COMPUTER INTEGRATED MANUFACTURING (CIM) AND

THE PRINCIPLE OF BUSINESS CONTROL

ROBIN ANTHONY GAMESTER TWOSE

DOCTOR OF PHILOSOPHY

THE UNIVERSITY OF ASTON IN BIRMINGHAM

APRIL 1991

THE UNIVERSITY OF ASTON IN BIRMINGHAM

COMPUTER INTEGRATED MANUFACTURING (CIM) AND THE PRINCIPLE OF BUSINESS CONTROL

Robin Anthony Gamester Twose

Doctor of Philosophy

1991

SUMMARY

In response to the increasing international competitiveness, many manufacturing businesses are rethinking their management strategies and philosophies towards achieving a computer integrated environment. The explosive growth in Advanced Manufacturing Technology (AMT) has resulted in the formation of functional "Islands of Automation" such as Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), Computer Aided Process Planning (CAPP) and Manufacturing Resources Planning (MRPII). This has resulted in an environment which has focussed areas of excellence and poor overall efficiency, co-ordination and control.

The main role of Computer Integrated Manufacturing (CIM) is to integrate these islands of automation and develop a totally integrated and controlled environment. However, the various perceptions of CIM, although developing, remain focussed on a very narrow integration scope and have consequently resulted in mere linked islands of automation with little improvement in overall co-ordination and control.

This thesis, that is the research described within, develops and examines a more holistic view of CIM, which is based on the integration of various business elements. One particular business element, namely control, has been shown to have a multi-facetted and underpinning relationship with the CIM philosophy. This relationship impacts various CIM system design aspects including the CIM business analysis and modelling technique, the specification of systems integration requirements, the CIM system architectural form and the degree of business redesign. The research findings show that fundamental changes to CIM system design are required; these are incorporated in a generic CIM design methodology.

The affect and influence of this holistic view of CIM on a manufacturing business has been evaluated through various industrial case study applications. Based on the evidence obtained, it has been concluded that this holistic, control based approach to CIM can provide a greatly improved means of achieving a totally integrated and controlled business environment. This generic CIM methodology will therefore make a significant contribution to the planning, modelling, design and development of future CIM systems.

KEY WORDS: CIM, CONTROL, SYSTEMS INTEGRATION, BUSINESS CONTROL, CIM DESIGN, CIM METHODOLOGY, CIM ARCHITECTURE.

ACKNOWLEDGEMENTS

Firstly, I would like to express my thanks to various people from the University of Aston, Lucas Aerospace and the Teaching Company Scheme for initiating this research work and selecting me as the research candidate.

During the course of the research and the preparations of this thesis, I have received help and support from many people, to whom I am indebted. In particular, I would like to mention the following people for their support, encouragement and guidance.

My gratitude goes to Dr. D.M. Love, my Supervisor, for his guidance during the preparation and completion of this thesis.

My appreciation goes to Mr. B. Turnbull, who as my immediate Manager, kindly enabled the continuation of the research after the completion of the Teaching Company Scheme program, and relieved me of certain commitments during the final preparation of this thesis. His advice, experience and help has been gratefully received.

My sincere thanks go to my father, whose advice, help and strength has given me the necessary fortitude to overcome those times when the spirit was weak.

Finally, my heart-felt thanks go to my dear understanding and patient wife Sarah, who has provided me with continuous encouragement and support throughout this research and helped me to develop the necessary motivation to complete this thesis.

DEDICATION

I would like to dedicate this thesis to our first born child who is eagerly awaited and should be born, all being well, 8th August 1991.

LIST OF CONTENTS

Page

Page

Page

Page

Page

List of Figures

Page

List of Tables

1. INTRODUCTION

1.1 Research area

The increasing competitiveness of the various international markets together with emergent external forces, such as fixed term/price contracts, 1992 open european market and single standards on price, quality and delivery, are causing industry to seriously rethink its various management strategies and philosophies. It is widely accepted that businesses need to respond to these forces by lowering manufacturing costs, improving responsiveness to market change, improving quality, shortening leadtimes and by improving control of the overall business process [Heard (1988), Meredith (1987) and Gerber (1988)].

Many businesses in response, have developed management strategies and philosophies based on the employment of advanced technology to improve the effectiveness of their various business processes. The application of information systems and technology to assist these business functions has been advancing for a number of years.

In particular, manufacturing industry has experienced a recent explosive growth in Advanced Manufacturing Technology (AMT). Many developments have however, been based on the traditional functional organisations and applied in a piecemeal way. This has resulted in the formation of functional "islands of automation", where each department parochially carries out its task efficiently, but there is no overall view taken of the process of which the department is a part. The need to integrate these "islands of automation" towards a total CIM (Computer Integrated Manufacturing) environment has generally been recognised [Thompson (1987), Lomas (1988), Savage (1986), Rankin (1987) and Haffendon (1988)]. The level or degree of integration has however, been primarily focussed on the information flow between these islands, and in some cases their inter-functional procedures, resulting in mere linked islands of automation. A more holistic view of CIM is required involving a much greater degree of integration [Huggins (1986), Jones and Webb (1987), Dempsey (1988), Voss (1988), Below (1987) and Reisch (1987)]. They all suggest that this more developed view of integration is necessary for the business to be effective.

This dissertation will examine the development of a holistic view of CIM where the various elements of a business are integrated in such a way that a business can be more effectively controlled. This research concentrates on examining this extended view of CIM (business element integration), its relationship to business control, and its affect on the various business element structures.

1.2 CIM, business control and total integration

The highly competitive and rapidly changing market environment together with the highly complex nature of the modern manufacturing facility is demanding a rethink of business control practiced. A more tightly controlled business environment is required [Meredith (1987), Baker and Koppel (1987), Jaeger and Baliga (1985) and Gerber (1988)]. One in which all business processes and the various resources including people, time, money, information, etc., are controlled in such a way as to optimise their effectiveness. Such control has been practiced in the process industry for years.

The application of computer systems to assist, and indeed control these processes, has been advancing for a number of years. It is envisaged that in the near future most of the business processes will in some way be assisted by computer technology. Much of the control traditionally exercised by section leaders, supervisors, and managers is being designed into the computer system such that the various processes and procedures are automatically controlled. If businesses wish to control the overall process of which these islands are a part, then the isolated control within these islands need integrating, such that high level control spanning the business can be exercised.

The implementation of computer systems and the application of control procedures affect the surrounding business environment, resulting in changes to various business elements. It can be seen that the merger or integration of two processes into one may result in the integration of other elements including roles, information, decisions and control. If the integration of those other elements is not considered then a sub-optimum or even a mismatch may result. System integration towards total business element integration (CIM) will have a profound effect on the whole business. Integration can be developed to optimise a business by exercising effective and integrated control.

It will be shown that an important relationship exists between the business integration philosophy (CIM) and the theory of control as applied to a manufacturing business. Within this framework, it will be argued that there is an underpinning relationship between these two subjects, which when examined and developed, can be used to establish a more effective means of developing a totally integrated and controlled manufacturing business.

1.3 Adopted research methodology

The research methodology will comprise five main stages. Firstly, the theory of CIM (Computer Integrated Manufacturing) and the theory of control will be examined; particular attention will be given to the developing holistic view of CIM and manufacturing business control.

The second stage of this work will investigate the relationship between CIM and business control, focussing on various aspects of integration to support two key business processes namely, New Product Introduction (NPI) and Manufacturing Operations (MO). A method of using systems integration to improve control by automatically closing the various control loops and supporting control loop interactions will be demonstrated. The demonstration will be performed using two industrial case studies, one based on a Project Control System and the other on a Manufacturing Resources Planning (MRP II) System.

Stage three examines the effect this holistic approach to CIM will have on business redesign. Particular attention will be given to the degree of business redesign required, the span of criteria one needs to consider and the likely changes to the business structure, the co-ordination and control mechanism and the power and political process.

The fourth stage discusses the importance of considering control during the development of a CIM design methodology, and examines its effects on the approach to CIM and the constituent steps required. Fundamental changes to the basis of CIM design are discussed together with numerous methodological changes, resulting in the development of a unique control based CIM design methodology.

Based on this unique CIM design methodology, the fifth and final stage discusses the requirements associated with the development of a CIM systems integration architecture, and concludes by proposing the adoption of a systems integration control framework and a particular architectural form.

1.4 Industrial case study

The case study is based at Lucas Aerospace (Engine Systems Division) Ltd., a subsidiary of Lucas Industries PLC. Lucas Aerospace produces small batches of high precision and sophisticated technical products. The product range includes fuel pumps, engine management systems and a range of ancillary equipment such as cryogenic cooling engines for the aerospace and defence industry. The industrial complex at Lucas Aerospace is fairly typical of a medium sized batch manufacturing company involved in the design, development and manufacture of sophisticated, precision machined and highly technical products.

In response to the increasing competitiveness within the aerospace and defence industry, Lucas decided to invest in information systems and technology, and complex multi-axis machining centres. Lucas being primarily functionally organised soon developed numerous "islands of automation". At the time of performing this research, Lucas Aerospace had installed 25 computer systems running on some 14 computers across 3 sites. Lucas soon recognised the need to integrate these systems in pursuit of a totally integrated environment, in which all personnel are able to work together towards common objectives. In addition, there were directives to improve the control of various business processes, including New Product Introduction (NPI) and Manufacturing Operations (MO).

It was decided that a collaborative research project with Lucas Aerospace would provide an excellent vehicle with which to develop and implement the holistic approach to CIM. Furthermore, such a vehicle would enable the refining and testing out of the relationship between CIM and control, provide a catalyst environment for the development and application of a unique control based CIM design methodology and act as a test site for examining the effects of CIM on the organisation.

In 1986, a teaching company programme was established involving Aston University and Lucas Aerospace. A collaborative research project was set up; the team had a total of 4 teaching company associates from Aston University and various Lucas staff. In consideration of the commercial as well as the academic importance of this work, full business reporting procedures were included in the project management. The research project started in 1986 and is currently undergoing full implementation. The author joined Lucas Aerospace in 1988 and is currently managing a major part of the implementation.

