeared disruptive, acknowledging the usefulness of the process and offering his support.

6.4. CAPM requirements

The company's irregular and fluctuating pattern of sales leads to particular problems for production management. Some customers place their orders in the form of regular schedules, within which they sometimes bring products forward or vary the requirements at very short notice. Other customers include dealers, who generally place larger orders, and individuals whose orders are generally for very small numbers or one-offs, often in very short time scales. The company's response to these different demands is to ensure at all costs that the large customers are always satisfied, even for their most challenging demands.

The effect of this is that Sales may make demands on Manufacturing at extremely short notice, for which the company at present suspends any other orders. Thus lead times can be from hours to weeks according to perceived urgency and current load on manufacturing resources, and orders for "less important" customers can be delayed almost indefinitely.

The comments received from Sales indicated that they were unable to give accurate promises to customers, because of a lack of information from Manufacturing. Manufacturing, on the other hand, saw Sales' arbitrary promises as a major problem.

One output from the workshop meeting was the common feeling that a simple rough-cut capacity planning tool should be implemented, which would act as a link across the Sales-Manufacturing boundary. It was also felt that Sales required accurate total manufacturing costs as a basis for pricing and to direct Sales effort. These two demands provide initial themes for the specification of a CAPM system.

The variation in demand must be matched by an approach to CAPM capable of responding to this variety. The problem can be considered from two points of view. The variety could be reduced, and Manufacturing could be enabled to meet the variety. A combination of these approaches was required.

Thus a solution must involve the company's Sales area, with a policy of reducing variety as far as possible, in this case by selling standard products. This could be supported by a training or awareness scheme for Sales staff together with the implementation of Sales procedures which involve presenting the customer with the option of purchasing standards under more advantageous terms (of cost and lead time) than specials.

A short term solution to the information system problem was generated by the workshop meetings. It consisted of a simple paper-based system for day-to-day scheduling, relying on a procedure in which each day's capacity would be loaded to 80%, the remaining 20% being held open until noon on the preceding day to allow rush jobs to be fitted in. This will provide an interim system solution which will help manufacturing to manage the variety.

For continued success and development it was clear that the boundary between Sales and Manufacturing must be monitored and lines of communication must be kept open. It was decided to implement a regular meeting between the two functions to look at the performance of current procedures. An agenda for this meeting was specified.

6.5. Comments on the Process Methodology

The process methodology enabled the company to establish an overall business strategy within which it can begin to develop improvement plans. This represents a major difference in approach from the company's first ideas on development and its reason for involving the research team, which were focussed upon systems development only. The process established

- An educative requirement in terms of educating Sales and Manufacturing about the effects of and requirements of high variety in the business;

- A procedural requirement in terms of establishing the need to check order completeness and pattern availability on receipt of an order and in terms of maintaining the procedures;

- A system requirement in terms of defining and specifying a short term rough cut capacity planning tool and the basic requirements for a CAPM system to be implemented in the medium term.

These infrastructural requirements could not have been arrived at by an approach which focussed at an early stage upon system software requirements, but were produced by a process which established the business context within which the future CAPM system must operate. The user-led approach was able to provide valuable outputs and to develop both the strategy and the strategy makers in a way which could not be expected from a consultant-led approach or from an analysis not based on business context.

The experience gained in this company demonstrated the importance of developing an understanding of the business, its direction and its problems, which was helpful in establishing the broad context in which a CAPM solution would operate. However, by understanding the process and gaining a better understanding of their own business, the company could take an overall view of the steps required to improve their operations. Whilst CAPM would be important, the organisational difficulties which existed may have, if left unresolved, prevented any advantage being gained from a better CAPM system. In the event, the company postponed further CAPM development until organisational issues had been dealt with.

Summary

This exercise demonstrated that the process methodology was effective in determining the context for CAPM. The various aspects of the methodology - pre-works, proformas, workshops - were found to be successful, although several lessons were learned about the conduct of the process.

It was felt that some potential reasons for CAPM failure which existed in the business had been recognised. These included the poor understanding by Sales and Manufacturing staff of each other's point of view, which may lead to great difficulties if a CAPM system was installed but the practice of informally breaking down part finished work to fit in rush orders was continued. Perhaps more importantly, the Strategic Analysis was able to make an attempt at anticipating future changes in manufacturing volume, product mix and manufacturing processes. These changes had not previously been considered as being of interest in the question of CAPM.

The result of this experience was that the research team were satisfied that the process methodology had been successful and would be worth further development.

Once the strategic business context within which the CAPM system must operate has been defined, attention may be focussed on the design of the CAPM solution.

Chapter 7. Elements of the CAPM system

The problem of determining the best CAPM solution for a particular business can now be considered. CAPM systems can be configured in many different ways. Proprietary computer systems and popular ideologies reflect different configurations, all of which have different characteristics.

7.1. CAPM system variants

The most common CAPM system classifications are MRP, MRPII, JIT, OPT and PBC. A common question in the literature regards the choice of system. However, these classifications are not exclusive and do not directly relate to specific business situations.

7.1.1. MRP and MRPII

Material Requirements Planning (MRP) systems are based upon computer applications used to issue orders for manufacturing or purchasing at the correct times so that the items required arrive when they are needed for production. The logic of these systems is based upon a lead time for each item, which is held by the system, together with a bill of materials (the U.S. term for the parts list) which identifies the items required at each stage of manufacture of the product. When the details of any order are entered in to the system, the requirements are calculated and the appropriate orders are initiated as they become due.

MRP is thus a system in which a complex set of calculations is handled automatically. The system has no need for stocks to be held if the lead times are correct, thus making it theoretically the most efficient and flexible way to plan production.

However the MRP approach has certain limitations. Stocks must be held if the planning time (the period between receipt of order and the date delivery is required) is shorter than the total lead time required to make the product. In this case stocks based upon forecasts of orders must be held, so that the lead time of the work remaining to be completed is shorter than the planning time. Stocks may also be held to guard against fluctuations or inaccuracies in the expected lead times.

The most significant problem of MRP is found in batch manufacture where a changing mix of products flows through a factory. In these circumstances, queuing for machines can increase actual lead times, so that either the planned lead times in the system must be increased, or extra safety stock must be held because of the reduction in planning time. Increasing the lead times leads to more work being in progress at any instant, since all work now takes longer. This increases the pressure on resources and further extends queues, leading to large batches and poor machine utilisation, in a spiral of diminishing returns.

MRP must therefore be carefully controlled if it is to be effective.

7.1.2. Just In Time (JIT)

JIT is a widely used and misused term which denotes a philosophy of good business based upon the smooth matching of production to demand, elimination of waste, simplification and continuous improvement. Its popularity stems from its association with Japanese manufacturers, most notably Toyota, and it is often used to refer to part of the Toyota production system known as "Kanban".

JIT is not an alternative to MRP, but in practice the move to a JIT philosophy requires extensive changes and provides extensive benefits to companies whose MRP systems are becoming complex and out of control. The JIT philosophy turns attention away from the regulation of safety stocks to increase the chances of delivering on time and instead focusses upon the basic control problem of the business, to match production to demand through simplified control, engineering improvements and the reduction of the "seven wastes" [70].

Kanban is the control system most often associated with JIT. It is a method of reducing the lead time to the customer and ensuring that production activity is matched to customer demand, not to forecasts or to the generation of inventory. Customer orders are fed to the final work station which performs the final operations to allow the product to be shipped to the customer. The parts required are drawn from a temporary storage location or the previous work station, where a small number (often one) are kept available. (Often it is only by assembly that the parts used become specific to a certain product type, so an order for a specific product can be dealt with by specifying what to assemble, the effective lead time being only the assembly time.) The withdrawal of the items creates a signal to upstream work stations to replace those moved forward. These signals ripple back to the start of the manufacturing route.

The Kanban system provides a very simple way of controlling the production of a limited range of products, and is especially useful if the range consists of variants on a standard where the variation comes from the assembly of alternative standard parts, as in the motor industry. The necessity to have available parts for all possibilities means that a very wide range would increase inventories. However the system provides many benefits, especially in its simplicity and the built-in philosophy of improvement.

JIT and the Kanban system are described in more detail in [71,72,73,74].

7.1.3. OPT

OPT or "Optimised Production Technology" is a commercial CAPM package. It is similar to the MRP approach in that it uses computers to issue orders to the shop floor and for purchasing, but it is different in that it does not rely on lead times to control the timing of activities. The major characteristic of OPT is its regard for bottlenecks in the production process. Bottlenecks limit the output of all products which must be processed by them, irrespective of the amount of work that can be produced at the same time by non-bottleneck resources. OPT develops schedules which take into account the effects of bottlenecks on deliveries, while preventing over-production of inventory at non-bottlenecks and thus maximising throughput while limiting operating costs and inventory costs.

OPT has found many successful applications, although the high cost of the software and the secrecy surrounding the algorithms used has limited its exploitation and assimilation.

A discussion of the development of OPT (including many references on the subject) is given in [75]. A very readable (if biased) discussion of OPT, JIT, Kanban and MRP is given in [76].

7.1.4. PBC

Period Batch Control, or PBC, is a control system much championed by John Burbidge as a solution to the problem of operating with low stocks in cases where line flow and Kanban would be unsuitable, such as in batch production. Burbidge regards PBC as a JIT control system together with OPT and Kanban[77].

The basis of the PBC system is the fixed production period, typically one or two weeks. Each week foremen (of group technology cells or similar units) are issued with works orders for the period, together with a summary of the load represented by that work. The foreman can create a schedule to achieve the demand since no other work can be issued for that period, and can take advantage of scheduling around similar setups and tooling requirements and close scheduling critical items.

PBC is dependent upon the reduction of manufacturing lead times by the use of product organisation rather than process organisation in the factory, and therefore depends upon the use of group technology[78]. Like the other JIT approaches it is also dependent on the creation of good relationships with suppliers to provide deliveries either on very short lead times or on a call-off basis.

A useful description of PBC is given in [79].

7.2. Choice of system

The implementor is thus faced with a wide variety of possibilities from which to choose, and is likely, if unguided, to seek guidance from the vendors of CAPM systems. This is most likely to lead to a recommendation to install MRP.

Apart from the information from system vendors, guidance on the choice of system comes from Burbidge and Parnaby et al.

Parnaby et al suggest that one of the determining factors in the choice of system is the percentage of products of three types:

> "Runners - Products which are regularly required and for which demand allows Kanban style repetitive manufacture within a defined manufacturing planning period.
>
> "Repeaters - Products for which although there is a steady demand it is insufficient to economically allow repetitive manufacture within the defined manufacturing planning period ie products at the start or end phase of their life cycle.
>
> "Strangers - Products for which demand will occur but at low volumes and irregular frequencies eg prototypes, or aftermarket sales. Also products which do not have .... repeating similar features and are suitable for jobbing manufacture." [80]

These authors suggest that runners - or groups consisting predominantly of runners - be controlled in the Toyota style with Kanban style work control and MRP for raw material provision. Strangers and repeaters can be coped with in this system, as long as they are similar enough to use the same production line. For environments with high proportions of strangers and repeaters, product centred modules or cells can be used as small sub-businesses, where the MRP system is additionally used to provide period based despatch lists which can be dealt with by cell controllers. Period Batch Control is also advocated, but it is suggested that it be controlled by a modified MRP.

Burbidge advocates Period Batch Control in preference to Kanban and other re-order point variants because of the problems of inventory and load smoothing[81]. While acknowledging that these have been overcome in many Japanese applications, it is contended that PBC would give similar results and be more widely applicable. MRP is criticised because the requirements are exploded back to the purchasing level, which means that it tends to require the forecasting of future orders for present purchases of material. Secondly, since MRP operates on individual item lead times, purchasing does not operate on the basis of buying sets of items which can be used together, so that variations lead to parts being available which can not be put together, which are seen as excess stocks or shortages according to whether or not assembly is required.

In many cases a hybrid solution is more appropriate for a given factory than any single approach, since there is generally a mix of products with different requirements. It is important to note that a methodology for developing a control infrastructure must provide a means of dealing with an infinite variety of hybrid variations, rather than the simple choice from a small number of alternatives. This means is provided by the task model described in Chapter 9. The control systems required for different product groups can form a basis for the development of groups for cellular manufacturing or Group Technology - integration of the control system design with the design of the factory.

For the implementor, however, criticism of the candidate systems and the wise advice that none of them is likely to be completely suitable is unlikely to be very helpful. The outcomes from CAPM implementations show that some of the characteristics of the systems involved only appear after implementation.

7.3. CAPM fit and flexibility

CAPM solutions are often sophisticated computer program suites developed at considerable expense over many years. The software companies who supply these products make some attempts to tailor the system to fit the needs of the particular company but have to weigh the benefits of such tailoring against the very real problems and cost of maintaining and developing a wide range of systems which could bear little resemblance to each other.

Almost inevitably the computer system implemented in any situation will be short of certain functionality - the system does not fit the application exactly. The lack of fit may necessitate work being done by humans in order to support the system. This may in fact prevent the savings due to the CAPM system being as great as forecast. For example, one of the companies visited found that the new CAPM system actually increased the workload (although it provided other benefits).

If requirements upon the CAPM system change for some reason, the change may be absorbed either by making an alteration to the system or by altering the functions of the people who support the system. Very small changes are likely to be absorbed automatically by people, such as for example the arising need to compare results with those of a previous period. Greater changes, such as the need for a new type of report printout may be accommodated by making changes to the system itself. Still greater changes, such as the need to operate in new ways, for example a change of scheduling rule, may be beyond the system's scope for adaptation and may result in a new task for people, possibly calling for additional systems such as a personal computer. Ways are found to fill the gaps left by a system which does not fit the current situation exactly.

Electronics companies tend to be individually unique with respect to their CAPM requirements, and they operate in a fast-changing and unpredictable environment. Faced with the problems of supplying CAPM systems solutions in this industry, vendors are attempting to produce generic solutions which through the selection of appropriate functional modules meet a good proportion of the requirements of a good proportion of their potential customers. Thus there will usually be a need for some functions to be performed outside the system. It is these external functions which provide the degree of tailoring to fit the needs of a particular company, and which must cushion the system from changing circumstances. Flexibility must come from the environment within which the CAPM system operates.

7.4. Implementation experiences

The following results come from some of the companies visited during the early stages of the research.

Company H installed a system which was geared to existing operating procedures. However, when the system began to be used, it was found that manual fixes which had previously been used to cope with eventualities such as late deliveries had not been designed into the system (they had not been known about). This meant that the new system could not operate as intended, because of the need to operate incompatible manual procedures, which had not previously been a problem.

Company I implemented a scheduling system to control manufacturing processes, but found that the route cards produced by the system had to be checked manually to produce purchasing requirements.

Company J found that the implementation of an MRPII system increased the workload of indirect staff to the extent that more people had to be recruited.

Company G found that it required manual operations to interface between its CAPM system and its CAD system.

Company A found that its MRP based CAPM system was rendered unable to operate by its policy of flexible manning in component stores, which led to very low data accuracy.

These examples show problems which have arisen in CAPM systems which are due to the interaction between the computerised and manual elements of the system. In each case, system design was based upon requirements definitions which failed to take into account the functions of the non-computerised elements of the systems.

An approach is required which takes into account the wider issues which arise in manufacturing companies including the management, integration and operation of both technology and people. These have been noted by Burns and Stalker[82], and more recently by Parnaby[83,84], and Bessant and Haywood[85]. The remainder of this chapter will look at the non-computerised elements in the CAPM system.

7.5. Non-computerised elements

For successful implementation, attention must be paid to the system type guidelines above and also to the "hidden" aspects of production management, the policies, procedures and practices involving people in the system.

7.5.1. Policies

A policy is a set of rules held by the company or its employees which governs the way it operates, and dictates the responses it makes to external pressures. For instance a company has policies which relate to its dealings with its employees which dictate under what conditions they are employed, what is expected of them, what actions are acceptable, etc. It will also have policies which relate to manufacturing, which may dictate the type of tools to be used for various jobs, the levels to which capacity must be loaded, the way work is to be prioritised, the way customers and suppliers are to be dealt with, etc. Policies reflect the values held to be important to the business and may often be traditional within the company.

Policies establish the broad framework which governs the way the activities are carried out. They are closely linked to strategies and must therefore be formulated at a level of management where the strategies for a particular area are formulated. In many companies policies are unwritten and are learned by individuals from the example set by the conduct of their more experienced colleagues. In some cases, especially where they relate to product quality, companies have made great efforts to establish and publicise their policies. This serves both to make employees explicitly aware of what is expected of them and to demonstrate to customers and other outsiders that the company is a well managed one in which acceptable policies are clearly set down.

7.5.2. Procedures

Procedures are instructions which dictate the way activities within the business are to be performed. Formal procedures describe the activities required in certain circumstances. They may include instructions issued to ensure the correct use of specific pieces of equipment, or those instructions which stipulate the course of action required to deal with sub-standard goods or customer complaints. Formal procedures may be found in quality manuals, safety manuals or other reference documents.

Informal or unofficial procedures are more likely to be found where methods of working have been developed to meet circumstances by the individuals concerned. The operation and possession of these procedures can form the span of control developed by an individual, and may provide benefits to the individual rather than to the interests of the company as a whole.

The procedures should lie within the policies, so that operation of the procedures fulfills part of the requirements set at the policy level.

7.5.3. Practices

Practices are the actual activities which are performed in the business. Often they are activities which fulfil established procedures, although the procedures may not be sufficiently detailed to identify them. Alternatively, the practices used in a certain situation may violate established procedures, in which case they may fulfil an unofficial procedure. Practices include, for instance, keeping extra products under the bench to combat bonus schemes, taking steps to verify customer orders, attending meetings. These all have an effect on the company at the level of the individual.

7.6. Tasks and decisions within Production Management

Having established that the way people work can be classified at different levels into policies, procedures and practices, the next section considers the activities which the people in the system undertake.

Production management can be thought of as a series of tasks and decisions which are necessary to the operation of the company. Production management provides information necessary to production, for instance:

work-to lists, schedules, works orders

purchase requirements lists, purchase orders.

Production management also processes information from other areas which is required for production,such as:

designs, works instructions, process layouts, bills of material, quality standards.

Another function of production management is in the recording and reporting of production information for use in other areas, such as:

production costs, performance to schedule.

In the production scenario where Computer Aided Production Management systems are being employed, many of the tasks which must be performed to provide this information will be performed by the computer system itself, while other tasks will continue to be dealt with manually.
A production management system may therefore consist of both manual tasks and computerised tasks. The system may be seen as an automated data processing task which requires some human intervention to manage and maintain it, especially to bring information and to take away the results. Alternatively the system may be regarded as a manual operation in which a computer is employed to support some operations.
The system can be configured in many different ways along a continuum from totally manual to mostly computerised. The system must however be treated as a whole with respect to the demands placed upon it and especially its flexibility and resilience to continue to operate when the demands change.

7.7. Interdependence of people, machines and computers

Production management concerns the performance of a series of tasks.
In some companies, all the tasks are done by people. In other companies, some of the tasks are performed by people and some by

computers. When machines and computers are introduced into companies to perform certain tasks, the tasks of people can be changed or removed and new tasks can be created.

The relationship between people and computers is often unsatisfactory, both from the point of view of the people concerned and from the point of view of designing efficient, flexible systems. People prepare material and information for machines and computers. People take the outputs from computers and translate them for other uses. People re-process the output from machines to perform functions which the machines cannot. In general, people seem to do the tasks that cannot easily be given to machines or computers. This means that people retain the jobs based on thinking creatively and the jobs which require flexibility to work in completely new ways, but it also indicates the simplistic way systems are often designed. (The design of the system will be looked at in the next chapter.)

Machines and computers are in general only able to perform a small range of tasks. Even the ones that are regarded as more flexible - such as Flexible Manufacturing Systems (FMS) - are not really flexible when compared to people. In some respects it is their very inflexibility which makes them attractive since their output is more consistent. In any application, machines or computers must be supported by people.

Consider the example of an automated component insertion machine used for assembling electronic components onto printed circuit boards (a "pick and place" machine).

To allow the machine to operate it must be provided with materials which it can accept. Circuit boards must usually be provided with location features to provide data for the machine's coordinate system. The components to be inserted must be held in tubes or bandoliers which present them in the correct orientation for the insertion head of the machine. If these conditions are fulfilled, the machine is able to produce its consistent output at high rates.

However, a major concern of many manufacturing companies, particularly in the electronics industry, is the ability to respond to a range of changing conditions. Whilst the pick and place machine can very quickly be switched to produce a different item from its pre-programmed repertoire, it requires human intervention to make allowances for any change in its supplies. For instance, if components are badly packaged, or packaged in a different way from usual they must be re-packaged for the machine to be able to use them. In the case of reversed polarity, the machine may not even notice the error and may continue, regardless, to insert components back to front. If pins were slightly bent, the machine would be likely to make a faulty insertion or possibly to reject the component.

In comparison, a human component insertor would have no such problems. In fact these problems would normally be dealt with at an unconscious level, not even being worthy of mention. The packaging would be disregarded, the component would be inserted correctly; the bent pin would be straightened. The human compensates automatically for the variations, and in addition, the human is likely to have very much shorter re-programming and set-up times.

In the case of the automated machine, it must also be noted that its supplies of materials must usually be delivered by human means, so the machine is also dependent on human intervention in the case where no disturbance occurs.

Thus the alternatives are a technological solution which is basically inflexible and a human solution which is basically very flexible.

This analogy can be applied to many kinds of machines and computers. A manufacturing system containing machines and computers always relies on the intervention of people to allow it to continue to work under changing circumstances.

The only way such systems can be useful is if they have an environment which is sufficiently stable to require no more flexibility than they can provide. But, as has been stated in Chapter 3, it is not stability but change which appears to prevail. Such systems must therefore be isolated from the environment by buffers of inventory or time, protected from the environment by people who care for them or replaced by systems which more closely match the environment.

Research has tended to concentrate on the development of ways of increasing the flexibility of technological solutions. An alternative is to improve the whole system by making better use of the human elements. A method of designing a system comprising human and computer elements is required. A modelling approach which can show the relationships between the various elements is the first step in developing such a method.

Summary

The CAPM implementor, even having established the context for CAPM, still has many choices to make in the design of the system. Whilst the rules of thumb of Parnaby and others are of help in determining the broad control technique required for each product group, the whole system and its day to day operations cannot be considered in isolation from the human and organisational factors including policies, procedures and practices.

The next chapter will look at the questions involved in the design of the system.

Chapter 8. The elements of the CAPM solution

The foregoing stages of the methodology, described in Chapters 5 and 6, have provided ways to define the business context within which the CAPM solution must operate and to establish the principal operating characteristics and requirements for the system. Chapter 7 has looked at the complexity of designing the CAPM system.

An approach to the specification of the complete system needed to meet the requirements is now required. This means identifying the tasks which must be carried out to meet the requirements, allocating tasks to people or computers and designing or specifying the computerised and human systems to fulfil the tasks.

To decide which (if any) tasks should be computerised, the optimum division of labour between the people and the computers must be determined.

8.1. Background

Many writers on production management systems are concerned not with the question of whether to computerise production management, but how. The assumption is made that different situations will indicate different priorities for computerisation.

The literature provides some help on the choice of system elements to computerise. Schofield and Bonney look at the statistical similarities between companies using eight typical CAPM modules, in order to suggest that these similarities show the predictors of necessity for computerising various tasks. A study by researchers at UMIST takes a similar approach but concentrates upon the development of a company classification scheme and an "ideal" module implementation sequence.

March and Simon look instead at the nature of the work being performed by the computer, in order to deal with the question of whether it is appropriate to allocate tasks of various types either to people or to machines. The applicability of their analysis here rests on the assumption that tasks consist of decisions. Their work is based upon deriving an understanding of the behaviour of people in organisations, particularly those individuals in executive (managerial) roles. Their work can be applied to production management, which consists largely of decisions which are routinised to varying degrees.

Singleton's contribution is also based upon the nature of the work, but from a psychological and ergonomic perspective not limited to decision-making.

8.2. Empirical approach - Under what conditions are various computer systems used?

This section looks at the applicability of computer systems in various situations.

8.2.1. Schofield and Bonney

Schofield and Bonney[86] were able to reprocess the findings of a survey of 186 manufacturing companies produced for the British Institute of Management[87], in order to investigate the business context in which production control systems were operating. This was based upon, but also testing, the assumption that production control requirements would depend upon the business context to such an extent that the nature of the context could be used as a predictor of systems requirements. This work provided a framework in which

> "any batch manufacturing company [or researcher] interested in 'comparing notes' can perform a self-assessment based on various relatively simple measurements."

The extent to which the work can predict the need for computer systems is based upon the two thresholds of "sufficiency" and "necessity". The sufficiency threshold for a particular area is crossed when a company reaches a position where it can usefully take advantage of a computer for that work. The necessity threshold is reached when the work in an area exceeds the limits of manual means, and thus computer assistance becomes necessary. Since the researchers observed that the companies only installed computers "in an ultra-conservative way", that is, when the necessity threshold was reached, the situation of a company installing a particular system was assumed to indicate the necessity for the particular system installed.

8.2.1.1. Correlations

The work attempted to correlate data on situational or environmental factors shown in Table 1 with data on system installation shown in

Table 2. The determinant factors found to correlate with the installation of each system are shown in Table 3.

Table 1. Factors used by Schofield and Bonney for classifying the manufacturing environment

Factor Code	Factor Description
1.	Overhead cost as a percentage of product cost
2.	Percentage of output, by value, made for stock
3.	Percentage of output, by value, made to order
4.	Number of different products manufactured
5.	Percentage of products new in last 12 months
6.	Number of live item records
7.	Number of different components in product with largest turnover
8.	Percentage of components, by number, made in house
9.	Percentage of components, by number, bought out
10.	Bought-out items' cost as percentage of product cost
11.	Labour cost as percentage of product cost
12.	Total manufacturing lead time (on average)
13.	Average delivery lead time - total manufacturing lead time
14.	Maximum delivery lead time - total manufacturing lead time
15.	Left blank for additions
16.	Average number of planned operations for component batches
17.	Maximum number of planned operations for component batches
18.	Number of sub-assembly stages for planning purposes
19.	Average assembly lead time
20.	Average delivery lead time
21.	Maximum delivery lead time

Table 2. Series of computer system types used by Schofield & Bonney

System Code	Computer System Description
1.	Any computer system for production planning and control
2.	Inventory status and recording
3.	Order entry
4.	Material requirements planning
5.	Re-order point stock control (or similar)
6.	Capacity planning
7.	Detailed shop scheduling
8.	Forecasting delivery promises
9.	Monitoring work-in-progress

Table 3. Relationship between discriminant function values and predictions of computer system usage, from Schofield & Bonney

System Code	[predicted by] Discriminant Factor Codes														
1.			4		6	7			12	14		17	18		21
2.	2		4	5	6	7						17			
3.	2		4	5	6	7						17			
4.					6	7	9	10		14		17	18	19	21
5.*			4		6	7									
6.		3			6	7			12			17			
7.		3			6	7			12		16	17	18		
8.					6	7							18		
9.		3			6	7			12		16	17			

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* In the published paper, the lists of factors for system types 5 and 6 are transposed between Table I on p117 and the distribution curves on p123. The table is shown here in the form believed to be correct.

