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A generic approach, employing information systems, for introducing manufacturing information systems in SME 's

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Abstract

This thesis presents an approach which the small and medium size firms can use in-house to introduce manufacturing information systems. The approach developed is generic and employs information system design and analysis techniques to guide Small and Medium size Enterprises (SME's) from specification of their need, right through to the implementation of an appropriate solution. Although there are various tools and methodologies that are available for large organisations needs, none are available for SME's. Therefore, the approach presented in this thesis provides original and significant improvements on current practice.

The approach emphasises the importance of taking a company wide approach to analyse systems throughout its various departments to establish bad practices and system flaws which may impinge on the performance of the manufacturing operations.

The research involved three independent stages. The first stage was the identification of the problem which was realised from two sources: literature survey and interviews with case study company managers. The second stage was the development of a novel approach. The final stage included the validation of the approach by implementing it in five different SMEs in the Devon and Cornwall region.

Through the use of this work, company's are encouraged to improve ownership and commitment to the manufacturing information systems by fully involving the relevant company personnel in identifying and resolving various problems. The approach proposed also helps managers understand how the various processes work in other areas of company, and can subsequently lead to improvements in other departments.

CONTENTS

List of Tables

List of Figures

Acknowledgements

I dedicate this thesis to my parents, Maqsood-ur-Rahman and Bilqees Akhtar who worked tirelessly to make sure that we had the best education. Even in adverse financial circumstances they never put any demands on us to seek any work on the expense of our education.

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Author's declaration

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other university award.

Signed ____________________

Date 7/2/2000.

Chapter 1

Introduction

1.1 Overview

The changing global industrial scene is forcing companies to evolve at an unprecedented rate (Vianen, 1993). The need to keep abreast of technological developments to improve productivity, quality and range of products to maintain performance is now of paramount importance (Williams, 1995). Despite the clear evidence for a need to acquire technical skills, and investment in technology, many companies are reluctant to move in this direction (Smith, 1995). This reluctance can be attributed two main factors: (i) the extremely sizeable investment required by a company, (ii) the total lack of experience with technology. This is particularly true in the case of Small and Medium Enterprises (SMEs), the DTI's classification for which is defined as those companies with fewer than 250 employees. Research presented in this thesis demonstrates that many SME's who wish to introduce new technology often do not know how to begin because of the ignorance of technology and the lack of know how on introducing new technology in their businesses. The use of outside consultancy services is often unsuccessful (Staughton *et al* 1992) because of the high costs involved in employing the consultants (Ibrahim and Goodwin, 1986). Therefore, any inappropriate measures, and those that utilise resources without providing the anticipated returns at the end, are an unnecessary waste of effort at a time when such expenditure is potentially dangerous to the security of the company. However, any measure that is capable of enhancing the competitive advantage of

SME's, without high costs, may therefore be considered to have huge potential for a wide variety of SME based applications.

This introduction explains the scope of this thesis, outlining the aims and objectives that the author has set out to achieve. It then goes on to explains the typical make up and characteristics of SME's . A sketch of demographic, geographical and industrial make up of Devon and Cornwall is drawn, this is essential as all case study companies for research and validation of the new approach are based in this region. Outline of the contribution to knowledge made by this thesis is also discussed. Prior to the conclusion of this chapter a description of the structure of this thesis is presented in the following section.

1.2 Aims and scope of the thesis

The aim of the research in this thesis is to help SME's introduce manufacturing information systems in their businesses without, requiring input from outside consultants. This is achieved by providing an approach which a company can use in-house to identify their problems / bottlenecks, define solutions and then implement the chosen solutions in their business. To meet these aims research was carried out to:

- Define and understand the goals for manufacturing, systems, manufacturing systems, information systems and manufacturing information systems.
- Compare Devon and Cornwall with the UK and the Europe and to identify similarities and or differences which are particular to the manufacturing companies in the Devon and Cornwall region.

- Review a few widely used Information Systems methodologies and to study the basis of a systematic study of systems analysis and design approaches.
- Investigate existing Computer Integrated Manufacturing (CIM) design methodologies and to establish their relevance to the SME's.
- Identify and establish the requirement for a methodology for introducing manufacturing information systems in SME's.
- Specify and validate a novel generic approach for designing and implementing manufacturing information systems SME's.

This research has demonstrated that, the management of most SME's do not fully appreciate and understand the meanings of various terminology key to this study including manufacturing, information systems and manufacturing systems etc. Therefore, it was considered necessary to explain and define, from original sources, the meanings of these terms.

The research also showed, that a typical SME frequently emerges from an individual, working from his garage, soon growing to two people and then rapidly growing to ten plus people. It was noted that although it was relatively easy to divide, manage and co-ordinate work between three to four people. However, as the numbers increased above five it became difficult to manage and organise the work between the people. This was due to the fact that although a company might be growing the systems do not grow with the company this often results in very chaotic situations.

As a result of the above findings a chapter is devoted to the study of systems and methodologies for developing systems.

1.3 Contribution of the research

This thesis has made a significant contribution to the knowledge in this field by developing a decision support tool which SME's can use in house to introduce manufacturing information systems in their businesses. It presents an approach which the SMEs can use in-house to introduce manufacturing systems and computer based manufacturing systems instead of having to employ expensive consultants. The author's extensive literature survey and case studies, in the Devon and Cornwall region, have revealed that there is no such methodology that is available for SME's anywhere. The use of case study implementations has proven the success of the approach being presented.

The approach, by employing information systems, will enable companies to introduce information systems and manufacturing information systems in to their businesses if no systems already exist. It will guide companies on developing the most appropriate solutions for those companies that can identify both the need and resources required. The in-house approach which this approach encourages will help to create more ownership and commitment from both the top management and people at the implementation level, which is essential if implementation is to create an operational environment capable of achieving maximum benefits and effectiveness for the company concerned.

Many methodologies exist for designing a Computer Integrated Manufacturing System (CIM) for large organisations. Further research has been published concerning the need for SME's to adopt new technology (Gibson, 1995) for their manufacturing systems to improve competitive edge. However, little research and no methodology exist to address the delivery mechanism which may be used to introduce manufacturing systems and computer based manufacturing systems. The research has established a significant contribution knowledge in this field by:

- Providing a novel approach which SME's can use in-house to introduce information systems and manufacturing information systems in their businesses.
- Providing new, easy to use, information mapping diagrams.
- Undertaking a comparative study of Devon and Cornwall with the UK and also with the rest of Europe to identify the special needs of SME's in the Devon and Cornwall region.
- Providing a comprehensive review of information systems methodologies, and design of CIM methodologies and by the identification of their deficiencies for the SMEs application.
- Establishing the requirement for a need for an approach to assist SMEs in introducing manufacturing information systems.
- Developing unique information mapping tools and qualitative decision making technique that are easy to understand and use.

1.4 Structure of the thesis

The contents of the chapters in this thesis are described below. The order of these chapters was mainly organised to facilitate the understanding of their contents.

Chapter 1: Introduction

This chapter provides an overview to manufacturing and the challenges faced by SME's. It then presents the scope and aims of the thesis to develop a generic approach to introduce manufacturing information systems in SME's. The main characteristic of the approach is that it is simple and practical enough for companies to use in-house. The chapter also outlines the significant contributions to research which this thesis has proposed.

Chapter 2: Research methodology

This chapter describes the research methodology which has been used to structure and manage the research. The methodology employed uses a literature survey and case study approach to establish the requirements for the design and validation of the new methodology.

Chapter 3: Characteristics of SME's in Devon and Cornwall

This chapter investigates the spread and frequency of SME's across various industrial sectors in all the above regions. It also analysis the total employment provided by the SME's in each of these regions to establish the importance of SME manufacturing companies on the regions. The chapter then considers the Information Technology (IT) infrastructure of the regions to establish the trends on usage of IT within the regions and availability of information to and capability of SMEs. The chapter also reviews various 'IT in manufacturing policies' introduced by SME's together with help and encouragement provided by the relevant local and national government bodies. The chapter concludes with an assessment of the special needs of SME's in the Devon and Cornwall region.

Chapter 4: Manufacturing, systems, information, information systems and manufacturing information systems

Chapter 4 addresses the definitions of systems, information, information systems, manufacturing systems and manufacturing information systems. Consideration is given to the aims and objectives of every manufacturing company, which are to reduce wastage, Work In Progress (WIP), lead times and increase productivity, quality and ultimately profitability of the company.

The chapter details routes to realising the above goals which can be achieved if a systems approach is applied in a company. The chapter concludes by emphasising the need for a structured approach to introduce company-wide systems that can guide the companies in realising the above aims and objectives.

Chapter 5: Review of existing information systems and Computer Integrated Manufacturing (CIM) design methodologies

Chapter 5 extends the descriptive phase of the research methodology, by focusing on the existing information systems methodologies and CIM methodologies which are available, and widely used. It was considered necessary to summarise some of the common information system methodologies as a close investigation of the current CIM methodologies reveals that most of the CIM methodologies have stemmed, and evolved, from the information systems approach and methodologies.

This chapter also describes the key common methodologies used for designing computer integrated manufacturing systems. Although based on the original information systems methodologies thinking the developers of these CIM methodologies have adopted for applications within manufacturing environments. However, almost all methodologies have been designed for application to very large organisations and using highly complex models and systems. Therefore, none of these methodologies can be applied to the SME application. The chapter concludes by emphasising the need for a simpler approach with specific needs for SME's in mind, as SME's often lack the qualified personnel to apply complex methodologies. SME's also lack finances to be able to hire outside consultants.

Chapter 6: Requirement of an approach for introducing manufacturing systems for SME's.

Chapter 6 builds on the conclusions from chapters 3 and 5, integrating these conclusions with the extensive research of SME's from the Devon and Cornwall regions, recommendations are made of a set of requirements for an approach capable of guiding and supporting the task of analysing, designing and implementation of information systems and manufacturing information systems.

Chapter 7: A new generic approach to introducing manufacturing information systems in SME's

A new generic approach is outlined in this chapter. The approach is divided into three phases, analysis, solution development and implementation. This chapter explains each of these phases in some detail and outlines the various steps involved at each phase. The chapter also explains the original mapping tools that have been developed with specific needs of the SMEs.

The particular structure of the approach has been developed for the ease of use to the SMEs and without there being a need to employ outside consultants.

Chapter 8: Validation of the new approach

Chapter 8 establishes the validity of the approach by outlining the outcome and results derived from the implementation of the approach in five case study companies. All aspects of the approach were tested and proved valid in the case studies. Whilst it would be extremely useful to test the full model within a company environment to establish the credibility of the complete approach. This is impracticable as the nature of SMEs is such that few will require full implementation, choosing instead the section of the approach considered to be relevant. This research has therefore inferred the validity of the entire model based upon the validation of the components.

Chapter 9: Conclusions

This chapter concludes the work by evaluating the progress made and suggesting ways in which the work may be further developed in the future. This work has provided a novel approach that SME manufacturing companies could use in-house to introduce information systems and manufacturing information systems in their companies. This approach will provide companies with structured steps to identifying the inherit problems of the company and then identifying solutions to those problems, which may be either introduction of new technology or redefining the existing structures and systems. And finally how to successfully implement the solutions.

1.5 Publications

The papers based on the author's research have been presented and published in the following conferences:

- Advanced Manufacturing Processes, Systems and Technologies (AMPST 96), Bradford, UK, 1996.
- Advanced Manufacturing Technology, Twelfth National Conference on Manufacturing Research, Bath, UK, 1996.
- Competitive Manufacturing, Twelfth Conference of the Irish Manufacturing Committee, Cork, Republic of Ireland, 1995.
- Advances in Manufacturing Technology, Eleventh National Conference on Manufacturing Research, Leicester, 1995.
- Applications of soft technologies for enhanced manufacture and management, Technology Transfer series, Plymouth, 1996.

- Technology Transfer and Innovation, Teaching Company Directorate, London, UK, 1997.
- New technology in SME's, Teaching Company Directorate, Belfast, Northern Ireland, UK, 1995

Copies of each of the above mentioned papers are presented in Appendix C.
As well as the above publications altogether three courses of two days duration were organised, with the University of Plymouth on the title " Introducing new technology for small businesses", for companies in the Devon and Cornwall regions. Also a seminars, of half a day duration, of the same title were organised, jointly with the University of Plymouth, DTI and Business Links. The author solely conducted all the courses and seminar, which were well attended, and received a very warm and positive response, from the industrialist, towards his methodology.

1.6 Summary

This chapter has sought to place the author's work in context and to define the aims and scope of the research. The aim of the research is to develop a generic approach which SME's can use in-house to introduce information systems and manufacturing information systems. In doing so an overview of SME's and the dynamic manufacturing environment has been briefly described. The contribution of the research to knowledge has been stated and the structure of the thesis has been described. To date no such approach exist which companies can use in-house and which has addressed the particular needs of the Small and Medium size companies.

In the following chapter, the author describes the research methodology which was used to structure this thesis.

Chapter 2

Research Methodology

2.1 Introduction.

This chapter outlines the research methodology adopted to develop a unique approach to introduce information systems and manufacturing information systems in SME's. SME's are defined by the European Commission to be any company with less than 250 employee's and turnover of less than £20M. The research methodology is multifaceted, and takes a comprehensive approach to tackle this problem, while simultaneously remaining aware of the practical issues involved.

The research took a triple-structured approach covering all aspects of the design and practical functioning of the manufacturing information systems. The work contained here, aims to have a practical dimension and orientation by the analysing and resolving of relevant issues that concern business. This leads to the development of methods that can be immediately integrated to fulfil their requirements. A 'systems view' (Wilson, 1984) has been used to shape the contours of these investigations. The development of the approach, which is described in chapter 7, arose from interviews and observations of actual companies. It was felt that this would lead to work that was more relevant to the needs of practical life applications (Checkland, 1981). This can be seen as a 'Grounded Theory' approach (Glaser and Strauss, 1967) to research.

The primary research was conducted in the form of case studies of SME's in the Devon and Cornwall region, in order to tailor the approach to fit any requirements that the companies had. It was the adaptation of a rudimentary prototype approach to genuine company applications, that provided the crucial component when designing the final approach. This chapter then, describes the primary research conducted, mainly in the form of case studies and then describes the secondary research which took the form of a literature survey.

2.2 Research strategy

2.2.1 The case study approach.

It has been observed by many authorities, that the nature of operations research has been divorced from reality to such an extent that it is an essentially artificial exercise (Meredith *et al* 1989). Instead, much more emphasis has been exerted upon the adoption of naturalistic paradigms (especially direct observation, case, action and field studies) and existential (primary interpretative) paradigms. Research carried out by Deising (1972), had determined the limitations of quantitative analysis to defining relationships within an organisation. Simultaneously, the study had found that quantitative analysis could not identify the actual inner, or interpersonal transactions which bring them about.
Taking into consideration the findings mentioned above, the case studies formed the backbone of the research into the design, testing and verification of the methodology. The case study approach opened up opportunities to explore specific factors in the implementation of new technology in the manufacturing industry. In fact Rickwood *et al* (1987) noted that,

> "the adoption of a case study approach provides opportunities for overcoming the restrictions of response imposed by the questionnaire in investigating the heterogeneity of procedures and their relationship with the context in which they are adopted."

The case study approach enhanced the research and the understanding of the author, by giving insights into the various factors at work within the manufacturing process. These would otherwise not have been identified. In adopting the case study approach, Romano (1989) states that the researcher has the opportunity to utilise a single- or multi-site case approach. He observes that a multi-site study analysis provides further insight in to the research problem. In addition, similar research conducted by Miles and Huberman (1985) found that,

> "by comparing sites or cases one can establish the range of generality of findings or explanation and at the same time pin down the conditions under which that finding will occur. There is much potential for both greater explanatory power and greater generalizability than a single case study can deliver."

In response to this and similar research, this study refers to research conducted at 17 SME companies in the region of Devon and Cornwall and focuses on five specifically, chosen to validate the salient points of the proposed novel technique.

2.2.2 Industrial partnership

A significant part of the research strategy, was to spend an appropriate length of time within one company. This was undertaken in order to incorporate into the approach, provisions for any organisational phenomena that was not observed in the shorter periods in which the majority of case studies were spent.

One year was spent working on a joint research project between the case study Company A and the University of Plymouth. Initially research was done to analyse the existing systems of the company and highlight the concerned areas. In the second phase, appropriate research was completed, with the resources from the University, and in collaboration with the staff of the company to identify ways and means to eliminate bottlenecks and other relevant areas that were hindering the production output. The final phase included the implementation of new systems and technologies.

The experience gained at Company A laid the foundation for further research in this area. The interaction between Company A, academia and close working relationship with the staff of the company enabled the author to formulate an awareness of a typical thinking process of a SME, typical production problems, lack of awareness of new technology, and resistance to new ideas and technology.

2.3 The research plan

The research for this thesis began with a survey of the literature available on the regional trends in Devon and Cornwall and current approaches to manufacturing systems methodology and information systems methodologies. This gave the author an insight into the region and the key problems and issues facing it. In addition, analysis of a survey conducted by the University of Plymouth Business School (Eddy at el,1996) into implementing new technology for competitive advantage, led directly to the integration of this research with the trends and problems of SME's in Devon and Cornwall. This was followed by visits to seventeen companies in the region where information was gathered and the rudiments of the methodology, formulated and tested. The authors findings were presented and discussed in seminars for the DTI and Business Link and published in several papers, see Appendix C. As a result courses were run for local SMEs in Devon and Cornwall on behalf of the University of Plymouth. In addition, over a year was spent in five companies where actual projects were undertaken to ensure the mature development of the approach.

A new generic model was developed from the research undertaken, which sought to guide SME manager's, from the stage of assessing the need to implement a new system, to monitoring and auditing the performance of the new manufacturing information systems. Validation of the model was undertaken as a continuous process in case studies, and the industrial placement, as well as in discussions with practitioners. The different parts of the research plan will be briefly discussed below.

2.3.1 Literature survey

This was undertaken to gain an appreciation of the issues involved, in the manufacturing industry and also in Devon and Cornwall. In addition to these benefits, the literature survey also provided a theoretical background to the work and reinforced the findings of the research.

The initial research undertaken, aimed to correlate the research that had already been conducted in this field. To this end, books were consulted on areas as diverse as 'Small Business Dynamics' (edited by C. Karlsson, B. Johannisson, and D. Storey) and 'Information Systems for Managers' (by G. Reynolds). Then different methodologies were researched in the fields of information systems and manufacturing systems, to ascertain whether they contained anything that could be applied to the small manufacturing business.

This research incorporated a large number of varying areas of expertise, of which the primary titles are detailed below:

- Information System Methodologies
- Manufacturing System Methodologies
- Tools and Techniques
- Manufacturing Management
- Information Technology
- Total Quality Management
- Studies of SME's
- South West Economical Research
- Human Factors
- Computers Integrated Manufacturing
- Stock Control Systems
- Manufacturing Planning and Scheduling Systems
- Flexibility
- Standards
- Implementation Issues
- Strategies within SME's
- Organisations
- SME Culture
- Business Statistics
- Production Management
- Material Requirement Planning (MRP)
- Manufacturing Resource Planning (MRP II)
- Information Systems
- Manufacturing Systems

The literature consulted showed that no work had been carried out on developing systems manufacturing implementation methodologies aimed at helping SME's in the region of Devon and Cornwall. In fact, no methodologies of this kind exist and there was no evidence that one is currently being developed.

2.3.2 Case study companies

There appears to exist a consensus among the literature consulted, that SME's in the region of Devon and Cornwall lag behind their competitors in both the production output, and employment of technology and its use, both in the UK and EU markets. During the course of the research the author visited seventeen manufacturing SME's in the region and established the view that production planning and scheduling were unorganised and employment of technology in manufacturing in the region was relatively insubstantial. However, detailed study had to be done to establish the reasoning behind this.

In order to fully understand the wider issues relating to the unorganised production and lack of technology it was felt crucial to study all key departments in a company rather than merely concentrating on the manufacturing department. It was revealed, by analysis of the existing systems of case study companies, in the initial research that in many cases it was not the lack of organisation, or absence of technology within the production department, but some other factors which resulted in delayed orders, poor quality and reduced output.

The study, therefore, included:

- Aims and objectives of the organisation
- History of the company

- Systems study of all departments
- Any formal methods and concept used in various departments i.e. Just in Time (JIT), Total quality Management (TQM) etc.
- Qualifications of employees
- Quality control standards in production
- The use of technology in all departments
- Information storage and retrieval systems in all departments
- Desires to obtain professional standards e.g. ISO 9000 etc.
- Future plans and strategic thinking i.e. expansion, diversification etc.

2.3.2.1 A brief descriptions of case study companies.

During the first phase of the research, seventeen companies were visited from the various manufacturing industrial sectors. The aim of this research was to establish and identify general trends, and issues of concerns for SME's when introducing new technology and systems into their respective organisation. A brief description of seventeen case study companies is given in appendix B; a detailed description of five of these companies is given in chapter 8, these companies were used to validate the approach by carrying out a real project. Due to confidentiality reasons the organisations cannot be identified and are simply numbered from 1 to 17 .

2.3.2.2 Information gathering

The research information was gathered from the above companies, through a series of semi-structured interviews. The interviews were conducted by the author at the sites visited. In almost all companies the author questioned the managing director, production manager as well as other senior managers. In addition to this the author also spent a significant amount of time speaking to supervisors and other workers on the shop floor.

A wide variety of questions were posed to the interviewees. The information collected at these interviews and observations noted on the shop floor provided a significant input to the development of the new approach.

A list of questions asked to managers and shop floor supervisors can be found in the chapter 6. The responses to these questions and analyses are detailed in chapter 6.

2.3.2.3 Data collection quality

Romano (1989) states, that the selection of data quality control methods for use in a case study methodology should be based on practical usefulness and easy implementation. In the case of the research detailed in this thesis, considerable effort was made to ensure that the individuals interviewed in each company were drawn from different backgrounds and different authority levels. Each case study visit was undertaken using a standard set of issues and topics and the emerging results of the work were regularly validated through discussions with the other scholars in the field. These procedures gave the data collection a balanced approach.

2.4 Validation of the approach using five case study companies

Whilst the approach for introducing manufacturing systems in SME's was developed from findings derived from this research. However, it was then essential to validate this work through practical implementation.

To validate the approach the author undertook genuine projects in five of the companies previously mentioned. The projects lasted from a maximum of one year to minimum of six weeks. During these periods, the author was contributing a minimum of 15 hours per week at the relevant company sites. Although parts of the approach worked tremendously well in all companies, the author could not verify full methodology life cycle in any one particular company. This was due to the differing constraints in each of the case study companies, e.g. lack of time, resources, internal politics etc.

Although it was not possible to verify the full life cycle of the approach, it proved feasible to test, and then verify the validity of all the different phases in the approach. The details of the projects, and practical results of the implementation of the approach are listed, in detail, in chapter 8. It is considered unlikely that 100% of the approach for introducing information systems and manufacturing information systems could be tested in its full cycle in any one SME environment due to the size and nature of this classification of company. Any single company is only ever likely to require a portion of the approach. However, in reality each SME will require different portion to its neighbour.

Ultimately, the main method of evaluating the work will be the views of users and others in the field. Since no approach had previously been developed to help SME's introduce manufacturing information systems in their businesses, the usefulness of a simple and yet thorough approach was self evident.

2.5 Conclusions

To produce a practical approach which would be useful to companies having to deal with genuine situations, the research methodology took a very practical on field-work approach, which sought to understand the problems of SME's from the user's perspective, rather than being totally all academic based.

The approach adopted, opened up several issues e.g. i) that deficiency in production, or poor quality is not always due to poor organisation in the production department, but can often be attributed to other factors in the company; ii) The absence of the implementation of new technology is not always due to lack of investment, or resistance to the technology. It may however, be due to the ignorance of the availability of this technology and lack of not knowing how to introduce new technology. Therefore, the emphasis of this research was placed on deriving an understanding of issue and then dealing with them in turn, so that they could be integrated together to form a simple approach with the potential to make an enormous impact on all SME's understanding these sort of activities.

To this end, 17 case study companies were initially visited, followed by carrying out actual projects in five companies. In the course of all the visits, discussions were held with senior managers as well as supervisors and other workers on the shop floor level.

In addition, findings of the research were regularly published, and courses and seminars, in conjunction with the DTI and business links, were held for managers from the Devon and Cornwall region.

The research has resulted in the development of a novel generic approach which companies can use on-site to introduce new technology in their business, and improve their systems to improve productivity, quality, reduce lead times and minimise wastage. No such approach was discovered to exist during the period of the research, and hence, this is believed to be an original approach, which has wide applicability to SME's throughout the UK and Europe.

Chapter Three

Characteristics of SMEs in the Devon and Cornwall Region

3.1 Overview

This chapter sets the theme for the research presented in this theses. It identifies and describes the characteristics of small businesses that must be considered when developing an approach that SME's will be using to introduce Manufacturing Information Systems in their environments. The research is primarily focused on the characteristics of SME's in the Devon and Cornwall region. A certain additional comparison is also made of SME's in the Devon and Cornwall region with those in the UK and Europe.

The chapter reports the findings both from the literature search and the authors visits to some 17 SME's in the region. The objective of these visits was to ascertain the most obvious issues inhibiting change in SME's. The detail findings of the various visits and conclusions made from it are detailed in chapter 6.

This chapter is divided into four main sections. The first section details the circumstances of the Devon and Cornwall region. It specifies the spread of industrial sectors, employment patterns and problems faced by businesses due to the region being a periphery region of the UK .The second section describes the characteristics of local SME's and is sub-divided into both general and technological characteristics. The general characteristics address issues such as financial resources, transportation problems and skills shortages. The technological characteristics concentrate on the current use of technology, investigates various IT in manufacturing policies, and the feasibility of adopting new technologies and approaches to initiate and support business change. In the third section a general comparison of SME manufacturing companies in the Devon and Cornwall region is undertaken, with comparison to the SME's in the UK and Europe. This section identifies the key differences between the region, the UK and Europe, and focuses on the use of technology in each of the regions. The fourth section describes the help available to SME's in the region, describing both the help from the private sector, and help available from the local and national government. Also considered is the research assistance from the two universities and various colleges of further education.

3.2 Devon and Cornwall

The counties of Devon and Cornwall represent a significant proportion of the South West region of the UK. Tourism is one of the region's main industries, but the outstanding beauty and variety of the area does not mask the fact that over the centuries, the counties of Devon and Cornwall have also been a highly active industrial area.

The people of Devon and Cornwall are resourceful, resilient, hard-working, flexible and friendly. Throughout the history they have turned their hands to most things as they sought to win a living from sea or soil – by fishing, ship building, or cargo carrying; by farming quarrying, or mining and tradition remain extremely strong in many areas.

They were and still are – explorers, traders, and inventors. They were and still are - survivors. Whilst major industries have surged and disappeared through boom and collapse, the two counties have seen them repeated to varying degrees throughout the centuries as requirements have changed. Yet through it all, the counties have adapted and survived (Hainden, 1991).

Today the industry of Devon and Cornwall is mainly in the form of small and medium sized firms (Gripaios, 1998). The counties have a variety of locally founded businesses, along with a mixture of national and multi-national businesses that have chosen to move or expand in Devon and Cornwall (Devon and Cornwall TEC, 1999).

There are approximately 35,800 businesses within Devon and Cornwall, of which, 90 % are small firms with fewer than 25 employees, 9% are medium sized (employing 25-250) while large firms (employing 250+) account for less than 1% of the total (Devon and Cornwall TEC, 1999).

3.2.1 Statistical overview of Devon and Cornwall

The combined population of Devon and Cornwall is just over 1.5 million. These figures swell by 0.5 million over the summer months through tourism (Office of National Statistics (ONS) mid year estimates 1997).

- Over half (51.6%) of the population is female (ONS mid year estimates 1997).
- Largest numbers of people working age are in the 25-34 and 35-49 age brackets (ONS mid year estimates 1997).
- There are approximately 36000 business units, of which the vast majority are small. This structure is very similar to that of the UK and has not changed significantly over the period 1991-1995 (Devon and Cornwall TEC (DCTEC), 1998).
- Around 90% of 16-18 year olds are in full-time education or training providing the basis for a world class workforce (Careers Service, DCTEC, 1998).
- The region had the second lowest crime rate in England and Wales in 1992, and in the year to June 1994, recorded crimes in Devon and Cornwall fell by 8.4% compared with the previous year (Regional Trends, 1994).

3.2.2 Spread of industrial sector

Devon and Cornwall continues to have a broad range of industries, including traditional ones such as fishing, mining and quarrying as well as the newer industries in high technology and electronic engineering. Agriculture and fishing still employ proportionately more people in Devon and Cornwall than they do in the country as a whole, despite their decline in recent decades (Devon and Cornwall TEC, 1998). This sector still accounts for 4% of employees in Cornwall (5,500 people), although this number has fallen by 18% in recent years and self-employment in the sector is highly significant (Gripaios, 1998). In Devon, 3% of employees are in agriculture and fishing (9,500 people), a figure which fell by 11% between 1991 and 1995. Where as 1% of employees in Devon, the South West and the UK are employed in the energy, water and mining sector, this figure rises to 3% in Cornwall (Gripaios, 1998). However, employment in this sector fell by nearly 13% in Cornwall between 1991 and 1995, falling by 37% nationally over the same period (Devon and Cornwall TEC, 1998).

3.2.2.1 Manufacturing

The manufacturing sector in Devon and Cornwall consisted of nearly 2,400 business units in September 1995, employing 76,500 people (see Table 3.1). In order of the number of businesses, the most important manufacturing sectors were, food products and beverages, machinery and equipment, transport equipment (notably ship building and repair), publishing and printing, radio, TV and communications equipment. Each of these sectors had more than 5,000 employees (Annual Employment Survey 1995, ONS). In addition, four of these sectors were among seven manufacturing sectors in the two counties which had a higher concentration of employment than nationally. These were manufacture of transport equipment and of radio, TV and communications equipment, which had more than twice the national share of employment, and food products and beverages, tanning and dressing of leather, wood products and cork, machinery and equipment, and medical and precision instruments, all of which were better represented in the Devon and Cornwall economy than nationally (Devon and Cornwall TEC 1998).

Table 3.1: Business units in manufacturing

Area	1995	% change 1991 - 1995
Devon and Cornwall	2,377	-17.9
Devon	1,628	-16.4
Cornwall	749	-21.3
South West	9,178	-10.3
Great Britain	114,837	-15.1

Source: Census of Employment 1991, Annual Employment Survey 1995. Office for National Statistics

In addition, there are several large companies, that employ a high number of people, within some of these important sectors in the local economy. For example, Devonport Management Ltd in Plymouth is the largest business in the transport equipment sector, while Nortel in Torbay, and British Aerospace, Toshiba and Ranco Controls in Plymouth, are important in the radio, TV and communications and machinery, and equipment sectors of manufacturing (Devon and Cornwall TEC, 1998).

3.2.2.1.1 Long term prospects for manufacturing in Devon and Cornwall

Long term prospects for manufacturing are relatively good. However, while output is expected to grow, the forecasts for employment in this sector show either low growth or decline (DCTEC, Annual Employers Survey,1997). The latter is likely to be the result of ' technological change, increased productivity, and more outsourcing of service tasks. However, outsourcing is likely to lead, to indirect employment growth in other industrial sectors, as long as local firms are available to sub-contract, to those large manufacturing companies, which are concentrating on core activities. Computing, professional, and other business services are likely to be the main beneficiaries of this change in business process management. However, in future, companies may show greater selectivity in their outsourcing, sometimes combining internal and external provision.

3.2.2.1.2 Short term prospects for manufacturing in Devon and Cornwall

Locally, short term prospects appear to be good, with manufacturing being only one of two sectors in which the employers expected an increase in their workforce. In fact, more than half of the manufacturing employers interviewed in July/August 1997 were expecting their workforce to grow in the next 12 months. Amongst manufacturing employers, 28% were expecting an increase in semi-skilled workers, 22% an increase in skilled/craft workers and 15% an increase in technicians/white collar staff (DCTEC, Annual Employers Survey,1997). Short term prospects were also good for other aspects of manufacturing. For example, 59% of manufacturing companies thought that there would be an increase in their business turnover while only 41% expected turnover to remain the static (Devon and Cornwall TEC, 1998). While 63% of manufacturers expected an increase in profits, only 11% expected a decrease.

3.2.2.1.3 Investment prospects in manufacturing

Investment prospects are also good with 64% of manufacturing companies envisaging an increase in investment in plant and equipment, and 59% expecting increased investment in training (DCTEC, Annual Employers Survey,1997).

3.2.3 Employment pattern

This section highlights the employment trends for the manufacturing companies in the Devon and Cornwall region.

A survey conducted by the Devon Cornwall TEC in 1997 reported that while the majority of manufacturing employers (86%) had been able to recruit staff from their immediate local area, 11% of manufacturing employers had to recruit staff from the rest of Devon and Cornwall. A total of 6% had been recruited from the remainder of the South West region, and 7% from the rest of the UK. Manufacturing companies which had recruited outside Devon and Cornwall (13%) had commonly done so because of their need for certain skills with the highest proportion (36%) recruiting engineering skills from outside the two counties, followed by 11% for managerial staff.

On average, manufacturing companies had 2.4 vacancies each at the time of the survey. Half of those vacancies were for skilled/craft workers, followed by 20% for semi-skilled workers and 13% for sales staff. Of the manufacturing companies surveyed, 60% envisaged difficulties in filling these vacancies, especially those for skilled/craft workers, and as many as 76% of manufacturing companies identified a genuine skills shortage as the reason for problems in filling posts (DCTEC, Annual Employers Survey,1997).

Difficulties such as skills shortages are not surprising given the apparent large scale absence of forward planning activities by manufacturers. For example, the author's visits to SME's revealed that 41% did not have a written business plan and 57% did not have a written training plan.

The relative position of employment in manufacturing in the Devon and Cornwall region is summarised in the Table 3.2 below.

Table 3.2 : Employment by industry: Devon and Cornwall, 1981 - 2001

Industry					Thousands
	1981	**1991**	**1996**	**1998**	**2001**
Agriculture etc.	36.6	39.7	26.3	25.1	24.7
Mining & Quarrying	6.8	4.2	3.8	3.4	2.6
Manufacturing	92.2	76.8	83.3	83.8	81.6
Utilities	7.4	5.6	3.8	3.4	3.2
Construction	35.4	51.4	31.4	33.2	34.2
Distribution, Hospitality	144.5	161.5	161.6	167.3	174.2
Transport and Communications	25.3	28.2	26.2	27.9	27.0
Other Market Services	65.1	94.6	103.6	110.8	121.8
Non-Market Services	121.6	178.5	173.4	180.0	187.7
Total	534.9	640.5	613.4	635.1	656.9

Source: Cambridge Econometrics/IER, (LEFM) 1997

This section has also assessed the importance of the manufacturing companies, in terms of providing employment to the local population, and has highlighted the need for forward and structured planning to ensure that the skills shortages are dealt with in an organised fashion. This has further reinforced the need for an approach that can assist the manufacturing companies in the region, to introduce new technology and systems without the extra costs of hiring the services of specialist consultants.

3.2.4 Problems faced by the businesses due to the region being a periphery area

This section concentrates on the issues, and the constraints which are faced by the manufacturing companies in the region due to the region being a periphery area of the UK. These issues must be taken into consideration when justifying the need for an approach to introducing new technology and systems into the manufacturing companies:

- Devon and Cornwall is a region within what is termed the "Atlantic Arc" of Europe, and is relatively peripheral to the main areas of economic activity within the UK and the European Union. The region lacks high quality, physical and electronic communications, which are essential to improving economic competitiveness, and attracting new investment into the area (Havinden, 1991).

- The region is inhabited by higher than average proportion of older people, which not only restricts the demand for the latest technology goods but also restricts the quality of skilled labour (Havinden, 1991).

- The region has a poor infrastructure of roads, rail and air which are vital to develop closer links with the customers in Europe and compete with manufacturers both in the UK and Europe (Havinden, 1991).

- The region has a relatively few industrial estates and locations available for new economic investment, and for relocations (Devon and Cornwall TEC, 1998).

- As discussed in the previous section, there is a severe shortage of skilled labour, as higher proportions of individuals in the region are in semi or unskilled jobs.

3.3 Characteristics of SME's in the Devon and Cornwall

The research presented in this section has been accumulated from the literature survey, discussions with practitioners and visits to SME's in the Devon and Cornwall region. In most cases the principal findings in the literature have been supported by the author's survey, with a few exceptions, that are of particular relevance to the Devon and Cornwall region, the details of which have been given in the chapter 6.

Small and medium size manufacturing companies are a significant part of the UK economy (Teaching Company Directorate, 1995). In 1995 the DTI report on small firms in Britain reported that 37% of all manufacturing employment was provided by the SME's. While SME's are important to the economy there is also growing recognition of their vulnerability in competitive markets (Staughton *et al* 1996).

Different criteria have been used to define SME's. The definition used for EC initiatives such as the Community Action Programme for Education and training in technology (COMETT) for example, identify an SME as having less than 500 employees. Brooksbank *et al* (1992) have suggested that the criteria of sales turnover, number of employees and chosen growth strategy should be used differentiate between large and small firms. Houldsworth (1992) classifies an SME as having less than 250 employees and less than £250M turnover. This definition is similar to that of the Teaching Company Directorate (1995) who suggest the criteria of less than 250 employees, turnover less than £16M or balance sheet total of less than £8M, and less than 25% owned by a company not meeting SME criteria. This last criteria has been used to identify SME's for this research.

The characteristics of SME's can be divided in to two parts: the general characteristics and technological characteristics.

3.3.1 General characteristics

ACARD (The advisory Council for Applied Research and Development, 1986) study on SME's in late eighties identified the of lack of financial of resources as being a key factor in the growth of SME's, particularly when trying to facilitate training, innovation, organisational development and research and development. This is a major factor preventing the advancement of SME's, given the high costs associated with the alternative of acquiring outside consultancy.

Another factor that has been identified (Curran et al, 1993) is that small companies often lack trained personnel to implement business change. This problem is also faced by the larger organisations. However, SME's have to deal with these problems without the specialised staff expertise and financial resources that are available to the large companies. This implies that SME's need to focus on the training of staff, to address the deficiencies in expertise. This can be achieved without the need for huge financial resources.

A Price Waterhouse (1991) report, while acknowledging the flexibility and dynamism of SME's, indicates the inability of SME's to undertake training on a large scale due to the lack of staff resources and time. The use of educational technologies which may facilitate a more flexible means for training could provide the new opportunities which are required in this area (Balcon 1990).

In addition to the lack of financial resources and trained personnel, further constraints are imposed by a short range management perspective (ACARD 1986, Ibrahim and Goodwin, 1986). These characteristics of small firms play a significant role in restricting the introduction of new technology and manufacturing systems. For an SME to identify the use of technology within the business, there is a need to first establish the strategic direction and plans of the company, which requires a longer range perspective. It is unlikely that appropriate technology and systems could be designed and implemented if there is no appreciation of corporate strategy.

3.3.2 Technological characteristics

This section identifies issues that sustain or restrict technological change in SME's. The implementation of Advanced Manufacturing Technology (AMT) and use of outside consultancy is discussed in this section.

AMT can provide as many if not more benefits to the SME's, than it does for large organisations (Merideth, 1987). These benefits include capitalising on flexibility, quality, and lead time reductions offered by the new technology. In earlier work, Meredith (1985) indicates that smaller companies are more selective in the implementation of AMT, in that their investment is focused on achieving pre-defined goals, such as increased quality, reduced lead time or some other area of potential competitive advantage.

The financial constraints identified (Ibrahim and Goodwin, 1986) suggest that the majority of SME's would be unable to attempt the introduction and implementation of AMT because of the high costs associated with its adoption. Although the financial resources are generally limited for SME's compared with the larger organisations, the author's research in this field reveals that small companies have indicated a large investment in production facilities for example, Computer Numerically Controlled (CNC) machine tools.

A number of critical issues associated with the implementation of technology are conducive to being a small company (Merideth 1981). The members of a project team are likely to possess a broader understanding of different areas of the business which would facilitate problems identified and solution development which is not constrained to individual and isolated areas of the business. This is in contrast to the more narrow perspective which may be held by a larger company which relies on individual departments, for example data processing, to lead the implementation of new technologies. In addition, the senior management team of a small firm is likely to be closer to the project than their counterparts in a larger company (Karlsson, 1993). This increases the possibility of obtaining a senior management, project champion to support the project.

3.3.3 Consultancy and SME's

Where the solution of strategic problems is concerned, SME's are found to have little expertise (Fuller 1994). These skills are typically acquired from external interventions using consultants. However, such external intervention does not guarantee success (Soh 1992). Lees and Lees (1987) suggest that SME's often overestimate the impact of consultant support. Consultants often do not understand the specific needs of the companies (Meredith 1981) and often try to apply methods and tools to SME's which are normally used in large organisations. This results in often over complex solutions or alternative solutions that are impractical and therefore waste resources.

Another problem associated with the use of specialist consultants, is the dependency of the companies on the consultants for future improvements to the systems, and technology that subsequently results in more costs. Continuous improvement is the key to successful system implementation, this can be difficult to achieve through the use of consultants. The use of consultants also means that no new development of company's own staff is initiated. This further poses confidentiality issues for the possible replication of company's products.

In the majority of cases, for most SME's to use outside consultancy, is beyond the limit of their financial budget. There needs to exist an approach that guides the company staff through to implementing new technology and systems in their companies. Such an approach is the focus of this research.

3.4 Study of SME's in Devon and Cornwall, the UK and the Europe

This section carries out a study of the SME's in Devon and Cornwall, the SME's in Europe and the rest of the UK. It aims to identify similarities and or differences that exist. The focus of which is to ensure that any new methodology that is developed takes into account the particular needs of the SME's in the Devon and Cornwall region. Also this study's objective is to highlight the advantages that companies in Europe and the UK have over the SME's in the Devon and Cornwall region.

It was thought that the development of the European Union (EU) would, increasingly concentrate business in large enterprises. However, in practice the process of concentration of business in large enterprises has not only ceased but also been reversed. All European countries including the UK, recognize the importance of the small firm sector in wealth and job creation (The European Observatory for SME's – Fourth Annual Report 1996). The countries of the EU can be separated into two groups. Firstly, the EU big four namely France, the United Kingdom, Italy and Germany, while in the second group are contained Ireland and Denmark (Eurostat/DG XXIII: Enterprises in Europe, Fourth Report, Brussels/Luxembourg, 1996).

There is a lack of consistency in international statistics about small firms, while certain classification of information are simply not recorded in some countries – and therefore not available. In addition, the sample base for various analyses also tends to vary greatly from country to country making any attempt at comparative analysis very difficult.

The problem reflects itself in the statistics on numbers and employment by the size of firm. The picture that emerges is however, remarkably consistent. SME's represent over 99.8% per cent of firms in all EU countries (European Observatory for SME's, Fourth Annual Report, 1996).

Employment patterns are more diverse, SME's employ between 60%, in France and 83%, in Italy and Republic of Ireland, of the work force. To some extent these differences reflect the definitional problems outlined above. The one country out of line is the UK where the small firm sector employs only 37 % of the work force (European Observatory for SME's, Fourth Annual Report, 1996) .

SME's in the EU tend to be more profitable than large firms (Ganguly, 1995). Alongside this SME's are generally less productive than large firms (using output, profit or value added per employee as a measure). The explanation for this is two-fold. Firstly small firms are actively substituting labour for capital because they face capital constraints and/or rationing. The second reason is that the cost of capital and labour are not the same for small and large firms. Capital costs are higher for small firms, due to higher interest charges and the labour costs are lower. Hence capital and labour will frequently be used in different firms according to their size, enabling both to be technically and cost efficient.

SME's in the UK follow a different trend, with research data on profitability showing that they are now marginally less profitable than large firms and that the situation is deteriorating (European Observatory for SME's, Fourth Annual Report, 1996). They are also less productive than large firms. In other words, they are inefficient using both capital and labour measures. The same is also true for the companies in the Devon and Cornwall region. It is therefore possible to draw conclusions about the efficiency and effectiveness of small firm management. This points to a need for improvement in management style and technique (Fuller 1994), and lack of employment of new technology (Meredith, 1986), which in the present climate of intense competition is one aspect that cannot be overlooked. This causes a real concern about this situation that cannot continue for long, especially in relatively disadvantaged regions of the UK like Devon and Cornwall.

There are several factors that affect the UK's economic performance, among them being capital costs, since the UK has the highest property rental costs for both office, and manufacturing space than any other EU country (Opportunities for Growth; an Economic Assessment of Devon and Cornwall, 1995). A further factor affecting the UK's performance is high unit labour costs due to production being lower per head than any other EU country while average wages are at the midpoint (Eurostat/DG XXIII; Enterprises in Europe, Fourth Report, Brussels/Luxembourg, 1996).

The UK has a unique tax environment within the EU, being favourable for businesses. The UK small businessman faces neither the burden of taxation nor the complexity of administration that many of his European neighbours face, while the Business Expansion Scheme offers unique and generous tax advantages to those investing in small businesses (Small Firms Report 1995, DTI).

Arguably the major requirement of SME's is a need for equity capital. Here the provision of tax incentives may have a part to play in that it can be used as an inducement for non-participant individuals to invest in SME's. Britain stands out here with its bold and generous Business Expansion Scheme. This allows the deduction of up to £40,000 in any one year from an individual's tax liability for investment in shares in unquoted trading companies incorporated and resident in the UK (Small Firms Report 1995, DTI).

None of the countries in the survey have any scheme approaching the generosity of the UK scheme (Small Firms Report 1995, DTI). Although Denmark has no special incentives for investment by non-participants, it does have a scheme whereby wage earners under 40 can make deductible deposits of up to 20% of their income in an 'establishment account' and use it for setting up their own business. In France private individuals investing up to 7000 FF a year in quoted or unquoted companies may claim a 25% tax credit. Germany, the Republic of Ireland, Italy and Switzerland offer no specific tax incentive for non-participants (European Observatory for SME's, Fourth Annual Report, 1996).

Management competency is a prerequisite to the success of any SME's trade. The scope of this competency is a key to the economic success of an SME and can be explained by its distinctive management practices which give it a competitive edge. Motivation to growth by either the proprietor or/and managers is a key pre-condition for business success. Clearly only entrepreneurs with a high motivation for stable growth, innovation, employment of new technology and a positive attitude towards effective delegation of tasks and responsibilities will be able to make their enterprises grow (Small firms in Britain, DTI, 1995).

3.4.1 Problems faced by SME's in employing new technology and the help given by the governments

SME's often lack the skills and capabilities required for the efficient production of modern technologies (Qurashi, 1996), and this is one industry that Devon and Cornwall will need to focus on if it is to make a long-term economic recovery. Special programmes have also been introduced to improve the ability of SME's to make use of various technologies.

In Ireland, the National Microelectronics Application Centre provides consultancy and advice to SME's regarding their technological needs. The main activity is to support small companies in their application of IT by providing technical solutions (FitzGerald, 1993) Science Budget: Review of State Investment in Science and Technology 1980-1993, Forfas Dublin, source: ESRI, Ireland). In Norway, the Industrial and Regional Development Fund (SND) supports programmes through which new products and innovations are developed in a close contact with, and according to the requirements of, the user, which may be a public institution or another company. The aim is to bind producers and users together and to enhance the flow of information between them.

The problems faced by SME's using these new technologies are changing; as the price of hardware and applications declines, so the problems which relate to the skills and training required to use these technologies have come to the fore. However, financial and infrastructure problems still exist and the need for consultancy and training is growing (IT Diffusion Policies for SME's, OECD, Paris, 1995).

One common problem that SME's share is the lack of national IT structures, and the poor suitability of these infrastructure and IT applications to SME's. In the Bretagne region of France, an attempt has been made to improve the availability of the infrastructure. A local network is open to everyone, and local authorities pay two thirds of the operating costs. The network provides access to many research centres, databanks, public authorities and the Internet. SME's have been major beneficiaries of this service, which provides access to information highways in a region far from the major axes of European development (Usine Nouvelle No. 2494 (March 1995), Aprodi, France). In the Netherlands, a Dutch organisation for SME entrepreneurs (MKB-Nederland) has started an interactive network for its members, through which entrepreneurs can seek advice and consult experts. The main function of the network is to help the entrepreneurs find the most relevant information sources (De Financiele Telegraaf 20.12.1995, EIM Small Business Research and Consultancy, the Netherlands).

SME's are in need of relevant and up-to-date information about the development and advantages of new technologies. However, the resources available to any company are limited by its size and SME's in many cases would not be able to make an extensive search for the information they require. One response to this problem is the Technological Innovation Cell in Flanders, which searches for and evaluates technical trends, as well as new products and processes, on behalf of local enterprises. In Austria, the Economic Promotion Institute has established the Interactive Information Centre in Graz where different IT services (e.g. simulation applications and training) are offered to the entrepreneurs (IFG Vienna, Austria).

The introduction of new technologies often requires substantial investments in both equipment and training and there are various national schemes throughout the EU providing help to SME's. In Italy there are regional laws that provide grants to SME's for the purchase of technologically advanced software (Mediocredito Centrale - Ouaderni di Politica Industriale - Osservatorio sulle Piccole e Medie Imprese. Febbraio 1995, source: Bocconi University, Italy). In Germany, subsidised loans are available to SMEs for either the production or purchase of these new technologies (FM Bonn, Germany).

3.5 Assistance available to SME's in the Devon and Cornwall

Whilst the British Government believes that all business works best when given the maximum freedom to operate, it also recognises that small firms often face particular difficulties and tend to function at a disadvantage to larger firms (Small Firms Report, DTI, 1995). These disadvantages include:

- greater difficulties in raising finance, particularly for small firms in high risk areas such as new technology;

- difficulties in penetrating overseas markets; and
- limited possession of management and other business skills essential for growth.

The Government is seeking to counteract the disadvantages which all SME's face. Research has indicated however, that there is additional value in focusing assistance selectively on those firms with the potential and management will to grow. The joint DTI/CBI, 1995 Winning report identifies the characteristics of a winning company, as follows:

- they are led by visionary champions of change;
- they unlock the potential of all their people;
- they understand their customers' needs; and
- they strive continually to improve the range and quality of their products and services.

The thread that runs through all these criteria is a recognition of the need for change, and a willingness to seek help in implementing and responding to change. In the small firm in particular, the role of the manager is crucial. While the government does make available a wide range of support in such varied areas as business planning, product development, marketing, training, exporting, accessing finance etc., the impetus for change lies in the hands of the firm (Business Link, 1997).

The government believes that its policy in support of small firms must evolve in partnership with small firms themselves (Chesterton Consulting Group, 1996), with their representative organisations, and with providers of business support at the local level (Small Firms Report 1995, DTI).

3.5.1 Business Links

In England, the Business Link is the normal single point of access for all DTI business services. For the first time, all businesses have a single, local place to go for a wide range of business support services. Business Links provide support for all firms, from start-ups to well- established businesses, but the focus is on those with potential for growth (Small Firms Report 1995, DTI).

The Personal Business Advisers (PBAs), who are at the heart of each Business Link, develop long-term relationships with local business clients to help support their development and growth. They are supported by specialist advisers in innovation and technology, exporting and design. Business clients also have access to a finance packaging service to help them to obtain the right mix of finance to meet their needs (Small Firms Report 1995, DTI).

3.5.2 Single Regeneration Budget

The Single Regeneration Budget (SRB), came into operation in April 1994. It combines 20 previously separate programmes into a single budget. From 1995/96 the Budget has been supporting new innovative projects, through the Challenge

Fund, with some £575 million funding available to the SMEs in the Devon and Cornwall region (An economic assessment of Devon and Cornwall, 1998). These new initiatives proposed and devised at local level, have been chosen through a competitive bidding round administered by the Government Offices. Business support is given prominence as a means of encouraging sustainable economic growth. Improving the competitiveness of the local economy is an important aspect of the Challenge fund objectives. SME's clearly stand to benefit from the Challenge Fund in terms of economic help, since over 100 of the new Challenge Fund projects have economic development as their key priority and aim to assist 60,000 new businesses (An economic assessment of Devon and Cornwall, 1998)

In meeting their objectives, successful bids are expected to maximise the leverage of private sector investment and intensify the impact of public sector resources by achieving greater coherence of expenditure, including maximum co-ordination with European Structural Funds. From this perspective, it is clear that SME's in Devon and Cornwall stand to benefit from their EU assisted region status.

The 1995 bidding round built up to a total of £200 million in 1997/98. The SRB bidding rounds have provided opportunities for developing imaginative and innovative business support schemes that form part of the wider regeneration strategies submitted for funding under the budget. Support for small businesses will continue to be an objective of the SRB (An economic assessment of Devon and Cornwall, 1998).

3.5.3 Training and Enterprise Council (TEC)

Small firms face particular problems in tackling their management skills and training needs. Time and resources devoted to training and management development when weighed against the pressures of keeping the business running, can appear disproportionately costly.

It is clear, however, that small firms do need to improve management and skills training (Caird, 1992). The government has paid particular attention to the needs of small firms in all its training and development initiatives. Considerable help is available in England through the Business Link and the Training and Enterprise Council (TEC) networks.

TEC's were established by the Government to restructure Britain's approach to training and enterprise development. In partnership with the local community, they enhance the nation's efforts to improve business performance and develop individuals. They have been given the task of determining the specific needs of their areas (Foundations for the Future; an Economic Assessment of Devon and Cornwall, 1994).

A new initiative, Skills for Small Businesses, is also available through TEC and Business Links. It aims to help firms overcome the barriers they face in improving the skills of their workforce by developing in-house training expertise.

A new package of consultancy support for small and medium-sized enterprises is being developed that will build on the success of the Enterprise Initiative Consultancy Scheme which closed in 1994. The new services will be delivered by Business Links (Small Firms Report 1995, DTI). The Diagnostic and Consultancy Service provides subsidised management consultancy to help firms. This new service is made up of two distinct elements:

- The provision of holistic diagnosis of business strengths and weaknesses for individual businesses; and
- Full strategic consultancy.

During 1998 all Business Links offered an Innovation and Technology Counselling service. Business Link clients received direct personal advice on any aspect of innovation or the application of technology from Innovation and Technology Counsellors (ITCs) (Devon and Cornwall TEC, 1998).

3.5.4 Teaching Company Schemes

The exchange of people between organisations has proved to be a very effective way of facilitating the transfer of technology and skills. The Teaching Company Scheme (TCS) aids technology transfer and provides industry-based training for high quality graduates through partnerships between academia and business. TCS programme costs are shared between the company and one or more government department or

Research Council sponsors (mainly the DTI and the Engineering and Physical Sciences Research Council). A target for DTI-supported TCS programmes is that 80% should involve smaller firms. The DTI established a network of TCS Centres for Small Firms, based in selected universities, to help small firms benefit from the skills of graduates. TCS Centres offer easier access to technology in universities, help to increase the number of TCS programmes with small firms and enable them to benefit from shared TCS programme administration. In its new role as Lead Department for TCS, the DTI is also looking to extend the scheme by encouraging support from government departments and other public sector bodies which currently do not sponsor TCS, or which only do so to a limited extent.

3.5.5 Technology Foresight Programme

Considering the future, the Technology Foresight programme, published in May 1995, has identified a number of emerging markets, and the technologies needed to underpin them, which are most likely to provide major opportunities for UK business over the next 10-20 years. The Government is disseminating the Foresight findings through a national programme of workshops and conferences to spread awareness, especially amongst small firms. Business Links and others, including Chambers of Commerce, Trade Associations and Research and Technology Organisations, will provide information about Foresight and promote follow-up (European Observatory for SME's, Fourth Annual Report, 1996).

3.6 Conclusions

This chapter has presented the spread of various industrial sector within the Devon and Cornwall region and has highlighted the above average concentration of SME's in the region, when compared with the rest of the UK. The chapter has also emphasised the importance of the manufacturing sector of the region and the need for this sector to become competitive by innovating and introducing new technology.

The chapter also presented the relative disadvantages faced by the SMEs by the region being a periphery area. The disadvantages include lack of skilled labour, lack of high quality physical and electronic communication, poor infrastructure of roads, rail and air network, fewer industrial estates for economic investments and the lack of technology suppliers in the region.

The chapter outlined the general and technological characteristics of the SME's, to include lack of finances available to the companies; lack of trained people; lack of staff resources and time; short range management perspectives; short-term perspective when investing in new technology; lack of technology appreciation and know how; and the close involvement of senior managers in any project, the last characteristic is a positive element.

A comparison is done of the SMEs in the Devon and Cornwall region with the SMEs in the UK and Europe. The chapter also outlined the various help that is available to SMEs in the region from the local and central government.

All the above characteristics and disadvantages of the companies require the SMEs to become more competitive by introducing new technology in their manufacturing operations. However, given the lack of know how of the available technology and skilled labour to implement new systems gives rise to a requirement that an approach be developed that could guide the companies from analysing the needs, developing and researching for solutions and successfully implementing the new technology.

Chapter 4

Manufacturing, Systems, Information, Information Systems and Manufacturing Information Systems

4.1 Overview

This chapter presents, in detail, the definitions of the fundamental concepts and terminology's which are necessary to understand the needs of manufacturing companies. The objective of the chapter is to understand the expectations of manufacturing information systems in relation to the overall content of this thesis.

This is achieved by looking at the original definitions of manufacturing, systems, information systems and manufacturing information systems. For any new approach to be considered to be effective it must be compared to its original definitions to establish its validity.

4.2 Introduction

Manufacturing, at its most fundamental level is concerned with taking materials, and then using resources, design and investment to create a commercial product. Hence, for manufacturing to take place, it is necessary for an industrial enterprise to have a supply of materials, with the required relevant technical properties. Also required are machinery and equipment capable of being operated and controlled to process the materials. A labour force adequately trained in the appropriate skills to operate and control machinery, and equipment is necessary, in order to achieve the required product to the predetermined desired quality.

The above aspects chiefly relate to product and quality. In addition to these aspects it is necessary to remember that each of the required technological processes require a specific amount of time to achieve the required conversion from one stage of manufacture to another. Since customers usually specify delivery requirements in addition to those of quality, it must be ensured that manufacture of the required items can be achieved by the stated delivery time or due date.

Furthermore, the resources required for manufacture must be consumed in as economic a manner as possible in order to ensure that the enterprise can cover its costs and generate sufficient income for re-investment, together with adequate rewards for shareholders etc. Therefore, it is necessary that the manufacturing resources of the enterprise are utilised in the most effective way, in order to meet the customers product quality and delivery requirements at an acceptable cost.

4.2.1 Efficiency in manufacturing

Over the past decade there has been much concern over the ability of U.K. manufacturing companies to satisfactorily perform efficient manufacture (Tepper, 1997). History is now replete with examples of industries successively falling prey to competition from abroad (IT Catalyst for Change, PA Consulting Group 1992). The reasons for these situations have been variously quoted as "poor delivery performance", "poor quality", "bad labour relations", "lack of liquidity", "declining market share" etc. More pointedly it has been said that

"the weakness in the U.K. economy lies squarely in the field of production and operations management. This is where the over-manning occurs, where jobs get delayed for delivery and the physical stocks are built up" (Nicholson, 1976).

Clearly, what is being referred to in Nicholson's statement is labour and resource utilisation, due date and need date performance, lead times, throughput and inventory turnover.

During the eighties and early nineties disturbing facts about these topics began to emerge. Labour costs were thought of as being unacceptably high and widespread cost cutting exercises were launched to drive this operational expense down. It is now well known that companies cut their labour forces as much as possible, at every opportunity. To achieve this for instance Jaguar, on introducing new axles into their XJ4O model re-designed the axles to contain 30% less labour content than the old axles (Weeks and Merrick, 1984). This re-design had large implications for manufacture. With less labour content in a new axle, it was quicker for the axle plant to build and arrange for just-in-time production. Of course it is important to remain aware of large increases in demand. When an increase in demand occurs the company will have to resist increasing their labour force to meet the increase in demand, preferring instead to work overtime or once again face the problems of over-manning in future months.

4.2.2 Delivery dates and throughput

The due date performance of U.K. manufacturing industry over the past decade has also received much criticism. Whilst analysing a case-study company as part of the research, a sample of due date performance revealed that 76.5% of the orders were completed late, and on average they were three weeks late. This is of course not the performance figure for the U.K. industry as a whole during this time period. With good due date performance, there is a greater possibility of "making money" by delivering goods on time. Perhaps more importantly, if a company is in a supplier network, there is an increased prospect of remaining in business with the customer. For factories with machine shops feeding assembly areas, delivery of components by the date specified is of primary importance as any delay could affect the production elsewhere.

Due dates, manufacturing lead times and throughput, are often inextricably connected. During this research it was noted that in many companies orders were completed late, due to the inability of the factory to produce within the planned lead times. The actual throughput time in the sample was found to be on average, 1.7 times the planned lead time, i.e. it was actually taking 1.7 times as long as intended to produce components. Throughput efficiency can be defined as:-

$$\frac{\text{Set up time + machine process time} \times 100}{\text{Total throughput time}}$$

Using this equation it was revealed that the actual throughput efficiency attained was 24%, that is on average the product was undergoing useful work only 24%

of the time spent in factory, compared to a planned throughput efficiency of 40%. In 1976 the British Institute of Management (BIM) conducted a survey in U.K. industry. The focus of this survey was to point out room for improvement in throughput efficiencies and to identify the standard as a target for U.K. industry. Included in the findings of this survey were statistics stating that 60% of all the companies surveyed had throughput efficiencies of less than 30%.

4.2.3 Inventory control

Another key point raised by Nicholson's earlier statement concerns stocks or inventory. Recently this area has received a tremendous amount of attention. This is due to importance of being able to release working capital which otherwise committed, thereby reducing the costs incurred in inventory handling and the subsequent reduction in the annual cost of servicing inventory. The Japanese focus attention on other reasons by using "the river of inventory" analogy. This is where high inventory is analogous to a high water level covering obstacles like rocks etc., analogous to capacity problems, bottlenecks and quality problems.

It is normal for companies to measure their relative inventory handling capabilities by measuring the rate at which they turn that inventory over, this relationship can be defined as:

$$\frac{\text{cost of goods sold}}{\text{inventory}}$$

An improvement in this ratio demonstrates reduced inventories, increased throughput or a combination of both. This leads to shorter manufacturing lead times, an uncovering of problems, and in general a more streamlined company, with the possibility of enhanced profits. During the eighties, companies in the USA and the U.K. turned their stocks over 3.2 times on average, whilst at the same time Japanese industry turned its stock over 6.0 times. This figure increased in the early nineties to 7.5 times, over 100% better than U.K. and American companies in repetitive manufacturing (Wantuck, 1992).

Example application from specific companies, demonstrates that this interest in inventory reduction is not necessarily one sided and that Western manufacturing companies have also taken the idea on aboard. For instance Ford Motor Company increased their inventory turns to 15.6 in 1993, and estimated a world-wide inventory saving of $2.8 billion. Ford's Engine Division reduced its total inventory by 42% between 1990 and 1993. Jaguar in 1992 began to turn their stock over 16 times a year and held less than a weeks stock of items with a high monetary value (Weeks and Merrick, 1994). Obviously there is a limit to which this increase in inventory turns can go as smaller stocks could imperil assembly operations. An assessment of supplier quality and reliability records, along with an evaluation of the risk involved for stock outs of important or critical parts must be undertaken before dramatic increases in inventory turns are made.

4.2.4 Future trends

As the world-wide competition increases it is expected that this will result in:-

- faster throughput time
- reduction in inventories

- reduction in set-up time
- reduction in work-in-progress (WIP)
- less storage space
- less internal transportation (fork lift trucks etc.)
- delivery and positioning of materials will became more important
- greater co-operation with suppliers
- better goods inwards procedures
- conveyor systems reduced in length
- plants becoming more responsive to the customer
- increased manufacturing flexibility
- decentralisation of manufacturing facilities
- more manufacturing tasks taken over by automated machinery
- groups of machines able to produce various products
- small numbers of employees with operators able to work more than one machine
- employees working closer together in clusters - having high expectations in terms of heating, lighting, facilities etc.
- manufacturing in clusters or cells, virtually mini factories (automatic or manual)
- layouts enabling operators to control more than one piece of equipment

- layouts permitting ease of transfer of parts and components
- operators and cell personnel requiring interaction with data, information and the overall manufacturing control system via terminals

The manufacturing environment will, even if has not done so already, move toward increasing computer control. Central to this control is the effective application of information systems and the optimal use of relevant technology.

4.3 Manufacturing

Manufacturing has been defined by the Oxford English Dictionary as 'making things on a large scale by machinery'. This remains an undiscriminating definition, which tends to ignore the difficulties and complications of manufacturing.

The complications of manufacturing will essentially depend on the nature of the manufacturing system, for instance the type of manufacture may be mass production or batch production, or some combination of both of these types. Difficulties in planning for and controlling manufacture will then be apparent in factors concerning the product, the company, the process, the market and supply. A number of these complicating factors are shown in Table 4.1.

Table 4.1 Complicating factors affecting production management
(Modified from Hollier, 1976)

The product	• the size of the product • the complexity of the product • the product range • product design • obsolescence of product design • the incidence of assembly operations in product
The Company	• size of the company, sales turnover, number of employees etc. • market position of the company • management structure and style of the company • business objectives of the company • the manpower structure and the industrial relations within the company • the number and size of individual manufacturing units
The Processes	• the production methods • the capital equipment used • manufacturing times • material flow and handling • dependence of one manufacturing stage on another • capacity available • labour skills • flexibility
The Market	• the number of customers • general price, quality and delivery performance in the market • delivery lead times • size and frequency of orders for product • stability of demand • forecasting accuracy • distribution system
Goods Inward	• lead times for orders on suppliers • numbers of bought out parts • numbers of accessed out parts • reliability of deliveries • number of sources

The above complicating factors contribute to making control of manufacture very difficult to achieve and clearly many different departments and functions are involved. Due to this it is vital that there is integration between these differing functions with recognition of causes and effects. Figure. 4.1 attempts to put this inter-relationship into perspective. It can be clearly seen that each element must, therefore, consider the needs of other elements being developed.