2. THE THEORY OF COMPUTER INTEGRATED MANUFACTURING (CIM)

This chapter considers the concept of CIM and includes an examination of a diverse range of both CIM definitions, CIM concept charts and CIM elements. It will be argued that the current view of CIM is limiting and consequently fails to show its totality. Furthermore, it will be argued that its perceived meaning is undergoing a gradual transformation through four phases and is probably best described as a business integration philosophy (BIP).

2.1 An introduction to CIM

In chapter 1.0, it was stated that the recent explosive growth in Advanced Manufacturing Technology (AMT) has led to the formation of functional "islands of automation". Moreover, it was noted that the need to integrate these islands in pursuit of a CIM environment is becoming increasingly recognised. CIM can be generally considered the result of integrating these various islands of automation. The islands to be included in a CIM integration environment is subjective and varies depending on the perceived view of the author, and indeed the type of business under study. Although there is no agreed list, the following seem to be common to most:

- CAD (Computer Aided Design);
- CAM (Computer Aided Manufacturing);
- CAE (Computer Aided Engineering);
- GT (Group Technology);
- CAPP (Computer Assisted Process Planning);
- MRPII (Manufacturing Resources Planning);
- MPS (Master Production Schedule);
- AMH (Automated Materials Handling);
- Robotics;
- JIT (Just in time);
- SFDC (Shop Floor Data Control);
- FMS (Flexible Manufacturing System);
- Financial ledgers, to include:
    - PL (Purchase Ledger);
    - SL (Sales Ledger);
    - GL (General Ledger).

2.2 CIM : the acronym

The acronym CIM stands for "Computer Integrated Manufacturing" and can be perceived as being both misleading and equivocal; it implies a focussed view, relating to the integration of computers within manufacturing. For this reason it can be considered a contributing factor to the misconceptions surrounding CIM.

2.2.1 Computer

The word computer in CIM implies that the scope of integration is limited to that which is possible through the use of computers. This being the case, the focus of CIM would be that of data integration between computer systems. Although important, this only represents one level or aspect of integration. As stated in chapter 1.0, various authors argue that CIM should address different aspects of integration.

The word computer should be omitted from the acronym as it precludes the total integration scope [Gunn (1986), Vowler (1987), Hartland-Swann (1986), the Ingersoll report (1986) and Thurwatcher (1986)]. Gunn (1986), suggests that the word computer obscures its meaning and goes on to say that computers are merely tools which allow integration. He re-labels CIM with MIM (Modern Integrated Manufacturing). Vowler (1987), states that CIM does not actually require computers, just good organisation, implying the word computer redundant. Hartland-swann (1986) and the Ingersoll report (1986), discuss CIM as an enabling technology to achieve integrated manufacturing and argue that CIM should be replaced with I.M. (Integrated Manufacturing), as this is the real goal. Thurwatcher (1986), argues that if the 'C' in CIM is used literally then the CIM strategy will be flawed. He argues that CIM should be replaced with SIM (Simplified Integrated Manufacturing).

2.2.2 Integration

The word integration in CIM is generally regarded as the most important word in the acronym, it represents the verb to integrate. The scope of its meaning however, is somewhat undefined. The Chambers dictionary defines integration as "the act or process of part unification to form a whole". The main concern with this definition, is it fails to mention the type of unification. Integration can take place in various forms including physical, data and strategy. Physical integration is concerned with the integration of physical elements. An example of this includes the integration of materials transfer across a factory using Automated Guided Vehicles (AGV's). Data integration is involved in establishing a central pool of data from which the various forms of information are resourced. The integration of strategy is concerned with adopting a common strategy across the business such that all effort is steered towards one goal. In fact it can be shown that integration is able to take place in various forms.

Below (1987), examined the meaning of pure integration and suggests that it is involved in the attainment of unity of correct commonality across various levels, including 1. physical, 2. data, 3. schedule, 4. functions, 5. attitudes, 6. principles and 7. purpose. He goes on to suggest that CIM is concerned only with integration level 2, that being 'data' integration. This is further argued by an IBM report (1987), which suggests that integration is concerned with the managing and directing of information across the business. Data integration is usually accompanied by other types of integration. For example, data integration invariably results in the integration of data management functions, which in turn calls for the integration of certain procedures and schedules, and may result in the development of a common purpose.

The particular view of CIM put forward by both Below and IBM is far too limiting; a wider view of CIM should be taken, one which does not exclude the integration of other business elements.

Wider views of integration are given by Na (1986) and Voss (1988). Na (1986), argues that computer integration is only one aspect of the true meaning of integration within the context of CIM, and that other integration aspects include manufacturing/production systems, hardware (machinery), software, material, suppliers, engineers and culture. Voss (1988), in a similar vein, defines integration as having five dimensions including strategy integration, material flow integration, technical integration, information integration and organisation integration.

Other authors including Tannock et al (1987), Dempsey (1988) and Stevens (1988), have argued the inclusion of other integration elements. Tannock et al (1986), argues that integration should include quality, and Dempsey (1988) and Stevens (1988), discuss the integration of the supply chain.

Various authors tend to use the word integration and interfacing interchangeably. Integration is more than just interfacing, it is concerned with establishing a controlled environment in which interfacing has been fully developed [Sadowski et al (1986) and Appleton (1985)].

From the discussions within this section it can be concluded that the types of integration, and indeed the elements of integration within the context of CIM, are ill defined, resulting in often conflicting parochial perceptions of its meaning.

2.2.3 Manufacturing

The word manufacturing in CIM attempts to define the application area of integration. It is generally accepted that the word manufacturing is inadequate.

The application area scope for CIM can be categorised as follows:

(a). Shop floor process only;
(b). Manufacturing related functions;
(c). All internal business functions;
(d). All internal/external business functions including customer/supplier links.

An examination of numerous published articles on CIM, refer to CIM definition literature review (Appendix A) and literature review results (Table 1), revealed that the application area most referred to is (c). It can therefore be suggested that the word "Manufacturing" should be replaced with "Business". Similarly, other authors have attempted to expand the scope of CIM by devising new acronyms. McHugh (1988), argues that CIM should be replaced with CIE (Complete Integrated Enterprise). Gunn (1986), in a similar vein argues that the acronym should be changed to CIB (Computer Integrated Business).

2.3 Discussion of CIM definitions

This section examines numerous definitions of CIM.

2.3.1 An examination of various definitions

The definitions of CIM vary quite considerably; to show this diversity six CIM definitions are listed, each of which define CIM in a different way:

- Lung (1988), defines CIM as a philosophy;
- Dutton (1986), defines CIM as a strategy;
- Thomas (1986), defines CIM as system network;
- IBM (1987), states that CIM addresses the total organisation;
- Ingersoll (1986), states that CIM involves the application of information technology and systems;
- Reisch (1987), implies a single facet view of CIM, that is, the manufacturing process area.

The six full CIM definitions can be seen in Table (1).

It can be shown that CIM has no standard definition, but varies depending on the view taken by the author. This is supported by Downsland (1986), Arnold and Johanson (1984), Jarvis (1986) and Boaden and Dale (1986). In particular Boaden and Dale (1986), performed a literature review of fifty CIM references, and found that there was a need for ten categories and three classes of definition. In order to establish how the definitions of CIM are changing, the author has performed a similar literature review of forty one CIM references. The forty one CIM definitions are included in Appendix (A).

To examine the various views of CIM, three classes of definition type were used including:

- single facet type;
- information technology/systems type;
- total organisation type, together with three categories:
    - system network;
    - strategy;
    - philosophy.

Author	CIM definition
Lung (1988),	- CIM is philosophy rather than a specific system or set of applications; it uses the advances in computers, information technology, communication standards, as well as database management systems, in order to ensure an efficient flow of information between operations and activities in an enclosed and integrated manufacturing environment.
Dutton (1986)	- CIM is a strategy for winning in manufacturing; it is involved in the sharing of manufacturing resources related to information collection, storage, processing and distribution, in such a way to optimise the performance of the total enterprise.
Thomas (1986)	- CIM is a unified network of computer systems controlling and/or providing information to the function of a manufacturing business in an integrated way.
IBM (1987)	- CIM essentially means tying together, via computer technology, all the various departments in an industrial company, so that they operate smoothly as a single integrated database system.
INGERSOLL (1986)	- CIM is an information structure supporting the free flow of all information resident in the system to any part of the system as needed.
Reisch (1986)	- CIM means linking all levels of the manufacturing process into an integrated information and control network.

Table (1): Six example CIM definitions

The results of the CIM definition literature review are shown in Table (2). Clearly, it can be seen that the most widely used definition is based on developing a system network for the total organisation. A comparison of the Boaden and Dale (1986) literature review against that of the author's (1989), reveals that a more complete "total organisation" view of CIM is developing. This comparison is shown in Table (3).

It is important to note that 80% of the references examined by the author post-date those examined by Boaden and Dale.

2.3.2 CIM: system, strategy or philosophy?

From examining the CIM definition literature review results in Table (2), it can be seen that out of the 41 definitions; 21 define CIM as a system network, 9 define CIM as a strategy and 4 define CIM as a philosophy, leaving 7 unclassified. The results show that CIM is likely to be viewed in a physical sense, that is, a system network, and less likely to be viewed as a philosophy or strategy. CIM is infact all of these; in a physical technological sense there would be a CIM system comprising the various CIM subsystems on a network, a strategy would be required in order to establish a clear direction, and in a philosophical sense, it is a way of working.

2.4 Discussion of CIM concept charts

As shown in the previous section many authors tend to view CIM in a physical and technological way. Such a tendency has resulted in the widespread development of CIM concept charts, particularly by system vendors. A CIM concept chart can be defined as a diagram showing the subsystems or elements of CIM together with their interconnections. The reason why system vendors use these charts is twofold. Firstly, computer vendors and system integrators, in an attempt to increase sales, focus on the physical side of CIM and draw diagrams to promote their many products as a CIM subsystem. Secondly, CIM is probably best illustrated using a diagram displaying the physical elements of CIM.