8.2.1.2. Testing

These relationships, from the BIM sample, were tested by Schofield and Bonney in the further examination of eight companies. The situational profiles were assessed and the statistical model supporting the correlations was used to predict the companies' computer requirements. The results showed a good match to the actual systems which had been installed. The match is shown in Table 4 (adapted from Schofield and Bonney's Table II).

Table 4. Showing the cases where predicted status and actual status of computer systems agreed (adapted from Schofield and Bonney).

(Blanks indicate incorrect predictions)

Company	Computer System								
A	1	2	3	4	5	6	7		
B	1	2	3	4	5	6	7		9
C	1	2	3		5	6		8	
D	1								
E	1	2	3	4	5	6		8	
F	1	2	3	4			7		9
G	1				5			8	
H	1	2	3	4	5	6	7	8	9

Most of the anomalies in the results related either to two particular companies or to three particular computer system types. Of the two companies, one (D) was currently in process of computerising, whilst the other (G) had only just moved into the area of "sufficiency" and had taken steps to improve its manual systems instead of computerising. The lack of system types 7,8 and 9 where they were predicted to be needed was attributed to

> "the difficulty that many companies have in introducing the more sophisticated systems in the difficult areas of production control".

8.2.1.3. Discussion

The recurrence of factors 6, 7 and 17 as determinants in Table 3 may suggest that many systems are implemented when data volumes increase, which would appear to relate CAPM implementation to company growth as suggested in Chapter 1. The factors which would be associated with high data volumes, 4, 6, 7, 16, 17 and 18, account for 35 of the 53 relationships shown, and with factor 12 account for all the factors appearing four times or more. Factor 12 may be related to factors 16 and 17. The factors which do not appear, 1, 8, 11, 13 and 20, also do not appear to relate to data volume in any direct manner.

8.2.1.4. Critique of Schofield and Bonney's work

This work highlights some of the points raised earlier in this thesis. Schofield and Bonney refer to a company which

> "had taken the approach of organising its manual systems as well as possible. In particular, the batching of work lent itself to display on a large production board and most of the control function was directed by correct operation of the board system".

The possibility that a solution based upon the simplest possible method may be more appropriate than a computer system, and that this may be true of other systems in other companies, is not explored.

The work shows correlations between the systems installed in the 186 companies and the situational factors (manufacturing profiles) which characterised the production situations. However the precise nature of the correlations is not given in the paper cited, and there is no evidence presented as to which of the factors determinant of a particular system type is the most significant. From the data reported it is also impossible to see at what level a determinant factor becomes significant. The usefulness of the work is thus limited to the qualitative statement that certain situational variables tend to lead to a requirement for certain production control system types, and that factors related to company growth are strongly related to CAPM usage. However, for any particular company it is impossible to know whether the levels of the determinant factors in the particular situation are high enough to be significant to the system requirements for the situation. Practical application of this work would be difficult.

8.2.2. UMIST

Work done at UMIST by Barber and Hollier took a similar approach to Schofield and Bonney, in that computer systems were related to the company situation.

8.2.2.1. Description

Six different company types were classified[88], and the reported success of eleven different CAPM sub-systems was assessed. From the relationships found, the most beneficial systems for the company type were identified[89]. The implementation sequence was also considered. This was based upon the factors:

"(i) interdependence of sub-systems,

(ii) potential for early realization of benefits and

(iii) company classification."

Later work at UMIST by Petty (as part of the ACME CAPM Initiative) developed a new classification system[90] and produced an idealised implementation sequence for each company class[91].

8.2.2.2. Critique of UMIST approach

The UMIST approach, like the approach of Schofield and Bonney, is centred upon the assumption that the solution to problems of complexity and variety in manufacturing is to install a suitable set of CAPM modules, which can be identified from the characteristic "profile" describing the company's situation. This approach however does not concentrate on the manual approach, looking mainly at the application of computerised solutions.

The assumption that all companies of the same type need the same CAPM systems, which underlies the UMIST work, can only be used as a rough guide since the variety of different possibilities in manufacturing means that within the broad classifications there are many possible situations and therefore many possible correct solutions.

Whilst Schofield and Bonney and the UMIST researchers have demonstrated general similarities between CAPM configurations found to be useful in companies with certain similarities, the derivation and prescription of systems requirements from situational parameters is of sufficient complexity and unreliability to make it difficult to apply to any particular company's situation. Success would only be a statistical probability. Instead, an approach based upon the nature of production management itself may be considered.

8.3. Theoretical approach

This section looks at the application of computers to different kinds of task.

8.3.1. March and Simon

In their study of the structure and functioning of organisations[92], March and Simon deal with the motivation and cognition of individuals within organisations, with special reference to decision taking. This work contrasts with the work described above since it is based upon the nature of the work done, rather than upon the business situation. Thus there is no discussion of CAPM modules or of company types. The findings can be applied in the question of whether to computerise a particular task, according to the extent to which the decisions involved in the execution of the task are "programmed". The approach concentrates on the work itself, rather than relating requirements to the more abstracted business context.

The individual is seen as a constant taker of decisions which affect his behaviour in the organisation. These decisions include those taken by executives in the control of the company, those taken by manual workers as to the way in which they operate, and those decisions taken by all members of the organisation such as the decision to participate. This analysis rests on the extent to which the individual has choice about actions. Even when a simple direct instruction is issued, the individual must decide how or whether to obey the instruction, with the extreme alternative being the withdrawal of labour.

The decisions taken in organisations are seen as being to varying degrees "programmed" or "non-programmed".

> "Decisions are programmed to the extent that they are repetitive and routine, to the extent that a definite procedure* has been worked out for handling them .... if a particular problem recurs often enough, a routine procedure will usually be worked out for solving it. ....
>
> "Decisions are nonprogrammed to the extent that they are novel, unstructured, and consequential. There is no cut-and-dried method for handling the problem because it hasn't arisen before, or because its precise nature and structure are elusive or complex, or because it is so important that it deserves a custom-tailored treatment." [93]

The difference between the two is that at one extreme the individual has to make a "search" for alternatives, or create new solutions to the problem, whereas at the other extreme the decision has been well rehearsed and the appropriate response is clear. At the simple end of the continuum, the decisions are described as "programmed", since the outcome depends upon the individual applying a routine set of criteria to the case to determine the outcome, which activity constitutes a "performance program". When the problem is new to the individual, no program exists for its resolution, and the individual must search for and evaluate alternative courses of action. When the individual applies creativity to a problem, the search for alternatives is also

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* Simon here uses the term "procedure" in a loose sense which includes practices and informal procedures as described in Chapter 7.

the development of a program to deal with the problem when next it arises.

March and Simon pursue the behaviour of the individual in investigating the limits on rationality in decision taking. The model of rational man assumes

> "(1) that all the alternatives of choice are 'given'; (2) that all the consequences attached to each alternative are known .... ; (3) that the rational man has a complete utility-ordering for all possible sets of consequences." [94]

In the absence of these ideal conditions, rationality can only be assessed with reference to a specified frame of reference - the company.

In considering the selection of either a human or automated decision taker, the limits of rationality apply equally to both if it is assumed that the computer is given a program which allows it to mimic the human it replaces. Thus the task performed by the computer depends upon its program, as does the performance of the human. The difference arises where the program is found to be lacking. The computer is unlikely to be able to pursue a search and develop new programs. Even an artificial intelligence application is unlikely to have all the necessary data to hand.

From this discussion can be drawn the implication that for information processing activities (which includes those of production management), the computer may be able to perform the tasks which are programmed to the extent that the constituent elements of the program can be (a) made available, that is, expressible in a useful form, and (b) used to make a suitable program for the computer.

The difficulty which arises here is that the programs developed by individuals are built up from their experiences and stored in their minds. Programs for even very simple tasks may include subroutines which are executed under certain conditions only; the nature of the conditions and their associated activities may prove very difficult to bring to a conscious level. Further, as has been stated in Chapter 7, the tasks of individuals are likely to consist of practices which fulfil only informal procedures and which may therefore only be known to the individual. Analysis of computer requirements often begins by considering the formal procedures.

8.3.2. Singleton

The problem of allocating functions to humans or machines is considered by Singleton[95], who includes computers under the heading of machines. Three views of the problem are presented. The following three sections are based upon Singleton's work.

8.3.2.1. Relative advantages

Based upon the work of Fitts[96], lists comparing the relative advantages of humans and machines in various ways can be developed. An example of a Fitts list produced by Singleton is shown in Table 5.

8.3.2.2. Differences between humans and machines

The Fitts list approach was criticised by Jordan[97] who pointed out that it was an approach which ignored the particular advantages of flexibility and adaptability which make humans fundamentally different

Table 5. Fitts list produced by Singleton

Property	Machine	Man
Speed	Much superior	Lag one second
Power	Consistent at any level Large constant standard forces and power available	2 horsepower for about ten seconds 0.5 horsepower for a few minutes 0.2 horsepower for continuous work over a day
Consistency	Ideal for routine, repetition, precision	Not reliable - should be monitored Subject to learning and fatigue
Complex activities	Multi-channel	Single channel Low information throughput
Memory	Best for literal reproduction and short term storage	Large store multiple access Better for principles and strategies
Reasoning	Good deductive Tedious to reprogramme	Good inductive Easy to reprogramme
Computation	Fast, accurate Poor at error correction	Slow Subject to error Good at error correction
Input	Some outside human senses, eg radioactivity Insensitive to extraneous stimuli Poor pattern detection	Wide range (10^{12}) and variety of stimuli dealt with by one unit, eg eye deals with relative location, movement and colour Affected by heat, cold, noise and vibration Good pattern detection Can detect signal in high noise levels
Overload reliability	Sudden breakdown	Graceful degradation
Intelligence	None Incapable of goal switching or strategy switching without direction	Can deal with unpredicted and unpredictable Can anticipate Can adapt
Manipulative abilities	Specific	Great versatility and mobility

to machines, rather than like machines with different specifications. This implies that tasks should be designed with the abilities of the human operator in mind, producing a design in which human functions are made use of, not subjugated to acting as part of the machine.

8.3.2.3. Delegation of function

Another approach is to look at the system in the way the technology evolved, that is, to extend the functionality of humans by providing devices to which functions could be delegated. This is the reverse of the "classical engineering" approach which used humans to fill the gaps of functionality which could not be provided by machines. Paradoxically, a system which has fewer people is much more dependent on each individual within the system, and therefore more vulnerable to human failings such as error or absence.

8.3.2.4. Job design considerations in the allocation of function

The use of human skills depends upon the nature of the skills available, and the skill of the system designer to create jobs which contribute to the overall system.

A set of graded tasks may be provided to allow different people to use their different skills; to provide job rotation or autonomous working groups; to provide a route for personal development, promotion or training.

Most importantly, the design of the system must result in meaningful, whole jobs to make the best use of people and to provide an acceptable working pattern. The reorganisation which the computerisation of tasks necessitates could affect the tasks people are called upon to perform, and the relationship between people within the company. This aspect is discussed in [98,99,100].

8.4. Implications for human and computer system design

The above discussion does not, unfortunately, give any simple rule for the choice of human or computer means for a production management task. Simon offers the doctrine of competitive advantage:

> "those tasks in which machines have relatively the greatest advantage in productivity over men will be automated; those tasks in which machines have relatively the least advantage will remain manual." [101]

From a more modern standpoint, and considering Singleton's contributions, Simon's use of "productivity" as a criterion of choice appears naive. We are now able to see other ways in which the decision may be taken. (Furthermore, the use of productivity as a global measure has been strongly questioned. See section 3.1.)

No mention has so far been made of the possibilities of using computers for non-programmed decisions. In fact it was forecast by Simon that simulation tools would allow computers to take on many non-programmed decisions. Leavitt and Whisler[102] suggested that this would result in a changing division of labour in the middle-management levels, with the effect of more jobs being separated out and allocated to "information technology" in the same way that Taylor[103] simplified and programmed manual work, with the effect of centralising the decisions, creativity and fulfillment to the top of the organisation. Zuboff suggests on the other hand that the effects and possible benefits of information technology could be much more far-reaching than the simple transition from manual to automated[104]. In any case, it is clear that the roles of computers must be carefully integrated with and developed in line with the roles of people[105].

A simple guideline would be to consider allocating programmable tasks to computers, while leaving the creative and "search" tasks to humans. Ultimately, however, it seems that day-to-day pressures on managers are likely to result in computers being given the tasks for which computer programs are most readily available. Although computers are moving into the field of non-programmable tasks and even consultancy by artificial intelligence etc, and the alternative strategy "informate" has been suggested as an alternative to "automate", (Zuboff) applications in the CAPM area at least are still seen as applications of partial automation. It would not be unreasonable to expect that computers would be given a selection of the programmable tasks, and that the rest of the programmable tasks, and the task of supporting the computers, would remain with humans.

This proposition was tested in a survey by Duprey et al[106] who found that computers were being used much less than expected by production managers, especially in small firms. The researchers suggested six possible reasons:

"(i) a lack of any attempt by the small business manager to identify programmable decisions.

(ii) a lack of an ability on the part of the manager to separate programmable and non-programmable decisions.

(iii) An ignorance of the capabilities of the micro-computer.

(iv) a belief held by small business managers (possibly true) that the available software packages are not directly suitable for their applications in the management of manufacturing.

(v) a belief that computing is a specialised task capable of being carried out only by highly paid professionals using very expensive equipment.

(vi) a fear of purchasing the wrong hardware or system for the particular application(s) required."

Broedner observes that

"Most managers and production planners follow a strategy to replace human work .... by enforced use of computers .... Since this strategy is in danger of creating new problems, the growing minority seeks to avoid them by reorganizing production and rearranging the division of functions between man and machine in a way that makes use of workers' skills instead of reducing them to operating servants." [107]

Evans' study of human error highlighted areas where poor application of computers had put individuals in positions where errors were likely.

"people are able to out-perform machines in many applications, but the price of human flexibility is fallibility. Unfortunately, application of the automation that is available sometimes results in jobs that are highly vulnerable to error because the relationship between man and machine has not been thoroughly thought through. In most companies the study revealed examples of computerized systems that had been optimised from a technical standpoint and left people to cope as well as they could." [108]

These reasons point to the need for more detailed understanding of the tasks involved in production management. Only when the nature of each individual task is understood can the choice of means for each task be assessed as the basis for the design of a whole system.

8.5. Humans versus computers - guidelines

Humans are more adaptable to change, and are especially good at making improvements to working practices, exerting judgement, changing from job to job, coordinating operations between individuals, dealing with variable input (information or material), correcting errors, and to some extent to changing output requirements (doing new things and accepting impossible demands).

> "The fantastic abilities of people to plan, remember, and use judgement, wisdom and intelligence extend far beyond the capabilities of computers and mechanization" [109]

Humans are less good at coping with extreme repetitiveness (such as high volumes of data, long production runs), maintaining consistent output over long periods, and coping with large numbers of input sources.

Computerised solutions are better at dealing with vastly repetitive tasks and coping with large data volumes and numbers of inputs, as long as the circumstances do not exceed the limits which were taken into account by the programmer.

Computerised solutions are less good at responding to changing output requirements, detecting irrationality, "thinking".

In situations of repetitiveness, such as where high volumes of data are involved, computerised solutions should be considered. In situations where frequent changes and new situations must be dealt with, manual approaches involving appropriate policies, procedures and practices may be more successful.

Summary

The design of the most appropriate production management infrastructure involves the careful use of the human and computer elements. This design process should be based upon the nature of the tasks themselves, since guidelines based upon the overall business type or class are difficult to apply. The comparative studies described above (Schofield and Bonney, Barber and Hollier) have produced research findings which suggest the use of certain systems in certain situations, but they are limited by the analysis being at the level of the module. This simplification compared to the complexity of the CAPM problem must mean that these findings can serve as no more than guides or checklists. The dangers of applying general findings to specific instances, any of which could be exceptional in many different ways, indicates the need for a more detailed approach in each individual company, and in each individual task.

Chapter 9. Modelling CAPM tasks

In designing an effective and flexible production management system, the allocation of duties between humans and computers and the integration of their activities to provide the required whole system must be considered. This analysis requires an understanding of the tasks themselves. For the implementor who may never have operated a CAPM system, it is impossible to determine what tasks will be required. If the user company is to take charge of its implementation without being led by consultants or vendors, some detailed guidance must be provided.

To address this requirement the author has developed the CAPM task model. It aims to provide a framework of CAPM tasks which can be used as a basis for the company to determine the structure of its own future system, once the initial stages of the process methodology have been used to define the context for CAPM and the broad requirements.

The CAPM task model can be used to translate the rough cut control strategies and control system objectives established previously into a set of required functions which the CAPM system must fulfil. These requirements can then be used to design the system, taking into account the demands made upon computers and software packages and upon people.

The model should improve understanding of the wide range of tasks which may be required, and it provides guidance on the circumstances under which each task is required, and the circumstances under which each task may beneficially be computerised.

The model focusses upon tasks, rather than upon the data which is used and produced by each activity. Whilst other modelling techniques (such as SSADM[110] or IDEF[111]) can show activities, their inclusion of data flows can complicate the process. By keeping the modelling technique as simple as possible it was hoped that it would be more clearly understood by non-experts. The focus upon tasks allows the model to be used to show changes in the content of the jobs of individuals and groups within the system.

9.1. Development of the task model

9.1.1. Tasks vs. modules

The comparative studies outlined in Chapter 8, and much of the literature on CAPM, use the "module" as the unit of analysis.

"Modules" are the discrete software packages which are offered by system vendors, allowing users with different requirements to assemble systems of different functionality. Each module provides support for tasks in a certain area of CAPM, such as Sales Order Processing or Capacity Planning. The modular approach can provide an implementation path which allows the company to develop a system in stages.

For the user-led approach to apply to the selection of system elements, the user must be able to determine the functions required of the system and make a choice with some idea of the consequences for the organisation. Questions about the changes in responsibilities and working practices are impossible to answer from the information provided about each module, partly because this depends on the circumstances of a particular implementation and partly because the matter is not usually addressed. In order to gain a thorough understanding of the system being designed, more detail is required.

Another difficulty with the modular approach is that the boundaries between modules are drawn differently by the different vendors. This means that modules with similar names may perform different functions, the purchaser possibly not aware of the exact functions until after implementation.

In order to reduce this ambiguity it was decided to produce a model describing the elementary tasks involved in production management. The model would help the company to determine which tasks it would wish to computerise, and which to retain as manual tasks. It would also provide a medium which could be used to ask a vendor whether a system would perform certain tasks, and what additional tasks would be entailed.

Extensive research in literature and through academic colleagues has shown that such a model has not previously been developed.

9.1.2. Approach

The generation of the task model was an iterative process based initially upon the group of case companies visited in the early part of the research.

To aid this process the author made use of a proprietary software tool produced to support consultancy work in information technology strategy.

Having gained an understanding of the operating arrangements of these ten companies, it was attempted to divide production management into its constituent tasks, and then to decompose these tasks into lower level elements, and so on as far as possible.

The model then underwent considerable development during which it was criticised and commented upon by academic colleagues, system vendors and users, and at all stages edited and improved. In the most recent stage of development it was modified and improved in the detailed study of two case companies. This will be described in section 9.2.

9.1.3. Tetrarch Hierarchical Business Modelling

Tetrarch is a comprehensive consultancy methodology for the development of an "Information Technology Strategy" supported by a range of software tools which manage the information generated in the process*. Tetrarch's Hierarchical Business Modelling tool was used for the construction of the task models.

Hierarchical Business Modelling is a technique which uses a tree-like structure to decompose a business into its basic activities. The top level box represents the business as a whole, and contains a statement

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* The Tetrarch consultancy tool is developed and owned by PA Consultants, a collaborating establishment in the CAPM Project. The usefulness of the Tetrarch package is gratefully appreciated.

of the corporate mission. The assumption is made that all the activities going on within the company contribute to the fulfillment of the corporate mission, so that the company's activities can be broken down level by level. This decomposition should lead to the identification of all the tasks performed.

The decomposition of activities uses a simple approach based upon the generic activities required to perform a task. These are:

plan the activity, and determine objectives;

procure the resources required to perform the activity;

procure the materials which will be transformed;

produce the required output (use the resources to convert the materials);

audit the success of the activity and the plan.

These five types of activity are used where possible to decompose each activity, and they are shown from left to right on the chart. In manufacturing terms they correspond to tasks of the following types, which represent the business transactions in the second level of the chart:

Maintain the Strategic Plan;

Maintain the Infrastructure;

"Get" Transactions;

"Put" Transactions;

Audit Performance and Mission.

"Get" transactions refer to the activities involved in acquiring and/or making the items (entities) involved in the business.

"Put" transactions refer to the activities involved in selling and/or delivering the products or services produced by the business.

The model is built up by decomposing each of these activities into its constituent parts down to a basic task level at which the information required in managing the business can be identified. The Tetrarch methodology then uses this information to identify informational entities, subject databases and information sets which are used in the identification of candidate IT systems. The model does not show the informational linkages between the boxes and is not used directly for system design. Thus, the information flows do not inhibit true decomposition in the construction of the model.

The Tetrarch software tool was useful for manipulation of the model but it was found to provide only poor quality printed output. For purposes of presentation and portability the models were redrawn using a software tool developed by the author for this purpose.

9.1.4. Task Characteristics

For each of the tasks in the model an attempt was made to determine why the task was required for the particular company. These task determinants will aid the use of the model as a template to determine which tasks are required in a company under investigation. A full set of supporting notes is included with the model.

Three types of task were recognised.

9.1.4.1. Core tasks

Some tasks appear to be necessary in every manufacturing company, in which case the situational characteristics could only affect the way in which the task was performed. These tasks were regarded as "core tasks". These included for example "Process orders", "Handle goods inward".

The decomposition of a core task could include optional tasks according to the way in which the core task was performed, particularly the decision whether or not to computerise the task. Thus the critical question for a core task is only how it should be done, which is determined by the lower level tasks of which it is constituted.

9.1.4.2. Optional tasks

In the cases where the task requirement was seen to depend upon a situational characteristic, the task was regarded as "optional", since there would clearly be cases in which the task was not required. Examples of these include "Confirm order to customer", "Inspect goods". Where they could be determined, the particular reasons for optional tasks being necessary were recorded.

9.1.4.3. Dependent tasks

A third category of tasks emerged. These were tasks which were found in the decomposition of optional tasks, but which were not themselves optional. These were necessary in any instance in which the parent task was required, thus depending upon the appearance or non-appearance of an optional task. For example, "Report capacity requirements" is an optional task whose decomposition must always include "Aggregate product profiles" and "Identify work for specific time buckets". These tasks are therefore compulsory in the case of the parent task being required. Tasks of this type were regarded as "dependent".

9.2. Validation and further development of the task model

The two main aims in validating the task model were to ensure that the model was sufficiently generic to provide a base which, by adding the lower levels of detail, could represent the CAPM system of a user company, and to ensure that the model could be understood sufficiently well to be useful to a user.

Two companies were used for this stage of the work. One of these companies used a totally manual CAPM system with no computer support whatsoever, while the other used a computer based system. The generic model and the two company subsets are presented in Appendices II, III, and IV.

9.2.1. Company K

This company, an electronics subcontractor, was regularly visited by an undergraduate student in connection with his final year project[112]. This access provided the data allowing the production management tasks within the company to be modelled.

This exercise aided the development of the model by identifying tasks which had not previously been recognised, such as "Check customer credit status", and by forcing restructuring where the decomposition was found to be incorrect, such as the differentiation between long term (planning) and short term (scheduling) tasks.

9.2.2. Company L

The production manager of a pharmaceutical company expressed an interest in the task modelling approach. A copy of the model was sent out and after a short time an invitation to discuss the model was obtained.

During the discussions which followed, it was found that most of the company's CAPM tasks could be mapped on the model without alteration. Some other tasks, such as "Monitor down-time", were added to the model.

9.2.3. Outcome of the validation exercises

These exercises represent a very limited validation of the task model. However, they provided encouraging results.

From the experience from Company K, although the structure of the model was confused in some ways, and tasks were missing, the model was sufficiently correct to imply that a generic model of this type was indeed possible.

The experience at Company L was encouraging because it showed that the model was able to be used to represent a non-electronics company, even though only electronics companies had previously been studied.

Another positive point from this experience was in its illustration of the way CAPM works - the manager concerned found that some tasks shown on the model were in fact being carried out informally by his own staff. This provided a better understanding of the operation of a system which he had previously designed, installed and managed.

Since some validity may now be attached to the model, attention now focusses upon its use.