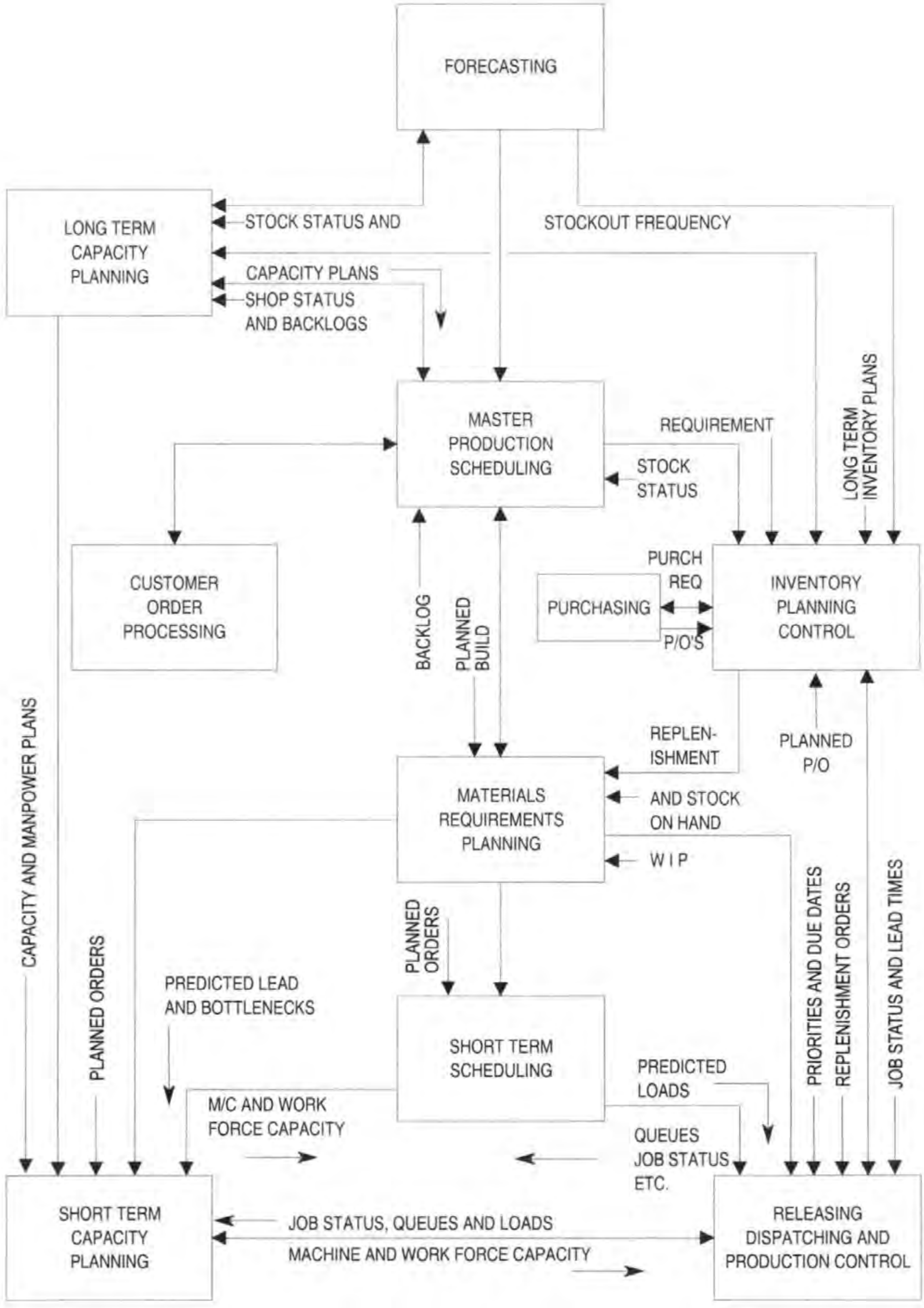


Figure 4.1 The interrelationship of manufacturing control

4.4 Systems

When considering Figure. 4.1 and the functions which it proposes it is clear that there is a system for manufacturing activity.

The word system has been variously defined as "a set of inter-connected parts that form a whole or together" (Hornby, Oxford English Dictionary, 1995), "any group of interacting variables which has some power of regulating itself by its own experience", (Vickers, 1955) or simply "any set independent variables" (McRae, 1971). McRae also concluded that it incorporates anything from cuckoo clocks to the solar system. The definitions become numerous and "resort to Webster's dictionary confuses rather than clarifies, with a generous offering of some seventeen definitions from which to choose" (Hoos, I.R., 1976). There is a tendency to see a system as it exists in objective terms. However, there is also a large subjective element involved. It may be that different spectators of the same system have differing concepts of the system, each thinking that their perception of the system is realistic. This will include a large subjective aspect to perceptions of reality. This subjectivity was presented by the Open University Systems Group (1981) who wrote "most writers who have attempted to define 'system' have ignored this subjective element, or at least not explicitly recognised it." The Open University Systems Group used, therefore, for their systems courses the following definition:

"A system is an assembly of parts where:

1. The parts or components are connected together in an organised way.
2. The parts or components are affected by being in the system (and are changed by leaving it).
3. The assembly does something.
4. The assembly has been identified by a person as being of special interest..."

Certainly the assembly of elements in Figure. 4.1 comply with the Open University Systems Group's definition of a system.

With the development of 'Systems Thinking' over the past years, the benefits of visualising an organisation as a system has received increased appreciation because management through systems concepts fosters a way of thinking which helps the manager recognise the nature of the complex problems and thereby operate within the perceived environment." (Johnson, 1964).

In the past, and to a large extent for many organisations at present, the most prevalently used approach to operations and problem solving has been, the "piecemeal" approach, which often leads to catastrophic results or sub-optimal solutions. Systems theory is concerned with developing a systematic framework, for describing the general relationships which prevail:-

"An ultimate, but distant goal will be a framework (or a system of systems) which will tie all disciplines together in a meaningful relationship." (Johnson, 1967).

Systems thinking can be seen as embracing a large spectrum of activity concerned with the operation of all complex systems and machines. Porter (1969) says

"As technology and society advance we must be concerned increasingly with the behaviour of the 'complete system' and not merely with the behaviour of individual parts of the whole."

Industrial organisation is then cited by Porter as an example:-

> "The structure of industry consists of a hierarchy of increasingly complex units. For example a single operation in a manufacturing plant can be regarded as an elementary component with an easily defined goal. The plant itself, involving as it does a multiplicity of interacting component operations, may be regarded as a unit with more complex goals than the individual component. A complex of plants and administrative offices, making up a single industrial organisation, constitutes the next higher level of complexity and hence of goals, and the total number of organisations which together form an industrial complex may be regarded as the 'system'."

The requirement was a basis for understanding and integrating the knowledge from a wide variety of specialised fields "... dynamic interaction is the basic problem in all fields, and its general principles will have to be formulated in all Systems Theory" (Bertalanffy von, 1952).

Through this has arisen systems theory – "the attempts to develop Scientific principles to aid us in our struggles with dynamic systems with highly interactive parts." (Ashby, 1964).

4.5 Manufacturing systems

Most researchers on this subject have worked within the framework of the two Oxford English dictionary definitions of manufacturing and systems and produced more definitive definitions of their own.

Dudley (1977) defines a manufacturing system as

"the way in which intimately related manufacturing processes and auxiliary equipment are organised and employed in the production of a specific product or component. " This he sees as different from a production system, which in Dudley's definition is "that which will normally embrace numerous manufacturing systems, that is the fly in which all production processes and production services will interact in an entire manufacturing company or factory unit"

Spur (1971) appears to support this by saying that a manufacturing system is

"a machine tool, (note that he talks in the singular), for transforming blank work-pieces into the shapes required by means of a manufacturing process and that a production system is "a plant of machines, devices, etc. for production of certain goods".

He further adds that both systems involve a flow of material, energy and information.

Parnaby (1979) introduces people into his definition of Manufacturing systems when he says that it is

"one in which raw materials are processed from one form into another, known as a product, gaining a higher added value in the process. The Output products from one manufacturing system may be the inputs to another. There is therefore considerable interaction. Such systems incorporate particular product dependent applications of science and technology via their processes and associated machinery and are usually complex. They directly involve many people who carry the process know-how and they interact in many complex ways with our social system and physical environment".

Parnaby also refers to the considerable interaction prevalent, the like of which is depicted in Fig. 4.1 and to the somewhat subjective content of "know-how" or experience to which the Open University Systems Group (1981) referred.

Some broader aspects were introduced by Hitomi (1978). He defines a manufacturing system as "a unified assemblage of hardware (including workers, production facilities such as tools, jigs and fixtures, materials handling equipment and other supplementary devices) supported by software which is production information (production method and technology)".

Interestingly Hitomi by his use of the word 'software' begins to acknowledge the presence of computers and computer aid. 'Information', a word that Parnaby hinted at, is also specifically mentioned by Hitomi. Hitomi adds

"the system performs on production objects (raw materials) to generate useful products with particular functions and utilities to meet market demand"

thereby recognising the external influence on any manufacturing system. He also points out a second aspect of manufacturing systems, a transformational aspect, when he defines them as

"the conversion process of the factors of production of raw materials into finished products aiming at maximum efficiency."

Efficiency is now mentioned by Hitomi as a goal to work towards; implicit in the word efficiency is measurement and some element of control.

Relevant to measurement and control Hitomi sees a third aspect

"the operating procedure of production, that is, the management system of production".

The management function in this context is the formulation of plans and the implementation of manufacturing activities to meet objectives and to effect some acceptable measurement of control over the process. Much the same sort of procedure that Figure. 4.1 is seeking to illustrate.

It would seem that "there is no clear concept of a manufacturing system acceptable to everyone" and that "much depends on the viewpoint, the nature of the industry and the type of product" (Parnaby, J., loc. cit.). Some consistencies do appear throughout the definitions though, notably that:- a manufacturing system is a subset of a production system, there are many interactions between the components of manufacturing systems and with the environment, and there are many orders of manufacturing systems depending on the number of machines etc. used. Perhaps most importantly "one essential requirement of all manufacturing systems, regardless of the types of production processes, machinery used and business environment, is that of long term stable operation in the face of continually changing constraints and external disturbances." Parnaby then goes on to lay that "this creates a need for a supply of information to facilitate control decision making by management". He further cites that the three basic functions of data acquisition and sorting, information flow, and systems control, should be deliberately incorporated (Kochhar and Parnaby, 1977). This they illustrate in Fig. 4.2 and Fig. 4.3.

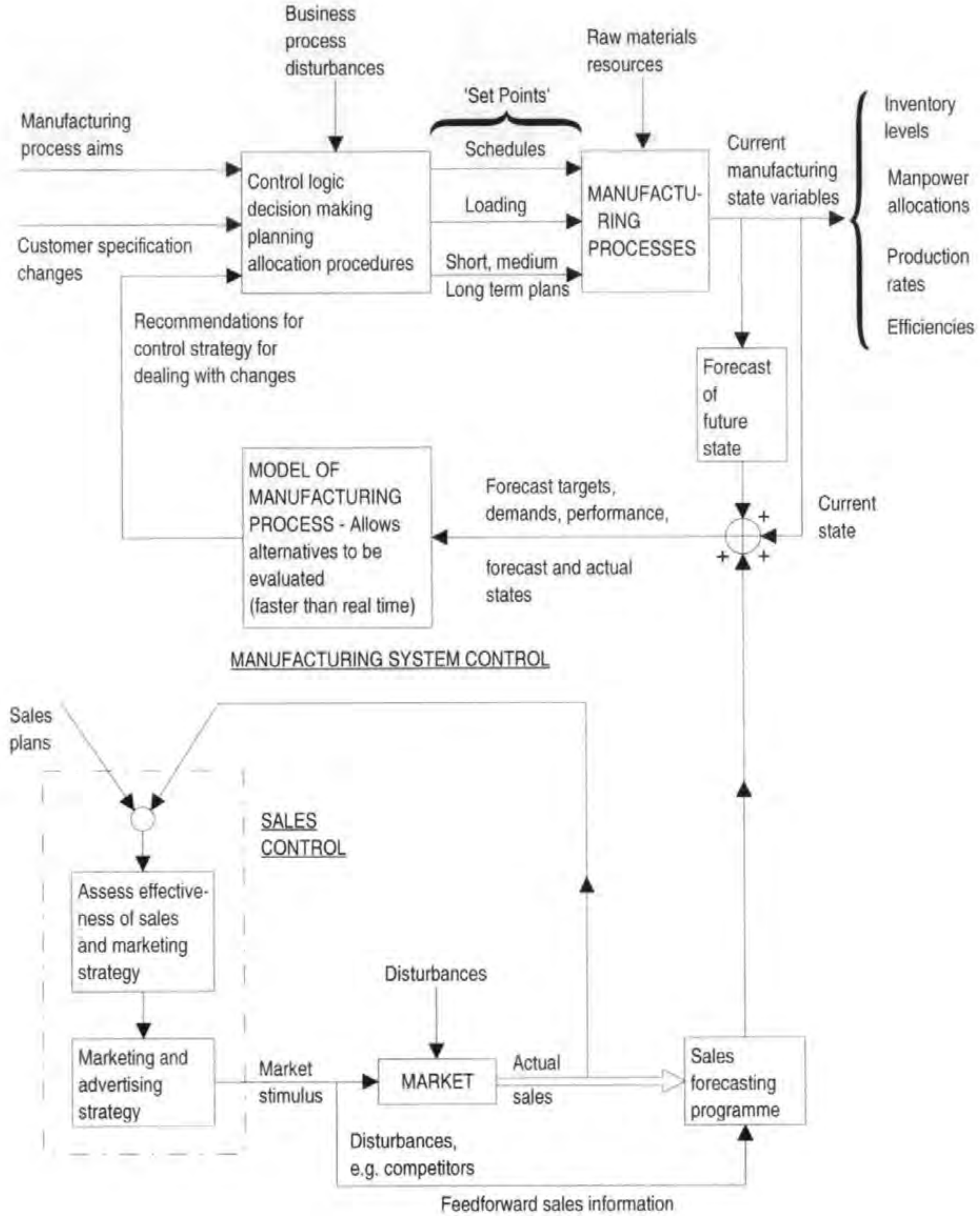


Figure 4.2 Elements of control

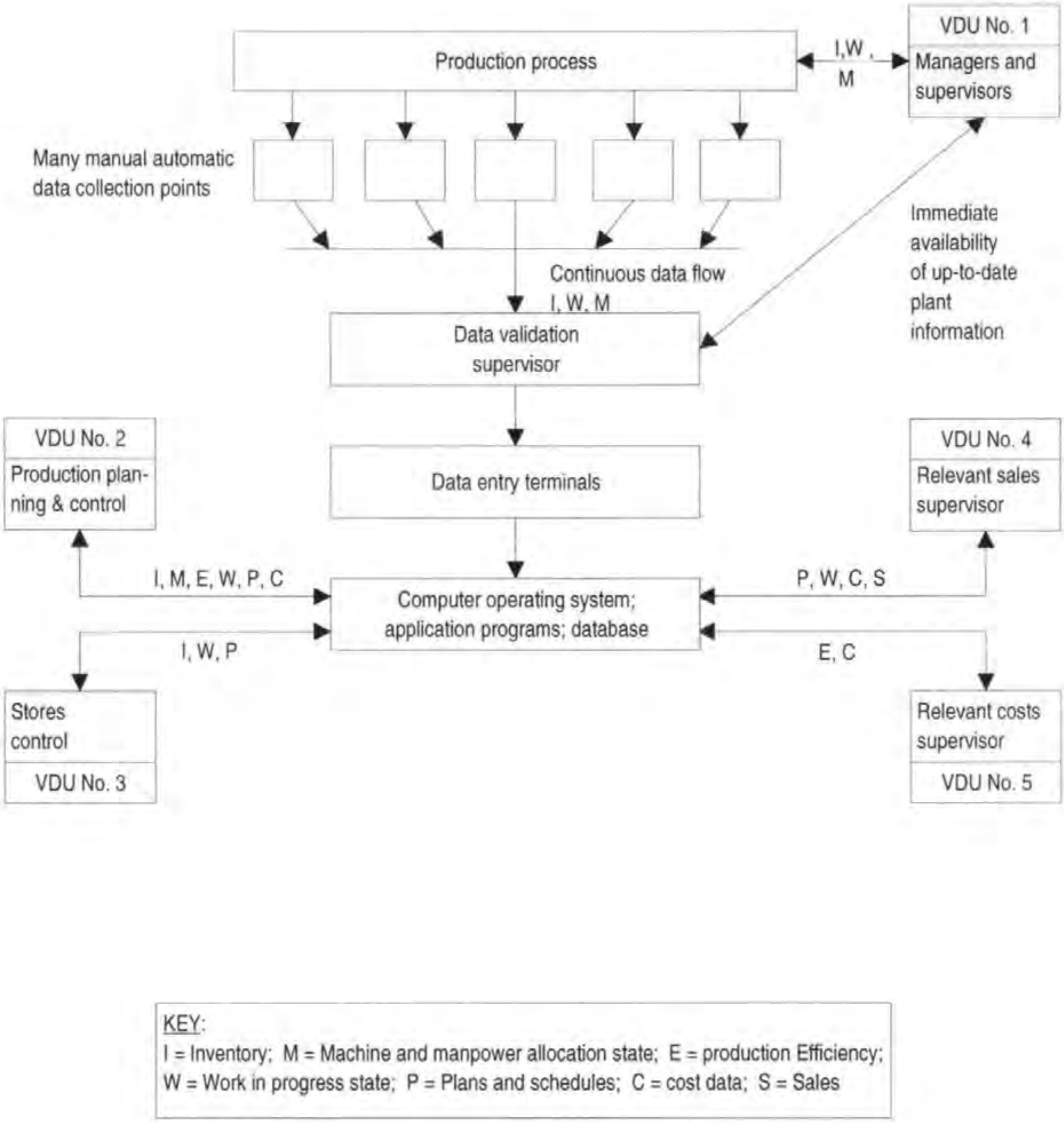


Figure 4.3 Production control

Clearly then, the efficiency and levels of control in a manufacturing system are highly dependent on the effectiveness of it's information system.

4.6 Information

The information handling in manufacturing may be either computer aided, manual, or a mixture of both. In practice, and based on research undertaken by the author, the reliability of a significant proportion of this manufacturing information is questionable. Effectiveness of any piece of information depends upon its source for the required degree of accuracy; on the information being of the right type, being reported at the right time, in the right format, to the right person, and so that the right action can be taken. There is also a need for factual rather than intuitive information, removing many uncertainties which may occur through lack of facts.

Basic to any information system is the information itself. When information is referred to in every day usage one may speak of factual information, valuable information, reliable information, precise information or true information. It is beyond doubt that an effective information system, manual or computer aided, should contain all these adjectives of information. Information is generally regarded as information about something such as objects, people, times, situations, events, places etc. Information also involves users, who act on the information, and informers or advisors.

As previously stated the adjectives 'useful' and 'valuable' when applied to information are related to a particular user whilst the adjectives 'factual' and precise' are not. The adjective 'reliable' when applied to information depends on the personal experience of the user of that particular source of information.

An example of this is the following piece of information, "we will make and despatch some machine tools". This statement has very limited use, it is almost valueless and contains little information content. However, if the statement is expanded to : "we will manufacture and assemble and despatch three machine tools in six months", there is much more information conveyed. The statement can then be modified still further to: "we will manufacture all the components required for the manufacture of machine tools 1,2 and 3 in machine shops A and B and, based on a component manufacturing lead time of one week per machine operation, have them ready for assembly in twenty three weeks. We will then take two weeks to assemble them and one week to despatch them to customer X in order to meet the delivery due date agreed upon". This latter statement is more precise than the former two, but whether the information content is useful or valuable depends on the user and the user's need. If the receiver of such information is the production manager, or production controller in the organisation, then it could be both useful and valuable information. If, however the receiver is in a personal function the information could be useless and valueless. The value of any information to the receiver of that information, can therefore be seen to be highly subjective.

4.7 Manufacturing information

Information requirements will to a large extent depend on the manufacturing methods used and the type of industry. For instance, some industries have particular requirements depending upon making to customer order or making for stock or more stringently, manufacturing for the pharmaceutical industry or for

Ministry of Defence contracts, where considerations of product traceability are of paramount importance.

There is also an important difference between the information which is required for planning purposes and that which is required for control. Planning often requires information from outside the manufacturing system, e.g. policies, objectives demand etc. Control is very much within the manufacturing system; with a need for the feedback of information on actual performances. These can then be compared with plans, and appropriate action can be taken to rectify deviations.

Taking Figure. 4.1, remains illustrative of typical manufacturing information, and may seek to convey the following:-

- forecasts of demand
- affecting long term inventory plans
- customer orders
- long term capacity planning
- with implications for manpower, capital investment, financial planning
- master production scheduling
- taking account of forecasting information
- capacity availability
- stock status information
- inventory planning and control
- records of stock on hand
- work-in-progress
- replenishment information for
- purchased parts

- manufactured parts
- requirements planning
- using inventory information
- basic engineering information from bills of material
- manufacturing lead time information
- and issuing planned orders
- short term capacity planning and scheduling
- machine and workforce capacities and utilisation
- job status
- queue levels
- loads
- priorities and due date performance.

All the above form a general overview of manufacturing information and as will be shown later, there is much more detail required for specific manufacturing systems.

Clearly the need for this manufacturing information is intended for planning and, as Kochhar and Parnaby (1977) have stated, control. This control can be production control exercised by personnel based on information flow perhaps aided by computer software, process control of technological plant, or system control of Flexible Manufacturing System (FMS) plant.

The nature of production control embraces the activities above and depicted in Figure. 4.1. Efficiency in production control means taking account of the circumstances that prevail and ensuring the company's best interests are served. This has necessitated the need to be able to react to these changing circumstances with speed of response and certainty of action.

There have been many unsuccessful attempts since the seventies at introducing computer aid to increase the speed of response and certainty of action, which has in the main been of a package nature. The problem has always been one of obtaining the right system the particular company. In order to achieve this some very detailed selection criteria need to be drawn up and adhered to. To complicate matters further the advances and developments of computer technology in the nineties have made some of the decisions made in the mid-eighties susceptible to change. Most of the successful attempts have therefore been of an evolutionary nature.

4.8 Information systems

The term information system was defined by Langefors in 1966 as the "collection, storage, processing and distribution of information" (Sundgren, 1977). The purpose of such a system is to serve and support the activities of the host organisation of which they are a part. Information systems have existed within organisations for as long as people have set up organisations.

As the end to which these organisations were employed changed, along with the technology of the organisations, so did the information systems requirements. The title information system is now almost synonymous with computer based technology.

It has also been shown that the introduction of information systems dependent on computer technology has changed the organisational structure (Bjorn-Anderson, 1977; Nygaard, 1987; Bartezzaghia et al., 1992). Whilst accepting the inevitability of organisational change, either in a planned or an evolutionary way, the denigrating statements about this change in terms of rationalisation, centralisation of decision making, and the resulting distribution of power away from traditional areas, are somewhat hard to justify. In practice, the implementation of the PC and the resulting shift back in decision making centres, has negated many of these arguments.

The once thought of 'computer threat' to the management of organisation has in fact dissolved like a mirage and information systems are very much an adjunct to management and not a substitute for it. This presents quite a challenge, because although it is possible to obtain information more easily and quickly than a decade ago, it is harder to decide what the information should be. It has made decision making more critical, the decision maker more professional, and the consequence of bad decision making more drastic.

Of course, information systems exist to serve and support the activities of the organisation of which they are a part. Any change in the information systems must seek to improve the ability of the organisation to accomplish its goals. In this sense both information and information systems have a value. They also have costs and benefits to the users. It is the establishing of this value, and the trading off of the costs with the benefits which have confounded practitioners in the field since the first practical applications.

4.9 Manufacturing information systems

Having previously considered the literature defining the words which make up the above title it is now possible to determine the framework within which this research will take place.

It is clear that in order to manufacture components, raw materials have to be changed in shape using a set of interconnected pieces of machinery which are probably operated or controlled by people. The planners will call upon information in order to progress these raw materials and components towards completion and a commercial end product, which they will endeavour to deliver to their customers on time, and with the objective of making money.

It is also apparent that, in this context, the words information and control are inevitably linked, and the control of manufacturing systems is very much as illustrated in Figure. 4.4 where there is a two layer relationship with the control and information system sitting on top of the manufacturing system and are distributing the relevant information to particular parts of the manufacturing system whilst effecting control. At the same time there is considerable feedback of information and data in the form of, for instance, stocks and work-in-progress, shortages, delays etc. in order to allow corrective action if necessary. The manufacturing information system should have considerable interaction between its elements and with other information systems such as payroll, financial planning, costing, computer aided design (CAD) etc.

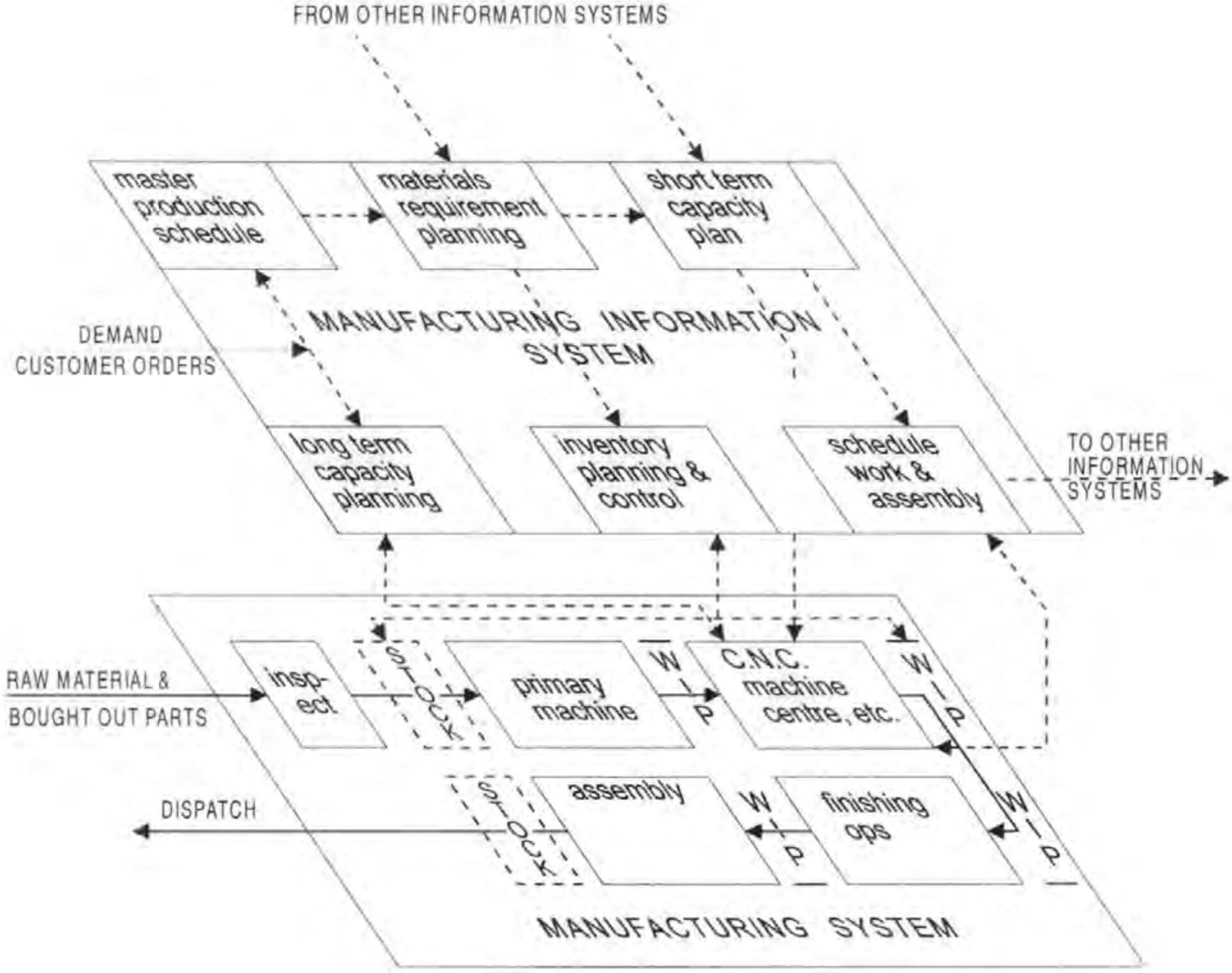


Figure 4.4 The control relationship between a manufacturing information system and a manufacturing system

The nature and relationship of manufacturing systems and manufacturing information systems, along with the explored literature provides guidelines of good practice for the design and selection of manufacturing information systems such as the computer aided production management system (CAPM) illustrated in Figure. 4.1.

Both manufacturing and manufacturing information are/can be part of systems which contain several items, e.g. for a manufacturing system this might include:- machine tools, jigs, fixtures, products and people etc. Similarly, in the case of manufacturing information systems, software modules or elements of the system are described as hardware. Under these circumstances, and circumstances which will be presented later in this research, the most useful definition of the systems in question is the Open university Systems Group definition. (O.U. Systems Group, 1981)

Table 4.2 The perspective of manufacturing information systems

System (O.U. Systems Group Definition)	**Manufacturing System** (Author's Definition)	**Manufacturing Information Systems** (Author's Definition)
A system is an assembly of parts where:	• Machine tools, jigs, fixtures • Raw Materials • Components • Buffers • People • Services	• Computer hardware • Software Modules • Data Collection Equipment • People
The parts or components are connected together in a particular way	• Product routings • Facilities layout • Logical sequence of operations to progressively produce a product	• Software modules arranged in a logical manner recognising the dependency of information being handled. • PC Servers • PCs
The parts or components are affected by being in the system and are	• Machine tools are operated and consume energy • Become worn • Depreciate • Materials are changed	• The software modules are used and information is produced which is accurate or pertinent for a moment in time

changed by leaving it	in shape • People have tasks to perform and earn a wage, both the tasks and the wage change or disappear or exit from the system	or particular circumstances • The information state changes • There are new updates • BOM runs • Changes in methods of manufacture • Changes in hardware due to Obsolescence • Advancement in technology • System capacity problems
The assembly does something	• Transforms work pieces into shapes • Material processed from one to another • Material changes shape as it passes from machine tool to another or one manufacture system to another • The product gains added value in the system • Creates a saleable product	• Produces plans of what is going to be manufactured • Assesses the impact of these plans on available resources (machines & manpower) • Might communicate with other information systems • Establishes some benefit
The assembly has been identified by a person as being of special interest	• Operations Planners • Process Planners • Methods • Manufacturing / Production engineers • Finance for capital investment proposals • Directors for acceptance	• Should be user defined • Participative approach towards system design • Choice of system needs to be made of detailed user advice • Needs to fit with overall company objectives • Be accepted by high level management

Using the O.U. Systems Group definition it is possible to see more clearly what is involved in a manufacturing information system and to recognise the similarities between manufacturing information systems and manufacturing systems. Some general points are shown in Table 4.2. These points, which will be explored in greater detail later, tend to lend support to the two tier relationship of manufacturing information systems and manufacturing systems illustrated in Figure. 4.4. Manufacturing information systems can now be defined more clearly as:

An arrangement of computer hardware and software, which includes an assembly of inter-related modules or elements directed towards providing manufacturing information, plans, and schedules, in order to effect some control over the manufacturing operations of an organisation, such that some, benefit can be achieved.

In the context of the above definition there has been a lot of interest generated in manufacturing information systems (variously named computer aided production control, CAPC, or computer aided production management, CAPM,) but little development to date for the type of application being considered by this research, particularly for the SMEs. According to some statistics from the National Computing Centre there are just over 11,000 U.K. installations of such systems in banking, finance and insurance but only some 2,500 in engineering industries. Many of these are used for sales and purchase ledgers, invoicing and payroll, and only about half are used for production planning and control. (NEDO 1994).

Most early manufacturing information systems were reflections of the manual planning and control systems with emphasis on separate systems for the various aspects of stock control, production planning and scheduling etc.

However, in the last ten years there has been a significant shift towards an integration of manufacturing information systems. This was clearly instigated by the interest and introduction in material requirements planning packages which purported to link with the capacity planning and scheduling. However, the linking of these modules and the understanding of them within the manufacturing function is a challenge which has not been too readily taken up (Mantz, 1993).

In order to take up this challenge an understanding at the user end of the market is needed, built on comprehensive research concerning the system. However, research lags well behind the state of the art in robotics, computer aided design (CAD), computer aided manufacture (CAM), and even microprocessor-controlled machine tools. Beyond the lag in knowledge about the "hardware" is an equally serious lag in academic knowledge about the management "software" that also forms part of these technologies, e.g. MRP, Kanban ..." (Miller and Graham, 1991).

Miller and Graham suggest that "several types of research dealing with new technologies should be available, Including information gathering, description and definition" and that "what is needed are comprehensive attempts to discuss the technologies in laymen's terms, covering the kinds of issues that aid management decision making". They further cite examples of technological alternatives that exist and how they should be selected "how should CAD/CAM and MRP systems be reconciled?" or choices have to be made between different versions of the same technology, what criteria are suitable to govern the decisions and how should they be weighted?" and "how are the economics to be balanced off?" Such questions are of great concern to currently practising manufacturing managers and directors, and precisely these questions and many similar ones have been raised during this research

4.10 Conclusions

This chapter has sought to define the basic concepts of manufacturing, systems, information systems and manufacturing information systems. The chapter has highlighted that there is no clear concept of a manufacturing system which is acceptable to everyone and that much depended on the nature of the industry and the type of products. The chapter also defined manufacturing information systems as an arrangement of computer hardware and software, which includes an assembly of interrelated elements directed towards providing manufacturing information, plans and schedules. This is undertaken in order to effect some control over the manufacturing operations of an organisation, so that some benefit can be achieved. This definition is synonymous with the definition of Computers integrated Manufacturing (CIM), which are considered further in chapter 5. In the next chapter CIM methodologies and their relevance to the SME's have been reviewed in more detail.

However, this chapter has also highlighted the complexities of various concepts and has identified the urgent need for an approach which is compact and yet flexible to meet the requirements of individual companies. By using such an approach small and medium size companies can hope to define and assess the need for their particular company, develop manufacturing information systems solutions and implement those solutions.

Chapter 5

Review of Existing Information System and CIM Design Methodologies

5.1 Overview

The previous chapter discussed and demonstrated that there is a system to manufacturing activity. The chapter also mapped the definition of system, as given by the Open University Systems Group to the various activities in the manufacturing system and manufacturing information system. It was established that the efficiency and levels of control in a manufacturing system are highly dependent on the effectiveness of its information system.

The purpose of information systems in manufacturing is to serve and support the various activities of a manufacturing organisation of which they are part (see fig 4.3). Therefore, for the effectiveness of any manufacturing information system it is vital that the various information systems are accurate and relay the information which is relevant.

Several analysis, design techniques, tools and approaches exist that assist in designing information system and Computer Integrated Manufacturing (CIM) systems (see Appendix A). These approaches and methodologies provide tools and techniques to analyse, map, design and implement systems. This chapter outlines several of these approaches and tools that are widely used by practitioners. The chapter also assesses the deficiencies of these, while evaluating their relevance and effectiveness for small and medium size enterprises.

5.2 Introduction

Initially this chapter considers the various information systems analysis methodologies which are widely used. These include, Structure Analysis Design and Implementation of information systems (STRADIS), Structured System Analysis and Design Methodology (SSADM), and Soft System Methodology (SSM). The chapter will then outline and assess the various mapping tools which are widely used to map the analysis of existing system, these include, IDEF0 Diagrams and Data Flow Diagrams. The chapter then outlines Computers Integrated Manufacturing (CIM) design methodologies, to include, Structured Analysis and Design Techniques (SADT), Graph à Résultats et Activités Interliés (GRAI) and Integrated Computer Aided Manufacturing (ICAM). The associated tools for the CIM approaches are also considered these include, CIM-OSA modelling framework, GRAI formalism and GRAI Integrated Method (GIM) formalism.

5.3 STRADIS

STRADIS approach was developed by Gane and Sarson in 1977, who built on the earlier work done by Myers and Constantine (1974) and later refined by Yourdon and Constantine (1978).

Gane and Sarson's book (Structure System Analysis, 1979) gives a description of an information systems development methodology, but not in any great detail. Their approach is restricted mainly to a series of techniques used in a structured fashion, which are applied to the development of an information system.

STRADIS is broken down into four stages:

- Initial Study
- Detailed study
- Defining and designing alternative solutions
- Physical design

The main tool used is a Data Flow Diagrams (DFD). At the initial stage the existing physical system is analysed and mapped using DFD's. The next stage is to abstract out the implementation detail from such diagrams to produce a set of logical system DFD's. The next step is to identify significant areas on the DFD's that may be considered to change with the introduction of information technology. These domains of change are reflected on a new set of logical DFD's and the implementation details are reflected on a new set of physical DFD's.

Gane and Sarson's methodology mainly concentrates on the analysis of systems, although the methodology is being refined into the area of implementation. The methodology is conceived as being a methodology applicable to the development of any information system, irrespective of size and whether or not it is going to be automated. In practice, however, it has mainly been used and refined in areas where at least part of the information system is automated. The methodology is considered relevant in situations where there is a backlog of systems waiting to be developed and insufficient resources to devote to all the potential new systems.

5.4 SSADM

SSADM (**Structured Systems Analysis And Design Method**) is an important methodology which is in widespread use in the UK Civil Service and government departments. It was developed by Learmonth and Burchett Management Systems (LBMS) and the Central Computing and Telecommunications Agency (CCTA) during the 1970s. Version 4+ was released in 1996. The framework of the methodology is depicted in five modules. These modules are further subdivided into stages, steps and tasks:

Feasibility study. The feasibility module consists of a single stage. This stage constitutes a high-level analysis and design exercise. It is under taken in order to determine whether or not the system can in fact meet business requirements.

Requirement analysis. This module consists of two stages. Stage 1, investigation of current environment is used to identify the current business environment and system in terms of major processes and data structures. Stage 2, business system options, is used to generate up to six possible logical models of systems.

Requirements specification. This module consists of a single stage – stage 3, definitions of requirements. During this stage more detailed documentation of requirements takes place.

Logical system specification. This module consists of two stages. Stage 4, technical system options, produces specifications pertaining to the technical and development environments for up to six options. One of the option is selected. Stage 5, logical design, represents the logical design of up to date processes, enquiry processes and dialogues.

Physical design. This module consists of a single stage: stage 6, physical design which takes the logical specification produced from module 4 and creates a physical database design and a set of program specification.

SSADM is good structured approach, however, it is mainly used for writing computer programs and does not deal with the implementation and maintenance of any given system.

5.5 Soft System Methodology (SSM)

SSM (Soft System Methodology) has been developed by Checkland at Lancaster University, with the most up to date version, mode 2, being outlined in Checkland and Scholes (1990). It is based on the belief that when analysing a system, it has to be viewed as a whole for any kind of meaningful conclusions to be drawn, as, when decomposed into its parts, it loses something of the whole which is unreproducible by each of the parts on their own. For this reason information systems cannot be viewed in an incomplete fashion as purely 'hard' systems - collections of data and processes - but as more complex 'soft' systems, within which there is a inseparable human element. Thus soft system models are better able to represent the complex workings of large, complex organisations. Soft systems thinking assumes that the purpose of a system is to arrive at more complex purposes or missions, and not simple goals, as a hard system might set out to achieve. The understanding of purposes and missions is achieved through debate with the actors who operate within the soft system.

SSM is broken down into seven stages, which are divided into two categories; these being a) the activities within the organisation which involve people in the problems, and b) the activities that analyse and resolve the problematic situations. The stages are as follows :

for a) 1. The problem situation : unstructured.

2. The problem situation : expressed.

for b) 3. Root definitions of relevant systems.

4. Conceptual models.

4a. Formal system concept.

4b. Other systems thinking.

for a) 5. Comparison of 'Conceptual models' with 'The problem situation : expressed'.

6. Feasible, desirable changes.

7. Action to improve the problem situation.

Stages 1 and 2 are an 'expression' phase during which an attempt is made by the analyst to build up the richest possible picture, not of 'the problem', but the situation perceived to be the problem or the urge for change. Stage 3 involves naming systems relevant to the perceived problem, and preparing concise definitions known as 'root definitions' of what these systems are, as opposed to what they do. To assist in forming the 'root definitions', the CATWOE mnemonic is applied to determine what it should contain.

C: Beneficiaries of the system.

A: Actors of the system.

T: Transformation of the system.

W: Weltanschauung, world view, or viewpoint.

O: Ownership of the system.

E: Environmental constraints in which the system must operate.

Stage 4 consists of building a model conceptualising the systems named in the root definitions at stage3, and their interactions with one another. Stage 4 model-building is fed by stages 4a and 4b. 4a is a general model of a human activity system including group behavioural science, etc. 4b consists of modifying or transforming the model into any other form considered suitable.

The conceptual models are then compared in stage 5 and set against the perceptions there. The purpose of this comparison is to generate debate in a bid to progress from a state of understanding to that of further understanding, and ultimately a solution in real terms. Stage 6 defines possible changes that are feasible, desirable, and aligned to the ethos and culture of the company.

Stage 7 involves taking action based on stage 6 to improve the problem situation. This in fact defines 'a new problem' and it too may now be tackled with the help of the methodology.

SSM involves all 'actors' (all the participants) in the processes to discover the problems at the heart of the system(s). It is an iterative process, with everyone involved, particularly the analysts, expected to learn as they go along. With no set of highly structured rules to follow it is often difficult to teach, and also, to gauge it's progress during a commercial project. The methodology concentrates on problem analysis, rather than the practicalities of designing and implementing an effective information system.

5.6 Data Flow Diagrams (DFD)

A data flow diagram is a representation of a system or subsystem in terms of how data moves through the system. A number of people have been involved in developing the data flow diagrams as an analysis and design tool. Among the earliest exponents of the method were DeMarco and Yourdon (DeMarco, 1979). Gane and Sarson have further modified and extended the technique.

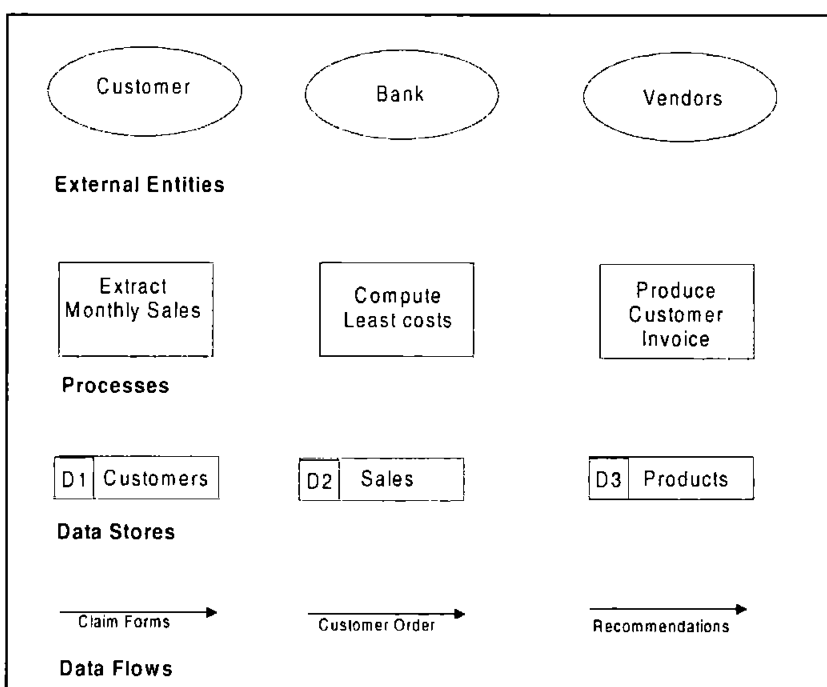


Fig 5.1 DFD Notation

5.6.1 Data flow elements

DFD's are made up of four basic elements: external entities, processes, data stores and data flows. Figure 5.1 shows the general shapes that represent different elements. Please note that notations used here are those by the British methodology SSADM.

5.6.1.1 External entities

These are logical classes of things and/or people which represent a source or a destination of transactions, e.g. customers, employees, supplier etc. Where a system with a defined boundary accepts data from another system or provides data to it, that system is an external entity. It is represented on a DFD by some form of rounded shape – circle or oval – with an appropriate name as in Figure 5.1. By designating something or some system as an external entity, it is implied that the entity is not under the control of the system, although it is possible to influence its behaviour.

5.6.1.2 Processes

A process is a transformation of incoming data flow(s) into outgoing data flow(s). A process is represented on a DFD by a labelled square or rectangle, as in Figure 5.1.

5.6.1.3 Data stores

Without making a physical commitment during analysis, it is noted there are places where there is a need to define data as being stored between processes. Data stores may be symbolised by a pair of horizontal parallel lines, closed at one end, preferably just wide enough to hold the name. Each store is identified by a D and an arbitrary number in a box at the left hand end for easy reference. When a process stores data , the data flow arrow is shown going into the data store.

5.6.1.4 Data flows

Data flow is symbolised by an arrow, preferably horizontal and/or vertical with an arrowhead showing the flow direction. Each data flow is seen as a pipe, down which parcels of data or 'things' are sent.

Each data flow is given a description. An identifier can, in addition to the description, be used to make the data flow as meaningful as possible to the user who will be reviewing the data flow diagrams.

5.6.2 DFD usage convention

The DFD technique uses a hierarchic structure. The top level data flow diagram for a system can be exploded or decomposed to become a lower level DFD in its own right. Each process at a lower level is related back to the higher level process and this is done by using an identification number. For example, a high level box numbered 10 can be decomposed into 10.1, 10.2, 10.3, etc. for the next level and subsequently further decomposed into an even lower level and identified by a further decimal suffix, e.g. 10.1.1, 10.3.2 and so on. This shows the relationship of process or activity, say 10.3.2 to 10 through 10.3.
Detailed rules regarding exception handling, error handling, construction methods and convention to be used, including arrow checking, etc. can be found

in many texts written on this subject, and it is not considered necessary to describe them in detail here. However, there are certain basic rules that must be satisfied in DFD construction and these can be summarised as follows:

- a source cannot leak data directly to a data store
- a data store cannot pass data directly to a destination

  (in both cases the data has to go through a process to give system control over itself)
- a data flow into a data store assumes that the process can also take data out
- data flow out of a data store is presumed to be read only
- data cannot flow from one store to another with a process
- no output without an input. Any process that is producing output by itself should be a source
- one cannot have only input into a process
- each sub-system must be a rectangle on the next higher level
- number of data flows in and out of each sub-system must match the data flows at the lower level

Although DFD is a good tool which is widely used in industry, particularly by computer programmers. However, the actual model can be difficult to read unless substantial care is taken to break down elements and sub-systems into a manageable size. Computer aid can help in this respect, but so far, almost all software packages have been developed for structured programming work.

5.7 IDEF0 diagrams

IDEF (Integrated computer-aided DEFinition) was developed by the US Air Force to describe the information and organisation structure of a complex manufacturing system. To date, the technique consists of five basic levels: IDEF0, IDEF1, IDEF2, IDEF3 and IDEF4. IDEF0 has evolved from the original technique of SADT (Structured Analysis and Design Technique) developed by Douglas T. Ross, of SofTech.

5.7.1 Concepts of IDEF

The basic concepts of IDEF are a combination of structured design analysis and human judgement that work best for a manufacturing system. These concepts can be summarised as:

1. Understand a system by creating a model that graphically shows things (objects or information) and activities (performed by men and machines). The model must properly relate both aspects.
2. Distinguish what functions a system must perform and how the system is to be built to accomplish those functions. The distinction must be clearly evident in a model.
3. Structure a model as a hierarchy with major functions at the top and successive levels revealing well-founded details. Each model must be internally consistent.
4. Establish an informal review cycle to 'proof-read' the developing model and record all decisions in writing. This ensures that a model reflects the best efforts of a committed team.

An important aspect of model building is establishing the orientation of the model to be produced. This is achieved by establishing the three aspects of the orientation:

1. The CONTEXT, which identifies the subject matter of the model by describing its boundaries.
2. The VIEWPOINT, from which the subject matter will be described and which governs the emphasis given to the various features.
3. The PURPOSE, or reason for which the model is being created and which will determine its scope, depth and structure.

Therefore, it starts by representing the whole system as a single modular unit – a box with arrow interfaces, Figure 5.2. Since a single box represents the system as a whole, the descriptive name written in the box must be general rather than abstract. This takes account of the above points and is known as context diagram, and helps to eliminate any confusion about the viewpoint, purpose etc. of the subsequent models.

IDEF0 is a technique that can be used to specify completely the functional relationship of any manufacturing environment. IDEF1 is used to describe the relationship between data items in the environment, such that a relational database model may be specified. IDEF2 is a simulation technique that can be used to investigate a systems dynamic behaviour. IDEF3 is for process design, and the latest addition, IDEF4, is an object-oriented approach to manufacturing software development. These techniques my be used independently. For the purposes of this thesis only IDEF0 will be considered.

5.7.2 Function block

IDEF0 model's basic element is called a function block , Figure 5.2. In this model, the individual function blocks are linked together in through the inputs, the outputs, the mechanism and the controls.

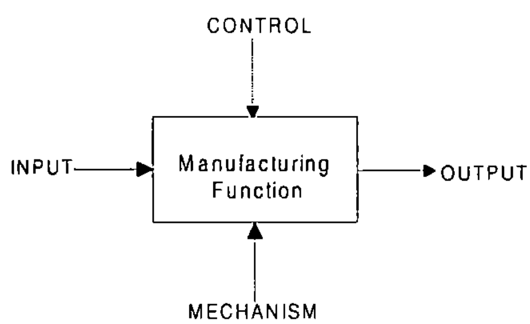


Fig 5.2 Basic building block of an IDEF0 model: the function

The inputs to a function entering the function block from the left are usually (but not necessarily) 'consumed' by the function to produce outputs. Raw materials are typical examples of these. The mechanism, represented by an arrow entering the function block from below, indicates the resources which are required to carry out the transformation process-such as tools, equipment and operators. All resources shown must be used as means to achieve the function. They only become part of the output if they are passed on by the function to support other function. The controls which enter from the top of the block may only influence the transformation process and they will not be consumed or processed themselves. It is important to note that all inputs, controls and resources must be used by a function. Also, that IDEF0 is a static representation of the system, indicating functional relationships, but not necessarily specifying any dynamic aspects within it.

5.7.3 Function decomposition

An IDEF model can be expanded to any level of detail. The highest-level function block describes the main purpose of the subject system and the lower-level function blocks describe the supporting sub-systems which exist to serve the upper-levels. At the uppermost level, a function block is usually labelled as function A0, which represents the overall system objectives and system boundary. If A0 consists of four sub-functions, then these will be called A1, A2, A3 and A4. Each of these sub-functions together with their associated inputs, outputs, controls and resources, may themselves be decomposed into the next level in the hierarchy. The sub-function blocks at the next level will be denoted A11, A12, .., A21,A22..., A31,A33 as can be seen in Figure 5.3.

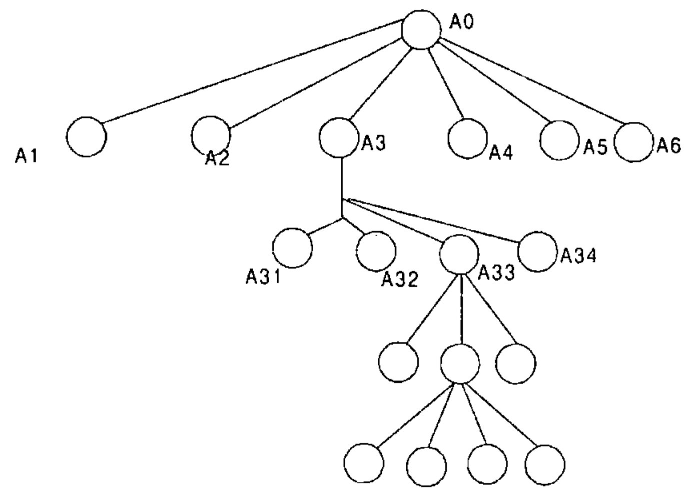


Figure 5.3 IDEF function levels

In theory an IDEF0 model could be decomposed any number of times, however, it is recommended that each function at a given level should be only decomposed into between three and six sub-functions.

The IDEF methodology is widely used for many types of systems design situation for mapping systems analysis and design. However, IDEF0 requires a considerable time to learn, it is cumbersome, function specification could be ambiguous and perhaps more importantly it is static in nature. Its hierarchy of function model cannot explicitly represent the conditions or sequence of processing. These are usually described in the text of a function's description, but not shown by the model itself. As a result a great deal of manual effort and interpretation may be required to identify the appropriate functions which should process a specific input and to verify their consistency.

5.8 SADT

Structured Analysis and Design Technique (SADT) was developed by Douglas T Ross, Board Chairman and founder of SofTech Inc. SADT has been further developed and refined at SofTech as a result of extensive use dating from 1973. It has so far been successfully applied to a variety of complex systems problems ranging from real time telephonic communication design, computer-aided manufacturing and military policy planning. SADT is a diagramming technique and primarily a methodology for producing descriptions of systems using this graphical language. It is a top-down methodology (in terms of the design process) and relies heavily on the use of functional decomposition to identify the key activities of a system and their inter-relationships. Concepts which from the basis of SADT can be summarised as follows.

- Complex problems can be best understood or expressed by building models to define what the problems are. The problems identification is sufficiently precise to serve as a basis for problem solution.
- The analysis and model building procedure are top-down, modular, hierarchic and structured to reflect the systematic thinking
- The model is represented by simple diagramming techniques which represent both 'things' (objects, documents or data) and activities (performed by people, machines, computers and software)
- The model consists of diagrams, texts and glossary cross-referenced to each other

- Functional model of functions to be performed is differentiated as much as practicable from a subsequent design model of how those functions will be performed.
- Analysis method supports a disciplined and co-ordinated team work
- All analysis and design decisions are in written form for open review by team members.

SADT uses IDEF diagramming techniques, in fact, IDEF0 is another name for SADT diagramming technique.

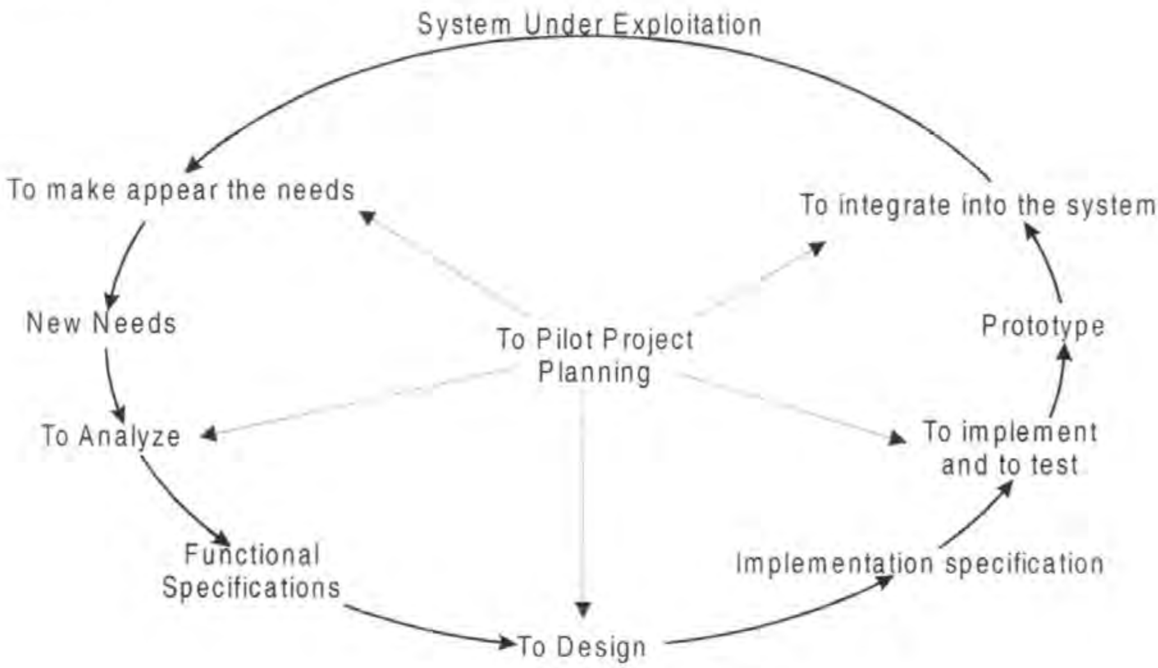


Figure 5.4 SADT project cycle

There are five steps in a SADT project (Figure 5.4)

1. ***Interview:*** Collect information on the system requirements and experience of experts

2. ***Authoring:*** Analyse the system, design the system and document the results
3. ***Reading:*** Review the analysis and design, observe errors and offer improvements.
4. ***Revising:*** Correct and improve the documents
5. ***Approving:*** Verify and accept technical content

A SADT project group is composed of :

- *Actor* (analyst): Person who studies the constraints and needs, and analyses system functions
- *Commentator:* Actor who criticises and comments other actors' work
- *Reader:* Person who reads the diagrams
- *Expert:* Person who gives information about the system
- *Technical committee:* Group of persons who criticise the analysis in each decomposition steps
- *Librarian:* responsible for all the documents of the project and dissemination of them
- *Monitor:* Specialist of SADT guiding actors to practice SADT
- *Instructor:* Specialist of SADT whose role is to teach actors and commentators to use SADT.

SADT is an exhaustive methodology which identifies recovers easy-to-miss details in a complex organisation. However, once the models have been developed, they are inflexible and require considerable effort to update them.

Models developed by an analyst or analysts, may be subjective and therefore reflect their viewpoint. Time delays, organisational responsibility, i.e. process control within a box, the flow pattern or path of things, e.g. stores, are not documented in these models.

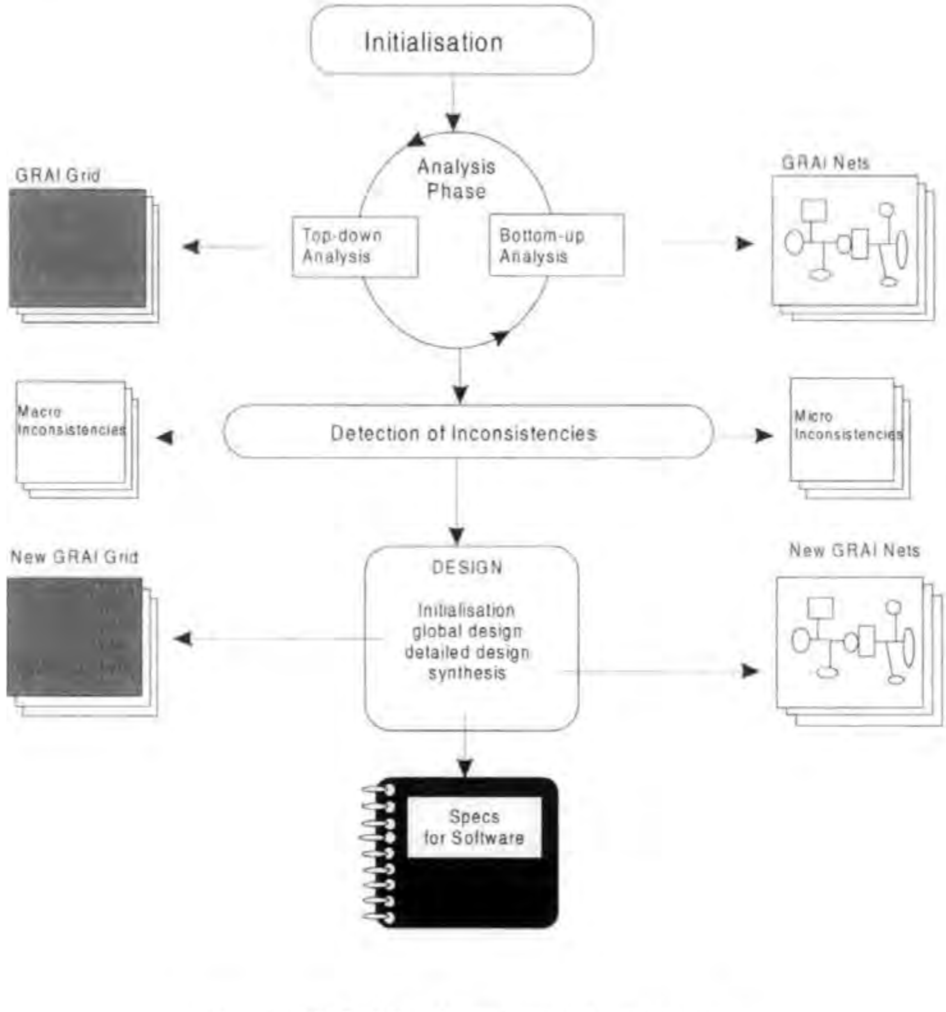


Figure 5.5 GRAI structured approach

5.9 GRAI methodology

GRAI (Graphe a Resultats et Activites Interlies) was developed by Doumeingts et al., 1987. It was specially developed for the design of managerial systems. The development of GRAI methodology is based on the argument that using formalised rules in the early phases will reduce errors in design and therefore improve overall system preformance. The GRAI approach mainly consists of two phases (Figure 5.5):

1. ***Analysis phase.*** At this phase the current behaviour and structure is studied. Disclosing constraints, goals and possible inconsistencies. The analysis uses the GRAInets and GRAIgrids, see Figure 5.6, of the current system to identify faults such as missing information flows, lack of updated information, poor synchronisation, wrong procedures, inadequate criteria, non-defined decision frames, missing vital Decision Centres (DCs) or incoherent co-ordination between DCs.

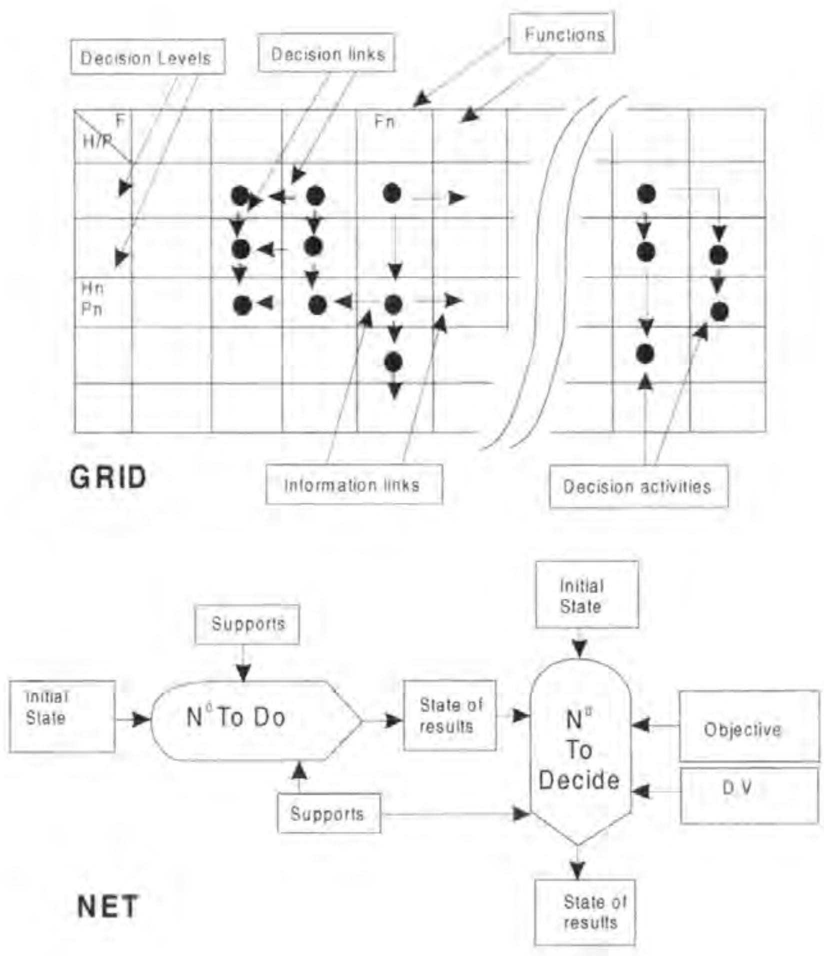


Figure 5.6 Structure of GRAIgrid and GRAInet (source:Doumeingts et al, 1992)

2. ***Design specification phase.*** This phase determines the functional specification, the basic framework and general behaviour of the desired system. This stage of GRAI can be further decomposed into three stages.

- *Conceptual modelling.* A conceptual model of the manufacturing system under study will provide direction for the design team's work. A GRAI conceptual model of a manufacturing system consists of three sub-systems, Figure 5.7. The physical system transforms material into products, and is co-ordinated by a hierarchy of control or decisional systems. The information system carries out all data transfers between and within these systems.
- *Structural modelling and functional specifications.* The designer attempts to create a system to fulfil certain criteria, using the conceptual model as an outline structure. The methodology uses the same GRAI tools to validate structural models, as using these will ensure that all control aspects are considered and that the processing of information required to support the decision making is well understood.
- *Operational-level specifications.* This stage is concerned with the detailed specification of system components.

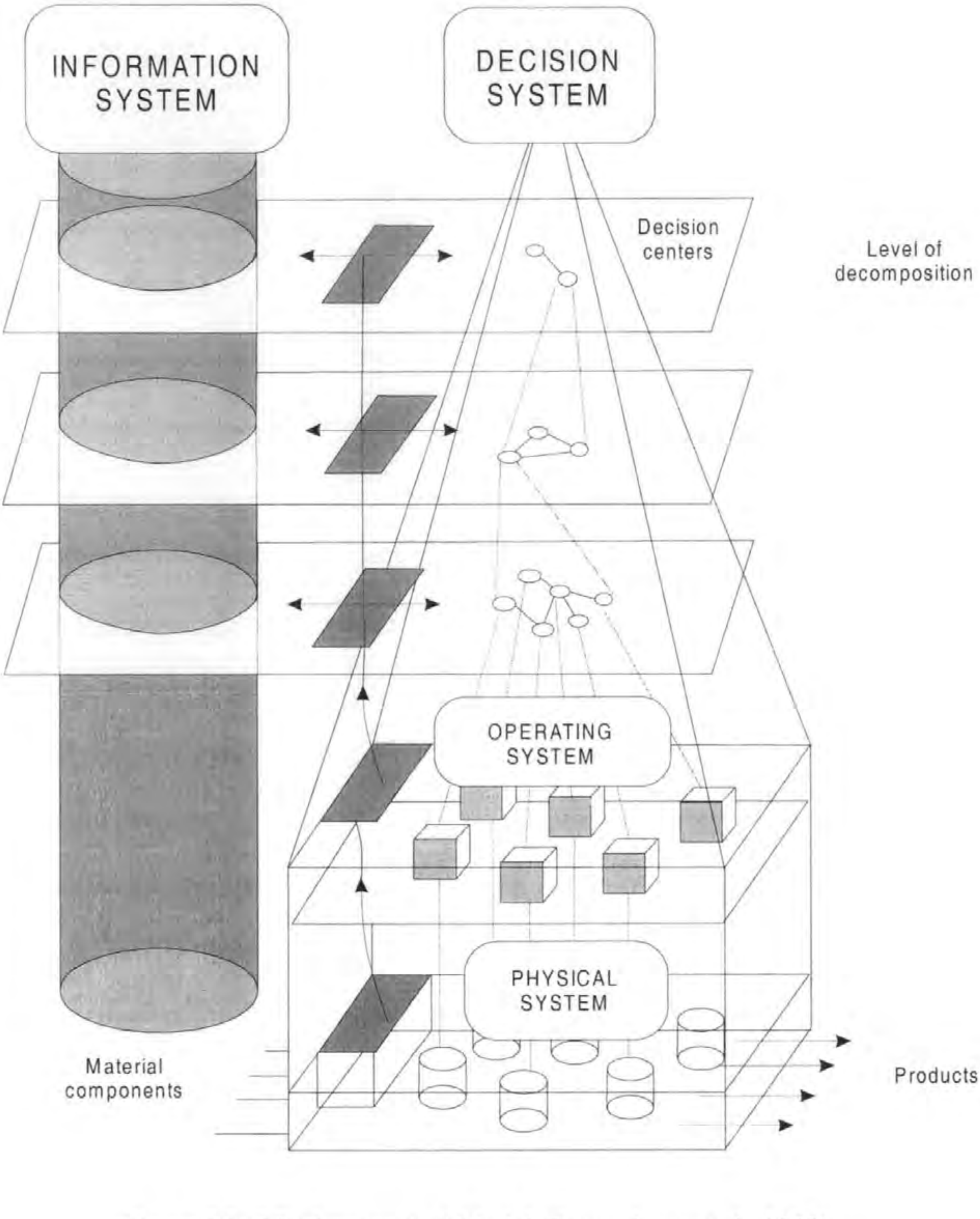


Figure 5.7. GRAI conceptual Model (Doumeingts et al., 1992)

5.10 Modelling Framework

Modelling framework is a new concept which was developed within the Esprit programme. Due to the complexity of CIM system, various formalisms, each allowing to model one aspect of a manufacturing system, need to be structured into a framework in which a complete CIM system model can be built. In a modelling framework all models needed for the analysis design and development of CIM systems find their place.

This section briefly lists the three such models to give the reader a flavour of the available tools and the complexity involved in understanding them and using them for a useful purpose.