This section examines various published CIM concept charts and argues that most of them can be considered both simplistic and limiting. Moreover, it

AUTHOR	YEAR	DEFINITION CLASSES			CIM		
		SINGLE FACET TYPE	INFORMATION TECH./SYSTEMS	TOTAL ORGANSTN	SYSTEM/ NETWORK	STRATEGY	PHILOSOPHY
Arnold & Johanson	1984			*		*	
Dunn	1984		*			*	
Smith	1984			*		*	
Garrett Turbine	1985		*	*	*		
White & Apple	1985			*	*		
Mize et al	1985		*				*
Claydon	1985			*			*
Alting & Lenau	1986			*	*		
Gunn	1986		*	*	*		
Crookhall	1986		*		*		
Thomas	1986			*	*		
Vernadat	1986			*	*		
Hewlett-Packard	1986			*		*	
Dutton	1986		*	*		*	
Fischer	1986			*	*		
Ingersoll 1	1986		*		*		
Ingersoll 2	1986		*	*	*		
Ingersoll 3	1986			*	*		
Ingersoll 4	1986				*		
Ingersoll 5	1986						
Ingersoll 6	1986			*		*	
Thomas	1986			*	*		
Ranky	1986			*	*		
Canada	1986			*	*		
Phelps	1986						
Downsland	1986			*	*		
Bertain	1987			*		*	
Riehn	1987			*			
Sibbald	1987						
Reisch	1987	*			*		
Ewaldz	1987		*		*		
Cowan	1987			*		*	
Rzevski	1987		*	*	*		
Vowler	1987			*		*	
Meister	1987			*			*
IBM	1987			*	*		
Spur and Specht	1987			*			
Little	1988			*			
Riesman	1988			*	*		
Lung	1988		*	*			*
Chuah	1989			*		*	
TOTAL		1	11	31	21	9	4

Table (2): CIM definition literature review results

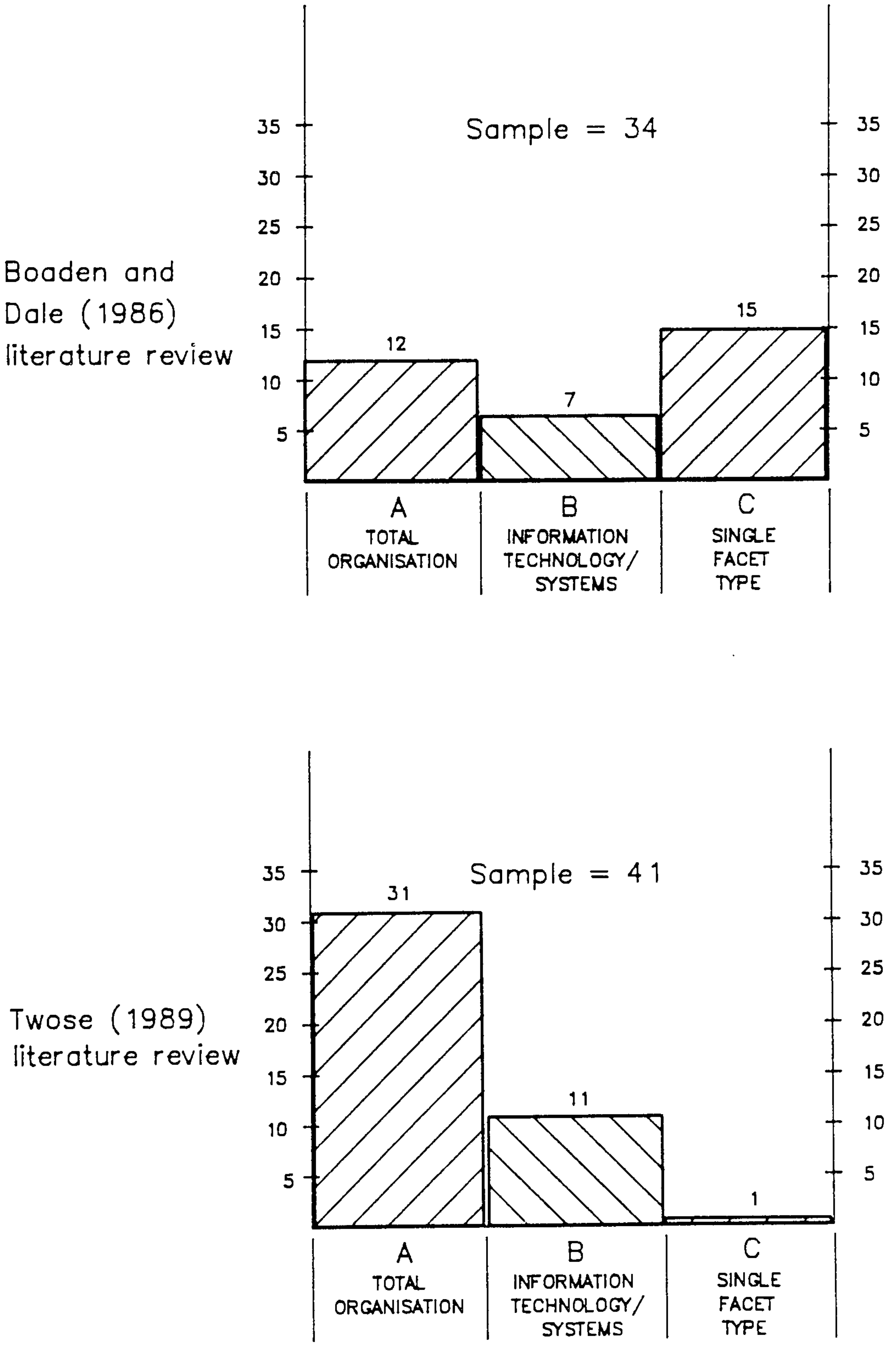


Table (3): A comparison of two CIM definition literature reviews is suggested that some of the vendors seem to have deliberately developed CIM concept charts based on their own parochial interests.

For the purpose of this section, three CIM concept charts have been examined including those from McDonnell Douglas Corporation (1986), Computervision Limited (1984) and Gunn (1986).

The charts can be seen in Figure (1), (2), and (3) respectively. An examination of each of the CIM concept charts reveal a number of individual features which detract from their credibility.

The McDonnell Douglas CIM concept chart:

- fails to cover the functional scope of a manufacturing organisation. It is deficient in the following areas including financial accounts, sales and marketing, commercial, research and development, product support and it seems production control;

- identifies a product design function which is specific to a PCB (Printed Circuit Board) manufacturing business. Such a function cannot be considered generally applicable across industry;

- references CAD, CAE, CAM and DNC, but excludes the perhaps more important, CAPP and MRP;

- has no provision for manufacturing philosophies like Group Technology (GT) and Just In Time (JIT);

- mixes up business functions with computer systems (islands of automation) and computer hardware; refer to the outer circle in Figure (1).

The Computervision CIM concept chart:

- Suggests that the CIM integrator is the CAD/CAM database, that is, the product model. If CIM is only concerned with the following upstream activities of the business, for example, product design, process design, jig and tool design and engineering analysis, then the suggestion maybe true. However, this is not so, CIM impacts on

Figure (1): CIM concept chart [McDonnell Douglas Corporation (1986)]

Figure (2): CIM concept chart [Computervision limited (1984)]

Aston University

Illustration has been removed for copyright restrictions

Figure (3): CIM concept chart [Gunn (1986)] both upstream and downstream activities, some of which include Master Planning and Scheduling (MPS) , Material Requirements Planning (MRP), stock control etc., which rely more on the Bill of Materials (BOM) and product routing than the product model itself;

- is very biased towards the sub-functions of a CAD/CAM system, many of which should not be considered as a general CIM sub-system, for example, Finite Element Analysis (FEA) , Integrated Chip (IC) design, kinematics etc.;

- illustrates functions which are not generally applicable across industry, for example, sheet metal fabrication, construction layouts and electrical, and at the same time omits certain functional areas, which one would consider applicable industry wide, including sales and marketing, accounts and finance, commercial and administration.

The CIM concept chart proposed by Gunn (1986):

- focuses almost exclusively on the physical CIM elements with no reference made to the functional areas of a business. The chart fails to illustrate the functional integration required to support the integration of the various systems.

- is biased towards the manufacturing areas of a business, the only element shown which is not considered to be manufacturing based is CAD. The list of elements shown is depleted, no mention is made of financial ledgers, project control, tool management or commercial systems.

From the above examination, it can be argued that each of the above CIM concept charts fail to show the true scope of CIM. In order to further validate this statement, a literature review of ten CIM concept charts was performed and similar shortcomings were exhibited by each. The CIM concept chart literature review is included in Appendix (B).

2.5 Discussion of CIM elements

Another method of establishing the perceived view of CIM is to examine the CIM elements supported. A CIM element literature review was performed; the results of the literature review can be seen in Appendix (C).

The results show that out of the twenty two proposed CIM elements, only ten are listed by 50% or more of the references. On average more than 70% of the references fail to mention the following CIM elements including office systems, project matrix team structure, engineering data management systems, project control systems, tool management systems, JIT philosophy, cell management, factory simulation, financial ledgers, invoicing systems, payroll systems and asset register systems. Such results, show a poor perception of the elements comprising CIM.

2.6 Phases of CIM

This section, based on some of the findings from section 2.3, examines how the definition of CIM has changed over time.

2.6.1 Phase 1. Single facet systems technology

During Phase 1, CIM was perceived as a single facet of systems technology, or more commonly known as an "island of automation". Examples of this included integrated CAD/CAM (Computer Aided Design/Manufacturing systems), NC/CNC/DNC (Computer and Direct Numerical Control) systems and MRP II (Manufacturing Resources Planning) systems. During this phase, the above acronyms were used interchangeably with CIM.

The Boaden and Dale (1986) literature review suggests that this phase has spanned a period of some five to ten years, ranging from the mid to latter part of the 1970's to the mid 1980's.