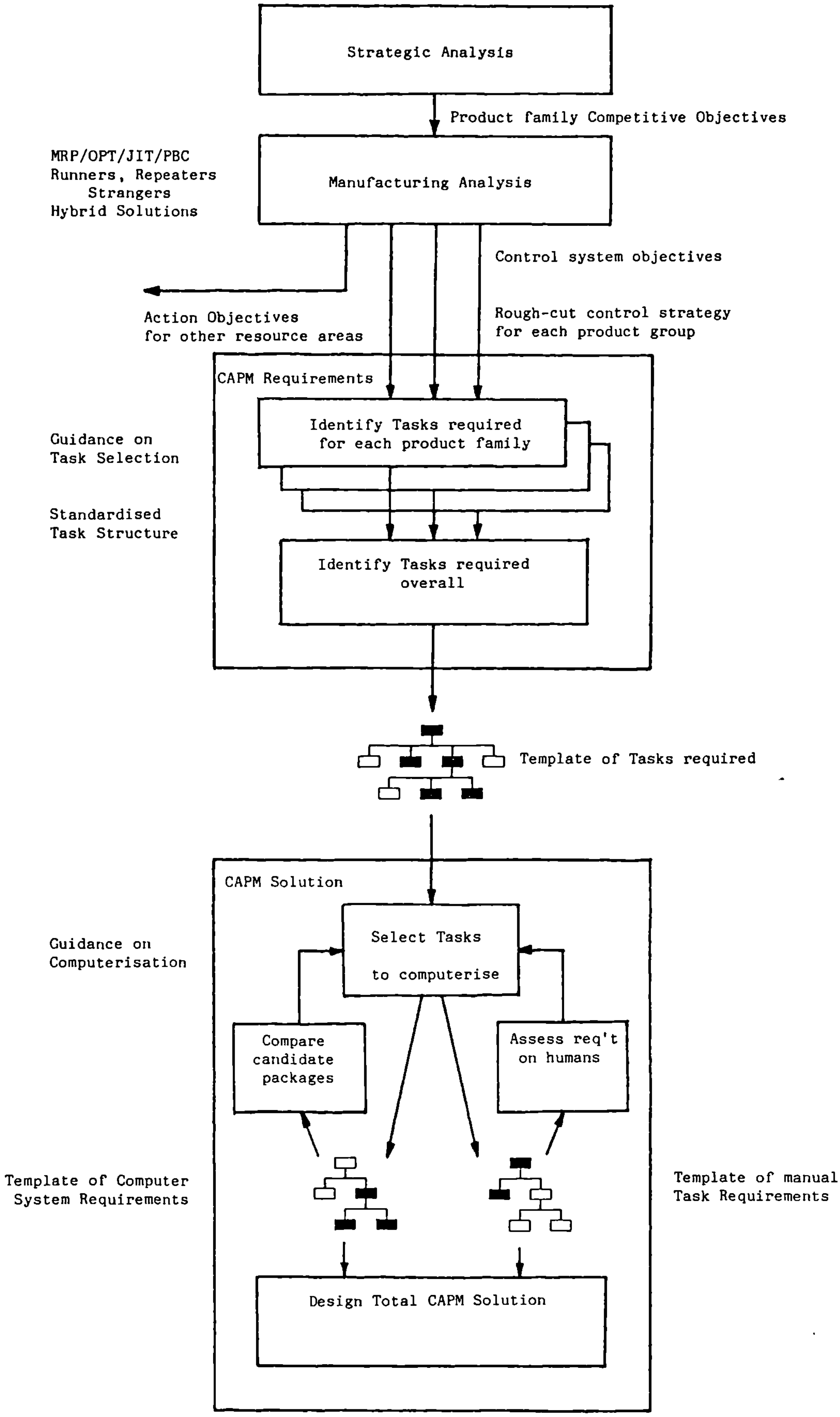
9.3. Use of the task model

The task model is primarily intended to be used as part of the Process Methodology. Its contribution is principally in the CAPM Requirements and CAPM Solutions stages, as shown in Fig.3.

The preceding stages of the methodology, Strategic Analysis and Manufacturing Analysis, which have been described in Chapter 5, establish the context within which the CAPM infrastructure must operate, and prescribe the rough-cut control strategy for each product group, together with control system objectives (such as data accuracy, update frequency) which serve as performance measures for the system. At the same time, action objectives for areas other than CAPM may be generated. Improvements in other areas (such as quality, engineering, communication) may be pre-requisites to the success of the overall project in the company. They may turn out to be more important than CAPM improvement.

The task model is used to structure decisions relating to the required configuration of the CAPM infrastructure, serving as a framework for discussion and as a model for examining the effects of alternative configurations of the system. The modelling process provides a basis for job design and consideration of other human factors such as

Fig.3. Contribution of task modelling to the process methodology for CAPM



policies, procedures and practices which affect the fit of the system to the organisation. The boundaries between individual jobs and group tasks can be identified, so that the users can be introduced to the system before installation and will know what to expect, thus smoothing the implementation process. User participation in the task modelling process may act as a vehicle to elicit detailed information and to gain user commitment to the process. Meredith points out that a computer-based system could require changes to organisation structure, decision processes and power structures, and that the users must be willing to accept changes[113]. This technique addresses this problem by ensuring as far as possible that the changes are foreseen and questioned, so that where appropriate new policies, procedures and practices can be implemented.

This is therefore a user-led team project, involving all those people connected with production management, and later, all those who provide or use production management data, or their representatives. These include foremen, storemen, production engineers, production controllers, etc.

Whilst the present work provides detail for the development of the overall system and the manual tasks involved, the detail of the analysis, selection and design of the computerised elements has been left to a complementary work, [114].

In order for the requirements to be identified in a way which ensures that different views are considered and which ensures commitment, the process must be a user-led, group activity as described in Chapter 1. The workbook associated with the complete methodology provides details of the different workshops involved, and specifies the preparatory work required before each stage[115].

9.3.1. CAPM requirements

During this stage of the process, the user team determine what tasks must be performed by the new system. This begins by an examination of the rough-cut control strategy which has previously been determined for each product group.

9.3.1.1. Task identification

Whilst each group will require the core tasks to be performed, the way in which they are carried out will vary. Thus the optional tasks must be selected.

The information provided with the model offers some guidance for this exercise. By way of illustration, consider a simple problem, that of whether or not the optional task "Record location of work" (161) will be required. The notes (see Appendix II) suggest that

> "Work location must .... be recorded in factories where there is no direct flow of work, ie where different jobs take different routes, and where lead times are long enough for the location of a particular job to be forgotten".

Thus the task would tend to be redundant for a product which will be controlled under a Kanban type control system.

It must be noted that the model cannot prescribe the most appropriate solution, but can only offer guidance to the user team who understand the complexities of their particular business.

9.3.1.2. Overall task requirements

Once the tasks have been identified for each product group in turn, an overall picture can be drawn out.

Since the task model deals with all production management tasks, (rather than using separate models for different control strategies) the task requirements for the product groups can be compared and overlaid to give an overall picture of the tasks which must be performed by the CAPM infrastructure as a whole.

The result of this stage is a template of tasks required. This does not necessarily imply that the various product groups must all be accommodated by a monolithic CAPM infrastructure which provides all the tasks. On the contrary, the various task requirements may show differences which imply the use of separate control systems. In the next stage of analysis, the possibility of dealing with product groups separately, in sets or in combination should be considered.

9.3.2. CAPM solution

A solution to perform all the tasks identified must be developed. As has been observed in Chapter 8, the solution should involve the most appropriate mix of manual and computerised tasks.

The approach which has been developed operates by dividing the tasks between humans and computers, and then assessing the implications for this choice in terms of the requirements which manual activities must fulfil and the requirements being demanded of computers. An iterative approach is required which begins from a rough division and develops a well-argued proposal in terms of two task templates drawn from the task model. One will show the manual task requirements, the other the computer system requirements. These templates provide a concrete basis for the design of the human task systems and computer systems required.

9.3.2.1. Selection of tasks for computerisation

The task model's notes also provide some guidance on dividing the tasks between humans and computers, under the heading "Computerisation indicators" for each task. These notes are largely based on repetitiveness and high volumes of data being handed over to computers. As has been pointed out in Chapter 8, there are many tasks involving non-programmed decisions, such as planning, which cannot be computerised. These tend to be in the upper levels of the model. In rapidly changing businesses, more flexibility may come from a strategy of retaining human flexibility in tasks which are programmable. Other circumstances such as the need to integrate operations with other areas which may be computerised may have a bearing on these decisions.

9.3.2.2. Candidate packages

If computerisation is considered for any task, an assessment of the available packages is required. It is not within the scope of this work to examine this area in detail but it is recognised that implementors will require considerable guidance on the derivation and use of assessment criteria.

This assessment should be sufficiently detailed to allow the manual tasks required to support the computer to be identified. These will include housekeeping tasks such as system maintenance and archiving, and also data preparation tasks such as keyboard input, which affect the design of the manual systems.

Since this stage requires candidate software packages to be compared to the requirements template, it may be possible as an alternative method to use the task model to identify the functions available from various packages.

9.3.2.3. Requirements on humans

The task model is now used as a framework to examine the work which must be done by humans. This includes the tasks from the model which were selected for manual means and any supplementary tasks which may be required to support computer operations.

Further decomposition of tasks into lower level elements may be required for job and task group design. It would appear that the future job-holders, with guidance from the facilitator, may be the best people to undertake this study.

9.3.2.4. Total CAPM solution

Once the division between manual and computerised tasks has been established to the satisfaction of all concerned, possibly after re-iteration, the design of the total system can follow. Being provided with a firm set of tasks and the means by which they should be achieved, the design stage can proceed on a firm foundation.

This stage involves the determination of what computer packages will be used, what tailoring will be required to their software, etc, and how the manual tasks can be translated into meaningful jobs for employees, bearing in mind the opportunity this creates to redevelop work groups and organisation structure.

Design of the total system involves producing and approving the policies, procedures and practices which are needed to support the company's CAPM requirements given the computerised support tools which may have been proposed. The total solution includes the activities of people, and these must be taken into account if a successful, integrated solution is to be the outcome.

Policies will be created throughout the process methodology, but at this stage there is an opportunity to acquaint the users with the policies. Policies which may be generated should reflect the findings from the analysis stage. For instance, "It is our policy to encourage customers to buy products from the standard range", or "suppliers must be encouraged to enter into call-off contracts".

Changed procedures arise from the different data linkages in the new system. For example, "When accepting a customer order, the available capacity must be checked by ....", etc.

Practices can be seen as the effects of policies and procedures upon the activities which people are called upon to perform during a day's work. Practices should be foreseen and discussed where possible, before the configuration of the system is finalised, since those who are expected to do the work should be able to provide the vital information to trap errors which may have been made. This process also aims to encourage a sense of ownership of the new system, by providing people with an opportunity to design elements of their own jobs.

In order to secure user commitment to the solution, it is recommended that the large user group should be involved in designing the total solution. As this involves a large number of people, the company may wish to divide this activity into functional areas, using the natural divisions of the branches of the CAPM task model.

Policies will have been established by the decisions taken about core tasks, but these must be identified by the facilitator and understood by the group, since these set the foundations for the way the system will be operated. Policies which are established at a higher level than production management, such as employment policy or pricing policy, are not open for discussion in this meeting, but comments must be noted and passed on, both to maintain the credibility of the company's commitment to solving its problems and to gain benefits from ideas coming from the process.

Practices, which evolve as people learn to deal with the requirements made of them, cannot easily be predicted in advance. However it should be cautioned that those who are not content with particular aspects of the system may develop ways of working which are to the advantage of the individual or group rather than of the company as a whole. For this reason, it is important to develop a good degree of understanding of and commitment to the system at this stage.

9.4. Simplification

The popular interest in Just-In-Time manufacturing and Total Quality Management represents a swing away from the "hard" technology of manufacturing to concentrate upon the "soft" questions such as "culture", or at least awareness of the way people work in the company.

JIT and TQM are policy issues which address working procedures and the practices concerned with production. They do not attempt to provide hardware and software solutions to manufacturing business problems.

The need for certain tasks to be computerised is avoided by the use of certain policies. For instance, in the Kanban system there is no need for the location of work to be recorded, since it can always be seen and does not stay on the shop floor long enough to get lost.

The simplification which is inherent in JIT, TQM etc removes the need for tasks instead of applying computers to try to cope with complex situations. Whilst some computer support is often necessary, the emphasis on simplification means that the computers which are implemented are much more effective.

9.5. Evaluation

The task model and the task modelling approach are validated by the experience of developing and testing the model in two case companies (section 9.2.3).

The model has also been exposed to professionals in the field including CAPM users, vendors and consultants, including the members of the SERC-ACME review panel who assessed the work done as part of the ACME CAPM Initiative.

Confidence in the model has been shown by EITB and London Business School who have both taken up the model for their own use.

The author has not had an opportunity to test the model in the design of a system. The company described in chapter 6 deferred further work on CAPM to concentrate on issues of business strategy.

9.5.1. Context

The task model forms part of the process methodology. This methodology was tested up to the point where use of the model would begin in the exercise described in Chapter 6. It was found that the process methodology enabled the company to examine its strategies and demonstrated the importance of developing an understanding of the business context before designing and implementing CAPM. The methodology also highlighted educative and procedural requirements which were pre-requisites to CAPM success.

9.5.2. Content and structure

The guidance notes cannot be fully evaluated until the model is used in a fully live exercise. Such an exercise will lead to improved understanding of the circumstances under which tasks are called for and of the reasons companies use for computerising tasks. After each exercise it is intended to develop this guidance by incorporating the experience gained.

9.5.3. Comprehensibility in use

The ease with which the model can be interpreted and used in a real-life exercise has not yet been tested. However the method of use of the model reflects a commonly used principle, "Read the instructions then cross out the boxes which do not apply".

An important advantage of the model is that it groups activities rather than data flows, which allows for a better understanding of the operation of the system. Previous attempts to produce generic models of CAPM using techniques such as $IDEF_0$[116] have had little success[117]. The richness of detail available in IDEF is superfluous to the selection of tasks.

Summary

The task model provides CAPM implementors with the first generic model of CAPM, guidance on determining the task requirements of the company, guidance for determining whether to computerise various tasks, and a framework for modelling the effects of these decisions on the resulting system and upon the work of people.

The task model provides a means with which the implementor can ensure that all aspects of CAPM are considered, can draw upon the experiences of others to aid the creative design process, and can make use of a framework which presents CAPM in an easily understandable form for discussion and communication. The task model thus contributes to the comprehensiveness of the design process and increases the commitment and understanding of those connected with the CAPM implementation.

Chapter 10. Conclusions

The work has provided an improved approach to CAPM implementation which should lead to the cheaper, quicker and better implementation of whole systems.

The process methodology provides a method of establishing or verifying business strategy as a basis for the design of the systems making up the infrastructure of the company. It is a process which puts forward no preferred solution or panacea but instead guides the user company through the information gathering and decision processes to determine the solution on the basis of the user's understanding and knowledge of the business. The approach can be used for other areas such as design, accounting (etc) systems.

The task modelling approach makes available a new tool which can be used within the context provided by the process methodology to help define CAPM tasks required in any manufacturing situation and help decide which tasks are best dealt with by computers and which are most appropriately dealt with by the human elements of the infrastructure.

The work has provided an introduction for future work on the choice between manual and computerised means for various tasks, and for work on the development of systems which contain both manual and computer elements.

10.1. Flexibility and an integrated strategic approach

Flexibility is an increasingly important characteristic for manufacturing companies to develop in order to increase their competitiveness in fast-changing world markets. Unpredictability of demand and competitive pressures means that companies must make strategic choices which allow them to look forward with a reasonable degree of certainty about the direction their business will take in the future. This in turn will allow them to take competent decisions about the use of resources. The hierarchical construction of the methodology in which each stage sets requirements for the following stage ensures that all solutions developed fit into the overall business strategy, and ensures the integration and cohesiveness of the system. CAPM is seen as a sub-system within the infrastructure which supports manufacturing activities.

10.2. CAPM in context

The range of different possible CAPM solutions is enormous. CAPM systems can be of various broad types, using various combinations of human and computer resources, amounting to vast numbers of possible means of dealing with problems specific to particular companies. The only way to design a CAPM system which meets the objectives of the business is to articulate the objectives of the business to provide the context within which the system must operate. This provides an opportunity to review the strategies of the company.

10.2.1. The need to develop the context

Attempts have been made to determine CAPM system requirements on the basis of the characteristics of companies employing various system types. These efforts have drawn out certain similarities between companies using CAPM modules, to the extent that some correlation between the predicted and actual status of companies can be determined from analysis of company characteristics. Unfortunately these correlations are not sufficiently reliable to provide an acceptable prescription of the CAPM needs of a company. These approaches stem from an approach to systems design which is based upon the use of a computer system which appears from measurable characteristics of the business to be suitable.

Instead the approach put forward in this thesis requires CAPM implementors to determine the context in which the system will operate, in terms of product groups, control requirements, competitive strategies, etc. so that the task requirements which the system must fulfil now and in the future can be determined. This approach is based on a study of the way the people in the organisation work, specifying computer system needs in order to support the activities of people. It is a systems approach which looks at both the human and the computer elements of the system. Once the CAPM system can be described in terms of the tasks of which it consists, decisions can be made on the means of achieving the tasks according to the nature of each task as it is in the particular situation of the company concerned.

10.2.2. Success of process methodology for developing the context

The user-led process methodology was found to be a most useful tool for determining the context within which the CAPM system must operate. It was found to rely on the commitment of senior management to take important decisions to improve their business, forcing the development of a strategy where previously none existed. It was found to develop a common understanding of the nature of the business, and exposed the resolution of differences of opinion and grievances as a pre-requisite to building useful team relationships.

Most importantly, in the test the methodology produced results which could not have been expected from a consultant or vendor led approach. Specifically, these were the exposure of an educative requirement to develop an understanding of the effects of the actions of the Sales and Manufacturing departments' actions upon the business; a procedural requirement to ensure the completeness of orders and the availability of patterns; and a system requirement in terms of the exposure of the need for a short term rough-cut capacity planning tool. Installation of a CAPM system based upon the characteristics of the business by other than a user-led process would not have led to these results. Business improvement opportunities which materialised easily from the user-led process would probably not have been made available since the user issues would not have been addressed directly - a proprietary software tool could have been installed with very little effect upon the company's real problems, and would have added complexity to a business which was becoming difficult to manage.

10.3. Design of CAPM system using the task model

Implementors of packaged CAPM solutions have generally implemented a set of modules appearing to be most appropriate to the company, and trained the company's staff to operate the new system. This approach is very much based upon the assumption that the system is more important than the people who operate it, since their work is structured by the system. A different view is to treat the people as the important elements, and to provide them with a set of computerised tools which help them to do their work. The approach proposed is one of joint optimisation and recognition of the links between human and computerised elements. The design of the whole system should take account of the characteristics of computers and the characteristics of people.

The task model approach provides a framework for designing the system which allows the people concerned to understand the tasks they will be asked to do. This is likely to lead to the overall system being more closely related to the nature of the work involved, since it holds the system up to question before it is ever installed. As it is also a tool which involves the users, their commitment to the new system is more likely to ensure a smooth implementation.

The task model has not yet been used for the design of a CAPM system. However, it has been approved by practitioners in the field and developed in the light of their experience, so that it can be used with confidence to aid the implementation process. The process of modelling the two companies shown in the Appendices has shown the validity of the model: the tasks used in the two companies are accommodated by the model, and even the process of validating the model led the Production

Control Manager of one of the companies to question the way certain tasks were carried out in his company. Thus the model has been of value to a user, whilst the fitting of the company activities into the model has increased the model's relevance and utility.

More important than the model itself, however, is the method of modelling, which allows a system to be designed around the tasks involved in production management taking into account those carried out by people as well as those by computers, rather than allowing humans to be marginalised by a data-flow based modelling approach.

10.4. Future work

This work provides an introduction to an approach to system design which engages the future users of the system in determining their objectives and requirements for the system. It provides the task model as a tool to aid and accelerate the process by providing structure and guidance.

Future work will contribute to the development of the process by gaining experience of more companies. It will further develop the task model, although user companies will in any case develop, alter and edit the model as they see fit.

The notes for guidance which accompany the task model may be improved as experience of a wider range of circumstances is gained.

Further experience will also lead to the development of the role of the facilitator in what can be a very difficult and complex political process. The control of meetings in which age-old problems come to light and the production of useful consensus from such chaos is a challenge which requires skills and techniques which must be identified and refined.

The question of human versus computer task allocation has been answered in this thesis by suggesting a framework of tasks, some characteristics of humans and of computers in a systems framework and proposing that the people who are expected to use the system should be involved in specifying the computer aids they need. The task model is the principal tool for this activity. The determination of which tasks are required in certain circumstances has also been addressed in the notes accompanying the task model.

This user-led task modelling approach is particularly important in developing commitment and mobilising the knowledge that only those closely involved to are able to provide. This has thus provided an engineering solution - a means of dealing with the problem. No attempt has been made to develop a theoretical basis for the question of the allocation of function. It may well be argued that at the task level, theories could be developed to provide easy answers to the allocation question, thus providing a body of knowledge and a theoretical basis to support the task model's guidance offered in terms of the reasons case companies have given for computerising or requiring certain tasks to be performed in certain ways. In the practical context, however, it may well be of more value to the company in terms of commitment and development of staff to allow the users to take their own decisions within the framework of the process methodology.

10.5. Contribution of the work

The work has provided a framework for the user-led implementation of CAPM systems and a tool for the design of the system itself which improves on current practice. The user-led approach has been extended beyond the cosmetic design of interfaces and screens to the specification of the system itself through the development of the task modelling approach. An approach to the development of strategy for manufacturing companies has been developed along with an understanding of the importance of strategy in setting the context for CAPM. This provides a basis for simplifying and improving manufacturing systems which can aid the competitiveness of manufacturing industry and improve the working life of those who are the human elements in CAPM systems.

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APPENDICES

Appendix I. Table summarising CAPM implementations

Company	Hardware installation	CAPM type	Production mode	Product range	Production method	Customers	Implementation failure	Software origin	Program
A1	MFr ICL	BOM + stock	batch	narrow	assembly	retailers			
A2	MFr IBM	MRP	"	"	"	"	inappropriate to JIT, costly	bought	COPICS
A3	MFr HP	MRP	"	"	"	"	poor req. defn -> unmodifying	bought,mod'ed, and unmodified	MM3000
B1	MFr ICL	MRP	batch	wide	assembly	industrial	lacked flexibility		
B2	MFr ICL	MRP	"	"	"	"	changed prod'n philosophy	modified	OMAC
B3	MFr ICL	JIT/MRP	"	"	"	"		modified	OMAC-JIT
C	none		job/sml batch	Wide 1000s	M/C + assy	MoD			
D1	MFr ICL	SOP + Accounts	batch	narrow	process, assy, + factoring	industrial	more functions required	bought	SAFES
D2	MFr ICL	SOP + Accounts +stock + SOR	"	"	"	"	more functions required	bought + added to	SAFES + additions
D3	MFr ICL + Apricot PC-Net	replacement SOP	"	"	"	"		bought + added to	SAFES etc + dBase III
E	Apricot PC-Net		batch	wide	assembly	industrial	Not in yet	bought	TIMS
F	MFr HP	MRP+sched.	batch + flow	narrow	M/C + assy	industrial	lacks flex	bought for all sites	MAS-H
G	Datapoint mini	Purchasing BOM +accounts	batch	narrow	assy, M/C, fabrication	industrial	lacked integration	developed by vendor	MARPACS

Company	Hardware installation	CAPM type	Production mode	Product range	Production method	Customers	Implementation failure	Software origin	Program
H1	MFr IBM	MRP	batch	Narrow	assembly	Retailers	overload, & lacked flex	elsewhere in company	
H2	MFr IBM	MRP	"	"	"	"	bought + mod	MacPac	
I	IBM PC-Net	a scheduler	batch	narrow	process	industrial	inadequate req'ts def'n	developed by vendor	AIMS
J1		Purchase O P	batch	wide	M/C + assy	industrial	inadequate functions		
J2	IBM MFr		"	"	"	"		bought	COPICS
K	none		batch	narrow	assembly	industrial			
L	IBM	MRP	large batch/flow	narrow	process	retailers		in-house	

Note: A1, A2, A3 etc refer to subsequent implementations at the same site.

Appendix II. Generic task model

Production Management Task Model - Task Descriptions

Tasks which are shown on the model but which do not themselves form part of Computer-Aided Production Management are included for the purposes of establishing context only and are not treated in detail. These include both the business areas external to production and the direct production operations themselves.

The possibility of computerising each task has been addressed at the lowest level of decomposition of each branch. If a task can be decomposed into subtasks, the possibility of computerising the task is understood by considering the subtasks.

1. Manufacturing Corporate Mission

Core (Context)

The corporate mission represents the overall task of the business unit. All activities within the business unit must contribute to the overall task of the business which is to fulfill its corporate mission.

Subtasks: 2,31,38,174,175

2. Define corporate strategy

Core (Context)

This activity is concerned with definition of the global goals and objectives of the business, especially the product range and the mechanisms by which the products are brought to market.

Subtasks: 3,16

3. Plan product portfolio

Core (Context)

The company must determine and re-examine the range of products which it offers to the market.

Subtasks: 4,5,15

4. Research Market Requirements

(Context)

The product portfolio must be based upon an understanding of the requirements of the market.

5. Design Products

(Context)

This activity makes new products available to complete the required portfolio.

Subtasks: 6,14

6. Modify existing designs

(Context)

Designs may be produced by development from previous designs.

Subtasks: 7,8,9,10,11

7. Verify change proposals

(Context)

Proposals for changes to designs must be verified, to ensure that the changes are the ones required.

8. Design solution

(Context)

This is the creative process by which solutions to design requirements are arrived at.

9. Appraise solution

(Context)

Solutions must be appraised to determine their likely effects.

10. Evaluate solution appraisals

(Context)

Competing solutions must be compared after appraisal, since the resources required to make changes are limited and priorities must be established. In addition, some solutions which may have been appraised and found beneficial individually may not easily combine together.

11. Implement change

(Context)

The solution must be implemented. This involves updating information held on the state of the product and its revision status.

Subtasks: 12,13

12. Update bill of materials

(Context)

The bill of materials for the product is updated to show the new arrangement, or a new bill for the new product is created. In companies where assembly is not involved, this information may be held in design files or on drawings.

13. Record update

(Context)

The revision is noted so that products conforming to designs before and after the change can be distinguished.

14. Create new designs

(Context)

This creative process produces new designs not based on previous designs.

15. Identify product range

(Context)

The available designs are identified in a form which allows the company to understand the current portfolio which it offers to the marketplace. Designs which are not available (if under development etc.) are identified.

16. Plan supply of products

Core (Context)

The company must strategically plan how its products will be supplied to the market. This involves determining policy (not individual issues) on, for instance, what type of product to make and what to buy, where to locate factories, what suppliers (or types of suppliers) to use.

Subtasks: 17,18,19

17. Decide make/buy option

(Context)

The company must form guidelines to indicate whether certain products, components or materials should be manufactured or purchased from suppliers.

18. Plan manufacturing facilities

(Context)

The company must determine what manufacturing facilities it requires, where they should be located, what work will be undertaken by each facility, etc.

19. Plan supplier arrangements

(Context)

The company must determine what suppliers to use.

Subtasks: 20,21,22

20. Issue request for quotations

(Context)

Requests for quotations are issued to prospective suppliers.

21. Record supply quotations

(Context)

Suppliers' quotations are recorded.

22. Select supplier

(Context)

Suppliers must be selected. At this stage they may be grouped as potential suppliers without allocating specific pieces of work. This may involve establishing contractual relationships with suppliers as well as auditing suppliers' quality standards.

23. Plan production

(Context)

The strategic planning process involves high level planning of production over a period of time, generally several years.

Subtasks: 24,25

24. Set production targets

(Context)

Target production and sales levels may be established.

25. Forecast order requirements

(Context)

Forecasting is required if the manufacturing lead time is greater than the delivery lead time the market can bear. This means that manufacturing has to work to expected or forecast orders rather than actual orders.

Subtasks: 26,29,30

26. Build predictive model

(Context)

Models of market behaviour may be produced to assist forecasting. This involves determining an approach to forecasting which may be the development of a procedure or a computerised tool.