5.10.1 CIM-OSA

The CIM-OSA (Computer Integrated Manufacturing – Open System Architecture) provides a reference architecture to help particular enterprises to build their own particular architecture as a set of models describing the various aspects of the enterprise (function, information, resource, and organisation) at different modelling levels (requirements definition, design specification, and implementation description). The reference architecture is separated into two layers: a generic layer providing generic building blocks (i.e., basic constructs of the modelling language, their types, and instantiation and aggregation rules) and a partial model layer providing a library of reusable partial models for some industry sectors (i.e., partially instantiated models that can be customised to specific enterprise needs). The enterprise modelling framework provides semantic unification of concepts shared in CIM system.

The structure of the framework for enterprise modelling follows the principles of CIM-OSA cube Figure 5.8.

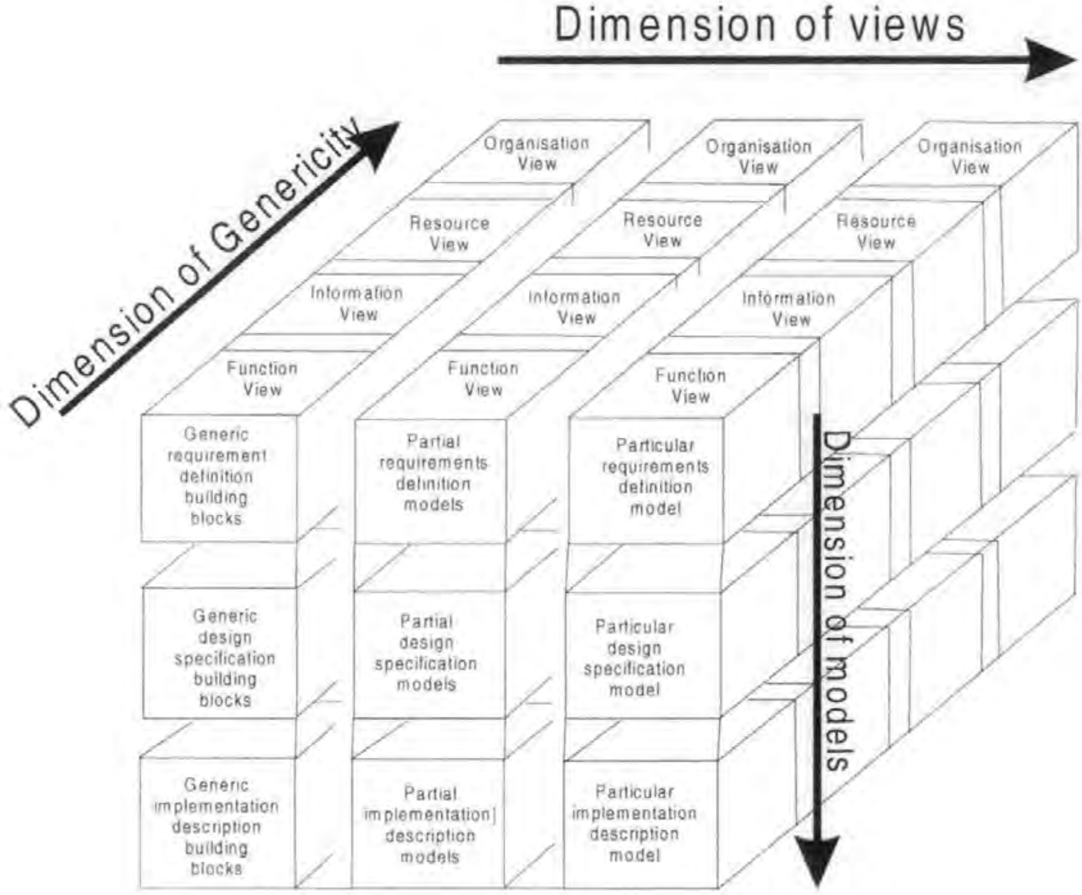


Figure 5.8 CIM-OSA modelling framework

It is structured according to three dimensions:

*1) **The dimension of genericity**.* There are three levels of generecity:

- The generic level, which defines the basic modelling constructs for components, constraints, rules, terms, services, functions and protocols
- The partial level, which contains partial models
- The particular level, which describes enterprise specific knowledge using constructs of the generic level

2) The dimension of models. There are three types of models:

- Requirement models define enterprise operations to be done and how they can be done.

- Design models specify how operations are to be performed to achieve the requirements.
- Implementation models describe the means and/or rules to be used in executing the enterprise operations

*3) **The dimension of views.*** There are four views

- The function view provides a hierarchically structured description of the functions behaviour and functional structure of the enterprise with relevant inputs and outputs.
- The information view provides the description of a structured set of enterprise objects that were identified in other views.
- The resource view provides a description of the resource organisation of the enterprise.
- The organisational view provides the description of the organisational structure of the enterprise, the responsibilities of the individuals and the organisational units within the enterprise.

5.10.2 GIM

The GIM modelling framework was developed within the Esprit Project 418 to support the GIM method (GRAI Integrated Method). GIM is a method to analyse and design integrated manufacturing systems. It uses the GRAI formalisms to model the decisional system, MERISE formalisms for the informational system and IDEF0 for the physical system. A future system is first defined at the conceptual level. Functionality, decisions and information as well as physical resources are organised at the structural level. The realisation level describes the designed system in terms of tangible components (Figure. 5.9).

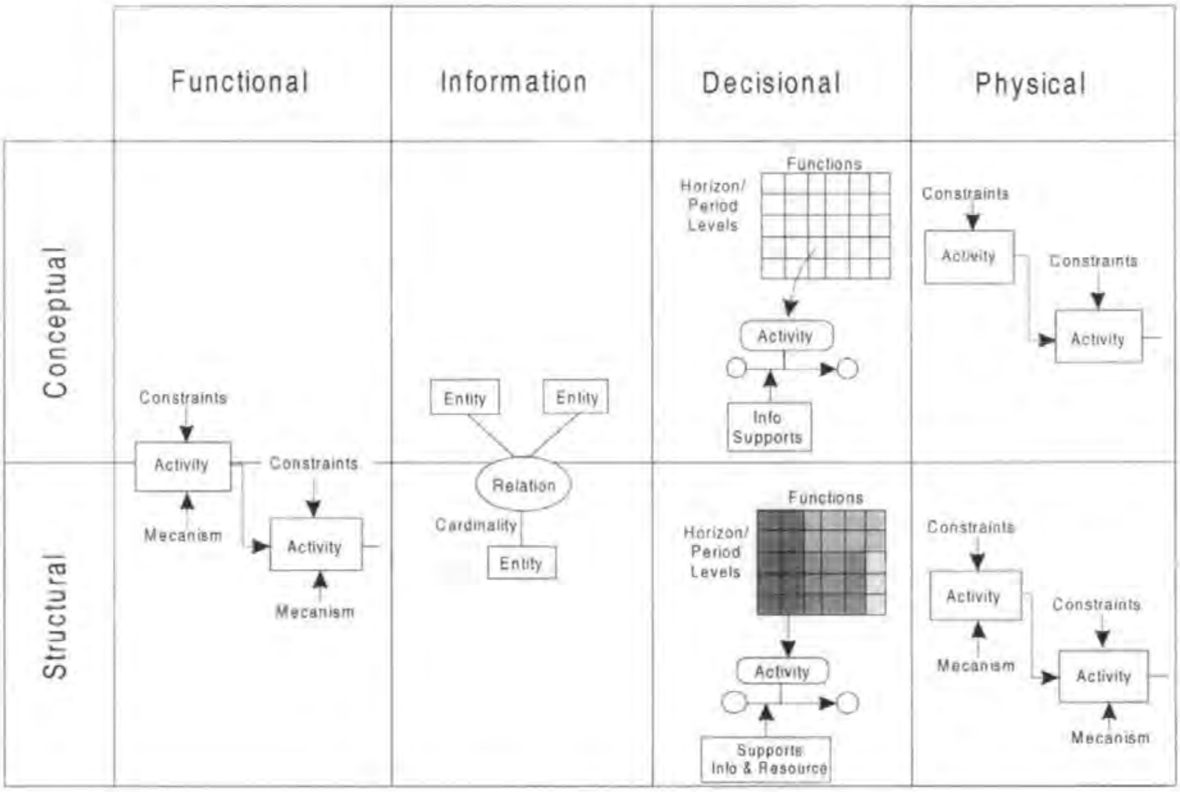


Figure 5.9 GIM modelling framework

5.10.3 IMPACS

The IMPACS modelling framework (Figure 5.10) was proposed within the Esprit Project 2338 IMPACS. It is based on the GIM modelling framework. One difference with CIM-OSA modelling framework is that the project life cycle axis is added to the IMPACS framework. This allows to show the relations between the abstraction levels and the main phases of a life cycle. For example at the analysis phase, only the conceptual level is of concern. But at the design phase, both conceptual and structural abstraction levels are considered.

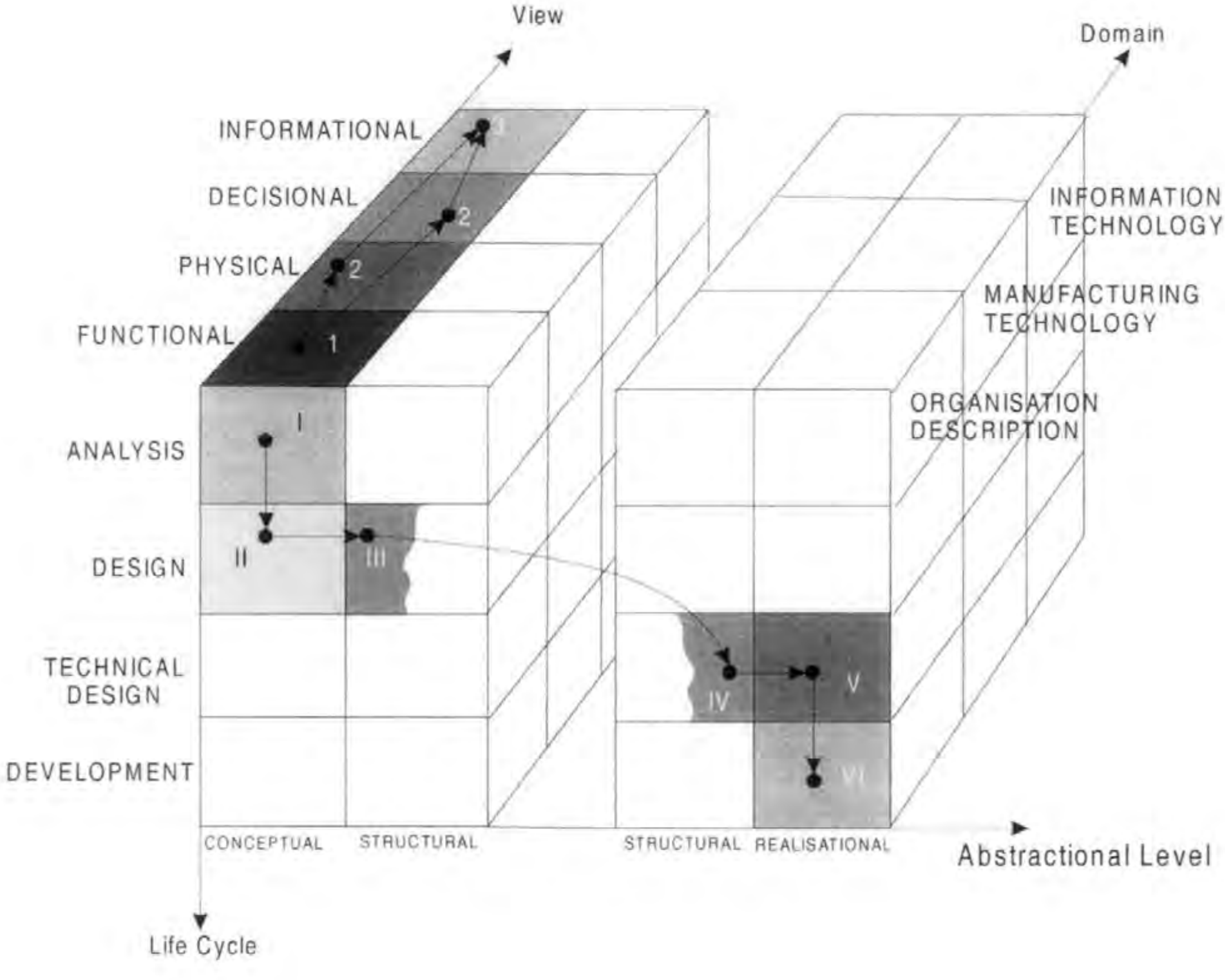


Figure 5.10 IMPACS Modelling Framework

5.11 Conclusions

The chapter has outlined the various tools and methodologies that are currently available and are widely used for information systems analysis and design of computer integrated manufacturing systems. Although these are useful for large organisations, who have substantial financial and human resources, these are considered inadequate for small and medium size enterprises.

The tools and approaches are far too complicated to be understood and used by SME personnel who often have more than one job to do and are racing against time. No one, above mentioned, methodologies or tools take the practitioners through the full project life cycle.

To use many of the above tools requires a substantial investment in software purchases and training of staff, which is normally out of the reach of SME's. To use the tools effectively requires experience of similar projects, which are not normally available to SME. And to acquire them from outside consultant organisation is too expensive for SME's. In any case, the employment of these methods in SME's will only unnecessarily complicate an already chaotic environment.

The above arguments further reemphasis the need for an approach which considers the particular needs of the SME's and is simple enough to be used in-house by the companies.

Chapter 6

Requirement of an Approach for Introducing Manufacturing Information Systems in SMEs

6.1 Overview

This chapter identifies the requirements for a structured approach, that will enable SME's to introduce manufacturing information systems within their firms. The chapter reveals that such an approach must be simple to both understand and use, so that the company's personnel can implement the approach in-house, without having to hire external consultants. The specification further requires that the approach must investigate the systems of the whole company, and identify and highlight any problem areas. These problems may then be tackled, either with the employment of new technology, or simply by re-organising the company's administrative and management systems.

The findings presented in here have been concluded from visits to some twenty five SME's in the Devon and Cornwall region. Structured, and face to face, interviews with managing directors and senior managers of some seventeen companies were also undertaken. During this research the author developed and presented several courses/seminars on various aspect of manufacturing for SME's in the region. The delegates were mainly managing directors and production managers. Discussion with these people further enhanced the author's understanding of the realisation of the problems faced by local SME companies.

This resulted in a further extension to the findings presented in this chapter. The information obtained has not been published before.

6.2 Introduction

While large firms have the financial leverage to utilise leading business consultants to implement change and/or introducing systems, most SME's cannot afford this quality of support. It is for this category of company that any approach to introducing manufacturing information systems, is likely to have most impact.

The proportion of self-employed people in the considered region is higher than the national average and it is, therefore, no coincidence that SME's are set to become the most significant driving force for the local economy (Opportunities for Growth, TECH Report, 1999). In fact SME's comprise of 99% of businesses in the region and employ 80% of the workforce (Qurashi, 1996). Defence and agriculture, the traditional industries that dominated the economy, are in decline and will have to enter a phase of restructuring and diversification (Grapious, 1998). Simultaneously, new industries, e.g. high technology firms, are in the ascendancy and will provide a key focus for future inward investment into the region, especially those which operate in the areas identified by the government foresight programme (Devon and Cornwall TEC, 1998). The foresight topics are those considered to be the areas with most potential for growth and impact on society over the next decade. The region's potential for export has not been fully exploited and so one of the keys to the region's future is export to the rest of the UK and the European Union on a much larger scale.

It is clear then, that although Devon and Cornwall occupy a peripheral geographical and economic location in the EU, there is a good opportunity to start to address this. Through vocational training of the workforce, and the effective and efficient use of technology the effect of these limiting factors can be reduced. It is only with an aggressive export expansion plan that the long-term future of the region can be safeguarded, and this is only possible with significant changes including technological advancement.

An overview of the manufacturing environment, infrastructure and relative position of the region vis-à-vis the European Union, is sufficient to highlight the various components needed for medium to long term growth and development. Devon and Cornwall have poor communications and transport facilities, which combined with geographical remoteness relative to their competitors, translate into a significant disadvantage for businesses located there. It is therefore, not surprising, that the export potential of the region is not being fulfilled and businesses continue to operate within the confines of the region. This means that market potential is stifled. Any attempt to offset these disadvantages, and change the situation into one, more favourable for the region would also require business to produce goods with reduced prices and increased quality. Lefebvre *et al* (1990) note that SME's are vulnerable to these disadvantages in a variety of ways. For example, they lack qualified personnel, they have problems finding adequate capital financing and they lack technological sophistication.

Therefore, in order to survive, SME's need to improve the manner in which they carry out their business activities. This applies particularly in SME's investment in new technology, necessary to compete in both domestic and global markets. Furthermore, the increase in labour costs are requiring SME's to focus on methods which will help them improve their competitiveness, reduce manufacturing costs, improve productivity and increase product/service quality simultaneously.

The introduction of technology in firms should not be viewed as a one-dimensional exercise, since the advantages accruing from it are considerable. According to a TEC report (Devon and Cornwall TEC, 1999) of the region's economic future, high technology will provide a key focus for new inward investment. However, correct implementation is crucial to success. Any company invariably consists of its employees, and their flexibility and skills are crucial to current workforce requirements. However, the TEC report demonstrated that employers in the region are not prepared to 'lose money' by releasing employees for training programmes. Most training in the region is conducted 'on the job' with a shift towards computer based and open/distance learning and it is in this work environment, that any approach for change could be used to substantial benefit by firms.

However, the requirement for an approach does not merely rest upon the need of business. Other important aspects need to be considered, including need for an awareness amongst managers for that need itself. The management is also required to have a sufficient level of competency and experience, to understand and implement any approach, and overcome initial problems that may arise. These problems could form one set of possible criteria in evaluating the feasibility of an approach for introducing manufacturing information systems. So the question should be extended from not just looking at a need for the availability of an approach, but also the feasibility of using that approach for the conditions that exist in Devon and Cornwall.

6.3 Responses to questions

This section reports the results of the visits to various companies, and the structured interviews with managing directors and other senior company staff. Interviews were conducted on a one-to-one basis with the author directing the questions and the interviewees responding to the best of their ability.

The questionnaire utilised for this study consisted of 19 questions of which the first four were related to the size and nature of the business operation. The first four questions were, used to contextualise the answers to the remainder of the questions thus giving a general view of trends at three different levels. Therefore, one is a view of trends at the general regional level ignoring the size and type of business, while the second is a look at businesses according to their size and the third showing trends amongst the different types of business.

As stated questions one to four consider the size of the business by the number of employees, the company turnover, and also the type of business. The rest of the questionnaire has been analysed question by question and each question has been stated for ease of understanding.

It was found that there existed a pattern in reply to the question and the size of the company, in terms of number of employees. Therefore, for the purposes of the presentation of this study the following categorisation was made as shown in Table 6.1:

Number of employees in the company	Category
Less than 15	Micro SME's
16 to 50	Developing SME's
51 to 100	Established SME's
100 to 250	Mature SME's

Table 6.1 Categorisation of SMEs

Q5. Have you served as an apprenticeship in a trade relevant to your current business?

This question can only indicate the general level of experience that managing directors have in their respective industries. The results of the question may be linked with the type of businesses making it relevant to the more general problem that may prevail in a particular industry. The extent to which this question has been answered with an affirmative would indicate whether individuals who are running businesses have experience of their manufacturing operations. This is very useful in the context of the implementation of manufacturing information systems, since it is often the small details gained by experience which make a successful change possible. However, this does not necessarily mean that managing directors who have spent time as an apprentice are also necessarily good business people. In fact, the research presented in this chapter has shown that generally the senior managers from the manufacturing operation experience background are poor at developing and executing business and marketing strategies.

The answer to this question varied from the type of industry and size of the business. Almost 90% of the managing directors from the mechanical engineering, with less then 15 employees replied that they had spent time on an apprenticeship. Whereas, 38% of the managing directors from the electrical engineering background, irrespective of the size company, replied that they had not spent time as an apprentice. It was generally found that a high proportion of managing directors from small SME's i.e. less than 15 employees had spent time as an apprentice. The higher the number of employees the less time senior managers had spent on apprenticeships. This indicates a clear pattern between the size of a company, in terms of number of employees and the background of apprenticeships of the managing director.

Overall, the study found that 56% of current managing directors had served relevant apprenticeships. This shows that almost half of the managing directors interviewed had not served apprenticeships and were not fully aware of the manufacturing operations and processes of their businesses. Therefore, a structured approach which identifies and maps the manufacturing processes of the business would be of benefit to this group. An information systems implementation approach, for analysis of existing systems, described in chapter 5, would be most suitable for identifying the manufacturing processes. As managing directors without apprenticeships would tend to have less knowledge of the businesses and therefore could offset this disadvantage with a structured approach.

The answers to the question also shows that the experience gained from an apprenticeship is typically passed from practical experience rather than the theoretical understanding of the processes. This can hinder the introduction of new technology because it was discovered that this group of people are often reluctant to change and find it difficult to adapt to the new approaches. Therefore, any new approach should appreciate this problem and should involve the people who would be using the systems from the beginning.

The main beneficiaries of a structured approach would be the senior managers, who would armed with the experience of all aspects of their business through an apprenticeship. This group forms a large number of the heads of businesses.

Q6. Do you have a degree, HND or similar higher qualifications?

The replies to this question would indicate a level of literacy and ability to understand theoretical concepts and procedures. This is a crucial measure to assess the level of complexity that any approach should adopt.

The replies varied according to the size of the company and background of the managing directors. Generally, 64% of managing directors replied that they had some kind of higher qualifications. However, it was notable that 95% of the managing directors from the apprenticeship background and had basic qualifications of O'Levels and CSE's. Also, 25% of the managing directors from the micro-companies had some kind of higher qualifications. The 38% of senior managers from the growing SME's replied that they either had higher qualifications or they were in the process of gaining higher qualifications on a part-time basis. Eighty % from the established SME's and 96% from the mature SME's replied that they had higher qualifications.

It was also noted that, generally, managing directors from micro SME's and developing SME's had qualifications relevant to the their industrial sector. Although, senior managers from developing SME's did show that they were interested in gaining qualifications in other areas of the business i.e. Marketing, IT etc. Senior managers from the established SME's and mature SME's had people qualified in other areas of the business as well as the those relevant to their industrial sector. It was rare to find senior managers with more than one higher qualification in different areas of the business.

The analysis of the replies has shown that there is a clear pattern between the size of the company and achievement of higher qualifications by the senior managers. As the 89% of companies in the Devon and Cornwall region fall in the category of micro-companies (Qurashi, 1996) the approach being developed should give due regard to the ability of the senior managers. And the approach should as simple as possible to understand and use.

Q7. Do you have any professional qualifications i.e. membership of Chartered bodies or Royal bodies?

This is a very important question since many of the qualities needed in gaining the above are also required for the comprehension, implementation and follow up of a systems change through using a systems implementation approach. Thus the suitability and level of sophistication of this approach can be partially assessed for the region. Professional qualifications demonstrate amongst the holders, a general willingness to excel in their particular industries, and to gain from the experience of other member individuals to remain at the forefront of any new ideas and or technology.

Only 20% of the managing directors had any professional qualifications or memberships of professional bodies. It was surprising to note that there was general ignorance of these bodies and what they could offer to their members. There was also a fear amongst senior managers of being rejected.

It can be concluded from the above that there is a lack of awareness of help available to SME's through professional bodies and hence lack of awareness of advancement in the various industries of the region. The new approach should highlight the sources of knowledge and help that could be available to SME's.

Q8 What is your main objective for your company growth and profit maximisation?

The question helps to expose the general psychological framework and attitudes of businesses in the region. The answers to this question could provide the author with an indication of how an approach will be utilised in different ways, depending on the nature and priority of the managing director. Firms with short-term profit maximisation or similar priorities will inevitably tend to shy away from investment in areas, which may not provide immediate short-term gains, but may prove lucrative in the long term. However, those businesses whose horizons are not limited to maximise profits in the short/medium-term, are more likely to invest in the new technology which would help them improve their market position in the medium/long-term.

The results also reflect the economic conditions that the businesses were operating in and this varies amongst different industries. It was concluded that most managing directors took an optimistic, though cautious route, opting to try for steady growth in the current economic climate. 62% of managing directors opted for steady growth strategies in the medium term, while only 12% were concerned with immediate profit maximisation. The 10% of the companies did not think that there was any potential for them to grow or that investment in new technology would necessarily bring them any benefit. Only 16% of the companies were planning for the long-term.

The replies indicate there seems to be a general fear of the growth of the economy and that majority of the companies in the region are not aggressive in selling their products. There was also pessimism about the long-term survival of companies and hence reluctance in investment to employ new technology.

The new approach should contain some measure of the cost-justification and return on the investment for managing directors. The approach should also contain elements which improve the productivity and competitiveness of the company without huge investment in new technology.

Q9. What are the problems in your manufacturing department and how do you intend to overcome these problems?

This question is related to the introduction of manufacturing information systems in overcoming the manufacturing problems. As such, the results provide important information about whether or not businesses see the restructuring of manufacturing processes and information systems as well as introducing new technology as relevant to their needs.

The managing directors indicated the following problems with their manufacturing:

- High lead times
- High Work in Progress (WIP)
- Poor Quality
- Stock control problems
- Lack of quality labour
- Poor Planning and scheduling
- Lack of co-ordination between various departments
- Absence of new production machinery due to financial constraints

On discussion with the managing directors, 59% said that they thought that by employing new technology they may be able to overcome some of the problems. However, only 18% said that they thought that there manufacturing information systems required restructuring or that their manufacturing processes needed to be improved. The remaining 23% said that they lacked time and personnel to identify the causes of the problems and how to overcome them, these were mainly managing directors from the micro companies.

It can be concluded from the answers that there was general awareness amongst the managing directors about the problems. However, only 18% thought that an information system approach was required to identify the problem areas. This indicates that 59% of the managing directors did not know how investigate the causes of problems and identify possible solutions.

The new approach must take a systematic step by step approach to identify the causes of the problems and highlight them in simple and yet meaningful way to the senior managers.

Q 10. Do you carry out training of staff at a regular interval (at least annually) within your Company and do you use any management or other tools?

The aim of this question was to measure the commitment of various businesses to training and general use of management tools. The question also give another measure of the awareness or ignorance of management techniques of managing directors in the region and how well they could understand and apply any new approach. It was found that only 38% of companies gave formal training to their staff and only 20% of the companies gave regular training. However, 70% of the managing directors stated that they used some kinds of tools and techniques to manage their businesses. The other 30% thought that the use of these tools was either waste of time or they considered that there were no relevance for their needs requirements.

24% of the companies did not think that they needed to give any kind of training to their staff and the remaining 38% said that they would like to give training but it was either too expensive or they could not afford the time to send people on courses.

The above facts show that 76% of the companies in the region are potential beneficiaries of the new approach. It can be concluded from the above facts that for the applications where management systems are in place, an approach for implementing manufacturing information systems will only enhance the performance of that business. It may also be concluded that those managing directors who are ignorant of these various management tools would almost certainly benefit from the introduction of this approach.

However, for an approach to be utilised by the most companies in the region, the approach must require little or no training to be effectively used as 38% of the companies indicated that they could not afford to send people away on training courses.

Q 11. Do you have long term plans to introduce new technology to your business ?

Answers to this question yield two important pieces of information concerning both the need and the relevancy of introducing new approach. Integrated together, the results from this question demonstrate the trends of business style at the various firms investigated. By highlighting any shortcomings in terms of planning techniques and more specifically, whether or not they have any plan or the right attitude for the introduction of new technology, relevant conclusions can then be made.

Although the majority of firms had a specific long term plan for marketing, it seemed that approximately 55% of the firms had no proper structured plan for dealing with the manufacturing problems aspects of their business. Only 35% of the companies had, mainly from the developing and established SME's, some plan to introduce new technology at the shop-floor level. 58% of the mature companies replied that they were looking at Enterprise Resource Planning (ERP) systems. Even those companies that had planned to introduce new technology had not identified the requirement in a structured manner. Instead, a laissez-faire approach was adopted by 47% of firms towards both aspects of their business.

This highlights an enormous gap in the manufacturing operations of these businesses, introduction of new technology and a structured planned approach for identifying the need and finding appropriate solutions. It is widely known that the companies that do not employ a structured approach often lead to unsuccessful implementation of technology and systems (Qurashi, 1996, Merideth 1984, Mohanty, 1993). Therefore, there is justification for a structured approach to be adopted.

Q12. In general, how would you describe the style of manufacturing planning activities within your company?

The aim of this question was to establish the general use of established techniques being utilised in the manufacturing planning. This will guide the development of any new approach to the level of detail of the approach should adopt.

The number of companies with some form of established techniques for manufacturing planning were shown to be in a minority of 46%, and out of this percentage of companies using computer as a tool for planning were found to be 20%. This percentage does not, however, represent the use of purpose written software for planning and scheduling, as some companies used spreadsheets for their and scheduling activities. While regular discussions seemed to form the majority of planning activities in the remaining 54% of the companies.

Again, there exists a clear divide between the various SME types. Micro SME's did little formal planning, with most of production decisions being made by the production manager on ad-hoc basis and as and when the need arose. Although, this was found to be relatively effective it was dangerous culture to have especially if the company had plans to grow in future. The new approach should address this need of micro companies. Developing SME's were found to be the most chaotic when planning and scheduling for manufacturing and had the worst records for delayed orders, poor quality products and high work in progress (WIP). On analysis it was discovered that the reasons for this were rapid growths of the company with little attention paid to the improvement to manufacturing systems. In other words manufacturing planning systems did not improve with the growth of the companies.

Established and mature SME's were found to be better at the manufacturing planing and employed some specialist software and personnel. However, it was discovered that many of these companies and poor implementation of the new technology and systems.

It can be concluded from all the answers to this question, that all SME type companies can benefit from a structured approach. Although, the use of the approach for the companies would be different depending upon the specific needs of the companies.

Q13. What kind of new technologies do you employ in your business ?

Although almost all of the companies stated that they had some form of computer systems for administrative work, e.g. word-processing, accounts, etc. Only about 52% of the companies said that they employed some kind of technology for manufacturing, these technologies ranged from CNC machines to CAD and networking. The remaining 48% of the companies employed no technology for manufacturing either for planning or at shop-floor level.

On further investigation the companies with no current use of technology in manufacturing, the following different reasons were noted:

- Lack of know how about technology
- Lack of finances
- Lack of understanding on how to implement new technology
- Lack of knowledge of available technology
- Lack of time and know how to investigate new technology

The above and further points are discussed in detail, later in the chapter. However, it can be concluded from the above facts that there is an urgent need for an approach that can guide SME's in the region to identify the need for technology and guide the companies in implementing the technology. Given the shortage of skilled labour, and the increased competition from the rest of the UK, identified in chapter 3, there clearly is a need for companies to invest in both core and in peripheral technologies that are crucial in areas of intense competition, and vital for further growth.

Q14. Generally was this new technology (as identified in Q13) introduced to exploit future possibilities or deal with current problems?

This question was addressed to the companies who had invested in some form of technology for their manufacturing, either at the shop floor level or at the planning and scheduling level. Sixty % of the managing directors replied that they introduced technology to improve production and quality in the short to medium term. While 30% said that either they thought they needed technology or they were pressurised by their customers to employ technology. However, only 10% said that they employed technology to improve their planning and scheduling.

Majority of the micro SME managing directors said that they were pressurised into introducing new technology by their bigger customers. Whilst majority of the established companies introduced technology to improve their quality.

Mature companies were planning for long-term as well as dealing with short term issues when introducing new technology.

The answers to this question throw light onto the attitudes of managing directors towards the use of technology and its role in the workplace which need to be considered when designing any new approach. It was found that firms tended to employ new technology to overcome short-term problems while at the same time hoping that IT will give them some future benefits.

Q15 Overall, how successful was the new technology in meeting the objectives you defined in the last question?

The aim of this question was establish whether there was careful planning done to identify the need for new technology and whether systematic approach was adopted to implement the changes. As it is not the technology by itself that can bring added benefit or give competitive advantage but the right technology and the right use and implementation of the technology that can give advantages (Julien, 1995).

Out of all the companies questioned only 26% said that new technologies met all the objectives for which they were purchased. 40% said that the introduction of new technology gave some benefit to their business, while 20% said that the new technology gave them no real added benefit. The remaining 14% said that introducing new technology had the opposite effect i.e. it made situation worse for them.

It can be concluded from the above that 74% of the companies were not entirely happy with the investment in new technology. And confirms the fact that the successful introduction of technology can only be realised if the need had been clearly identified prior to any investment. Hence the need for an approach that guides the companies from identifying the need to implementing the technology.

Q16 How was the implementation done, step by step or sudden and was there any pre and post implementation testing?

Even a correctly identified need for the technology, and the subsequent investment in that technology can not guarantee successful return on investment. Implementation must be carefully planned to achieve this (Geisler, 1992). The aim of this question was to identify how much of the lack of benefit from introducing new technology, identified in the previous question, can be related to the poor implementation plan.

All the firms using a gradual and carefully planned implementation process succeeded in introducing the technology effectively and efficiently. The unplanned and laissez-faire approach was shown to be ineffective in the implementation of new technology, yet a substantial minority of companies (33%) used this approach. Moreover, it is found that nearly half of the companies surveyed had no system of pre-implementation testing and 38% either failed in, or did not conduct post-implementation monitoring and control. The lack of return from the investment was reported by companies of all sizes.

A new approach that defines and guides companies for the most effective way of implementing new technology would be of benefit in this situation where confusion exists as to the most effective way of implementing new technologies. The approach must also contain steps to ensure that pre and post implementation testing is carried out to a satisfactory standard.

Q17 Did you have any past experience of introducing new technologies ?

It was determined that 70% of companies in the mechanical and electrical industry had little or no experience in introducing new technologies, this also proved to be the industry where the introduction of new technology either had adverse affect, or gave no real value. Eighty five % of rest of the companies said that they had no experience. However, all companies considered that they had received some help from the suppliers of their technology. 95% of all companies stated that they did no company wide study of the company's processes and systems before investing in new technology.

The extent of supplier support or back-up was severely lacking, with only 47% of businesses receiving satisfactory levels of support. Other external support, i.e. from government bodies e.g. chambers of commerce, business links etc, for the companies was negligible with only 16% receiving support from other sources. Furthermore, only 47% of managing directors regarded themselves a skilful in change management.

It can be concluded from the above that the companies did attempt to introduce define the need, purchase the technology and implemented it without any experience and little help from supplier or any other sources. This had resulted in making either poor choices for the kind of technology or failing to enquire for the crucial things like after sales support and future compatibility of the systems. The new approach should present a set of criteria which the managers can use to enquire for the suitability of the system for future use as well as the short term. Poor return from the investment was also due to the absence of company wide analysis of the information systems.

Q18 Did you do cost justification for investing in new technology?

Taking into consideration the economic climate that the industries are operating in and also the fierce competition within the industries, as highlighted in chapter 3, every aspect of the manufacture of products has to be performing at an optimum level. The aim of this question was to investigate if the companies who invested in technology had made an assessment of what would be the return on the investment.

Almost all companies replied that they were presented with some calculation from the supplier of the technology on possible increases in productivity and hence the turnover. However, about 50% of the companies replied that they did not use of the formal methods for calculating the time it would take them to gain return on their investment. The other 50% said that their accountants did calculation for them using a payback method or net present value method.

Although, the managing directors also said that they thought that the estimate for the return on the investment was either exaggerated or underestimated.

It can be concluded from the above replies that companies need to be aware of the formal methods of cost justification on investment. Therefore, the new approach must present these methods, their use and the advantages and disadvantages that they present.

Q19 Would your company benefit from guidance for future investment in new technology ?

The aim of this question was to establish if the managing directors and senior directors of the companies thought that there was need for a formal approach that they could use to introduce information systems and new technology in their business.

All companies who had not invested in any new technology said that they would like some guidance on how to approach the introduction of technology. Seventy % of the companies who had invested in IT previously said that they would like some formal guidance and the other 30% said that they felt that there were in better position to implement any IT project.

6.4 Disadvantages of SME's in the Devon and Cornwall region

Both chapter 3 and the results of the interviews with managing directors of SME's have identified several disadvantages that firms in the region face. These can be summarised as:

a) Lack of know how of technology

b) Lack of finances

c) Lack of understanding on how to implement new technology

d) Lack of knowledge of available technology

e) Lack of skilled labour

f) Devon and Cornwall being a periphery region

g) Lack of time and know how to investigate new technology

6.4.1 Lack of know how of technology

The author's extensive field work in the Devon and Cornwall region indicated that there exists a general ignorance about technology, and the advantages that technology presented for the businesses. Even though many companies indicated that their competitors were gaining competitive advantage over them by employing new technology. They had no specific views concerning the areas of the business and the key technologies that they require. These companies also do not understand how their business can benefit as a result.

6.4.2 Lack of finances

Even where the companies know the technology that needs to be introduced in their companies, they are prevented from doing so due to a lack of funds available to the companies. However, the author observed that companies were generally looking to invest in manufacturing systems e.g. CNC machines, Computer integrated manufacturing (CAM) etc. but failed to realise the potential that IT could bring in other areas such as planning and scheduling. This type of application cost significantly less than manufacturing systems. The companies were also, generally, unaware of financial help available from the local and national government bodies to assist with introducing new systems. This type of help can make the implementation more affordable and beneficial.

6.4.3 Lack of understanding on how to implement new technology

The results of the questionnaire highlighted that for many companies the investment in technology did not yield the expected results. This is mainly due to the fact that even those companies that have the time, staff and financial resources to implement technology often failed because they did not adopt a structured implementation policy. The author observed that most companies adopted a 'big bang' approached where overnight firms shifted from old systems to new systems. This results in chaotic situations and consequently staff refusing to work with new systems and reverting back to old systems. Often significant quantities of time, information and product are lost through the inevitable problems that occur with big bang implementation. Conversely, incremental implementation can reduce the risks considerably.

6.4.4 Lack of knowledge of available technology

The companies that were enthusiastic about introducing technology and were willing to invest funds, often found it difficult to know what to purchase. Most senior managers were found to be unaware of what was available in the market place to assist them in improving their business. This occurs both at the administrative and management level as well as manufacturing systems level.

6.4.5 Lack of skilled labour

The author also found that the companies that had rightly invested in the relevant technology were not utilising this technology to its full capabilities. This was mainly due to the fact that many members of staff found it difficult to grasp prime concepts that were pre-requisites to using the certain features. The staff also concluded that it proved difficult to use manuals that came with systems, and usually the training that was given was insufficient. The companies found vendor support expensive and therefore prohibitive.

6.4.6 Devon and Cornwall being a periphery region

Most IT suppliers for systems relevant to SME's in the region, are based outside the Devon and Cornwall counties. For a supplier to investigate the requirement for a company often means a day's journey, and it was concluded that suppliers were not willing to make the journey unless there was an opportunity for a substantial order. There are also supplier held workshops and seminars to demonstrate the latest technology, most of which are not available on a local bases.

Being a periphery region also means that companies must produce and perform at more optimised level than many of their competitors. This compensation for extra costs of transportation that had to be accounted for. For some companies in London, for example, it was cheaper for them to import goods from Europe then to have them transported from Devon and Cornwall.

6.4.7 Lack of time and know how to investigate new technology

Typically, SME's work to their full manpower capacity, often fire-fighting. Lack of time available to them often leads to companies unable to do research in evaluating and improving their systems and operations. The author noted that senior managers lacked the know how of how to do the research i.e. where to look, who to contact etc.

6.5 Reasons for the implementation of new technology.

This section present some of the other reason that senior managers of SME's in the region gave for investing in new technology.

1) ***Safety*** – many jobs in manufacturing such as welding, involve some degree of danger to the employee and using technology for these tasks would improve the general level of safety of employees.

2) ***High cost of raw materials*** – the application of technology to many tasks would increase the efficient use of materials, thus enabling the firm to make savings.

3) ***Improved product quality*** – this aspect of product manufacture is one of the key concerns of manufacturing companies and upon it rests the future of the firm. Any method that would enable companies to produce products of a higher quality, is of substantial benefit to the firm in terms of customer satisfaction, image and higher productivity.

4) ***Reducing manufacturing lead time*** –the time it takes to deliver a finished product from the time it was ordered by a customer, is of major importance in any firm. Technology has a role to play in many firms when there is a need to reduce the lead-time.

5) ***Reduction of WIP*** – work in progress (WIP), results from a lack of planning and insufficient scheduling of work on the shop-floor. The introduction of new technology would help to alleviate this perennial problem.

6) ***The high cost of not employing new technology*** – most businesses operate in an environment of fierce competition and the strength of a business is related to its position amongst competitors. As an increasing number of businesses transfer an increasing percentage of their work into automation, any business that wants to retain its position will also inevitably have to automate.

6.6 Conclusions

In today's global and dynamic manufacturing environment where the suppliers and customers no longer have to be to confined to the local region or even the country the cost of not investing in new technology can be substantial. This is particularly the case for companies in the Devon and Cornwall, who have extra disadvantages, as highlighted previously in this chapter and also in chapter 3.

Therefore, there is a requirement for an affordable, and accessible approach, which companies can use in-house to introduce information systems and manufacturing information systems in their companies. As SME's have limited financial resources with which to hire the expertise of an outside consultant. An approach that would guide companies, that lack in-house expertise, in identifying needs, specifying the systems and implementing the systems would be invaluable.

An approach must be simple to use and must take into account the disadvantages of SME's in the region it must also guide the companies throughout full life cycle of the proposed project. Such an approach must provide the company with ownership of the project. Because it will develop in-house, This approach will further enhance expertise as well as creating greater ownership and commitment from the companies own staff.

There is currently no such approach available to guide SME's, therefore, any approach developed must adopt a structured approach in identifying the need and proposing suitable solution. The approach should also encompass the required technological, organisational and infrastructural dimension.

The chapter has identified the current use of technology within the SME's in the Devon and Cornwall region, it has also identified the disadvantages faced by the SME's in the region. The chapter established that for companies to make use of an approach it must be structured and easy enough for companies to use in-house.

However, for any approach to be effective there must be a commitment from the senior management in adopting the approach, freeing staff to work on the project and making financial commitments. The following chapter presents an outline description of the novel approach that will fulfil the requirements stated. The approach is then validated in chapter 8, using case study applications, to ensure its effectiveness during implementation.

Chapter Seven

A New Generic Approach to Introducing Manufacturing Information Systems in SME's

7.1 Overview

The implementation of new technology in manufacturing gives rise to several advantages including improved productivity, higher quality, efficient use of resources etc (Meredith, 1987). However, what is less appreciated are the complexity and manifold risks associated with the process of introducing new technology (Julien, 1995, Geisler, 1992) .

This chapter presents a description of a new generic approach which small and medium sized companies can use in-house to introduce a manufacturing information systems. The approach deals directly with the issues that were raised by the managing directors of various companies in the region, as presented in the previous chapter. The approach is designed to be simple and yet highly effective, and has given due consideration to the issues and problems faced by the SME companies in the Devon and Cornwall region. The approach has also introduced an original method for making qualitative decisions to choose appropriate IT systems for specific applications and has developed additional novel mapping tools which are essential if successful implementation of this new approach is to be achieved.

The approach has evolved during five years of extensive research in the region. The research has been integrated with the results from visits to many SME companies, together with discussions and evaluation of the proposed approach with the practitioners / academics in the field. The validity of the approach was established through practical implementation of the approach in five SME's in the region, (see chapter 8 for details). The case studies proved that the approach was effective, and could be followed by any such company wishing to achieve similar success.

7.2 Introduction

The approach outlined in this chapter has been developed independently of any software or hardware vendor. This ensures that the outcome of the approach is appropriate to the company, and is not dependant upon vendor or consultants, as this would create a reliance on certain hardware and software that would not be beneficial to the desired outcome.

Typically, when an outside consultancy services are employed there is little or no involvement of company personnel. This lack of involvement results not only in lack of ownership by the company personnel, but also the company being tied to the providers of the consultancy. Consultancy service organisations generally do not attempt to develop the skills of client staff. Therefore, in the future, any amendments to the system would require rehiring of the consultancy services.

The author's approach achieves results by involving company personnel from the outset. The company has the ownership and complete control of the project throughout its life cycle. Hence any actions identified are fully supported, and more likely to be implemented successfully. The company also retains the expertise gained and is able to cope with any future alterations.

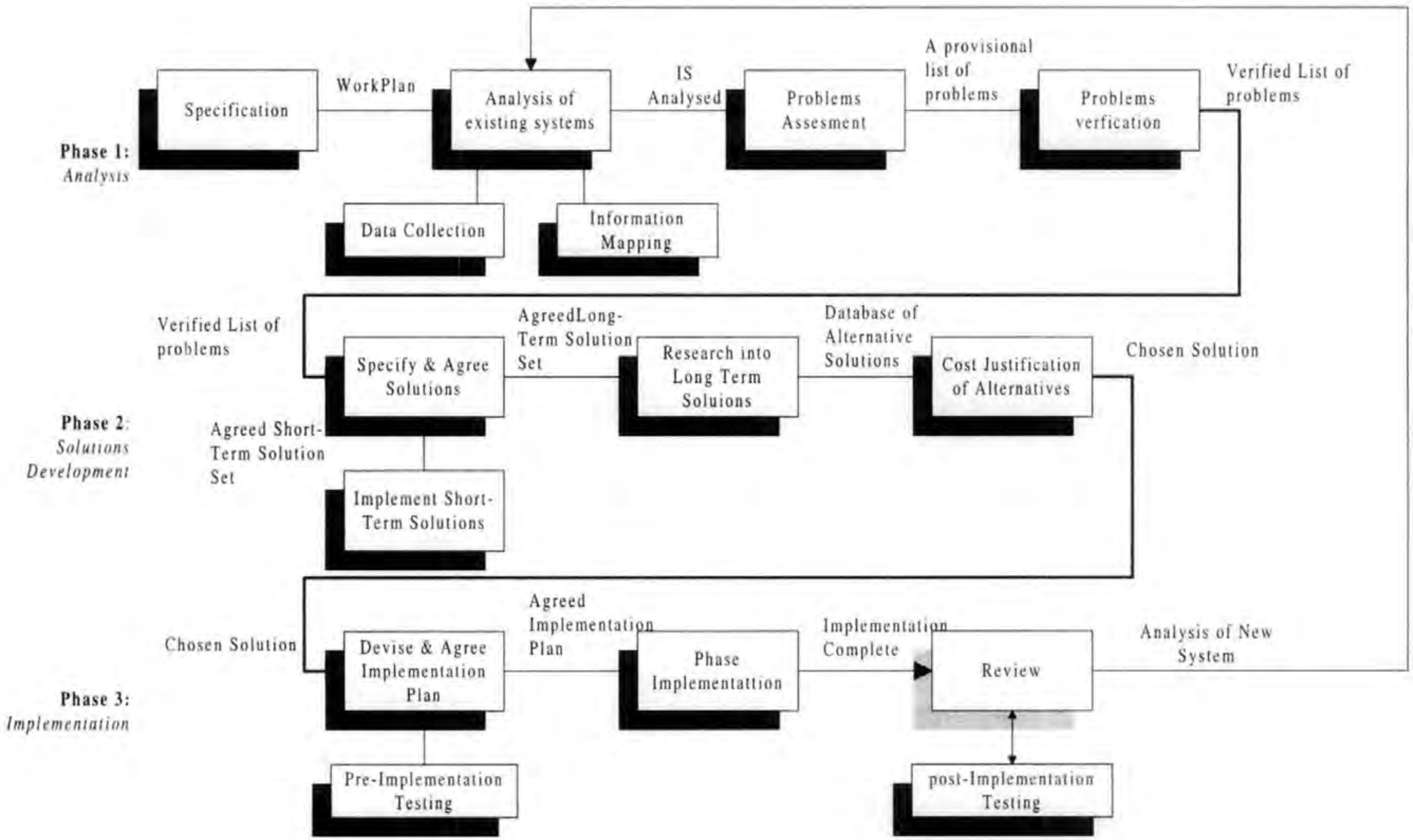
For the company, using the approach, it is important that a project manager is identified who will be completely responsible for the project through its life cycle. It is vital that the person chosen has a good understanding of the overall requirements and strategic direction of the company. This manager should ideally be either a senior member of company staff, or somebody who has full support of the senior management. This is important because the achievement of lasting change in any organisation requires commitment right from the top level if it is to be successful (Tranfield and Smith, 1988).

It is important to note that the approach proposed does not deal with the strategic analysis or direction of the company. It is assumed that strategic aspects are considered by the senior management. The approach is concerned with the improvement of company's information systems and the introduction of manufacturing information systems with the implementation of new technology. However, it is crucial that any company utilising this approach has undertaken a strategic analysis of its market, competitors, future trends, the economy and its future direction etc.

7.3 Content of the new approach

Figure 7.1 represents an overview of the approach, showing the structured phases and steps involved. The approach has been divided into three phases, Analysis, Solutions Development and Implementation. Although any company using this approach is encouraged to apply the full approach, the division of the approach

Figure 7.1 The Model For New Approach



into phases makes it simpler for the companies that may feel that they certain phases are not applicable in their case due to the completion of earlier work. For example, a company may wish to use the approach to develop their solutions, if they previously undertaken the analysis of their existing systems.

The Figure 7.1 shows the three phases and the various steps involved at each of the phases. The output from the phase 1 is the input to phase two, and the output from phase two is the input into phase three. The rest of the chapter will discuss and explain each of the phases and their respective steps. Although a detail explanation of each step is presented, however, it is not perceived that a company utilising the approach would necessarily use all the phases and the steps.

7.3.1 Phase 1 - Analysis

This is the first of the three phases of the new approach, this phase has four different steps as indicated in the Figure 7.2 below. This is an important first phase, as prior to designing any manufacturing information system and implementing any new technology that will give a company its competitive advantage, it is important that the characteristics of the business's current operations are clearly understood. The primary output from this phase is a list of problems and bottlenecks that have been identified. This list can then be used as an input to the next phase which attempts to provide solutions to the problems identified.

Depending on the current practices of the company, the analysis could reveal wide-ranging issues e.g. that problems may lie with the staff commitment rather than lack of technology or lack of quality may be due to the insufficient procedures etc. These issues might require substantial changes to the way the company operates. Alternatively the analysis may conclude that the company is already operating at a best possible optimum level, within the limited resources that are available. The analysis could also identify any additional requirements that the company may have.

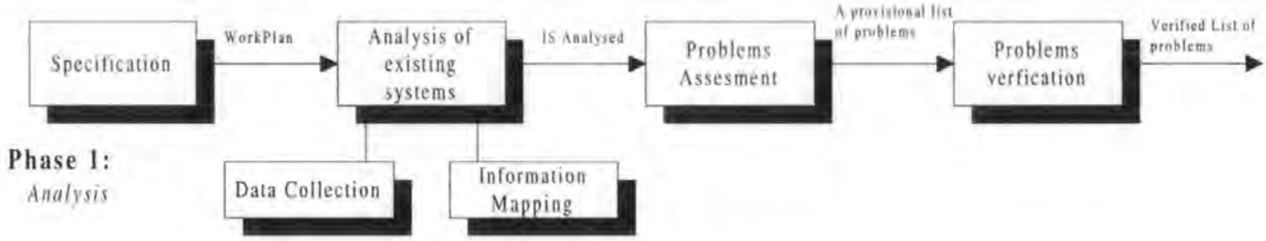


Figure 7.2: Phase 1 analysis

7.3.1.1 Project specification

Project specification is an important first step in introducing manufacturing information systems. At this stage the designated person in-charge of the project will layout a brief explanation of the reasoning behind the project. They will aim to answer questions including, what problem is being solved?, how will the project will be co-ordinated ?, What is the estimated time for the project ? Who will be involved in different parts of the project ?, What are the estimated costs (these should initially include the man-hour costs, and later the costs of introducing new technology) ?.

The costs and time estimates should not be considered as being too rigid at this stage as the author's experience of SMEs has demonstrated that companies often have to fire-fight situations within the company, and the project co-ordinator may be called in to do other tasks. Similarly, it is difficult to estimate costs from the beginning as the analysis of the current system will identify the problems. Once discovered they may not necessarily require financial investment.

However, it is important, at this stage, that a Gantt chart is produced listing, in logical order and estimated time, the various steps and tasks involved to complete the different stages of the project. The tasks required to be undertaken at this stage can be summarised as:

1. Brief description of the project
2. Estimated time required
3. Estimated costs
4. Identification of people who may possibly be involved
5. Gantt chart listing the steps and tasks involved

It is not expected at this stage that all the estimates should be highly accurate, instead they act only as guide. No money for new technology should be budgeted at this stage.

The project specification not only clarifies the objectives and tasks for the project co-ordinator, but also the documentation produced at this stage will help other understand the nature and direction of the project. Therefore, the project description and other relevant documents produced at this stage should be widely circulated within the company, from shop-floor supervisors, to the administrators and senior management. This will have two benefits (i) that everybody will feel part of the project and (ii) the recipients may give useful ideas and feedback.

7.3.1.2 Analysis of existing information systems

As defined in chapter 4, an information system is a set of procedures that collect, (or retrieve), process, store and disseminate information to support decision making and control. Every organisation has a set of information systems that generate some form of information, and interact with other information systems within the organisation to facilitate decision making and productivity.

Information systems can be informal, for example office gossip, or they could be formal with set and pre-defined criteria and procedures. If a system conforms with this i.e. collection, processing, storing and dissemination of information, then it may be classed as an information system. The information can be collected for example, verbally, fax, purchase order, e-mail etc. The mechanism for storing could be, a persons memory back of a scrap paper, a filing system or a sophisticated computer databases. Processing may be achieved with manual calculation, guess work, calculation or by using a sophisticated computer systems / packages. Dissemination may also be performed, verbally, via carefully thought out forms or via badly thought out forms, e-mail, or computer systems etc. Any system, or way of working, that has the above characteristics, is known as an information system. In SME's it is the mechanism of exchange of the information, and the quality of information between the information systems of various departments, that determines whether the company is productive, produces high quality products etc. It should be noted that an information system may employ mechanical or electrical equipment as well as computer based systems.

This section outlines the approaches that can be used to analyse a company's existing information systems.

Data collection

The process of data collection to analyse any existing information systems should be completed on a departmental basis, i.e. manufacturing or sales departments etc. This may be done in four different ways:

(i) ***Interviewing people*** – interviewing people in SME's should be undertaken as informally as possible. It was established from the case study companies that company personnel often feel intimidated and stressed when they are subjected for a formal interview. The interviewer should ideally be a person from another department and preferably not a senior manager as the intention of the exercise is to establish the facts as far as possible. An employee might be reluctant to speak frankly to a senior manager or a person from the same department. This situation may have the affect of limiting and distorting, the data collected. Interviewing undertaken by a neutral party is therefore much more beneficial to the quality of the end results.

The interviewer should start by explaining the purpose of the interview and assuring confidentiality. The first few minutes may be used for social chat before asking the relevant questions. The interviewer should restrict the questions limited to those which find out the interviewees understanding of how information systems in the department work. It is vital to obtain the interviewees understanding of the system, and not what the interviewee thinks the systems is, or even what it should be. It was discovered in the case study companies that often the perception of the manager, or a person in the department of how the information systems works, and how it actually works, were remarkably different. It is essential that this difference views is recorded as it is one of the key foundations for the information environment.

The information should be recorded using diagrams and descriptive text. Details of the proposed mechanism for recording this information is included in the next section. A flip chart may also be used or even a simple notepad could also suffice. It is important that before the interview is finished, the interviewer should provide a summary of the information they have gathered and should seek the interviewees agreement on the correct understanding of what the interviewee has both said and meant.

Interviews should be conducted with different people from the same department and preferably with those who represent a range of positions i.e. from the administrative secretary, manager of the department and also supervisors within that department. All of staff should be asked the same questions, although the wording of the questions may be altered to understanding for the interviewee. This may identify the different understanding of the same system by different people and could also highlight many related problems within the department.

(ii) ***Observation*** – Observation is an important part of the analysis of the existing systems, which should be repeated throughout the analysis process. Observations often provide clues about why the current system is not functioning properly. Experience of the case study companies revealed that many managers and supervisors provided false answers to make their particular system appear to be superior than it was in reality. This could be due to the fact that either the person deliberately gives the false information to hide any weaknesses within that individual or did not understand the workings of the system.

In any case the observations of the departments, and even very small and unexpected incidents, can all be significant in later analysis. It is therefore vital that they are recorded at that time. Many observations will be unplanned, however, there must also be a planned observation. This should involve watching an operation for a period to see exactly what happens. It is recommended that formal observations should be undertaken with the agreement of the users/operators, as covert observation can undermine any trust and goodwill that the analyst manages to build up. The observation is particularly good for tracing bottlenecks, and should be used for checking facts that have already been noted.

(iii) ***Record searching*** – Time constraints can prevent a systems analyst from making as thorough an investigation as he might wish. Record searching can enable conclusions to be drawn from a sample of past and present results of the current systems. This involves looking through written records to obtain quantitative information, and to confirm or quantify information already supplied by user staff or management.

During record searching, information can be collected about, unused forms, the accuracy of data held in the system, the frequency with which the files are updated, the volume of file data and transactions, frequencies and trends. Using the information, an assessment of the relevance of the information can be made and the usefulness of existing information can be questioned if it appears that some file data is merely updated, often inaccurate or little used.

Furthermore, all of the information collected by record searching can be used to cross-check information given by users of the system. Whilst this does not imply that user opinion will be inaccurate, discrepancies can be evaluated and the reasons for them discussed.

(iv) ***Document analysis*** – When investigating the information flow through documents, it is useful to collect the documents which demonstrate how this information is organised. These documents may include formal lists, organisation charts, reports and forms. In order to fully understand the purpose of a document and its relevance and importance to the business, the questions should be asked about how, where, why and when it is used.

This technique is particularly useful when employed with one or more of the previously mentioned techniques. The author found this technique very applicable for case study companies. In the case of company A it was able to recommended that 40% of the documents should be discarded as they served little or no use to the company. As such they proved to be an unnecessary burden to maintain and file.

Four techniques have been highlighted that should be used to collect information about the company and its flow of information. These techniques can be used in isolation, or in combination, to gather the information about the current system and to understand any requirement for any new system. This information needs to be recorded graphically using a mapping technique to assist in the ease of reading.

Information mapping

Typically at the data collection stage a considerable amount of information is collected, which may include notes made from the interviews, observation records, sample documents and lists of problems and requirements, as perceived by the staff of the company. Before any conclusions can be drawn from the data that has been collected, it is important to record this information in an unambiguous and concise manner. In this way the data may be used to verify the information gathered, and develop the new system. As recording information entirely in sentences and paragraphs is often more confusing to both the recorder and the reader, a pictorial way of recording the information is preferred as it aids understanding.

There are various very useful techniques such as Data Flow Diagrams (DFD) and ICAM Definition Diagrams (IDEF0), that are discussed in chapter 5 and appendix A. However, these techniques are often too complicated for the SME companies to use. SME companies also lack time and resources to send personnel away on training to master these techniques. The author has therefore developed two new techniques that can be used by the SME's. These require little or no training and the case studies have shown that they are highly effective. These new techniques are easily understood and can be used by anybody who has not come across graphical techniques before. These two techniques are known as:

I. Input Output Diagram (IOD) and

II. Information Flow Diagrams (IFD)

Input Output Diagrams (IOD)

Input output diagrams are very simple to use and record the information coming in and going out of any particular department. The diagrams also map out to whom the information is being sent and from where it is being received. This way of recording the information simplifies the movement of information and, when studied, the usefulness of the information. The Figure 7.3 shows a sample of IOD from a case study company.

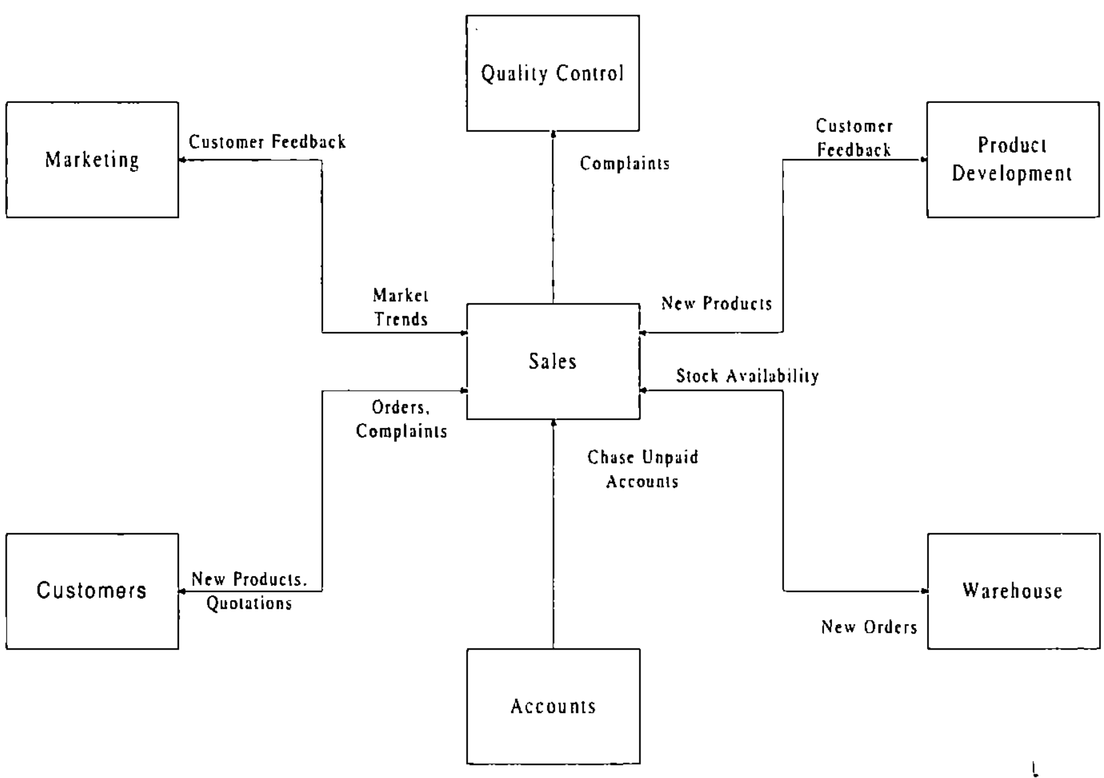


Figure 7.3 An Example of an Input Output Diagram

These diagrams should be drawn during the data collection stage. The rectangle in the middle represents the department being studied and the arrows coming in and going out of the rectangle represent the movement of information to and from the department. It is vital to record both the direction of the flow, and the type of information that is being delivered / received. It is also useful to note how the information is being transferred i.e. verbally, via computer etc. However, sometimes how the information is transferred is dictated by the culture of the company i.e. all information is transferred verbally or using forms, in which case it is not necessary to record the detail.

When applying this technique, during the case studies, the author was able to establish that some departments who were constantly meeting and exchanging verbal abuse at each other, in reality, had no useful information to communicate. More importantly their problem really lay with another department. These diagrams can also be used on their own without the need for overall study of the information systems of a business.

The use of these simple diagrams was highly appreciated by the case study companies and also by other practitioners in the field. As a direct result of this research, one of the case study companies decided to use this diagram technique to record the information requirement from all their major suppliers and customers.

Information Flow Diagrams (IFD)

Information Flow Diagrams, Figure 7.4, are used to record the flow of information from when the information enters into a department or a company to when it leaves the department or company. These diagrams show the path that information follows and the processes that it goes through. The IFD's can be used to pictorially to record the flow of an order from when it arrives at the company, the processes it goes through and the time it is despatched.

The IFD's use simple rectangles to record which departments the information is going into and coming out from. The use of arrows is applied to provide the reader with an understanding of the direction of the flow of the information. For established and mature SME companies, version 2 of the IFD's, Figure 7.5, can be employed. In this version 2 the triangular boxes are split into three compartments. The first compartment lists the kind of information being processed, the second compartment notes the time it takes to process this information and the third compartment lists the how the information is conveyed. This version 2 of the IFD can be used by micro SME's, when they are mapping the overall functioning of the system, if they feel. Experience of the case study companies discovered that some SME companies found it difficult to use version 2 of IFD. This was because version of the IFD required a lot more detailed information to be mapped on a single diagram, this was found to be difficult to achieve, and was confusing to some members of the staff.