2.6.2 Phase 2. Total organisation systems technology

From the mid to latter part of the 1980's, industry in general found themselves with numerous "islands of automation", all of which had been installed independently of one another. It was realised that information produced by one system was an input requirement of another. This led to major investigations to support the information flow between business functions and their computer systems. In an attempt to cut non value added activities, manual entry of data from one system to another was replaced by automatic interfaces. This resulted in a physical network of integrated systems (islands of automation) capable of supporting and managing the intersystem information flow. This view of CIM is classified as Phase 2. The author's literature review in 1989 suggests this phase has spanned a period of 5 years, ranging from mid 1980's to late 1980's.

2.6.3 Phase 3. Integration of systems into business environment

Towards the latter part of Phase 2, various authors were realising that the implementation of systems integration was affecting the immediate surrounding business environment. It was found that a far greater improvement in business performance can be realised from systems integration, when the surrounding business elements are changed to accommodate . This is supported by Hartland-Swann (1986), Jones and Webb (1987), Rzevski (1988) and Chuah (1989), all of whom discuss the importance of developing the right business environment in line with the development of systems and their integration. They each identify the need to modify business functions/process, change information structure and flows, decay functional boundaries, modify control procedures, change skill requirements inline with new and changing roles and alter decision making flows.

This view of CIM is classified as Phase 3, that is, the integration of systems into the business environment.

The concept of integrating systems into the business environment is shown in Figure (4). The business environment is shown as a network of processes (processes A to L), all of which are related to the business environmental elements, namely people, roles, decisions, information etc,. Processes G and H are supported by systems G1 and H1 respectively. The development and integration of systems G1 and H1 should be accompanied by business element integration, such that an optimum fit can be achieved between the integrated systems and their surrounding environment. The relationship between business elements and the business redesign considerations for CIM Phase 3 is discussed in chapter 5.

2.6.4 Phase 4. Total integration of the business elements

Phase 4 of CIM is concerned with the integration of the various elements within a business, such that they are all considered equally and collectively during the integration design process. Business elements such as people, decisions, functions, organisation structure and culture should be considered equal to the more common business integration elements, systems and information.

Recent discussions on "Pure Integration" regarding the integration of these various elements demonstrates that the thinking underpinning CIM Phase 4 is developing. Voss (1988), Dempsey (1988), and Below (1987), all discuss a wide range of elements that one should consider during business integration. Once CIM Phase 4 is reached then perhaps the acronym CIM should have the "C" and the "M" replaced as suggested in section 2.2

2.7 CIM reviewed and defined

It can be seen from the previous section that CIM is undergoing a gradual transformation through four phases. It is not until phase 3 or 4 is reached that a more complete view of CIM is developed

CIM can be viewed as a philosophy which sets the direction for a company towards total business integration, where the elements of a business including control, information, people, processes, computer systems, decisions, organisation structure and business culture are integrated to form a unified whole, such that all elements are mutually supportive and capable of maximising benefits to the business. The integration scope to include all internal business functions and all external links to customers, suppliers and business partners.

Conceptually, three aspects of integration can be considered. Firstly, work structure integration, which involves the integration of business processes, the people that perform them, the information processed by them, their associated decisions and controls. Secondly, enabling technology integration, which is primarily concerned with the development of a CIM systems integration architecture. Finally, organisational integration, which involves the integration of organisational structures.

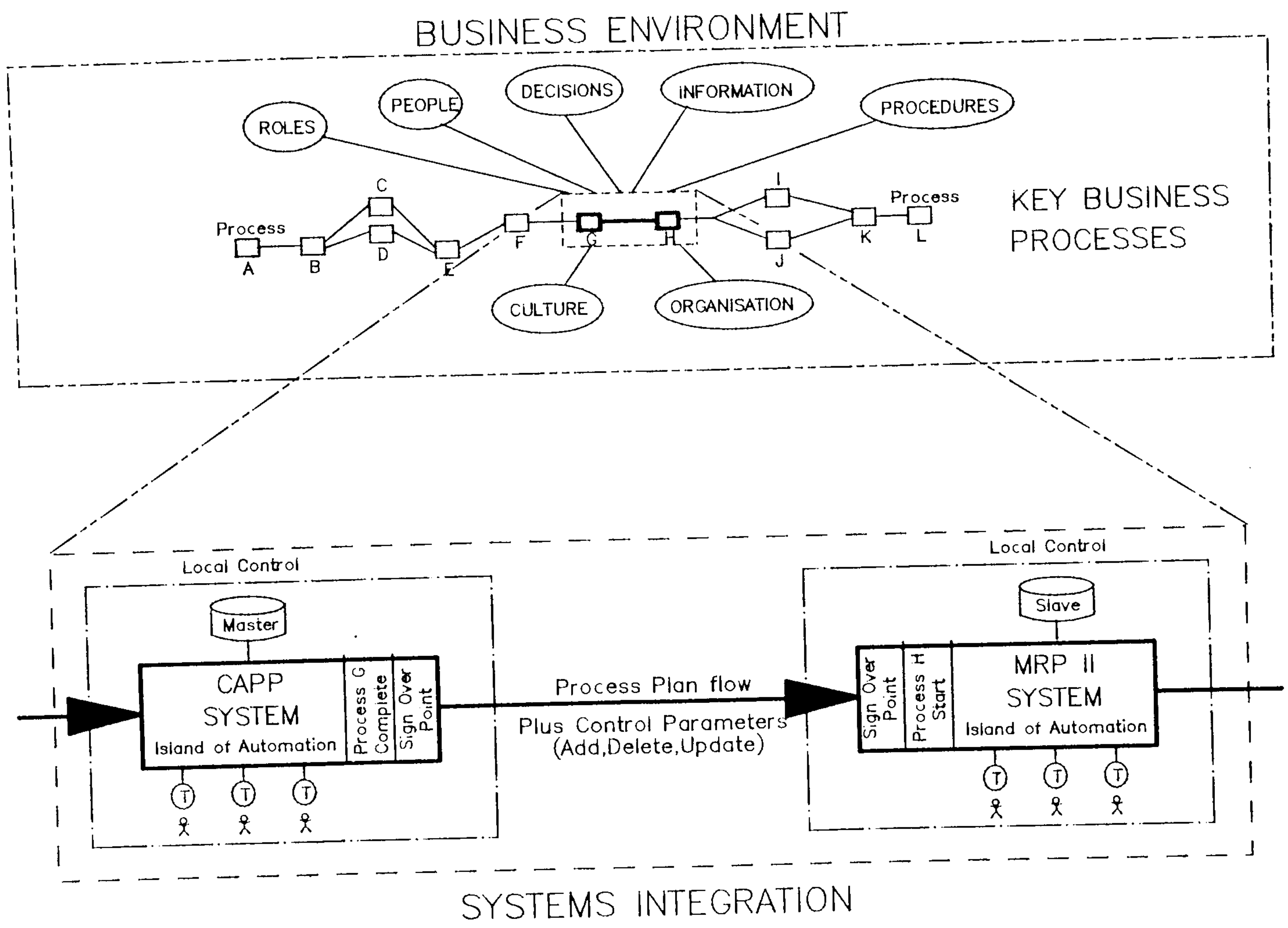


Figure (4): Integration of systems into business environment

3. THE THEORY OF CONTROL

This chapter considers the concept of control and includes an examination of how control can be applied to a manufacturing business.

3.1 An introduction to control

In chapter 1.0, it was stated that the highly complex nature of the modern manufacturing facility and the highly competitive marketplace is demanding a more tightly controlled business environment. One in which all business processes, plus the various resources including people, time, money and information etc., are controlled in such a way as to optimise their effectiveness.

Business control in this context is generally regarded as management control. Both Boyce (1967) and Eilon (1979), the respective authors of two books devoted to management control, stress that the term "control" is somewhat loosely employed in the management literature, and that the concept of overall control has been neglected. This is somewhat surprising, since the word control is generally understood and usually defined unequivocally in dictionaries. According to the Oxford Dictionary, control is the "power or authority to direct and govern; a standard for comparing and testing".

Specific types of control have been employed in businesses for a number of years. These are often associated with specific business functions including financial control, budgetary control, cash flow control, production control, stock/inventory control, new product introduction control and quality control. Such controls are an evolutionary development based on the functionally organised business and are usually performed in isolation from one another. In effect, it can be said that "islands of control" have developed, which is analogous to recent trends in computer system developments.

3.2 The fundamentals of control theory

This section examines the fundamental concepts and elements underpinning any control process.

3.2.1 The elements of control

Prior to examining the elements of control, one needs to consider the general relationship between planning and control. The following authors including Boyce (1967), Bentley (1984), Eilon (1979) and Emery (1969), all distinguish between planning and control. They view planning as the setting of standards, objectives, policies, budgets, schedules and resources, and control as the measurement of actual performance followed by the comparison with standards and corrective action where deviation occurs to ensure standards are met.

Planning and control are so closely related and inter-dependent, that it is impractical to separate them. There is little point in drawing up detailed plans if control is not exercised to ensure plans are met; on the other hand it is impossible to administer detailed control if there are no plans to control against. Planning therefore, should be a subset of control [Rhodes (1984), Flamholtz et al (1985), Jones and Webb (1987) and Baker and Koppel (1987)].

The author proposes that there are five elements of control:

1. Plan;
2. Action;
3. Measurement;
4. Feedback;
5. Comparison and Evaluation.

Planning as previously stated is involved in defining objectives and goals, determining policy, laying down of operating procedures to guide achievement of objectives, establishing schedules and plans, and the setting of standards.

Action is the process of executing the various plans within an environment.

Measurement is involved in receiving key information on the activities of the undertaking and measuring results.

Feedback is basically an information transfer mechanism, in which the measured actual results are fed back to where the standard are held.

Finally, comparison and evaluation is involved in comparing the measured actual results against the previously generated standards and examining any deviation, followed by an evaluation to decide on the necessary corrective action or replanning.

3.2.2 Closed control loops

The five proposed control elements should be performed sequentially to form a closed control loop, starting with planning and finishing with comparison and evaluation. In practice however, elements 1 and 2 are normally performed and 3, 4 and 5 largely abandoned. This is due to the fact that elements 1 and 2 need to be performed in order to get the functional work done, where as 3, 4 and 5 are post work elements, which can be considered non productive monitoring activities, that demand considerable time and effort.