Subtasks: 27,28

27. Collect history data on market

(Context)

Forecasting must be based upon available data about the market.

28. Incorporate appropriate forecasting technique

(Context)

The model used for forecasting may incorporate various techniques to produce predictions from available data.

29. Produce forecasts

(Context)

The forecasting model is operated to produce forecasts.

30. Evaluate forecast technique

(Context)

The success of the forecasting technique must be audited so that the technique can continually be improved and so that the correct level of confidence can be attributed to forecasts.

31. Maintain corporate infrastructure

Core (Context)

Concerned with the maintenance of facilities and resources such as financial, personnel, buildings, capital equipment etc., to provide the framework within which the company operates.

Subtasks: 32,33,34,35,36,37

32. Maintain fixed assets

(Context)

33. Maintain capital/investment resources

(Context)

34. Maintain and train personnel resource (HRM)

(Context)

35. Maintain information systems

(Context)

36. Maintain supplier relationships

(Context)

37. Maintain market/ customer/ dealer relationships

(Context)

38. Get products to sell

Core

Concerns the acquisition of the products the company offers to the market.

Subtasks: 39,105,147,173

39. Plan manufacturing (MPS)

Core

This activity is used to plan the manufacturing activities during the next operating period. It involves the maintenance of the Master Production Schedule (MPS).

Subtasks: 40,95

40. Process orders and enquiries

Core

This activity provides the company with the information required to produce schedules for manufacturing.

Subtasks: 41,64

41. Process enquiries

Core

The processing of enquiries could entail a range of activities from producing a quotation for complex or new work to reading the current price from a catalogue.

Subtasks: 42,43,54,63

42. Receive enquiry from customer

Core

The company takes note of the requirement of the customer.

Manual: Incoming customer enquiries are recorded on an enquiry form, or similar, which serves as reference for quotation purposes. If the enquiry is to be handled by reference to a catalogue, it may not be recorded, although this provides an opportunity for follow-up.

Computer: The enquiry details are recorded by entering on VDU or by completing an enquiry form for subsequent keying. The computer may provide details such as price, availability, etc.

Computerisation indicators: Number of enquiries; requirement to provide instant feedback to customer on price, availability.

43. Check feasibility of work

Core

This activity is to ensure that the order can be met. Therefore the manufacturing capability and capacity must be checked together with material availability.

At its simplest this may be handled by an individual who has sufficient detailed knowledge of company's capability and current situation, such as the production manager or foreman of a small company.

Subtasks: 44,45,50,53

44. Check customer credit status

Core

Companies may accept orders from certain customers without actively checking their status, although the act of identifying the customer as "known to be ok" itself constitutes a passive check of status.

Manual: Companies may black-list non-payers, when the task consists of checking against the list, or they may pursue more sophisticated manual investigations. A common alternative is simply to check that the customer has no outstanding debts to the company.

Computer: Computers may be used to hold black-lists derived in various ways from customer accounts files. The checking task may then consist of interrogating an enquiry screen.

Computerisation indicators: number of customers; linkages to other systems such as finance or credit-ratings.

45. Check manufacturing capability including quality

Core

This activity is performed to ensure that not only can the order be manufactured but also that it can be produced to the customer's required quality standard. Like many of the "check" tasks it may be performed implicitly rather than actively.

Subtasks: 46,47,48,49,

46. Identify facilities required

Core

The facilities required to complete the order must be identified.

Manual task.

47. Identify skills required

The skills required for the work must be identified, so that any unavailable skills are noticed. This task is not required when the skills required for the type of work done are minimal.

Manual task.

48. Compare facilities and skills to requirements

This activity is performed to identify the potential costs of accepting an order which may have requirements beyond existing capabilities. A judgement must be made to determine if the potential of the order will justify the expense of acquiring the required resource.

Manual task.

49. Identify equipment or training needs

The activity is used to identify any additional resource which is required by the company to produce a given product. This identifies the potential costs to the organisation of taking on the order.

Manual task.

50. Check manufacturing capacity and due date

The current manufacturing capacity and schedule must be checked to determine if and when the order can be fitted into the schedule. This is not required if the capacity utilisation is very low.

Subtasks: 51,52

51. Receive resource requirement profile

Information is required on the resources which will be used during the manufacture of the product.

Computerisation indicators: profiles may be stored on computer if there are a large number of different profiles which increase the complexity of the task.

52. Compare requirement to existing schedule

The resources required for the order in question are compared to the existing schedule to determine the earliest completion date, and any over-capacity which may result from meeting the date required. Not required when capacity utilisation is very low.

Computerisation indicators: Master production schedule and resource profiles held on computer (see task 94).

53. Check material availability (gross)

In many cases of one-off orders it is necessary to make a check that the required material can be made available for the order. The material is not allocated until the order is firm (Task No.80). Where the work is of a regular nature this task is not required. Nor is it required in subcontract work where all the components are supplied by the customer.

Computerisation indicators: many different types of product use different types and quantities of material, or unusual materials; large numbers of different orders; uneven demand.

54. Determine price to customer

Core

Two methods may be used to determine the price of a product to the customer:-

1. Cost Plus: Price is based on an estimated cost of production plus a profit factor.

2. Market Based Pricing: Price is based on prevailing market conditions such as demand and competition.

Subtasks: 55,60

55. Determine manufacturing cost

Manual: Cost-plus pricing requires calculations to determine the manufacturing cost based upon certain assumptions appropriate to the business. This is often the role of a costing engineer or estimator.

Computer: The calculations used for determining manufacturing cost are often computerised, even in companies which have no other computer aids to production management. In this case the computer program applies all the standard rates used in the company to the work in question. This requires the details of the work in terms of time usage of various resources to be entered into the machine. Where the processes and time on each process are available in a computer system, the manufacturing cost is more likely to be calculated automatically.

Subtasks: 56,57,58,59

56. Identify processes required

The processes required to complete the work in question must be identified in order to determine the cost of all the operations. Often this may be done by varying the details for previous similar or related jobs.

Manual: It is often the job of an Industrial Engineer or Planning Engineer to determine the way a product should be made. This may involve the generation of a process instruction or "layout", although at this estimation stage this may not be done in detail.

Computer: Various tools exist to help the planning engineer or estimator ranging from simple calculation aids to Computer Aided Process Planning (CAPP) tools which may be integrated into CAPM systems. In all cases the required processes must be identified manually, although this may be aided by the use of a computerised checklist.

Computerisation indicators: Large number of different items which are processed in different ways, such as when making mechanical equipment composed of large numbers of different parts.

57. Estimate process times

For each operation in the completion of the job the time must be estimated. This is then used to determine the cost of the operation. Various computerised tools are available to support the job of the estimator, by supplying the times of various elemental operations in order to generate "synthetic" times.

Computerisation indicators: large number of operations in the processing of the product, which would allow error if done manually.

58. Apply standard cost rates

Standard costs are often used which represent the operating cost of the various resources used in the completion of a product. These costs are multiplied by the time estimated for the work to use the resource.

This activity can be done manually or as part of a computer system.

Computerisation indicators: Where costs will be used in another computer system; where large numbers of jobs require costing, ie high levels of new product introduction or modification.

59. Compare with previous costs

Comparison with previous costs may optionally be used to moderate cost estimates, or as a basis for the estimate.

Manual check (possibly drawing information from computerised costs system).

60. Consider market relationship

Activity to determine the market based element of the price to customers where the price is not based solely upon the manufacturing cost. This element depends upon the relationship of the company to the marketplace as a whole and to the particular customer concerned.

Subtasks: 61,62

61. Estimate demand elasticity (max price)

Involves considering the price the market can tolerate for the product concerned. Relates the price to the "going rate".

Manual task.

62. Check customer relationship

Involves considering the relationship of the customer to the company with respect to pricing. Favoured customers may be offered discounts, related or internal customers may be charged transfer values which involve no element of profit.

Computerisation indicators: large number of customers, complex discounting or internal pricing scheme.

63. Issue quotation to customer

Core

The customer is informed of the price of the proposed order.

Computerisation indicators: where customers are linked to the company by data transfer systems

64. Process orders

Core

Orders received from customers are processed to appear on the manufacturing schedule.

Subtasks: 65,68,79

65. Receive order from customer

Core

Manual: Orders received through various means are normally recorded on standard order forms.

Computer: Some companies are establishing direct data links to allow approved customers to enter orders direct into their CAPM systems.

Subtasks: 66,67

66. Copy order into standard format

Orders may be copied onto standard forms or entered into a computer (or both) in order to expose missing information, and to make the information available in a standard format for reference.

Computerisation indicators: To provide data entry for computerised order processing (See tasks 76,77,94)

67. Check for missing information or ambiguity

Orders may be checked as they are processed.

Manual: By identifying anomalies or by structured checklists or procedures.

Computer: The data entry screen may refuse to accept anomalous or incomplete data.

Computerisation indicators: To provide data entry for computerised order processing (See tasks 76,77,94)

68. Confirm feasibility of order

Core

This activity is similar to the method of processing an enquiry. Some or all of the required information may already be available, and the enquiry is simply turned into an order. In other cases, more information may be required at the firm order stage.

Subtasks: 69,70,75,78

69. Check customer credit status

May be required if not already checked at the enquiry stage.

Computerisation indicators: number of customers; linkages to other systems such as finance or credit-ratings.

70. Check manufacturing capability including quality

Core

This activity is required to determine the capability of the organisation to provide the product. This means confirming that the company is capable of the type of work required and capable of meeting the required quality standards.

Subtasks: 71,72,73,74

71. Identify facilities required

Core

The facilities required for the order must be identified.

Manual task.

72. Identify skills required

The skills required for the work must be identified, so that any unavailable skills are noticed. This task is not required when the skills required for the type of work done are minimal.

Manual task.

73. Compare facilities & skills to requirements

Core

This activity is performed to identify the potential costs of accepting an order which may have requirements beyond existing capabilities. A judgement will need to be made to determine if the potential of the order will justify the expense of acquiring the required resource.

Manual task.

74. Identify equipment or training needs

Core

The activity is used to identify any additional resource which is required by the company to produce a given product. This identifies the potential costs to the organisation of taking on the order.

Manual task.

75. Check manufacturing capacity and due date

Core

This activity is performed to check that the order can be fitted into the manufacturing schedule for completion by the due date, or to determine the date by which the order could be delivered.

Subtasks: 76,77

76. Receive resource requirement profile

Information on the resources which will be used during the manufacture of the product is required.

Computerisation indicators: profiles may be stored on computer if there are a large number of different profiles which increase the complexity of the task.

77. Compare requirement to existing schedule

The resources required for the order in question are compared to the existing schedule to determine the earliest completion date, and any over-capacity which may result from meeting the date required. Not required when capacity utilisation is very low.

Manual: Resource requirements are compared to the existing schedule. Various timetables are tried to find the best fit.

Computer: A what-if facility may be used to show the effect on the schedule of completing the order by the required date, the earliest finishing date without disrupting other work, or other possibilities such as rescheduling certain items. The computer here serves as a decision tool.

Computerisation indicators: Master production schedule and resource profiles held on computer (see task 94); complex product profiles and schedules from many-level bills of material and many different products on the schedule.

78. Check material availability (gross)

This activity is required to confirm the availability of the materials required to complete an order, which may be held in stock or ordered from suppliers.

The relevant scheduling decisions will need to be made so that components and materials are made available at the correct time for the manufacturing process. This requires knowledge of the supplier delivery lead times for the material needed.

Computerisation indicators: many different types of product use different types and quantities of material, or unusual materials; large numbers of different orders; uneven demand.

79. Formalise order

Core

This activity is used to formally load the firm order onto the manufacturing facility. The previous activities have confirmed the feasibility of manufacture of the order and identified the resource and material needs of the order.

Subtasks: 80,81,93,94

80. Allocate material (gross)

The material allocation activity depends on the type of order which is being processed and the material handling methods used by the organisation. If the business is working to order, material requirements may be based on the gross material requirements for the orders received over a given time period. If the organisation is working to stock, buffer stocking based on demand forecasting is likely.

Material must be allocated to orders if it is possible for the material to have more than one use.

Computerisation indicators: Large numbers of different materials.

81. Produce works instructions (layouts)

Core

Works instructions provide the detailed processing needs of a given product. The information provided should be of sufficient detail for the operators to perform the tasks required to complete the order.

Manual: It is often the job of an Industrial Engineer or Planning Engineer to determine the way a product should be made.

Computer: Various tools exist to help the planning engineer ranging from simple calculation aids to Computer Aided Process Planning (CAPP) tools which may be integrated into CAPM systems. In all cases the required processes must be identified manually, although this may be aided by the use of a computerised checklist.

Subtasks: 82,85,92

82. Check customer requirements

This activity is required to identify the customer needs for a given order. This requires analysis of the information provided by the customer. Additional communication with the customer may be required to clarify specific needs.

Subtasks: 83,84

83. Check drawing issue etc

The drawing number and issue are often formally specified on a customer order. Under some conditions it is possible for earlier issues of the design to be made available to the manufacturing department. This activity is required to ensure that the product is manufactured to the required design. Not required in companies where drawings are not used, such as in process industries.

Manual task.

84. Check parts list

Where a parts list corresponding to the drawing issue is required, it is possible that the parts list is of an earlier revision than the drawing.

Manual check.

85. Generate instructions

Core

An activity is required for the generation of detailed instructions which will allow a given operator on the shop floor to manufacture a given product to the required quality level given the appropriate resources. This activity is used to ensure that sufficient level of information is made available from the customer definition of the product. This activity may require a dialogue with the customer, which may need to be formally recorded to support any enquiries in the future.

Subtasks: 86,89

86. Generate process instructions

Core

This activity is required to generate the process instructions required to manufacture the product.

Subtasks: 87,88

87. Apply normal process methods

Core

A selection from the company's normal working methods, suitably modified, are specified for the order.

Manual task, possibly with computer support such as word processing to produce instructions in standard format.

88. Confirm with customer

The process instructions generated may have to be agreed with the customer, especially where customer requirements are unclear.

The results of this dialogue are documented to support any future enquiry which may arise on the order.

Manual task.

89. Generate inspection instructions

Core

This activity is required for the generation of specific quality instructions needed to produce a given product.

Subtasks: 90,91

90. Apply normal inspection procedures

In those situations where normal quality levels are either stipulated or implied by the customer, no specific quality instructions need to be generated. Standard quality procedures are documented in quality manuals etc. Elements from the manuals may be used in the preparation of inspection instructions for particular products.

Manual task, possibly with computer support such as for word-processing and filing completed instructions.

91. Confirm with customer

When the quality requirements of a specific order have not been clearly identified by the customer, or where the customer's requirements are special or unusual, a dialogue will need to take place between the quality engineer and the customer. The results of this dialogue must be formally recorded.

Manual task.

92. Collate / assemble instructions

Core

This activity is required to collate all the information needed to manufacture the product to the required quality standards. The information should be sufficiently detailed to allow an operator to manufacture the product.

Manual task, possibly using computer support such as word processor.

93. Confirm order to customer

Some businesses issue a copy of the formalised order to the customer for confirmation purposes. This may not occur where manufacturing is to stock and orders are met from stores of finished goods.

Manual: A copy of the order is prepared and sent to the customer.

Computer: Formalisation (or release) of the order may automatically generate a copy of the order for the customer.

Computerisation indicators: large numbers of orders require confirmation.

94. Add order to manufacturing schedule

Core

This activity entails releasing the order into the schedule so that it can be timetabled.

Manual: The order may be entered on a job list, schedule chart or similar.

Computer: The order must be entered, or if it was previously an enquiry it must be located and added to the schedule.

Computerisation indicators: numbers of orders and work centres requiring scheduling increase complexity beyond the level at which a manual system can cope.

95. Maintain manufacturing schedule

Core

This is often done by the regular Master Production Scheduling meeting. It involves rescheduling and adding new orders to the schedule in such a way as to allow all orders to be completed by their due dates.

Subtasks: 96,102

96. Plan capacity utilisation

This activity ensures that the schedule makes appropriate use of manufacturing capacity, ie scheduling to smooth out capacity requirements. This may not be required if capacity utilisation is very low.

Subtasks: 97,101

97. Report capacity requirements inc excesses

Capacity requirements change when the product mix changes. These changes may be random or seasonal. Changes may lead to overloading of manufacturing resources.

Subtasks: 98,99,100

98. Aggregate product profiles

Dependent upon 85

Product load profiles which describe the capacity requirements for the manufacture of each product are aggregated together to give a picture of the capacity demands generated by the schedule.

Computerisation indicators: large number of products; complicated profiles (many different process routes); large number of scheduled workcentres.

99. Aggregate load for spares

Load profiles for the production of spares requirements are aggregated to give a picture of the required capacity over time. This is only required in those companies who supply spares or replacement units or provide after-sales support.

Computerisation indicators: large number of products; complicated profiles (many different process routes); large number of scheduled workcentres.

100. Identify work for specific time buckets

Dependent upon 85

The aggregate demand for specific processes for each period is identified.

Computerisation indicators: large number of products; complicated profiles (many different process routes); large number of scheduled workcentres.

101. Produce simulation for decision making

In circumstances where a mix of products take different routes through a factory the effects of schedule changes can be difficult to foresee. In these cases simulation tools may serve as an aid to decision making.

Simulation tools may be linked to production control computers to allow direct loading of tested schedules, or to allow capacity requirements to be downloaded to the simulator.

Can only be computerised.

102. Confirm master production schedule

Core

This activity fixes a satisfactory production schedule for a given time period. This represents a point beyond which any change is likely to cause disruption to deliveries. A signing-off authorisation is usual.

Manual: This authorisation can only be done manually. It represents an important control point.

Subtasks: 103,104

103. Confirm work in time buckets

The first stage of confirming the MPS is to check that the allocation of work to time buckets conforms to capacity and other requirements.

Manual check.

104. Issue MPS document

Once the schedule is checked, an authorised version is issued. This provides a view of the requirements on production as they appear at present. This is the framework within which more detailed scheduling can take place. Each MPS document is an update on the previous issue.

Manual authorisation.

105. Obtain raw material

Core

This activity represents the acquisition of the raw material and components required to manufacture a product. Two sources of components are available to a manufacturing organisation: bought out or made in. Similar scheduling decisions will need to be made irrespective of the component source. The major difference will be the need to consider either supplier delivery lead time or manufacturing lead time for the component.

This activity includes both ordering materials and physically receiving them.

Subtasks: 106,133

106. Issue manufacturing and purchase orders

Core

This activity is needed to order material from either an external supplier or the factory:

Bought out components: raise a purchase order to the relevant supplier.

Made in components: raise a works order to have the required components manufactured.

In order to raise and issue orders, the material requirements must be identified. This can be done either by maintaining stock levels (ROP) or by identifying requirements for specific orders (MRP). Both methods may be used in the same business.

Subtasks: 107,110,121

107. Identify requirements (ROP)

This activity is used replenish stock levels once the stock level diminishes to the re-order point.

Subtasks: 108,109

108. Monitor stock levels

Dependent upon 107

Manual: This activity may be done by a storekeeper, who may also be responsible for comparing levels to the re-order points.

Computer: Alternatively the stock transactions may be registered on computer, allowing the computer to monitor stock levels. In this case the manual task of checking the accuracy of the information (stock audit) is necessitated.

Computerisation indicators: where on-line stock information is required. However this is not generally the case under re-order point control: those items which require close control are often controlled in other ways.

109. Flag items below re-order point

Dependent upon 107

Items whose stock levels have fallen below the re-order point are identified.

Manual: Stock levels are compared to standard re-order points. This may be done less formally by detecting empty bins or stock locations, such as in the two bin system or some forms of kanban.

Computer: Stock levels are compared to standard re-order points. The computer may list the items which must be re-ordered, or ordering may be initiated automatically.

Computerisation indicators: where automatic ordering is required.

110. Identify requirements (MRP)

The material requirements for each of the orders scheduled for a particular period are identified with reference to the Bill of Material, and aggregated to identify the gross requirements. These are then "netted off" against any available stock to determine the ordering requirements. MRP also takes note of the stage in assembly at which an item is required, its own manufacturing lead time or procurement lead time and the time taken to raise the order, so that the system can also give the correct date for the order to be raised to prevent excess stock. Most MRP systems also contain rules about minimum ordering quantities, and can also be made to operate as re-order point systems. MRPII systems combine these functions with capacity planning and thereby collect data on performance, allowing lead times to be adjusted automatically.

Manual: Although the term Material Requirements Planning is used for computer systems, the tasks can be done manually where products are not too complex. This is then referred to as a "purchase to order" system, as components are only ordered from suppliers (or the factory) when required for a particular job.

Subtasks: 111,116

111. Identify gross requirements

Component requirements for the items on order are identified by reference to the Bill of Materials. Lead times are used to determine the ordering period for each item. Requirements for common items falling in the same time period are then added together.

Subtasks: 112,113,114,115

112. Receive customer order information

Dependent upon 111

Computer: Customer Orders are simply read from the order database into the MRP module, having previously been put in.

Manual: The equivalent manual task is to collect together the orders relating to the time period in question.

Computerisation indicators: large numbers of different orders.

113. Explode orders (BOM)

The Bill of Materials, which describes the components required for each product, is used to identify the quantity of each item required for the orders. This is required in businesses where parts are assembled to form products. If there is no assembly, such as in a subcontract machine shop, this activity is unnecessary.

Computerisation indicators: large numbers of products; products with large numbers of different components.

114. Totalise gross requirements for each item

Requirements are grouped by item type to give the total or gross requirement for each item.

Computerisation indicators: large number of item types.

115. Produce gross requirements list

The gross requirements must be collated into a list or data file suitable for comparison with stock files. This is the output stage of Task No.111.

Computerisation indicators: large number of item types.

116. Identify net requirements

The gross requirements for any item in the same period must be ordered. However, any stock of the items currently available must be subtracted from the requirements to prevent overstocking. The situation of having unallocated stock may arise from using a re-order point system (safety stock), from ordering excess such as scrap allowances, from order cancellations, or from ordering components for the same product in different lot sizes. In other circumstances, gross requirements are equal to net requirements.

Subtasks: 117,118,119,120

117. Receive gross requirements for each item

Dependent upon 116

The input for this stage is the list or data file showing the gross requirements by item.

Computerisation indicators: large number of item types.

118. Identify unallocated stock level for each item

Dependent upon 116

Stock which has already been allocated to orders but which has not yet been issued must be subtracted from the total stock level of each item to give the amount of stock available.

Computerisation indicators: large number of item types.

119. Allocate stock to orders

Stock which is available and required for the orders currently in question must be allocated to those orders so that it can no longer be counted as available.

Computerisation indicators: large number of item types.

120. Net off stock against requirements

Dependent upon 116

Available stock is subtracted from the gross requirements for each item, to give the amount of each item for which orders must be raised.

Computerisation indicators: large number of item types.

121. Issue orders

Core

This activity is used to generate orders to authorise production or purchase of the net requirements for each item.

Subtasks: 122,127,130

122. Sort requirements by source

Core

The supplier of each item, whether external or in-house manufacture, must be identified. Items from the same supplier will thus be dealt with together. The source of an item is often stored in an Item Master file.

Subtasks: 123,124,125,126

123. Receive net requirements list

This is the list of requirements generated in Task No.119.

Computerisation indicators: large number of item types.

124. Identify source for each item

Computerisation indicators: large number of item types.

125. Produce list of bought-out requirements

Computerisation indicators: large number of item types.

126. Produce list of made-in requirements

Computerisation indicators: large number of item types.

127. Issue purchase orders

Core

Orders to suppliers are raised. If this task is computerised there may be a manual check on orders before they are issued.

Subtasks: 128,129

128. Receive list of bought-out requirements

This is the list generated in Task No.125.

129. Generate purchase orders for bought-out requirements

Computerisation indicators: large number of purchased items.

130. Issue works orders

Core

Orders authorising manufacture are issued. Live orders may be stored until the start date is reached, or the computer may hold orders until they are due before printing them out.

Subtasks: 131,132

131. Receive list of made-in requirements

This is the list generated in Task No.126.

132. Generate orders for made-in requirements

The orders must be generated. This may be done by a computer, especially where MRP is in use, or by manual means. Orders for made-in requirements may be in the form of batch cards, travellers, work-to lists, etc. Computer-issued orders may not be produced until they are due for release, being held in a pending file.

Computerisation indicators: large number of orders issued; large amount of data (such as routing information, quality information) with each order.

133. Handle goods inward

Core

Goods received from suppliers must be checked and recorded so that necessary actions such as payment or rejection can be initiated.

Subtasks: 134,139,143,146

134. Check goods against order

Incoming goods are normally accompanied by a delivery note. This document details the order as despatched by a supplier. It is standard practice to check the delivered quantity against the purchase order in companies where suppliers cannot be trusted.

Many "Just-in-Time" or "Total Quality" companies are developing relationships with suppliers which render this task unnecessary.

Subtasks: 135,136,137,138

135. Count goods

Dependent upon 134

Manual task.

136. Identify shortage/excess

Dependent upon 134

This activity is performed to identify a discrepancy between the quantity detailed on the purchase order and the quantity actually delivered by the supplier.

Computerisation indicators: large number of incoming items; order information can be made available in a computer system.

137. Raise shortage note

Shortages in delivery are likely to impact on the manufacturing lead time of an order. The relevant authority in manufacturing is notified of these shortages so that the appropriate action may be taken.

Computerisation indicators: large number of incoming items; order information can be made available in a computer system.

138. Raise goods-in note

A goods in note is generally raised to record the quantity of goods actually received from a supplier for a given order. This information is used for the settlement of incoming invoices from the supplier.

Computerisation indicators: large number of incoming items; order information can be compared to goods-in data in a computer system.

139. Check goods quality

The need for this activity is dependent on the supplier relationship. If there is a high level of confidence in the quality level of the incoming goods, then a goods-in inspection may not be required.

Subtasks: 140,141,142

140. Inspect/ test goods

(Context)

Dependent upon 139

141. Raise reject note

Reject notes may be used to indicate the reasons for which goods are unacceptable.

Computerisation indicators: large number of incoming items; order information can be made available in a computer system.

142. Raise defect note

Defect notes may be used where part of an order is defective or where the quality of the goods means that they can only be used under special conditions.

Computerisation indicators: large number of incoming items; order information can be made available in a computer system.

143. Relocate goods

Goods supplied may need to be moved to the appropriate manufacturing area or to the stores. This is not required in some Just-in-Time companies who arrange for deliveries to arrive at the time and place they are required for manufacturing.

Subtasks: 144,145

144. Deliver to point of use

145. Place in stores

146. Update records

Stock records must be updated when stock is received for two reasons:

1. to initiate payment

2. to allow the stock level to be monitored and made use of by a computerised stock system.

Computerisation indicators: large number of incoming items; order information can be made available in a computer system.