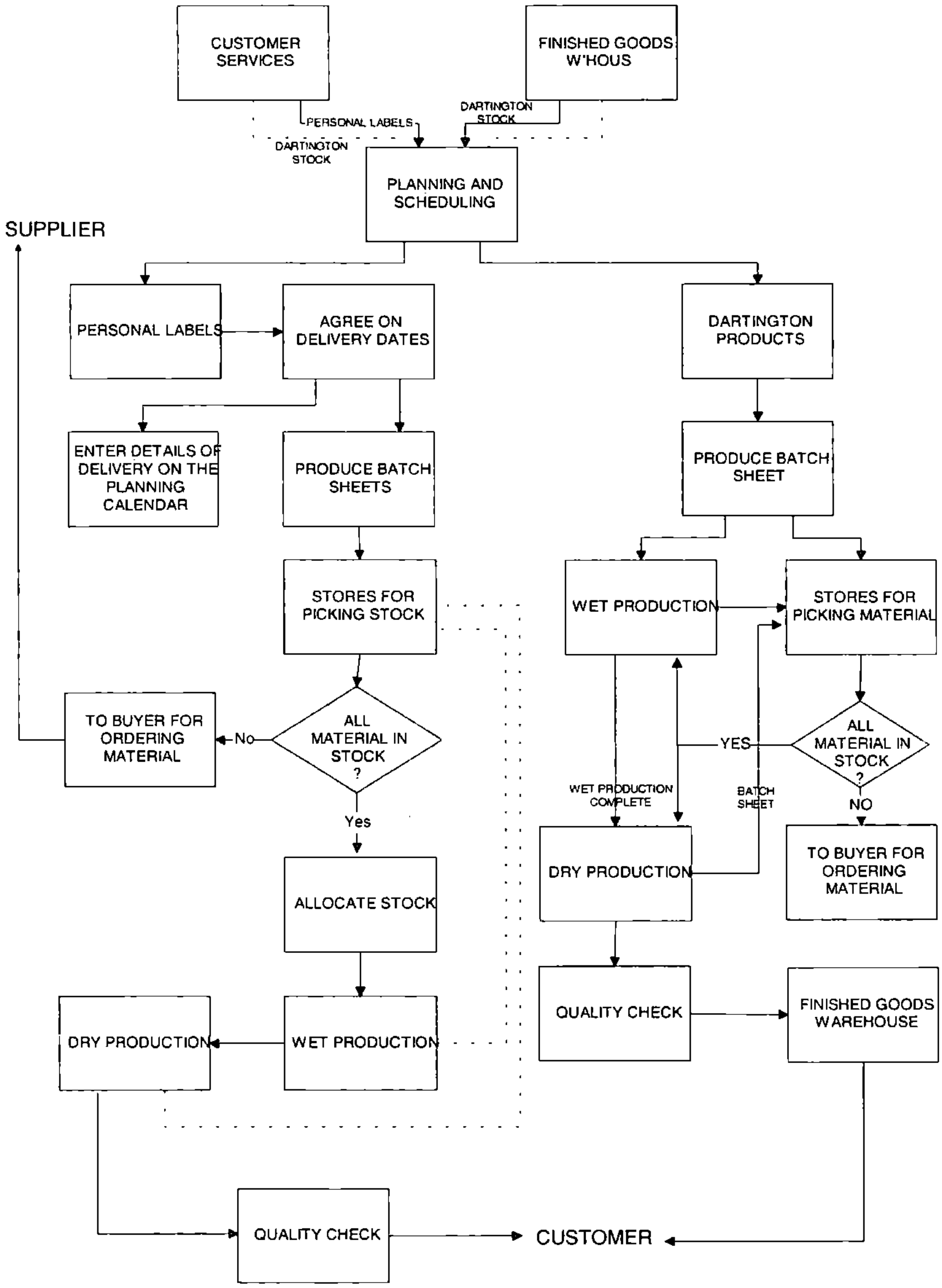


Figure 7.4 A sample of Information Flow Diagram – version 1

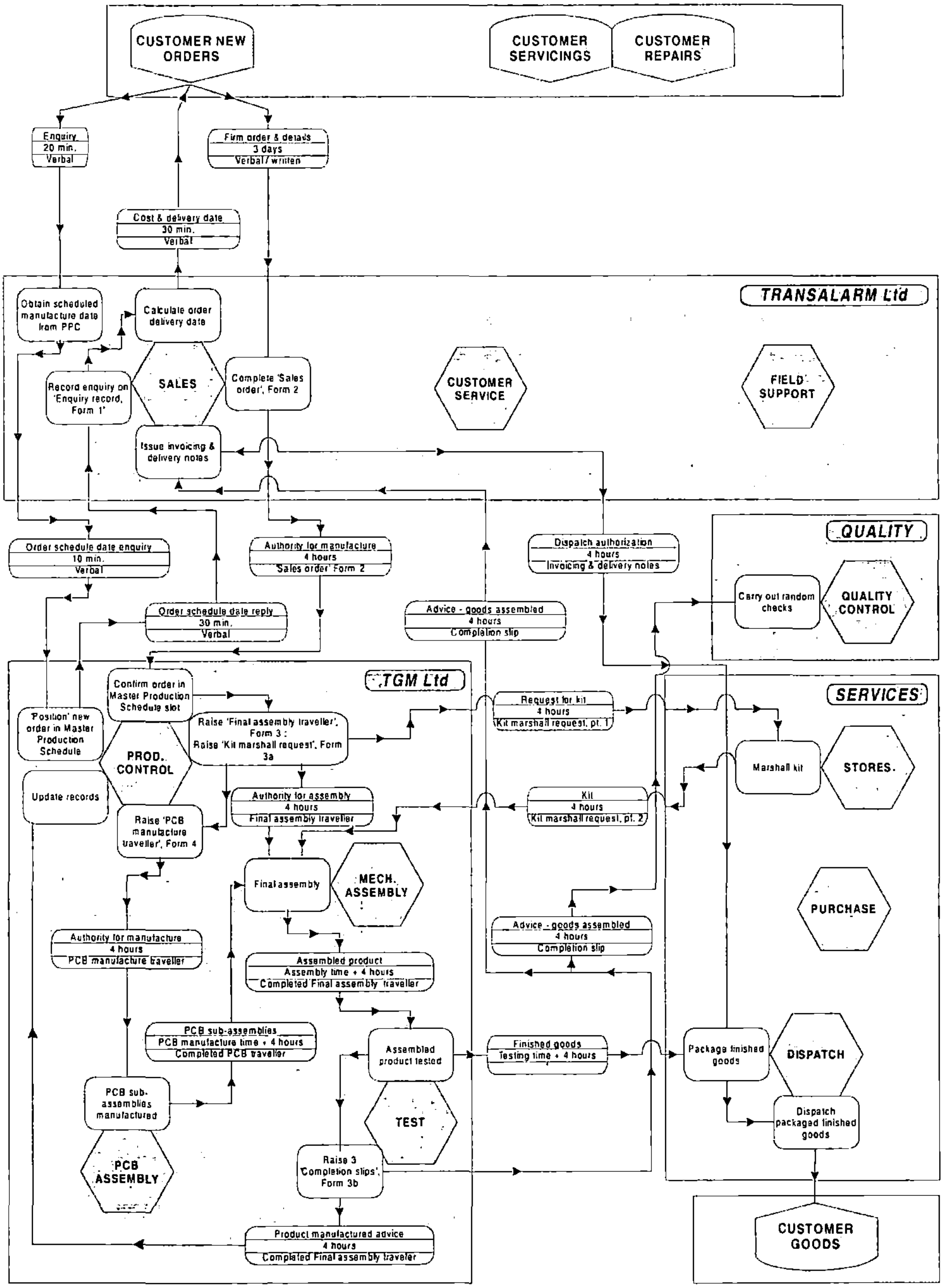


Figure 7.5 A sample of information flow diagram – version 2

The IFD's employ diamond shape box's, as used in flowcharting technique to represent a question or decision to be made. The information flow diagrams can be employed to represent the overall working and interaction of enterprise wide information systems. IFD's can also be used to show a flow of information for a department, however, there must always exist an IFD for the whole company. Once drawn the diagrams can then be used to assess the bottlenecks and problem areas. New diagrams can be drawn to show the resolution of the bottlenecks previously identified.

IFD's are an original approach to mapping information and were developed to make the graphical representation of information for SME's easier to understand and apply. However, with the case studies undertaken, some people still found them little difficult to create. It was noted that, most of the people who used the diagrams found them much easier to use, and follow, then conventional methods like data flow diagrams and ICAM definition Diagrams (IDEF0).

7.3.1.3 Problems assessment

The previous section outlined the approach and techniques to analyse and map the existing information systems of a company by asking questions, gathering documents and recording details about the current systems by using two diagrams, IOD and IFD. In this section, consideration will be given to assessing the inherent problems that a company might be having, and identifying techniques that can be used to specify these problems for clear identification.

A study was undertaken to identify if there were any available tools that could be utilised to assess these problems, and that would also be relevant to SME environment. However, no such tool could be identified for application to SME's. The tools that do exist are highly complex in nature and are aimed at large multinational organisations. As such they were found to be irrelevant in the case of SME's. For the approach presented in this chapter the author has recommended the following two techniques:

(i) A list from company staff – This list of problems is made primarily from the interviews of the company staff. All problems that are perceived by the company staff are written down and if more than two people report the same problem then it is highlighted. It is important to realise that this is a list of the perception of the problems by the company staff, and does not necessarily mean that the problem exists. However, they must be noted and their causes identified.

These concerns should be written according to the departments that report them and if it relates to another department then it should also be written down i.e. production department reports that there is a problem with sales department. These difficulties should then be listed under the production department. The reason for this is that the production department see the sales department as being a problem but the sales department may not see it as being a problem, connected with sales.

(ii) Assessment of information flow diagrams – The IFD's should be carefully considered by the relevant company staff and brainstorming should be achieved to identify why bottlenecks appear at certain stages of the diagram. Although, this is a very subjective way of assessment the case studies have demonstrated that this method is highly effective as it encourages people to talk about the flow of information, and they can then relate to the issues involved rather then just applying another tool or technique.

For the case study companies, the IFD's were presented and the discussion was carried out with all the people who were either interviewed or approached at the data collection stage. Brainstorming was then undertaken to identify why certain areas represented on the IFD were bottleneck areas in the company. A list of all the possible causes was made, and then discussed to identify the range of potential solutions.

7.3.1.4 Problems verification

Once a record of the problems reported and identified has been made, then the list must be verified. It is important to note that the list should not be circulated at this stage, as the experience from the case study indicated that people started looking at other peoples perception of the problems, and started criticising them, rather then verifying the accuracy of the problem that they reported. Therefore, either the project manager should personally go round and verify the problems or alternatively only the problems reported by the individual should be sent to them.

Any false conclusions that may have given rise to imaginary and/or virtual problems can be rectified at this early stage.

The end result from the verification stage is a list of the problems that need to be addressed and resolved. This forms the input to the phase two of the new approach.

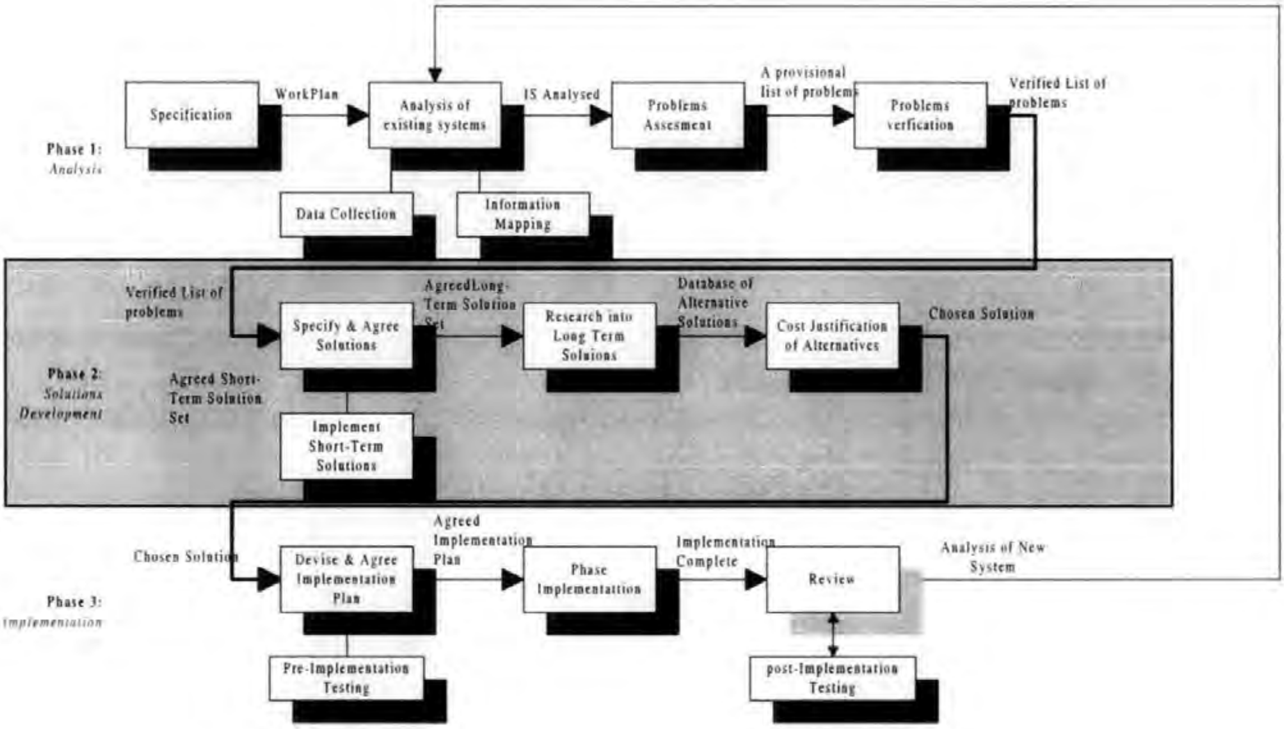


Figure 7.6 Outline of the stages in the second phase

7.3.2 Phase two – Design of the new system

The objective of the previous phase was to understand the existing information systems of a company and to make a list of the problems that have been identified. The aim of this phase is to help resolve the problems identified either by introducing new technology or simply by reorganising the existing information systems and eliminating the troubling factors. Figure 7.6 outlines the stages involved in this phase.

It is important in this phase to involve as many of the managers and supervisors, who will be using the system, as possible. As analysis of the questionnaire presented in the previous chapter, experience of case studies and research has shown that that one of the main reasons for the failure of new technology to successfully meet all its objectives, is due to the scepticism of employees. With the employment trends of the past two decades, there is an assumption, that new technology is linked with significant job losses. It is therefore no surprise, that employees feel threatened and not in control of the situation, this especially true if they are kept in the dark about the new system being developed / introduced to the company. If people are made to feel that they own and are involved in the project, then the chance of it succeeding is increased enormously.

7.3.2.1 Specify and agree solutions

The critical step to resolving the problems identified in the previous phase, is to split the problems into two categories. (i) Those that require no new investment and can be overcome by using available in-house resources, (ii) and those problems that require implementing new technology. These need to be carefully identified, and a set approach presented in the rest of this section should be followed.

Problems requiring no investment – Case studies revealed that typically 80% of a company's problems can be resolved using in-house resources and reorganising of various systems. This includes problems such as reorganising administration, redefining management structure, rearranging shop-floor layout, redesigning existing forms and documents, agreeing the format of information presentation between different departments, agreeing the means of communicating information.

Reorganising administration – The examples of this include reorganising or organising the filing structures, and reorganising the layout of the administrative office so that people can easily access the information that they need. Clearly marking in-trays or filing cabinets with information that they contain. Organising a system so that mail or information destined for somebody reaches them immediately. Although many of the examples seem very simple and obvious, the case studies revealed that by the lack of organisation of the above, caused unnecessary stress and time wastage.

Redefining management structures – ill defined chains of command or management structures can considerably confuse the operations of an organisation and its employees. This confusion can lead to work being duplicated, people having different perception of what is required and could further create rift between the employees of the business. In the case study example of Company B, 40% of the problems were eliminated by revisiting and redefining the management structure. Here the efforts should be made to eliminate any duplication of the chain of command and/or repetition of tasks by different people within the same organisation.

Rearranging of shop-floor Layout- In case study company A, the quality of the company's product was being affected due to the poor layout of the production machines on the shop-floor level. The batches of products were required to travel up and down the shop-floor for the various stages of work to be undertaken. There are sophisticated computer packages such as, 'Factory Layout' etc. that can be used to work out the optimum lay out of machines on the shop-floor. However, for most SME's, a simple diagram of the shop floor can be either hand drawn or sketched out on a simple design package stating the existing set-up. This diagram can then be redrawn to present the optimal layout.

Redesigning of existing forms and documents – forms and documents can be redesigned so that they contain all the information that is required by the people who have to implement them. For this case study the author was able to eliminate 40% of the forms and documents by redesigning them so that they contained the relevant information necessary for final production and delivery.

Agreeing the format of information presentation between different departments- This requires a simple meeting between two or more departments that share information. This information may be presented electronically, or manually. However, all parties must agree to a standard format of the information i.e. should it be presented on a spreadsheet in a certain layout. This means that information can be categorised and will help departments to cut time spent rearranging information for their use. In one of the case study companies one piece of information was being represented in completely different layouts by the sales department, warehouse and production department.

Agreeing the means of communicating information – This activity compliments the previous one, but now the departments must agree a suitable method of communication e.g. electronic, manual forms or verbal.

There are no specific techniques that are being suggested for this section as the resolutions to the problems are simple in nature and just require somebody to co-ordinate them to make sure that they are resolved and relevant people sit together to discuss them and agree on solutions. Any solution will be bespoke to the individual company.

Problems requiring investment

This should be a list of all those problems that cannot be resolved in-house and may therefore, require some financial investment and new technology to be introduced. However, before a decision can be made on where to invest money, the Information Flow Diagram must be drawn to indicate where the IT systems will be introduced to overcome bottlenecks. Introduction of new technology may also mean that the changes would have to be made to the information systems flow of the company. This should also be reflected on the IFD for the new system.

Before considering undertaking the research for the availability of a suitable new technology and then choosing from the alternatives the additional benefits of following the framework described below should be considered carefully. Due consideration at this stage will make it simpler for any future upgrades to the system.

- *Easy to use* – Any new system, however good it may be, will not be effective if the user finds it difficult to grasp the concepts and principles involved. Therefore, the suitable system must be user friendly, easy to understand, not difficult to learn how to use and straightforward to operate and apply.

- *Flexible* – It was determined that in the case study companies, during the new system design stage, the system expectation were not clear e.g. the expected production output etc. However, during the pre-implementation stage, new system requirements often emerge, a flexible design should be able to accommodate these new requirements. Any system that is formalised and rigid will not prove adequate for implementation in situations where a high number of variable are involved.

- *Cost effective* – the benefit of any new system to an organisation must be weighed against its financial costs. There are many examples of firms that over-invest in technology or purchase systems far in advance of their requirements. This can results in the company struggling financially as the rate of return on investment is low and systems are under-utilised. Cost justification techniques are considered later in the chapter.

- *Maintainable* – the reliability of the new system is central to its usefulness in the medium and long term. Any system that is unreliable will be a constant drain on the resources of the organisation and disruptive to its work. Therefore, a good system should be easy to maintain.

- *Portable* –any software / hardware that are purchased to support the new system design should be portable. The hardware must be able to function under different operating systems, and software must be able to run on these new operating systems. The rapid changes in software and hardware development can make a system idle relatively quickly, if it does not meet this portability criteria. Also any new system should not be limited by space or time, otherwise it will have to be replaced due to physical expansion or geographical relocation of the company.

- *Reliable* – Too often the companies that are heavily dependent upon computers find that they stop functioning as a company when their computer systems stop functioning. Any new system must be tested for its reliability, and ideally should be supported in the open market so that a company is not dependent on the supplier of the product for support. Some supplier companies charge extortionate costs when they know that nobody else can provide the necessary required support.

The point must be re-emphasised that when the new systems are being discussed and planned, the people who will be using the final systems must be consulted and their points of view taken on board. Also at this stage of designing the manufacturing information systems, the designers must not define what technology they should be using instead they should be concerned with the various options available to help them overcome their problems. The design should contain statements such as, "we need to have a better stock control system"; "the planning and scheduling system should be introduced to overcome bottlenecks at planning stage"; "We need some kind of Material Requirement Planning System (MRP)" etc. By this means this stage can identified the problem areas in the manufacturing information systems that require new technology to make the company more efficient.

Research and discussion presented previously in this thesis has revealed that a high percentage of the companies who introduced technology to overcome their problems, did not consider that the introduction of new technology had helped significantly to provide the company with the necessary competitive advantage. The reason for this lack of performance was due to a poor definition of the requirements and expectation to be derived from the new system. The approach presented in this section greatly assisted the case study companies to overcome this particular problem and can help any other company.

Having defined and agreed the requirements for the long-term solutions the next stage is to research into the available technology.

7.3.2.2 Researching into long-term solutions

Chapter 6 identified that managing directors who wished to introduce some kind of technology into their businesses, did not know what technology was available, or where to begin looking. This stage provides a brief guide to where research should be concentrated to identify the technology, for a company's particular need.

Guides and magazines – While the Yellow Pages may be adequate for some general needs, a list of specialist magazines and guides would need to be consulted for more specific needs. Its possible to locate specialist magazines on manufacturing management and control, as well as computers in manufacturing etc. Help in this search can be obtained from the professional engineering institutions.

These journals and magazines are not only useful to identify the potential suppliers of the technology who may advertise in them, but are also useful since periodically these magazines and journals review the technologies and report on the case studies of companies who implemented the technology. This can provide crucial guidance to the suitability of the technology for a company's specific requirements.

Government organisations - various governmental organisations like DTI, Business Links etc. have been set-up to help SME's identify new technology. These organisation, typically, have an IT aware/dedicated person responsible for keeping track of the technology available. Contact with these organisation can prove to be a crucial source of information.

However, government organisations are often considered by businesses to be inefficient, and consequently this source of reference is currently underused by most companies. Essentially, the DTI can also assist by acting as a source of help to businesses through subsidies and grants. Chapter 4, identified the government bodies dedicated to providing help for SME's in the Devon and Cornwall region. A good example of this is of case study Company C, whose problem were jointly resolved by Devon and Cornwall Business Link and the research proposed in this thesis, thereby enabling them to save the company three hundred thousands pounds.

Academic Institutions – the contemporary links between academia and industry are very weak and this is primarily due to ignorance on the part of small businesses and the level of help and co-operation that is available to them. Local universities and colleges of further education have the resources who can help identify the suitable technology for a company and are always looking out for possible case study companies to help and to learn from them in a two way interactive partnership.

Most small businesses are simply not aware of the opportunities that are available through academia. However, based on the experience of universities working with large businesses, the potential for helping smaller companies is enormous.

There is a current climate for universities to support technology and science parks. This is potentially the case with the University of Plymouth (through the Tamar Science Park) and also from the University of Exeter.

Internet – Internet is one of the best ways to identify possible suppliers of technology. An increasing number of companies are setting-up web sites, and are conducting business over the internet. A search can be conducted by typing in the exact requirements, this allows search engines to operate and identify suitable information.

Having completed the research, the company's outcome should be a list of possible suppliers, who must then be contacted to obtain promotional literature. Possibly a representative should be engaged to visit the company to present their technology and gain an understanding of the company's needs. A database of different technology solutions can then be made to help make the final decision. This database of alternatives should contain a summary of the various solutions, and hardware/software requirements for the solutions. Table 7.1 below shows a sample of an example item in such a database.

Table 7.1 A sample entry in database of alternatives

Product Entry

Name:	CS/3 Manufacturing Systems
Company:	Tetra.
Hardware Requirements:	2 x Pentium III servers, with four CPU's and 6 x 17 GB Hard Drives
Software Requirements:	NT Server or UNIX operating systems
Price:	£60000 + 10% Maint PA.
Key Words:	Bill Of Materials, Inventory, MRP, Shop Floor Control, Master Schedule, Purchasing, Costing, Order Entry.
Memory Requirement:	1 GB RAM per server
Source Code Language:	C++
No. Installed:	350
Compatibility's:	Database in SQL language
Reports and/or Related References:	Computers in industry review Nov 99
Cabinet File Address:	05-50

Abstract: The Mullinet Manufacturing System is an advanced software product that enables management to control planning and operations in the manufacturing process. It consists of eight applications that functions independently or as part of a fully integrated, closed-loop, net-change, MRP II system.

At the end of this exercise there should be a list of about ten to twelve alternative solution entries to choose from. However, before a decision is taken on the choice of the system the criteria suggested in the next section should be considered against every alternative on the list.

Selection criteria

With the immense advances in technology over the past two decades, it is very difficult for everyone to keep abreast of all the changes taking place. Selection criteria is therefore an indispensable guide for managers, to ensure that they make the correct choice when opting for a new technology. Consequently, the approach presents a selection criteria that is comprehensive in nature, as it deals with several facets of the technological change.

Compatibility of the system – the question of the compatibility of the system is an essential one. Any system purchased must be compatible for both present and future use / requirements. It is pointless to change from using IBM compatible machines to Macintosh, when all employees had training and experience in the former, and the information stored was in disks compatible with only the original systems. Some of these changes may be predictable, however most will not be. Furthermore, the system should be able to cope with most future changes that may need to be made. There is no purpose in purchasing a system that will become redundant before it has paid for its investment. For example, when installing a computer network, a pessimistic estimation of the computer capacity needs to be made based upon estimated future workload. The estimation would naturally change from business to business depending on the different situations in various industries and any company specific forecasts.

Reliability of the system – the costs of maintaining technology are relatively high and can become prohibitive, especially to the small business, if that technology is unreliable. For example, if a computer network formed the backbone of a company's information system, the cost of any malfunction would have to measured in terms of both the financial cost of rectifying the problem and also by the work disrupted and orders lost / delayed.

Expense of the equipment – many companies 'have gone out of business' attempting to upgrade their technology, and it is of the utmost importance that the technology being purchased is adequate for their use, and within their financial range. Along with aspects of the company's internal financial situation, the external financial trends in the company's industry, must also be taken into consideration.

Warranty and support – an assessment needs to be made on whether any warranty and support is sufficient for the needs of the organisation, and the quality of the equipment.

User-friendliness – from experience gained in case study companies, it was analysed that a major obstacle to the successful implementation of new technology in companies, was due to the mental barrier presented by employees. One reason for this psychological barrier stems from the lower level IT skills that the work force possess. Providing them with a user friendly system should minimise the problem.

Training programmes – A further method of tackling the psychological barrier is through formal training programmes. Therefore, any suppliers offering training programmes in the use of the new technology should be given priority status.

A novel technique for decision analysis

The previous section listed the selection criteria which must be used to short list a selection of suitable suppliers and systems. This section outlines a novel decision analysis approach, developed in this research, which can be used to make the final decision. The approach consists of asking a series questions about the alternatives. Once this is done, it should then be possible to rank paired comparison alternatives based on the information obtained. The approach obtains the most satisfactory alternative to satisfy the needs of the company. It also provides ranking of all alternatives.

After criteria for selecting alternative solutions are defined, the decision making process can begin. Solutions that are inefficient can be eliminated immediately. An inefficient system is one that is equivalent or lower in all criteria and lower in at least one criterion compared to an existing alternative. To demonstrate how this works consider that a Company X needs to buy a planning and scheduling System. The company undertakes some research and finds out from various sources that systems 1 to 20 all solve their planning and scheduling problems. The company can then rate each alternative on three criteria: cost, compatibility and system support (see table 7.2). To make a decision weighting should be given to each category for each alternative and then the system with the highest score should be selected. In the above example the weighting is given between (-15 and 25), however, a company utilising this technique can agree on some other weighting.

System	**Criterion 1:** Cost	**Criterion 2:** Compatibility	**Criterion 3:** System Support	Total
1	-10	13	4	7
2	-8	4	10	6
3	-12	5	15	8
4	-6	10	7	11
5	-5	19	11	25
6	-8	4	3	-1
7	-6	20	23	37
8	-10	1	1	-8
9	-7	12	1	6
10	-8	4	2	-2
11	-4	6	1	3
12	-10	1	22	13
13	-5	20	9	24
14	-7	3	3	-1
15	-9	8	5	4
16	-12	9	10	7
17	-6	5	10	9
18	-15	6	3	-7
19	-2	16	10	24
20	-7	3	11	7

Table 7.2 A Set of Alternatives

A careful review of the alternatives may reveal some inefficient choices, i.e., there might be systems that beat other systems in all three categories. For example alternative 7 is better than alternative 6 with respect to each of the three criteria. Therefore, alternative 6 is inefficient and can be ignored. The top three (this is an arbitrary number, some companies may choose less while others more) options from the list should be considered further and the rest be discarded. A cost justification exercise must then be undertaken on these alternatives and a final decision can then be made. The following section describes the techniques for cost justification of any investment.

7.3.2.3 Cost justification

The purpose of any investment is to realise a return on that investment. Investing in new technologies is no different and there are several techniques in assessing the value of different technologies. Below, a brief description of the two well known techniques is given. (for further details please see Drury, 1997)

(i) Pay back method – this is a number of years it will take before estimated annual savings resulting from the use of new technologies, will equal the net investment made. The typical pay back period for any new manufacturing system is typically five years.

(ii) Net present value – this is the present value of the total estimated savings over the life of the proposed investment, i.e., after allowing for an assumed minimum attractive rate of return, less the initial net investment.

Disadvantages of the cost justification methods

As with many systems in which several variables are in operation, the error margins of any measure and subsequent calculations are considerable. Consequently, the tracing measurement and allocation of many cost elements are inaccurate. In addition, due to the hard-headed practise of management accountancy, the value of intangible benefits, such as the time saved by staff, or the improved image of the company are assumed to be of no financial value. Another consequence of using cost justification methods is that the value of the long-term benefits is disregarded.

The nature of modern analytical disciplines requires that any system under observation and analysis is compartmentalised. This same philosophy is applied in management accountancy, and so no allowance is made for the beneficial effects of a proposed project on other parts of a company. This and other deficiencies of cost justification methods should be appreciated and taken into consideration during the application of it to any investment.

The cost justification exercise should suggest the best alternative from the financial perspective. The solution should be collectively agreed on and selected. A careful implementation planning approach is required for the smooth and effective implementation of the new system. The next phase of the approach present the a structured approach for implementation of the solution.

7.3.3 Phase three – system implementation

The previous two phases of the approach have outlined, in some detail, the process of identifying the requirements for a company and then investigating a suitable system. Even having identified the requirements and investigated the right system the new system could still fail to give the expected results if the system is not implemented correctly. This is an important phase of introducing any new system. However, as investigated and identified from the visits to the companies (chapter six) in the region, this phase is often underestimated, resulting in devastating results.

The implementation of technology in firms is a complicated matter and many considerations, such as, the location of servers and workstations, the layout of offices, wiring for networks etc. have to be made. The considerations also need to be made on the different phases of the implementation of the new system e.g. what departments should be automated first, the training of different modules to staff of the different departments etc. prior to any 'Live' implementation the testing of the new system also needs to be carried out to ensure that the system performs well and provides expected results according to the solution design identified previously. The Figure 7.7 below shows that this phase has three stages and two sub-stages steps in this phase of the model of the new approach.

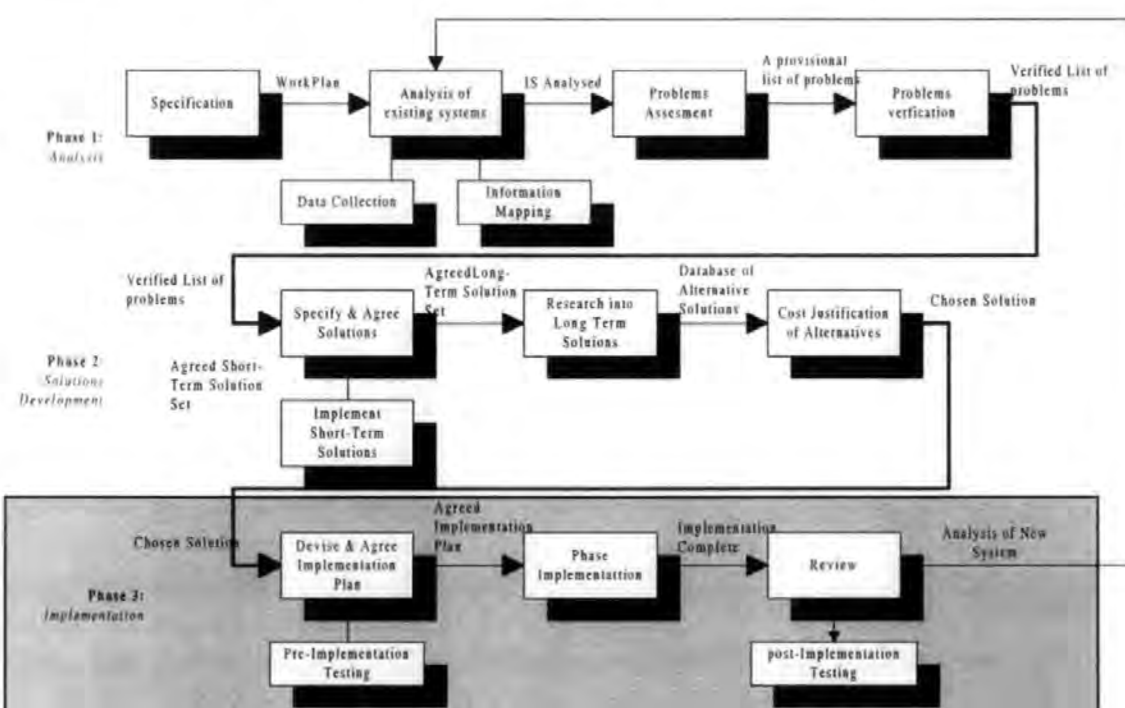


Figure 7.7 Phase 3 – system implementation

7.3.3.1 Devise and agree implementation plan

As reported in the last chapter, for a few companies the investment in technology failed to yield the expected benefits due to the ineffective implementation. The companies typically adopted a 'Big Bang' approach. Whereby new system, overnight, replaced the old system. Resulting in confusion, loss of confidence and rejection of the system by the staff of the company. Even though the training was given in the use of the new system. However, to suddenly leave the old system and adapt to the new one was found to be very difficult, because people forgot what they learnt at the training and also training could not cater for all eventualities.

There is therefore, a need to adopt a different approach to implementation. The Figure 7.8 shows three possible approaches to implementation. (i) Big Bang Approach, (ii) Parallel Approach and (iii) Step Approach.

The Big Bang approach has already been discussed and disadvantages highlighted. This approach is not suitable for SME manufacturing systems implementation. The literature review confirmed that this approach is not adopted for even large organisations. The only case for a big bang approach would be at a situation where any other approach is impossible, for example the market data for stock exchange which is live and alters every few seconds.
The Parallel approach is suitable for micro and developing SME's as the system is not expected to be very big in these companies and therefore having two systems running side by side is a practical option.

The Step approach is particularly suitable for a systems that spans the whole enterprise and requires different modules for different departments, for example planning and scheduling module for the manufacturing department, stock control

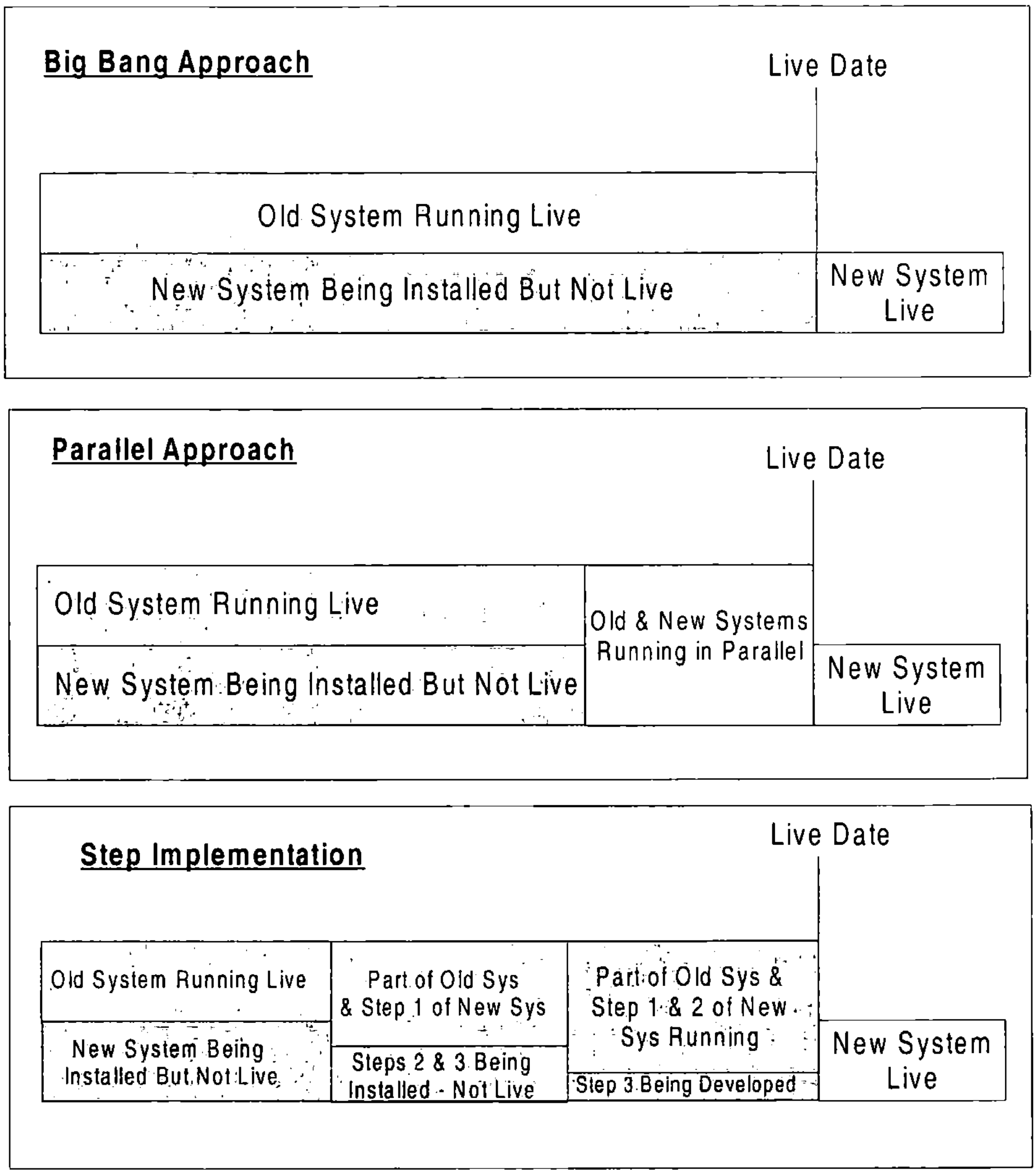


Figure 7.8 Three System Implementation Approaches

module for the warehouse and accountancy module for administration etc. In this scenario each department would be automated individually, allowing time before next department is automated so that the staff of the first department can master their module.

This stage of the implementation phase should conclude by collective agreement of all parties concerned on what approach of implementation would be followed. The next stage outlines the practical steps involved in implementing.

7.3.3.2 Phase implementation

The Planning of system implementation can be divided into six different steps:

a) Identify stages
b) Priorities stages
c) Identify activities
d) Allocate resources
e) Implement plan
f) Implement next stage

The first step in the system implementation is to identify the various stages that may be required to complete the implementation. This may include identifying the departments that need to be automated, and when and what are the requirements that need to be met such as wiring of the network, purchase of the appropriate furniture etc. This stage should include a complete list of stages, which may be over one month or six months and more.

The next step is to prioritise the stages identified in the previous section. The strategy of any company is central to the configuration of its priorities and it is these priorities that may determine the order in which new technology is implemented, in some companies. An example of the link between priority of a company and order of the steps of implementation was Case Study Company A. This company had to introduce itself into the High Street store market, in order to cope with the high demands on its systems, the information systems had to be upgraded to electronic data interchange (EDI) first which was required to deal with major companies and then the manufacturing systems needed to be changed to produce a higher volume of products.

The priority of the steps may also be dictated by the ease of implementation, for example it may be easier to introduce the new system in accounting department because the staff in the department may be relatively more computer literate then other department.

Having prioritise the steps the next stage is to identify all the tasks that have to be undertaken to complete the priority step. This will include a list of all the activities that are required to complete this step. Which may include tasks like, purchase the hardware kit, install operating systems, delivery date for furniture delivery, booking of training room for training etc.

The fourth stage is to allocate resources for the tasks identified in the previous section. This should include, booking time of key individuals, commitment from the financial director for spending money, agreeing on the dates when systems will be installed etc.

If one is satisfied with all the above steps, then the plan should be implemented. And finally, only after successfully implementing the previous phase should one move to the next. This ensures that the various phases of implementation link into each other and form a coherent whole.

There may be cases where two or more phases have to be implemented simultaneously, therefore the management needs to ensure that in such cases the confusion is minimised and the staff are sufficiently trained and confident to work with the new system.

7.3.3.3 System review

Any new system must be reviewed regularly to ensure that it is giving the desired results and that there are no deviations. This could be achieved by the following method:

- Set review criteria
- Audit new system
- Compare to initial audit
- Report findings
- Agree action plan
- Set next audit interval

To leave the new system running without any initial monitoring or review would defeat the purpose of implementing a new system. Review criteria have to be defined and adhered to. The review criteria reflects the priorities of the company and so each part of the new technology and its implementation are subject to a review, the importance of which is determined by the relative importance of that particular part. In brief, the review criteria ensure that the new technology and its implementation is achieving the objectives of the company.

An audit in the accounting profession seeks to determine the financial state and health of a business. By analogy, any audit of the new manufacturing system would reveal its strengths and weaknesses, thereby indicating the extent to which it has been successfully implemented.

There are many ways in which the system could be audited and different parts of the system would need to be analysed in different ways. Methods of measurement could include the inspection of productivity levels, or even a questionnaire.

Essentially, the implementation of manufacturing systems seeks to achieve an improvement in some part of the company organisation, financial strength or quality of product. Whatever aims the implementation of new technology has, the results have to be compared with any previous record of performance and this is done through a systematic and comprehensive comparison between the initial audit and the latest audit of the new system. This exercise should identify the improvement in the reduction of lead times, improvement in quality, and savings made due to less pilferage etc.

Any findings that are made from comparisons between the old and new manufacturing systems, need to be presented to senior management in the company and an action plan agreed upon for the corrective actions.

The action plan of senior management within the company needs to consider the following; firstly any problems needed to be listed in order of priority, then the steps specific to the resolutions of each problem should be laid down and responsibility allocated to various personnel.

The timing of the next audit has to be set by considering some aspects of the Manufacturing systems. The first aspect involves the lead-time of the products since any meaningful audit would have to allow the system to run over many cycles. In addition, other variables should be allowed to run their cycles in order to obtain sound results and subsequent knowledge of the system.

7.4 Conclusions

This chapter has presented a novel approach that SME's can use in house to introduce manufacturing information systems in their business. The approach drew extensively from the research done in Devon and Cornwall, in particular with structured visits and interviews with seventeen SME's in the region. The approach also drew lessons from the mistakes made by SME's when introducing new technology.

The new approach presented is a substantial improvement over the existing in-company or vendor led approaches, the latter of which tend to tie companies in to very costly and open-ended relationships. Where users are not involved in identifying problems devising solutions to their own problems, nor do contracting consultants devote much effort to developing the skills and knowledge of company staff. This results in the lack of commitment from the company staff and poor use of the new system.

By using this original approach, in-house, the company will not only have a documented record of all the various stages, but will also have in-house trained and experienced who may be able to deal with in future expansion to the system glitches in the system.

The content of the approach consists of three phases – Analysis, Solution Development and Implementation. Each of three phases have a number of stages, which are further divided into various steps.

From user-friendly perspective the approach has been simplified as far as possible with the avoidance of any complicated techniques. The approach has introduced novel information mapping and other decision making techniques, that are easy to use and apply. The approach is original and comprehensive in nature that leads a user from identifying the need for new technology to the implementation. Chapter 8 considers the implementation of this new approach within case study companies to validate its performance.

Chapter 8

Validation of the New Approach

8.1 Overview

For any new approach to be considered valuable and deserving of recognition, it must be demonstrated, in 'real-time' experiments to prove that it is relevant and practical to the industry concerned. The case study technique was chosen to be the most suitable method of validating the proposed approach. However, the inherent disadvantage of this technique is that it only considers a specific application. To overcome this several case studies are required to obtain a reliable conclusion. Also, the case studies have been chosen as they employ various combinations of phases / activities, thereby making the test process more robust.

To establish the suitability of the new approach, for introducing manufacturing information systems in SME's in the Devon and Cornwall region, the approach was validated in two different stages. First of all the evaluation of the approach was undertaken at a seminar, delivered by the author and organised jointly by Plymouth Teaching Company Centre, DTI and Devon and Cornwall Business Links for the managing directors from SME manufacturing companies in the region. Secondly the approach was demonstrated, and applied to five companies in the region. The above validation and evaluation methods allowed the author to facilitate enhancement to the approach, as well as establish its validity at the practical level. This chapter, therefore presents the results of these validations.

8.2 Evaluation by seminar to practitioners

To facilitate the enhancement and revision of the approach, it was initially presented and discussed at a seminar delivered by the author. The seminar was attended by 16 practitioners. Ten of these delegates included managers and senior directors from the local manufacturing SME's, who were planning or considering improving their businesses, by employing new technology. Two delegates were academics from the manufacturing and business school at the University of Plymouth. The remaining four delegates were from the local offices of Business Link and the DTI.

Initially, a presentation of the conclusions discussed in chapter 6 concerning the manufacturing businesses in the Devon and Cornwall region, along with problems faced by such companies, was made to the participants. Subsequently the new approach was presented, explaining how the problems experienced by these companies could be overcome, by employing the new approach. Explanation of information systems and their use in manufacturing was also undertaken.

Following the presentation, each company represented considered the applicability, and usefulness of the approach to their own company.

The discussion after the presentation consisted of question / answer and feedback sessions. The responses gained were extremely positive, with almost all participants appreciating the long overdue, need for such an approach. The company representatives, particularly, welcomed the simplicity and the ease of use of the approach, as well as the use of information systems analyses technique to understand the existing systems. The use of Input /Output diagrams and information flow diagrams for mapping the existing information systems was also greatly appreciated due to its simplicity of development compared to the enormous quantity of information generated as a result.

The participants were asked to consider if they felt that they could use the approach in-house, without any help from outside, and whether anybody would employ the approach in the near future. The general consensus indicated that the approach was simple and yet effective for companies to use. The participants from the Business Link and DTI suggested that the approach be put in the form of a workbook for companies to use. The other companies agreed, and the DTI representative further offered to publish such a book.

At the end of the seminar, a managing director from of one of the companies indicated that he would like to use the approach in his company, and offered his company as a case study example. A representative from the Business Link also suggested a local company, that could benefit from the use of this approach. The second and more detailed stage of validation, reports on the case study results for both of the companies together with the applications to three other companies.

8.3 Validation by case study

This stage of validation involved the actual implementation of the new approach at five local SME manufacturing companies in the Devon and Cornwall region. The approach was used at these companies with the company providing a project co-ordinator who was responsible for the overall implementation of the project, and the author involved as an observer/ guide to the use of the approach. The observations provided insight into the feasibility of the proposed approach in the real environment. The results obtained from the case study are 'Commercial in Confidence' and are described while maintaining the anonymity of companies.

8.3.1 Company A

Company A is a food manufacturing company, it produces high quality food products including mandarin in liqueur, high quality salad dressings, Christmas puddings, chocolate fudge etc; in total the company has 103 different products. Its current share is 30% of the market in Britain, and it also exports to the USA and Australia. Some of the major customers of this company include, Harrods, Boots, Marks and Spencer, and other speciality food companies. The company's products are seasonal based with 80% of sales being achieved from June to December. Although the company has been established for over one hundred years, there have been several changes in management, the most recent of these was in 1993. The company employs fifteen permanent staff and employs a further forty, during the peak period. The company's turnover in 1995 was £1.2 million.

The company has some two thousand stock items, which are supplied by about forty companies, the majority of which are located in the Devon and Cornwall region. Some stock items, mainly glass bottles and specialist food items, are also imported from the continent.

The company contacted the University of Plymouth for help and consultancy in overcoming various problems in the manufacturing department: Ninety % of all orders were being delivered late at that time. There had also been several problems in the quality assurance area, particularly in the level of alcohol in jars being either too much or too little; occasional discovery of fruit flies in the jars, and poor hand finishing on packaging. The company had about £250,000 committed to work in progress. There were severe stock control problems, with production often being halted because of the insufficient levels of stock.

The project at Company A lasted for over six months, it started with a meeting between the author, project co-ordinator and the Managing Director to define the project specification. The Table 8.1 shows the results of this discussion. Please note that the project specification, at this stage, is only a guide and not to be adhered to strictly.

Project Description: To determine an IT solution for manufacturing problems. **Project Co-ordinator**: A. Anybody
List of problems to be solved: • Long lead times • Poor quality • Poor stock control • High work in progress
Estimated Time for the Project: Six to Eight Months
Personnel expected to be involved during the project: • Accountant • Production Manager • Warehouse Manager • Sales Manager • Managing Director • Supervisors from the Shop floor • Administration Secretary
Costs Estimation: **Software Solution: £40,000** **Installation: £ 5,000** **Other costs: £ 5,000** **Total Budgeted £50, 000**

Table 8.1 Project specification for Company A

The diagrams below indicates the results of an analysis, recorded using Input / Output Diagrams and Information Flow Diagrams:

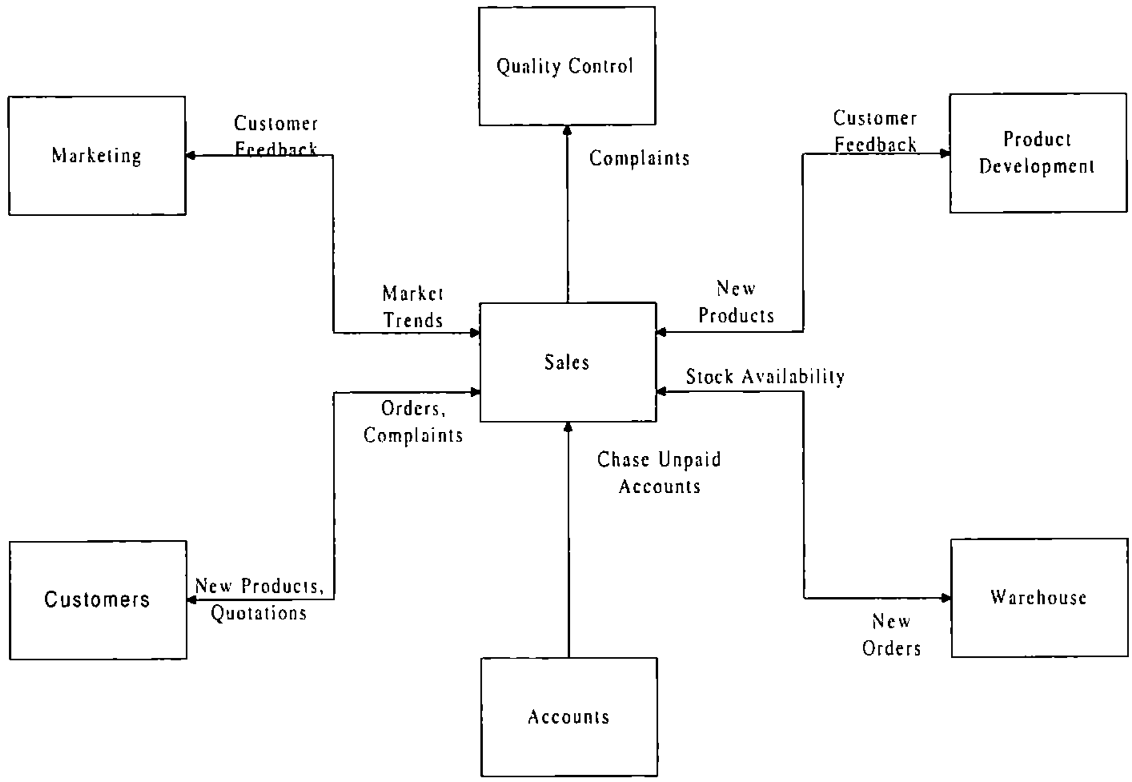


Figure 8.1 Shows Input / Output Diagram for Sales Department for Co A

The above diagrams shows the communication between the sales department and the other departments within Company A. It should be noted that the sales and production department, had no information to exchange and yet in practice the two departments were constantly meeting to discuss production plans and schedule. Also, there was a one way communication process from accounts to sales and from sales to quality control. Similar diagrams were drawn for all departments. The Diagrams below shows the Information Flow Diagrams IFD's for the various activities:

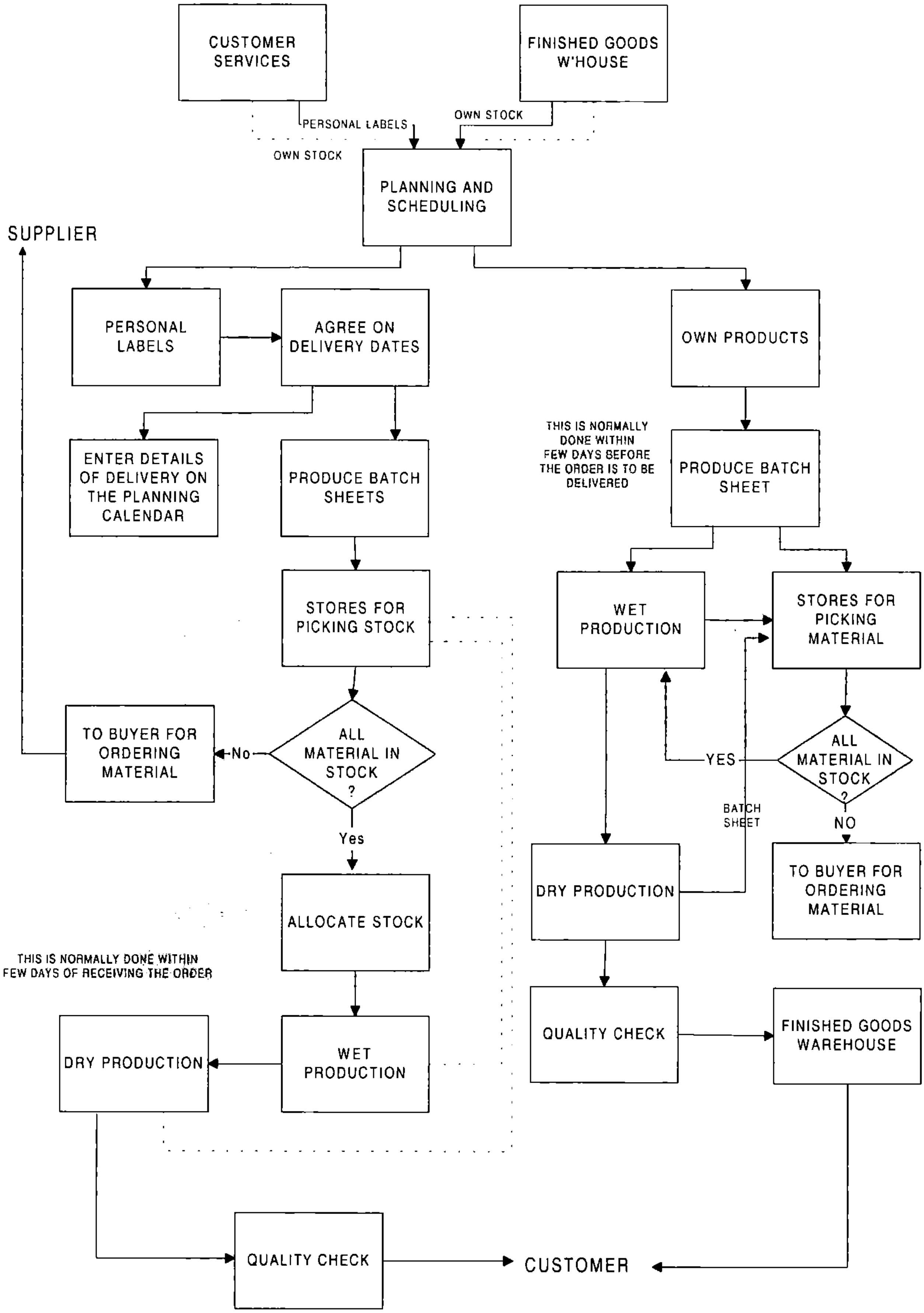


Figure 8.2 Current planning and scheduling system for Company A

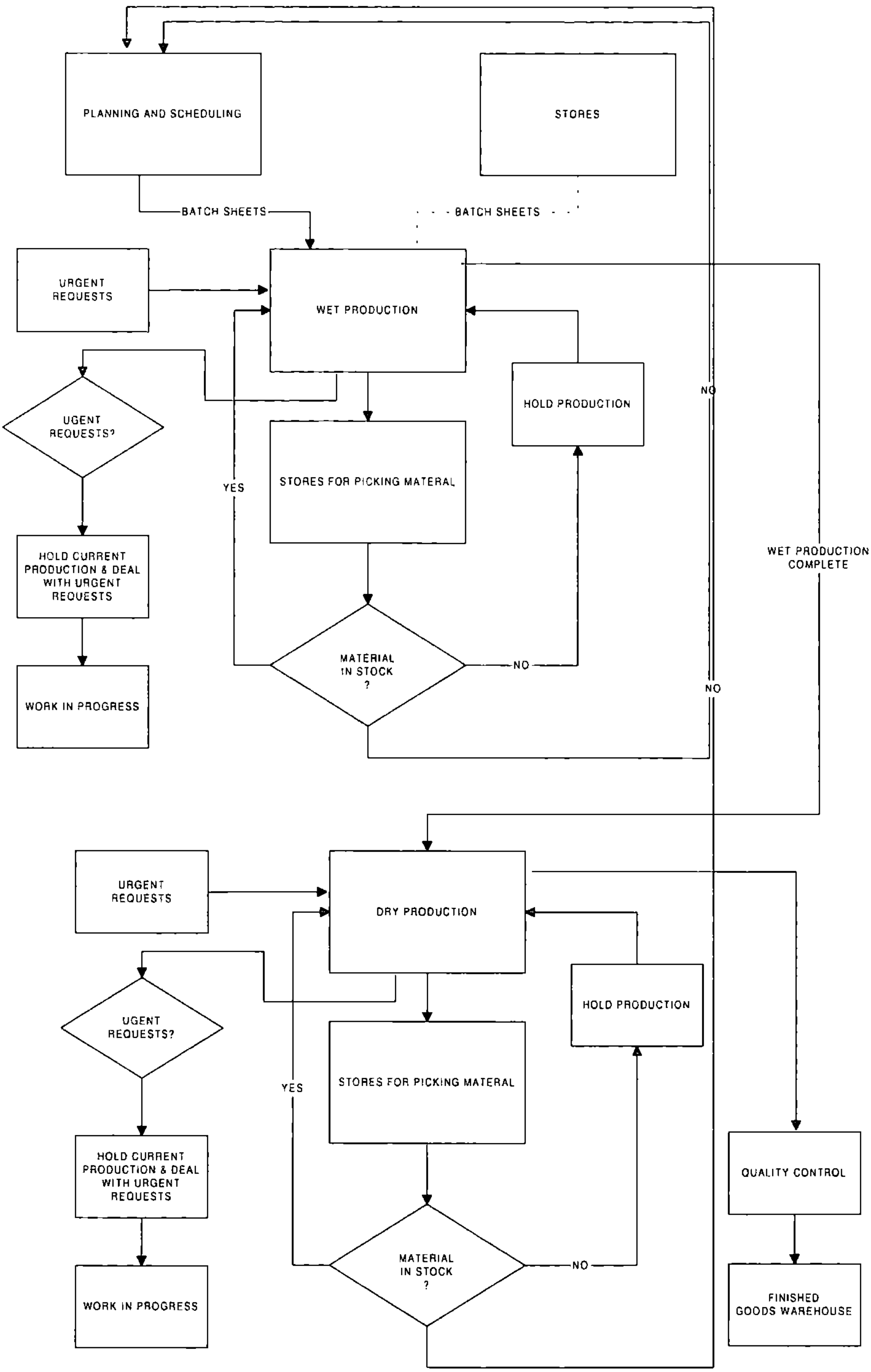


Figure 8.3 Current production system for company A

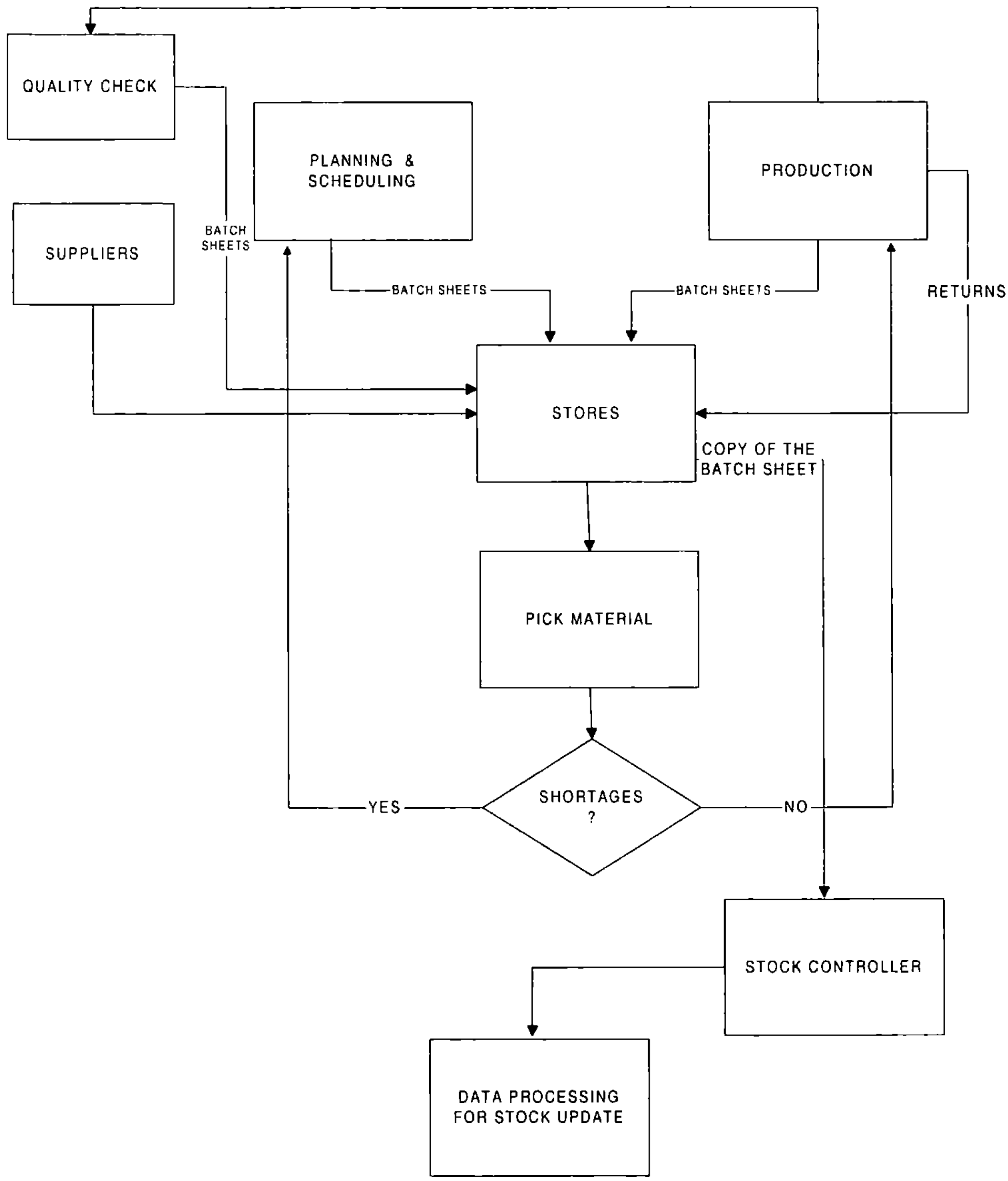


Figure 8.4 Current systems for stores for Company A

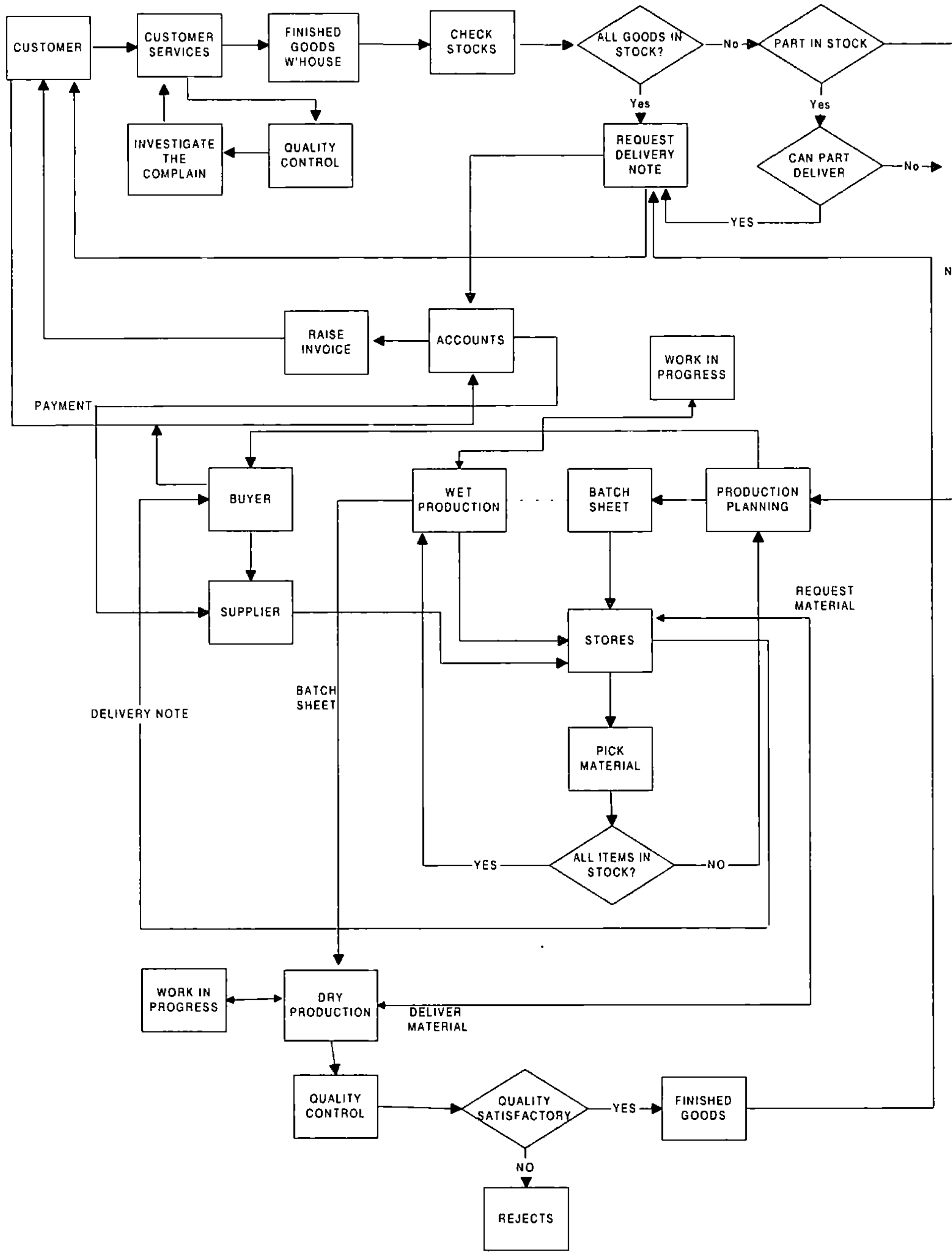


Figure 8.5 Overview of order handling system for Co A

Figures 8.2 to 8.5 demonstrate the analysis of the existing systems of the various departments. These diagrams can then used to compile a list of all the problems identified. It must be realised that the diagrams were compiled following the application of various techniques to assist the analysis process, i.e. Interviews, observation, document searching etc. The Table 8.2 is the list of problems created from the various problems as perceived by the company staff and the assessment of the diagrams.

Identified problems for Company A

1. **Incomplete information passed between different departments.**
2. **The orders from customers not clear**
3. **Poor planning and scheduling**
    (a) Duplicate booking of shifts
    (b) Too many or too few production staff arranged
    (c) Poor estimate of time required to complete a batch, often too little
4. **Poor production control**
    (a) Too many people on shop floor
    (b) Too many orders being made at the same time
    (c) Production forms difficult to understand
    (d) Untrained staff
    (e) Poor layout of the production machines
5. **Poor stock control**
    (a) No mechanism for recording out of stock items
    (b) Long lead time on many stock items
    (c) No recording of the movement of stock in and out of warehouse
    (d) Poor understanding of finished goods requirements
    (e) Poor or no estimation of stock requirements
    (f) Poor quality stock
    (g) Poor storage of stock – items passing sell-by dates
    (h) Difficult to locate stock items in the warehouse
6. **Lack of team work and too much backbiting / slandering**
7. **Significant amount of unaccounted stock items and finished goods**
8. **The existing IT technology underused due to fear of IT**

Table 8.2 List of problems identified for Co. A

The problems were then separated into those that could be resolved with in-house resources and those requiring investment and introduction of IT system. The Table 8.3 lists the problems and the in-house solutions.

Short term problems and in-house solutions

1. ***Incomplete information passed between different departments***

Solution: Call a meeting with department heads and define the exact information requirement between each department and the format.

2. ***The orders from customers not clear.***

Solution: Design an order form laying out the exact information required from the customers. And implement the form strictly so that no order is processed until the order form is completed, even though the form may have to be completed by the sales team.

4 (d). Untrained staff

Solution: Devise a training programme, that must be attended by all employees when they join the company.

4 (e). Poor layout of the production machines

Solution: Arrange a meeting with the shop floor supervisors and the production manager to devise a suitable shop floor layout for the production machinery. Then arrange for the movement of the appropriate equipment.

6. Lack of team work and too much backbiting / slandering

Solution: Call a company conference at a hotel and openly discuss issues and provide solutions via team games etc.

9. The existing IT underused due to the fear of IT

Solution: Run an in house IT training programme

Table 8.3 List of problems and solutions to be resolved in-house

For the case study company A, all the above solutions were successfully implemented. However, it was considered that an IT course was not sufficient to dispel the fear of IT. The company conference, although costly, was particularly well received and appreciated by all, it was decided to make it an annual event. The various other problems listed in Table 8.2 were to be resolved by implementing a suitable system with modules for, production planning and scheduling, production control and stock control modules. A matrix of six alternatives was made. Table 8.4 below shows the package names and the weighting given to each options.

System	**Criterion 1:** Cost	**Criterion 2:** Compatibility	**Criterion 3:** System Support	Total
Tetra Chameleon	-5	8	10	13
Pegasus Opera	20	10	15	45
Sanderson	-15	1	7	-7
Caliach	5	20	1	26
Visual Manufacturing	-15	15	8	8
Mapics	-20	15	7	2

Table 8.4 Matrix of alternatives

The top 2 were chosen as the best option, being Pegasus Opera and Caliach systems as they had the highest total. Table 8.5 indicates the calculations for the payback method of cost justification.