If effective control is the target, then the five elements should be configured as a closed control loop. A conceptual chart showing a closed control loop is illustrated in Figure (5).

The need to provide closed control loops is supported by Arthur (1986), Boyce (1967), Flamholtz et al, (1985), Rembold et al (1986) and Jones and Webb (1987).

Arthur (1986), whilst discussing the operational aspects of shop floor planning and control, states that a complete planning and control system requires "closing the loop", beginning with planning, continuing with execution of the plan and feedback, and then replanning. He argues that the planning and control loop is applicable at any level within a manufacturing operation.

Boyce (1967), illustrates the importance of a closed control loop in an engineering servomechanism used for the automatic control of a process. He further states that the same control cycle exists in all applications of the control technique in management.

Flamholtz (1985), incorporates a closed control loop in a core control system, which is said to control the behavior of people in ways that lead to the attainment of organisational objectives.

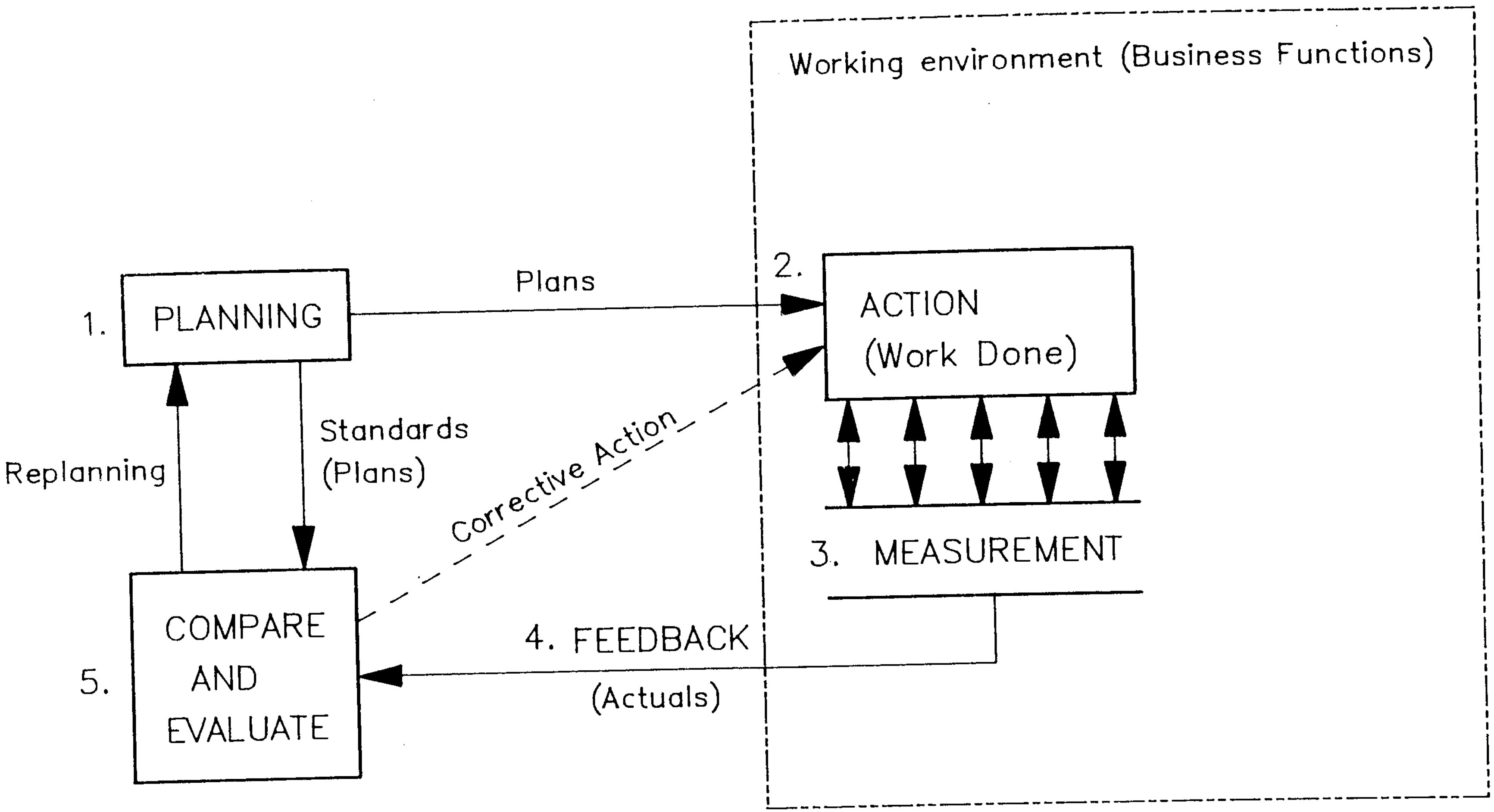


Figure (5): A closed control loop

Rembold et al (1986), argues the use of interconnecting control loops for a hierarchical manufacturing control system.

Jones and Webb (1987), include a closed control loop in their process control model.

It follows therefore that the control loop forms the core mechanism in achieving control.

3.2.3 The importance of information

The closing of a control loop is primarily based on supporting the information flow between the various control elements. A typical control loop is heavily loaded with control information of various types, including plans, strategies, policies, budgets, schedules and standards, actual performance information, that is, actual levels of work done, comparison information and variances (plan versus actual) and decision support information.

Much of the control information flowing within the control loop is dynamic and only applicable for a finite length of time, normally determined by the control response time of the loop. In order to maximise the effectiveness of a control loop, one should ensure that the information is timely, accurate, consistent, unequivocal, selective and interpretable.
The importance of information in control theory is emphasized by Eilon (1979), Daft and Lengel (1986), Handy (1987), Bentley (1984), Jones and Webb (1987) and Boyce (1967).

3.3 Control theory applied to businesses

This section examines the application of control theory to a manufacturing business environment.

3.3.1 Effective business control

According to various authors the process of business control and the management role has become less effective over a period of years. In

1975, Mintzberg performed an industrial study and found a marked degeneration in the management role. In a similar vein both Meredith (1987) and Gerber (1988), point out that the managerial control process in business has degenerated and that it is rare for all departments of an organisation to work together, reasonably synchronised, towards a common goal. Such findings highlight the need for the reinstitution of effective business control.

A major concern of a business should be exercising effective control, such that the members of the organisation direct their efforts towards the attainment of organisational objectives, whilst ensuring a stable structure of internal relations and stable mechanisms for structural adaptation and change. The need for business control is further emphasized by Jaegar and Baliga (1985) and Baker and Koppel (1987).

Numerous theories have been advanced to explain control in organisations [Olsen (1978), Hofsteide (1978) and Ouchi (1977)]. Among these the cybernetic model is the most frequently referred to [Lawler (1970), Giglioni and Bedeim (1974)]. In this model, control is accomplished through monitoring of performance, comparing it to a given standard, and taking appropriate actions to correct any deviations. It can be seen that this closely resembles the general definition of control given in section 3.2.

It can therefore be deduced that the closed control loop concept is applicable to business control.

3.3.2 Corporate planning - strategy development

Business planning, element one of the business control loop is concerned with the determination of "policy", that is, the laying down of the aims of the organisation and the general principles on the basis of which it will operate, including that of the organisation structure. To get all departments of an organisation to work together in a synchronised manner towards a common goal relies on the development of integrated plans, all of which are underpinned by the organisational goals [Kruse (1988) and Miesing (1984)]. Kruse states that integrated business planning is required to ensure that functional strategies are a part of a cohesive overall business strategy and that functional tactical plans form a comprehensive action plan to meet jointly agreed objectives for best overall business performance. This is further supported by Miesing (1984) who has termed it "congruential planning".

In order to achieve integrated plans, the top level business plan must be decomposed into sets of lower level plans; the decomposition flows from strategic plans through tactical to operational plans, to form a hierarchy. It is these, the operational plans which set the standards for the bottom level operational control.

As stated previously, a key aim of business control is to get all departments of an organisation to work together in a synchronised manner towards a common goal. It can be seen therefore that the strategic, tactical and operational plans should be integrated laterally across the business functions or departments. This would enable the various levels of plans across the business to be tied back to the common business goals. Levels of plans are sometimes modelled hierarchically through the departments of a business, such models are generally regarded as planning hierarchies.

Planning hierarchies, to support business control have been proposed by Rhodes (1984), Bentley (1984) and Boyce (1967).

Rhodes (1984), proposes a three level hierarchy of control which uses three types of plan, including strategic, tactical and operational. He implies that the three levels are capable of being overlayed on top of a business, but makes no reference to the association with organisation structure. Rhodes, implies that a particular department is capable of being assigned to a particular planning level, this however is not strictly true. A specific department maybe engaged in more than one planning level, for example, various departments at different levels within the business maybe engaged in both tactical and operational planning. This is likely to represent a major shortfall in the proposition given by Rhodes.

Bentley (1984), supports a four level planning hierarchy which includes the use of four types of plans, namely business, resource, activity and performance standards. Each type of plan is tied specifically to a line management level, which again similar to that proposed by Rhodes, creates unnecessary and indeed unwanted planning restrictions.

The planning hierarchies proposed by both Rhodes and Bentley fail to show the relationship between the planning levels and the organisational (departmental) structure. Such an omission may cause planning application problems within departments and difficulties in achieving synchronised planning across the business. For example, the mapping of planning levels onto the organisation structure would clearly define departmental planning levels and provide a mechanism for lateral integration of the departmental plans across the business.

A similar approach to this is taken by Boyce (1967), who bases the planning hierarchy specifically on the organisation structure, and overlays three planning levels on top, including overall departmental plans, sectional plans and usage plans. A possible limitation of this approach, is the restricting of departmental planning to one particular type of planning level.

A more effective planning hierarchy can be developed by combining the views taken by Rhodes, Bentley and Boyce. The developed hierarchy is shown in Figure (6).