147. Manufacture products

Core

This activity represents the production activities together with the closely related management tasks. This includes low level scheduling activities, the processing of work through the factory, and the monitoring of factory performance.

Subtasks: 148,154,167

148. Low level scheduling

Core

Low level scheduling is used to counteract day to day variances on the shop floor, in order to meet the higher level production plans.

Subtasks: 149,150

149. Receive works order

Core

150. Allocate resources

Core

Resources must be allocated to orders as work progresses.

Subtasks: 151,152,153

151. Identify resource requirements

Core

The exact resource requirements in terms of the type of resource required and the time required must be identified. This information may come from works instructions, route cards etc.

Manual task.

152. Identify resource availability

Core

The availability of the resources must be identified so that a viable schedule can be created. Variations in resource availability may arise from a wide range of factors including machine breakdown, absence of operators, etc.

Manual task.

153. Allocate resources to orders

Core

The allocation of resources to orders involves the creation of a timetable or schedule.

Manual task. Some computer tools are available which act as decision support tools for this task, allowing the user to see results of working to particular schedule combinations.

154. Process work through factory

Core

Work must be processed through the factory according to the low level schedule in order to produce a product which is ready for despatch to the customer.

Subtasks: 155,158,159,162

155. Release work to shop floor

Core

At the correct time, orders are issued to the shop floor so that work can begin.

Subtasks: 156,157

156. Issue works instructions

Core

Works instructions may be issued with works orders, or separately. In some businesses, work is processed according to standard instructions which are only issued when changes occur.

Computerisation indicators: instructions need to be issued with orders; instructions are stored on computer (because of length or to remove filing).

157. Issue material

Core

The material required for an order is issued to the shop floor.

Manual task.

158. Perform operation or inspection as per instructions

(Context)

Core

Progress of work through a factory generally consists of a series of discrete operations and inspection operations, which may be carried out in different areas by different people.

159. Transfer work between resource areas

Core

Different factories have different arrangements for moving work between processes ranging from no movement or static build for capital items through production lines, automatically guided vehicles, to works movement operators who operate a delivery service within the factory. These arrangements are related to product and process complexity.

Subtasks: 160,161

160. Split batch or expedite etc

Conditions may dictate the need to split batches in order to process a small number of items more quickly, or to make special arrangements to expedite certain work. This activity represents the failure of the low level schedule, brought about by changing circumstances, and is therefore required in emergency only. Splitting and expediting may cause more disruption. When a batch is split, the new batch created must be fitted into the schedule. Expediting means disrupting the schedule to rush an order through.

Manual fix.

161. Record location of work

Management control often relies on knowing the status and location of every order. Work location must therefore be recorded in factories where there is no direct flow of work, i.e. where different jobs take different routes, and where lead times are long enough for the location of a particular job to be forgotten. These two cases tend to arise together.

Computerisation indicators: centralised control requires information to be brought together from around the factory.

162. Prepare product for despatch

Core (Context)

Certain operations are required which are not part of the manufacture of the product.

Subtasks: 163,164,165,166

163. Test product

(Context)

Product testing may be performed separately to production, especially where different equipment is required.

164. Label/mark product

(Context)

Product identification may form a final operation where the label provides certification of quality or warranty.

165. Store product

(Context)

Finished goods may be stored before despatch routinely in make-to-stock companies or temporarily in make-to-order companies.

166. Pack product

(Context)

Packing may be a separate task, especially where products are stored unpacked then packed for shipping. This activity depends upon the nature of the product concerned.

167. Monitor factory performance

Core

Monitoring factory performance provides feedback for the improvement of the manufacturing of products.

Subtasks: 168,169,170,171,172

168. Monitor work in process level

The level of work in process (or work in progress) is a meaningful monitor in companies where the flow of work is not constant either because of changing product mix or because of a variety of product routes through the factory. In a process plant the WIP level is a design variable of the manufacturing system. In a mixed factory the WIP level is a measure of the efficiency of the manufacturing system.

Computerisation indicators: centralised control; varied production routes; long lead times.

169. Monitor output level

170. Monitor due date compliance

171. Monitor cost

172. Monitor down-time

173. Evaluate manufacturing performance

Core

The business must continually reassess the performance of the means it uses to get products to sell. This includes the return on investment of the factory, output quality and reliability, manufacturing methods, suppliers, etc, and is the feedback on the degree to which manufacturing plans and targets have been met. This activity is not concerned with the day to day running of manufacturing operations, but with their existence.

Manual task which may make use of computer aids to collate data.

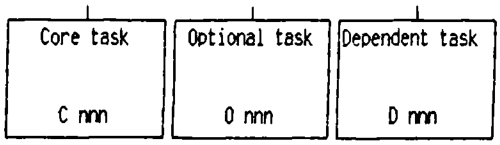
174. Deliver product to customer

(Context)

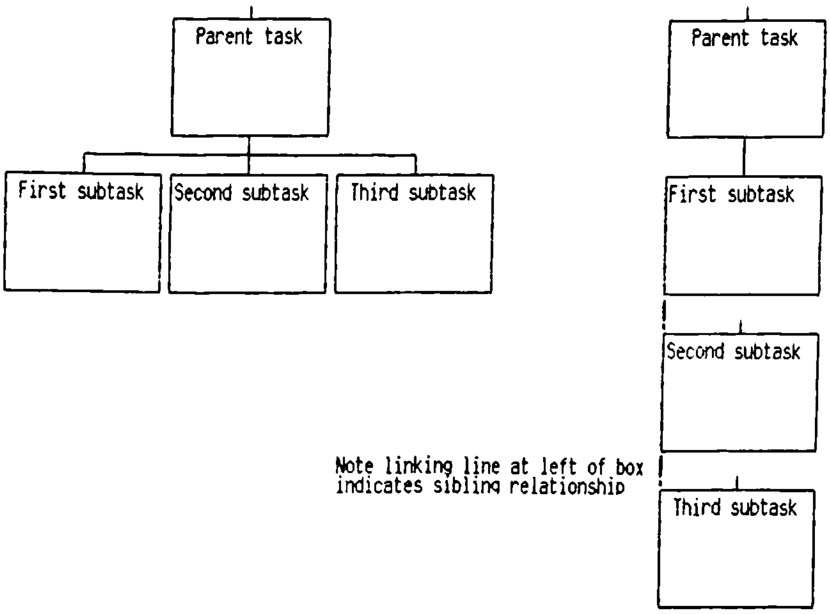
175. Monitor corporate performance

(Context)

Conventions used in Task Model



Equivalent alternative formats used to show child tasks:



Stephen J Childe 1990

Appendix III. Company K

This company is an electronics subcontractor assembling and testing printed circuit boards. Components and bare boards are either purchased from suppliers or supplied by customers. Much of the company's work consists of pre-production and prototype runs for which there are no firm designs, methods or bills of material. Consequently the company operates to very short time scales and has great difficulty in scheduling work.

The company currently has no computer aids to production management, although planned expansion is expected to necessitate computer assistance.

3. Plan product portfolio

This is not appropriate in the case of a subcontractor where a portfolio is not offered to the marketplace. Instead the company offers a range of services which must be planned in a similar way.

42. Receive enquiry from customer

Incoming customer enquiries are recorded on an Enquiry Form. The Sales Engineer raises an Enquiry Form, irrespective of the source of the enquiry and records the following information:

> Customer: Name, Address, Contact Name, Contact Position, Telephone number, Fax number
>
> Quotation: Quotation Number, Date in, Date required, Date out
>
> Order: Drawing Number, Quantity, Delivery Details, Component source (Free issue/ procurement), Quality Assurance required, Samples provided.

43. Check feasibility of work

This activity is performed within the Sales department by making the following enquiries:-

1. Production Management: To ascertain the feasibility of producing the order by the specified delivery time, taking into account the existing loads on the shop floor.

2. Production Engineering: To confirm the feasibility of manufacturing the order using the existing resources and to identify any additional tooling requirements.

3. Quality Department: The enquiry process is used to identify the cost implications of any special quality requirements for the order.

44. Check customer credit status

This process is performed when processing an order. Orders will not be accepted from organisations which have historically had a poor settlement record.

46. Identify facilities required

This activity is under the control of the Production Engineer. The documentation and sample provided by the customer is analysed to identify the processes that will need to be performed to manufacture the product. This activity relies on the skills and experience of the Production Engineer.

54. Determine price to customer

The costing mechanism used within this organisation relies on standard costing methods. Each order is costed according to a standard number of processes within manufacturing, taking into account the number of components within the product and its assembly complexity. Standard unit labour costs are used according to the skill level required for each process. This is thus a cost-plus approach.

55. Determine manufacturing cost

This activity is required to estimate the manufacturing cost of the order. The following activities are used to determine individual unit cost of the product.

56. Identify processes required

Each of the processes required to produce a standard product is known to the Costing Engineer. The additional processes required to manufacture the product are identified from the sample or documentation provided by the customer.

57. Estimate process times

This activity relies on the expertise and experience of the Cost Engineer. The engineer is required to estimate the time taken for each of the processes identified by the previous activity. Process times are detailed for those processes which have a historical precedent. Those processes for which no standard time is documented are either determined by an enquiry to the Production Engineer or by the nearest equivalent standard time.

59. Compare with previous costs

A historical record is maintained of all the orders completed by the organisation. The information is used to determine the accuracy of the Standard Costed Order. This process is used as both a feedback on the costing methods used by the company and to confirm the cost of the product.

60. Consider market relationship

This activity is implicit to the costing process. Experienced Sales and Cost Engineers are able to estimate the current rates for manufacturing a given order, and in some situations the cost the customer or market is likely to bear. The activity is used to ensure that quoted prices are within the bounds of what is acceptable for the industry.

61. Estimate demand elasticity (max price)

This activity is used to estimate the potential price that the market is likely to tolerate. If the estimated cost of production of an order is not significantly lower than this then policy decisions are required to either cut the cost of production, modify the method of costing orders or consider an alternative product as a potential source of revenue.

63. Issue quotation to customer

A formal quotation is issued to the customer stating both price and delivery date for the order. A copy of the quotation is retained by the company in case a firm order is placed by the customer.

64. Process orders

All production is to order. A works order package is generated to standardise the form of incoming orders. A more detailed product description is provided by customer samples, drawings and parts list. A number of copies of the works order package are produced and distributed to the relevant authorities within the company.

65. Receive order from customer

Incoming orders are processed within Sales and Administration. The customer has usually made a formal enquiry to the organisation regarding price and delivery date and has received a quotation. Orders received by the company must refer to the quotation document raised for the corresponding enquiry.

68. Confirm feasibility of order

This activity is usually performed by a number of separate members of the organisation. Each member is considered to be the authority for some aspect of the manufacture of the product and is responsible for determining the feasibility and impact of the order.

71. Identify facilities required

This activity relies on the experience and skill of the Production Engineer in determining the processes required to manufacture the product. The facilities required are determined by these processes.

72. Identify skills required

The processes identified in the earlier activities provide input for this activity. For each of the processes the level of skill required is identified so that the appropriate costing and scheduling decisions may be made.

73. Compare facilities & skills to requirements

The additional tooling and skill requirement are identified during the initial processing of an order. Any tooling and fixtures required to complete the order are included in the quoted price. Capital equipment needs are identified when a number of orders can not be accepted, and when an appreciable impact on sales revenue is noticed.

74. Identify equipment or training needs

This activity is performed by the production engineer. During the processing of the order details, any special tooling or skill needs are identified and an order placed with the appropriate authority.

75. Check manufacturing capacity and due date

A high level manual schedule is maintained detailing the orders currently loaded on the shop floor. Additional production loading sheets are maintained detailing the gross hours available for each operation on the shop floor. When an order is accepted, the estimated process hours are taken from the available hours. This system provides a view of the remaining hours which will be available for a given time period up to two months in advance.

76. Receive resource requirement profile

The resource usage of each order is based on the production engineer's estimate.

77. Compare requirement to existing schedule

If insufficient resources are available to complete the order by the required delivery date, lower priority orders are shifted to accommodate the order. If this approach is not suitable then further resources or overtime work will be considered.

78. Check material availability (gross)

Material requisition is usually based on a single order. Procurement policy ranges from free issue to full procurement.

Free issue contracts are issued on the basis that the customer provides the entire kit of parts required to complete the order and the business is effectively providing an assembly and test service.

Full procurement contracts are issued on the basis that the business is responsible for the procurement of all the materials required to complete the order. This type of contract offers more profit potential as a margin may be added to the raw material costs.

The availability of procured material must be checked.

80. Allocate material (gross)

The organisation works entirely to order. Material procurement is based on individual orders. A number of purchase orders are raised against a given works order. Only when a commonality in material needs across orders is noticed is an aggregated purchase order raised. All materials purchased (except consumables) are thus already allocated to orders.

81. Produce works instructions (layouts)

The Production Engineer receives a works order package from the Sales department. The information provided usually includes:-

Drawing Details: a detailed part drawing describing the product.

Parts List: identifying all the component and material needs of the product.

Bare Board: an unpopulated PCB which may be used to test the flow soldering process.

Populated Board: a fully populated board showing the required product.

From this information a detailed assembly package may be produced.

82. Check customer requirements

This activity is performed by the Production Engineer. The information provided by the customer is analysed and a detailed assembly package is generated which is used by the operators manufacturing the product. If insufficient detail is provided by the customer then a detailed dialogue with the customer is often required to clarify specific aspects. A formal record of this dialogue in the form of fax copies is maintained to provide support to any future query which may arise.

83. Check drawing issue etc

This activity is a simple validation process to confirm that the correct issue drawing has been received for the order.

84. Check parts list

The activity is used to confirm that the parts list corresponds directly to the drawing details provided by the customer. For each of the components on the drawing the related part information is checked off against the parts list.

86. Generate process instructions

The information provided by the customer is analysed to identify the processes required to manufacture the product. The results of this investigation are recorded in the form of an assembly data package, which provides sufficient detail for an operator to manufacture the product.

87. Apply normal process methods

The generation of detailed works instructions relies on historical precedent. The processes used in the past to manufacture products are likely to be used in the manufacture of a given product. This information is formally maintained in past assembly data packages, and informally in the form of knowledge and experience of the Production Engineer.

88. Confirm with customer

Correspondence is stored, usually in the form of fax copies, in the "Common Manufacturing" file.

89. Generate inspection instructions

This activity is performed by the Quality Engineer. If the product is to be manufactured to accepted industrial standards, then the quality requirements are well known throughout the site and special instructions are not generated. If a particularly high level of quality is stipulated by the customer a detailed quality plan is generated to assist both the manufacture and the inspection of the product.

91. Confirm with customer

The results of any dialogue with the customer are recorded the form of fax copies in the "Common Manufacturing" file.

92. Collate / assemble instructions

Both the process and quality instructions are collated into a package known as the assembly data package.

94. Add order to manufacturing schedule

This activity involves taking the works order number, description and quantity and placing the information on the master production schedule.

95. Maintain manufacturing schedule

A high level production schedule is maintained by the Production Manager. This details firm orders placed with the business and due to be delivered within a three to six month time horizon. Generally delivery dates are detailed on the production schedule and start dates calculated from the manufacturing and supply lead times using a backward loading technique.

96. Plan capacity utilisation

This activity is performed by the Production Manager. Loading sheets are maintained detailing the gross resource hours available for each of the manufacturing processes for a given week. When a firm order is placed on the Master Production Schedule the gross process requirements for the order are deducted from the available resource hours. The hours remaining on the loading sheets represent capacity which is available for future orders.

97. Report capacity requirements inc excesses

This activity is required to identify any overloading of the production facility during any given time period. This situation indicates that a rescheduling activity is required. High priority orders for important customers take precedence over existing orders which may need to be shifted. Under exceptional conditions the acquisition of additional resource or the use of overtime may be considered.

102. Confirm master production schedule

The organisation works to a one-month time horizon. Any changes made to the production schedule after the freeze point are expected to impact on the delivery of the order.

105. Obtain raw material

All components are sourced externally to the organisation. Components are obtained either through a free issue agreement with the customer or via procurement from the relevant supplier.

106. Issue manufacturing and purchase orders

All component sourcing is external to the organisation. A number of purchase orders are raised for a given customer order.

107. Identify requirements (ROP)

ROP is used for consumables only.

108. Monitor stock levels

An enquiry is made from time to time to ascertain the existing stock levels.

109. Flag items below re-order point

If stock held is below the re-order point, a purchase order is raised manually.

110. Identify requirements (MRP)

Material requirement is based on individual orders. No aggregate ordering of components takes place, unless component commonality happens to be identified during the order processing stage.

111. Identify gross requirements

Component requirement is based on an individual order, therefore no grossing takes place across a number of different orders.

112. Receive customer order information

Customer orders are received in the form of a works order package. The gross material need is calculated from the order quantity.

113. Explode orders (BOM)

The parts list information (provided by the customer) is exploded to identify the material needs for a single unit, for those orders for which material must be purchased. (Many orders use free issue components supplied by the customer.)

114. Totalise gross requirements for each item

Requirements are not grossed since most orders use free issue components. This activity will be required if the company expands into full procurement business.

121. Issue orders

All components are sourced from external suppliers by raising standard purchase orders.

133. Handle goods inward

This process is handled using a number of manual procedures. A Goods Received Note is raised for incoming deliveries.

134. Check goods against order

A manual file of outstanding purchase orders is maintained. This information is cross-referenced against the supplier delivery note.

135. Count goods

All incoming goods are counted to ensure that the quantity delivered matches both to the number on the delivery note and to the purchase order.

136. Identify shortage/excess

The expected delivery quantity is detailed on the relevant outstanding purchase order. If there is a discrepancy between this quantity and the quantity delivered by a supplier then the appropriate action is taken.

137. Raise shortage note

If there is a discrepancy between the quantity on a purchase order and the quantity delivered by the supplier, a shortage note is raised to identify to manufacturing the unavailability of materials. No mechanism exists to handle the over delivery of goods for the return to the supplier.

138. Raise goods-in note

A Goods Received Note is raised detailing the following information:-

> Date Raised, Supplier Name, Purchase Order No., Works Order No., Advice Note No., Item No., Description, Quantity Advised, Quantity Received, Quantity Accepted, Quantity Rejected, Reject Note No., Inspection Default Report No., Shortage Note No.

139. Check goods quality

A goods in inspection system is used mainly to identify that the correct items have been delivered. This is intended to identify potential assembly problems before the manufacture of an order.

140. Inspect/ test goods

This activity is a visual inspection of all incoming goods to ensure that they conform to the specified standard. No component testing takes place.

141. Raise reject note

A reject advice note is raised to identify the rejection of goods to the supplier. The following information is detailed.

> Serial No., Supplier Name, Supplier Address, Date Raised, Purchase Order No., Supplier Advice Note No., Supplier Release Note No., Inspection Default Report No., GRN No., Item No., Description, Specification, Issue No., Quantity Received, Quantity Rejected, Reason, Date Dispatched.

142. Raise defect note

An inspection defect report is raised to identify the reason for the rejection of incoming goods. The following information is detailed on the document:

> Serial No., Originator Name, Date Raised, Purchase order No., Works order No., Quantity Inspected, Quantity Defective, Inspection Level, Report Details, Corrective Action, Approved By.

143. Relocate goods

A kit marshalling process takes place in Stores to produce a complete kit of components for a given order to be released to manufacturing. Any shortages in the kit are notified to manufacturing on a shortage note.

144. Deliver to point of use

The completed kit of components is delivered to manufacturing together with its route card.

148. Low level scheduling

The low level scheduling activity is performed by updating the production loading sheets. The estimated process time for an order are deducted from the gross hours available for the process over a given time period.

149. Receive works order

Orders are released to the shop floor in the form of a standard Works Order package. The following information is detailed:

> Works Order No., Date Raised, Originator Name, Customer Name, Customer Address, Delivery Address, Telephone No., Fax No., Customer Order No., Estimate No., Item No., Description, Drawing No., Issue, Quantity, Unit Price, Assembly and Inspect time, Delivery Schedule.

150. Allocate resources

The low level scheduling information is maintained on production sheets for each of the work centres. A team leader for five to six operators is responsible for ensuring that the correct work is completed to schedule. The actual process time for each product is recorded.

151. Identify resource requirements

The processes required to be performed to manufacture the product have been identified during the cost estimation phase. The resources required to manufacture the product directly correspond to these processes. The total number of hours required for each process is detailed on the costing sheets.

152. Identify resource availability

The gross number of hours available for each resource over a given time period is detailed on the production loading sheets. The resource availability is determined by the remaining hours available after the process hours for the order have been deducted.

153. Allocate resources to orders

Process hours are allocated to a given order by deleting the estimated process hours for the product from the hours remaining for that process.

154. Process work through factory

Most of the products manufactured by the business follow a standard route through the shop floor as shown below:

First stage Assembly: (Op 1)

Load components onto board
First stage inspection
Film wrap
Crop
Flow solder
Remove masking and film wrap
Clean
Inspection and touch up

Second stage assembly: (Op 2)

Clean locally
Fit ICs to sockets
Add labels
Final inspection

155. Release work to shop floor

Orders are formally released to the shop floor in the form of a Works Order. The content of this document has been detailed in Task No.149.

157. Issue material

Materials are issued to the shop floor in the form of a kit. The kit contains all the components needed to manufacture a given order.

158. Perform operation or inspection as per instructions

During the progress of work through the shop floor the work is inspected as per quality instructions. For industrial quality products standard quality practices are adhered to. For products demanding a higher level of quality, the inspection procedures are dictated by the Quality Plan.

159. Transfer work between resource areas

The required route for the product is detailed on the route card. When work has been completed at one work centre it is signed off and passed to the next stage.

162. Prepare product for despatch

Immediately an order completes final inspection, it is packed and despatched to the customer. The products are packed in electrostatic protective packaging and labelled, and a despatch note is raised. Finished goods are not stored.

Manufacturing Corporate Mission C 1
Define corporate strategy C 2
Plan supply of products C 16
Plan production O 23
Forecast order requirements O 25
Produce forecasts O 29
Evaluate forecast technique O 30
Maintain corporate infrastructure C 31
Maintain fixed assets C 32
Maintain capital/ investment resources C 33
Maintain / train personnel resource (HRM) C 34
Maintain information systems C 35
Maintain supplier relationships C 36
Maintain market / customer / dealer relationships C 37
Process orders and enquiries C 40
Process enquiries C 41
Receive enquiry from customer C 42
Check feasibility of work C43
Check customer credit status C 44
Check manuf. capability including quality C 45
Identify facilities required C 46
Determine price to customer C 54
Issue quotation to customer C 63
Determine Manufacturing cost O 55
Identify processes required O 56
Estimate process times O 57
Apply standard cost rates O 58
Compare with previous costs O 59
Consider market relationship O 60
Estimate demand elasticity (max price) O 61
Check customer relationship O 62
Receive order from customer C 65
Confirm feasibility of order C 68
Check manuf. capability including quality C 70
Identify facilities required C 71
Identify skills required O 72
Compare facilities and skills to requirements C 73
Identify equipment or training needs C 74
Check manufacturing capacity and due date C 75
Compare requirement to existing schedule O 77
Check material availability (gross) O 78
Check customer requirements O 82
Check drawing issue etc. O 83
Check parts list O 84
Process orders C 64
Formalise order C 79
Allocate material (gross) O 80
Produce works instructions (layouts) C 81
Generate instructions C 85
Generate process instructions C 86
Apply normal process methods O 87
Confirm with customer O 88
Generate inspection instructions C 89
Apply normal inspection procedures O 90
Confirm with customer O 91
Collate / assemble instructions C 92
Confirm order to customer O 93
Add order to manufacturing schedule (programme) C 94
Get products to sell C 38
Plan manufacturing (MPS) C 39
Maintain manufacturing schedule C 95
Plan capacity utilisation O 96
Report capacity requirements including excesses O 97
Aggregate product profiles D 98
Aggregate load for spares O 99
Identify work for specific time buckets D 100
Confirm master production schedule C 102
Obtain raw material C 105
Issue manufacturing and purchase orders C 106
Identify requirements (ROP) O 107
Monitor stock levels D 108
Flag items below re-order point D 109
Identify requirements (MRP) O 110
Identify gross requirements O 111
Receive customer order information (schedule) D 112
Explode orders (BOM) O 113
Issue orders C 121
Sort requirements by source C 122
Issue purchase orders C 127
Issue works orders C 130
Handle goods inwards C 133
Check goods against order O 134
Count goods D 135
Identify shortage/ excess D 136
Raise shortage note O 137
Raise goods in note O 138
Check goods quality O 139
Inspect goods D 140
Raise reject note O 141
Raise defect note O 142
Relocate goods O 143
Deliver to point of use O 144
Update records O 146
Deliver product to customer C 174
Monitor corporate performance C 175
Manufacture products C 147
Low level scheduling C 148
Receive works order C 149
Allocate resources C 150
Identify resource requirements C 151
Identify resource availability C 152
Allocate resources to orders C 153
Process work through factory C 154
Release work to shop floor C 155
Issue works instructions C 156
Issue material C 157
Perform op or inspection as per instructions C 158
Transfer work between resource areas C 159
Prepare product for despatch C 162
Test product O 163
Label/ mark product O 164
Pack product O 166
Monitor factory performance C 167
Evaluate manufacturing performance C 173


Manufacturing Corporate Mission C 1
Define corporate strategy C 2
Plan product portfolio O 3
Plan supply of products C 16
Maintain corporate infrastructure C 31
Maintain fixed assets C 32
Maintain capital/ investment resources C 33
Maintain / train personnel resource (HRM) C 34
Maintain information systems C 35
Maintain supplier relationships C 36
Maintain market / customer / dealer relationships C 37
Get products to sell C 38
Plan manufacturing (MPS) C 39
Process orders and enquiries C 40
Process enquiries C 41
Receive enquiry from customer C 42
Check feasibility of work C43
Check customer credit status C 44
Check manuf. capability including quality C 45
Identify facilities required C 46
Identify skills required O 47
Compare facilities and skills to requirements O 48
Identify equipment or training needs O 49
Check manufacturing capacity and due date O 50
Determine price to customer C 54
Determine Manufacturing cost O 55
Issue quotation to customer C 63
Process orders C 64
Receive order from customer C 65
Confirm feasibility of order C 68
Check manuf. capability including quality C 70
Identify facilities required C 71
Identify skills required O 72
Compare facilities and skills to requirements C 73
Identify equipment or training needs C 74
Check manufacturing capacity and due date C 75
Receive resource requirement profile O 76
Compare requirement to existing schedule O 77
Formalise order C 79
Produce works instructions (layouts) C 81
Confirm order to customer O 93
Add order to manufacturing schedule (programme) C 94
Maintain manufacturing schedule C 95
Confirm master production schedule C 102
Confirm work in time buckets O 103
Issue MPS document O 104
Obtain raw material C 105
Issue manufacturing and purchase orders C 106
Identify requirements (ROP) O 107
Monitor stock levels D 108
Flag items below re-order point D 109
Identify requirements (MRP) O 110
Identify gross requirements O 111
Receive customer order information (schedule) D 112
Explode orders (BOM) O 113
Totalise gross requirements for each item O 114
Produce gross requirements list O 115
Identify net requirements O 116
Receive gross requirements for each item O 117
Identify unallocated stock level for each item O 118
Allocate stock to orders O 119
Net off stock against requirements O 120
Issue orders C 121
Sort requirements by source C 122
Issue purchase orders C 127
Issue works orders C 130
Handle goods inwards C 133
Check goods against order O 134
Count goods D 135
Identify shortage/ excess D 136
Raise shortage note O 137
Raise goods in note O 138
Check goods quality O 139
Inspect goods D 140
Raise reject note O 141
Raise defect note O 142
Relocate goods O 143
Deliver to point of use O 144
Place in stores O 145
Update records O 146
Manufacture products C 147
Low level scheduling C 148
Receive works order C 149
Allocate resources C 150
Identify resource requirements C 151
Identify resource availability C 152
Allocate resources to orders C 153
Process work through factory C 154
Release work to shop floor C 155
Issue works instructions C 156
Issue material C 157
Perform op or inspection as per instructions C 158
Transfer work between resource areas C 159
Record location of work O 161
Prepare product for despatch C 162
Test product O 163
Label/ mark product O 164
Store product O 165
Monitor factory performance C 167
Monitor work in progress level (WIP) O 168
Monitor output level O 169
Monitor due date compliance O 170
Monitor cost O 171
Monitor down-time O 172
Evaluate manufacturing performance C 173
Deliver product to customer C 174
Monitor corporate performance C 175

Appendix IV. Company L

This company produces toiletries, dental products, medicines and medical products. Production involves dispensing, various combination and mixing processes, metering into tubes, tablets, sprays etc, display packaging and transportation packaging. The company uses several types of specialised processes, some of which are dedicated to particular products or product types. A wide variety of raw materials are used, ranging from extremely expensive drugs used in very small quantities, to cheaper bulk items. The product range is approximately 500. There are large numbers of similar products which require identical processing using different containers, for instance export items require different packaging and labelling.