Payback calculations for Pegasus Opera andVisual Manufacturing				
Year	Pegasus Opera		Caliach	
	Return	Payback	Return	Payback
0	-20,000	0	-35,000	0
1	5,000	5000	5,000	5000
2	7,000	12000	8,000	13000
3	7,000	19000	8,000	21000
4	7,000	26000	8,000	29000
5	7,000	33000	8,000	37000

Table 8.5 Cost justification using payback method

From Table 8.5 the best system, using payback method of cost justification the best option is Pegasus Opera. This option pays the return on investment in just over three years. Caliach system takes nearly five years to payback the return on investment. Therefore the option of Pegasus Opera systems was selected.

It was decided to purchase and implement the various modules of the system over eight months, and to run the system on the existing network and servers. The Table 8.6 summarises the evaluation results of the approach for Company A. These results were summarised by the project co-ordinator and the MD of the company A.

Approach assessment by Company A
Role of the approach: The division of the approach into three distinct phases and the structured stages of the approach was found to be particularly useful. The language of the approach was considered to be easy to understand and follow by the project co-ordinator. No problems were encountered in the progression through the approach.
Project management tools: Although the use of the Gantt chart was found to be useful to layout the various tasks in a logical sequence. However, it was felt that some kind of technique / tool could have been added to manage the personal times of the peoples involvement in the project and day to day running of the company. It was also felt that some tool could have been added to measure the in tangible losses and gains, i.e. peoples time away from the company and image of the company etc.
Tools and techniques: The use of tools and techniques within the approach were regarded as useful for generating and recording relevant information. The use of input / output diagrams and Information Flow Diagrams were particularly appreciated for recording the information gathered through analysis stage. It was highlighted that some guidance on pre-implementation testing could be useful to assess the systems before going live.
Structure and guidance: The structure and guidance of the approach was sufficiently simple to allow the comprehension of the logical progression of the approach. The structure and approach used was "*ideal for small manufacturing companies*". Structure and guidance allowed the project to be implemented in small chunks without the worry of losing track of the project.
Implementation: Different approaches to implementation provided an insight into importance of this phase and highlighted the fact that the project fail to give the expected results, if the implementation phase is not well planned.

Table 8.6 Evaluation of the approach from Company A

In addition to the above evaluation, the MD of Company A regarded the approach as a highly useful tool to understand the actual working of the company and highlight the causes of many problems. He was particularly appreciative of the analysis phase and the various techniques that it suggests. The use of diagrams to map the flow of information and processes was also greatly valued. However, it was suggested that it would be an advantage if general templates of various forms e.g. order forms, works forms etc. were provided as examples. Any company can then modify these example forms to their specific needs.

8.3.2 Company B

Company B is a company specialising in manufacturing and mounting far-reaching lifts on all kinds of vehicles, with world-wide customer base. Major customers include Dubai Airport, British Telecom, and South West Electricity Board. Company B are the second largest manufacturers in its sector in the UK. The annual turnover of the company for 1997 was £1.4M and it employs 20 permanent skilled staff.

The MD of the company approached the University of Plymouth's Mechanical Engineering Department, for assistance in overcoming problems with quality control, and quality assurance. All orders were being delivered late, even when the lead times were twice as long as some of their competitors. The MD of the company was provided with an overview of the approach, and he agreed to use the proposed approach to resolve the problems identified.

The various diagrams and list of problems etc. are given in Appendix B. It was decided to use version two of the information flow diagram for this company to record the analysis of existing systems and designing a new system. The case study of this company only utilised the first phase of the approach, analysis, as it was discovered that all the problems within the company related to poor management, and ineffective systems, rather then absence of any technology. A significant number of problems were overcome by redefining the organisation structure, and redefining job roles and job descriptions.

The company managing director evaluated the approach, (Table 8.7), and highly commended it. He further added that without the approach he would have invested more money into new technology rather then identifying the core issues. The MD suggested that the analysis phase should include a list of possible questions to ask interviewees that the user of the approach can utilise in his/her investigation.

The Figures 8.6 and 8.7 demonstrate the use of second version of information flow diagrams used for this case study.

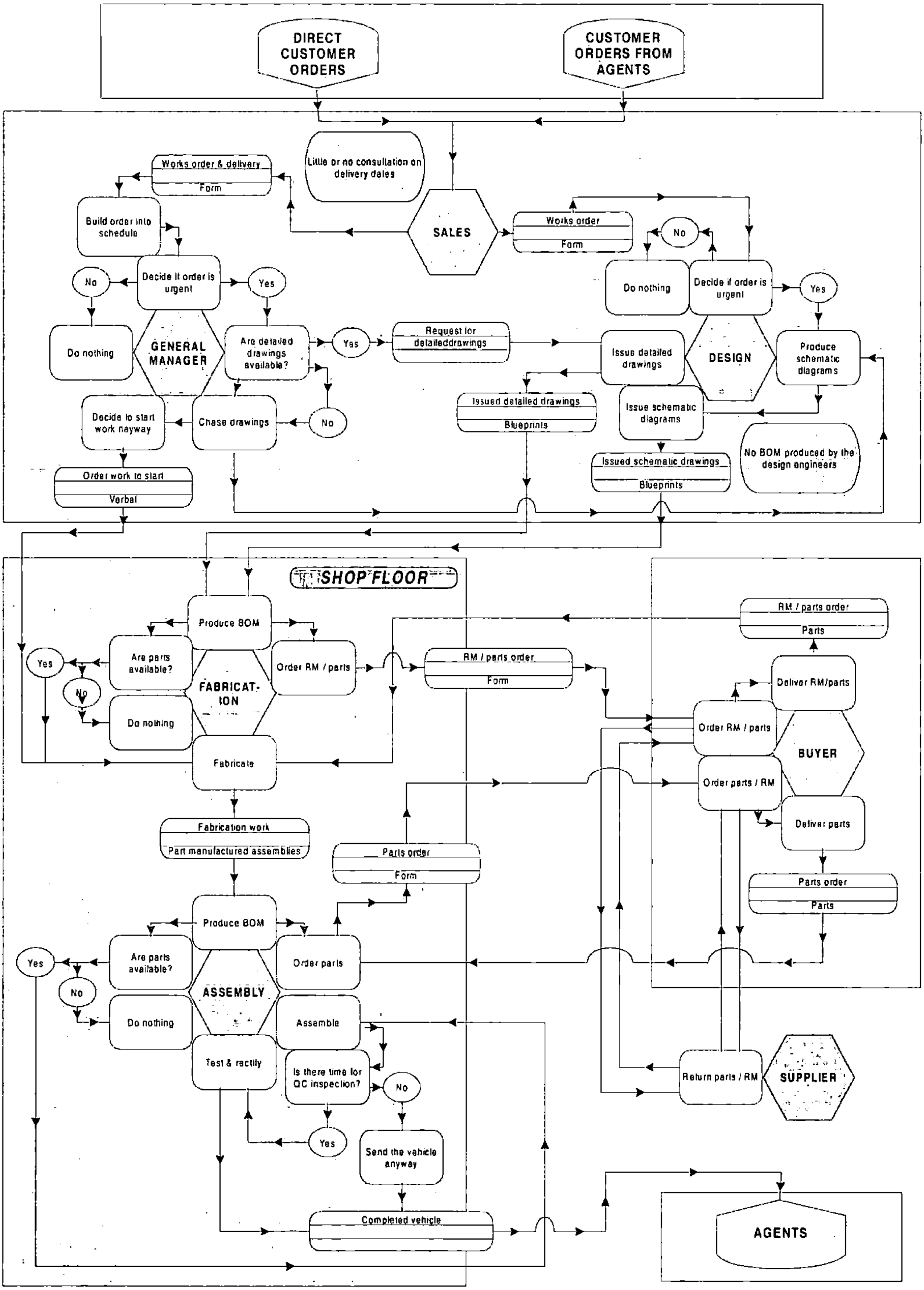


Figure 8.6: Existing customer order processing system mapped using version 2 of Information Flow Diagram (IFD)

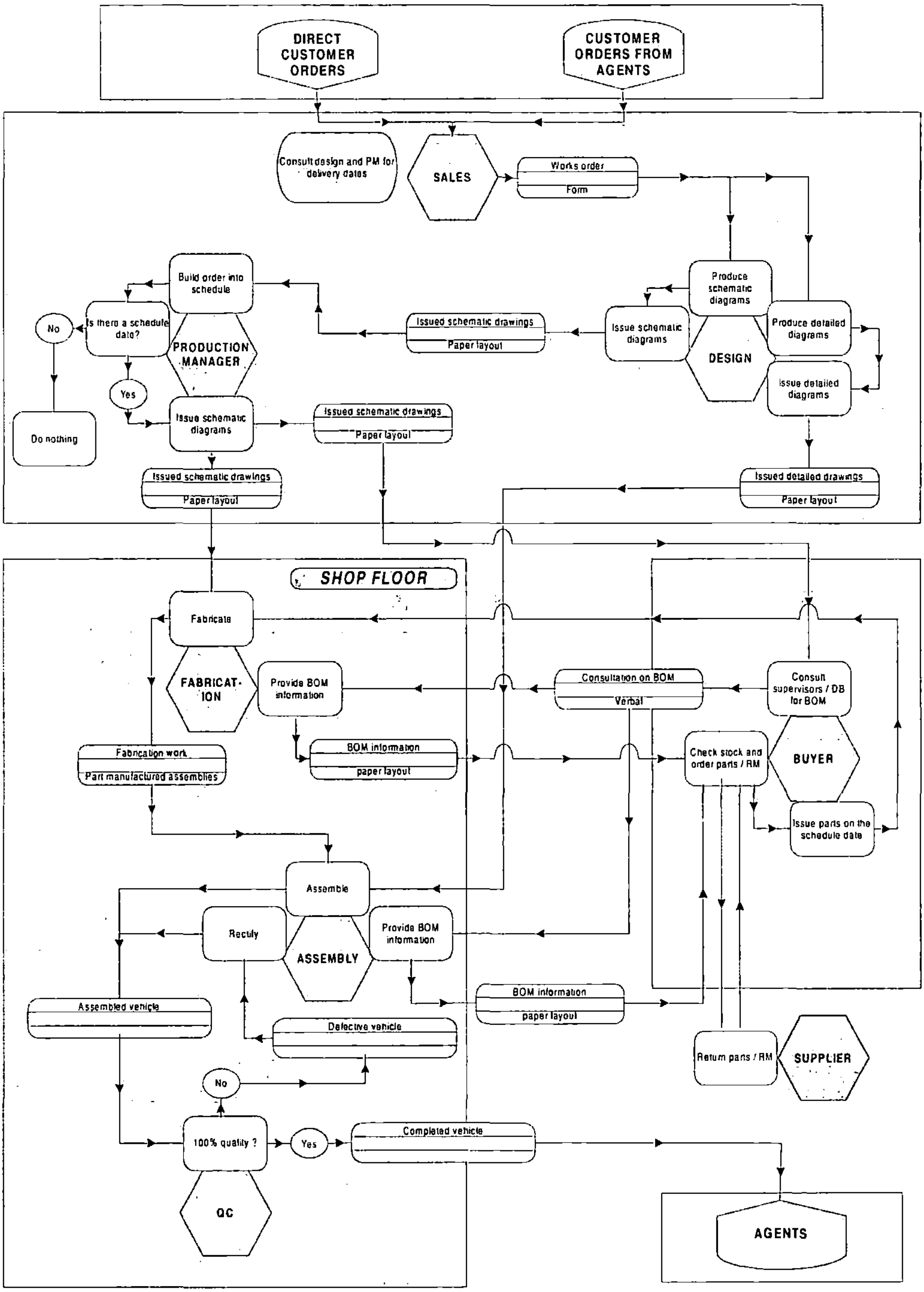


Figure 8.7: Revised customer order processing system mapped using version 2 of Information Flow Diagram (IFD)

Approach assessment by Company B
Role of the approach: The role of the approach was crucial as without the analysis techniques and guide from the approach the company may have invested substantial sum in new technology. The approach was sufficiently simple to allow for the easy understanding of the concepts and techniques.
Project management tools: The company had already been using Gantt charts on Microsoft Project 98 and find the software appropriate for the needs of managing small scale projects.
Tools and techniques: The use of simple diagrams to map the current information was found to be exceptionally useful. The use of three storey rectangular boxes for recording various information was also much appreciated. The MD was interested in learning other mapping tools and suggested that a brief introduction of other techniques like Data Flow Diagrams and IDEF0 diagrams would be useful.
Structure and guidance: The structure and guidance of the approach was Excellent, it was simple and yet highly comprehensive and effective. The approach made the company consider in areas where it would have otherwise ignored. The language of the approach was to be non-technical which made the readability and understanding to be very user-friendly.
Implementation: The ideas in the implementation phase make the company aware of possible pitfalls and makes the process of implementation much smoother and controlled.

Table 8.7 – Evaluation of the approach by Company B

8.3.3 Company C

Company C is a small surf board manufacturing company in Newquay. It employs about twelve people. The turnover of the company in 1997 was approximately £0.75M pounds. Surf manufacturing is a very specialist market, with the majority of the sales occurring in the summer. Normally each surf board is hand carved from polyurethane board with finishing touches applied according to the demand from the customer.

The company was referred by the local Business Link and the DTI office for help, and guidance in developing some kind of an automated machine that could shape the first process of the board, according to a defined shape. The company had a limited budget of about £40,000 to develop this machine. The company's own research indicated that there was only one machine of this kind available in Brazil costing more than £0.5 million.

Although this case study did not require the full use of the approach, it did however, make use of the research by utilising part of the phase 2 of the approach, regarding researching for the solution. This case study is also an excellent example of the collaboration between manufacturing company, academia and the DTI.

After extensive discussion between the author, MD of the company the University of Plymouth Mechanical Engineering Department and research from the internet, and journals it was identified that a similar machine was developed by the Ministry of Defence (MoD) for building ship-models. After visiting the MoD to look at their prototype, the manufacturers of the prototype were approached and an outline of the requirement for the Company C was presented.

The AutoCam company based in East-Anglia, subsequently visited the Company C in Newquay and gave a quotation of about £30,000 for the development of the required machine.

The MD of Company C was grateful for the assistance provided by the approach and the author. He further added that although the ideas for the research for suitable technology, presented in the approach, were simple but he would not have thought of them if the guidance was not there and would have wasted considerable time and resources. The full approach was not applicable to this company.

8.3.4 Company D

Company D manufactures and markets security boxes that are used by security companies to take the money in and out of banks. These boxes have a built-in device so that if the boxes are stolen, the device will trigger the release of red dye that would stain the money. The company has a major share of the UK market, and exports to a few European countries. The company employs 140 people.

Even though the company has grown two fold in the last six years, due to increase in export, unfortunately the systems within the company never grew with the company. At the time of the case study the company had severe problems in almost all departments, including sales and administration. The quality assurance was a major problem with 20% of the goods being returned due to the bad quality. It was the feeling of the MD that he no longer understood the manufacturing processes of the company. Although, a new production manager had been appointed recently he also struggled to understand all the processes.

Following a visit to the university by a company representative, the author visited the company in return and decided to employ the new approach. The co-ordinator from the company was the production manager. Version 2 of the information flow diagrams were employed to map the existing systems and to design a new system. This case study lasted for over four months, and when completed various new systems were designed and implemented for the company. It was also the intention of the of the manufacturing manager to invest in an ERP system, but unfortunately due to the internal politics of the company this did not materialise. However, the work carried out, using the approach was considered to be extremely successful.

The evaluation results presented in Table 8.8 represents comments made by the manufacturing manager of the company.

Approach assessment by Company D
Role of the approach: The company found the approach to be practical for understanding the various information systems of the company. The company has decided to use the various techniques for recording any new information systems. The approach provided the company with logical steps in identifying bottleneck / weaknesses in the existing information systems. The approach also provided the company with ideas, e.g. effective layout of shop-floor machines etc. to increase productivity and minimise pilferage's.
Project management tools: The company did not think the use of Gantt charts alone were sufficient for management of complex project. Suggestions were made to include various principle embedded in computer packages like Microsoft project, and Visio to be included as part of the approach.
Tools and techniques: The company was appreciative of the various techniques for analysing the existing information systems. The use of record searching and document analysis was more effective for the case of this company. The version 2 of Information Flow diagrams were praised for their simplicity in recording complex information. However, the company felt that the cost justification techniques presented in the approach were too simple and overlooked many issues like the intangible benefits etc.
Structure and guidance: The structure of the approach was ideally suited for the company. It allowed the company to work with the approach at their own pace. The guidance was simple to follow and gave a lot of ideas at various stages of the analysis and new system design. The analysis techniques were applied to all departments of the company including accounts and sales & administration.
Implementation: No specific comments were made as the company did not use this phase of the approach..

Table 8.8 – Evaluation of the approach by Company D

8.3.5 Company E

Company E manufactures furniture for handicapped and special needs children. The company supplies furniture to special needs schools throughout the UK, and is the only supplier of its kind in the Devon and Cornwall region. The company has been in existence for over ten years. In 1997 the turnover for the company was just over £900,000.

The company had developed from a one man band to 20 employees, over the ten years. The various procedures and systems of the company developed without any planning or systems thinking. The company approached the University of Plymouth for assistance in overcoming problems in stock control, quality control, long lead times and manufacturing planning. The company decided to become a case study company for the new approach as they could see the potential benefits. A manager from the company was appointed as the project manager.

Detailed system analysis were conducted using the techniques and tools presented in the approach. It was discovered that majority of the problems lay in the company having poor information systems and procedures in place. The management structure was also re-organised. At the solution development phase it was concluded there was not a need for any investment in new technology because the almost all problems could be resolved by re-organising the information systems and management structure. The evaluation of the approach was done by the project co-ordinator, please see Table 8.9.

Approach assessment by Company E
Role of the approach: The approach played a crucial role in understanding the current systems of the company and re-organising new systems. It was noted by the company that the approach was too broad and comprehensive for there particular needs. Some aspects of the approach were found too difficult to understand, particularly during the implementation phase.
Project management tools: The Gantt charts were found to be useful for the project management. However, the company felt that it was too time consuming to initially make the Gantt charts and then updating them on regular basis.
Tools and techniques: The input / output diagrams played an important role in understanding the communication between different departments. The use of version 1of information flow diagrams, was also useful in understanding the overall processing of orders and stock control management.
Structure and guidance: The analysis phase was found by the company to be well structured and guidance provided was sufficient to lead a novice through an important phase.
Implementation: The implementation phase was not appreciated by the company. It was found to be over complicated and not relevant or practical for the company's needs.

Table 8.9 – Evaluation of the approach by Company E

8.4 Conclusions

This chapter has validated the new approach for introducing manufacturing information systems in SME's in the Devon and Cornwall region. The chapter has outlined the two approaches to the validation. The first approach was in the form of seminar conducted in collaboration with local DTI offices, and the University of Plymouth, for the practitioners and academics in the manufacturing industry. The seminar was considered to be a success with much appreciation of the approach and suggestion for the improvements. The feedback obtained from practitioners has indicated that the approach has an essential role to play in developing and introducing information systems in SME's. Any specific comments were incorporated in the approach.

The second stage of the validation was conducted by implementing the approach in five case study companies. In all case studies 'real' problems were resolved using the tools and techniques outlined in the approach. The approach was only fully tested in one of the companies, however, from the results obtained it can be concluded that the approach had all the elements to support all the case study companies, should the approach be fully utilised. In comparison to the alternative approaches, the new approach has proven to be both cost effective and user friendly, both factors being crucial for successful application in the SME sector.

The validations presented in this chapter have concluded that the approach is a unique and original approach to identifying and resolving many of the problems faced by the SME's in the Devon and Cornwall region. This novel work received considerable praise from the practitioners and case study companies and when widely available is expected to have enormous impact on small companies in the region.

Chapter 9

Conclusions

9.1 Introduction

This work has developed a novel approach, that SME manufacturing companies can use in-house, to introduce information systems and manufacturing information systems in their companies. This approach will provide companies with structured steps to assist them in identifying the inherent problems of the company, and then identifying solutions to those problems, which may be either the introduction of new technology or redefining of the existing structures and systems. Finally it demonstrates how to successfully implement the solutions identified.

The research has presented definitions of manufacturing, systems, information, information systems and manufacturing information systems. It has also suggested that an information system approach will provide a more appropriate way to identify problems, and develop solutions. The approach has developed novel information mapping tools that are easy to understand and implement for small and medium size companies.

The intensive literature survey, and meetings with practitioners has revealed that currently there is no such approach available in a form which is both accessible and affordable for SMEs. There is no such methodology or approach that can take the user from identifying the need through to implementing the solution. Yet it is simple enough to be comprehended and successfully be implemented by people with little or no understanding of carrying out such projects previously. Although, the work has concentrated on the needs of SMEs in the Devon and Cornwall region, the research has indicated that no such approach is available for SMEs anywhere.

This work has also provided the foundations for future work, to further develop and refine the approach and creates the basis for the creation of a workbook to aid implementation. Tools and techniques that have been suggested can be further developed to provide templates for various forms etc. However to do this, it is recommended that additional case studies must be conducted, particularly with companies that can fully utilise the entire approach.

9.2 Devon and Cornwall scenario

Manufacturing in today's dynamic and somewhat turbulent market, is not straightforward. Companies no longer face competition from just their local rivals, but with tremendous development, and adoption of the internet technology by the buyers, the competition is now global. In such environment it has become vital for manufacturing companies to produce high quality products, with less lead time, and at an affordable cost to the consumer. This can only be achieved if the companies are highly efficient in the use of their resources.

The manufacturing sector in Devon and Cornwall is relatively small compared with many other UK regions. In 1998 it accounted for 16% of total employment in Devon and Cornwall, compared with 21% in the UK as a whole. The manufacturing companies in the region suffer from the extra disadvantages of being in the periphery region of the country. The region suffers from the lack of skilled labour, poor transportation network, lack of local suppliers, lack of local customers, lack of technology support and awareness etc.

Given the inherent disadvantages suffered by the manufacturing companies in the region it is therefore more important that companies have the necessary tools and mechanisms available to them, to continuously improve their businesses, and offset many of the stated disadvantages, e.g. lack of skilled labour etc. by employing efficient systems and new technology they can attempt to remain competitive.

9.3 Information systems and manufacturing information system

For small manufacturing companies to survive in today's buyer market, it must have significant competitive advantage. Knowing the limitations of a company in terms of production capacity, manpower capacity, resources available, can provide the company with the extra advantages of having information available to make reliable decision on taking new orders, knowing exact lead times on products, and maintaining consistent quality.

The research has suggested that a company should follow the information systems approach when analysing and understanding the existing workings of the company, and developing new systems. Information systems are any systems, whether manual or automated, that collect, store, process and disseminate information. Manufacturing systems are an arrangement of computer hardware and software, which includes an assembly of inter-related modules, or elements directed towards providing manufacturing information, plans, and schedules, in order to effect some control over the manufacturing operations of an organisation, so that some key benefit can be achieved.

This research has suggested that taking the information systems and manufacturing information systems approaches when defining a company's operations / use of resources can provide the necessary extra benefits of being able to make reliable decisions and hence lead to the desired competitive advantage over rivals.

9.4 Requirement for an approach

Those companies that want to improve their information systems within their companies, and introduce manufacturing information systems, often do not know how to implement their ideas. What they lack is a 'road map', that will guide the company towards making the correct decisions.

The figures presented in the research show that a large proportion of firms suffer greatly, due to a lack of awareness of the different possibilities available to them. Up to 30% of the costs in the implementation of new technology, are associated with design and consultancy and a shocking 40% of automation attempts fail. In fact, many companies have gone into receivership in an attempt to automate.

Taking into consideration the ignorance surrounding new technology, the research has established that many of these bankruptcies could have been prevented, if adequate guidance was available to companies when making the important decisions. The research also found that 25% of companies did not optimise the benefit from their technological change, while 20% of companies over automated under the misguided notion that more technology equals better results. These figures demonstrate the misuse and misapplication of technology in most firms and the need for a structured approach that can guide the companies when they are defining and implementing their new technology and systems.

The guide must adopt a structured approach in order to enable firms to identify the problems, develop solutions and implement effectively. The approach must also be easy to understand and apply without the need for an outside consultants. The approach must also be comprehensive enough to guide the user from identifying the need to implementation.

9.5 The new approach

The novel approach presented in this research concentrated on developing a well structured process for introducing manufacturing information systems. The approach utilises the information systems analysis and solution development techniques to specify requirements and needs. It avoids mistakes, made by methodologies that are used for large organisation which are overcomplicated and not dealing with all aspects of projects, by making the approach comprehensive and yet easy to understand and follow.

The information system approach ensures that the right questions are asked and provides some tools /techniques to help at various stages of analysis. It also ensures that the true causes of problems and bottlenecks are identified and the information needed to develop solutions is articulated in a clearly understandable form. The approach ensures that the relevant personnel are involved in the process of identifying, defining and implementing any new systems. This ensures the likelihood of any systems being readily accepted by all concerned. The division of the approach in to three phases also ensures that the approach can be used in separate parts. For example a company may want to only use the analysis phase to identify and map their existing systems, and may not necessarily wish to invest in any IT solutions. Other phases can also be used in isolation.

This in-house approach is the only approach of its kind available to SME companies in the Devon and Cornwall region, and an extensive literature survey has revealed that that it appears to be unique even from a world-wide perspective. The use of such approach gives the companies a complete control over their projects and will also develop in-house skills, which may not be gained when outside consultants are employed.

The approach has proved to be effective when applied to the case study companies in the Devon and Cornwall region. The ease of use of the approach has received many commendations and much appreciation from the companies. The academics from the University of Plymouth and the regional offices of DTI and Business Links also commended the work.

9.6 Contribution of the work

This work has provided a unique approach that SME companies can use in-house to introduce information systems and manufacturing information systems to their businesses.

The approach presented has been built on original work undertaken in the Devon and Cornwall region, and also by making some comparison and reviewing the region with the rest of the UK and Europe. The requirements for the approach have been established through the use of structured interviews and free flowing discussions with not only the MD's of the company, but also with the supervisors and other managers. This method is considered more superior then that of using just questionnaires which only answer the questions presented, and not necessarily represent the true picture.

The work has defined information systems and manufacturing information systems in the context of SMEs, and has developed original information mapping tools and qualitative decision making technique that are easier to use than existing tools and techniques available, and hence more appropriate for SMEs.

Furthermore, this approach will make it considerably easier for the company and its staff to take ownership of the systems as well as developing new in-house skills that will enable the company to make any future changes, or additions to the existing systems without the need for outside consultants. For companies to be able to modify and manipulate any implemented solutions for their company is crucial, if they are to maximise the benefits they are to derive.

9.8 Future work

The work has provided a first step in providing an approach for SMEs to introduce manufacturing information systems, using in-house resources.

Further work is required to refine and develop the approach by applying it to more case study examples, where the full approach could be implemented to derive the full spectrum of results .

This approach can be further enhanced by making the approach into a workbook format, that could simplify the various steps by providing templates for various forms and techniques and examples of case studies. There is also a need to develop cost justification techniques that are specific for the use of SMEs, and have some way of measuring the intangible benefits that may be gained from the investment in technology.

There is also a scope to develop the approach into a computer package that will provide support in both managing the project as well as assisting in various aspects the approach for example design tools to draw diagrams, sample interviewing questions, samples for manufacturing forms, order forms, etc.

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Appendix A

Information Systems and CIM Design Methodologies

Information System Methodologies

Overview

This Appendix outlines, in detail, some of the most widely used Information system methodologies in commercial environments. The methodologies are presented here so that their principle and concept could be followed are supplementary to chapter 5.

Methodology 1: STRADIS

Introduction

STRADIS (Structured Analysis Design & Implementation of Information Systems) was conceived by Chris Gane and Trish Sarson as a methodology to formalise the use of structured design in the development of any information system. It was envisaged as being applicable to any size of information system development project and to cope with any degree of intended automation. The methodology is based upon earlier work on structured design by Stevens, Myers and Constantine (1974) and later refined by Yourdon and Constantine (1978) and Myers (1975 and 1978).

Gane and Sarson's book 'Structured Systems Analysis' (Gane and Sarson, 1979) gives a description of an information systems development methodology, but not in any great detail. Their approach is restricted mainly to a series of techniques - used in a structured fashion - which are applied to the development of an information system. Both it's strengths and weaknesses result from this fairly narrow perspective, in that structured design is a useful way of tackling information system design, (especially through it's use of Data Flow Diagrams (DFD) and functional decomposition) but it does not address either any preceding information system problems and their resolution, or the implementation of the newly designed information system. The methodology does, however, epitomise the use of it's chosen techniques amongst the many other methodologies which use them.

The stages of the methodology

STRADIS methodology is broken down into four stages :

- Initial study
- Detailed study
- Defining and designing alternative solutions
- Physical design

Expanding each of these :

Initial study

To ensure that the systems being studied are the ones most worthy of development, an initial study is carried out. A costs and benefits analysis establishes the viability of continuing to develop each of the systems under consideration. Systems Analysts gather information from managers and users, existing strategic information systems plans and in-use documentation are considered. DFD's (Data Flow Diagrams) of existing systems are produced and time and cost estimates for the construction of more detailed analyses are produced during this phase.

On completion of this stage, a report is produced outlining a proposal, which is presented to the management, who then decide whether to accept and proceed to the detailed Study phase. The following must be noted for this stage:

- This is not a feasibility study, and doesn't produce the same depth of information.
- No review of alternative approaches is included.
- There is no commitment to implementation required from the owners at this stage (although the cost of the Detailed Study has to be born).

Detailed study

Throughout the detailed study, the existing system is researched in detail, to allow managers to review in more depth and decide whether to proceed or not. Potential user groups are identified as senior managers, middle managers and end users and their interests and needs are determined through interviews. From this, a draft logical DFD is prepared, extending beyond existing system boundaries to also include interfacing systems. The DFD is decomposed and each process described using process logic representation techniques such as decision trees and tables, structured English. The overall correctness is checked by reviewing and 'walking through'. The mechanics of DFD construction and functional decomposition are illustrated and discussed in the next chapter.

The review of costs and benefits of the new system, carried out in the Initial Study, is further refined. The impact of it's implementation, on the organisation, is analysed and alternative proposals are laid out. Management then decide whether to proceed, basing their decision on this study presented by the analysts.

Defining and designing alternative solutions

At this stage of the methodology the objectives of the organisation, which may be stated as, for example, to increase revenue, are translated into system objectives to enable a range of alternative solutions to be presented. System objectives are specific and from these a DFD of the proposed system is produced. This should display a level of detail which shows that the important objectives are being met.

During the next stage, the design phase, analysts produce a range of alternative solutions to varying combinations of cost, implementation timescale and objective satisfaction. Based upon this stage's report, an alternative is chosen with which to proceed. The report should contain:

- The current system's flowcharts/DFD.
- A statement of the current system's limitations.
- The new system's flowcharts/DFD.

and for each alternative proposal

- Associated costs and benefits.
- A programme for implementation.
- Associated risks.

Physical design :

At this stage designers convert the chosen alternatives into a physical design through :

1) Refining and finalising both the process detail of the DFD (including error and exception handling), the data dictionary content and the interface design, with the users.
2) Designing and establishing the database; data stores are introduced.
3) Rationalising the database; and the data store via normalisation.
4) Distinguishing between 'transforming' and 'transacting' processes on the DFD and deriving a modular hierarchy.
5) Defining clerical tasks.

Finally, the costs associated with the system's development and implementation are estimated, being based principally upon :

- The time required to develop the system modules.
- The computer system required.
- The costs of peripherals and data communication.
- The time to develop training and documentation.
- User / system interaction time
- System maintenance time.

Methodology 2: Information Engineering (IE)

Introduction

The exact origins of IE are unclear, but it has it's roots in both the data modelling development work done by Clive Finkelstein, in Australia in the 1970s, and later, a collaborative venture between him and James Martin, and also systems development work by Ian Palmer and colleagues at CACI Inc. International, also in the 1970s. IE has also become diverse in it's approaches, through independent development around the world and commercial popularisation - most importantly by James Martin. Martin himself regards IE 'as a generic class of methodologies', not as a single dogma.

IE is claimed to be a methodology that covers all aspects of the information system development life-cycle. It is viewed as a framework which covers the fundamental things that have to be done to design and implement a high quality system, within which a range of techniques are utilised to achieve system development and support the framework. The techniques in current use may change (as they are not part of the framework), to be replaced by alternatives that are more appropriate as required. The framework itself is seen as still evolving - in particular with the use of automated tools and 4GL systems development – but it is a practical, applicable and proven management tool. It's results reflect the needs of clients. IE is based on the precepts that:

- Information is more stable than the processes that operate on it, so placing an organisation's data types (and it's data structure) at the information system's centre provides a more stable basis for the system's operation.
- Communication within the methodology is best achieved through the use of diagrams. Each technique is oriented towards producing diagrams and these are produced at each major stage. Organisational complexity would normally necessitate the use of an automated support tool in diagram production.
- The methodology is defined as 'top-down' i.e. an organisation and system overview is taken and broken down into areas of interest, which are solved on their own, but as part of the whole. Therefore, the overall objective remains the same, whilst detail objectives change as system design progresses.

The levels of the methodology

Four levels are identified, and these are broken down further into phases. The levels are :

- Information strategy planning
- Business area analysis
- System planning and design
- Construction

Information Strategy Planning (ISP) :

This is an analysis of the overview of the business and its corporate objectives and is seen as the fundamental starting point of the methodology. Although it may not necessarily be carried out by the IE analysts but by the corporate managers, this positions the information system in support of the business's objectives. ISP has four elements :

Current situation analysis

Analyses the organisation's current position in terms of the strengths and weaknesses of it's current systems, and the preliminary information architecture is defined.

Executive requirements analysis

Managers input their preferences, needs and perceptions. Critical Success Factors (CSF's) are identified at a high level, as well as for the decomposed elements.

Architecture definition

An overview is taken of the information layout in terms of function and distribution. And an ideal business system, plus supporting technology and support function, is defined.

Information strategy plan

Information architectures are separated into logical business areas and development and implementation plans are drawn up. The ISP is completed, stating the chosen strategy, including priority projects.

Business area analysis

At this stage a detailed data and function analysis is performed on the previously identified business areas. Tasks in this stage are :

Entity and function analysis

This task involves analysis of entity types, relationships, processes and dependencies, also at this task function hierarchy and dependency diagrams are constructed. Attributes and information views are defined.

Interaction analysis

The relationships between data and functions are examined to determine the nature of those relationships. Entity life-cycles and process logic are also analysed and process action diagrams prepared.

Current systems analysis

The 'old' and 'new' systems are modelled in the same way for the purposes of comparison and to ensure the transition is smooth. Canonical synthesis is used to bring together different functional views of data in an entity model, duplications are removed through normalisation, producing a syntheses of views.

Confirmation

Here the previous results are cross-checked for completeness, correctness and stability. Possible changes to the business are examined for their impact.

Planning for design

The parts of the model to be developed are defined and implementation procedures and design objects are planned.

System planning and design :

Here a logical system is designed for each previously identified design area using the following steps :

Preliminary data structure design

A first attempt is made to convert the entity model to the structure of the DBMS.

System structure design -

Business processes are mapped to procedures using DFDs.

Procedure design

Data navigation diagrams, dialogue flows and action diagrams are drawn up.

Confirmation

The work to date is checked for completeness, it's adherence to IE rules and usability by the users.

Planning for technical design

Implementation areas are defined and technical plans are prepared. This results in the production of a business systems specification detailing the information flows and user procedures, the results of business area analysis and the proposed user interfaces. Those parts of the above to be computerised are designed using the following routine :

- Data design
- Software design
- Operations design
- Verification of design
- System test design
- Implementation planning

Summary

This stage's output is a technical specification for the system and a plan for construction and implementation.

Construction and cut-over

At this stage the computing environment, development procedures, database and modules are constructed. Systems are constructed and integrated. Documentation is generated. Testing and user acceptance is carried out. Cutover is the controlled changeover from the old to new system and is sequenced as follows :

- Preparation : schedule preparation and training.
- Installation of new software
- Final acceptance
- Fan-out : installation at each location.

- System variant development : system modification to suit local conditions.

After full implementation, the system's performance is periodically evaluated, tuned and maintenance carried out.

The highly structured and ordered framework of IE has made progressive automation possible. The framework is a modifiable 'encyclopaedia' of data objects and their inter-relationships. The scope of IE across the systems development life-cycle is probably the widest of the methodologies.

Methodology 3: SSADM

Introduction

SSADM (**Structured Systems Analysis And Design Method**) is an important methodology which is in widespread use in the UK Civil Service and government departments. It was developed by Learmonth and Burchett Management Systems (LBMS) and the Central Computing and Telecommunications Agency (CCTA) during the 1970s. Version 4 was released in 1990.

The phases of SSADM, and it's rules and guidelines, are precisely defined, this makes it highly amenable to controlled project management and also user training. Comprehensive standards provision and controlling documentation are also a feature.

The structure of the methodology

The framework of the methodology is depicted in five modules, which themselves range across seven stages, which are as follows :

Feasibility

- Feasibility study

Requirements analysis

- Investigation of current environment
- Business systems options

Requirements specification

- Definition of requirements

Logical system specification

- Technical system options
- Logical design

Physical design

- Physical design

The stages are now outlined :

Feasibility

The technical viability of the project is established, and the potential benefits weighed against costs. Techniques such as interviewing, questionnaires and DFD's are used to investigate the scope, requirements and feasibility of the new system. Current system weaknesses are used to help define the potential alternative solutions, which are outlined in a report.

Investigation of current environment

The work in the feasibility stage is repeated, but in greater detail. DFD's are decomposed to further levels of detail and conflicts and inaccuracies worked out. Existing data flows, processing methods and data are examined and mapped and used to assess new system requirements. Processes and entities and their relationships are studied, and activity catalogues created. A report on the current environment is output.

Business systems options

Those user requirements, from the previous stages that can be justified using cost-benefit analysis are incorporated into an range of business system options. From these, an option is chosen by management and a system specification produced, which forms the basis for next stage development.

Definition of requirements

The full specification of requirements is produced from the selected business option at this stage. The requirements catalogue is updated and the logical entity and data flow models are refined. Functions are documented in detail and relationships between users and functions are also recorded. Jackson Structure Diagrams (JSD's) are use to show input and output structures. Entity life histories are constructed, which record events that affect an entity during it's life cycle. Lastly, a check of the authority of the requirements specification is carried out, that the functions are properly defined and that objectives are still being met.

Demonstration prototypes of critical dialogues and menu structures may be developed and users asked for feedback. This involves users during development whilst helping to validate work to date.

Technical systems options

In this stage, specific hardware and software configuration options are identified and reviewed by management. Technical choices are made in consideration of any existing system constraints, organisational impact, time and cost factors and development strategy.

Logical design

The dialogue and menu structures and designs are defined for users. Update processes and operations and enquiry processing are defined. Rules for validating data are specified and final detail for the control of operations following events is completed. The design, in general, is brought to a state ready for physical design.

Physical design

The skills of Analysts, Technologists and Programmers are brought together to produce a physical systems solution from the logical design. The logical design is mapped using a Function Component Implementation Map (FCIM), which maps each logical function component onto the physical components of the operating system. The logical data model is converted into an appropriate DBMS design. Storage, timing and performance are optimised.

Conclusion

SSADM is clearly a structured approach, and it's basic techniques of entity modelling, entity histories and DFDs, have made it a methodology that is easily taught; and it is a part of many UK university Information Systems degree programs. It's techniques and tools are widely known and good implementation is possible using skilled key personnel. It is supported by a range of computer tools which help with analysis and design, which, together with the importance it places on documentation standards and also the detailed guidelines it provides, eases the system development process.

Methodology 4: JSD

Introduction

JSD (Jackson Systems Development) has been developed from Jackson Structured Programming (JSP) by Michael Jackson. Jackson views the systems development process as being almost identical to that required to develop programs. He says 'We may think of a system as a large program', consequently JSD's goal is to produce software systems, not, primarily, information systems. Important stages in the information systems development life-cycle are not covered by JSD, including :

- Project selection
- Cost Justification
- Requirements analysis
- Project management
- User interface
- Procedure design
- User participation
- Database design
- File design

Although more recent commercial versions, by different authors, have included some of these aspects in their versions i.e. Davies and Layzell (1993).

The central problem for JSD is finding the hidden path between the presentation of a system specification and that system's final production as a completed, executable and supportable program. For Jackson, the answer is to use process scheduling and real-world modelling. Also, systems are dynamically, not statically, modelled giving a more accurate rendition of real world systems.

The JSD structure

JSD progresses through three stages, which between them cover six steps. This is structured as follows :

Modelling

- Entity action.
- Entity structure.

Networking

- Initial model.
- Function.
- System timing.

Implementation

- Physical system specification.

During Modelling, entities, entity events and structures, and entity life-cycles are described to represent the elements of the real-world systems being analysed. Networking extends the model through input and output analysis. And Implementation translates the specification, through final detail resolution and code production, into an executable system program.

Entity action

Real-world entities are defined, for example : supplier, sales, part etc. To be defined as an entity, an object must :

- Perform or suffer actions in a significant time ordering.
- Must exist in the real world outside the system that models the real world.
- Must be capable of individual instantiation with a unique name.

Entity actions describe how entities behave within the system. In JSD, entities perform or suffer actions. Actions must :

- Be regarded as taking place at a point in time, rather than extending over a period of time.
- Take place in the real world outside the system and not be an action of the system itself.
- Be regarded as atomic and cannot be decomposed into sub-actions.

Entity and action attributes are stated. Entity attributes add information about the entity and are updated by it's entity actions, and action attributes originate beyond the system boundaries and trigger the action.

The output from this step is a list of entities, their actions, and attributes for each of these actions.

Entity structure

Here, the actions performed or suffered by entities are ordered in time. JSD structure diagrams are produced which express the life-span of an entity hierarchically. These show a hierarchical decomposition of an entity's life-time. Entity role separation is essential, for example if there is no link between 'promotion' and 'training' along a career path, then two separate JSDs are needed. In essence, the entity diagrams show entity activities processing in time, without concurrency, and from the entity's birth to it's death. Diagram drawing is supported by the Program Development Facility tool. A set of Jackson Structure Diagrams is generated by this step.

Initial model

In this step a process model is created, which emulates real world system activity. A sequential process is created for each entity type, and these are designed to operate at real-time speeds. Structure text (similar to Structured English) is used to define process models and diagrams are drawn up to show the interconnection between processes. Structure text definitions can later be expanded (since it resembles a high-level Algol-like programming language, see figure *). Data stream connection or state vector connection is used to model process connection. JSD System Specification Diagrams are used to map the network of inter-process communications.

This step's output is a systems specification diagram and set of structure texts, both modelling a set of communication processes.

Function

The previously created model is extended, by the addition of functions, to also model outputs resulting from combinations of events. Structure text is evolved to reflect this change.

A refined system specification and structure text set is completed at the end of this stage.

System timing

In this step, system process timing, in relation to real-world timing (in terms of acceptable delays, time lags etc), is established within the model. Specifically, time delays between input receipt and the production of outputs is studied. Inter-process timing, as well as in-process timing, is considered. Time Grain Markers (TGM's) are used to co-ordinate processes. Technical and user constraints are used as guides to timing of processes. This step results in processes merged with TGM's, producing a time aware process model.

Implementation

JSD's interpretation of implementation considers one subject; how to share processors amongst processes. The physical implementation of a complete information system is not a concern, and JSD doesn't address this issue. Guidance is given on how to translate the model into a set of sub-routines and programs which cater for multiple processing on multiple processors, or if desired, single process processing on one or many processors. JSD Systems Implementation Diagrams are used in the translation to code.

Conclusion

The strength of JSD is it's ability to model real world systems, not just in terms of entities and their actions, but dynamically, catering accurately for concurrency, timing and process scheduling, producing a real-time picture of events. It's weakness lies in it's self-acknowledged incompleteness, in so much as it concentrates on producing a working information system regardless of any existing system and IT strategies, problems or with regard as to physical implementation and subsequent maintenance. Jackson sees, however, his system development approach as the most valid, in comparison with static, entity model based systems designs.

Methodology 5: (SSM)

Introduction

SSM (Soft Systems Methodology) has been developed by Checkland at Lancaster University, with the most up to date version, mode 2, being outlined in Checkland and Scholes (1990). It is based on the belief that when analysing a system, it has to be viewed as a whole for any kind of meaningful conclusions to be drawn, as, when decomposed into its parts, it loses something of the whole which is unreproduciable by each of the parts on their own. For this reason information systems cannot be viewed in an incomplete fashion as purely 'hard' systems -

collections of data and processes - but as more complex 'soft' systems, within which there is a inseparable human element. Thus soft system models are better able to represent the complex workings of large, complex organisations. Soft systems thinking assumes that the purpose of a system is to arrive at more complex purposes or missions, and not simple goals, as a hard system might set out to achieve. The understanding of purposes and missions is achieved through debate with the actors who operate within the soft system.

Checkland has developed SSM through 'action research', where his methods have been actively tested within client organisations. Modification to SSM has come from feedback and learning, and it is therefore field proven. Central to the methodology, is first to find the overall or world view; the resulting information system flows from this.

The stages of the methodology

SSM is broken down into seven stages, which are divided into two categories; these being a) the activities within the organisation which involve people in the problems, and b) the activities that analyse and resolve the problematic situations. The stages are as follows :

for a) 1. The problem situation : unstructured.

2. The problem situation : expressed.

for b) 3. Root definitions of relevant systems.

4. Conceptual models.

4a. Formal system concept.

4b. Other systems thinking.

for a) 5. Comparison of 'Conceptual models' with 'The problem situation : expressed'.

6. Feasible, desirable changes.

7. Action to improve the problem situation.

The problem situation : unstructured

Problem owners - managers, the business owner - and others involved in the problem situation are consulted to discover the nature of the information system problem. Varying views of the problem are taken and, also, an impression of the existing physical information structure, including informal communication means and practices, is formed.

The problem situation : expressed

The problem situation is analysed during this stage. The impressions already formed are laid out diagrammatically, to aid communication between problem solvers and owners. No method is stated as the best way to map the impressions, but Checkland uses Rich Picture Diagrams. These can show process structures and the inter-relationships between processes. The people involved, the tasks being performed, the system's environment, the owner and clients, can all be included on the diagram Departmental conflicts, communication difficulties, and other 'bottlenecks', can also be depicted.

Root definitions of the relevant systems

Problem themes are discussed with problem owners and relevant systems that provide a viewpoint on the problem, are identified. Problem solvers and owners then decide which view to use to assist with problem resolution and a rich picture, followed by a root definition of the chosen system are constructed. Checkland describes a root definition as 'a concise, tightly constructed description of a human activity system which states what the system is' (Checkland, 1981). For example, a root definition for a hotel administration system might be 'to provide the highest standards of care and service to all paying guests, and provide an effective and discrete hotel administration service.' The root definition is constructed using CATWOE, which stands for :

Client - the beneficiary or victim of the activities.

Actor - the person who carries out the change.

Transformation - the change.

Weltanschauung - the world view that gives the root definition meaning.

Owner - the sponsor of the change.

Environment - the wider system, of which the problem system is a part.

Building conceptual models

Conceptual models are developed from the root definitions, and laid out in diagrams. They conceptual model is a model of the system which shows how it performs, and should be closely related to the human activity system it describes. The models are discussed and refined until agreement is reached between solvers and users on the correctness of the root definitions and conceptual models. This iterative process is intended to tease out conflicts of interest, ideology etc. to illuminate the true overall, or underlying, nature of the problem.

Comparing conceptual models with reality

Conceptual models are compared to previously stage 2's rich pictures, and the nature of the problems discussed leading to recommendations on what changes need to be made to resolve them.

Assessing feasible and desirable changes

The recommended changes are analysed and those considered worthwhile are drawn up as proposals.

Action to improve the problem situation

This stage considers the actions recommended in the proposals. SSD is mainly concerned with identifying system problems, and goes no further in discussing how to implement any chosen information system solution.

Conclusion

SSM involves all 'actors' (all the participants) in the processes to discover the problems at the heart of the system(s). It is an iterative process, with everyone involved, particularly the analysts, expected to learn as they go along. With no set of highly structured rules to follow it is often difficult to teach, and also, to gauge it's progress during a commercial project.

The methodology concentrates on problem analysis, rather than the practicalities of designing and implementing an effective information system.

Methodology 6: Multiview

Introduction

Multiview's approach is attributed to Wood-Harper, Antill and Avison. It combine 'hard' and 'soft' views of information systems development to offer a more balanced and realistic methodology, which reflects the balance of human and technical components found within a real-world problem situation. It's broad approach is mirrored in the scope of it's influences i.e. STRADIS, IE, ETHICS, SSM.

Action research has been used to test and prove ideas, and the methodology has developed information systems in a range of organisations of various sizes, down to those much smaller than other methodologies have been applied to.

A central tenet of MULTIVIEW's approach, is contingency; that is because of factors such as the range of organisational environments, the unpredictability of problem situations and the varying levels of analyst's skills, not all approaches, techniques or tools will work in a proscribed manner, but certain of these should be used as befits needs. To this end, much of MULTIVIEW is derived from other methodologies, these stages, techniques etc. being seen as the most useful at that point.

Multiview stages

There are five defined stages :

1) Analysis of human activity
2) Analysis of information (information modelling)
3) Analysis and design of socio-technical aspects
4) Design of the human-computer interface
5) Design of technical aspects

To ensure that both human and technical sides of the development process are covered, the methodology proposes that it should assist in providing the answers to five questions, which are :

1) 'How is the computer system supposed to further the aims of the organisation installing it?'
2) 'How can it be fitted into the working lives of the people in the organisation that are going to use it?'
3) 'How can the individuals concerned best relate to the machine in terms of operating it and using the output from it?'

4) 'What information system processing function is the system to perform?'
5) 'What is the technical specification of a system that will come close enough to doing the things that have been written down in the answers to the other four questions?'

By involving all those participating in system development - users, managers, analysts etc. - in answering these questions, MULTIVIEW hopes to balance the technical with the human aspects, the task-related questions with the issue-related questions en-route to providing a more multi-faceted , and hence effective, information system.

Analysis of human activity

Based on the ideas of SSM, a world-view of the organisation (of any size or type) is arrived at, through debate with the problem situation participants. Rich pictures are used to stimulate communication and debate and produce an understanding of the problem situations. Problem themes (for instance; inter-departmental communication breakdown, or supplies shortage) are pulled out and relevant systems which may help to solve the difficulties are identified. A root definition, based on one view, is agreed and refined (using CATWOE) and this forms the basis for the construction of a conceptual model. The conceptual model is compared with the rich picture for it's correct representation of 'real' events and any necessary enhancements made. At the end of this stage, a clear root definition and conceptual model describes the area of concern.

Analysis Of Information

Entities and functions are analysed in a two phase process. These are :

1) Development of a functional model :

The main function is identified and decomposed as far as possible, and this is then portrayed in a hierarchical model. DFD's showing sequences of events are produced from the functional decomposition.

2) Development of an entity model :

Entities and their inter-relationships are extracted, and an entity model constructed.

Analysis And Design Of The Socio-Technical Aspects

MULTIVIEW bases the work of this phase on ideas borrowed from Mumford's ETHICS, which insist that the resulting information system will be enhanced if those whom it affects are given the chance to help design it, modifying it in consideration of job satisfaction, the type and nature of tasks to be performed, morale etc. During this stage, a range of alternative solutions covering both human and social, and also technical, priorities are drawn up. These are graded according to how well they fulfil social, technical, cost, resource and constraint objectives. The technique of Future Analysis (Land, 1982) is used to assist in setting the objective criteria, based upon statements of potential future scenarios. This stage's output is the role set, and the computer and people task requirements.

Design of the human-computer interface

Initially the technical design of the human-technical interface is designed. Decisions are made on how users will interact with the computer, whether, for instance, batch or on-line processing is to used. Detail about the nature of inputs and outputs, how information is to be reported etc is worked out. These requirements are then translated into a description of the technical requirements needed for computer system design.

Design of the technical aspects

By this stage the technical requirements of the system, incorporating the necessary human and social influences, have been analysed and the development process concentrates on the technical design of an information system specification. MULTIVIEW gives an outline technical specification, which is the output from this stage, and is as follows :

- *Application subsystem :* performs functions computerised from the function chart.
- *Information retrieval subsystem :* responds to enquiries regarding stored data.
- *Database maintenance subsystem :* updates and error checks data.
- *Control subsystem :* checks and alerts for user, operator, machine and program errors.
- *Recovery subsystem :* assists with system repair after error detection.
- *Monitoring subsystem :* monitors system activities.

- *Database :* where data is stored in an organised fashion.

After design, the system is tested and subsystems enhanced or corrected where required. MULTIVIEW sees an information system not as a static, leave-alone design, but stresses that the development process should be regarded as continuous, where the users change the system to suit their needs as they require, in order for it to continue meeting organisational, human and technical objectives.

Conclusion

MULTIVIEW aims to develop information systems whose performance is optimised through ensuring that both human and technical aspects are given fair consideration in the development process, and also, by taking the parts of other methodologies that it sees as useful within it's own context, and using these help to integrate the human and technical influences into the system design. The methodology is designed to be flexible enough to be applied across a wide range of organisational problem situations and sizes.

Current Methodologies For Introducing CIM Systems

(adopted from Doumeingts G., review of Information systems methodologies, 1995)

Overview

This appendix is supplement to chapter 5 and outlines some of the most popular CIM design methodologies that currently exist. These are also presented to give the reader appreciation of complexities of these methodologies and to further emphasis the need for an approach that is appropriate for SME cases.

Introduction

Developing detailed specifications during the design of modern CIM systems has become a very complex task. The design must take into account a number of constraints (cost, quality, flexibility, time, evolution), and grant the resulting system better efficiency. The choice of hardware and software is a direct consequence of this design process, which means that taking the wrong choice may have dramatic consequences on investments. Among the various elements (previous experiences, objectives, etc.) which may influence the final design, the choice of a modelling technique is of paramount importance.

CIM (Computer Integrated Manufacturing) is used to describe the process of integration of all the elements involved in manufacturing, by means of computer techniques. Over the last ten years. CIM has been confined to a purely technical interpretation. Today, the many difficulties encountered in the course of various implementations have shown that such a narrow outlook is not satisfactory:

economic, social and human aspects must be taken into account. Therefore, a broad definition of CIM, below, suggested by Vallespirsss would be more appropriate.

"CIM refers to a global approach-in an industrial environment which aims at improving industrial performances. This approach is applied in an integrated way to all activities, from designing to delivery and after-sale, and uses various methods, means and techniques (computer and automatic techniques) in order to simultaneously improve productivity, decrease costs, meet due dates, increase product quality, secure flexibility at local or global level in a manufacturing system and involve every actor. In such an approach, economic. social and human aspects are at least as important as technical aspects." This broad definition shows that a CIM solution cannot be bought: each firm must devise its own, which explains why methodologies must be made available so that CIM systems can be built.

Designing a CIM system meets with a number of difficulties:

- The system is extremely complex; it involves not only technical aspects but also economic, social and human aspects which must be integrated. Moreover, it may be highly automated and, computerised.
- All the knowledge that is needed to design the system is not to be found in one single person. Instead, this is a group work.
- The designing process is impossible to model: only experience can teach it, and references are scant.

Definition of concepts

The word "methodology,"' means a set of methods which involve the use of:

- reference models and architectures,
- modelling formalisms and their associated graphical tools,
- a structured approach.

Reference model or architecture is a very important concept in CIM. However there is no world-wide accepted definition of architecture. An architecture of CIM systems can be defined as a structured set of "models" which represent the invariant building blocks, of the whole CIM system. The architecture can be considered as a basis for the design and the implementation of CIM systems. These models, which contain the invariant elements and the relations between these elements, describe respectively the "WHAT" (what a CIM system is conceptually composed of), and the "HOW" (how a system technically works), and show how to transform the models into realities, i.e. the working system. A modelling formalism is a mean to represent pieces of knowledge that have to be transmitted unambiguously. It allows to build models according to associated concepts. A model is an abstract, simplified representation of reality. A manufacturing model can only represent a set of selected elements concerning the domain studied, and in agreement with defined objectives. A system can be represented by various kinds of models based upon various points of view. A good model should amplify the important characteristics and conceal the details which are considered to be of low or of no importance. In the domain of CIM, models are supported by mathematical formalisms, languages and/or graphical tools.

In modelling, we distinguish between structure models and simulation models. Structure models define the basic concepts, the elements and the relations between these elements from a static point of view. Simulation models, on the other hand, take the concepts defined in the structure models and introduce the "time" factor: they take the dynamic evaluation of the model into account. Generally speaking, a structured approach defines a sequence of steps to be followed when applying a methodology to solve a problem. In a CIM design methodology, the structured approach should cover the whole life cycle of the CIM project which is split up into several steps (analysis, design, development, implementation, operating). All these steps should be perfectly defined and based on the project type structure, consisting of particular actors whose roles are clearly defined. Indeed, I will show later that it is fundamental to define precisely the various steps that lead from specification to implementation. This point has been insufficiently debated up to now. For each of these steps, models should be designed and validated. At the present stage of development, only the analysis phase and the design phase are linked. A lot of work remains to be done before reaching the stage of development. One may however find instances of links within the exploitation phase.

Reference models and architectures

Here I will present some well known reference models for designing CIM systems such as the ICAM, CAM-I and NBS models developed in the USA, the GRAI model developed in France, MMCS, IMPACS and the Knowledge-based factory model developed within the frame of the Esprit Programme.

ICAM

ICAM (Integrated Computer Aided Manufacturing) was one of the biggest CIM projects in the US and lasted from 1978 to 1983. The objective of the project was to improve the use of information technology in the field of manufacturing and particularly within the aerospace industry. A "model of Manufacturing" (Softech, 1981) was elaborated in this frame. The objective of this model was to display the main functions of manufacturing and the relationships between them (Fig.1). The model has a hierarchical decomposition based on a top-down approach.

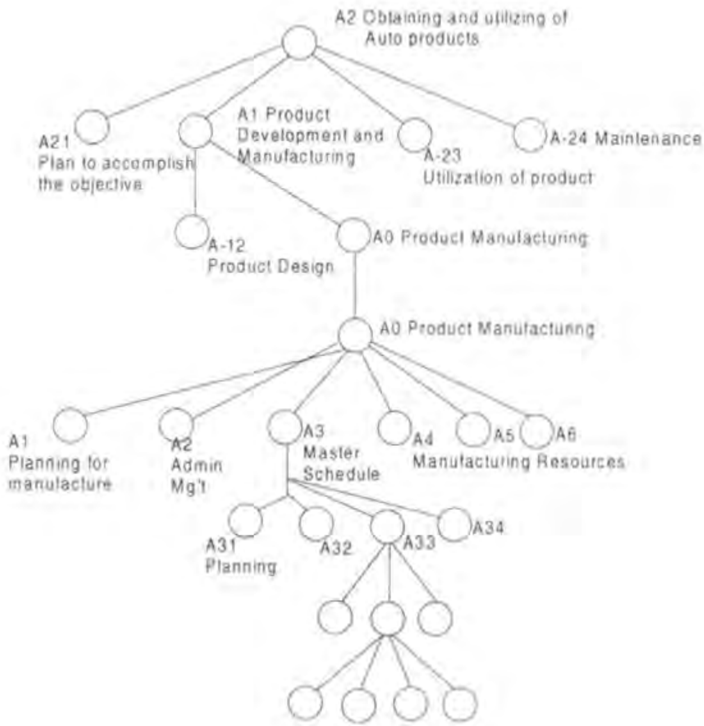


Fig 1 ICAM Model

CAM-I

CAM-I proposed a factory model(CAM-I, 1979). Two levels of this model (shop level and cell level) were described in the "Factory Management" project. The CAM-I model proposed four levels of decomposition (Firm, Factory, Workshop and Cost Centre) in which the seven main functions (Fig. 2) may always be found (decide, design, plan, acquire, make, verify and deliver).

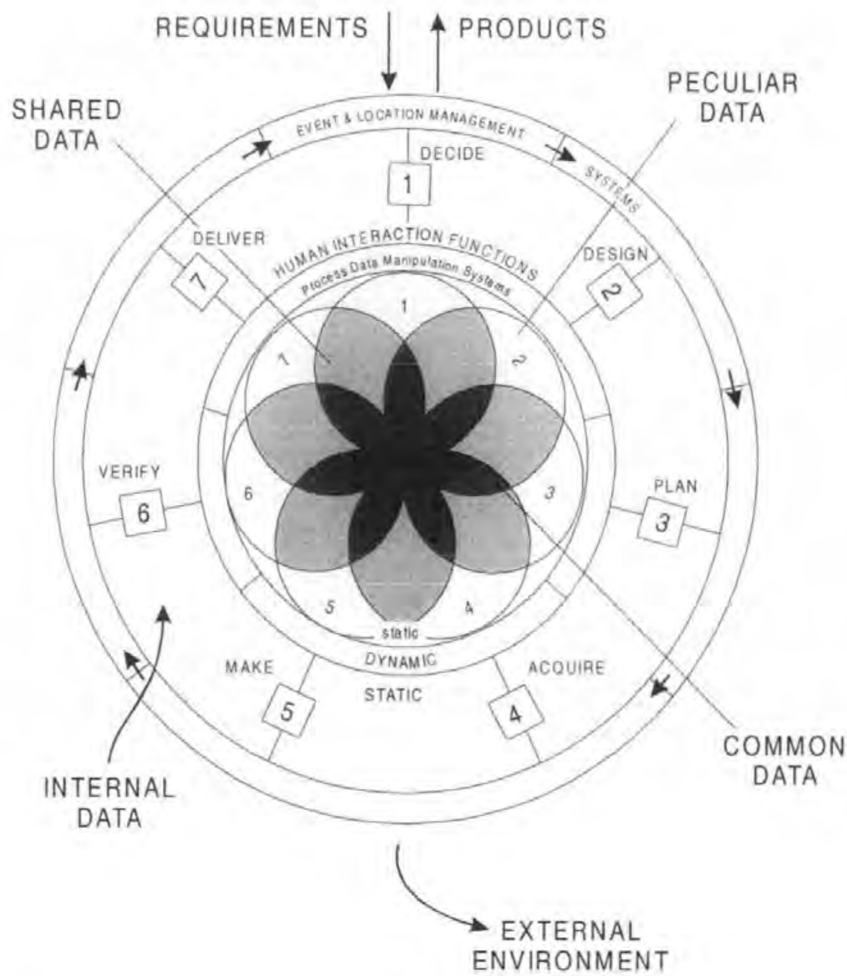


Figure 2. CAM-I Model

NBS

The National Bureau of Standards (NBS), renamed National institute of Standards and Technology (N1ST), elaborated a model of manufacturing systems (Fig. 3) extremely flexible in order to emulate a wide variety of manufacturing cells. This approach fits particularly well in a fully automated manufacturing environment. The NBS model has a hierarchical structure divided into five levels: factory, shop, cell, workstation and machine. Today this model has been widely accepted as a basic reference. The NBS model lays the emphasis on communication links for information exchanges, based on the hypothesis that all elements in the firm can have access to information, and can communicate with all the other ones.

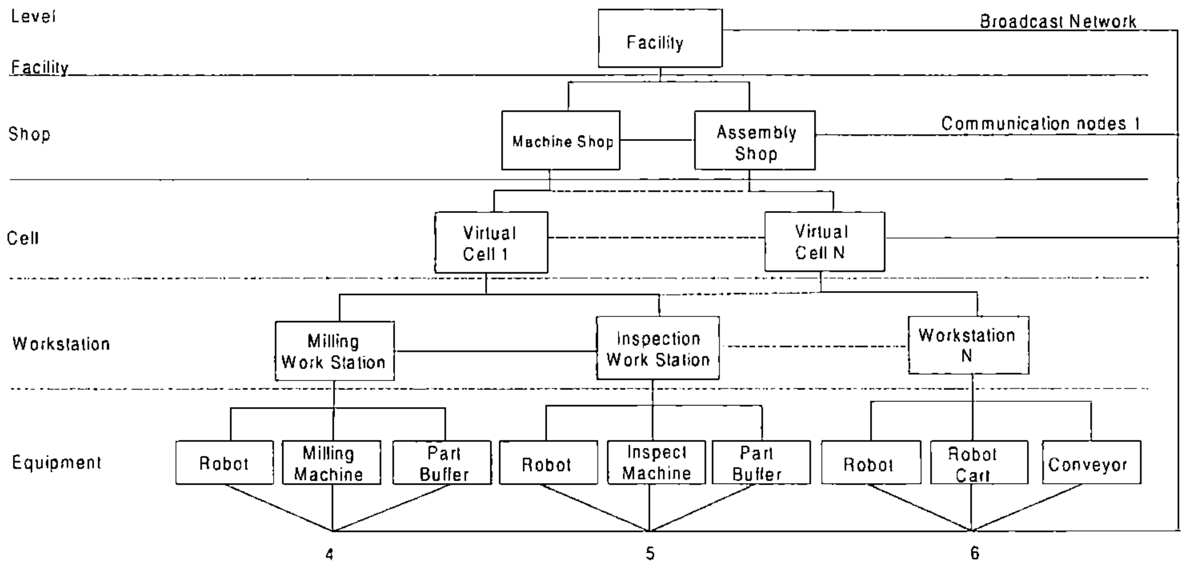


Figure 3. NBS Model

GRAI

GRAI models (G. Doumeingts, 1984) were developed within the GRAI method context to meet the needs of the modelling of decision systems. The GRAI models consist of a macro reference model for manufacturing systems (Fig 4) and a micro reference model for decision centres. The macro model is used to express our perception and ideas on a manufacturing system which is decomposed into a decision sub-system, an information sub-system and a physical sub-system. The macro model has a hierarchical structure within which decision centres are identified. The micro model is used to represent the internal elements of a decision centre.