3.3.3 Decision making

Decision making is an activity which is generally considered to be an integral part of most business processes. The importance of a decision is normally related to the level of the business process, that is, the higher the level of the process, the greater the importance of the decision. As already argued, most processes within a business can be associated with a control activity, it follows therefore that decisions can be tied back to control elements. Although decisions are present in one form or another in all control elements, they are more prominent in control elements "plan", "action" and "comparison and evaluation". In support of this Boyce (1967), argues that a decision is part of a decision activity loop and further suggests that they are infact super-imposed onto control loops. He fails however, to mention the method of overlay.

The decision activity loop and its method of overlay onto control loops is illustrated in Figures (7) and (8) respectively. The "activity" element of a decision activity loop, as shown in Figure (8), overlays directly on top of the control elements. It can be shown that the decision activity

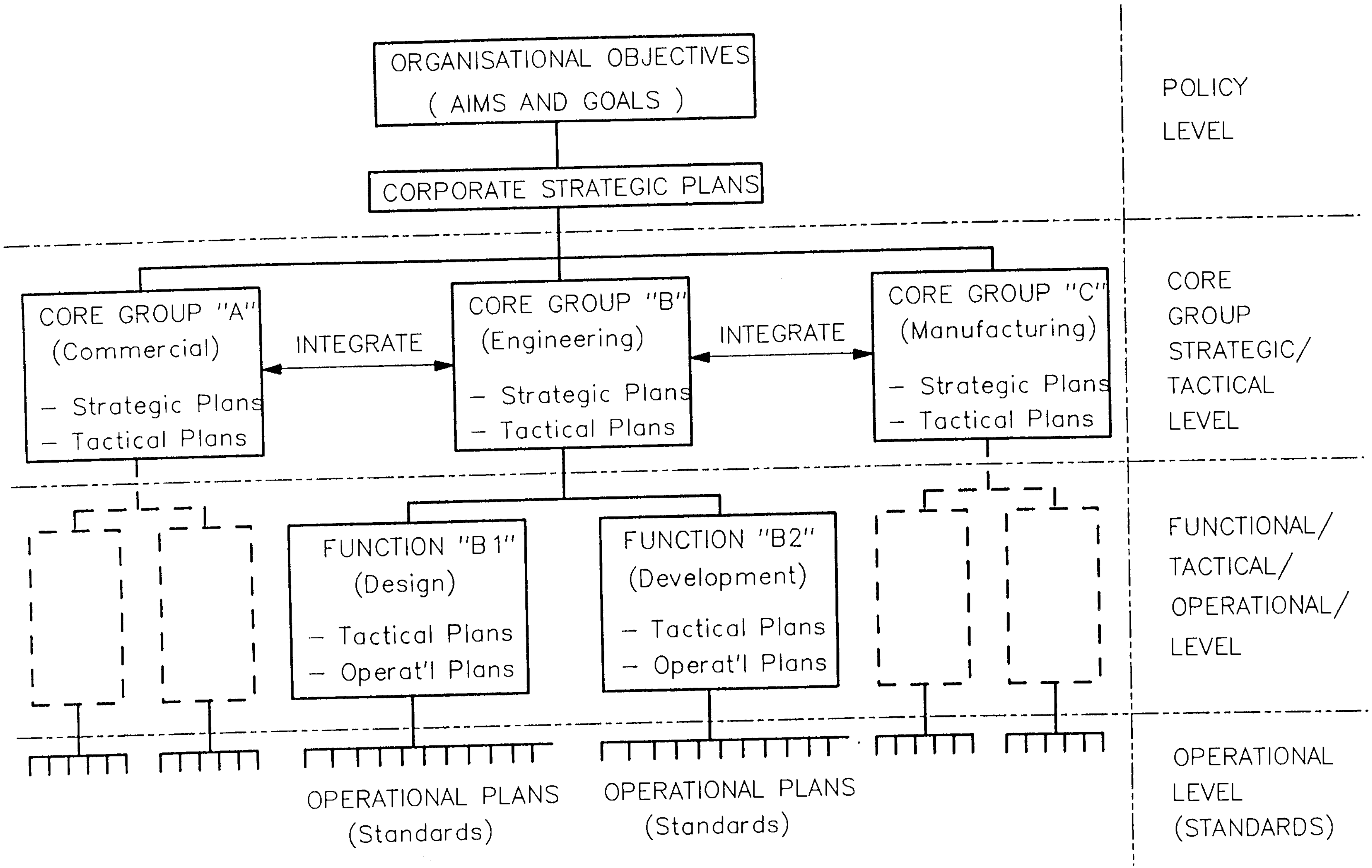


Figure 6 : A Levelled Planning Hierarchy
(Adapted from Rhodes (1984), Bentley (1984) and Boyce (1967)

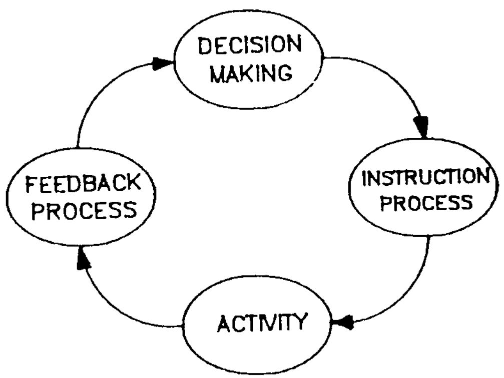


Figure (7): A decision activity loop

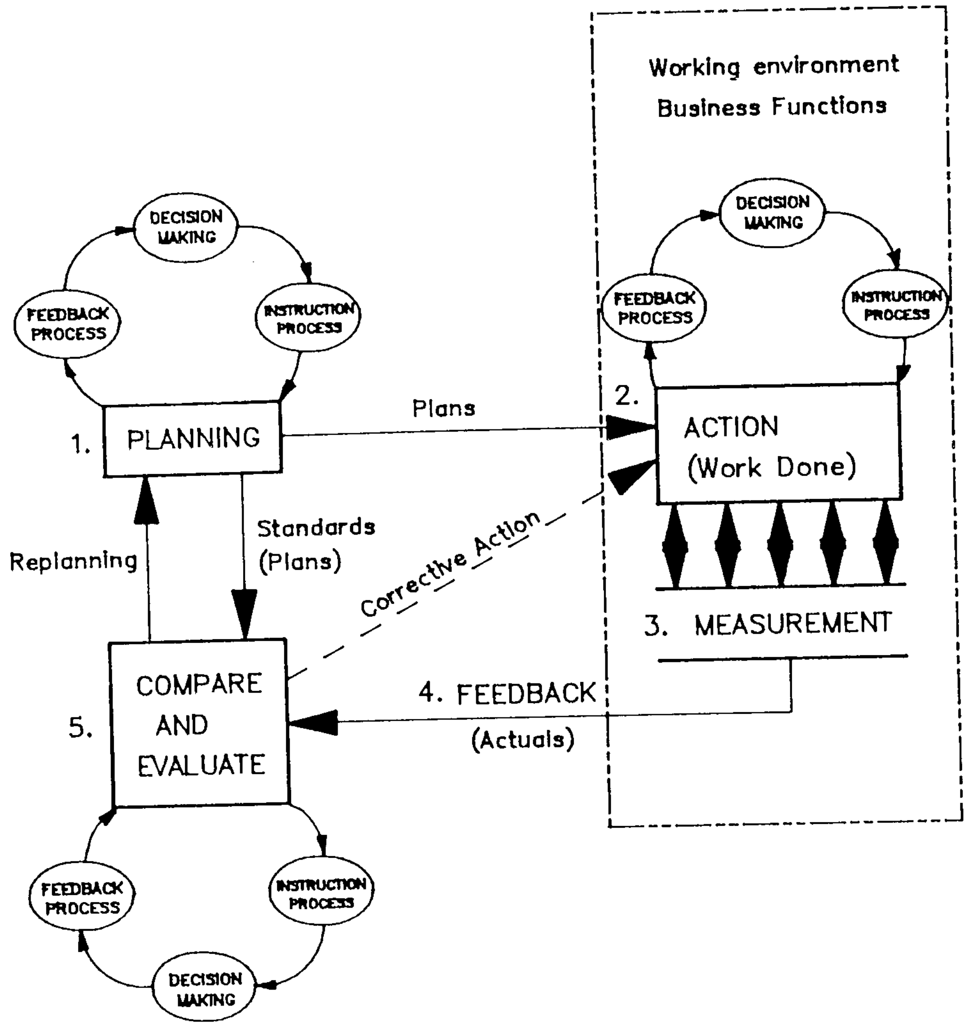


Figure (8): The overlay of a decision activity Loop onto a Closed Control Loop

loop may also be present within the individual control elements, but not in quite the same form. An example scenario illustrates this:

> A designer is given a detailed plan by his/her manager to design a new fixturing mechanism for a machine. The designer will infact make many decisions in accordance with the decision activity loop in establishing a design. The "action" oriented decisions are not subject to the same relationship to the control loop as those decisions associated with "planning" or "evaluation and comparison", as they do not normally impact on the other control elements.

From the previous scenario it can be seen that decisions are an integral part of a control loop and maybe present, in one form or another, in all control elements.

It follows therefore, that the establishment of effective control should include an examination of decision making and their overlay onto control loops.

3.3.4 Management

It is widely agreed that management personnel, from section leader to managing director are generally responsible for control loops. Invariably it is the manager who develops plans, actions work to be done, compares and evaluates actuals against plans and subsequently replans. This is indirectly supported by Mintzberg (1975) and Boyce (1967), both of whom state that managers are involved in planning, organising, coordinating and control.

It follows therefore, that the management hierarchy can be related to the business control hierarchy.

3.3.5 Control, its relationship to other business elements

It has been shown within this chapter that the elements of control have a relationship with various business elements including information, decisions, management and business functions (departments). Such relationships can be illustrated by constructing business element relationship charts, refer to Figure (9). The diagram is based on the standard entity/relationship chart and should be interpreted as follows.

A manager is 'responsible for' one or more 'control elements/loops'.
A 'control element/loop' is the 'responsibility of' a manager.