Production control is computerised, using a form of Period Batch Control with MRP purchasing. The software was written in-house.
A special control requirement is the complete traceability of all items to the batch of raw materials used.

Production Management Task Model - Company L

2. Define corporate strategy

The strategy is formulated by the parent company and ratified by the UK board of Directors. Details of these procedures were unavailable.

3. Plan product portfolio

All tasks in this area are carried out by the parent company and the marketing department. They are not regarded as part of Production Management.

16. Plan supply of products

This is a strategic activity of the parent company.

41. Process enquiries

All enquiries are dealt with by the sales department following receipt of forecast requirements.

42. Receive enquiry from customer

Enquiries are handled by field sales representatives who refer to standard price and discount arrangements.

43. Check feasibility of work

This task is performed implicitly by Sales staff who work to the current range which the company has available. Enquiries for products which are not currently available are handled by the parent company.

44. Check customer credit status

Customer status is investigated manually by sales staff with reference to customer accounts if necessary.

54. Determine price to customer

Price is determined on a cost-plus basis.

55. Determine manufacturing cost

Manufacturing costs are calculated manually from the product structure information held in computerised product files and operating cost records for each manufacturing line held on paper.

63. Issue quotation to customer

Individual quotations are not issued. Standard prices are quoted for most sales. However, the prices charged to certain major customers are negotiated with the customer at Board level.

65. Receive order from customer

Orders are received from the Marketing Department in the form of forecasts. From the point of view of Production management, these forecasts are in fact firm orders, as Marketing demands production to forecast.

68. Confirm feasibility of order

In this company the product details are already confirmed before any orders can be accepted, so this activity is concerned only with the resources required to complete the order.

70. Check manufacturing capability including quality

The company only accepts orders for products in its catalogue, thus ensuring it is capable of supplying them. The processes used by the company are continually checked to ensure that they meet the required quality standards.

73. Compare facilities & skills to requirements

Facilities and skills resources available are continually adjusted in the light of the changing market situation but not in response to any particular order.

75. Check manufacturing capacity and due date

All orders are entered on the CAPM system as they are received, and a cursory check of the orders identifies any unusual ones which may disrupt the normal timetable of the manufacturing period.

76. Receive resource requirement profile

This information is held in the CAPM system.

77. Compare requirement to existing schedule

Once all orders for a production period are received, the schedule for the period is established. This is a manual task using the computer as a decision aid. The schedules for each period are normally alike. This is an example of Period Batch Control (PBC).

78. Check material availability (gross)

No check on material availability is required as long as orders are from the normal range and there are no problems with suppliers. Any supplier problems of which the company becomes aware cause this check to be made manually when processing orders.

81. Produce works instructions (layouts)

All activities relating to the generation of works instructions are dealt with at the product development stage and are subject to statutory approval and trials. These activities are thus separated from Production Management. The instructions generated are entered into the CAPM system where they may be used but not altered by production staff. The instructions form part of the product structure file which also contains the Bill of Materials.

93. Confirm order to customer

A copy of the order is generated by the system when the order is entered.

94. Add order to manufacturing schedule

Orders are transferred into the schedule once all orders for the period have been received. The orders are entered as they are received, so all can be added at once.

95. Maintain manufacturing schedule

The computer is used to provide a schedule of work for the production period, indicating when a line must produce each product batch.

96. Plan capacity utilisation

This activity is done entirely by computer. Capacity variations such as holidays are entered. The system takes all the orders for the manufacturing period and assigns each a start and finish date.

97. Report capacity requirements inc excesses

This is greatly simplified by the use of Period Batch control, where all manufacturing periods are basically similar.

102. Confirm master production schedule

The schedule is approved and authorised by the Production Control Manager.

106. Issue manufacturing and purchase orders

All orders are issued by the production control computer. Some checks are done manually.

108. Monitor stock levels

All stock transactions are allocated and recorded by computer, and the computer monitors the levels. These are printed out. Regular stock audits take place at intervals according to the value of use of each stock item.

109. Flag items below re-order point

A printout of stock levels is examined by Production Control staff to determine which items must be re-ordered in the light of current production orders. This permits flexibility since the ordering is not based upon a predetermined level.

110. Identify requirements (MRP)

Computerised MRP.

111. Identify gross requirements

Gross requirements are calculated by the production control computer.

112. Receive customer order information

Performed by the Production Control computer.

113. Explode orders (BOM)

Performed by the Production Control computer.

114. Totalise gross requirements for each item

Performed by the Production Control computer.

115. Produce gross requirements list

Performed by the Production Control computer.

116. Identify net requirements

Performed by the Production Control computer.

117. Receive gross requirements for each item

Performed within the Production Control computer.

118. Identify unallocated stock level for each item

Performed by the Production Control computer.

119. Net off stock against requirements

Performed by the Production Control computer.

120. Allocate stock to orders

Performed by the Production Control computer.

121. Issue orders

Performed by the Production Control computer. The list of bought-out requirements is checked by the Buying department before the orders are raised, to allow manual intervention such as rounding up to convenient shipping quantities or altering dates to meet current supply conditions.

130. Issue works orders

Works orders are held by the planning department until due. They are then issued to the warehouse staff who draw the required materials from stock and pass them to the appropriate production line.

133. Handle goods inward

Goods received from suppliers are registered, checked for quality, and transported to the warehouse where they are available for production use. All information relating to status and location is stored on computer.

134. Check goods against order

Arrival of goods is registered on computer (by order number). The computer shows the quantity expected and generates a Goods In Note.

135. Count goods

All incoming goods are counted to ensure that the quantity delivered matches both the number on the delivery note and the purchase order.

136. Identify shortage/excess

The quantity received is entered in the computer system. The purchasing module then registers the outstanding quantity as a shortage or as a part order.

137. Raise shortage note

The purchasing system lists short orders so that action may be taken by purchasing staff. Orders where the expected quantity is exceeded are also identified. Notes are stored in the system and are not usually printed.

138. Raise goods-in note

The GIN is raised using the computer. An identifying label bearing a unique lot number is printed out for identification of the goods in the warehouse. The lot number is unique and therefore provides traceability from the raw material to the finished product.

139. Check goods quality

Receipt of goods is notified to quality control staff. All goods must pass quality tests before they can be released for manufacturing.

140. Inspect/ test goods

All incoming goods are checked.

141. Raise reject note

Rejection of any goods is entered on the computer system to be handled by purchasing staff.

142. Raise defect note

Any special notes are entered into the computer system. A serial number is allocated to the defect note as if it were a note on paper. These notes re-appear when the goods are allocated to an order.

145. Place in stores

Goods are placed in stores once the Goods-In checking has been completed.

146. Update records

The new stock location is registered on the computer.

147. Manufacture products

Manufacturing is controlled on a day to day basis by production managers according to the schedules and orders provided by the Production Control department.

148. Low level scheduling

Low level scheduling is done on paper by shop floor staff who monitor the progress of each order.

149. Receive works order

Works orders are printed by the computer and passed to the warehousing foreman for the material to be picked. The order includes a picking list which identifies the batch of material to be used and its location.

151. Identify resource requirements

The production line to be used for each order is shown on the Works Order. Only labour has to be allocated.

152. Identify resource availability

Production staff must make themselves aware of the state of resources including labour availability in order to assign resource to orders.

153. Allocate resources to orders

Staff are allocated to appropriate areas. Schedules are maintained by shop floor supervisors.

154. Process work through factory

Most of the products manufactured by the business follow a standard route through the shop floor as shown below:

Warehouse staff pick bulk stocks

Quantities required are measured out by Dispensary

Production line operators perform all necessary production operations (typically mix, pack, box, wrap)

Quality control staff sample-test work in progress and check all finished goods.

155. Release work to shop floor

Work is released to the shop floor by the supervisor concerned once the materials have been provided by stores.

156. Issue works instructions

Works instructions (from the product structure) are issued with the works order.

157. Issue material

Warehouse staff receive the works orders and pick the required material, then transport it to the appropriate area of the factory, where production begins according to the schedule.

158. Perform operation or inspection as per instructions

Each operation is carried out according to instructions from the product structure file which are printed on the Works Order.

159. Transfer work between resource areas

Warehouse staff transport goods to dispensary and to the first operation. Work then flows along the production line, then warehouse staff transport it to the finished goods store.

160. Split batch or expedite etc

In extreme cases where capacity is urgently required, batches may be stopped and put into storage to be completed later. Batches are never split.

161. Record location of work

All movements of work are recorded by manual entry into the computer. status is recorded whenever an operation is finished (eg dispensing, quality test).

162. Prepare product for despatch

Products are ready for despatch when they come off the production line, although they are generally stored before being despatched according to customer requirements.

163. Test product

All testing is done by sampling goods taken from the production line during processing.

164. Label/mark product

Labelling and marking is part of the production process.

165. Store product

All finished goods are placed in the finished goods stores.

166. Pack product

Products are packed on the production line.

167. Monitor factory performance

All the required parameters of production are reported by the Production Control computer. These include WIP, output and down time. Other factors are measured outside the production area, and are therefore not used to improve manufacturing performance. (eg due date compliance, cost.)

168. Monitor work in process level

Recorded and reported by the Production Control computer.

169. Monitor output level

Recorded and reported by the Production Control computer.

170. Monitor due date compliance

Monitored by the Marketing department.

171. Monitor cost

Monitored by the accounting Department.

172. Monitor down-time

Monitored manually.

173. Evaluate manufacturing performance

The company monitors due date compliance and costs at this level.

PUBLICATIONS

The following pages show the author's publications relevant to this work.

Weston N
Maull R S
Childe S J

An approach to CIM - creating a coping system

Proceedings of IERE Factory 2000 Conference, Cambridge

(IERE Publication No.80)

1988

AN APPROACH TO CIM - CREATING A COPING SYSTEM

N WESTON*, R S MAULL*, S J CHILDE*

SUMMARY

This paper stems from an ACMÉ research project jointly held by Plymouth Polytechnic and Sheffield Business School which has the aim of assisting electronics companies to develop and implement integrated manufacturing systems.

In this paper we concentrate on those companies within the electronics industry developing CAPM systems. Early findings suggest that time horizons have shortened considerably and that these companies are facing particularly turbulent environments. We outline the requirements for flexibility and propose a solution based on the development of contextually bounded infrastructures.

1 Introduction

In recent years much emphasis has been placed on the importance of introducing advanced manufacturing and information technologies into British industries. These technologies result in an approach to manufacturing which differs from traditional approaches in the extent to which the computer is used in the design of products, in the design of the production process, in manufacturing and test and in the management and control of the manufacturing system. Undoubtedly, for those companies able to harness and utilise these technologies effectively the rewards derived from improvements in manufacturing competitiveness are substantial.

Unfortunately, the results of introducing Advanced Manufacturing Technology (AMT) and Information Technology in many companies have been unsatisfactory when evaluated against technical, user, business or organisational criteria and it is not unusual for the performance of the implemented system to differ markedly from that which was originally conceived. One of the reasons for this stems from the fact that the benefits from large scale investment in such technologies often cannot be fully exploited without also undertaking a major reorganisation of the company, involving a redistribution of activities and intelligence and a fundamental rethink of manufacturing strategy and systems. The problem of achieving these benefits is further compounded in an environment where it is difficult to define current requirements and near impossible to predict future ones.

2 The Electronics Sector

2.1 Background

Recent evidence [1,2] suggests that the UK electronics sector is one of the fastest growing industrial sectors in Europe. Turnover grew by 37% during the period April 84 to April 86 with a corresponding growth in net profit before tax. Return on capital employed in 1985/86 was 19% for the industry as a whole whilst the stock turnover ratio was 7:1, remarkably low when compared to Japanese figures which indicate ratios in excess of 25:1.

In comparison to the rest of UK industry, 1983 saw a growth in electronics output of 21% compared to 1.9% for manufacturing as a whole. Evidence such as this supports the view that whatever "recovery" took place in the UK during 1983 it was by and large electronics led. However, these figures mask an underlying malaise. In terms of international competitiveness, the UK had a trade deficit in electronics in excess of £2 billion in 1987 which is forecast to quadruple by 1993.

2.2 Research Method

The case study methodology was selected in order to identify and represent the rich picture in terms of content and context in which CAPM systems are being introduced.

The principal means of data collection for the cases has been focused interviews with key personnel from collaborating companies. The aim of these interviews has been to elicit information on the following:

- the historical account of the development of the current CAPM system;
- the level of integration and the interfaces to wider manufacturing and business systems;
- the kind of computer support and information systems required for business

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planning and production management activities;

- the important organisational and attitudinal issues;

- the complexity and dynamic characteristics of the CAPM implementation environment and the wider system environment.

Fieldwork sought to establish whether the following were significant in practice:

- that the environment faced by companies within the defined electronics manufacturing sector was complex, dynamic and perceived as highly uncertain by those involved in the implementation of effective CAPM systems;

- that the key to the successful implementation of CAPM systems lay in adopting a multi-disciplinary approach embodying a top down, business driven orientation rather than the installation of a software product;

- that successful implementation required a fundamental rethink of manufacturing strategy and systems and a redistribution of activities and intelligence.

3 Requirements for Flexibility

Recent research carried out by the authors in a number of companies engaged in surface mount, PCB connectors and in developing electronics for the automotive industry has indicated that the ability to respond flexibly to changing market requirements is a key to competitive success.

This requirement for flexibility is supported by a number of other research findings. Bentley [3] has pointed out the difficulties in predicting future market requirements in Electronics. Slack [4] has stated that "flexibility is the least understood of manufacturing objectives", Burbidge [5] has focused on the development of a production control system for flexible production systems whilst Skinner [6] and Schonberger [7] both address the need for flexibility in making manufacturing competitive.

In such an environment a major problem for companies is coping with uncertainties in supply and demand on one hand and the need to utilise manufacturing facilities efficiently on the other. Experience suggests that companies are responding to these competitive pressures through the increasing use of AMT. Hollier [8] has described AMT has having three legs; Computer Aided Design, Computer Aided Manufacture and Computer Aided Production Management. As part of ACME's CAPM initiative this research has focused on the implementation of CAPM systems.

4 Computer Aided Production Management

CAPM can be thought of as encompassing all computer aids supplied to the production manager. This includes 3 main information processing activities [9].

SPECIFICATION
ensuring the manufacturing task has been defined and instructions produced.

PLANNING AND CONTROL
planning the timetable, adjusting resources and priorities and controlling production activity.

RECORDING AND REPORTING
recording and reporting production status and performance for liaison with other departments and future use in specification, planning and costing.

These individual modules may be implemented separately, e.g. in the form of "micro based spreadsheets" [3]; in an integrated environment such as through the full exploitation of MRPII, or in some intermediate level of integration.

4.1 CAPM Failures

A number of major Electronics companies have been investigated with the objective of determining the implementation success, or otherwise, of their CAPM systems. It is apparent that failure rather than success is more often the outcome. This can be attributed to a number of causes:

- the CAPM requirements were not defined correctly;

- the CAPM requirements were defined correctly but the wrong system implemented;

- the CAPM requirements were initially defined correctly but these subsequently changed as a result of either new manufacturing strategies or new information requirements;

- the implementation was badly managed;

From the findings to-date the most significant of these failures would seem to be attributable to subsequent changes in the requirements of the system and the need to satisfy, principally, two new demands. The first of these as a result of changes in the manufacturing strategies employed and secondly new information requirements and the integration of the CAPM system to other business systems such as quality and finance. Despite recent advancements and developments in the integration of information technology this is still a major problem area.

Thus, as was recognised in a CAPM State-of-the-Art Report [9], the key to full exploitation of CAPM does not lie in the implementation of a particular system to address a specific need but in the development of flexible infrastructures within which organisations can continue to respond to change.

5 Infrastructures

Hill [10] has defined manufacturing infrastructures as the "controls, procedures, systems and communications combined with the attitudes, experience and skill of the people involved" whilst Skinner [6] has defined manufacturing infrastructures as the "policies, procedures and organisation by which manufacturing accomplishes its work. Specifically production and inventory control systems, cost and quality control systems, work force management policies and organisational structure". Interestingly Skinner differentiates between structural elements, the number, capacity and location of plants, and the equipment and process technology. The infrastructure includes the people, systems and procedures.

The authors believe that the deficiency with both definitions is that they fail to include equipment, although Skinner includes this within his definition of structure. The authors believe that machines and equipment are part of the infrastructure. For instance, flexible machining and modular conveyor systems can add to the flexibility of a manufacturing enterprise. In recognition of this deficiency we propose an eclectic definition incorporating, machines, people, systems, procedures, controls, communications and organisational structure.

When the environment is highly dynamic and the markets turbulent single point solutions are inappropriate and ineffective. In such a situation the authors propose that the way forward lies in the development of infrastructures to provide adaptability and flexibility and to facilitate the continual evolution of the organisational system. Evidence from research so far undertaken suggests that these infrastructures need to address computing and informational, technical and organisational factors in an integrated manner in order to achieve the necessary level of responsiveness to changing and often unpredictable demands.

The implications for the design of CIM systems are revolutionary. Traditional methods involving the specification of a design are no longer valid because of the difficulty, or impossibility, of defining the "ends" required - when the "ends" are subject to continual change. The focus of attention must therefore be directed at ensuring that the "means" are available to cope with the variety of potential demands on manufacturing. This can only be achieved through the development of an appropriate set of flexible infrastructures.

The authors recognise that there is a trade off between flexibility and cost. To attempt to develop infinitely flexible systems able to respond to every change in the environment - even if this were technically feasible - would be prohibitively costly. It is therefore proposed that contextually bounded infrastructures are developed which are circumscribed by the nature of the core business activities.

The challenge to those concerned with the creation of infrastructures involves firstly identifying and removing the barriers inhibiting the development of well structured, flexible, modifiable and maintainable systems and secondly, promoting the establishment of systems with performance parameters consonant with the requirements of the wider system. Modular design strategies, modular CAPM packages, fourth generation languages, fault tolerant computers etc. are examples of current technologies which facilitate this desired system state.

The premises under investigation within this, and the overall research project [11], have implications that challenge conventional notions concerning the design and implementation of integrated manufacturing systems. It is proposed that the focus of attention should no longer be placed on gaining a good understanding of the existing system state and forecasting future requirements, but rather on the process of creating appropriate infrastructures.

5.1 An Approach to the Design and Implementation of Infrastructures

An approach to the design and implementation of infrastructures is currently being developed whose theoretical foundation is based upon contingency theory [11]. The objective is to provide users and practitioners with a structured set of guidelines for the implementation of infrastructures whose features will be contingent on the organisational environment. The attributes of the infrastructures relate to the degree of flexibility needed to meet new requirements. For example the level of flexibility of the informational infrastructure is dependent upon the compatibility of the system components and the level of data and informational integration [9].

The approach begins with an external appraisal and internal analysis of the company carried out with company staff. Users articulate current and future degrees of flexibility along a series of dimensions such as changes in manufacturing strategy, changes in integration requirements, etc. along with the limitations imposed by the existing manufacturing facilities. The output of this stage is a "fingerprint" of the company and its current position relative to its environment.

From this it is possible to compare the "fingerprint" against benchmarks of best practice and make a judgement of the appropriateness of the infrastructures currently in operation against those of the best performing companies with similar environmental characteristics. System components with the appropriate degree of flexibility to cope with the potential set of demands on manufacturing can then be selected.

The final stage of the implementation approach concerns bringing about the changes identified as appropriate and necessary. Intervention is based upon guidelines drawn from best practice [12] but can be thought of as involving change along a continuum from incremental to step function.

6 Conclusions

The approach outlined in this paper addresses the need to develop flexible CIM systems to respond to rapidly changing environmental conditions. It is based upon the concept of flexible infrastructures as a means of coping with the uncertainty of the market place.

The paper has focused upon the development of infrastructures within the Electronics sector as an example of the types of infrastructures required in markets which are undergoing particularly rapid change.

The authors postulate that those trying to design CIM systems in response to rapidly changing markets should focus on the means of achieving flexibility through the implementation of appropriate infrastructures rather than designing CIM systems on the basis of existing requirements. The authors have recognised that it is not feasible to design infrastructures which are capable of dealing with all possible outcomes. Infrastructures should be contextually bounded through the environment in which it operates.

These early investigations have extended our knowledge of infrastructures and their desirability for flexibility. The research team have begun to apply the approach in evaluating individual companies and are attempting to develop a situational variety matrix which will place individual companies within a framework of variety. From this a reference model of best practice will be derived which will assist other electronics companies to determine the appropriate degree and type of flexibility required for their environment.

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This paper stems from research conducted under the CAPM programme of the ACME directorate of the Science and Engineering Research Council. The objective of the research is to develop a user led methodology for the implementation of integrated manufacturing systems within the electronics sector.

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DESIGNING FLEXIBLE INFRASTRUCTURES FOR CAPM SYSTEMS

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with acknowledgement to
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Introduction

This paper discusses some of the early results of a three year research project sponsored by the ACME directorate of the Science and Engineering Research Council. The research is multi-disciplinary in nature, incorporating ideas from the fields of Engineering, Computing, Management Science and Organisational Behaviour. The aim is to develop a methodology for the design and implementation of integrated manufacturing systems within the electronics sector and is focussed upon the range of applications known as Computer-Aided Production Management (CAPM).

Computer Aided Production Management

CAPM can be thought of as encompassing all computer aids supplied to the production manager. This includes three main information processing activities [1].

Specification
: ensuring the manufacturing task has been defined and instructions produced.

Planning and Control
: planning the timetable, adjusting resources and priorities and controlling production activity.

Recording and Reporting
: recording and reporting production status and performance for liaison with other departments and future use in specification, planning and costing.

These activities are often performed by the following modules or functions:

Master production scheduling
Stock recording
Capacity planning
Detailed scheduling
Materials requirements planning

Order processing
Bill of materials processing
Work in progress monitoring
Costing
Performance analysis
Etc.

These individual functions may be implemented separately, e.g. in the form of "micro based spreadsheets" [2]; in an integrated environment such as through the full exploitation of MRPII, or in some intermediate level of integration.

Requirements for Flexibility

The research to date has indicated that the ability to respond flexibly to changing requirements is a key to competitive success. This appears to be true even in the areas where the products do not change quickly, change often coming from increased competitive pressure on delivery, cost and quality or from the challenges of implementing new technologies such as surface mounting.

Many companies seem to approach these problems by a combination of the three legs of Advanced Manufacturing Technology described by Hollier [3]: Computer Aided Design (CAD), Computer Aided Manufacture (CAM), and Computer Aided Production Management (CAPM). As part of ACME's CAPM initiative this research has focussed on the implementation of CAPM systems.

Research Method

The case study methodology was selected in order to identify and represent both the context in which CAPM systems are being introduced and the nature of the systems themselves, the content.

The principal means of data collection for the cases has been focused interviews with key personnel from collaborating companies. The aim of these interviews has been to elicit information on the following:

- the historical account of the development of the current CAPM system

- the level of integration and the interfaces to wider manufacturing and business systems.

- the kind of computer support and information systems required for business planning and production management activities

- the organisational and attitudinal issues which were important to the implementation the complexity and dynamic characteristics of the CAPM implementation environment and the wider system environment

Outcomes of CAPM Implementations

It is apparent that failure rather than success is more often the outcome of CAPM implementations. This can be attributed to a number of causes:

- the CAPM requirements were not defined correctly;

- the CAPM requirements were initially defined correctly but they subsequently changed as a result of either a change in manufacturing strategy or new information requirements and subsequent integration difficulties;

- the implementation was badly managed.

Requirements definition was vague in many of the cases studied to date. This appears to stem from the fact that the reasons for implementing the system were unclear. Some of the more vague reasons for implementation of systems were because related companies used similar systems or because it was felt that manufacturing was out of control.

However from the findings to-date most failures would seem to be attributable to changes in the requirements of the system brought about by the need to satisfy two new demands. The first of these is as a result of changes in the manufacturing strategies employed, such as the change to a "pull" system involving the need to process orders and schedule work in new ways, physical reorganisation such as the removal of a part of the manufacturing facility to another site, or the introduction of a new product causing changes in production volumes. The second comes as a result of new information requirements and the need to integrate the CAPM system with other business systems such as quality and finance. Despite recent developments in the integration of information systems this is still a major problem area.