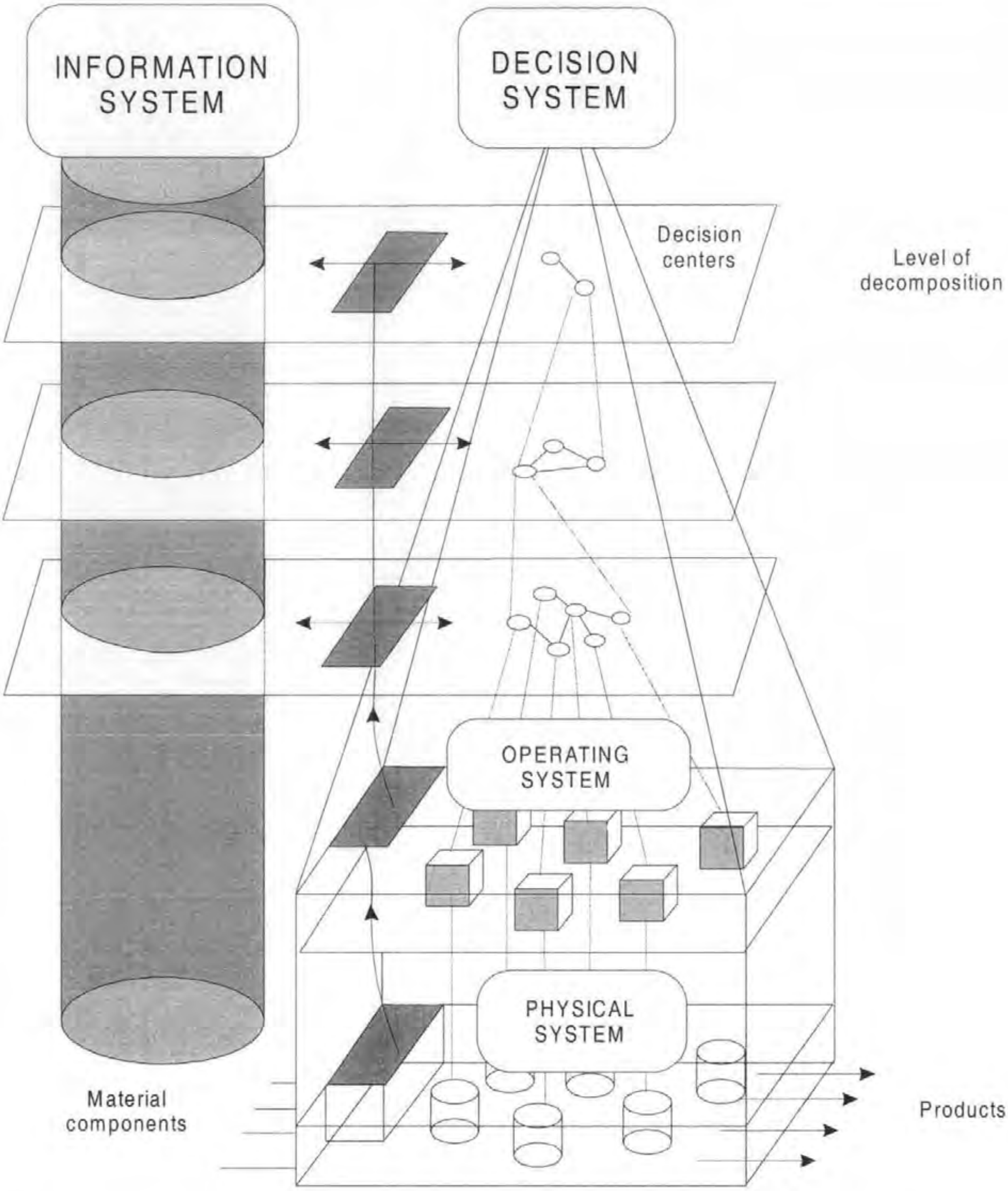


Figure 4 GRAI Macro Reference Model

MMCS

The MMCS architecture (Manufacturing Management Control System) as shown in Fig. 5 was developed within ESPRIT Project 418 (Open CAM System), in which GRAI was involved. The MMCS architecture (Procos, 1988) deals with shop and cell planning and control with carefully defined interfaces. These interfaces transform, where necessary, the external data view into the MMCS view. Via a database, the system is able to interface with the available MRP systems at factory level. At the heart of the MMCS are the controllers reflecting the same structure at shop and cell levels.

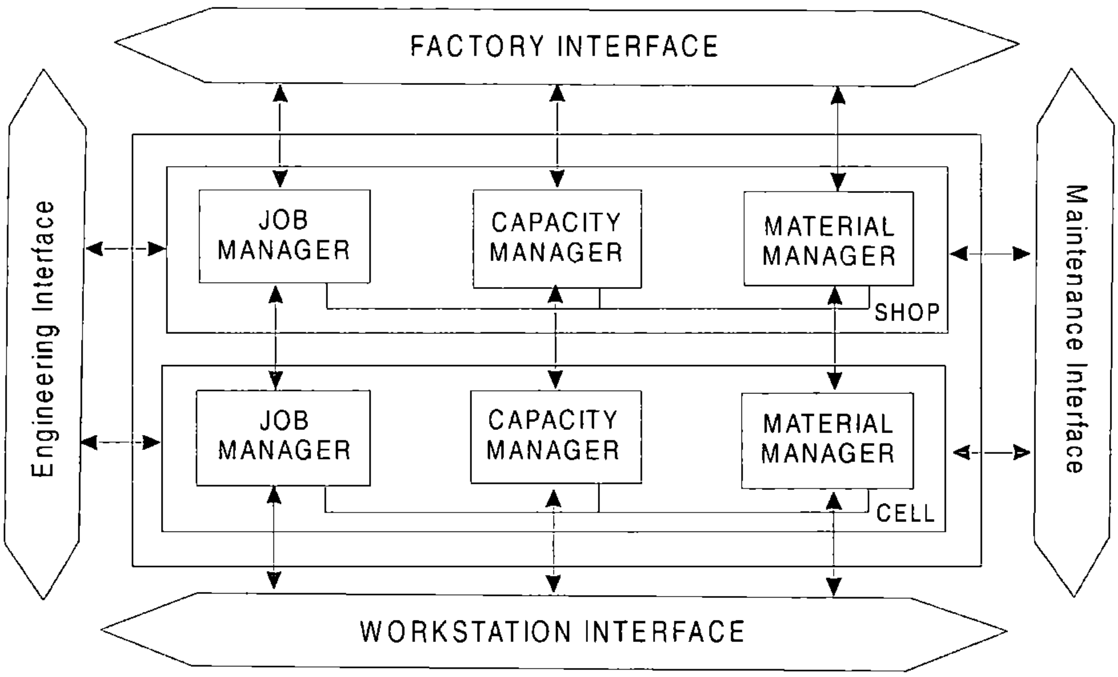


Figure 5 MMCS Model

ESPRIT Projects 932 and 2434

Most CIM projects performed within the ESPRIT programme are strongly information processing oriented. However the decision-making is a very important aspect of CIM which cannot be ignored. That is why the ESPRIT Project 932 was launched.

ESPRIT Project 932 has defined a knowledge-based real-time reference model (Fig. 6) to support decision-making at shop-floor level. This reference model (Philips Gmbh, 1988) is based on the NBS model and the GRAI model, with the intelligent work cell controller concept. A controller performs three basic tasks (Planning, Quality Control, Preventive Maintenance). Project 932 finds its sequel in project 2434. ESPRIT Project 2434 is concerned with real-time CIM controllers for distributed factory supervision. The results achieved in Esprit Project 932 are used directly in ESPRIT 2434. The objective of this project is to make the modern production philosophies (OPT. JIT, LOP, etc.) available on the factory floor, by delivering decision support to each relevant function of the factory using knowledge-based software techniques.

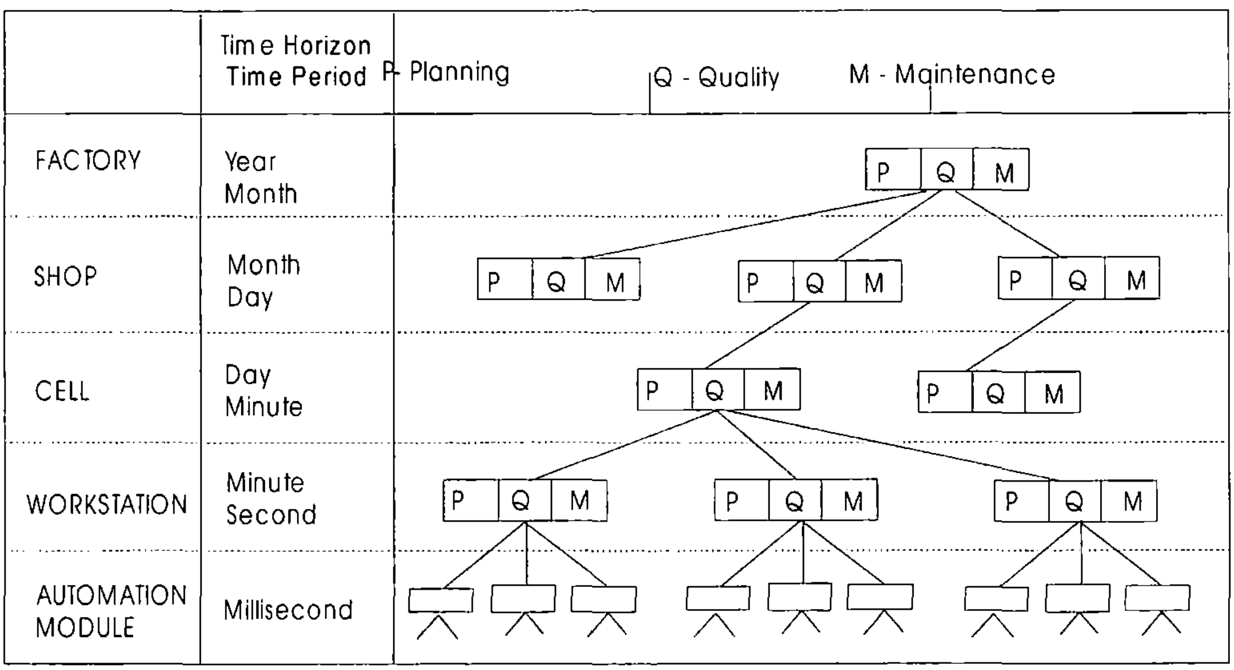


Figure 6 Knowledge-based factory control model

IMPACS

ESPRIT Project 2338, IMPACS, is probably the first attempt to design integrated planning tools that would bridge the gap between global planning and production control based on very long-term strategic planning (3 to 5 years), and real-time control at cell level. The IMPACS reference model (IMPACS, 1991), is shown in Fig. 7

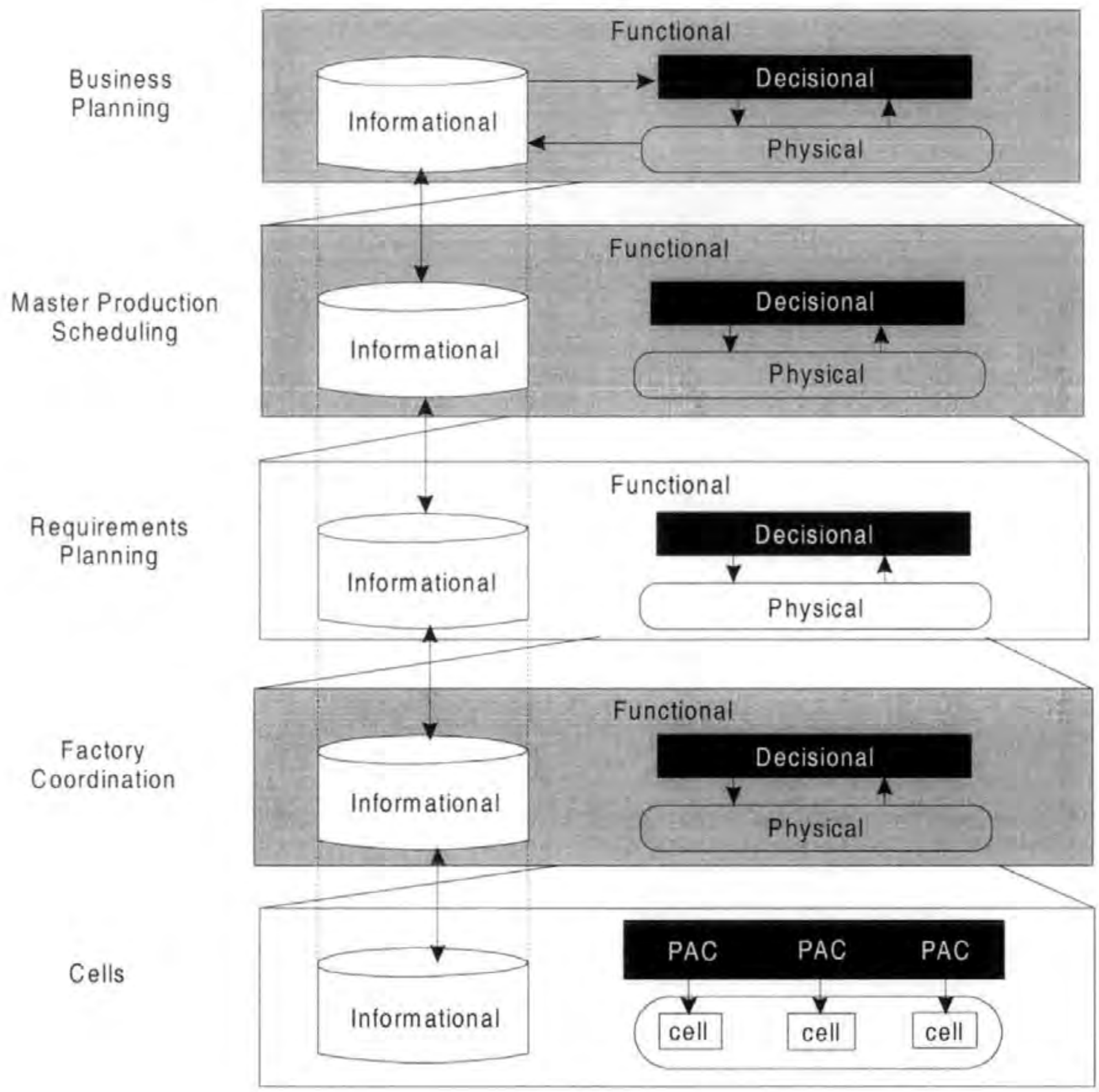


Figure 7. IMPACS Reference Model

Remarks about models and architectures

The ICAM and CAM-I models developed earlier in the US are the basis for the other developments. The ICAM model is supported by the IDEF formalism, which is widely used. No modelling formalism was developed within the CAM-I approach. In the "Factory Management Project" of CAM-I, the DFD (Data Flow Diagram) developed within the frame of the SSAD method is used.

The NBS model is today widely accepted as a reference model for an enterprise to decompose the factory into its basic resources (machines, equipment, etc.). No modelling formalism has been developed for the NBS approach. The GRAI model is supported by the GRAI grid/GRAI nets formalisms and a structured approach Although prototyped and tested in several companies, the MMCS model is being challenged by a more generic model developed within the ESPRIT Project 477: COSIMA (Brown and Duggan, ESPRIT Project 477). This model is called PAC (Production Activity Control). The basic principle of PAC is the recognition of five basic building blocks representing the functions required for production control at the shop and cell levels: Scheduler, Dispatcher, Mover, Producer and Monitor. The knowledge-based reference model insists on the decision-making aspect and uses some important concepts of the GRAI model, such as decision horizon/period and decision frame. GRAI grid and GRAI nets formalisms were used to support the knowledge-based 932 model. The IMPACS model insists on integrated solution and decision making for production planning and control. A set of decision support tools are developed to support the elaboration of a manufacturing strategy which is to be understood, interpreted and used correctly at the various planning and control hierarchies. The lowest level of IMPACS model is consistent with the PAC model.

We can see that all these reference models are heterogeneous. This heterogeneity comes from the various points of view on which each approach is based. However, the common aspect emerging is that a reference model gives global and basic concepts which are structured to guide the CIM system design. This globality would be a guarantee for the future integration of the designed system.

Basic modelling formalisms

Many modelling formalisms have been developed within the frame of various projects. In the following, the IDEF and DFD formalisms developed in the United States, and the MERISE and GRAI formalisms developed in France.

IDEF

IDEF mainly consists of IDEF0, IDEF1 and IDEF2 (Fig. 8). IDEF0 (Mayer, 1990) is used to model the functional aspect of a manufacturing system with a hierarchical decomposition technique. IDEFI is based on the entity/relationship formalism (Chen P.P, 1976), and used to model information/data. IDEF2 allows to build a dynamic model for simulation. IDEF formalisms are the most known and used in the world. IDEFI is now extended to IDEF1x.

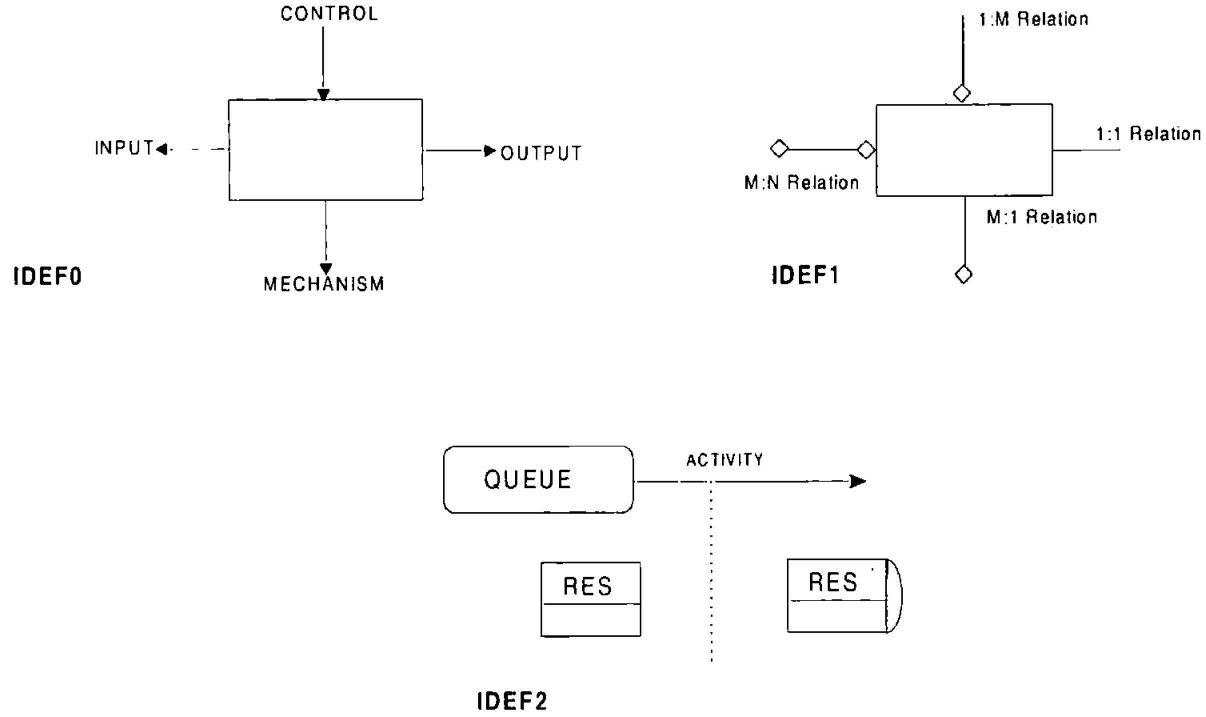


Figure 8. IDEF Formalism

DFD

The DFD formalism (Data Flow Diagram) has been developed within the SSAD method (Gane and Sarson, 1977). The objective of a data flow diagram is to give people a way of constructing a logical model, which must be distinguished from a physical system model. The word "logical" here means anything non-physical. This logical model constructed by the data flow diagram should graphically show what a system is composed of, e.g. the "WHAT", not "HOW". In a data flow diagram, data flow, data stores and data process should be represented as descriptive and as meaningful as possible. However the model should also be concise and easy to read. What we want to do with a data flow diagram is to stay only at the logical level, identifying each of the data elements, data flow and processes that are meaningful, and next, put the detail of data in the data dictionary (Fig. 9).

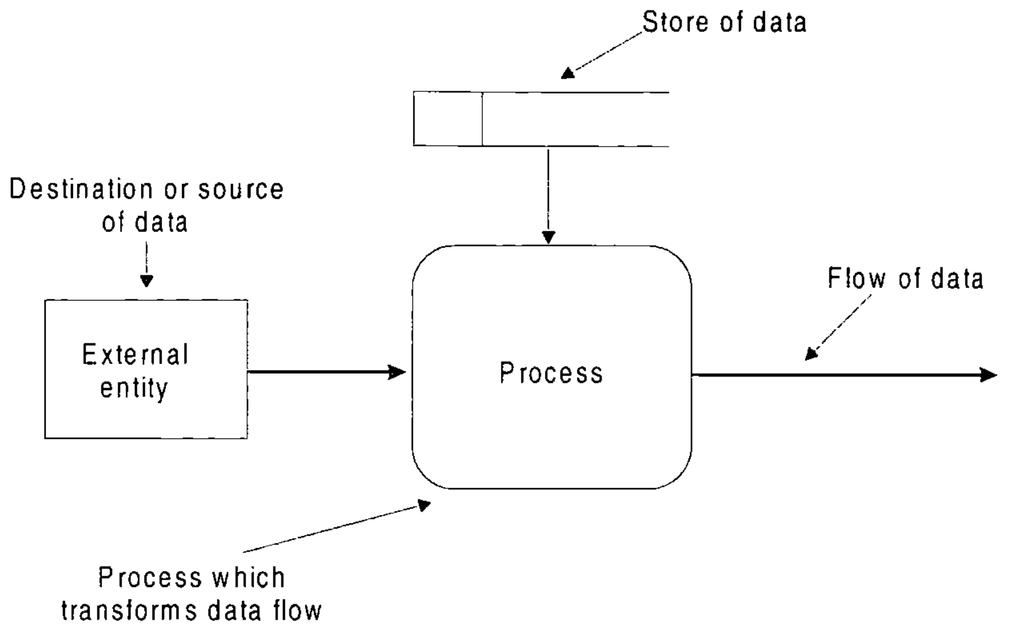


Figure 9 Data Flow Diagram Formalism

MERISE

MERISE is a method for the design of information systems(Tardieu, Rochfeld and Colletti, 1983). Within this method, a formalism has been developed to model the data processing aspects, which is based on the principle of Petri nets. MERISE considers that the entity/relation formalism is not sufficient to model various aspects of information systems. First, the entity/relation model is static, an information system cannot be reduced to a passive memory which stores the data without actions. Second, it does not consider technical feasibility and functioning efficiency. Besides the data structure modelling problem, it is considered that in a natural information system, data and processing are closely related-particularly from the user's point of view. A data processing modelling tool should describe the major functions and working of the system without considering the means needed to support the working system.

The process uses the information brought by the event and generates the results. The notion of result is the same as that of event. The result is an event created by a process and used by a next process. The synchronisation represents a condition which is a logical function of events and which must be true to launch the activity (Fig. 10).

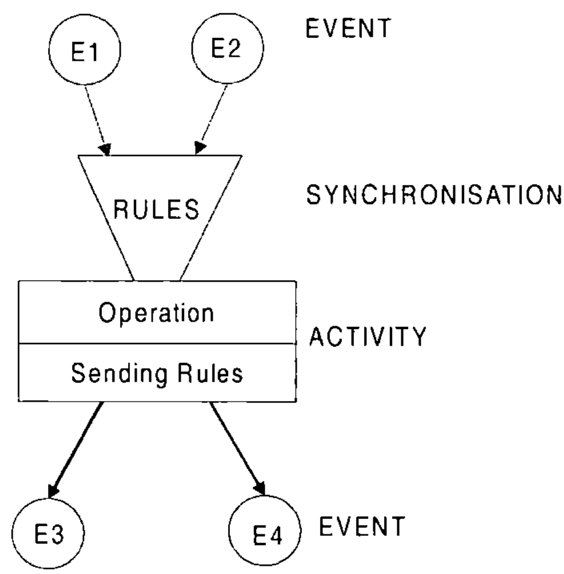


Figure 10. MERISE data processing formalism

GRAI

The GRAI formalism consists of GRAI grid and nets (Doumeingts, 1984). The GRAI grid allows to model a decision system and nets allow to model the decision activities of each decision centre identified in the grid. In the GRAI grid, a double arrow represents a decision link and a simple arrow represents an information link. A decision link cannot cross levels in creating a level short-circuit, but an information link can. A decision link leads always from a higher level to a lower level or is used to connect two decision centres of the same level, but never from a lower level to a higher level. However, an information link can connect any two decision centres liberally. A decision link is made of decision variables, decision objectives and decision constraints. A decision link provides a decision frame to another decision centre. An information link transmits the decisions made in one decision centre to another decision centre as information (Fig. 11).

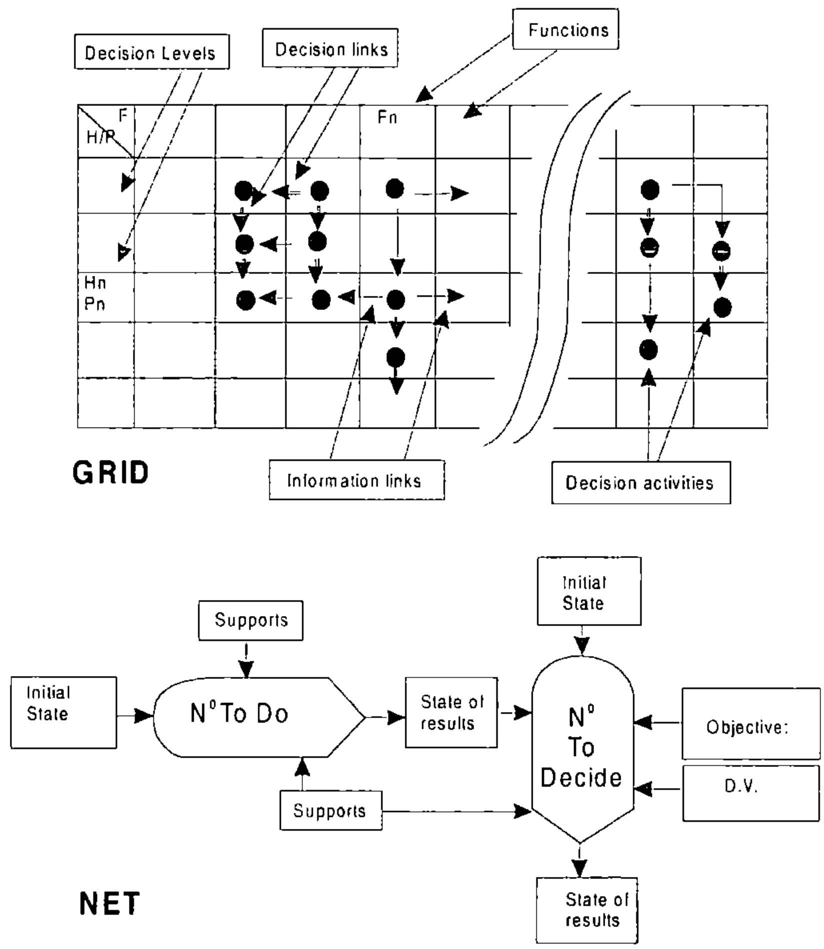


Figure 11 GRAI Formalism

GRAI nets could be considered as an adaptation of existing graphical tools, such as Petri nets, GRAFCET nets and PERT nets to meet better the needs of decisional activity representation. By using GRAI nets, the result of one discrete activity can be connected with the support of another discrete activity. With GRAI nets, four fundamental elements arc to be identified:

- to do or to decide (activity name),
- initial state (main input of an activity),
- supports (information, decision frame, methods and materials),
- results (results of an activity).

Remarks about modelling formalism

IDEF0 is quite general. It is the most used formalism in the world, not only for the analysis of an existing system, but also for the design of information systems. IDEFI is extended to IDEF1x, developed and tested by DACOM through various Air Force and private projects with both major aerospace corporations, such as General Dynamics, McDonnell Douglas, Rockwell International and General Electric, and with non-aerospace corporations, such as ARCO, security Pacific National Bank and Schering Plough. IDEFI is used to build an information model, while IDEF1x is more suitable to build a semantic data model. IDEF1x is also more rich in semantic. Graphical representation is also improved.

Both IDEF1 and DFD deal with modelling of information systems. IDEF1 is more oriented to the modelling of data structures. DFD is more computer-implementation oriented for software development. In fact most information modelling tools are entity/relation based, they are used to describe the structure of data. The MERISE data processing tool is the first one which allows to study the behaviour of information systems. IDEF1 is static, whereas the MERISE data processing model is dynamic. The combination of these two formalisms allows to build a complete model of information systems.

The GRAI formalism is the only one which is used to model decision making systems while most of existing formalisms are too oriented towards the modelling of information processing or functions rather than decision aspects of the overall problem.

Modelling framework

Due to the very complexity of CIM systems, various formalisms, each allowing to model one aspect of a manufacturing system, need to be structured into a framework in which a complete CIM system model can be built.

CIMOSA

The CIMOSA (Computer Integrated Manufacturing Open System Architecture) modelling framework has been developed within the ESPRIT Project 688 (AMICE Consortium, 1989) . The CIMOSA modelling framework is well known and is adapted by the European standardisation organisation body CEN/CENELEC as ENV 40 003 for enterprise modelling (Fig. 12).

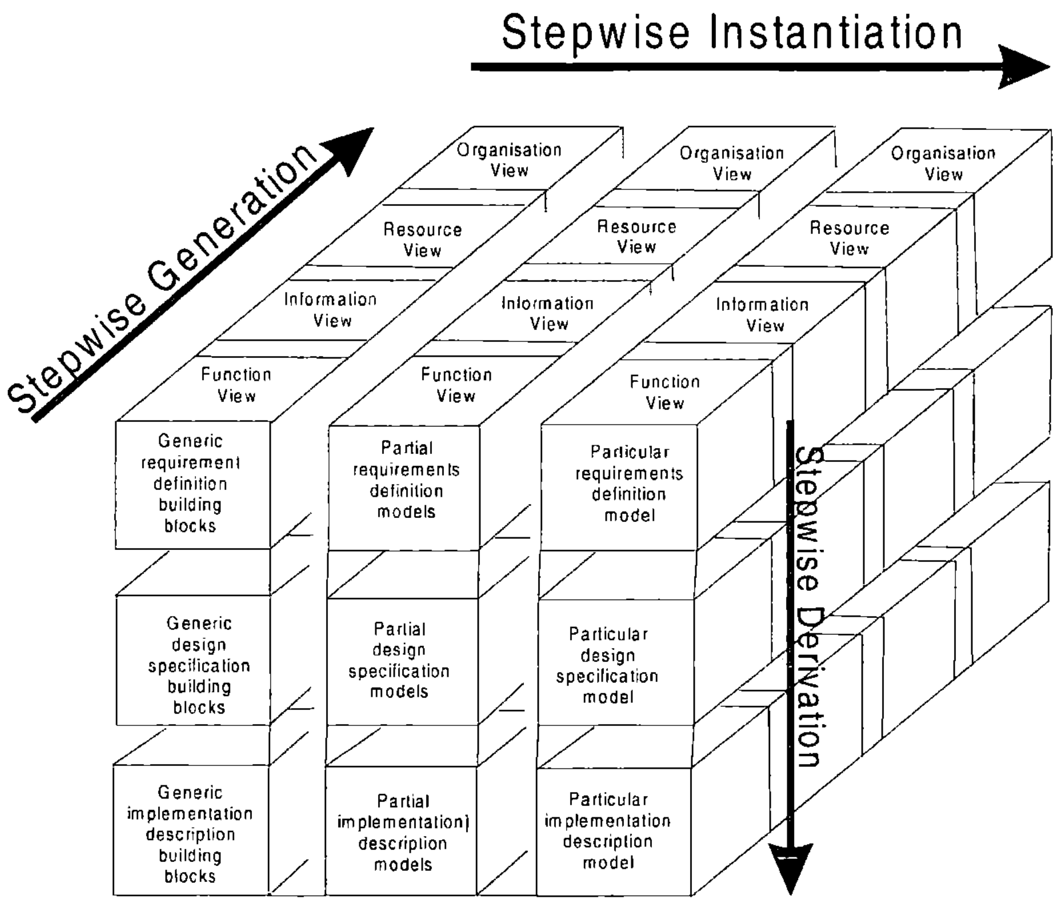


Figure 12 CIMOSA Modelling Framework

GIM

The GIM modelling framework was developed within the Esprit Project 418 to support the GIM method (GRAI Integrated Method). GIM is a method to analyse and design integrated manufacturing systems. It uses the GRAI formalisms to model the decisional system, MERISE formalisms for the informational system and IDEF0 for the physical system. A future system is first defined at the conceptual level. Functionality, decisions and information as well as physical resources are organised at the structural level. The realisation level describes the designed system in terms of tangible components (Fig. 13).

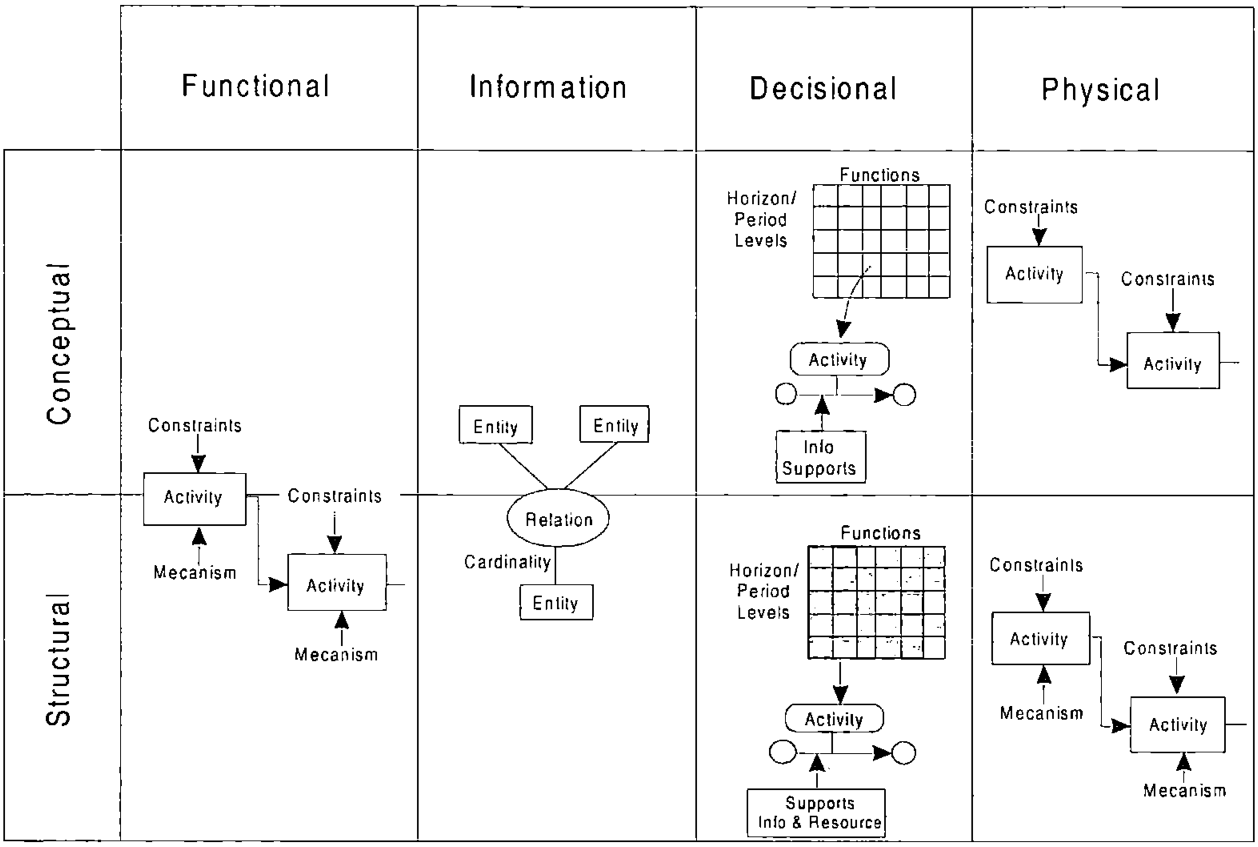


Figure 13 GIM Modelling Framework

IMPACS

The IMPACS modelling framework (Fig 14) was proposed within the Esprit Project 2338 IMPACS. It is based on the GIM modelling framework.

Remarks on modelling framework

Modelling framework is a new concept developed within the Esprit Programme. When designing a CIM system, various concepts and models need to be defined and built in order to ensure the completeness, consistency and integration between the concepts and models, In a modelling framework all models needed for the analysis, design and development of CIM systems find their place.

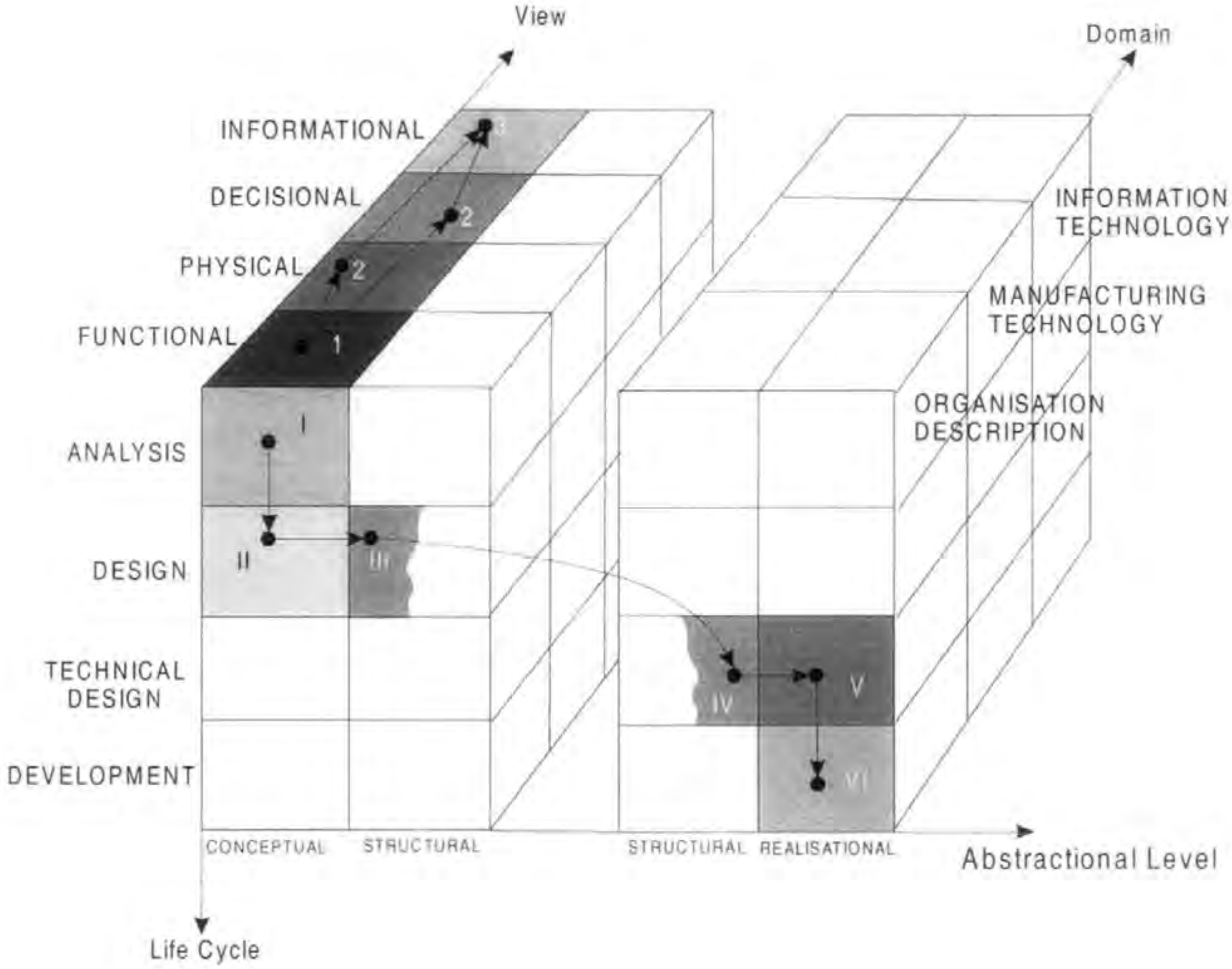


Figure 14. IMPACS Modelling Framework

The early GIM modelling framework developed within the Esprit Project 418 has two dimensions. it is extended to the IMPACS modelling framework within the Esprit Project IMPACS. One difference with the CIMOSA modelling framework is that the project life cycle axis is added to the IMPACS framework. This allows to show the relations between the abstraction levels and the main phases of a life cycle. For example, at the analysis phase, only the conceptual level is of concern. But at the design phase, both conceptual and structural abstraction levels are considered.

Structured approaches

Structured approaches aims at giving a "project dynamics" to concepts described above. Before looking at the existing approaches, some theoretical developments are presented which could be a theoretical basis to operational approaches.

Theoretical basis

Basic structured approach

The structured approach puts the design process in a prominent position and generally associates to this step-by-step process a functional view of the system studied. This approach leads to study the system more by activities the system must execute than by data it must manage. The two main principles of the structured approach

(1) the module decomposition;

(2) the flows study.

The decomposition of a module into sub-modules builds up a hierarchy to be designed within a top-down approach. The functional modules enable a step-by-step specification down to a very detailed level of modelling. The flows study leads to understanding each module as a black box and to highlighting flows moving between modules. IDEF0 and SADT are based on this approach.

Systems theory approach

This approach aims at describing the entity and at designing it as a whole, progressing in its environment. The systemic approach uses three techniques to understand a system:

(1) analogy, which leads to comparing different domains;

(2) modelling, which aims at showing a real complex system under a simpler form;

(3) simulation, the purpose of which is to test the model by looking slits behaviour when external elements acting upon it are made to vary and by extending conclusions to the real system.

The GRAI model is based on this approach.

Object approach

The object approach is the most recent. 1t comes from considerations about programming languages. The main principle of this approach is that a system must own external' quality factors in order to completely satisfy users. These factors can be defined as: -

- *validity*: ability to exactly realise the tasks defined by specifications;
- *robustness*: ability to run even under abnormal circumstances;
- *extensibility*: facility of adaptation when specifications are changing;
- *reusability*: ability to be usable as a whole or by p5rts for a new application;
- *compatibility*: ability to be combined with other systems.

One of the main goals of the object approach is to meet two of these external quality factors: extensibility and reusability (modularity).

Rodenacker's approach

Rodenacker's basic idea is that a system or a machine to be designed can be modelled and defined from a functional point of view. For instance, three types of inputs and outputs of a machine could be: energy, material and information. The functionality of the machine is shown as a transformation of these three flows. Thus, requirements as expressed in a standardised way as a combination of inputs/outputs and thus as a functional expression.

In another respect Rodenacker showed that a machine is hierarchically structured. The function is structured in elementary sub-functions, each of them being a physical phenomenon supported by an elementary facility. The last step of design is the assembling of the facilities selected. Within this approach, there is the idea of correspondence between functions and facilities. This last concept is a first step towards a systematic design approach: the designer can systematise his memory, reasoning process and results models. A lot of CAD systems have been developed in accordance to Rodenacker's works.

Asimov's approach

Asimov's domain of interest are the sequences of steps within a design process. He proposes an elementary design process which is valid for any domain of design (Fig. 15).

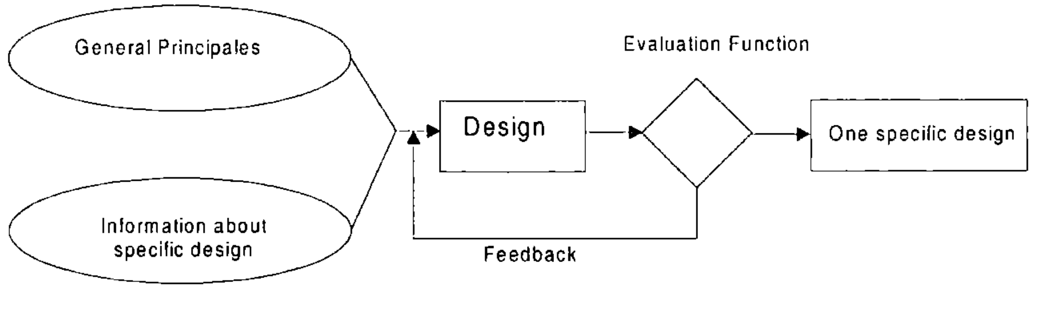


Figure 15 Asimov's generic process of design

Connection with the IMC model

It is interesting to establish a connection between the two previous approaches and the IMC model (Intelligence-Modelling-Choice) for decision processes. According to this model a decision process is composed of three main steps:

(1) the "intelligence" or "identification" step (identification of current status);

(2) the "modelling" or "design" step (elaboration of solutions);

(3) the "choice" (choice of the best solution).

Yoshikawa's general theory of design

The General Theory of Design has evolved from the framework of Yoshikawa's work about automation of thinking within design activities [19]. This theory includes works shown before. Yoshikawa has proposed it for a partial automation of design within the framework of the definition of a method to build up CAD systems.

It is an axiomatic approach. From a topologic model of human intelligence, he proposes the following theorems about design process:

- Design requirements are functionally expressed.
- The solution to a design problem is expressed in terms of attributes the set of which is infinite.
- An entity or an object is characterised by a set of attributes or properties.
- The set of attributes being infinite knowledge has no limit too. Thus the definition of a solution to a design problem is possible and immediate.

When all these theorems are true, it is certain that design requirements expressed in term of functions have a solution in the space of attributes. After the design requirements have been detailed, a sequence of concepts converging to one point inside the entities set is achieved (each entity is defined by a set of attributes). When the knowledge environment is ideal, this process is achieved without any problem. Thanks to a perfect structure of memory and a sufficient process speed the convergence immediately comes up. Functional requirements are instantaneously turned into a description of the solution attributes. When the designer is a human being, some of his weaknesses make the knowledge environment not ideal. Other solutions must be found to make the design process more "automatic".

Design paradigms

Design paradigms are the precepts for design and make a generalisation of works such as the ones shown afterward.

Generator -filter paradigm

The design process is composed of a generator and a filter (Fig. 16). The generator produces solution proposals. The filter dismisses solutions not relevant to requirements and constraints. The filter output is a set of feasible and identified solutions. The design process is in fact composed of a succession of generator-filter couples enabling to reach a good solution. Completeness of the solutions set exploration is linked to the quality and originality of the generator.

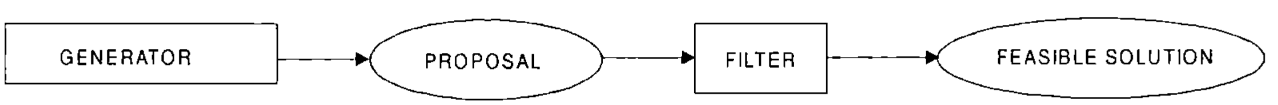


Figure 16 Generator-filter Paradigm

Analysis-synthesis-evaluation paradigm

The design process is composed of three main steps (Fig. 17):

(1) requirements analysis;

(2) solution synthesis;

(3) solution evaluation.

Feed-back loops between these steps are possible.

Requirements are recorded and analysed before beginning the definition of a design solution: every significant requirement must be expressed before the synthesis step. The synthesis is only deduced from requirements. Performances of future objects are evaluated in order to choose the most interesting solution. Evaluation is different from filtering (previous paradigm): filtering dismisses solutions not relevant to requirements, evaluation is processed afterwards. It chooses the best solution when several ones are possible. Evaluation also tests whether the solution is feasible.

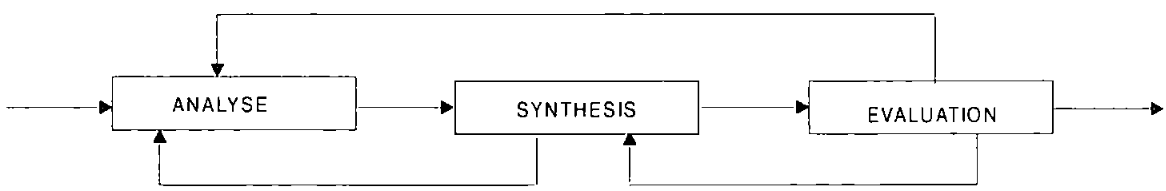


Figure 17 Analysis-synthesis-evaluation paradigm

Algorithmic paradigm

The set of design problems is rarely well structured or, more precisely speaking, difficult to be structured in a good way. However some of them can get a good structure. If the design sub-problem has clear boundaries and if requirements evaluation criteria are known and numbered, then a design algorithm can be built and it guarantees a correct solution. Thus the design algorithmic paradigm is also the automatic design paradigm. Several formalisms can be used, for instance:

- Mathematical equations and inequalities. The design problem is brought back to the resolution of a system of n equations and m parameters.
- Catalogue in which solutions can be reached through several input criteria.

Artificial intelligence paradigm

Because of the structuring problems, design requirements do not own accurate evaluation facilities. Because of the number of design parameters to be taken in account, definition of an understandable and complete set of design requirements is not possible. Thus artificial intelligence gives a design framework composed of two spaces:

(1) design status space;

(2) knowledge space linked to the designer.

The design status space is composed of:

- initial problem status;
- design goal;
- intrinsic constraints of the object studied;
- every other status reached during previous attempts to reach the target status.

The knowledge base is a combination of all pieces of knowledge which can be reached while the design process.

The design process is a sequence of changes of the current design status. For each change the current design status triggers a relevant action from the knowledge base.

This action leads to a new current design status. The kernel of this paradigm is the utilisation of heuristics, because the number of design statuses is potentially infinite. Heuristics are decision-making, enabling to reduce the inquiry domain inside the design status space.

Design process

The major design problem is the research of possible actions. Simon thinks that measuring the design criteria satisfaction is generally possible: it is an optimisation problem. Doubts may be expressed about this opinion: in some cases a designer cannot pass an objective judgement on the solution he gets. According to Yoshikawa it is a knowledge structuring problem. He demonstrates that the design solution is immediate within the case of an ideal knowledge base (everything is known). Some design process models. however, enable to take in account the choice of solutions according to functional design requirements. They enable to define a rough correspondence between functional concepts topology (requirements) and attribute concepts (possible solutions).

- Straight correspondence model (catalogue model). The two sets have the same cardinality and are finite: to one specific requirement is always corresponding the same solution (from the attributes point of view'). Thus no artefact is created. the model acts only at a memory and the knowledge base does not evolve. It is a borderline case because there is no real design process in this model.
- Production model. The principle of this model is to define a rules set to produce solution (attributes) according to requirements. Constraints must be taken in account according to the system to be designed.

- Calculus model. This is a numerical calculus problem which can be applied if the number of functions and attributes is finite and if objects to be designed are of numerical nature. This model has a good convergence rate but is limited to a "mathematical" design. -

- Paradigmatic model. The principle is that the design process is a sequence of actions inside which each action reduces one difference between the current status and the status desired.

After this theoretical point of view, we will now see some operational approaches

SADT approach

The most universal principle used in SADT is to bound the context. Every subject and every action is to be seen only as part of a larger whole that provides the context for detailed considerations, or activities. Authors are taught to state the context consciously when passing from one context to another. SADT insists on the work of groups, so it allows the choice of the best result. SADT obliges to store, in a written form, all the important choices made during the analysis and design.

There are five steps in a SADT project (Fig. 18):

(1) *interview*: collect information on the system requirements and experience of experts;

(2) *Authoring*: analyse the system. design the system and document the results:

(3) *Reading:* review the analysis and design, observe errors and offer improvements;

(4) *Revising:* correct and improve the documents;

(5) *Approving*: verify and accept technical content.

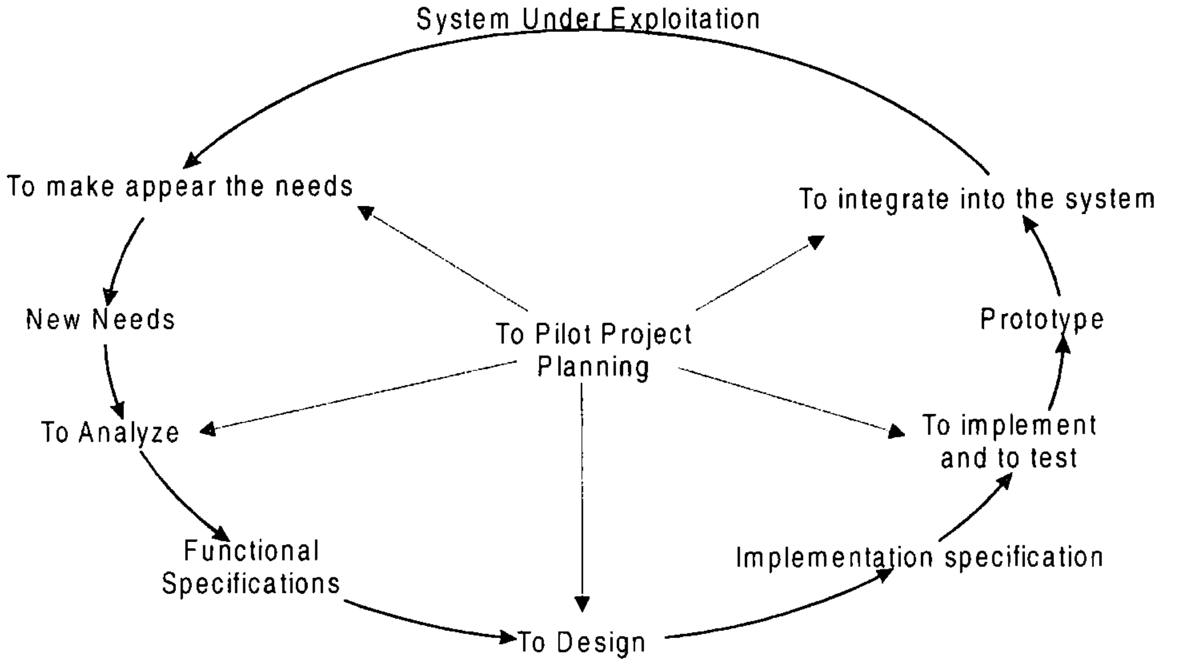


Figure 18 SADT Project Cycle

A SADT project group is composed of: -

- *Actor* (analyst): person who studies the constraints and needs, and analyses system functions; -
- *Commentator*: actor "'ho criticises and comments other actors' work; -
- *Reader*: person who reads the diagrams; -
- *Expert*: person who gives information about the system; -
- *Technical committee:* group of persons who criticises the analysis in each decomposition step; -

- *Librarian*: responsible for all the documents of the project and the dissemination of them; -
- *Monitor*: specialist of SADT guiding actors to practice SADT; -
- *Instructor*: specialist of SADT whose role is to teach actors and commentators to use SADT.

MERISE approach

The MERISE methodology consists of six steps:

(1) Defining a master plan aiming to link organisation strategic goals and information needs;

(2) Preliminary study allowing to get a compromise between conflicting constraints;

(3) Detailed study going from the choice made during the preliminary study to the achievement of the "functional specification book" (general to details);

(4) Completion split up into two phases. (i) technical study describing data organisation, data stores, processing framework and software, (ii) programming;

(5) Implementation, concerning starting up preparations, setting up of the organisation, starting up;

(6) Maintenance, concerning system adaptations according to user needs, environment and technical progresses.

GRAI approach

The application of the GRAI method must be structured and abide strictly within good procedures. its use requires:

- a synthesis group composed of the main future users;
- an analyst-designer (or several if necessary);
- a group with expertise on techniques required for system design;
- the interviewed people.

The GRAI approach mainly consists of two phases (Fig. 19):

(1) The analysis phase: to analyse the current system, to collect all data necessary for designing the new system;

(2) The design phase: to design the system from data collected during the previous phase, by analysing the inconsistencies between the current system and the reference system.

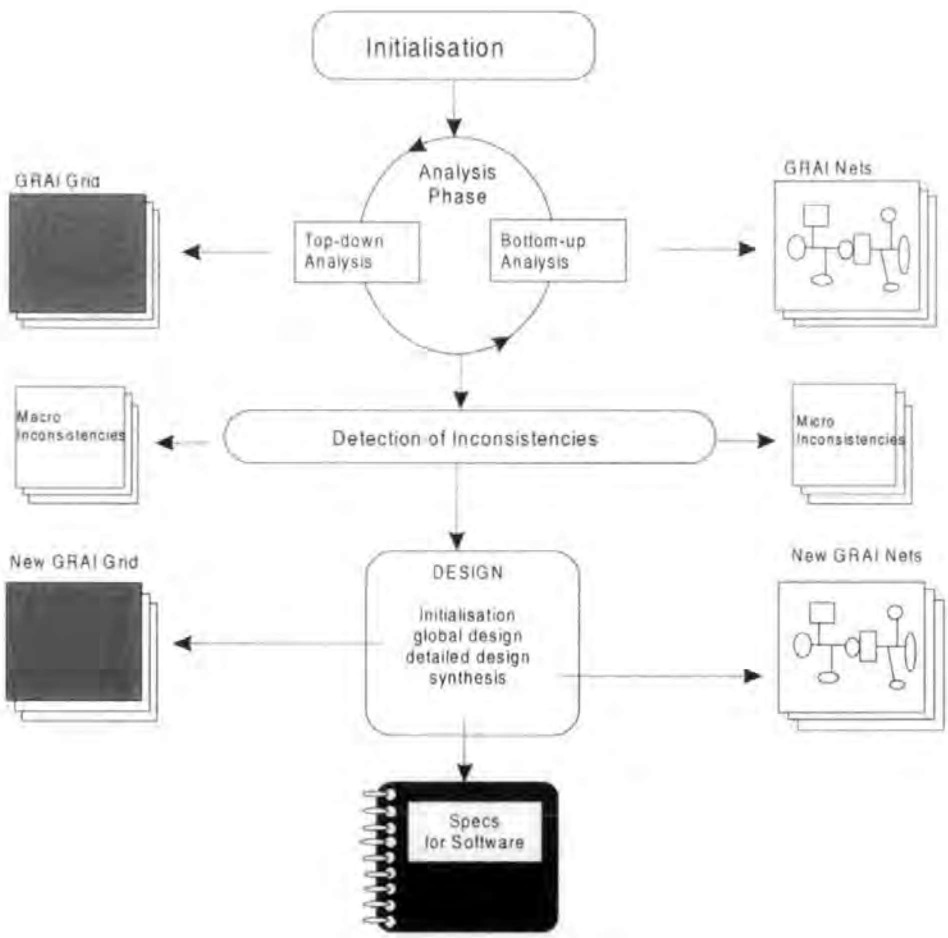


Figure 19 GRAI structured Approach

The analysis phase consists of a top-down analysis and a bottom-up analysis. Top-down analysis consists of drawing up a frame showing the structure of the decision centres of the current system by using GRAI grid. Bottom-up analysis consists, for each decision centre, of analysing in detail: decisions made in the decision centre, variables used in making decisions and frame of decision (constraints on variables, criteria, etc.). This analysis is supported by GRAI nets which represent both activities (decision or process) and iii formation required by the activities The aim of the analysis is to find defaults in production management systems. There are three possible types of inconsistencies:

(1) transmission of information;

(2) specific to a decision; and

(3) co-ordination between decision centres. These inconsistencies may be solved in the design phase in which a new structure of production control system is defined.

The design phase includes two steps:

(1) Drawing a frame representing the new structure of the Production Management System;

(2) Drawing the GRAI nets which show', for each decision centre, the main specifications of information and decision.

The result of this structured approach is the specifications of the Production Management System.

GIM approach

GIM starts by an initialisation phase which defines the problem to be solved, the domain and the objective of the project. During the second phase, a global model of the studied enterprise is built with the IDEF0 tool. The objective is to analyse the different flows in the enterprise and to locate the manufacturing system. The third phase is to model and to analyse each sub-system within the manufacturing system (decisional, informational and physical). At this step, we make a separation between the PMS described by tools coming from GRAI and MERISE, and the physical system described by IDEF0. The analysis phase consists of a top-down analysis and a bottom-up analysis. The aim of top-down analysis is to build macro models (functional and physical models by IDEF0, decisional model by GRAI grid and data model by MERISE). The bottom-up analysis allows to build the micro models (decisional model by GRAI net, physical model by IDEFO). The fourth phase is the detection of inconsistencies on the three sub-systems. For that purpose we use some formal rules defined by the GRAI method, some' coherence tool and reference models. Afterwards, the objective and the goal of the design phases are detailed and the system constraints are analysed. The other steps concern design with several levels of detail which correspond to the different abstraction levels: conceptual, structural and physical (Fig. 20).

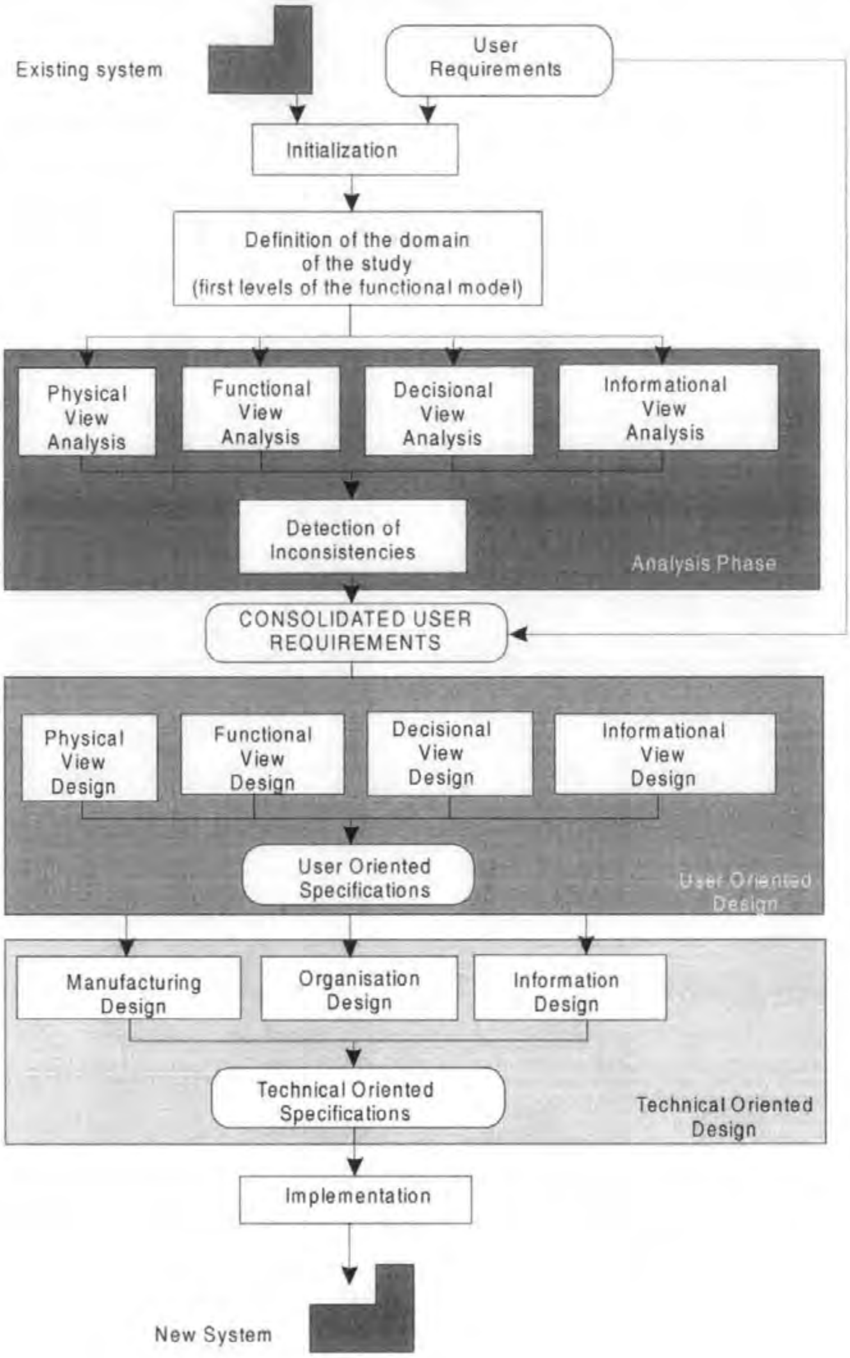


Figure 20 GIM Structured Approach

Conclusions

Nowadays, CIM can no longer be reduced to a purely technical approach. The only guarantee to design an adequate CIM system is to use a methodology which involves and mobilises all the people concerned, and which takes into account function, information, decision, organisation resource/physical, as well as economic, social and human aspects. A global methodological approach should be able to incorporate simultaneously the coherent use of methods, formalisms and reference models/architectures. Most existing approaches (ICAM, CAM-I, MERISE, SADT, GRAI, etc.) are noticed to have been developed separately in order to tackle only one particular aspect of CIM. The need to integrate these various approaches generate coherence problems with regard to the concepts that are developed. The research work carried out within the ESPRIT programme, especially GIM. CIMOSA and IMPACS, tries to integrate the various techniques needed to design an efficient CIM system into a global approach.

In this way, concepts we have presented as constructs of a methodology (reference model, modelling formalisms, structured approach) are found in most of current design approaches. Thus, this frame is a good basis to understand the role of each of these concepts in design. However, the approaches presented are very different from one to another and many concepts and terms are used in different ways.

Recently, the IFAC/IFIP Task Force on Architectures for integrating Manufacturing Activities and Enterprises has carried out a comparative study on three selected architectural approaches: CIMOSA, GIM and PERA (Purdue Enterprise Reference Architecture). Based on this study, the Task Force started to define a complete architecture associated with a methodology: GERAM (Generic Enterprise Reference Architecture and Methodology) for the analysis and design of Integrated Manufacturing Systems.

Appendix B

A brief descriptions of companies interviewed
and
Diagrams for case study companies

A brief descriptions of companies interviewed

Company 1

Company 1 is part of the Dartington group of companies. It produces high quality food products like, mandarin in liqueur, high quality salad dressings etc. Company 1 customers include Harrods, Boots, Marks and Spencers and other speciality food companies.

Company 2

Company 2 is a company specialising in manufacturing and mounting far-reaching lifts on all kinds of vehicles, it has world-wide customer base. Some of its customers include Dubai Airport, British Telecom, and South West Electricity board. Company 2 are the second largest manufacturers in its sector.

Company 3

Company 3 is a surf-board manufacturing company based in the UK capital of surf boarding Newquay. Company 3 is a seasonal company with 70% of its revenue coming from sales during the summer. Company 3 is one of the largest surf-board manufacturing company in Newquay. All its customers are individual surf-board enthusiasts.

Company 4

Company 4 is a small company based in North Devon that specialises in importing of angling equipment, e.g. fishing rods, tackles, reels etc. It distributes, wholesale only, its imported goods to various outlets throughout the UK.

Company 5

Company 5 offers a design, manufacture and installation service for materials handling systems. The company has customers throughout the UK, although the majority are food processors in Devon and Cornwall, where the company has a market share of 50%.

Company 6

Company 6 is a bakery based in South Devon that produces and markets a range of pastries for corner shops, craft bakeries and public authorities through the South of England.

Company 7

Company 7 designs, manufactures and markets electronic and fibre-optic connectors and harnesses, and the associated application and production tooling. At their North Devon manufacturing facilities they produce approximately 2.5 billion terminals each year, these are sold throughout the world to customers such as Sony, Ford, IBM, Apple and British Gas.

Company 8

Company 8 manufactures and markets security boxes that are used by security companies to take the money in and out of banks. These boxes have a built-in device so that if the boxes are wrongfully snatched, the device would set off red dye that would stain the money. The company has a major share of the UK market and exports to a few European countries.

Company 9

Company 9 manufactures furniture for handicapped and special needs children. The company supplies furniture to special needs schools throughout the UK, and is the only supplier of its kind in the Devon and Cornwall region.

Company 10

Company 10 is the UK leader in the manufacture of modular power supplies and is part of a multinational company that is the world's largest power supply group. This company has been trading for over 35 years and employs about 250 people. This was the largest company visited.

Company 11

Company 11 is a manufacturer in the market of wholesale plants. The company sells 2-3 million plants each year and holds an estimated 2% of the UK market. The company's annual turnover includes 10% export revenue. The company has been growing at the rate of 20% per annum.

Company 12

Company 12 is an independent private company. The principal product of the company is a range of high quality assembled kitchen units, mainly sold direct to house builders within its geographical region. It is estimated that the company holds 5% of the market in the Devon and Cornwall region.

Company 13

Company 13 designs, manufactures and markets a range of microwave guides. These are used by the defence and telecommunications equipment manufacturers. The customers include British Aerospace, GEC and Ericsson. The company commands a 65% market share of the UK market, 30-40% of the mainland Europe market and significant part of the North American market; approximately 65% of the company's turnover is export.

Company 14

Company 14 is a privately owned company founded in 1970. It designs, manufactures and markets a range of oceanographic and hydrometric instrumentation. The majority of the company's turnover comes from the sale of self-recording, and direct reading multi-parameter current meters. The company's customers include the NRA, Ministry of Agriculture Fisheries and Food (MAAF), the Defence Research Agency (DRA), and Seatronics.

Company 15

Company 15 is an independent private company. The principal product is a range of garage forecourt equipment (e.g. jetwash, air pressure equipment, little bins, screen wash fillers etc.) mainly sold direct to the large oil companies. It is estimated that this company holds 15% of the UK market, 5% of its revenue is from export.