Effective business control can be more readily achieved when these business elements have been orchestrated to maximise the effectiveness of their relationship with control. The importance of examining and maximising the effectiveness of the various relationships is supported by Radford and Richardson (1987), Handy (1987), Rhodes (1984), Miesing et al (1984) and Eilon (1979). They each discuss one or more of the aforementioned relationships, but not the complete picture.

3.3.6 A conceptual business control model.

Within this chapter, three types of hierarchy have been discussed, each of which are related to control elements. By combining the planning, management and departmental (functional) hierarchy with the control loop, it is possible to construct a conceptual business control model, which is capable of modelling business plans against relevant business functions and their associated management levels in an integrated way. It is suggested that establishing control, based on this model should be more effective. An example model is proposed in Figure (10).

An examination of the model resulted in the following observations. All processes, no matter where they fit into the organisation, can be tied back to a control element; the business control problem is rather complex and the information flow and decisions are being made at all business levels.

3.4 Control levels and hierarchies

This section examines the use and application of control levels and hierarchies to assist business control.

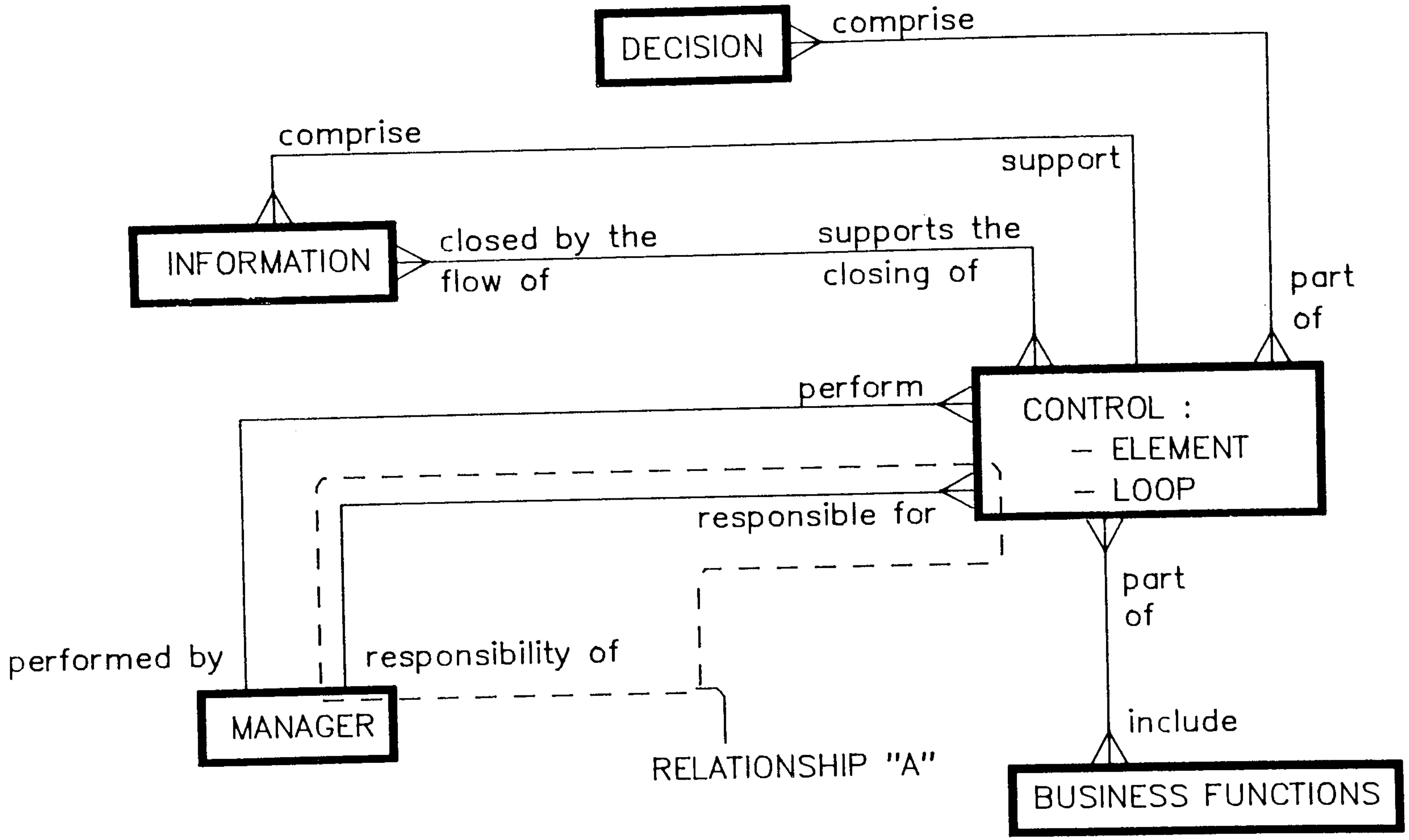


Figure (9): A control based business element relationship chart

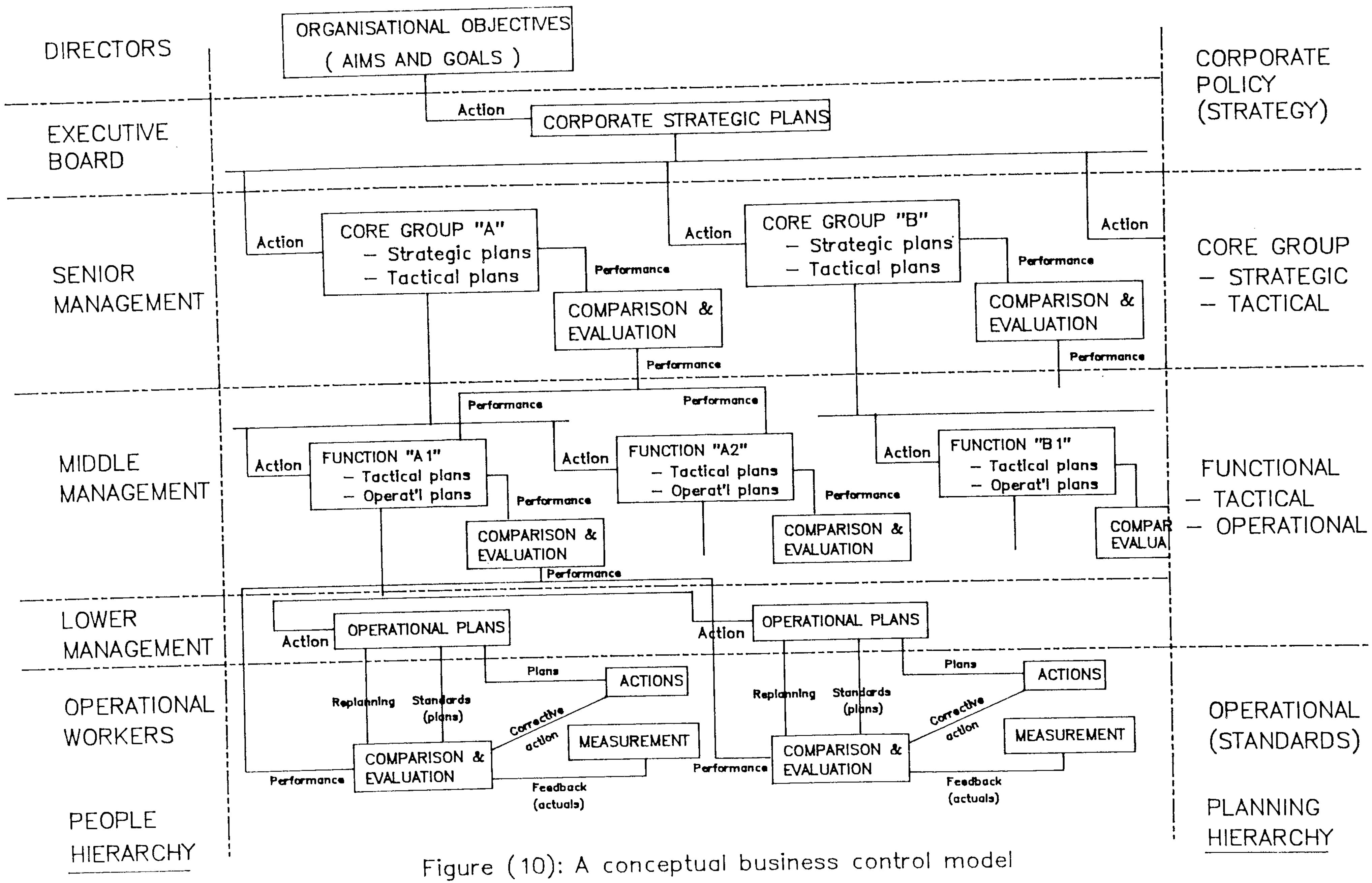


Figure (10): A conceptual business control model

3.4.1 Control loop interactions

In section 3.3, it was argued that in order to achieve effective control all control loops within the organisation should be tied back to an integrated hierarchy of plans. It was shown that a high level plan maybe decomposed into a series of lower level plans to form a hierarchy. As planning is element one of the control loop, the same decompositions applies to control loops. This provides a means of tracing all the control loops back to the organisational goals. The decomposition of control loops can be termed 'control loop nesting'. An example of control loop resting is shown in Figure (11).

Control loop nesting as shown in Figure (11), involves the vertical interaction of control loops by decomposition. Control loops can also interact horizontally across business functions. This is found when two or more control loops, action work packets, which they themselves are related through a precedence. An example of a horizontal control loop interaction is shown in Figure (12). The figure illustrates a precedence link between two 'action' elements, namely "design product" and "process plan product".

It can therefore be argued that control loops interact both vertically and horizontally across the business. Effective control can be more readily achieved, when both vertical and horizontal control loop interactions have been examined.

Control loop interaction is discussed by both Bentley (1984) and Rembold et al (1986). They both highlight the need for vertical control loop interaction (nested control loops), but fail to identify the need for horizontal interaction.

3.4.2 Control hierarchies

Control hierarchies have been used by industry for a number of years. The theory of hierarchical control originates from the process industry; many of the key concept of this hierarchical approach can be traced back to Mesarovic (1970), Anon (1974), Hiatt and Peterson (1977), Lefkowitz (1977) and Project Staff (1977).