Traditional methods involving the specification of a system design are no longer valid because changing requirements mean that the envisaged end state is unlikely to be precisely what is required for any length of time, if at all. The focus of attention must therefore be directed at ensuring that the means are available to cope with the variety of potential demands on manufacturing by facilitating a range of system end states. Thus the focus of attention must move from the "ends" to look at the means to the ends, which points to a consideration of the system design features such as modularity (etc etc) but also it becomes vitally important to consider the support systems, the infrastructure. Thus, as was recognised in a CAPM State-of-the-Art Report [9], the key to full exploitation of CAPM does not lie in the implementation of a particular system to address a specific need, since this implies a static solution. Rather we propose that the key lies in the development of flexible infrastructures within which organisations can continue to respond to change.

Infrastructures

Hill [4] has defined manufacturing infrastructures as the "controls, procedures, systems and communications combined with the attitudes, experience and skill of the people involved" whilst Skinner [5] has defined manufacturing infrastructures as the "policies, procedures and organisation by which manufacturing accomplishes its work. Specifically production and inventory control systems, cost and quality control systems, work force management policies and organisational structure".

Meredith [6] also considers the importance of the infrastructure in automation strategies, which must be seen to include CAPM. Meredith's definition of the infrastructure is "the network of non-physical support systems that enable the technical structure to operate".

More specifically the infrastructure can be defined by the functions it fulfills in facilitating, supporting and controlling manufacturing activities. There are six principal functional areas providing the six principal requirements for production. These are:

Designs;
Methods, routes and part programs;
Orders, schedules, work lists;
Maintained machinery, tools and equipment;
Materials;
Trained personnel.

In order to achieve flexibility in manufacturing, it is necessary to have the flexibility or capacity required in the infrastructure. For instance it has been observed that increased production rates have caused difficulties in the areas of material procurement; increased rates of new product introduction may cause problems in Design or Methods Engineering. Meredith [6] observes that automation is often held back by the managerial and infrastructural problems involved. It should be noted that the three legs of AMT mentioned earlier are in the infrastructure area:

CAD - Design infrastructure
CAM - Methods infrastructure
CAPM - Order flow and Materials infrastructure

It is recognised that there is a trade off between flexibility and cost. To attempt to develop infinitely flexible systems able to respond to every change in the environment - even if this were technically feasible - would be prohibitively costly. It is therefore proposed that contextually bounded infrastructures are developed which are circumscribed by the nature of the core business activities.

The challenge to those concerned with the creation of infrastructures involves firstly identifying and removing the barriers inhibiting the development of well structured, flexible, modifiable and maintainable systems and secondly, promoting the establishment of systems with performance parameters consonant with the requirements of the wider system.

Results to date

The research team have begun by investigating the infrastructures within electronics companies. The output from this phase of the work has been some initial understanding of how infrastructures help companies to cope with changing manufacturing requirements. Some examples of infrastructure flexibility have been apparent.

One components manufacturer employs staff on a "core and peripheral" basis with the peripheral staff on short-term contracts to allow numbers to be adjusted to match trends in production volumes. This is applied to staff of all types including office staff such as purchasing and finance. Another company producing electronic products makes much use of outworkers paid per piece and subcontractors to allow adjustment. Although both these systems add to the flexibility of the companies' infrastructures there is a price to be paid in terms of the skill level and commitment of people employed only intermittently. The latter solution also leads to a greater procurement activity.

The use of an expert system in the design area has allowed one electronic product manufacturer to cope with a demand for a very wide number of variations to a range of products in a very short time. This means that the design-supplying part of the infrastructure is very flexible. The same system can also perform cost estimating for the product although it has yet to be integrated with the CAPM system to automatically order the parts required.

The ability to reconfigure systems is an example of infrastructure flexibility. One company has deliberately expanded its data processing and programming staff in order to be able to reconfigure the CAPM system to suit any change in the business. However this has caused difficulties in incorporating software upgrades since their system has been customised to the extent that software supplied by the vendor is no longer compatible. Another approach to the same aspect of flexibility was shown by a company whose main criterion for the choice of CAPM system was the accessibility of the programmers and their arrangements for tailoring and updating the system.

Conclusions

This paper has attempted to show that changing requirements can result in the failure of a CAPM system developed as a static solution to a particular problem at an instant in a company's development, even when the system requirements are correctly defined and the system's implementation is well managed. It has attempted to highlight the importance of an approach to flexibility which ranges wider than the implementation of any single system and which involves the development of flexible infrastructures to allow companies to adapt and adjust. Infrastructures should be tailored to suit the nature of the business concerned and the next phase of the research will investigate further the details of infrastructure elements in order to assist companies to develop flexible infrastructures.

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"Just-In-Time" manufacture: an overview

Research Paper No.4 on ACME Research Grant GR/E 56577

Sheffield Business School, Plymouth Polytechnic

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"Just-In-Time" Manufacture:

An Overview

Stephen J Childe

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Just-In-Time Manufacturing: An Overview

Stephen J Childe
The CIM Institute
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October 1988

Introduction

"Just-In-Time" is a popular and widely used expression which has as many meanings as users, since it stems in part from the recent increase of interest in Japanese manufacturing practices. It especially common to confuse JIT with the Toyota production system known as "Kanban", which is one of a range of techniques used in manufacturing under the Just-In-Time banner. This paper attempts to give some understanding of JIT concepts as they appear in a small sample of the wide range of JIT literature. A useful general description of the application of JIT is given in [1].

"Make what we want, when we want it"

The most fundamental concept of JIT is the simple notion that it is good business to make what the customer requires at the time it is needed, rather than to invest money in work in progress or finished goods stock, which represent unnecessary capital tied up in the business. This can be seen to be true by a simple analysis of the three main business indicators Net Profit, Return on Investment and Cash Flow (see [2]).

Net Profit depends upon the difference between revenue generated by sales and the operating expenses incurred in manufacturing. An increase in inventory results in increased stockholding costs together with the possibility of excessive amounts of work on the shop floor actually inhibiting production and therefore reducing sales. Thus inventory has a negative effect on Net Profit. Whilst some businesses claim that a stock of finished goods is necessary in order to satisfy customer requirements quickly, the inventory still has a negative effect on net profit and should be minimised.

Return on Investment is in broad terms the ratio of net profit over assets employed. Thus for high returns the company strives to reduce the level of assets employed. Inventory, both of finished goods and of work in progress represents a part of the finance tied up in the company and should therefore be reduced as far as possible. It would perhaps be more appropriate to regard inventory as a liability rather than as an asset.

Cash Flow is improved if less of the money earned from sales has to be reinvested in the business. If inventory can be reduced while sustaining sales, there will be a once-off improvement in cash flow. On the other hand, if inventory increases for some reason this excess must be financed to the detriment of cash flow. Cash flow is also affected by the costs of stockholding.

JIT Delivery and Call-Off

Whilst JIT calls for products only to be produced as and when required, the philosophy extends to only purchasing the materials and parts required for immediate use. In Toyota's production facility in Japan parts for motor car assembly are delivered several times per day in lots of just a few hours' production. At this extreme no space is required for the storage of the parts, the loading bays backing directly on to the appropriate part of the production line. The effects of this system on cash flow are obvious: no money is spent on parts until the parts are actually required for assembly. Many companies regard regular delivery as the main element of the JIT methodology, although it is perhaps only one of the most noticeable effects.

JIT deliveries do not necessarily occur on a daily basis. In industries such as aerospace where batches are small and lead times long, many companies are experiencing great benefits from ordering supplies in monthly batches whereas in the past six-monthly or annual orders have been the norm.

An objection to regular ordering is the cost of raising purchase orders. One solution to this is the call-off method explained in [3]. Under this system the supplier is given a schedule of the demand for the item for the coming year, based upon sales forecasts. The supplier is then required to supply each week or month the number called off. The supplier can then follow the call-off exactly, if his lead time is short enough, or he can produce at a mean demand rate using a small buffer to cover the fluctuations between call-off periods. Only one purchase order need be raised, which relates to the schedule forecast for the year. This is also advantageous for the supplier: demand is smooth in comparison to producing infrequent large batches, cash flow is improved, inventory is kept low and the contract is secure for a long period.

JIT and Kanban

Kanban is one of the fundamental issues of JIT manufacturing. It is a method of regulating shop floor production so that nothing is made until it is needed, also allowing whatever is required to be produced very quickly (ie with a very short lead time to the customer). More detailed explanations of the Kanban system are given in [4] and [5].

As is often mentioned in the literature, Kanban is a Japanese word for card, (as in playing card) or for a symbol or sign (as in a pub sign). In the present context it represents the cards used for regulating production. It can also represent any other sign, symbol or message used for this purpose, such as the coloured golf ball which is rolled down a tube to the appropriate workstation in one Japanese factory.

Kanban operations are controlled by the final stage of production, such as despatch, packing or testing. Customer orders are fed to the final workstation which then performs the final operations to allow the product to be shipped to the customer. The requirements for this stage of production, such as an untested unit or a set of parts and sub-assemblies required for final assembly, are drawn from the workstations which produce them in a set quantity, which depends on the rate of demand. In the single-card kanban system a card is issued which authorises the movement of the work to the next workstation and the production of a new quantity of parts to replace those moved forward. In single-card kanban, the card is often replaced by a container or an empty space on a rack which either holds the quantity of items or nothing, if they have been moved on. Thus it is the empty container which authorises a new lot of parts to be produced. In this case the part finished items are kept at or near the place they are produced. If lot sizes or components are large, and if there are many varieties of items in production it may become necessary to establish a stores area. In this case the dual-card kanban system is used, where parts are requisitioned from stores using a C-Kanban (conveyance) and then the stores issues a P-Kanban (production) which is the instruction for a new lot to be made to replenish the stores stock. Where containers or cards are used (or golf balls), these continually circulate between the same production stages, so containers can be designed to suit a particular item to prevent handling damage.

The number of containers in circulation regulates the amount of inventory in production. The containers can then be reduced in size so that buffer stocks are gradually reduced until problems occur when a particular workstation can no longer restock the buffer quickly enough, which effectively stops production, since no production is allowed without the kanban. When this occurs the problem is obvious and the resources of production personnel can be deployed to deal with it. Similarly, production stops if any workstation finds that the parts or materials supplied to it are defective. Therefore the system allows bottlenecks and quality problems to be continually identified and alleviated on the shop floor with the close involvement of shop floor personnel. Thus Kanban provides both a means of continually improving the methods of production, and a means of measuring the improvements.

JIT and Total Quality Management (TQM)

A company attempting to use JIT techniques is attempting to remove the comfortable slack which provides a buffer against market changes, defective products or breakdowns. If these buffers are to be reduced without causing catastrophic problems, great care must be taken to ensure quality in all areas of manufacturing operations.

Personnel must be well trained so that they know what steps to take to monitor and control the quality of their own work. This may mean that operators take over some of the functions of inspectors, becoming familiar with the principles of statistical process control (SPC) so that processes can be corrected before defective parts are ever produced. They must also therefore learn to perform simple maintenance and adjustments on their machines and equipment. Most importantly, it means educating all members of the company so that they appreciate the effects of good and bad quality on the business.

Equipment must be both capable and available. Capable machines are those whose output tolerances are statistically acceptable with reference to the design tolerance of the item produced. Availability refers to the amount of time the machine is able to be used for production. This is kept high by ensuring that Planned Preventative Maintenance (PPM) is carried out on a regular basis, to ensure that unpredicted breakdowns, which will significantly disrupt a JIT company, are kept to an absolute minimum.

The quality of supplies is also important to JIT. This means both the correctness of the products supplied and also their delivery on time. Either defective supplies or late supplies will cause a standstill in production. Many JIT companies are putting great stress on the quality of supplies and are engaged in supplier development programs. This means educating the suppliers about JIT and Total Quality, especially SPC, and in many cases sending out methods engineers to help suppliers to develop their own methods. At the same time this means developing a trusting relationship with suppliers, and usually only allowing one source for each item, with long term ordering. This means that it can become worthwhile for the supplier to improve, even though the JIT customer concerned may only represent a small fraction of the supplier's work. Many companies still believe that JIT will not work because they do not have enough "clout" to force it on a particular supplier. However, if JIT and TQM are operated to the advantage of both companies there is little need for coercion.

Another element of TQM which is very relevant to JIT is the establishment of a system of performance measures which can show the company how its improvements are working. This is important to retain the commitment of both management and employees to the JIT initiative. Some useful measures are the following:

Due date compliance - the proportion of on-time deliveries;

Right first time - the proportion of products completed without any need for re-work;

Stock turnover ratio - the number of times the inventory is turned over per year, or Sales/total inventory;

Lead time - the time taken for a product to pass through the manufacturing process from the time the first goods are received to the time the product is shipped. Lead times can also be measured through specific parts of the process. Lead times should be short.

JIT and Material Flow

The traditional way of arranging manufacturing facilities has been to group together machines and processes according to their type. In the early years of industrialisation this allowed specialists with certain skills to retain a craftsman approach, the skills being combined in products by the careful routing of products from one trade group to another. This system worked well while there were only a few different products in the system, with clear relationships between the process areas. A good example of this method can be seen at Abbeydale Industrial Hamlet, Sheffield, where scythes and other blades have been manufactured since the eighteenth century.

However, this system began to become very complex in the post-war period especially during the 1960s. As product ranges grew, the number of routes taken between process areas multiplied with the effect that process areas no longer saw clear relationships with each other. This led inevitably to the use of route cards, progress chasers, WIP tracking systems, etc, and with the concurrent growth of computer power led to companies putting their faith in more and more powerful computers to sort out the morass. Unfortunately the imposition of a complex computer system upon a complex problem has increased complexity yet further. This has been recognised most notably by John Burbidge (see [6]) who has led a crusade against process organisation.

Burbidge's alternative is to plan the production facility around the flows of material. This is called Product Organisation, and leads to the subdivision of factories into areas often known as "cells" in which a group of workers complete particular sets of products or components, which are then passed to a customer area for the next stage of manufacture. Thus within the group must be a range of different skills which allow various operations to be performed.

An important benefit is that lead times within cellular manufacturing units are generally much shorter than in conventional process organisations. This is because the cell team tend automatically to schedule work through the cell dynamically, responding to any day-to-day occurrences which can upset a schedule set remotely over a fixed period. Also, the lead times within the cells become more stable since the cell is less complex. This allows scheduling of work between cells to be more accurate. Cells are also the ideal vehicle for group improvement activity, especially since the team members have to pass their work on to their team mates, providing instant feedback and peer-group pressure to maintain quality. This has the great advantage that the group becomes responsible for a tangible product and can to some extent control the way the product is produced. Cells can be monitored on a short term basis for performance improvement, using the performance measures set out above. The effects of group working upon morale, quality etc have been observed at Volvo [7] and Phillips [8]. The cell is also a vehicle for the setting of improvement targets and for communication, consultation and participation.

For details of the techniques used to establish cells, such as Production Flow Analysis, refer to [6].

Cell Autonomy and Ownership

The advantages of cellular manufacturing arise in large measure from the fact that the cell team are able to operate as a semi-autonomous work group with the power to reschedule or modify their own working methods. Since the cell team "own" a distinct part of the manufacturing process they are held responsible for the successful completion of their orders. Together with this responsibility must be given the means to achieve output and output improvements. Cell members must therefore be given adequate training to allow some flexibility between the various operations within the cell, training in quality requirements and SPC, and training in methods engineering and where appropriate in programming and maintaining machine tools. It is also important to ensure that the cell is able to own all the operations required on a product passing through the cell, so that borrowing another cell's machine and the queuing problems this causes are kept to an absolute minimum. This can be achieved in many cases by providing duplicates of certain cheaper pieces of equipment, the cost being more than compensated by the inventory savings of JIT.

Period Batch Control is a production control technique which sets firm orders for cells over a given order period. This technique allows the cell to understand the requirements on it for the period and gives it the responsibility to produce the goods, thus avoiding the difficulties created by standard hour and other arbitrary performance measures which can result in the production of high standard hours figures but no parts which fit together [9][10][11].

JIT and Batch Sizes

In order to ensure that inventory is kept to a minimum it is important to smooth out loads and to produce items in small batches. Traditionally, it has been common to calculate batch sizes using the notion of economic batch quantity, balancing inventory costs against lost production due to set-up times. This method assumes that the set-up time is a "given" and therefore matches uneconomic long set-up times with uneconomic long batches. However, Shingo (of Toyota) has drawn attention to this and developed a simple approach to the reduction of set-up times [12]. Although originally developed for the rapid exchange of press tools in automotive plants, the methodology applies to all machine tools and equipment.

The methodology first looks at the elemental activities involved in the set-up and classifies them as Internal or External. Internal set-up operations must be done on the machine and require the machine to be stopped, such as the loading of jigs to the worktable. External operations can be done off the machine while it is still running the previous job, such as procuring and assembling tools. All internal operations must be examined to see if they can be converted to External. This can mean for instance providing location devices and presetters to allow all adjustments to be performed off the machine. All remaining internal operations must then be examined to see how they can be improved. For instance, quick change devices such as those already commonly used for the location of components can be used for the location of jigs and fixtures.

Shingo's approach, which consists of a few engineering tips and a serious attitude to a problem that has often been ignored, has resulted in some enormous time savings, such the changeover on a six-axis boring machine being reduced from three days to 2 minutes 40. This approach means that small batches or single items can be produced with enormous savings in inventory.

JIT's small batches have other benefits apart from inventory reduction, such as the reduced number of items that are lost through incorrect processing or design obsolescence. Lead time is also affected. As batch sizes get smaller, the batch size has more of an effect on lead time, so that reducing the batch size reduces the lead time. This is particularly true in cellular operations where there is little or no queuing between operations. (In many conventional process-organised factories the lead time is dependent almost entirely on queuing time. In this case, the total batch processing time may only account for 1 to 5 percent of the total lead time, the rest being idle. It should be pointed out here that for a constant demand rate the inventory level is directly proportional to the lead time.)

JIT and Waste

The concept of eliminating waste is central to JIT. Shingo has put forward the Seven Wastes which must be eliminated for successful efficient JIT operations. The wastes are:

Overproduction - or production of items too early, which causes unnecessary inventory, eg large batches;

Stock - stock itself causes wasted transport, equipment and space, operations to locate items, money (tied up in stock) and storemen;
Transport - Inefficient layout causes unnecessary transportation - transportation adds no value to the product;
Waiting - operators should always be occupied on something useful;
Operation - poor methods lead to poor quality, damage to parts in assembly, rework, danger;
Worker movement - unnecessary fetching and carrying is wasteful;
Defective parts - cause rework, disassembly, damage to related parts, and the time spent making them was wasted;
Equipment - it is wasteful to use equipment which is more than capable of doing the job.

JIT and Material Requirements Planning (MRP)

Material Requirements Planning forms the centre of most of the western computer-based approaches to production control. In its commonest form MRP is used to "explode" the product to give the parts and materials requirements for manufacture, providing a timetable for the issue of orders to the shop floor and to suppliers to ensure that all parts required are available on time. MRP is very similar to project management tools like network analysis often used for major capital projects such as in civil engineering. It is important to understand that MRP relies on accurate lead times being available for all activities.

Many writers have concentrated on the supposed choice between MRP and JIT, (generally referring to Kanban) although more recently several papers have considered the extent to which MRP and JIT can work together.

MRP is in fact a tool which attempts to meet the goals of JIT, ie to produce products whilst holding the lowest possible inventory. In fact MRP can theoretically operate with zero stock while the Kanban system - unless heavily modified - requires small stocks between workcentres.

MRP has often resulted in shortages of parts together with excessive stocks. In many cases this can be attributed to the use of large batches and poor use of the MRP system, but it is also partly due to the fact that MRP hides shop floor problems with stock. Shortages lead to order quantities being increased and late orders result in batches being processed together, thus creating a more lumpy load. Quality problems lead to "scrap allowances" rather than to the solution of the problems, which therefore remain hidden.

However the most fundamental problem with MRP is its reliance on lead times. Lead times can never be correct. In a factory with several possible process routes the effects of lead time inaccuracies are to create temporary queues of work between workcentres. These queues increase exponentially with the amount of work on the workcentre, and thus lead times depend on the amount of work in the factory. Even the most sophisticated "Closed-Loop" MRP systems can only respond to increasing queues by increasing the planned lead times. This means that the system releases more work onto the shop floor, with a consequent increase in inventory, queuing and lead times. Thus lead times and inventories tend to spiral upwards, whilst parts needed for assembly are often stuck in queues when they are required. Thus there is the additional effect that it becomes more and more difficult to find parts to assemble, so deliveries become late and chasers replace A1 priority jobs with AA***. Thus nothing can be made until it is late. No orders are ever shipped on time.

Given these problems, it would at first appear wise to avoid MRP. However, it does have the ability to cope with a wide range of products being produced, which can lead to unnecessary stocks in the Kanban system. It can also be difficult to extend the Kanban system to large numbers of suppliers. A solution which appears to be becoming increasingly popular is to use a simplified MRP system for the procurement of supplies, together with a Kanban-type system for control within the factory. This removes from the MRP system the problem of time-phasing orders against lead times, apart from purchase lead times. A single level bill of material can be used, which indicates the bottom level purchase requirements for any product. The issue of purchase orders can then be triggered either by the completion of a product (rather like the Reorder Point system) or from the Master Production Schedule. This is outlined in [13].

Continuous Flow Manufacturing

Continuous Flow Manufacturing is the name used by IBM for the philosophy of production put forward in the Excel project at the Havant plant. The strategy fits into the general outline of JIT given above, but perhaps the name is more appropriate since it draws attention to the aim of producing a continuous flow of material through the plant, rather than the disjointed, lumpy flow associated with large batches. The Excel project is described in [14].

Conclusion

Just In Time is a philosophy of good business based on the smooth matching of production to demand, and the elimination of waste. It is not an alternative to tools such as MRP but it provides a simplifying approach which allows such tools to be considered against the real aims of a manufacturing business. JIT is nothing new, but a reawakening of manufacturing to the nature of the business.

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Childe S J

Flexibility through the design of manufacturing infrastructures

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FLEXIBILITY THROUGH THE DESIGN OF MANUFACTURING INFRASTRUCTURES

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BACKGROUND

This paper stems from an ACME-sponsored research grant held jointly by the CIM Institute, Plymouth Polytechnic and the Change Management Research Unit, Sheffield Business School entitled "The development of a user-led implementation methodology for integrated manufacturing systems within the electronics industry". The paper is based upon the early results of this work.

INTRODUCTION

The research project represents the largest single grant awarded under the ACME Computer Aided Production Management (CAPM) Initiative and is focussed on the problems of implementing CAPM systems in the electronics sector. The work arises from the history of poor success in the implementation of various kinds of Advanced Manufacturing Technology. A number of authors have highlighted the problem including Voss (1) who noted that 57% of AMT applications were seen as unsuccessful and Ingersoll Engineers (2) who placed the figure at 50%. These findings imply that the implementation of AMT must be approached in a different manner to conventional technologies, particularly as the companies implementing AMT were generally no strangers to the implementation of machines and equipment. It is also interesting to note that many companies experiencing benefits from AMT achieved 75% of the benefits before the actual installation of the technology, Bessant and Haywood (3).

Computer Aided Production Management is itself an example of Advanced Manufacturing Technology. The research project's working definition of CAPM includes the processing of orders from customers to the shop floor, materials provisioning systems such as MRP, WIP tracking, bill of materials control and all computerised aids to the production manager, including planning, scheduling, controlling, recording and reporting functions.

CAPM IMPLEMENTATION

The Single Point Solution

The traditional systems design approach incorporates the following stages:

1 Definition of the current state - analysis of current procedures and problems;

2 Definition of the proposed system - definition of requirements which the new system must fulfil;

3 Specification, selection and design of system components and configuration with respect to the requirements definition

4 Training of personnel and system installation.

This approach is one which models the future system upon the present and past system, taking advantage of technological developments such as faster processing, labour savings etc. and making suitable allowances to prevent the known shortcomings of the present system being manifested in the future system. This approach has been the basis for much work developing the implementation of AMT which pays attention to issues such as user acceptability, for example Robey (4), and the development of project management strategies, for example Tranfield and Smith (5).

CAPM Implementation Failures

The research so far has looked at CAPM in a sample of thirteen electronics companies. Failure was regarded as any shortcoming which required the CAPM system to be altered significantly from the way it was implemented, or a failure of the implementation process which resulted in the system being either very late into use or not in use as intended. From this sample comes the schematic diagram in Fig.1. which shows the four typical modes of CAPM failure.

It is perhaps surprising to observe failures which resulted from an inadequate requirements definition, which led to the wrong system being implemented. Possible reasons for this, such as over selling by vendors or the installation of "familiar" systems will not be considered here. Having correctly defined the nature of the system requirements, some companies unfortunately failed to implement a system which fulfilled these requirements. Again, the reasons for this are not the subject of the present paper. Another way CAPM implementations fail is by managing the project badly so that the system arrives very late, is short of necessary functionality or capacity, or is the subject of difficulties such as poor training or consultation leading to its non-use.

The most common mode of failure, however, occurs when the requirements change to the extent that the system is then short of functionality or capacity, such as when the company grows, or moves to a position where the system is no longer appropriate, for example when manufacturing changes from MRP type batch logistics to a Kanban system. The change in requirements ultimately renders obsolete any system which has been designed and implemented in the traditional way. It is possible for this type of failure to happen even before the system has been implemented. Unfortunately there is no easy answer to this problem beyond making "best guess" predictions of the future. It is not easy to expect the unexpected. In our experience this is the most common failure mode, and it appears to be a characteristic of the traditional approach to system implementation, which results in "single point solutions" which are suited to the business at a particular point in time.

THE NEED FOR FLEXIBILITY

The Electronics Market

The UK electronics market is one of the fastest growing in

Europe, experiencing rapid change both in the marketplace and in the functionality of products. Change is common and unpredictable. For example:

- Shortening product life cycles demand more frequent introduction of new products, which require new designs, equipment, materials, and methods;

- New process technologies such as surface mount can lead to obsolescence of existing products requiring companies to adopt new methods;

- Manufacturing volumes can change suddenly, causing changes in manufacturing strategy.

Some Possible Solutions

Some companies attempt to resist competitive pressure by carving out a niche in which there is little or no competition. For many companies this is a successful strategy but it can fail if a serious competitor moves into the niche, or if the niche is removed by a change in the market. Furthermore this strategy leaves the company more open to the consequences of market changes because ways of coping with change will not be developed.

Under certain conditions it is feasible for companies to attempt to control the market. This strategy can not be regarded as widely applicable.

How Flexibility Helps

Flexibility is used here to denote how well a company can respond to changed requirements, whether imposed by the needs of the market (reactive) or by the anticipation intentions of the business itself (proactive). Flexibility is often a goal of manufacturing strategy but as Slack points out (6) it is not one that has a clear meaning. Slack was able to discern four distinct types of flexibility:

> "Product flexibility: the ability to introduce novel products, or to modify existing ones.
>
> Mix flexibility: the ability to change the range of products made within a given time period.
>
> Volume flexibility: the ability to change the level of aggregated output.
>
> Delivery flexibility: the ability to change planned or assumed delivery dates."