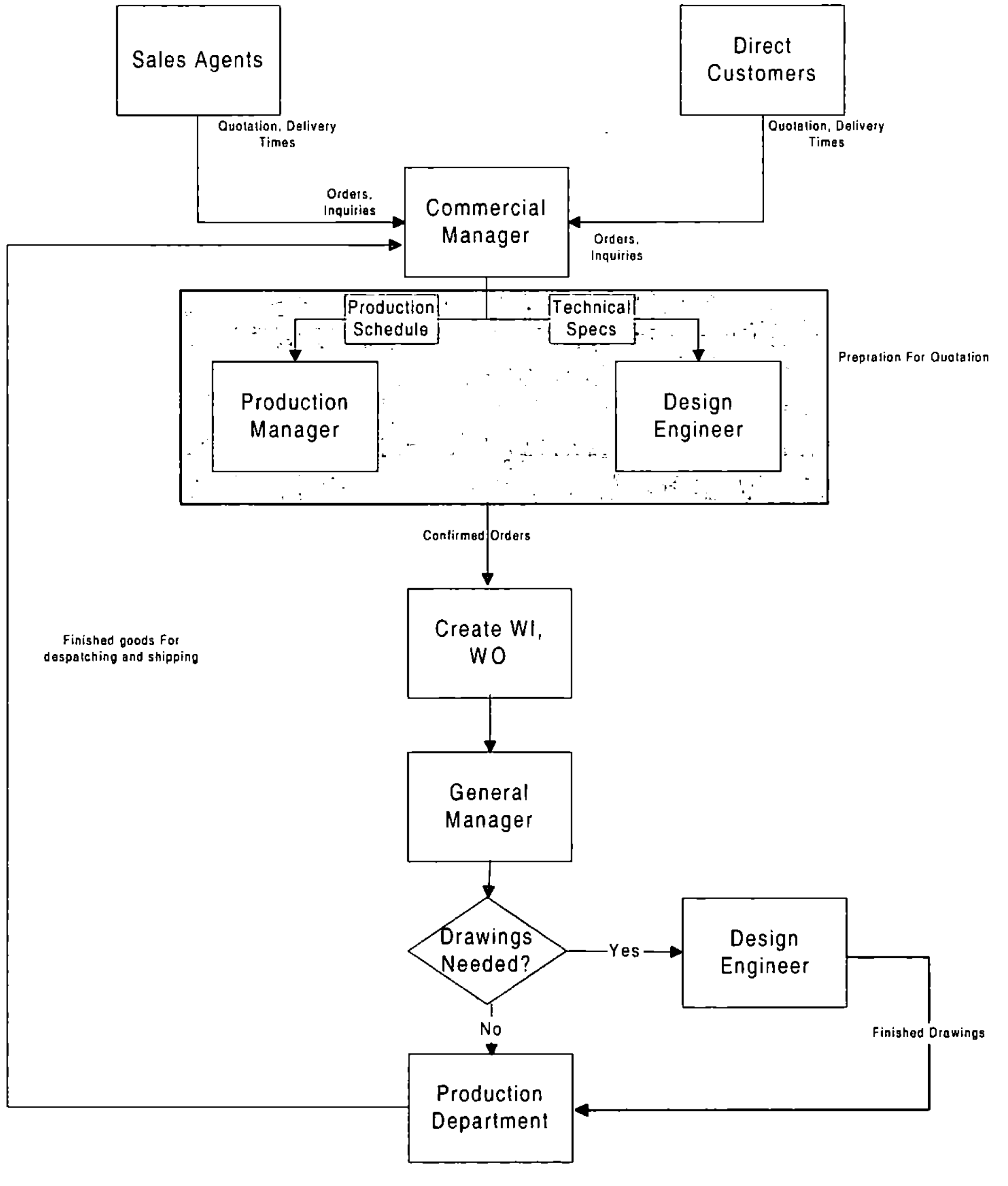
Company 16

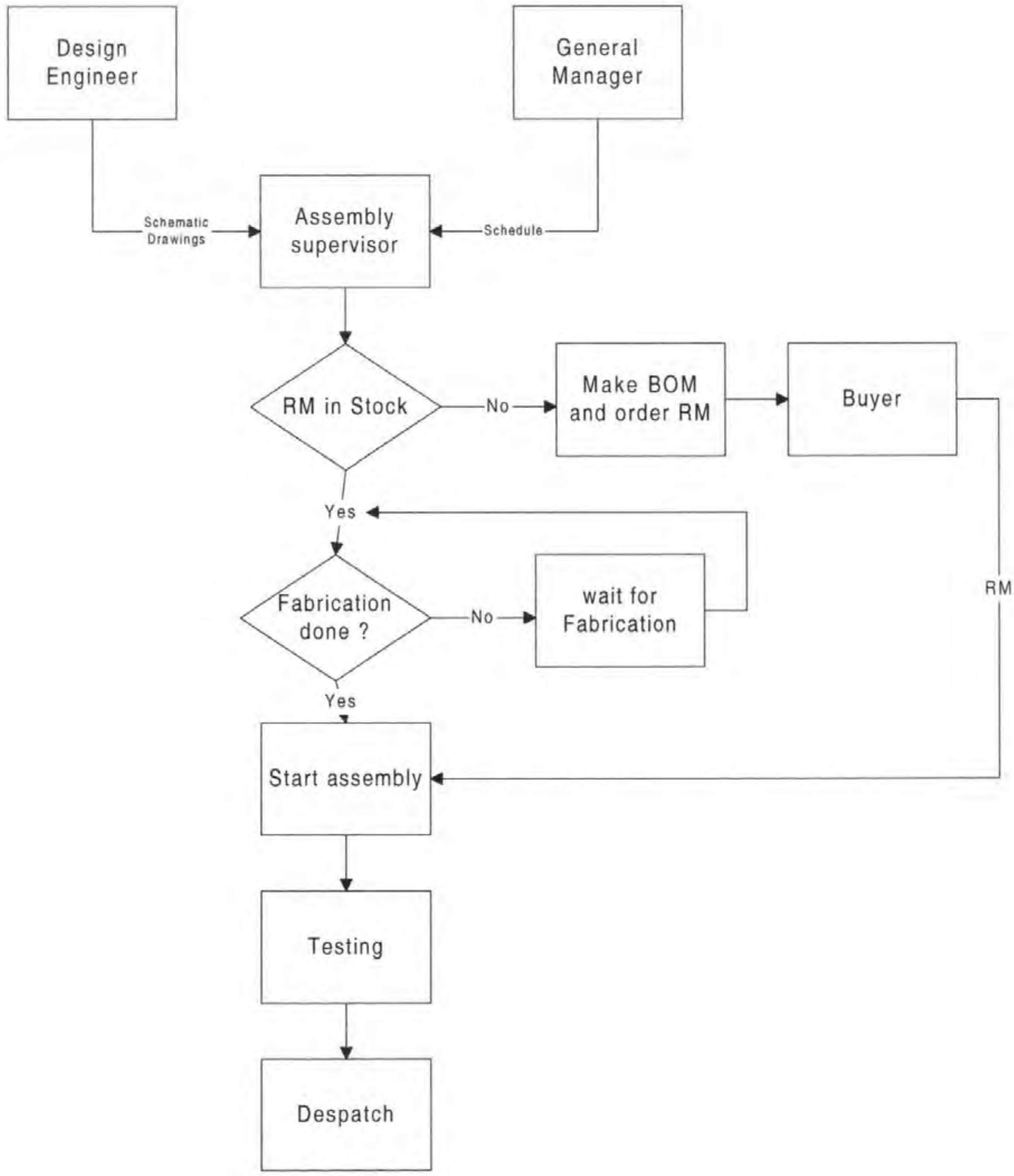
Company 16 is a major manufacture of microprocessors for a specialist sector. The company's customers include NASA in the USA. The company commands 20% of the UK and 35% of company's turnover is generated from export and overseas business.

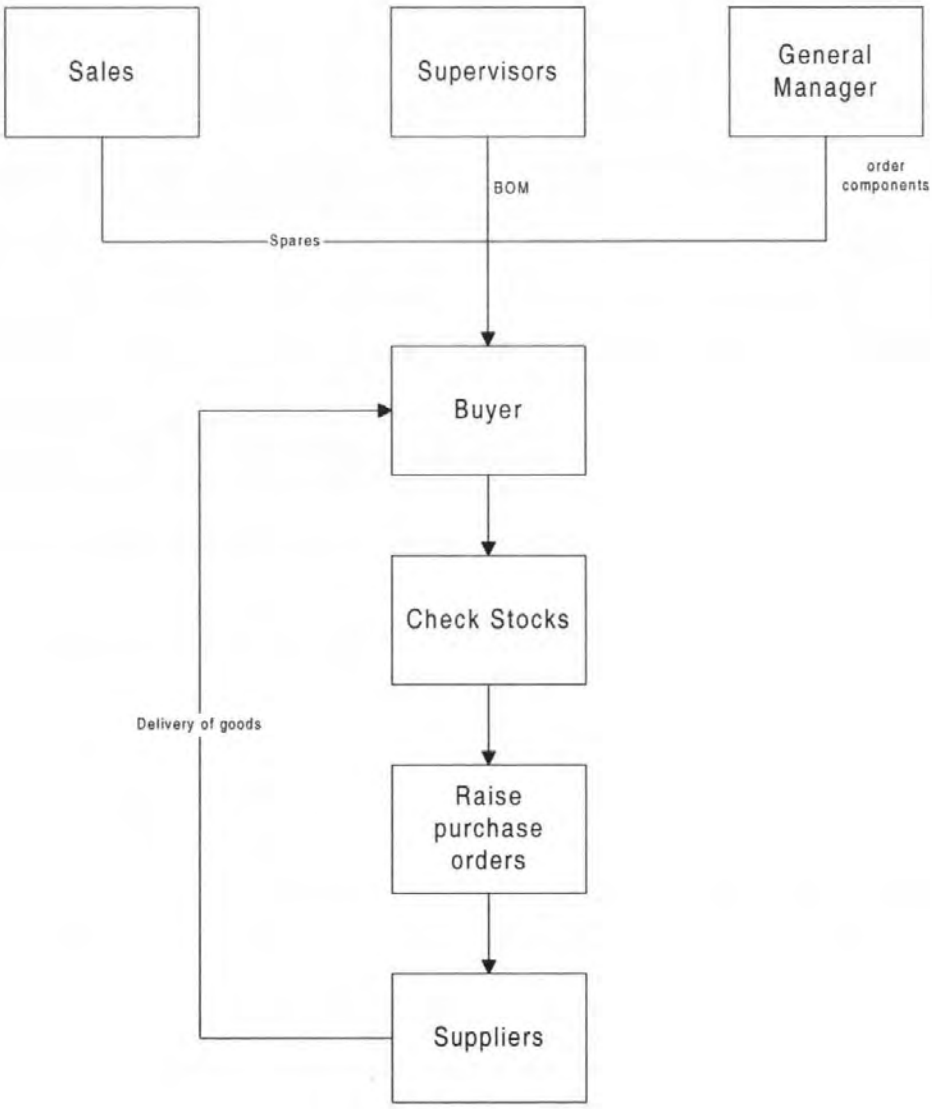
Company 17

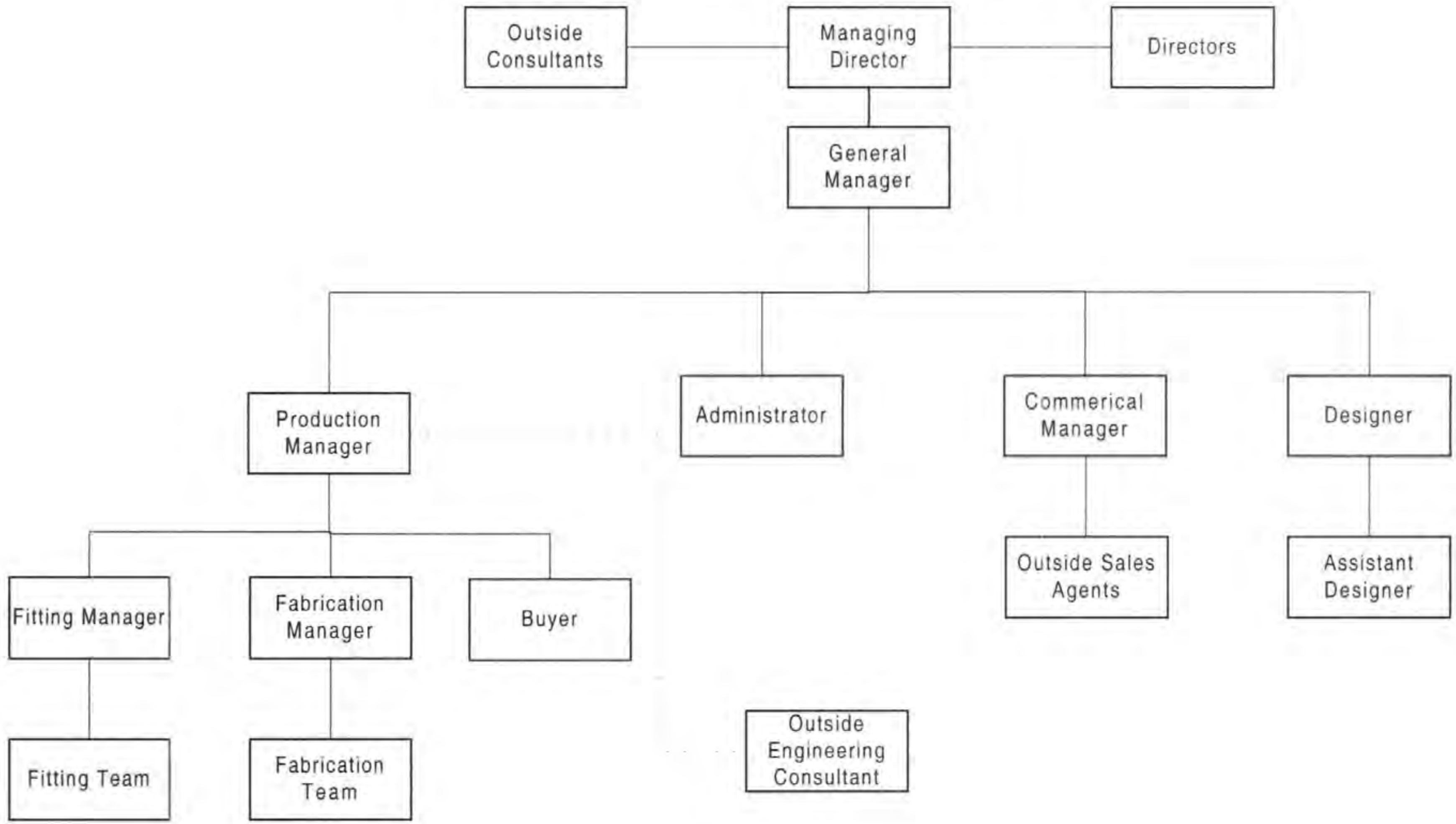
Company 17 is a specialist thin film company which supplies advanced thin film coatings for a wide variety of commercial military applications.

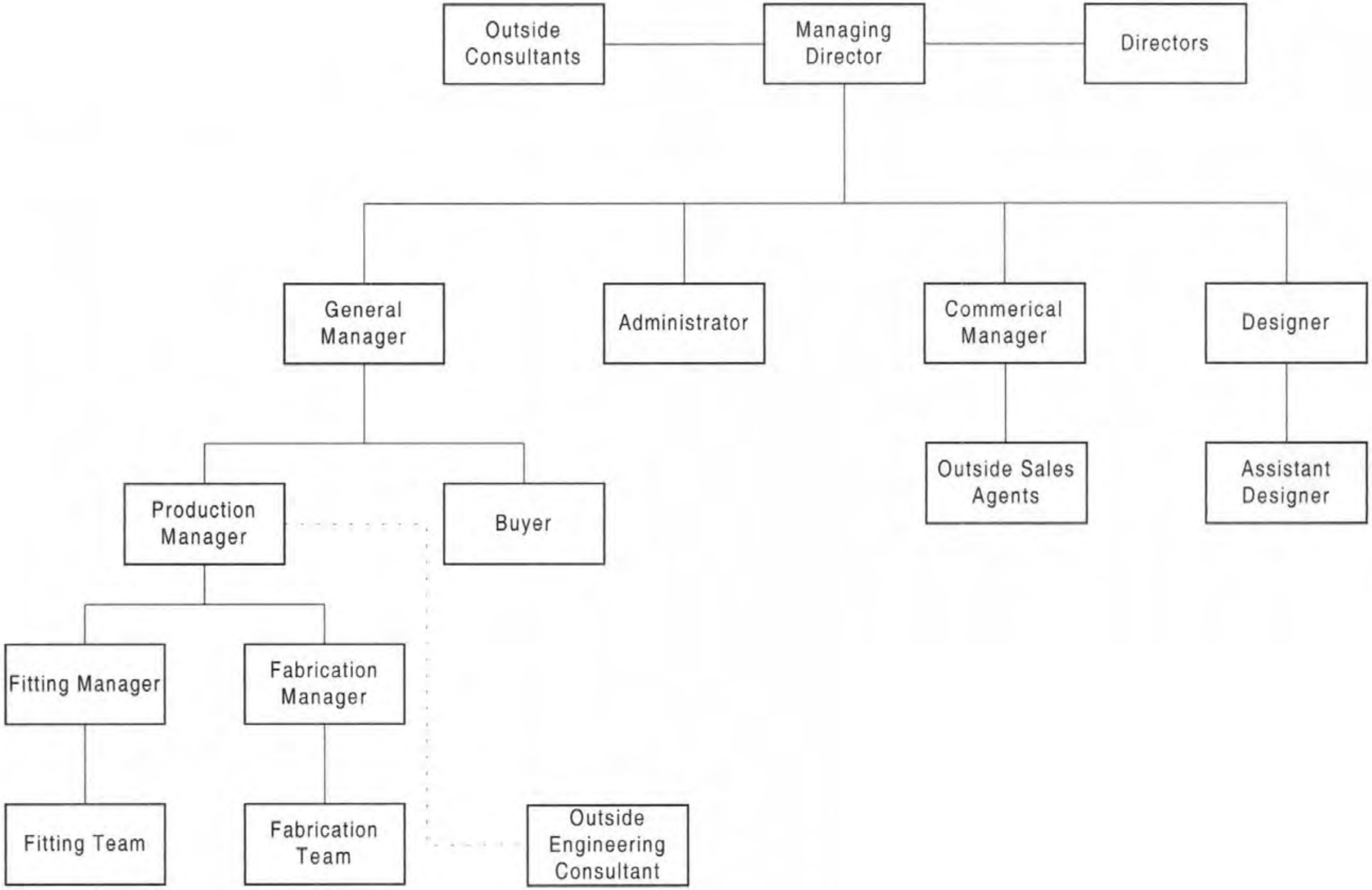
Diagrams For Case Study Company B

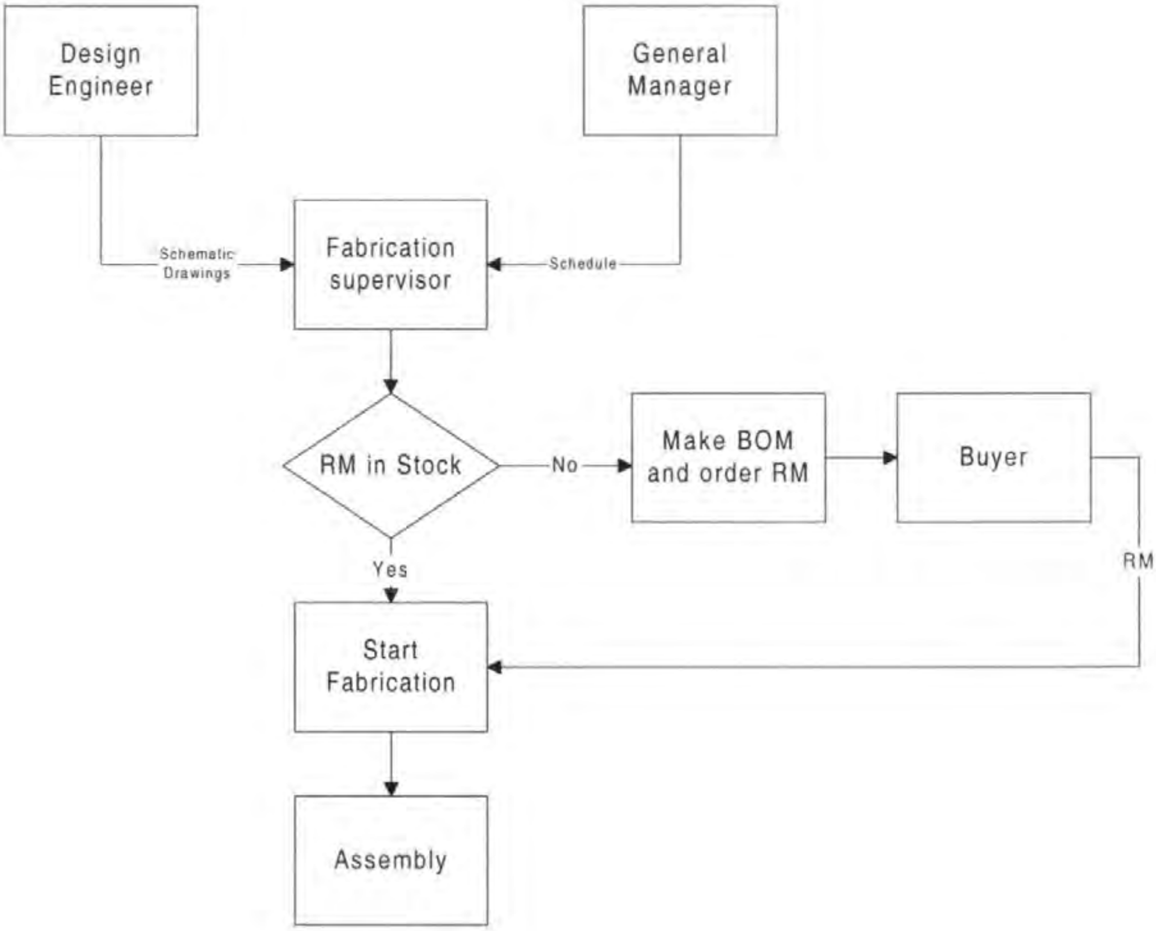

Sales Agents
Direct Customers
Quotation, Delivery Times
Quotation, Delivery Times
Orders, Inquiries
Commercial Manager
Orders, Inquiries
Production Schedule
Technical Specs
Production Manager
Design Engineer
Prepration For Quotation
Confirmed Orders
Create WI, WO
Finished goods For despatching and shipping
General Manager
Drawings Needed?
Yes
Design Engineer
No
Finished Drawings
Production Department

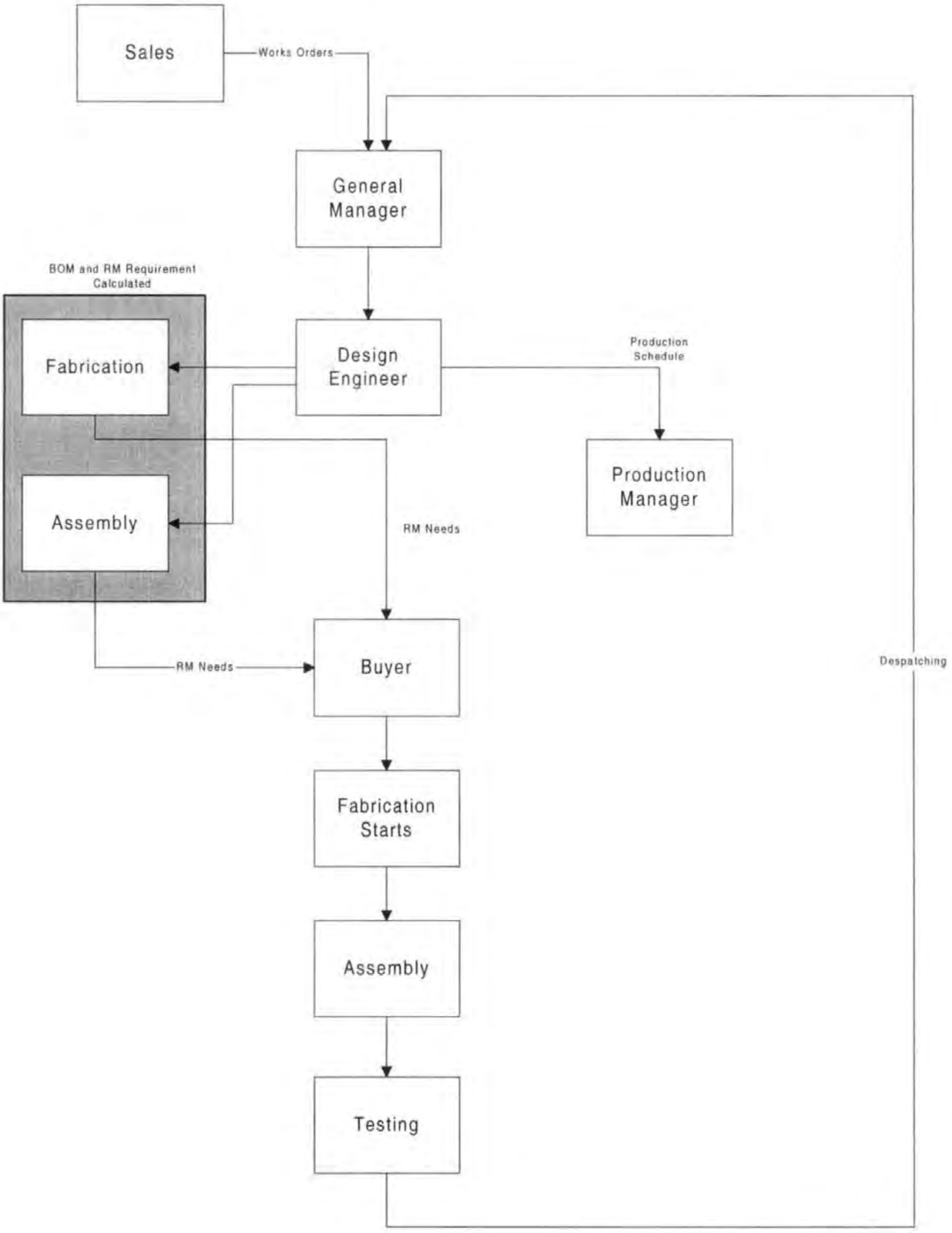

Design Engineer
General Manager
Schematic Drawings
Assembly supervisor
Schedule
RM in Stock
No
Make BOM and order RM
Buyer
Yes
Fabrication done ?
No
wait for Fabrication
RM
Yes
Start assembly
Testing
Despatch


Sales
Supervisors
General Manager
BOM
order components
Spares
Buyer
Check Stocks
Delivery of goods
Raise purchase orders
Suppliers

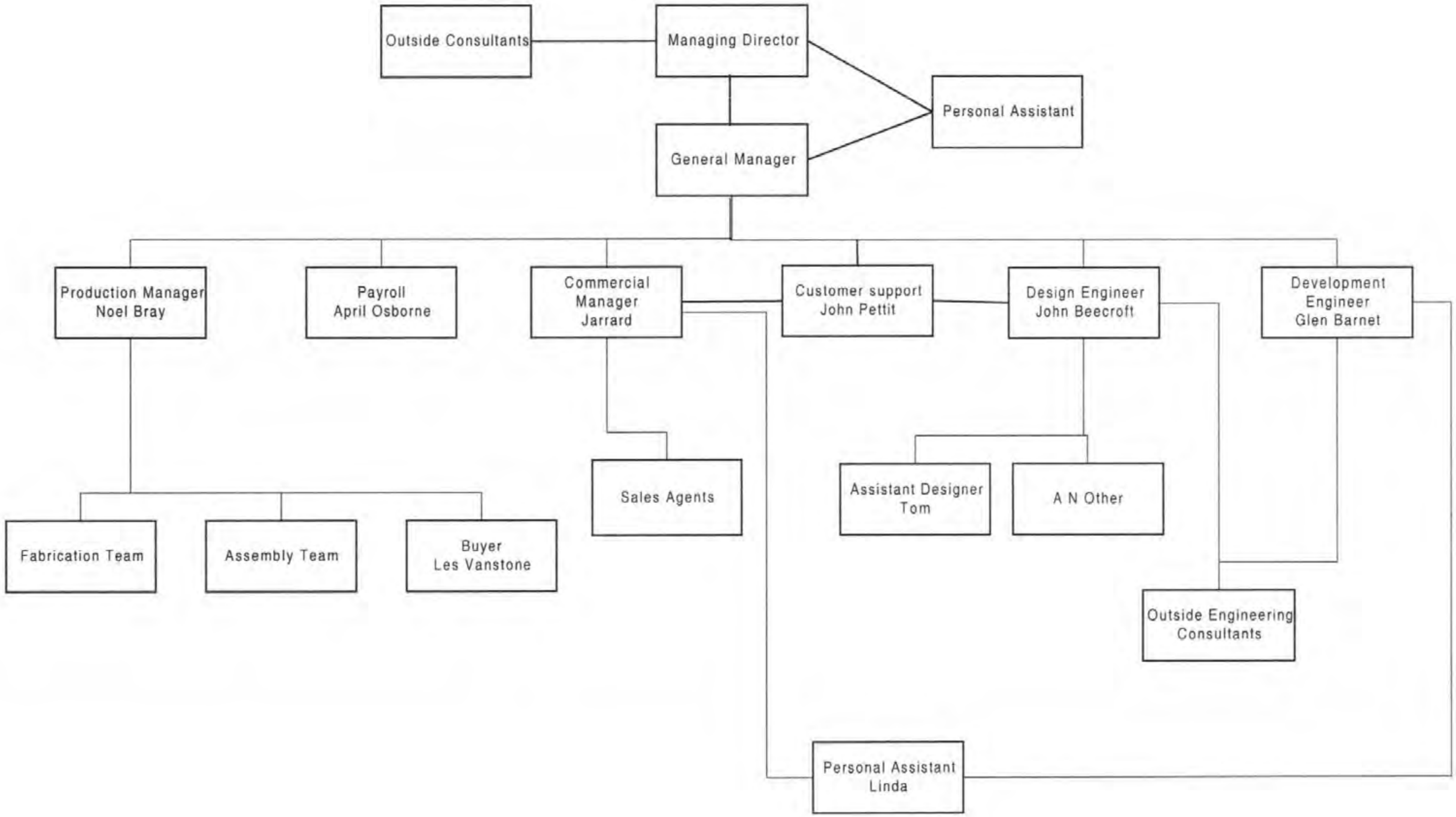

Outside Consultants
Managing Director
Directors
General Manager
Production Manager
Administrator
Commerical Manager
Designer
Fitting Manager
Fabrication Manager
Buyer
Outside Sales Agents
Assistant Designer
Fitting Team
Fabrication Team
Outside Engineering Consultant

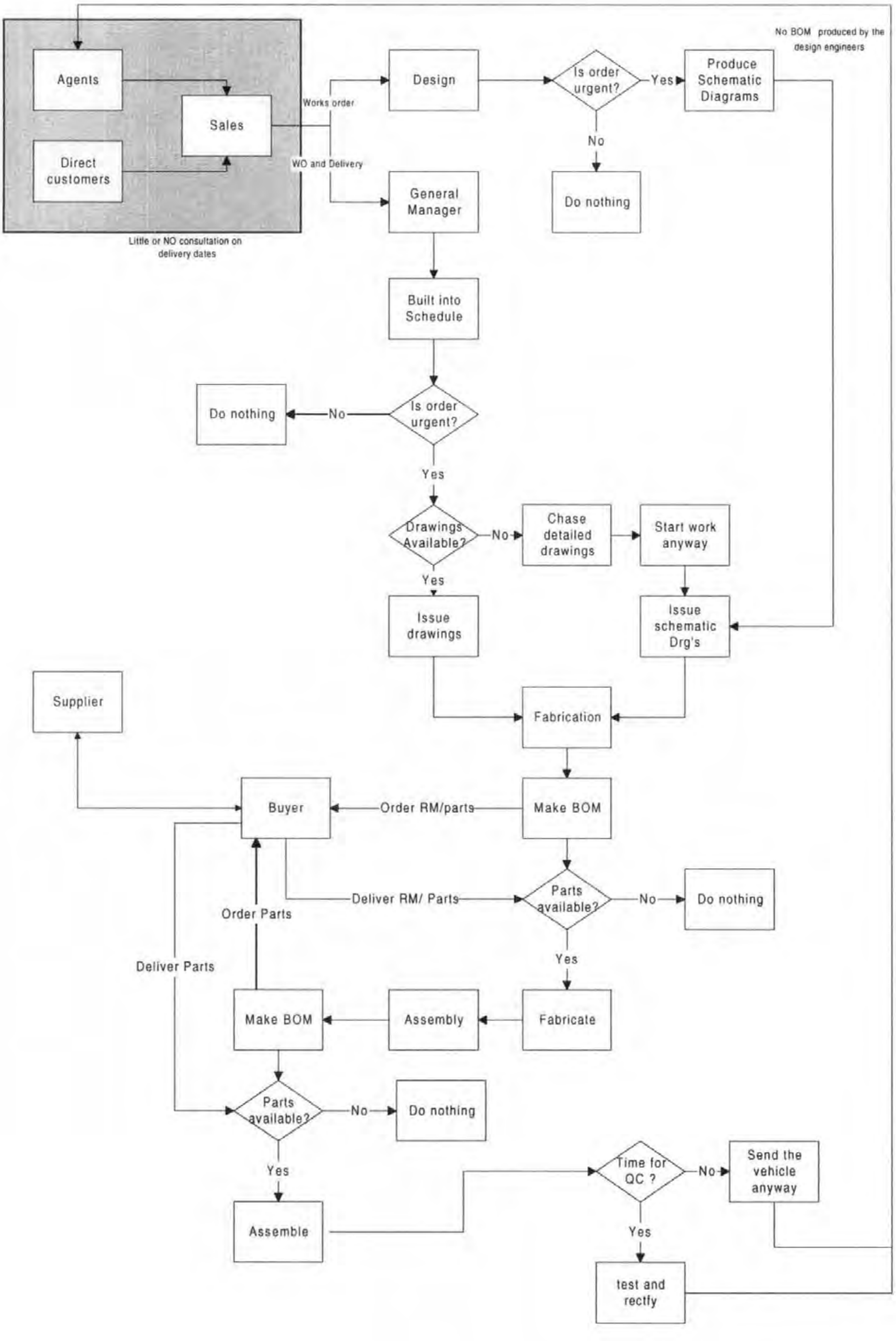

Outside Consultants
Managing Director
Directors
General Manager
Administrator
Commerical Manager
Designer
Outside Sales Agents
Assistant Designer
Production Manager
Buyer
Fitting Manager
Fabrication Manager
Fitting Team
Fabrication Team
Outside Engineering Consultant


Design Engineer
General Manager
Schematic Drawings
Fabrication supervisor
Schedule
RM in Stock
No
Make BOM and order RM
Buyer
Yes
RM
Start Fabrication
Assembly

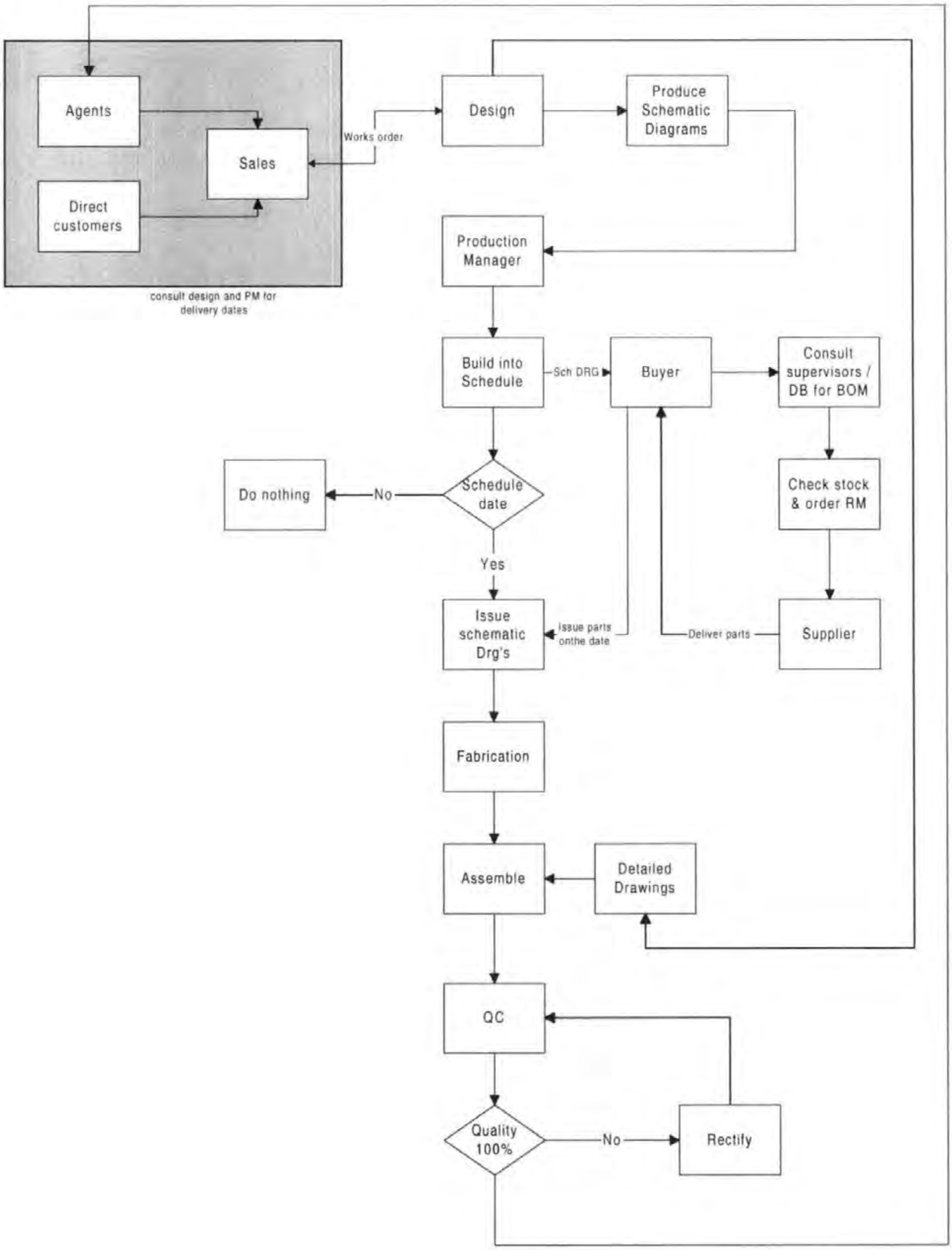


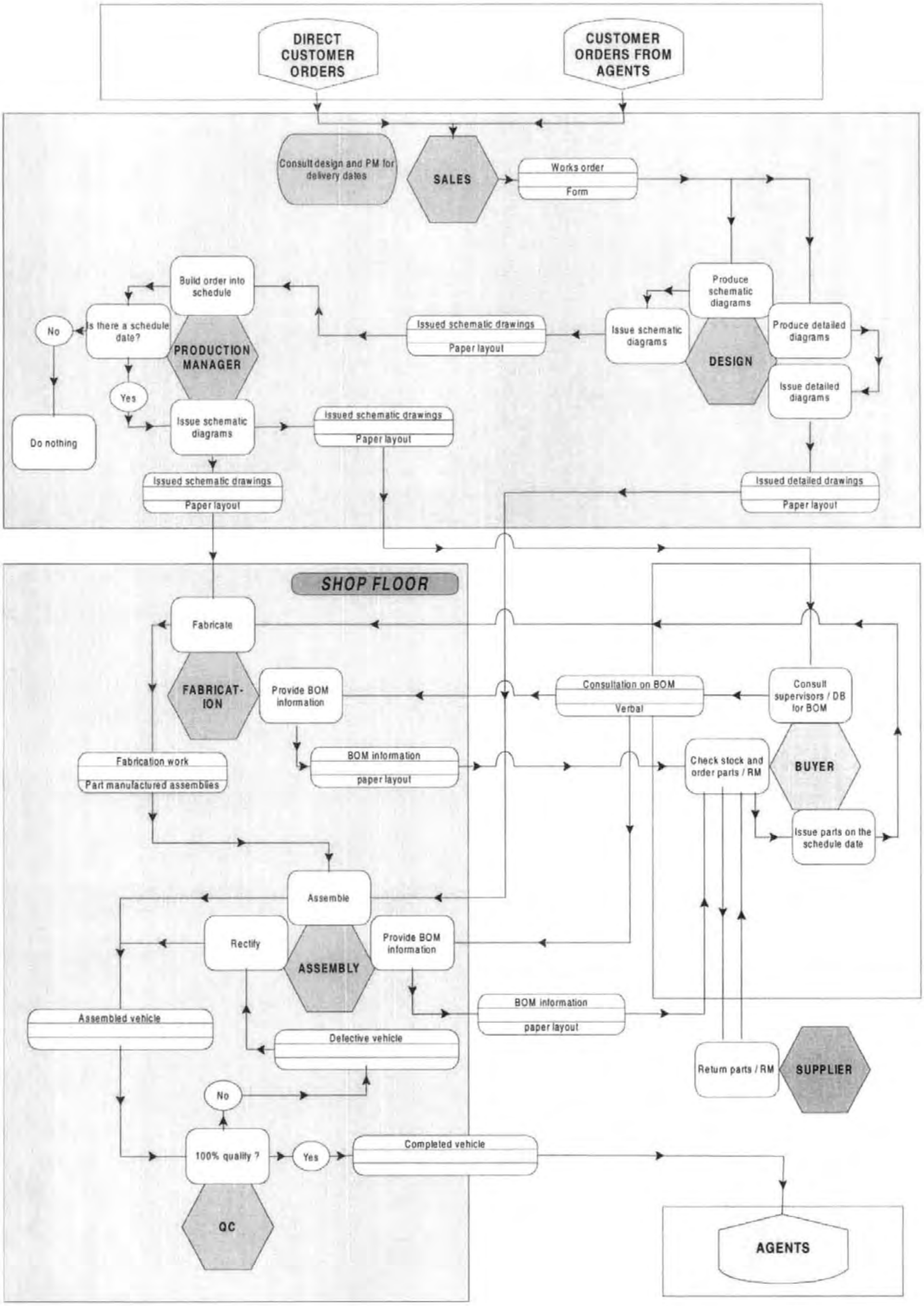
Sales
Works Orders
General Manager
BOM and RM Requirement Calculated
Fabrication
Assembly
Design Engineer
Production Schedule
Production Manager
RM Needs
RM Needs
Buyer
Fabrication Starts
Assembly
Testing
Despatching


Outside Consultants
Managing Director
Personal Assistant
General Manager
Production Manager
Noel Bray
Payroll
April Osborne
Commercial
Manager
Jarrard
Customer support
John Pettit
Design Engineer
John Beecroft
Development
Engineer
Glen Barnet
Sales Agents
Assistant Designer
Tom
A N Other
Fabrication Team
Assembly Team
Buyer
Les Vanstone
Outside Engineering
Consultants
Personal Assistant
Linda

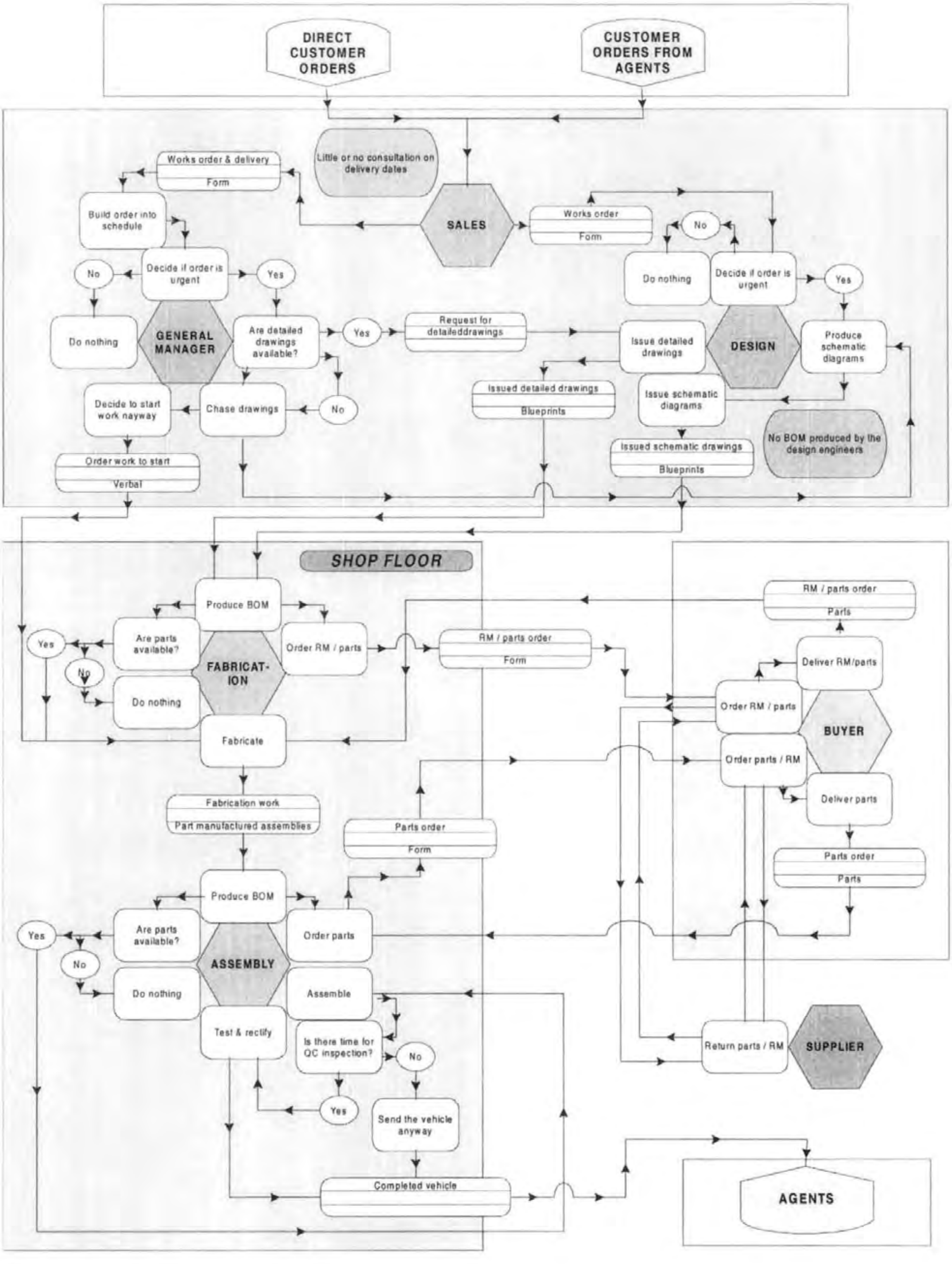


Agents
Sales
Direct customers
Little or NO consultation on delivery dates
Works order
WO and Delivery
Design
Is order urgent?
Yes
Produce Schematic Diagrams
No BOM produced by the design engineers
No
Do nothing
General Manager
Built into Schedule
Is order urgent?
No
Do nothing
Yes
Drawings Available?
No
Chase detailed drawings
Start work anyway
Yes
Issue drawings
Issue schematic Drg's
Supplier
Fabrication
Buyer
Order RM/parts
Make BOM
Deliver RM/ Parts
Parts available?
No
Do nothing
Order Parts
Deliver Parts
Yes
Make BOM
Assembly
Fabricate
Parts available?
No
Do nothing
Yes
Time for QC ?
No
Send the vehicle anyway
Assemble
Yes
test and rectfy

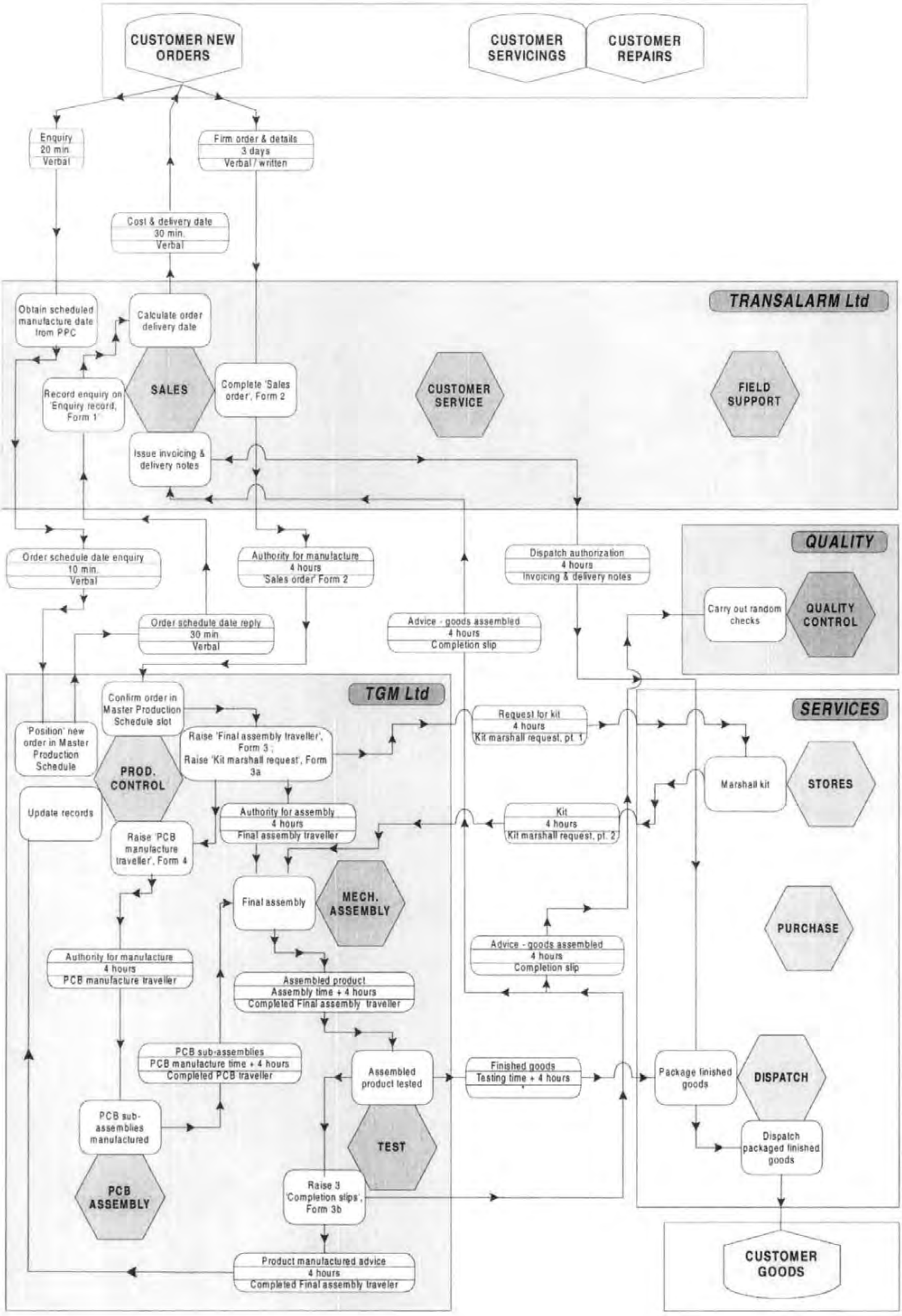

Agents
Sales
Direct customers
consult design and PM for delivery dates
Works order
Design
Produce Schematic Diagrams
Production Manager
Build into Schedule
Sch DRG
Buyer
Consult supervisors / DB for BOM
Check stock & order RM
Supplier
Deliver parts
Do nothing
No
Schedule date
Yes
Issue schematic Drg's
Issue parts onthe date
Fabrication
Assemble
Detailed Drawings
QC
Quality 100%
No
Rectify



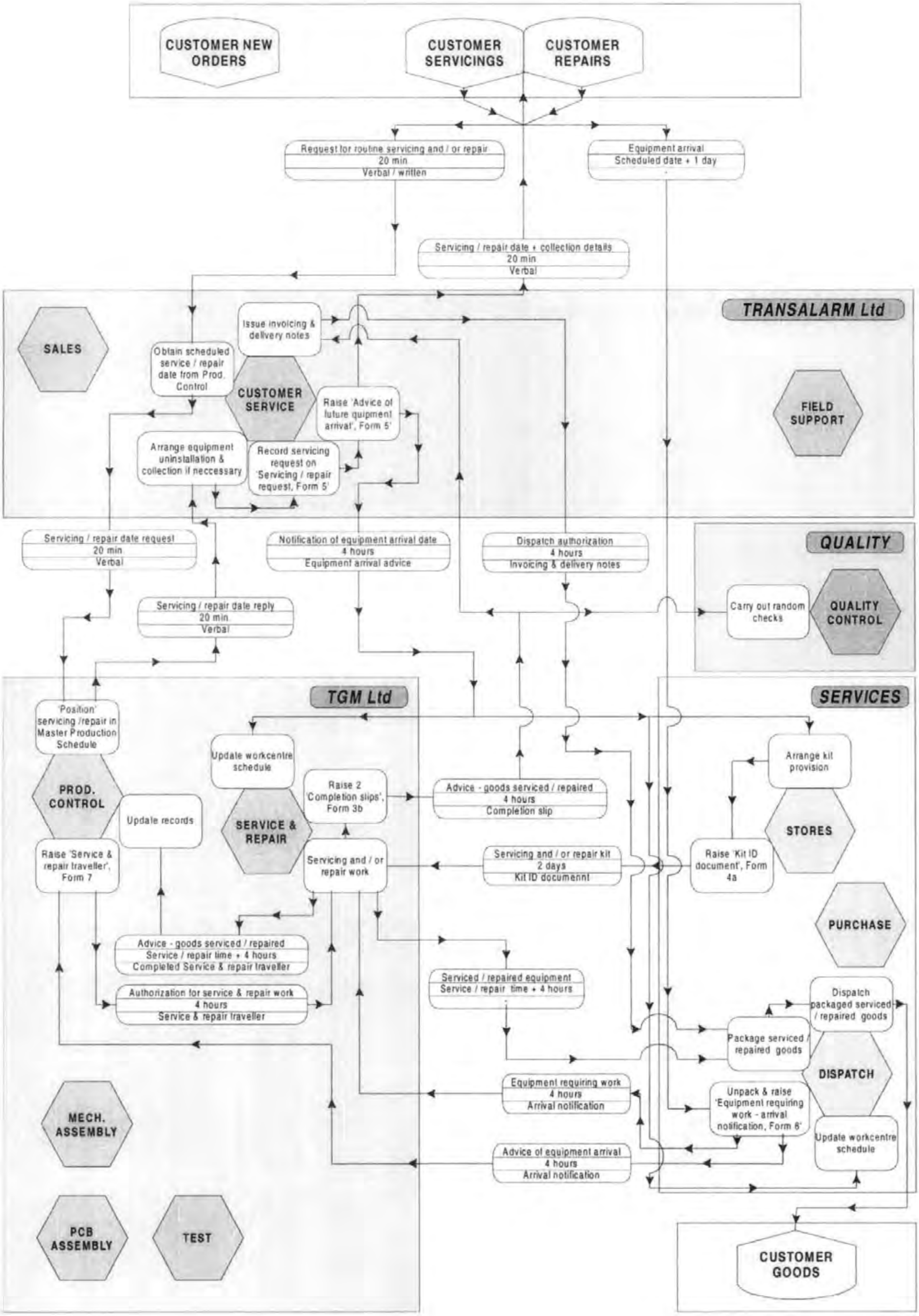
DIRECT CUSTOMER ORDERS
CUSTOMER ORDERS FROM AGENTS
Consult design and PM for delivery dates
SALES
Works order
Form
Build order into schedule
Is there a schedule date?
No
Yes
Do nothing
PRODUCTION MANAGER
Issued schematic drawings
Paper layout
Produce schematic diagrams
Issue schematic diagrams
Produce detailed diagrams
DESIGN
Issue detailed diagrams
Issue schematic diagrams
Issued schematic drawings
Paper layout
Issued schematic drawings
Paper layout
Issued detailed drawings
Paper layout
SHOP FLOOR
Fabricate
FABRICAT-ION
Provide BOM information
Consultation on BOM
Verbal
Consult supervisors / DB for BOM
Fabrication work
Part manufactured assemblies
BOM information
paper layout
Check stock and order parts / RM
BUYER
Issue parts on the schedule date
Assemble
Rectify
ASSEMBLY
Provide BOM information
Assembled vehicle
BOM information
paper layout
Defective vehicle
Return parts / RM
SUPPLIER
No
100% quality ?
Yes
Completed vehicle
QC
AGENTS


DIRECT CUSTOMER ORDERS
CUSTOMER ORDERS FROM AGENTS
Little or no consultation on delivery dates
Works order & delivery
Form
Build order into schedule
SALES
Works order
Form
No
Decide if order is urgent
Yes
Do nothing
GENERAL MANAGER
Are detailed drawings available?
Yes
Request for detaileddrawings
Issue detailed drawings
DESIGN
Produce schematic diagrams
Decide to start work nayway
Chase drawings
No
Issued detailed drawings
Blueprints
Issue schematic diagrams
No BOM produced by the design engineers
Order work to start
Verbal
Issued schematic drawings
Blueprints
SHOP FLOOR
Produce BOM
RM / parts order
Parts
Are parts available?
FABRICAT-ION
Order RM / parts
RM / parts order
Form
Deliver RM/parts
Do nothing
Order RM / parts
BUYER
Fabricate
Order parts / RM
Deliver parts
Fabrication work
Part manufactured assemblies
Parts order
Form
Parts order
Parts
Produce BOM
Are parts available?
Order parts
ASSEMBLY
Do nothing
Assemble
Test & rectify
Is there time for QC inspection?
Return parts / RM
SUPPLIER
Send the vehicle anyway
Completed vehicle
AGENTS

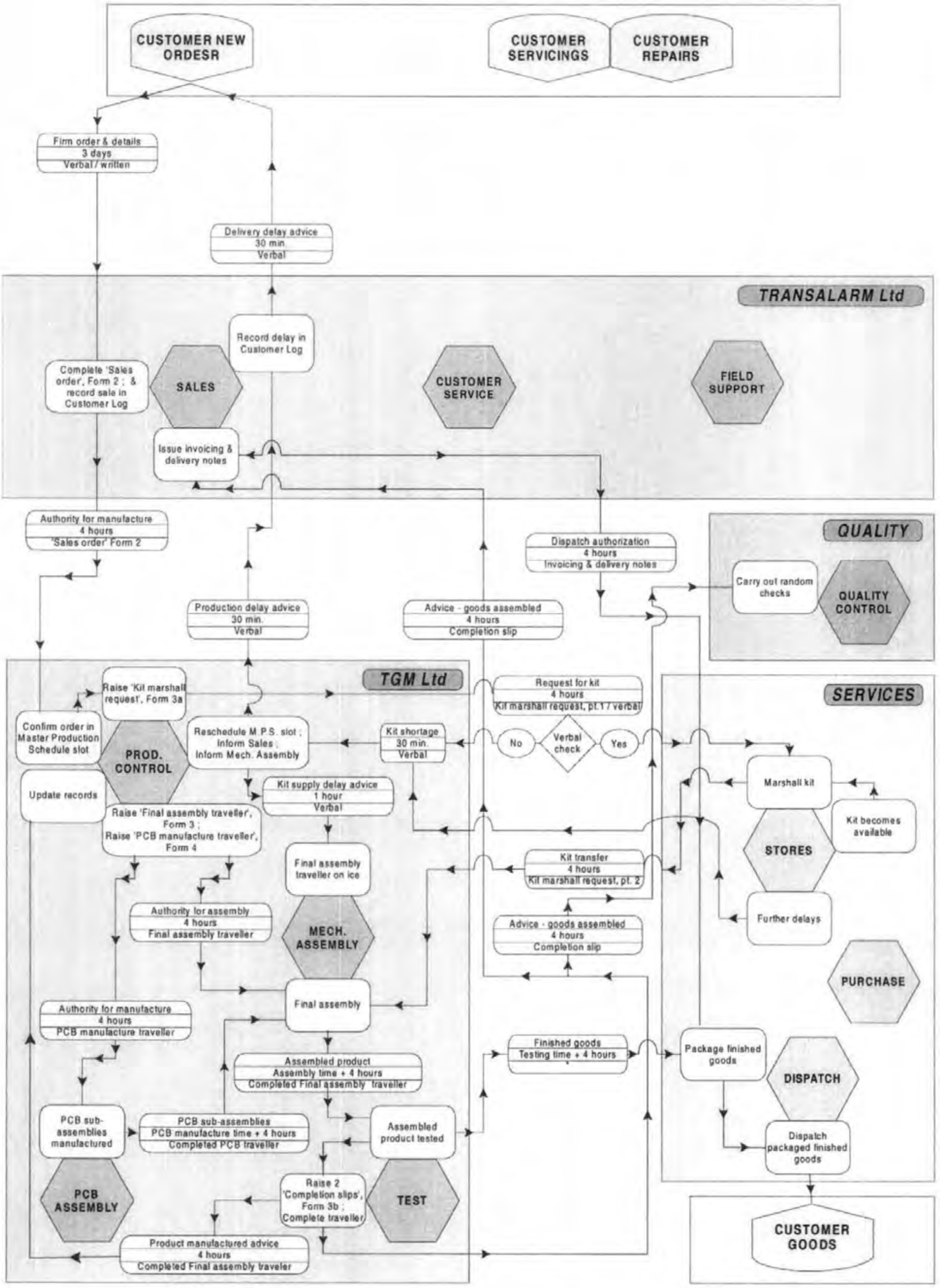
Diagrams For Case Study Company D



CUSTOMER NEW ORDERS
CUSTOMER SERVICINGS
CUSTOMER REPAIRS
Enquiry
20 min.
Verbal
Firm order & details
3 days
Verbal / written
Cost & delivery date
30 min.
Verbal
TRANSALARM Ltd
Obtain scheduled manufacture date from PPC
Calculate order delivery date
Record enquiry on 'Enquiry record, Form 1'
SALES
Complete 'Sales order', Form 2
CUSTOMER SERVICE
FIELD SUPPORT
Issue invoicing & delivery notes
QUALITY
Order schedule date enquiry
10 min.
Verbal
Authority for manufacture
4 hours
'Sales order' Form 2
Dispatch authorization
4 hours
Invoicing & delivery notes
Carry out random checks
QUALITY CONTROL
Order schedule date reply
30 min.
Verbal
Advice - goods assembled
4 hours
Completion slip
TGM Ltd
SERVICES
Confirm order in Master Production Schedule slot
'Position' new order in Master Production Schedule
PROD. CONTROL
Raise 'Final assembly traveller', Form 3 ;
Raise 'Kit marshall request', Form 3a
Request for kit
4 hours
Kit marshall request, pt. 1
Marshall kit
STORES
Update records
Authority for assembly
4 hours
Final assembly traveller
Kit
4 hours
Kit marshall request, pt. 2
Raise 'PCB manufacture traveller', Form 4
Final assembly
MECH. ASSEMBLY
PURCHASE
Advice - goods assembled
4 hours
Completion slip
Authority for manufacture
4 hours
PCB manufacture traveller
Assembled product
Assembly time + 4 hours
Completed Final assembly traveller
PCB sub-assemblies
PCB manufacture time + 4 hours
Completed PCB traveller
Assembled product tested
Finished goods
Testing time + 4 hours
Package finished goods
DISPATCH
PCB sub-assemblies manufactured
TEST
Dispatch packaged finished goods
PCB ASSEMBLY
Raise 3 'Completion slips', Form 3b
CUSTOMER GOODS
Product manufactured advice
4 hours
Completed Final assembly traveler



CUSTOMER NEW ORDERS
CUSTOMER SERVICINGS
CUSTOMER REPAIRS
Request for routine servicing and / or repair
20 min
Verbal / written
Equipment arrival
Scheduled date + 1 day
Servicing / repair date + collection details
20 min
Verbal
TRANSALARM Ltd
SALES
Issue invoicing & delivery notes
Obtain scheduled service / repair date from Prod. Control
CUSTOMER SERVICE
Raise 'Advice of future quipment arrival', Form 5'
FIELD SUPPORT
Arrange equipment uninstallation & collection if neccessary
Record servicing request on 'Servicing / repair request, Form 5'
Servicing / repair date request
20 min
Verbal
Notification of equipment arrival date
4 hours
Equipment arrival advice
Dispatch authorization
4 hours
Invoicing & delivery notes
QUALITY
Carry out random checks
QUALITY CONTROL
Servicing / repair date reply
20 min
Verbal
TGM Ltd
SERVICES
'Position' servicing /repair in Master Production Schedule
Update workcentre schedule
Arrange kit provision
PROD. CONTROL
Raise 2 'Completion slips', Form 3b
Advice - goods serviced / repaired
4 hours
Completion slip
Update records
SERVICE & REPAIR
STORES
Raise 'Service & repair traveller', Form 7
Servicing and / or repair work
Servicing and / or repair kit
2 days
Kit ID documennt
Raise 'Kit ID document', Form 4a
PURCHASE
Advice - goods serviced / repaired
Service / repair time + 4 hours
Completed Service & repair traveller
Serviced / repaired equipment
Service / repair time + 4 hours
Dispatch packaged serviced / repaired goods
Authorization for service & repair work
4 hours
Service & repair traveller
Package serviced / repaired goods
DISPATCH
Equipment requiring work
4 hours
Arrival notification
Unpack & raise 'Equipment requiring work - arrival notification, Form 6'
MECH. ASSEMBLY
Update workcentre schedule
Advice of equipment arrival
4 hours
Arrival notification
PCB ASSEMBLY
TEST
CUSTOMER GOODS



CUSTOMER NEW ORDESR
CUSTOMER SERVICINGS
CUSTOMER REPAIRS
Firm order & details
3 days
Verbal / written
Delivery delay advice
30 min.
Verbal
TRANSALARM Ltd
Record delay in Customer Log
Complete 'Sales order', Form 2 ; & record sale in Customer Log
SALES
CUSTOMER SERVICE
FIELD SUPPORT
Issue invoicing & delivery notes
Authority for manufacture
4 hours
'Sales order' Form 2
QUALITY
Dispatch authorization
4 hours
Invoicing & delivery notes
Carry out random checks
QUALITY CONTROL
Production delay advice
30 min.
Verbal
Advice - goods assembled
4 hours
Completion slip
TGM Ltd
Raise 'Kit marshall request', Form 3a
Request for kit
4 hours
Kit marshall request, pt.1 / verbal
SERVICES
Confirm order in Master Production Schedule slot
PROD. CONTROL
Reschedule M.P.S. slot ; Inform Sales ; Inform Mech. Assembly
Kit shortage
30 min.
Verbal
No
Verbal check
Yes
Update records
Kit supply delay advice
1 hour
Verbal
Marshall kit
Kit becomes available
Raise 'Final assembly traveller', Form 3 ; Raise 'PCB manufacture traveller', Form 4
Final assembly traveller on ice
Kit transfer
4 hours
Kit marshall request, pt. 2
STORES
Authority for assembly
4 hours
Final assembly traveller
MECH. ASSEMBLY
Advice - goods assembled
4 hours
Completion slip
Further delays
PURCHASE
Final assembly
Authority for manufacture
4 hours
PCB manufacture traveller
Finished goods
Testing time + 4 hours
Package finished goods
DISPATCH
Assembled product
Assembly time + 4 hours
Completed Final assembly traveller
PCB sub-assemblies manufactured
PCB sub-assemblies
PCB manufacture time + 4 hours
Completed PCB traveller
Assembled product tested
Dispatch packaged finished goods
PCB ASSEMBLY
Raise 2 'Completion slips', Form 3b ; Complete traveller
TEST
CUSTOMER GOODS
Product manufactured advice
4 hours
Completed Final assembly traveler

Appendix C

Publications

The papers attached to this appendix were presented and published in the following conferences:

- Advanced Manufacturing Processes, Systems and Technologies (AMPST 96), Bradford, UK, 1996.
- Advanced Manufacturing Technology, Twelfth National Conference on Manufacturing Research, Bath, UK, 1996.
- Competitive Manufacturing, Twelfth Conference of the Irish Manufacturing Committee, Cork, Republic of Ireland, 1995.
- Advances in Manufacturing Technology, Eleventh National Conference on Manufacturing Research, Leicester, 1995.
- Applications of soft technologies for enhanced manufacture and management, Technology Transfer series, Plymouth, 1996.
- Technology Transfer and Innovation, Teaching Company Directorate, London, UK, 1997.
- New technology in SME's, Teaching Company Directorate, Belfast, Northern Ireland, UK, 1995

PLYMOUTH TEACHING COMPANY CENTRE

UNIVERSITY OF PLYMOUTH

The Design Process For A Management Information System Applied To A Manufacturing Company

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ABSTRACT

It is the aim of this paper to describe the design process for a manufacturing based management information system. Prior to the design and specification of required computational resources, it is shown that significant advantages may be achieved in terms of the effectiveness of the final solution and in its acceptance by the relevant employees, by initially concentrating on the development of the manual information systems present.