All these types of flexibility are important to many of the companies investigated in the course of the research.

Slack noted also that managers tended to focus on the flexibility either of specific machines or of labour, rather than upon the flexibility of the manufacturing business as a whole, whilst the distinction between range and response flexibility was a source of confusion. "Range" is the range of states which a system can achieve, such as the range of parts a machining centre can machine, whilst "response" is the ease with which changes can be made within the range. When designing a manufacturing system, it is important to understand the types of flexibility required.

Much attention has been placed upon the flexibility of machine tools, especially with the development of Flexible Manufacturing Systems (FMS) - machines which have a very fast response to change within a given range. However it appears that flexible technology on the shop floor has to be supported by a flexible infrastructure.

THE MANUFACTURING INFRASTRUCTURE

The infrastructure consists of the systems which support the manufacturing activity. It has been defined by Hill (7) as the "controls, procedures, systems and communications combined with the attitudes, experience and skill of the people involved" and by Skinner (8) as the "policies, procedures and organization by which manufacturing accomplishes its work, specifically production and inventory control systems, cost and quality control systems, work force management policies and organizational structure".

Meredith (9) also describes the infrastructure as "the network of non-physical support systems that enable the technical structure to operate."

The infrastructure is critical to the manufacturing operation since manufacturing can only respond to the marketplace at the rate at which market information is translated into instructions for manufacturing in the form of orders, schedules etc, and at the rate at which new designs, equipment and materials can be provided.

It can be seen that Slack's four types of flexibility cannot be provided by structural means alone - the flexibility of the infrastructure would restrict even the most flexible manufacturing hardware by failing to provide the support required.

Hill presents an outline typology of infrastructures, describing some of the characteristics that infrastructures should possess in different types of manufacturing situation, such as batch, job, flow etc. However this outline does not address the question of the implementation of infrastructures with particular required characteristics. Thus a more detailed understanding of the functions of the infrastructure is required.

The provision of orders, schedules, designs, equipment and materials has been mentioned earlier. It is proposed that the functions of the infrastructure are to provide the following inputs which completely support and control the manufacturing activity:

1 Designs;

2 Materials;

3 Methods information, such as manufacturing layouts, works instructions, process instructions, quality procedures, NC part programs;

4 Orders, such as work-to lists, job schedules, picking lists, batch cards and travellers;

5 Facilities, such as the plant and equipment, machinery, fixtures, tools and gauges;

6 Trained and motivated personnel.

Thus the infrastructure provides three physical requirements (material, facilities and personnel) and three informational requirements (designs, methods and orders). The various aspects of CAPM are involved with the purchasing of materials and with the processing of orders. It is proposed that a CAPM or other implementation must aid the responsiveness of the business and must therefore form part of a flexible infrastructure.

These six functions of the infrastructure provide a framework which allows analysis and design of infrastructures in specific company situations. It provides a basis upon which decisions can be taken with regard to the amount of flexibility required in each functional area.

Infrastructure Design

The design of manufacturing infrastructures must be based upon establishing performance parameters for the various infrastructure elements. In any area there will be limits of range and response which will limit the infrastructure's performance as well as modifiability which will affect the infrastructure's adaptation to a new business scenario. The range and response criteria must be established to allow the infrastructure to operate within a range of situations which can be regarded as likely situations in the business. Thus, as in structural terms a milk bottle manufacturer would not provide sufficient flexibility to switch production from milk bottles to printed circuit boards, in the infrastructure area a pcb manufacturer would not train designers in the area of milk bottle design. Although a wide range and a speedy response would seem ideal, the practical operationalisation is to set limits to the desired performance, within which any change could be met. The setting of these limits is thus a strategic question for the direction of the business, which is being addressed by the process methodology currently being developed by the project team.

INFRASTRUCTURE FUNCTIONS

Design Function

Flexibility of the design function relates to the rate at which new designs can be provided. Company A, a manufacturer of domestic electronic goods, found that increased flexibility and Just-In-Time manufacturing on the shop floor together with a continuous improvement policy created a demand for thousands of design modifications per year. The existing procedure became overloaded, and the company is now considering ways of improving this function.

Company B, a computer manufacturer, also found that increasing numbers of design changes were required, and were able to implement a computer-based design change management system to facilitate the passing of information between departments and to monitor the progress of all change requests.

Material Function

Materials can be a severe limiting factor to flexibility. Company B finds that long procurement times, such as three months to purchase an "ASIC" chip from Japan, are a limit to the company's responsiveness. This has also caused quality and inventory problems due to boards being assembled as components become available rather than in line with the customer order schedule.

In the electronics industry the total manufacturing lead times and therefore the responsiveness to customer demands depend to a large extent on the procurement lead time, since the actual manufacturing lead time is relatively short. In Company C, a manufacturer of defence-related products, steps are being taken to improve the time taken to issue purchase orders and to improve supplier relationships in order to become more responsive.

Company D, a components manufacturer, has improved its ordering process so that all purchasing is managed by less than one person and a typist. This appears to provide the appropriate level of flexibility for this business.

Methods Function

Company E, a subcontract assembler, has no area with specific responsibility for method engineering, since the business is built around one specific method only and all products are processed through the same route. This company has decided to have no flexibility of methods. If this technology becomes obsolete, the company will face difficulties in responding quickly.

Company F, a component manufacturer, requires little methods flexibility to meet day to day changes, which tend to be of mix only. However it has assembled a highly skilled team for the development of new process equipment to create a specific market advantage.

In some companies, for example company D, methods work is carried out by the design department.

Order Processing Function

Most of the companies investigated are conscious of the importance of processing orders quickly. For example, companies D and F both allow major customer to enter orders by data transfer direct into the orders database. Some other companies were considering this possibility.

Company G manufactures tailor-made electronic equipment. Customers ordering from this company are able to speak direct to a design engineer who can quickly tailor the design as required, provide a price and pass the order immediately to manufacturing.

Facilities

The companies investigated had made little attempt to develop flexibility in the area of provisioning tools and equipment, relying generally on external equipment manufacturers, tool manufacturers and maintenance contractors. However this must limit the responsiveness of the companies to changes requiring new processes or tooling. The case for tool management and a review of tool management functions based mainly on metal-cutting FMS is presented by Carrie and Bititci (10).

Personnel

Flexible personnel approaches have been implemented by almost all the companies. This generally involves operators moving between different operations.

Company F has attempted to de-skill all direct operations and to employ operators on short term contracts to provide numerical flexibility.

Company E contracts out some operations and employs outworkers on a subcontract basis.

Personnel flexibility is treated in detail by Gustavsen (11) and Atkinson (12).

CONCLUSIONS

This paper has presented the six basic functions of the production management infrastructure.

It has described the way overall manufacturing flexibility depends upon the performance of the infrastructure as well as that of the physical elements.

In a competitive and fast-changing market a CAPM or other AMT implementation can only have lasting success as part of an integrated strategy which includes the design of an appropriate flexible production management infrastructure.

Business strategy must dictate the amount and type of flexibility required in each functional area. Particularly in the context of AMT implementation, it is important to consider the infrastructure so that the AMT performance is not limited by the support functions.

Some examples of infrastructure configurations have been presented. Further work is intended, which will aim to provide an understanding of the performance of various infrastructure functions configured in different ways and to develop a process methodology to lead companies through the implementation process.

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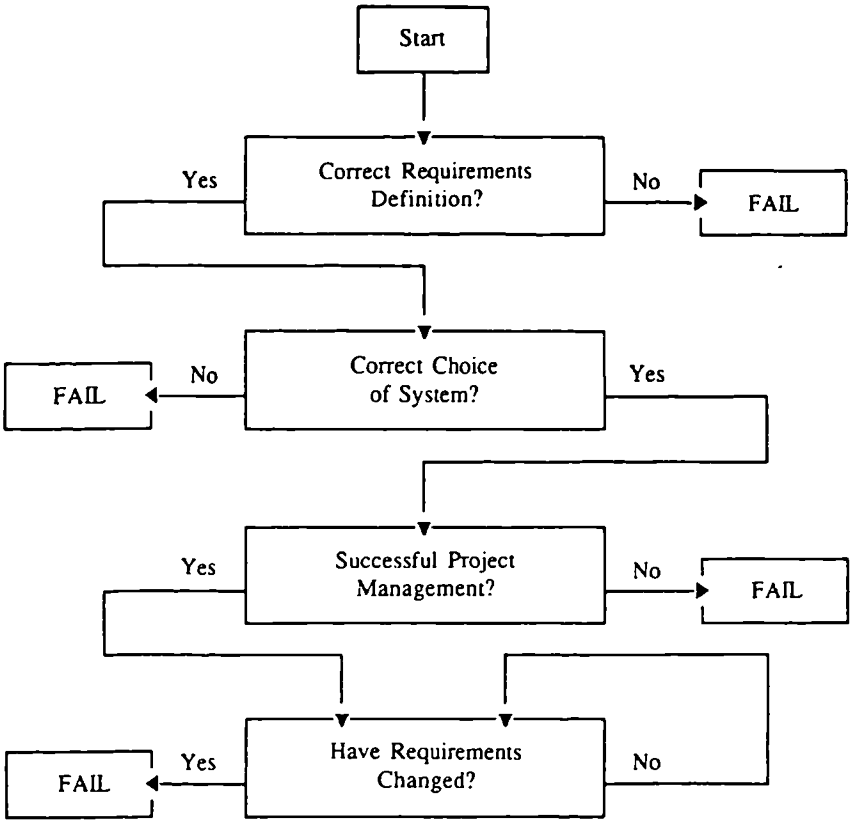

Figure 1 CAPM Implementation Failure Modes

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A bibliography of literature connected with the development of a user-led implementation methodology for computer aided production management (CAPM) systems in the electronics sector

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A Bibliography of Literature Connected with the Development of a User-Led Implementation Methodology for Computer-Aided Production Management (CAPM) Systems in the Electronics Sector

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A methodology for the design and implementation of resilient CAPM systems

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A Methodology for the Design and Implementation of Resilient CAPM Systems

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Introduction

For a variety of reasons outlined within the body of this article, the approach taken to this research task has been strongly contextualist and strongly processual. In summary, this is because of the dynamic nature of many companies in an environment which is producing a requirement for rapid, idiosyncratic manufacturing and computer aided production management (CAPM) adaptability both in the design and implementation of systems.

The article begins by outlining the results of research into the reasons for CAPM systems failure[1]. Using these results, the research team have developed a methodology based on the concepts of flexible infrastructures — those policies, procedures and practices that support the hardware/software configuration of the CAPM system. The methodology is examined stage by stage to specify the context in which the CAPM system is installed and to focus on the implementation of an appropriate CAPM systems and infrastructure configuration. The article concludes with a brief case study based on a recent application of the methodology.

Fieldwork Results

From our discussions with CAPM practitioners, company visits and from surveying the literature, a number of factors which lead to immediate or eventual failure of CAPM systems have been identified.

- Requirements were defined incorrectly.
- Requirements were defined correctly, but the wrong system was implemented.
- Requirements were defined correctly, the right system was implemented, but requirements changed over time and the system failed.
- The correct system was defined and implemented, but implementation was badly managed resulting in failure.

Of these four principal causes of failure the third, involving changed requirements, is of considerable importance. It is important because even when requirements are defined correctly and the correct system is specified and implemented successfully, subsequent changes in requirements can lead to failure. Thus even systems which are currently performing well, but which lack the flexibility to respond to new requirements, are potential failures. Such a characterisation of failure mode has particular significance for the fast moving electronics sector. Three primary reasons for changes in requirements have been identified:

- Large scale changes in manufacturing volumes;
- Changes in integration requirements;
- Changes in manufacturing strategy.

For our purposes we regard systems which do not meet the requirements and which need to be replaced as outright failures. Systems which only partially fulfil their requirements we regard as partial failures. Systems which are able to fulfil current requirements but which lack the flexibility to respond to new demands, the team regard as potential failures. Failure Modes are:

Outright	—	System is replaced.
Partial	—	System does not meet requirements.
Potential	—	System cannot meet new requirements.

It is apparent from these failure modes that traditional approaches to CAPM implementation are unlikely to succeed. At best the outcome will be a system capable of meeting current requirements before decaying into partial failure and subsequent outright failure.

In highly stable manufacturing situations this process may take some time, however in other situations the mismatch between the system implemented and current requirements may develop so rapidly that almost immediate replacement is required. The lack of flexibility in many CAPM systems currently considered as potential failures is likely to result eventually in outright failure.

In our view, the manufacturing sector epitomises the need for flexible manufacturing of which so much has been written recently[2]. What is clear from our study of CAPM failures is that CAPM systems and their supporting infrastructures can be major constraints on the overall flexibility of manufacturing systems. Slack's[3] typology of flexibility into product, mix, volume and delivery are all critically affected by the type of CAPM system deployed and it is important that companies determine the flexibilities which underpin their strategic competitive edge.

Infrastructures

The research team believe that user companies need to move away from the development of a single point CAPM solution toward the development of CAPM systems which are capable of adapting to changing demands. However, the CAPM system is only one of a range of systems which support manufacturing and which needs to be considered as an integrated whole. Similarly, CAPM solutions are much more than software. They involve the policies, procedures and practices which govern the software use and which therefore restrict or enhance its flexibility. These support systems have been dubbed "infrastructures" and have been considered by several writers[3,4,5,6,7,8].

CAPM Infrastructures

The project team have applied the concept of infrastructures to computer aided production management. The CAPM infrastructure provides a set of policies, procedures, systems and knowledge that surrounds the processing of customer orders, to provide information such as work-to lists, job schedules, picking lists, batch cards, travellers and material orders.

An example of a flexible set of CAPM policies, procedures and controls is seen in Company A. They have designed an infrastructure which can support the CAPM activities required for two quite different manufacturing strategies. Part of their manufacturing system operates under a continuous flow just-in-time (JIT) strategy whilst the rest is controlled through a material requirements planning (MRP) push system. The CAPM system itself is a product of information systems policies, procedures and controls which are geared to securing a flexible solution. This is manifested in the use of a modular hardware and software design approach, and in the use of common data protocols to allow communication between the modules and to other systems.

Examples such as this are rare. More frequently, the group has found examples of systems that are currently successful but which have only restricted potential since they are the products of short-term CAPM policies. These systems appear to be restricted in terms of the manufacturing strategies that they can support, the integration that can be achieved and the volumes of data that can be processed.

CAPM vendors have traditionally tended to focus on the supply of the hardware and software of systems to the exclusion of the policies and procedures which must be put in place to ensure success. However we note that some vendors are now attempting to develop these elements through more emphasis on "service" rather than supply.

Principles of a Methodology

Because of these and our own fieldwork results, the research team have taken as a basic premise that electronics companies show sufficient idiosyncrasy to make individuality a working assumption in developing a generic methodology. Following this argument, the only feature common to all user companies is the process of introducing the CAPM system. Thus the methodology developed by the research team has to address the process of implementation within the whole range of electronic companies rather than developing a prescriptive solution for individual segments.

Implementation methodologies inevitably tend to be more extensive pieces of work than design methodologies because, if for no other reason, it is impossible to think of *how* to implement without prior consideration of *what* to implement. In this sense it is probably more appropriate to think of devising a CAPM *development* methodology than focusing only on implementation. However, any methodology needs to specify two main characteristics. First, it must identify the salient variables to be taken into account, thus dimensionalising the problem. Second, it has to order these variables or dimensions to enable the user to progress in an orderly and understandable way from an initial to a new situation (in this case from no CAPM or ailing CAPM to a flexible CAPM).

From the argument above, the primary design principles for CAPM tailored for electronics companies are that they should address the dimensions of context in which the CAPM is situated and should focus primarily on the process of introduction rather than the specification of a single point solution. Therefore, what is required is the development of an implementation methodology which:

- articulates the company's business strategy with respect to manufacturing;
- identifies the nature of the manufacturing system to support the business strategy;
- simplifies the CAPM task and then identifies the CAPM modules required;
- matches CAPM requirements against CAPM solutions (software plus infrastructures) to ensure a good business fit;
- ensures that the implementation of the methodology is managed according to good implementation practice.

All of these principles are followed through in the development of a user-led CAPM methodology.

The CAPM Methodology

The CAPM methodology, has three main features:

- Resilience, developed through a top down approach.
- Human factor considerations, in that the methodology is user-led.
- Facilitator provides guidance through the process.

Figure 1 represents the hierarchical framework of the methodology. Although represented schematically as such, it is non-sequential in operation, and there is considerable iteration between stages.

Business Strategy

The process begins by taking a company through a process of product rationalisation. Working in conjunction with the facilitator the company develops an understanding of its key stakeholders. A stakeholder is an individual or group who influences or is influenced by the company. This influence may stem from the possession of resources, the dictation of alternatives, or authority (possibly through legislation). Examples of stakeholders include competitors, suppliers, employees and customers. Stakeholder analysis provides the strategic context for the specification of the manufacturing system and the subsequent CAPM requirements. It is a vital backdrop, difficult to undertake adequately from within the company, and usually needing a skilled facilitator to bring it to an effective conclusion.

The methodology then requires the company to take a strategic view of its product families, distinguishing between those that are profitable, those which may become profitable and those that are unprofitable. Data from the stakeholder analysis are used to identify the directions in which product families are expected to move. This stage enables a company to rationalise its product portfolio and identify potential market opportunities for new products.

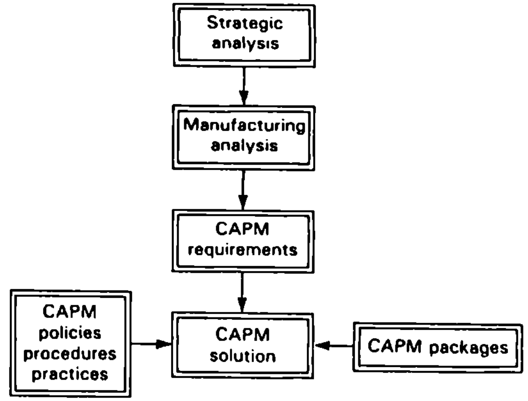

Figure 1. Hierarchical Framework of the CAPM Methodology

The third element of the strategic analysis is to relate order winning criteria to each individual product family in turn. This uses a technique called "price of non-competitiveness" (PONCII). Here the facilitator derives an estimate of the gain to be made from improvements in order winning criteria. For example, by using this technique in a local engineering company the research team were able to identify that a 10 per cent drop in price on a particular product family would generate a 20 per cent increase in turnover.

Manufacturing Strategy

This stage begins with a manufacturing audit. This identifies both the structural (machines, labour, etc.) and infrastructural (policies, procedures, controls and systems) factors that have a direct bearing on production. These are then matched against individual product family order winning criteria in a resource impact analysis. The next activity is to identify those factors that can be changed to enable individual product families to meet the competitive criteria derived from PONCII.

Because of the complexity involved in developing a complete methodology for each of these manufacturing areas and because of the focus of the CAPM initiative, the research team have concentrated on developing a methodology which identifies an appropriate CAPM solution. The research team recognise that CAPM systems cannot be implemented in isolation. However, the broader based methodology is intended to be the focus of future work.

CAPM Requirements
This stage is about how to set up CAPM systems to produce those product families on the competitive criteria established earlier. It incorporates a simplification procedure following a number of "rules of thumb"[9]. For example, in Company B the lead time needed to obtain material from a supplier exceeds the planning time in which material must be made available to meet delivery dates. In this case these families need their inventory management systems to run according to re-order point logic. However, the danger with re-order point is that it is based on ***look back*** (previous use) criteria and could easily lead to stock-outs or high safety stock levels. The only alternatives are to extend delivery dates, or procure material more quickly or shorten the manufacturing cycle time.

In families where the material lead time is less than planning time a company can use ***look ahead*** logic. This may utilise MRP, MRPII or JIT where JIT attempts to bring safety stocks and safety lead times towards zero whilst developing lot for lot sizing[9]. Yet moving an existing MRP system towards this would have major implications for purchasing control systems, policies and procedures — in fact these and not the software may be the constraints on moving to a JIT system.

Another simplification procedure surrounds the choice of manufacturing control system and depends on predictability of demand. For example:

Repetitive manufacturing	—	*Just-in-Time*
Some repetitive	—	Mixed *Kanban*/MRP system, using MRP for material procurement
Mostly non-repetitive	—	MRP
Very non-repetitive	—	Project management tools.

The next stage is to match company profiles against CAPM modules. These may include bill of materials (BOM), sales order processing (SOP), capacity planning, work in progress (WIP) tracking, purchasing, shop order release, stock control, etc. These tasks can be accomplished either by software or by the infrastructure e.g. WIP tracking is a module available in most CAPM software packages, however it may equally well be undertaken as a shopfloor practice under a manual system.

Deciding whether or not the task is required is contingent upon the number and unpredictability of several manufacturing system variables including number of items per product, number of levels of BOM, degree of commonality of parts, number of sequential operations in a manufacturing routine and the number of workcentres. Therefore, establishing whether or not, for example, a purchasing module is required is contingent upon the number and unpredictability of the variables required to support purchasing order processing.

CAPM Solution
This stage matches the CAPM task requirements against existing software packages to identify a best fit. A set of features of the major CAPM packages is compared against the requirements from stage three and an appropriate package selected. This fit is then improved through "tailoring" the software package. However, the principal business benefit is obtained through the improved fit offered by the infrastructures. For example, a company may have chosen a CAPM configuration based on an MRP system for material procurement. Clearly, accuracy of the BOM and inventory status files are of critical importance. The control of these data items has to be carried out through company policies, procedures and practices, such as locked stores, daily stock checking, improvements in the control of the BOM, change proposals and change notes.

Implementation
In implementing the CAPM methodology their are four key managerial activities:

Audit and Vision Build — This activity uses the stakeholder analysis of the strategic analysis phase to develop corporate mission statements and a business plan complete with a set of four to six central values with which company members can identify.

The Cascade — This activity spreads the word through the management team. The mechanism suggested is a series of workshops which allow the plans to be discussed and questioned. This may go on after structural reorganisation and may involve some training and development work.

Sprinting — In this stage, bursts of activity are paced with bursts of stability and consolidation. The activities (or sprints) are short discrete projects which each have measurable targets of success and a fixed time frame. They are managed from the top of the company and are seen to be so, involving all company members. Each sprint is focused on a key element of the changes required. The sprint is a high-energy burst which cannot be sustained over long periods. However its strength is that in a short time it can make a clear move from A to B (a morphogenic change). Support and enthusiasm are generated by the high energy and high profile of this stage.

The Performance Ratchet — This stage takes over from the sprints and continues to make incremental improvements to the performance of the company. Success of these morphostatic changes is ensured by getting the activities done by the most appropriate people. The performance ratchet is pushed onwards by making ever higher demands from the departments and individuals concerned — targets are continually raised.

Case Study

Background

The company is a small mechanical engineering manufacturer which dominates its UK marketplace with a 50 per cent share of the market. It also sells heavily into a variety of European countries, including France, Holland and Scandinavia. The company recognises that, while it appears to occupy the high ground in the market, revenues are being squeezed from two important directions. Competition, particularly from Southern Europe is rapidly intensifying. This is due, in part, to the use of more advanced casting methods. At the same time, raw material costs are spiralling. As a consequence, turnover has remained constant during 1989 and profits have fallen by 30 per cent.

Results

The research team undertook a rigorous application of the methodology over a period of three months. Each stage was taken in turn and worked through with the help of proformas and a series of technical briefings. Because of two severe constraints imposed by the company, i.e. cash restrictions and limited technical knowhow, a CAPM software specification was to prove impossible. However, it is interesting to note that the solutions that were identified (and being implemented) were based on the CAPM infrastructure.

The company was experiencing considerable variations in demand that had to be matched by an approach to CAPM capable of responding to this variety. The problem could be considered from two points of view. The variety could be reduced, and manufacturing could be enabled to meet the variety. A combination of these two approaches was attempted.

(1) The company's sales team were given a policy of reducing variety as far as possible, in this case by selling standard products. This was to be supported by a training or awareness scheme for sales staff together with the implementation of sales procedures which involved presenting the customer with the option of purchasing a standard product under more advantageous terms (of cost and lead time) than a special.

(2) A short-term solution to the information system problem was generated by the workshop meetings. It consisted of a simple paper-based system for day-to-day scheduling, relying on a procedure in which each day's capacity would be loaded to 80 per cent, the remaining 20 per cent being held open until noon on the preceding day to allow rush jobs to be fitted in. This provided an interim system solution which would help manufacturing to manage the variety.

In addition it was also recommended that a link between sales and manufacturing be established to identify problem areas. This would enable sales and production to agree on lead times and delivery dates over a monthly period. In combination with the manual card-based tool it would enable sales to estimate (fairly accurately) a lead time for an order.

For continued success and development it was clear that the boundary between the sales and manufacturing functions must be monitored and lines of communication must be kept open. It was decided to implement this regular meeting between the two functions to look at the performance of current procedures.

Conclusions

There are a number of reasons why a methodology is the most appropriate way of improving manufacturing competitiveness. Typically, UK manufacturing has resorted to the use of outside consultancies to improve manufacturing. However, the consequences of this are that the consultant provides a "quick fix" without the user gaining a full understanding of his processes. The result is a company that has an increasing dependency on the consultant. By using a documented methodology, a company will have a record of its progress through the various stages and can return to the process as necessary without additional costs. Furthermore, the use of proven techniques in methodology reduces the risks of failure, prescribed deliverables help to gain management commitment and guidelines ensure uniformity of application by providing auditability and assisting in the transference of skills.

The CAPM methodology has been developed through funding provided by the ACME Directorate of the SERC through its CAPM initiative. The project team began by concentrating on why CAPM systems were failing. The team quickly identified the major reason — that requirements were changing over time. To cope with these changing requirements the research team have developed a methodology that places the CAPM purchasing decision in the context of the changing business needs which it has to support.. This is achieved by taking a "look out" over the foreseeable planning horizon using the stakeholder analysis. Furthermore the CAPM requirement had to be seen as part of the complete manufacturing system. Consequently, the first two stages of the methodology address the business and manufacturing contexts. The third stage takes the output from the manufacturing analysis and matches this to a CAPM requirements specification. The final stage is to match this requirement against existing CAPM packages.

The application of the methodology has proved to be a particularly fruitful part of the research and has benefited both the company and the development of methodology. For the company, a series of policies, procedures and practices were identified that should enable the company to improve its ability to cope with demand fluctuations. For the research team the case study has highlighted the learning process needed in developing such a methodology. The further refinement of the methodology based on the case data is currently taking place and is expected to be included in the development of a software package to facilitate stages three and four.

References

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