INTRODUCTION

When considering the current dynamic manufacturing environment it has clearly become imperative that companies manufacture to ever increasingly tighter schedules and higher quality specifications in order to maintain profit margins. Key goals in any manufacturing company are to reduce lead time and work in progress (WIP) with wastage minimised, while at the same time to remain competitive in their markets, which may extend world-wide.

The success or failure of an organisation was traditionally attributed to many factors, e.g. employment of capital, plant equipment, quality of skilled labour, etc. In recent years handling of information within a company has become just as relevant and vital. Therefore, for a company to achieve its objectives it is imperative that the information must be controlled in an orderly and organised manner. Due to the recent computational development the nature and handling of information have become much more complex. If not well organised and understood, there is a significant possibility that detrimental effects on the company's position may result.

The application of Information Systems (IS) has been established in industry for several years. These systems consist of a set of fundamental procedures that collate, process, store and disseminate relevant information[1], thus supporting the decision making and control within the organisation. This has been extended by the principles of Management Information Systems (MIS). The MIS methodology is designed to serve the monitoring, controlling, decision making and administrative activities of an organisation[1]. Implementation of these MIS principles can be computer based (CBMIS). The system may therefore be designed to focus on daily, weekly, monthly and annual summaries of various accounting and manufacturing transactions. This Teaching Company Scheme case study is based on a low volume/high margin food manufacturing company where the primary objective was to increase the output without necessitating an increase in production resources. This paper aims to explain how this process will be achieved by first developing manual information systems for individual departments, and then subsequently using the basis of these systems, to develop an integrated CBMIS.

SPECIFICATION OF THE PROJECT

The first, and most significant, stage of the system design is the project specification which should include precise definition of the project's boundaries, management expectations, duration and also the limits of the financial commitment that the company is willing to undertake .

It is of great importance to realise that whatever is agreed at this stage will form the basic structure of new system development and subsequently will be employed as a 'bench mark' by which to measure the success or failure of the system design. It is therefore a pre-requisite of any successful system design that this initial stage is undertaken in a thorough manner.

EXISTING SYSTEM: ANALYSIS

It is preferable when commencing the design process to start with no preconceived ideas and limitations. However, in reality this is rarely the case as there are always obstacles and constraints within an organisation which need to be considered before a system can be designed. To develop an MIS system it is necessary to understand the existing system. Figure 1 shows a model for system development which was used for the case study.

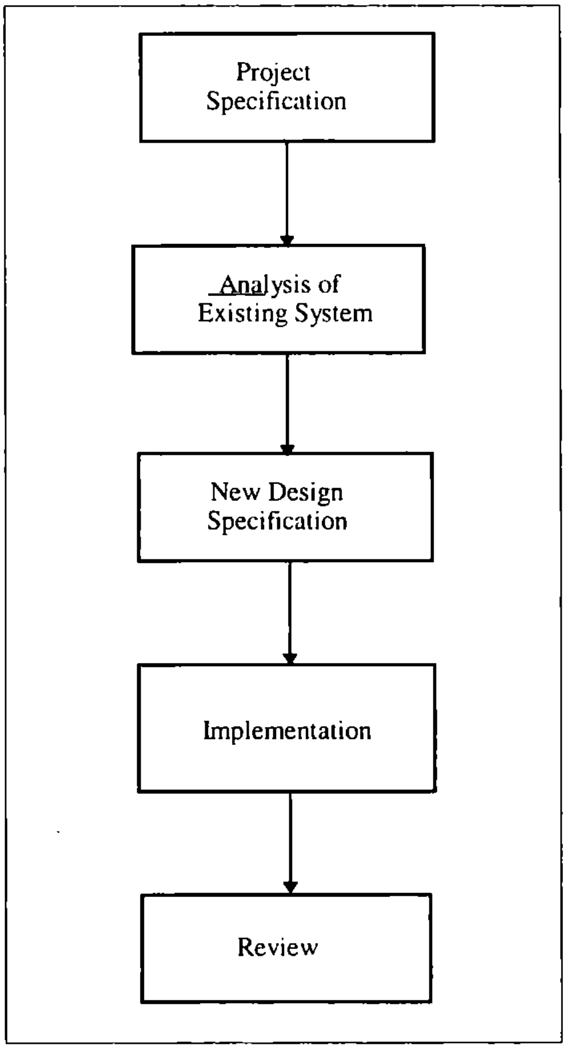

Figure 1. System Development Model

EXISTING SYSTEM: UNDERSTANDING THE ORGANISATION

The initial consideration when attempting to understand a company is to identify the actual structure, e.g. the operation may be very centralised with nearly all decisions being focused at head office. If this is the case then clearly the IS must reflect this. Conversely, if the organisation allows considerable autonomy to managers in subsidiary parts of the business then the system must be designed to provide these managers with their necessary requirements to run the business effectively. The system must therefore be tailored to closely reflect the structure of decision making[2]. In addition, the existing IS's in the various departments must be understood and evaluated. This can be achieved by utilising a sequence of methods.

The most significant tool for finding out how the existing system works is the personnel interview. It is best to interview all of those concerned with the system, even though this appears to provide more sources of information than is absolutely necessary. Some of these sources will make mistakes, so the extra sources help to identify where this has occurred.

The use of a systematic approach to gathering the information should help to minimise the risk of leaving gaps in the information gathered. The use of a standard data collection form by the analyst is often helpful at this point, assisting the interviewer to ensure that nothing is missed through open ended questions.

Inviting the interviewee's observations and opinions can prove helpful and may help to form relationships ready for the stage when change must be implemented. The questions should be worded carefully. They should not offend and must enable the analyst to identify all information used, what it is used for, why the process is carried out, where the information is derived from and where its subsequent destination is[2].

Observation is another key element in building up a picture of how the existing system operates. Useful insight into the problems and inefficiencies of the system are often easier to spot by actually watching the job being performed. A further useful technique is to search through written records to verify information obtained from other sources, and to check information on data accuracy, data volumes etc. and to look for anomalous events.

While using these methods, it can be extremely useful to collect copies of all documents which flow around, and to trace their movements and use from the originator to the point where the document is destroyed. It is normal for elements of the information gathered to be incorrect. Therefore, to obtain a clear and accurate picture of the existing system is a meticulous process of checking, re-checking and cross checking.

RECORDING GATHERED INFORMATION

The information gathered must be recorded in an unambiguous and concise manner as it will be used to critically analyse the system and explain the relevant internal mechanisms to others. The choice of techniques utilised is dependant upon the size of the company and complexity of the system. However, Data Flow Diagrams (DFD) are the most common technique. As the case study involved a relatively small company it was sufficient to use simple data flow diagrams without the necessity for any subsequent steps being invoked. Considering this company, there are two key stages required for completion of the final diagram. Context Diagrams which are similar to a top-level DFD with the exception that the whole sections of the system are identified only as a 'black boxes'. External entities and data flows in and out of the system are drawn ,but no processes or data stores are shown (Figure 2).

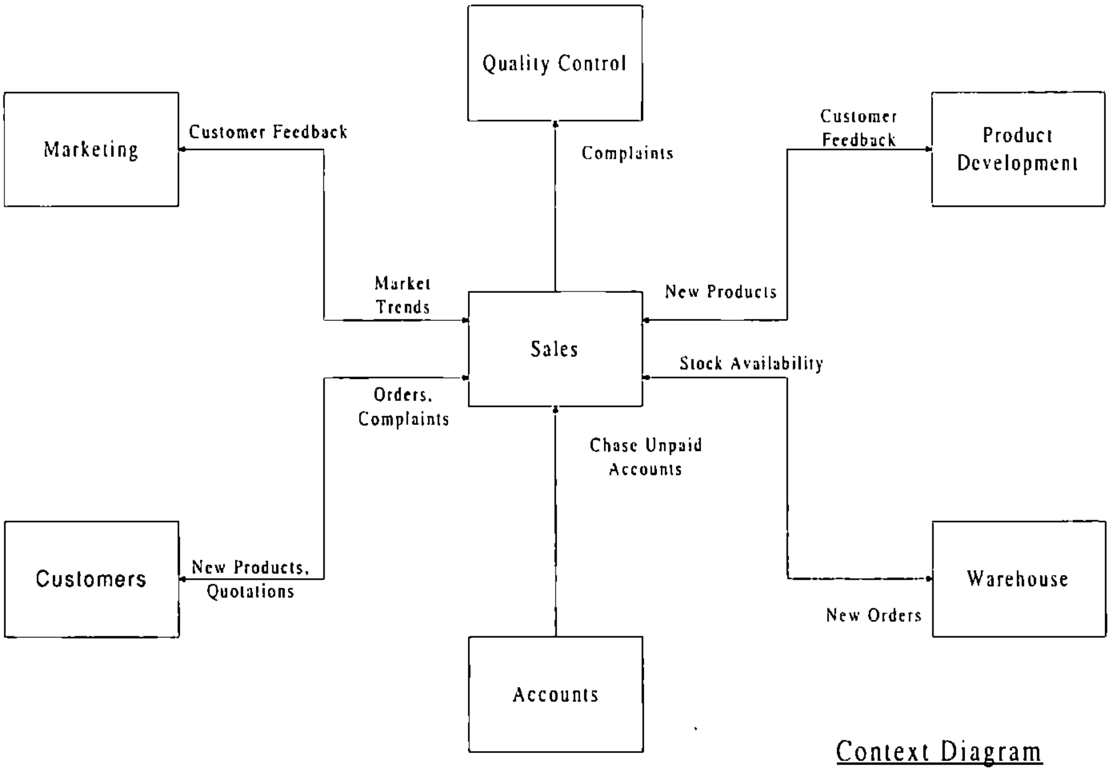

Figure 2. Context Diagram

Document Flow Diagrams indicate the movement of information through a particular system in a defined way (Figure 3). In this study these diagrams were sufficient for moving to the subsequent stage. However, in more complex system design these diagrams would be used as a preliminary level prior to producing DFDs. To confirm that the information gathered, and diagrams mapped, correctly represent the workings of the existing system, it is essential that the diagrams are verified with the information providers, with any errors or omissions noted and corrected. When verifying the diagrams care should be taken to represent the true, and not assumed or ideal, situation[3] as it is the established natural instinct of most people to hide sort cuts and deviations from supposed activities.

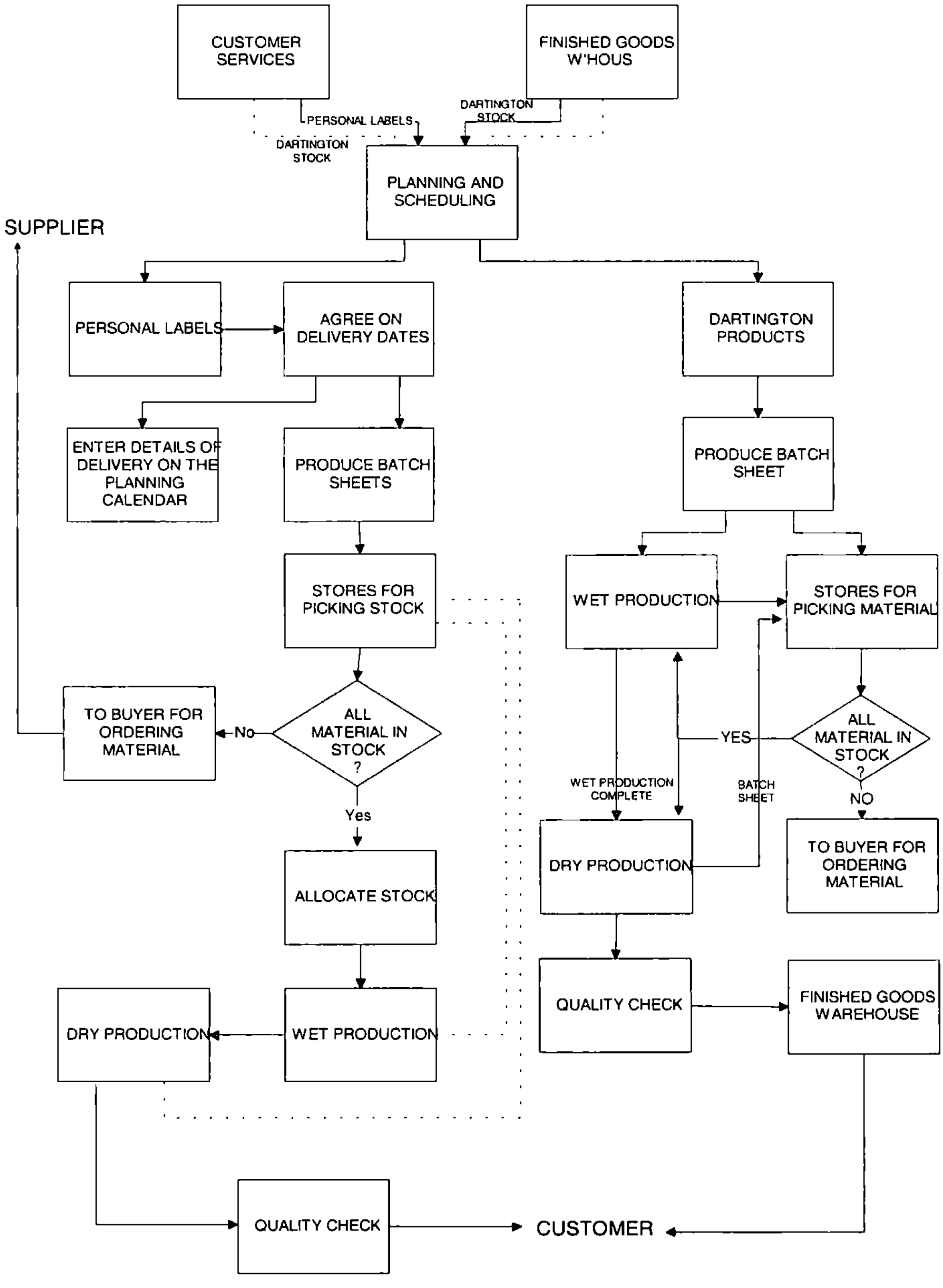

Figure 3. Document Flow Diagram

EXISTING SYSTEM: CRITICAL ANALYSIS

At this point, the information has been collected on the existing system and recorded using text and diagrams. It is now important to critically analyse the underlying logic of the system in order that the problem areas may be highlighted. A list of problems and their causes should be produced and verified by the managers from the relevant departments. Confirmed problems may now be investigated with due regard to the priority needs of the business.

NEW SYSTEM: DESIGN

After identifying the problems with the existing information systems in the various departments, it is important to make sure that they are functioning correctly on an individual basis before an integrated MIS is designed. When designing the MIS the primary objective is always to design a system that is capable of delivering the functions required by the client to support the business objectives of their organisation[4]. The system must, therefore, conform to the customer's requirements, each function being delivered in a manner which meets expectations in terms of service performance.

Whilst there are alternative ways in which these requirements may be met by a physical design solution, there are a number of other objectives that require consideration if a suitable design is to be produced. Flexibility of the design should enable future requirements of the business to be incorporated without undue difficulty. Reliability of the design must be secure against human errors, deliberate misuse and/or machine failure, to ensure that data will be stored without corruption.

The final design is required to be easily maintainable, since this significantly reduces the maintenance costs which usually represents a high proportion of the total lifetime cost of the system[4]. The design must work within the financial constraints of the company and justify the money invested. In addition, security of the design is essential to protect the confidentiality of the data, particularly when commercially sensitive. It may therefore be important to build in methods to restrict access to authorised users only.

CONCLUSIONS

This paper has mainly concentrated on the development of manual information systems, as it is vitally important that a logical flow of information through various departments needs to be identified before IT resources can be employed[2]. This approach is significantly different from the traditional method of designing MIS, whereby the existing manual systems are simply transferred to a computer system.

The approach taken in this paper ensures that each department is running efficiently, and aims to eliminate bad practices within a company. No matter how sophisticated a computer system may be, if the people using the system do not conform their working styles and habits to accommodate the computer based system, then for the successful implementation of that system will always be in doubt. Therefore, any system analysis and design must take into account the organisation culture. New systems must be developed collectively with the people directly involved in running the system. Once a system has been designed in this manner, so that people can appreciate and understand the design, then the subsequent computerisation will be simplified.

ACKNOWLEDGEMENTS

The authors wish to thank the Teaching Company Directorate (EPSRC/DTI), University of Plymouth and Dartington Foods (UK) Ltd for their support to undertake project Grant Reference Number GR/J62487.

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Development of a factory automation model for SME's

MR Z. Qurashi, Professor R. Burns and DR M N Polkinghorne

1.Introduction

The technology of factory automation involves the application of mechanical, electrical/electronic and computer based systems to enable the increased efficiency and economy of process operation. The 1990's is established as a period of intensive competition on both a national and international basis. For companies in Western Europe facing the relative labour cost disadvantage in comparison to the developing nations, there is increasing evidence that the only route to survival is to exploit the competitive advantages possible in the areas of quality, productivity and flexibility that are valuable by factory automation. There are five major categories of automation , these can be defined as engineering design, manufacturing Planning, manufacturing control, factory automation and intelligent systems/ computers. Automation may also be realised by the interaction of these main categories.

Many small and medium size companies are concerned about the automation of their manufacturing operations, but do not know where to begin. This paper aims to assess the automation needs of SME's in the Devon and Cornwall counties, which have larger proportion of SME's than elsewhere in the UK. And suffer from relative disadvantages of a periphery area i.e. transport, shortages of skilled labour etc. The paper identifies the current utilisation of FA by the firms in the Devon and Cornwall assess the factors hindering Factory Automation (FA). Based on the analysis of the above factors a model for automation in the SME's is presented.

2. The Economic Scenario Facing Devon and Cornwall Companies

Devon and Cornwall provide an attractive environment and a high quality of life for the local workforce. The area has over 36,000 businesses of which 89% have fewer than 25 people but between them employ 1/2 million people. A further 146,000 individuals are self employed.

The manufacturing sector in Devon and Cornwall is relatively small compared with many other UK regions. In 1991 it accounted for 16% of total employment in Devon and Cornwall compared with 21% in the UK as a whole.

However, in terms of overall employment, manufacturing in Devon and Cornwall has significantly outperformed the rest of the country in recent years. The dramatic reduction in manufacturing employment recorded elsewhere in the country has been largely avoided in Devon and Cornwall, although in common with other sectors, there has been a significant drop in manufacturing employment levels since 1989. The 1993 Devon and Cornwall TEC Employer Survey shows expectations of marginal job increase in manufacturing and engineering. Managerial, skilled and clerical occupations will be the most buoyant, whilst professional occupations are set to decline.

Although there are clear signs of optimism in the sector, there is no room for complacency. In fact, the biggest perceived constraint on business growth in the next year is a static or declining market (particularly in manufacturing, though less is in engineering) and the availability of finance. The manufacturing firms which are faring best are those with markets extending across the UK or internationally.

2.1 Emerging Trends

- Large companies and those operating in niche or Hi-Tech areas have the best survival rates and growth prospects.
- Exports will be crucial for the future of the manufacturing and engineering sector.
- A cautious optimism has emerged amongst employers, resulting in recent recruitment and investment in plant and machinery.

2.2 Key opportunities

- Sales to the rest of the UK and exports to America in the short term and Europe in the medium term should be encouraged.
- The manufacturing base of Devon and Cornwall needs to be augmented to match the UK base.
- There is a need to encourage diversification of activity across the sector.

Given the limited resources and technical know how many of the above opportunities may never be realised by SME's.

3. Areas of Automation

Automation can be implemented into several areas of manufacturing. We have grouped them into five major categories: Engineering Design, Manufacturing Planning, Manufacturing Control, Factory Floor Automation and Intelligent Systems and Computers. Automation can also be realised in the interaction of these categories. In this section we discuss the five areas of automation mentioned earlier.

3.1 Engineering Design

Engineering design is the transformation of ideas into specifications. Computers can aid in the designing process by maintaining an engineering database, analysing and optimising engineering designs and preparing visual drawings for presentation.

3.2 Manufacturing Planning

Manufacturing planning is the translation of engineering design into the optimal processes that will be used in production. This includes process planning, quality control and facilities planning.

3.2.1 Process Planning

Process planning addresses the question of how a part is to be manufactured in the most practical , economical way. Process planning is a decision-making process. The process planner has to specify which machine to use, which operations to perform on each machine and their sequence, and which tooling and cutting conditions to use. It is a series of decisions, where each of the decisions impose constraints on the following ones.

Group Technology (GT) is a term to describe the grouping of similar parts into families for the manufacturing efficiency. These similarities can be manipulated in a systematic way to improve operations. Common similarities that can be used to classify parts include shape, dimensions, specific machining required, tolerances, etc. GT is closely involved with facilities layout since the machines are grouped to reduce distances. GT can also improve the design and process planning areas of manufacturing by requiring a database to be built.

Computer-Aided Process Planning (CAPP) requires the generation of an operation sequence (or routing sheet) to manufacture, based on the input data. The routing is developed by identifying the specific characteristics of the part in question and relating these characteristics to their corresponding appropriate manufacturing processes. Appropriate parts classification and coding, usually based on GT, precedes the use of automated process planing system. CAPP achieves reduction in time and cost of manufacturing a part beyond that achieved by mere standardisation of parts. A variety of similar parts can be processed through the same sequence of machines, but the operations required at each machine may vary between parts.

3.2.2 Quality control

Quality control is concerned with the problems of detecting poor quality in manufactured product and taking corrective action to eliminate it. Traditional manual methods of inspections are both time consuming and expensive.

New approaches to the quality control function are emerging that are drastically alerting the way inspection and testing are performed. These new approaches are based on advanced sensor technologies often combined with computer-based systems to interpret the sensor signals. In addition, new software tools are being developed to automate the operation of complex sensor systems and to statistically analyse the sensor measurements.

3.2.3 Facility Planning

Facilities planning can include facility location and layout. Plant layout can be divided into layout generation and layout evaluation. In the facility layout we wish to minimise the materials handling costs, maximise flexibility and maximise production rate.

3.3 Manufacturing Control

Manufacturing Control begins when demand forecasts are translated into a Master Production Schedule (MPS) that lists products, delivery dates and quantities. Manufacturing control includes activities that assure optimal use of machines, manpower and materials. Manufacturing control includes Material Requirement Planning (MRP), production scheduling, shop floor control and capacity planning.

3.4 Factory Floor Automation

The fourth main area of manufacturing automation is factory floor automation. This includes materials handling, inspection and assembly. Many of the other areas are concerned with automating information processing, whereas this area includes physical equipment.

3.5 Intelligent Systems and Computers

This area includes: numerical control, computer numerical control, direct numerical control, programmable controllers, robotics, Computer Aided Design and Manufacture (CAD/ CAM), microprocessors, flexible manufacturing systems, man-machine interfacing, artificial intelligence and expert systems. The ultimate goal is to have a computer integrated manufacturing system (CIMS). CIM is a system that recognises and supplies computer services to each phase of the manufacturing cycle independently while at the same time maintaining a database that serves as a single source of data for all company activities and applications.

A flexible manufacturing System (FMS) is a conglomeration of automation technologies. It incorporates automated materials handling, direct numerical control and group technology principles to produce a product. The resulting system can include machining centres, numerically controlled machines and related processes. Parts can be transported via automated guided vehicles or automated retrieval and storage systems.

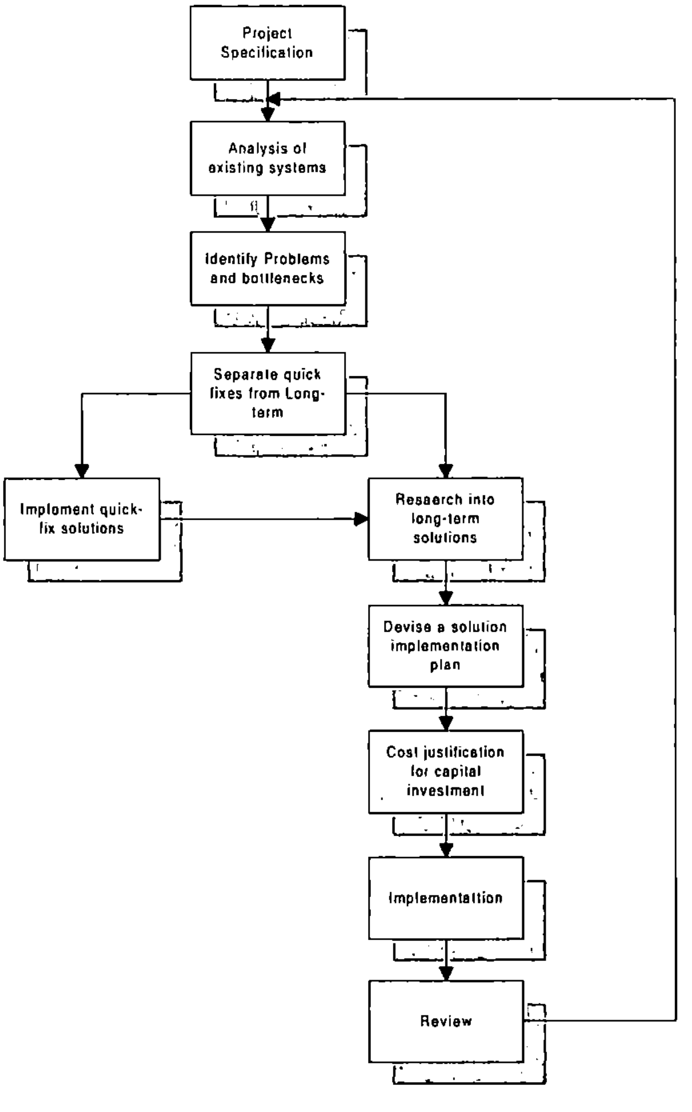
Artificial Intelligence (AI) is the next generation of computerised manufacturing systems. The purpose of artificial intelligence is to allow machines to possess human-like qualities. AI systems are currently emphasising expert systems, robotics natural language understanding and machine vision / voice recognition. Machines possessing human characteristics can then be used to solve problems by making their own decisions. These machines are smart and can learn from their past experiences and also analyse current situations.

AI has many potential applications in the manufacturing area. For example AI can oversee the development of high level plans, schedules, budgets and directives to meet demands. These systems can be adapted to work with modern factory equipment. It is just a matter of time before AI ill emerge into all levels of the factory to become an integral part of every organisation.

4. A Methodology for selection of automation system

It must be kept in mind that the aim of automation is not to replace workers with machines but to employ current technology to meet multiple objectives of manufacturing companies to reduce cycle times, reduced costs and increased quality.
The following model can be used to implement automation in small businesses (fig 1)

Figure 1. Model For Automation Small Businesses



It is important to use a system approach to identify problems and solution in a company. Without this approach, wrong decisions can be made. Optimising or improving a specific subsystem will not necessarily improve the entire system. Establishing better co-ordination among subsystems is more important.

Information Systems (IS) consist of a set of fundamental procedures that collect, process, store and disseminate information to support decision making and control. Analysis of IS in a company will identify how information flow and activities are performed within a company and the affect of flaws in the system on the final output of the company. The information collected should be mapped diagramatically to assist in easy understanding of the system (fig2). After the analysis of the IS it may be realised that, in some cases, poor quality or late deliveries may not necessarily be due to the lack of advanced equipment but poor practices and bad communication within the company.

Having done the analysis of the IS the next stage is to critically analyse the system and identify the bottlenecks. A list of problems and their causes should be produced and verified by the managers from the relevant departments. Confirmed problems and bottlenecks can now be investigated and measures can be taken to illiminate them.

To choose a Advanced Manufacturing Technology (AMT) to illiminate the problem or bottleneck identified during analysis, research on various technology available is a necessary step. A list of major books, guides and magazine that provide information can normally be obtained easily from many sources including, DTI and local universities. Some organisations will even perform a search based on preferences for a particular technology.

The manuals and guides listed are extremely helpful for finding out what manufacturing technologies are available in the market, their prices, specifications, compatibility, reliability (e.g. how many have been installed successfully). The trade magazines usually contain practical articles in the development or application of different approaches for industrial, production, and manufacturing engineering problems. They also contain a lot of advertisements and reference cards for further enquiries.

An important step before selecting among automation alternatives is to record information in a logical form. A database for different alternatives should be made and the following questions should be asked when selecting the appropriate:

* How compatible is the system for present use?
* How compatible is the system for the future use?
* How reliable is the system?
* How expensive are the equipment?
* How much Warranty and support comes with the system?
* How user-friendly is the system?

* Does the vendor provide a training program?

After careful assessment of the answers to the above questions the most suitable system should be selected and simulation should be run.

Simulation is used to monitor the behaviour if a given system under different constraints. This may or may not involve the use of actual machines and relevant systems. A computer based graphical simulation package can give a good visual understanding of how a system would behave in the real life.

Simulation is a very cheap method to ensure that a system will produce the desired results before huge sums of money is invested in the purchase of equipment, software etc.

In identification of the most suitable system the costs justification must be done before the equipment etc. are bought . There are various methods that can be used to assess the cost justification some of them, most commonly used in manufacturing, include:

* Payback method
* Net Present Value method
* Uniform Annual Value method
* Rate of return method

The final stage in automation is implementation of the system and training of the people who will be using the system. This should be done gradually and on incremental basis i.e. process at a time, while the older system is still running.

5. Conclusions

In this paper we have presented some of the areas, terminology and methods of automation with particular reference to the issues of Devon and Cornwall. We cannot stress enough the importance of overall system approach to the problems and solutions. Certainly any company that follows this thorough process will benefit in choosing methods for automation. They can also benefit by automating the non-manufacturing sectors, e.g. the administrative tasks. This should help to reduce the total cycle time significantly. As a first step we also recommend developing islands of automation, particularly in the areas of shop floor control and process planning. It should also be noted that having gone through the method, outlined in the paper, the conclusion may well be that no automation is required in your particular company except for reorganisation of information system and better communication.

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APPLICATION CONSIDERATIONS FOR A MANUFACTURING BASED MANAGEMENT INFORMATION SYSTEM

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ABSTRACT

It is the aim of this paper to describe the design process for a manufacturing based management information system. Prior to the design and specification of required computational resources, it is shown that significant advantages may be achieved in terms of the effectiveness of the final solution and in its acceptance by the relevant employees, by initially concentrating on the development of the manual information systems present.

1. INTRODUCTION

When considering the current dynamic manufacturing environment it has clearly become imperative that companies manufacture to ever increasingly tighter schedules and higher quality specifications in order to maintain profit margins given the existing economic climate. Key goals in any manufacturing company are to reduce in lead time and work in progress (WIP) with wastage minimised, while at the same time to remain competitive in their market, which may extend world-wide.

The success or failure of an organisation was traditionally attributed to many factors, e.g. employment of capital, plant equipment, quality of skilled labour, etc. In recent years handling of information within a company has become just as relevant and vital. Therefore, for a company to achieve its objectives it is imperative that the information must be controlled in an orderly and organised manner. Due to the recent computational development the nature and handling of information have become much more complex. If not well organised and understood, there is a significant possibility that detrimental effects on the company's position may result.

The application of Information Systems (IS) has been established in industry for several years. These systems consist of a set of fundamental procedures that collate, process, store and disseminate relevant information Laudon and Laudon [1], thus supporting the decision making and control within the organisation. There has also been further extension by the principles of Management Information Systems (MIS) which have been developed to further this process. The MIS methodology is designed to serve the monitoring, controlling, decision making and administrative activities of an organisation. Implementation of these MIS principles can be computer based (CBMIS). The system may therefore be designed to focus on daily, weekly and monthly summaries of various accounting and manufacturing transactions. This Dartington Foods (UK) Ltd case study is based on a low volume/high margin food manufacturing company where the primary objective was to increase the output without necessitating an increase in production resources. This paper aims to explain how this process be achieved by first developing manual information systems for individual departments, and then subsequently using the basis of these systems, to develop an integrated CBMIS.

2. SPECIFICATION OF THE PROJECT

The first, and most significant, stage of the system design is the project specification which should include precise definition of the project's boundaries, expectation, duration and also the limits of the financial commitment that the company is willing to undertake. It is of great importance to realise that whatever is agreed at this stage will form the basic structure of new system development and subsequently will be employed as a 'bench mark' by which to measure the success or failure of the system design. It is therefore a pre-requisite of any successful system design that this initial stage is undertaken in a realistic manner.

3. EXISTING SYSTEM: ANALYSIS

It is preferable when commencing the design process to start with no preconceived ideas and limitations. However, in reality this is rarely the case as there are always obstacles and constraints within an organisation which need to be considered before a system can be designed. To develop an MIS system it is necessary to understand the existing system. Fig. 1 shows a model for system development which was used for the case study.

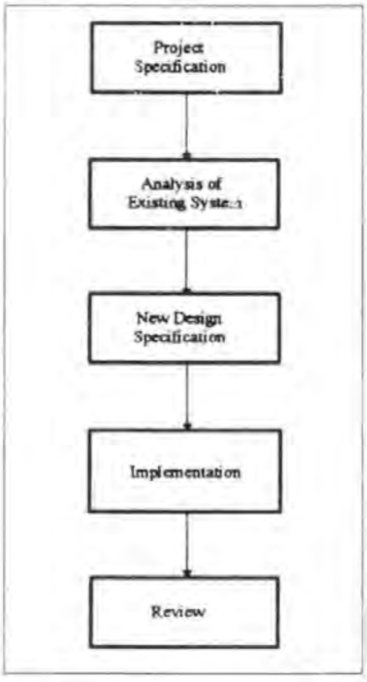

Figure 1. System Development Model

4. EXISTING SYSTEM: UNDERSTANDING THE ORGANISATION

The initial consideration when attempting to understand a company is to identify the actual structure, e.g. operation may be very centralised with nearly all decisions being focused at head office. If this is the case then clearly the IS must reflect this. Conversely, if the organisation allows considerable autonomy to managers in subsidiary parts of the business then the system must be designed to provide these managers with their necessary requirements to run the business effectively. The system must therefore be tailored to closely reflect the structure of decision making Shields *et al* [2]. In addition, the existing ISs in the various departments must be understood and evaluated. This can be achieved by utilising a sequence of methods.

The most significant tool for finding out how the existing system works is the personnel interview. It is best to interview all of those concerned with the system, even though this appears to provide more sources of information than is absolutely necessary. Some of these sources will make mistakes, so the extra sources help to identify where this has occurred.

The use of a systematic approach to gathering the information should help to minimise the risk of leaving gaps in the information gathered. The use of a form by the analyst is often helpful at this point, assisting the interviewer to ensure that nothing is missed through open ended questions.

Inviting the interviewee's observations and opinions can prove helpful and may help to form relationships ready for the stage when change must be implemented. The questions should be worded carefully. They should not offend and must enable the analyst to identify all information used, what it is used for, why the process is carried out, where the information is derived from and where its subsequent destination is, Shields *et al* [2].

Observation is another key element in building up a picture of how the existing system operates. Useful insight into the problems and inefficiencies of the system are often easier to spot by actually watching the job being performed. A further useful technique is to search through written records to verify information obtained from other sources, and to check information on data accuracy, data volumes etc. and to look for anomalous events.

While using these methods of studying the flow of information, it can be extremely useful to collect copies of all documents which flow around, and to trace their movements and use from the originator to the point where the document is destroyed. It is normal for elements of the information gathered to be incorrect. Therefore, to obtain a clear and accurate picture of the existing system is a meticulous process of checking, re-checking and cross checking.

5. RECORDING GATHERED INFORMATION

The information gathered must be recorded in an unambiguous and concise manner as this information will be used to critically analyse the system and explain the relevant internal mechanisms to others. The choice of techniques utilised is dependant upon the size of the company and complexity of the system. However, Data Flow Diagrams (DFD) are the most common technique. As the case study involved a relatively small company it was sufficient to use simple data flow diagrams without the necessity for any subsequent steps being invoked. Considering this company, there are two key stages required for completion of the final diagram. Context Diagrams which are similar to a top-level DFD with the exception that the whole system is identified only as a 'black box'. External entities and data flows in and out of the system are drawn ,but no processes or data stores are shown (Fig. 2).

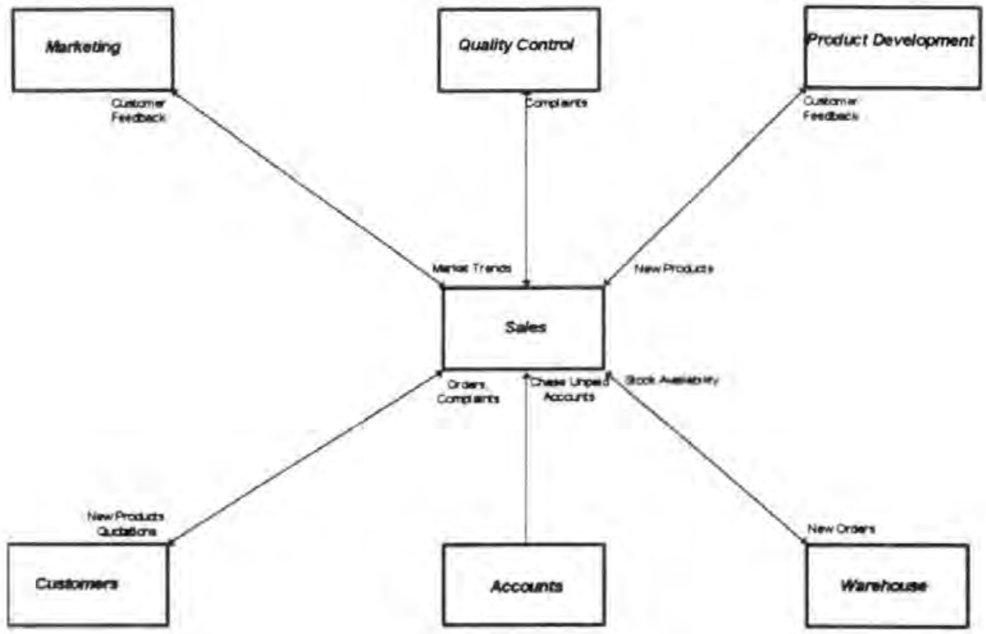

Figure 2. Context Diagram

Document Flow Diagrams indicate the movement of information through a particular system in a defined way (Fig. 3). These diagrams were sufficient for moving to the subsequent stage. However, in more complex system design these diagrams would be used as a preliminary level prior to producing DFDs. To confirm that the information gathered, and diagrams mapped, correctly represent the workings of the existing system, it is essential that the diagrams are verified with the information providers, with any errors or omissions noted and corrected. When verifying the diagrams care should be taken to represent the true, and not assumed or ideal, situation Riggs [3] as it is the established natural instinct of most people to hide sort cuts and deviations from supposed activities.

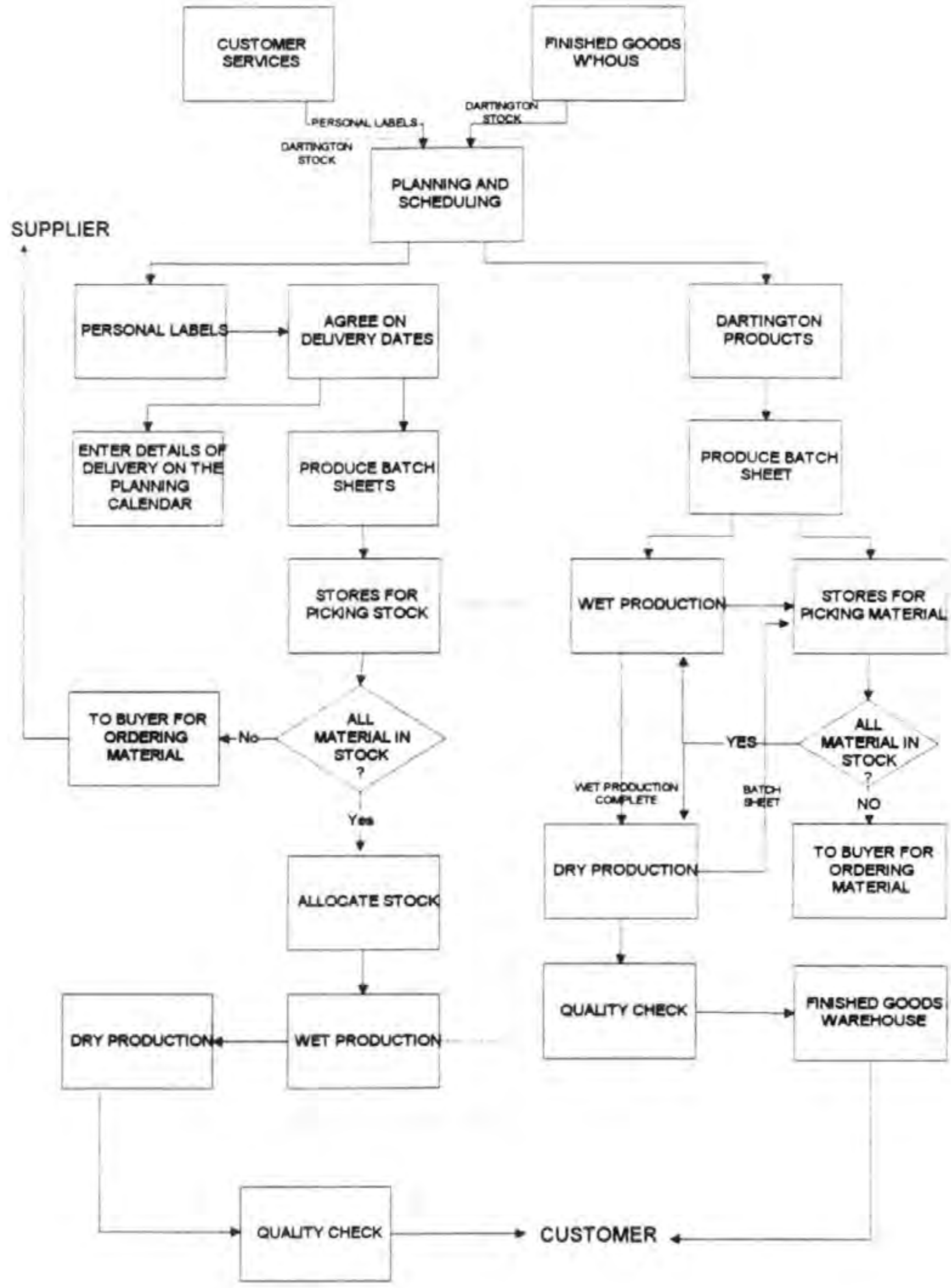

Figure 3. Document Flow Diagram

6. EXISTING SYSTEM: CRITICAL ANALYSIS

At this point, the information has been collected about the existing system and recorded using text and diagrams. It is now important to critically analyse the underlying logic of the system in order that the problem areas may be highlighted. A list of problems and their causes should be produced and verified by the managers from the relevant departments. Confirmed problems may now be investigated with due regard to the priority needs of the business.

7. NEW SYSTEM: DESIGN

After identifying the problems with the existing Information systems in the various departments, it is important to make sure that they are functioning correctly on an individual basis before an integrated MIS is designed. When designing the MIS the primary objective is always to design a system that is capable of delivering the functions required by the client to support the business objectives of their organisation East [4]. The system must, therefore, conform to the customer's requirements, each function being delivered in a manner which meets expectations in terms of service performance.

Whilst there are alternative manners in which these requirements may be met by a physical design solution, there are a number of other objectives that require consideration if a suitable design is to be produced. Flexibility of the design should enable future requirements of the business to be incorporated without undue difficulty. Reliability of the design must be secure against human errors, deliberate misuse and/or machine failure, to ensure that data will be stored without corruption.

The final design is required to be easily maintainable, since this significantly reduces the maintenance costs which usually represents a high proportion of the total lifetime cost of the system. The design must work within the financial constraints of the company and justify the money invested. In addition, security of the design is essential to protect the confidentiality of the data, particularly when commercially sensitive. It may therefore be important to build in methods to restrict access to authorised users only.

8. CONCLUSIONS

This paper has mainly concentrated on the development of manual information systems, as it is vitally important that a logical flow of information through various departments needs to be identified before IT resources can be employed Shields *et al* [2]. This approach is significantly different from the traditional method of designing MIS, whereby the existing manual systems are simply transferred to a computer system.

The approach taken in this paper ensures that each department is running efficiently, and aims to eliminate bad practices within a company. No matter how sophisticated a computer system may be, if the people using the system do not conform their working styles and habits to accommodate the computer based system, then for the successful implementation of that system will always be in doubt. Therefore, any system analysis and design must take into account the organisation culture. New systems must be developed collectively with the people directly involved in running the system. Once a system has been designed in this manner, so that people can appreciate and understand the design, then the subsequent computerisation will be simplified.

Acknowledgements: The authors wish to thank the Teaching Company Directorate (EPSRC/DTI), University of Plymouth and Dartington Foods (UK) Ltd for their support to undertake project Grant Reference Number GR/J62487.

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DESIGN OF A MANUFACTURING BASED MANAGEMENT INFORMATION SYSTEM

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[2]Plymouth Teaching Company Centre, University of Plymouth, Plymouth, U.K.
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This paper describes the design process for an information systems applied to a manufacturing company. By concentrating on the development of the manual information systems present prior to the design and specification of required computational resources, it is demonstrated that significant advantages may be achieved both in terms of the effectiveness of the final solution and in its acceptance by the relevant employees.

Introduction

In today's dynamic manufacturing environment it has become essential that companies manufacture to tighter schedules and high quality specifications in order to make profit, or indeed survive the current harsh economic climate. Key goals in any manufacturing company are to reduce in lead time and work in progress (WIP) with wastage minimised, while at the same time to remain competitive in their market, which may extend world-wide.

Traditionally, the success or failure of an organisation was mainly attributed to factors such as the employment of capital, plant equipment, quality of skilled labour, etc. However, in recent years handling of information within a company has become just as relevant and vital. Therefore, for a company to achieve its objectives it must control its information flow in an orderly and organised manner. Due to the recent computational development the nature and handling of information have become much more complex. If it's not well organised, and understood then it can cause detrimental effects on the company.

Information Systems (IS) have been utilised by companies for many years. Such systems consist of a set of fundamental procedures that collect, process, store and disseminate information to support decision making and control. This has been extended by the principles of Management Information Systems (MIS) which have been developed to further this process. The MIS methodology is designed to serve the monitoring, controlling, decision making and administrative activities of an organisation. Implementation of these MIS principles can be computer based (CBMIS). The system may therefore be designed to focus on daily, weekly and monthly summaries of various accounting and manufacturing transactions. The case study is of a low volume/high margin manufacturing company where the aim was to increase the output without necessitating an increase in production resources. This paper aims to explain how this can be achieved by first developing individual department's manual information systems, and subsequently the basis of these systems, to develop an integrated CBMIS.

Project Specification

The initial and most important stage of the system design is the project specification which should include precise definition of the project's boundaries, expectation, duration and also the limits of the financial commitment that the company is willing to undertake. It is important to realise that whatever is agreed at this stage will form the basis of new system development and subsequently is employed as a yard stick to measure the success or failure of the system design. It is therefore a pre-requisite of a successful system design that this initial stage is undertaken in a realistic manner.

Analysis of Existing System

Ideally when designing it is preferable to start with no preconceived ideas and limitations. However, in reality this is rarely the case as there are always obstacles and constraints within an organisation which need to be considered before a system can be designed. To develop an MIS system it is necessary to understand the existing system. Figure 1 shows a model for system development which was used for the case study.

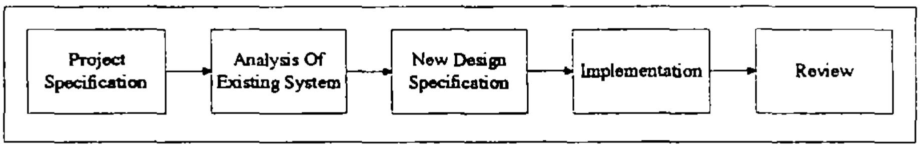


Figure 1. System Development Model

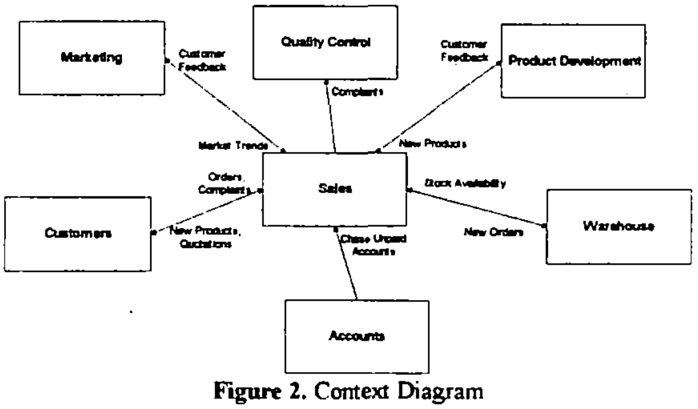
Understanding the Organisation of the Existing System

The first consideration when attempting to understand a company is to identify its actual structure, e.g. it may operate in a very centralised fashion with nearly all decisions being made at head office. If this is the case then clearly the IS must reflect this. Conversely, if the organisation allows considerable autonomy to managers in subsidiary parts of the business then the system must be designed to provide these managers with their necessary requirements to run the business effectively. The system must therefore be tailored to closely reflect the structure of decision making. In addition, the existing ISs in the various departments must be understood and evaluated. This can be achieved by utilising a sequence of methods. The main tool for finding out how the existing system works is the personnel interview. It is best to interview all of those concerned with the system, even though this appears to provide more sources of information than is absolutely necessary. Some of these sources will make mistakes, so the extra sources help to identify where this has occurred.

A systematic approach to gathering the information should help to minimise the risk of leaving gaps in the information gathered. The use of a form by the analyst is often helpful at this point, assisting the interviewer to ensure that nothing is missed through open ended questions. Inviting the interviewee's observations and opinions can prove helpful and may help to form relationships ready for the stage when change must be implemented. The questions should be worded carefully. They should not offend and must enable the analyst to identify all information used, what it is used for, why the process is carried out, where the information is derived from and where its subsequent destination is. Observation is another key element in building up a picture of how the existing system operates. Useful insight into the problems and inefficiencies of the system are often easier to spot by actually watching the job being performed. A further useful technique is to search through written records to verify information obtained from other sources, and to check information on data accuracy, data volumes etc. and to look for anomalous events. While using these methods of studying the flow of information, it can be extremely useful to collect copies of all documents which flow around, and to trace their movements and use from the originator to the point where the document is destroyed. It is normal for elements of the information gathered to be incorrect. Therefore, to obtain a clear and accurate picture of the existing system is a meticulous process of checking, re-checking and cross checking.

Recording Gathered Information

The information gathered must be recorded in an unambiguous and concise manner as this information will be used to critically analyse the system and explain the relevant internal mechanisms to others. The choice of techniques utilised is dependant upon the size of the company and complexity of the system. However, Data Flow Diagrams (DFD) are the most common technique. As the case study involved a relatively small company it was sufficient to use simple data flow diagrams without the necessity for any subsequent steps being invoked. Considering this company, there are two key stages required for completion of the final diagram. Context Diagrams which are similar to a top-level DFD with the exception that the whole system is identified only as a 'black box'. External entities and data flows in and out of the system are drawn ,but no processes or data stores are shown (Figure 2).



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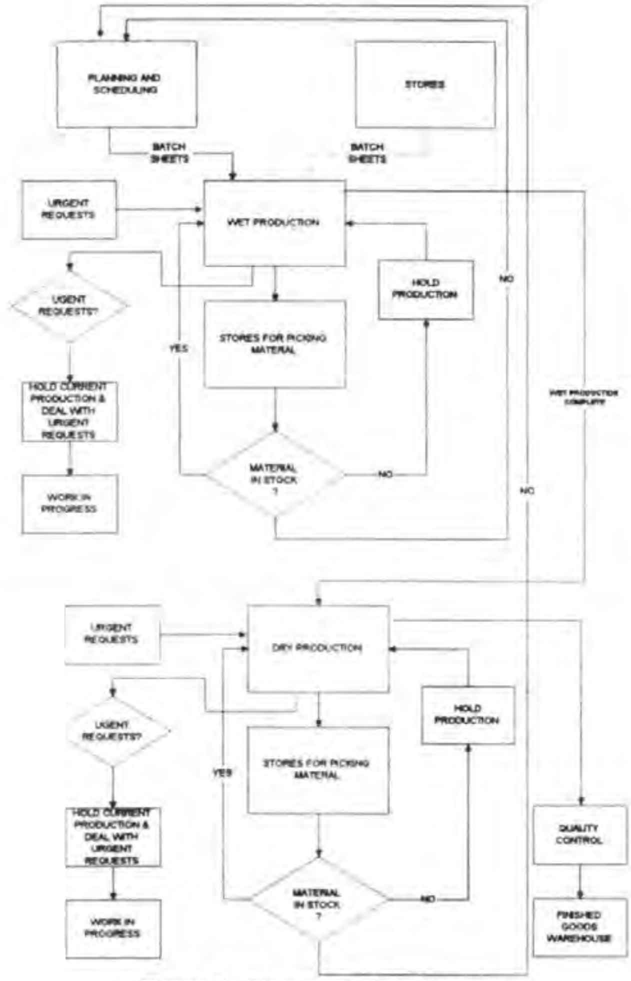

Figure 3. Document Flow Diagram

Critical Analysis of the Existing System

At this point, the information has been collected about the existing system and recorded using text and diagrams. It is now important to critically analyse the underlying logic of the system in order that the problem areas may be highlighted. A list of problems and their causes should be produced and verified by the managers from the relevant departments. Confirmed problems may now be investigated with due regard to the priority needs of the business.

New System Design

Having identified the problems with the existing Information systems in various departments, it is important to make sure that they are functioning correctly on an individual basis before an integrated MIS is designed. When designing the MIS the primary objective is always to design a system that is capable of delivering the functions required by the client to support the business objectives of their organisation. The system must, therefore, conform to the customer's requirements, each function being delivered in a manner which meets expectations in terms of service performance.

Whilst there are alternative manners in which these requirements may be met by a physical design solution, there are a number of other objectives that require consideration if a suitable design is to be produced. Flexibility of the design should enable future requirements of the business to be incorporated without undue difficulty. Reliability of the design must be secure against human errors, deliberate misuse and/or machine failure, to ensure that data will be stored without corruption. The design is required to be easily maintainable, since this significantly reduces the maintenance costs which usually represents a high proportion of the total lifetime cost of the system. The design must work within the financial constraints of the company and justify the money invested. Security of the design is essential to protect the confidentiality of the data, particularly when commercially sensitive. It may be important to build in methods to restrict access to authorised users only.

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The economic impact of the Teaching Company Scheme on the local manufacturing base

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SYNOPSIS

The Teaching Company Scheme is a government part-funded initiative to facilitate the transfer of technology from Academia to Industry. Each programme is run on a two year basis, employing one or more graduates who are located at a company for the duration of the project and act as the catalysts to enable a process of technology transfer to occur. This paper considers five such completed Teaching Company programmes and demonstrates the impact that co-operation between academic and industrial establishments can have on the local manufacturing base.

1. INTRODUCTION

The changing global industrial scene is forcing companies to evolve at an unprecedented rate. The requirement to keep abreast of technological developments to improve productivity, quality, range of products and other performance measures is now paramount. Despite the clear evidence for a need to acquire technical skills and investment in technology, many companies are reluctant to move in the direction of automation. This reluctance can be attributed two main factors: the extremely sizeable investment required by the company, and the total lack of previous experience with such technology. This is particularly true in the case of Small and Medium Enterprises (SMEs), the DTI's classification for which is defined as those companies with fewer than 250 employees.

Any measure that is capable of enhancing the competitive advantage of this size of firm may therefore be considered as being very timely. However, inappropriate measures, and those that utilise resources without providing the anticipated returns at the end, are an unnecessary waste of effort at a time when such generosity is potentially dangerous to the health of the company. To be able to indicate the success of past assistance offered to SMEs can therefore become a highly useful tool in assessing where to place maximum efforts in the future. This paper therefore investigates the impact of the Teaching Company Scheme on five manufacturing case study companies based in the South West region of the UK.

2. TEACHING COMPANY SCHEME'S OPERATIONAL CONSIDERATIONS

The Teaching Company Scheme (TCS) has been in existence since 1974 when it was introduced with the following aims and objectives [1]

1. To raise the level of industrial performance by effective use of academic resources.
2. To improve industrial methods by the effective implementation of advanced technology and new ideas.
3. To develop able graduates for careers in industry.
4. To give staff broad and direct involvement with industry to benefit research and to enhance the relevance of teaching.

The TCS is operated through a national body named the Teaching Company Directorate (TCD) who act as the interface between the Universities and the funding bodies such as MAFF, DTI, EPSRC etc. Joint funding for each programme of work is also obtained from the associated company. The ratio of this funding is dependant upon the size of the company with Small and Medium Enterprises (SMEs) receiving the largest government contribution. At the time of writing the cost to an SME is about £9k per annum per graduate employed.

The TCS may be regarded as being a two-year technology transfer partnership between the University, the Company and the Graduate, each gaining considerably from the experience. Recently the emphasis is moving more towards meeting the requirements of SME's where the need for technological assistance, and the subsequent impact on their competitive advantage, has proven to be far more significant.

Figures released for the South West region demonstrate that almost 99% of local businesses are within the classification of SME, i.e. less than 250 employees in total (including any membership of a larger group). Approximately 5% of these local SMEs operate in technological discipline fields, e.g. manufacturing engineering, and it is this type of company which has the most potential to gain from the support and technological interaction offered by involvement in the TCS.

Current policy has been to co-ordinate several TC programmes from regionally based centres across the UK. The South West regional Centre is located at the University of Plymouth and runs an average of 25 TC programmes. Obviously there is enormous potential for enhancing the local manufacturing base, clear indication of which can be demonstrated by detailing five specific TC programmes as SME case studies.

3. LOCAL MANUFACTURING BASE

Devon and Cornwall provides an attractive environment and a high quality of life for the local workforce. The area has over 36,000 businesses of which 89% have fewer than 25 people but between them employ 1/2 million people. A further 146,000 individuals are self employed.

The local economy is slowly emerging out of recession. There is a feeling of cautious optimism, although the region as a whole continues to under performed compared with the UK and Europe. Generally, the upturn in the local economy is slow and it is felt that established small and medium sized companies have the best prospects for growth and will provide a strong base for the area's future. In particular, provision of support and management development will be important to help these businesses which, coupled with networking and more exporting, could yield further economic growth.

The manufacturing sector in Devon and Cornwall is still relatively small compared with many other UK regions. In 1991 it accounted for 16% of total employment in Devon and Cornwall compared with 21% in the UK as a whole [2].

However, in terms of overall employment, manufacturing in Devon and Cornwall has significantly outperformed the rest of the country in recent years. The dramatic reduction in manufacturing employment recorded elsewhere in the country has been largely avoided in Devon and Cornwall, although in common with other sectors, there has been a significant drop in manufacturing employment levels since 1989. The 1993 Devon and Cornwall TEC Employer Survey shows expectations of marginal job increase in manufacturing and engineering. Managerial, skilled and clerical occupations will be the most buoyant, whilst professional occupations are set to decline.

Although there are clear signs of optimism in the sector, there is no room for complacency. In fact, the biggest perceived constraint on business growth in the next year is a static or declining market (particularly in manufacturing, though less is in engineering) and the availability of finance. The manufacturing firms which are fairing best are those with markets extending across the UK or internationally [2].

The main influence on economic prospects in Devon and Cornwall will undoubtedly be the performance of the national economy. This is only just beginning to come out of such a deep and prolonged recession that high growth rates would be required for many years to restore output levels to those of the previous boom. An added problem in the UK is the deficit of government's finances which is not being helped by slow growth in the economy. This has required tax increases and public expenditure restrictions which have also had an impact on restraining demand. Emerging trends and key opportunities for SMEs may be defined as [2]:

Emerging Trends

- Large companies and those operating in niche or Hi-Tech areas have the best survival rates and growth prospects.
- Exports will be crucial for the future of the manufacturing and engineering sector.
- A cautious optimism has emerged amongst employers, resulting in recent recruitment and investment in plant and machinery.

Key opportunities

- Sales to the rest of the UK and exports to America in the short term and Europe in the medium term should be encouraged.
- The manufacturing base of Devon and Cornwall needs to be augmented to match the UK base.
- There is a need to encourage diversification of activity across the sector.

Given limited resources and technical know how, many of the above opportunities may never be realised by SME's. However, the introduction of Teaching company Scheme has in many cases, allowed a considerable quantity of specific relevant knowledge and skills to be transferred from academia to industry resulting in low cost and high benefits. In addition, there is frequently an increase in their competitive advantage within the global manufacturing environment.

Case studies of five companies on Teaching Company Schemes are presented and the enhancement in profits and competitive advantage are highlighted.

4. TCS CASE STUDY FOR COMPANY A

The SME Company A is a major manufacture of process [3] for a specialist sector of this particular market (estimated as 20% of UK market alone). Previous annual turnover exceeded 0.5 million pa of which approx. 35% was generated by export and overseas business. Although company growth was increasing at a rate of 30% pa, it had become apparent that due to intense competition, a new initiative was required to enhance their competitive advantage.

The objective of the TC programme was to develop a fully automated version of the existing process equipment and for this purpose the Company required extensive transfer of technology from the University. In parallel to the main programme of work, a novel product was to be designed which could be used to demonstrate the functionality of the newly automated process. Clearly this novel product was anticipated to have considerable commercial potential in its own right.

5. TCS CASE STUDY FOR COMPANY B

The SME company B is a major manufacturer of garage equipment [4]. It is estimated that the company commands some 15% of the UK market. Previous annual turnover was 1.5 million of which 5% was export. In order to meet customer requirements, and to increase turnover, the company required the implementation of a quality management system and to gain quality approval to BS5750.

The objectives of the TC programme were therefore to devise and implement the required quality management system for the company and thereby gain BS5750. In addition, development was required of an analysis programme to cover both existing products and those under development. The two objectives were seen as being complimentary and without certain areas of redesign, the quality requirements of the existing products could not be achieved.

6. TCS CASE STUDY FOR COMPANY C

Company C offers a design, manufacture and installation service for materials handling systems [5]. The company has customers throughout the UK, although the majority are foods processors in Devon and Cornwall where the company has a market share of 50%. Previous annual turnover was £600k. Over the last few years the company has grown substantially and the order book (over £150k) suggested that the growth would continue. The forecast was that the turnover would increase by 50% over the next two years. This service and product development strategy was placing a considerable extra burden on the management, staff and systems of the company.

The objective of the TC was to provide the company with a set of effective systems and procedures. In doing so the programme was expected to make a significant contribution to the introduction of Information Technology and quality management in the company. The new systems and procedures were expected to yield increased sales through reduced lead times, improved product quality/costing information and also reduced costs due to improved materials/resource management.

7. TCS CASE STUDY FOR COMPANY D

Company D is a manufacturer in the market of wholesale plants [6]. The Company's turnover was in the excess of £1.2m of which 10% was export. The company sells some £2-3m plants each year and holds an estimated 2% of the UK market. The company employs some 35 people and over the last few years the company has grown at a rate exceeding 20%. A medium term objective of the company was to maintain the level of growth by a strategy of new market and product development. However, the Company did not have the resources to carry out the marketing and development operation support systems which will be critical in the implementation of their strategy.

The objectives of the TC programme were to develop and implement a strategy of growth by exploiting export opportunities and increasing turnover by 40%. This was to be carried out through the identification of new products and markets and the development of an infrastructure of operations support system. The programme was expected to increase the turnover from £1.2m to £1.7m, leading to an increase in profit of £70k pa. Improved operations support systems leading to improved resource utilisation were also anticipated.

8. TCS CASE STUDY FOR COMPANY E

Company E is an independent private company. The principal product of the company is a range of high quality assembled kitchen units mainly sold direct to house builders within its geographical region [7]. The turnover of the company was over £1.1m. It is estimated that the company held 5% of the market within its region. In order to increase turnover and the customer base the company were planning to move into retail kitchen market.

The objectives of the TC programme were to develop and implement a marketing strategy which would enable the Company to trade in the retail built-in kitchen market. The programme was expected to increase turnover from £1.1m to £2.5m, increase levels of customer numbers, improve profitability and improved ability to withstand competition from continental suppliers.

9. RESULTS AND CONCLUSIONS

Table 1 summarises the objectives and results achieved in the each of 5 case studies. The actual benefits gained from the TC programmes far exceeded the expected objectives.

There have also been considerable indirect benefits such as the close interaction forged between local industry and the University. This link has also resulted in further courses and research being devised which are more closely tailored to the needs of industry.

Clearly, when considering example manufacturing case study companies described in the paper, the Teaching Company programmes have achieved a considerable contribution to enhancing each company's competitive advantage. In all cases benefits have been gained by each of the partners involved, i.e. the Company, the University and the Graduate. The schemes have been sufficiently flexible to allow for modification to the objectives during the two year period which has ensured that not only are the objectives achieved, but more importantly that those objectives are still valid. Particularly in the case of SMEs, changing operational considerations may alter priorities. This can be reflected, to a certain degree, within the scope of the TCS which is a further benefit when compared to more rigid alternative methods of support. Practice has demonstrated that the interaction between the University and the Companies involved and allowed the expected transfer of technology, but more importantly it has generated further collaboration, and interchange of ideas, in many complementary fields of application, e.g. consultancy, undergraduate project placements, provision of case-study material for teaching purposes etc. Each graduate received the opportunity to register for a higher degree (MSc or MPhil) and in addition received a comprehensive package of both educational and practical training.

Table 1 Results from case study TC programmes

COMPANY	Targets	Achieved	Other Benefits
A	Increase in turnover by £150k Increase in profits of £40k	Turnover increased by £300k Profits increased by £145k	Future growth expected at 15-20% New product
B	Obtain BS5750 Reduction in costs of 10% (£150k) Develop analysis programme	BS5750 Obtained Costs reduced 13% (£200k) Introduced value analysis programme	Computerised clerical system Purchased new plant
C	Increase in turnover £300k Increase in profits £80k	Turnover increased by £300k Profits increased by £100k	Change in Company's culture Introduced computer system (50% saving) Improved company image (resulting in new orders of £250k)
D	Increase in exports 40% Increase in turnover from £500k Increase profits £70k	Sales increased by £114k Profits increased by £40k	Improved production efficiency New systems for: Fully integrated operational management Inventory planning and control
E	Increase in turnover £1.4m Increase in customer base	Orders increased by 50% Customer base increased by 200% Profits increased by 12%	Customer database Improved quality of information Increase in retail business

The TCS objectives as defined in section 2 appear very ambitious when under initial assessment. However, it is obvious from the results presented that it may be one of the few genuine methods of support for SMEs which actually does benefit all three partners involved.

10. REFERENCES

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