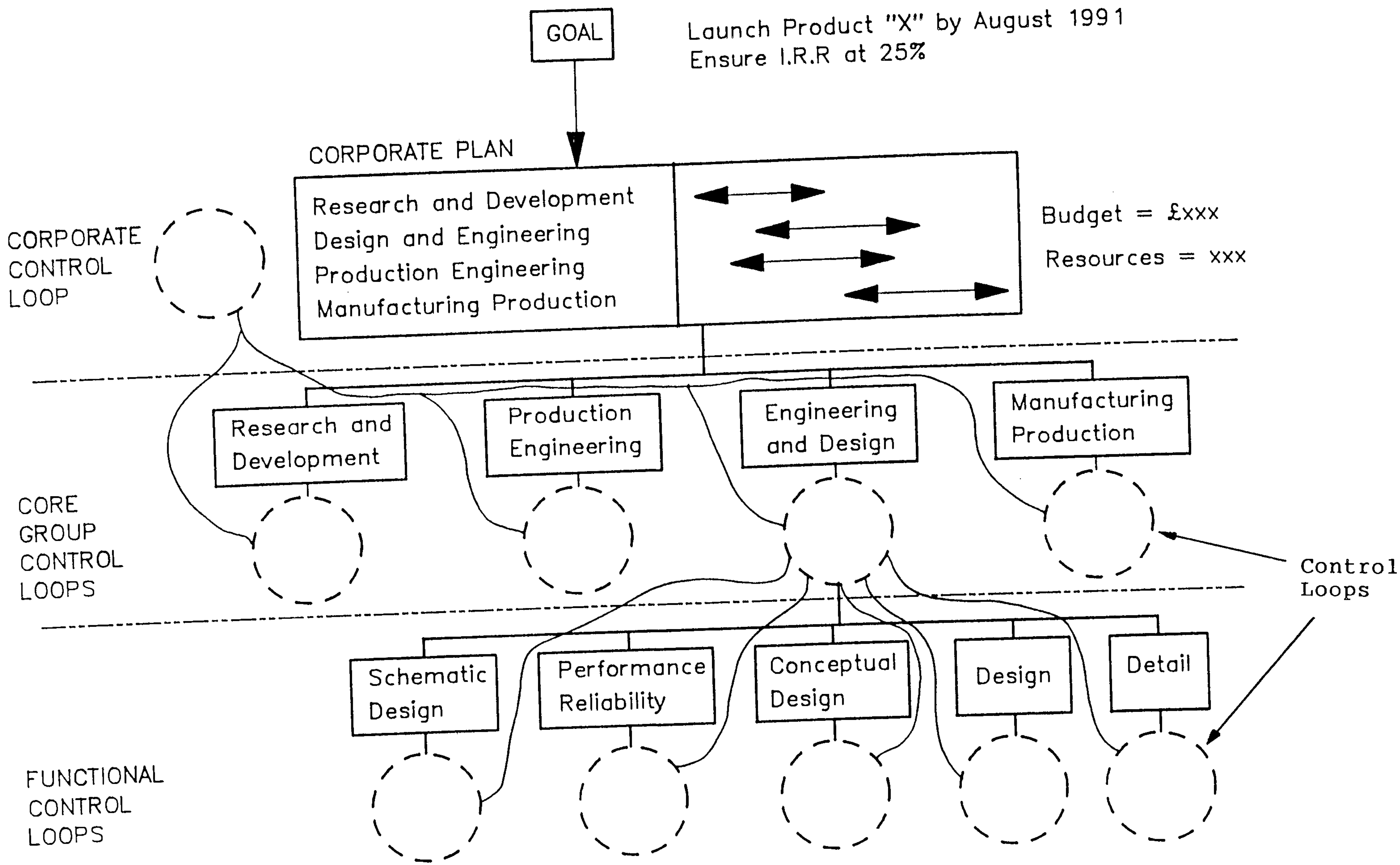


Figure (11): Control loop nesting

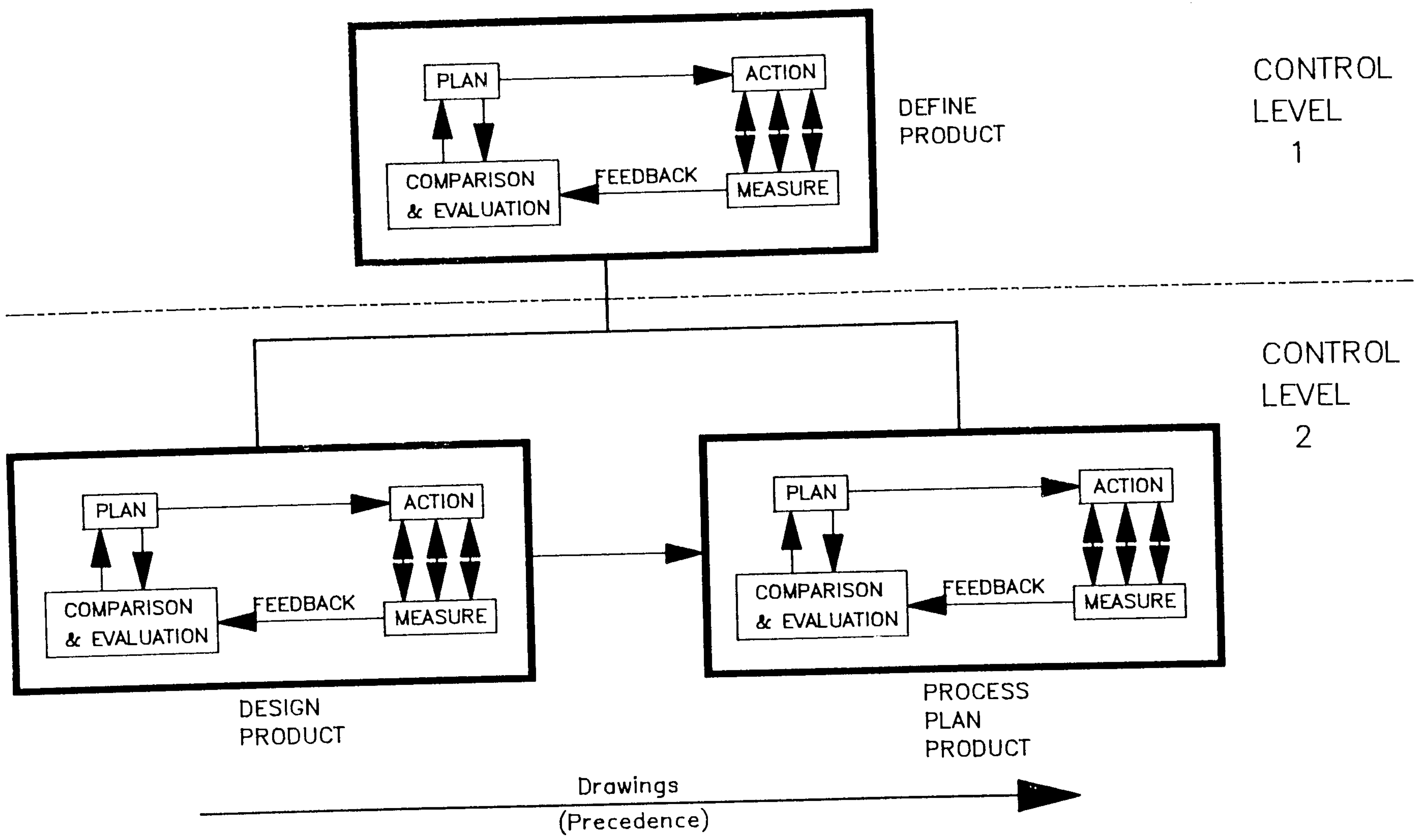


Figure (12): Horizontal integration of control loops

Today the use of hierarchical control models to study and examine control requirements is common place throughout the process industry [Metzger and McCarthy (1986), Kluchar (1987), Brosvic (1984) and Williams (1986)]. A natural progression from these developments has been the adaption of the hierarchical approach to detailed production planning, scheduling, and control of automated manufacturing [Baker et al (1986), McPherson and White (1986), O'Grady and Menon (1986), Helming and Vasile (1987) and Gershwin (1986)].

This hierarchical approach to establishing effective control, will be equally applicable across all manufacturing industry as manufacturing becomes more automated and flexible, resulting in a narrower differential between the problematic and control characteristics of process and manufacturing industries. This is in fact supported by Baker et al (1986) and Williams (1986), Both of whom suggest that computer based industrial control systems will be the medium for all plant control requirements in the future. They further forsee that such control systems will be based upon generic, hierarchical architectural forms which can apply to all types of industry.

A further development has been the use of control hierarchies to model the control level requirements associated with, decisions, functional control, manufacturing systems, computer hardware, and the control cycle time frame. This latest development has witnessed the most important application of the hierarchical control model, that is, its use to model business control requirements against other key business elements. Examples of these, have been proposed by Parnaby (1987), Rhodes (1984), and CIM task force (1988).

Throughout this chapter, the various control elements and loops have been modelled hierarchically. It follows therefore that a control hierarchy is a particularly convenient way of representing the control requirements of a business.

Business modelling using control hierarchies is examined further in chapter 7, where they are used for modelling control requirements during CIM system design.

3.5 Integrated control

In section 3.3, it was argued that in order to get all departments of an organisation to work together in a synchronised manner towards a common goal, one needs to adopt an integrated planning approach based on a hierarchical structure. It was also argued that a complex inter-relationship exists between control and the various business elements.

In section 3.4, it was shown that control loops interact both vertically and horizontally across a business creating a network of nested control loops.

The above arguments indicate that control elements and complete control loops are likely to interact with one another and various business elements right across the business. Such interactions necessitate an integrated approach to business control such that the various interactions can be effectively supported. It follows therefore that an integrated approach to business control is required [Boyce (1967), Flamholtz et al (1985), Miesing et al (1984) and Lawrence and Lorsch (1967)].

Boyce (1967), examines the control activities of an enterprise using a multi-facetted pyramid model. He visualises that an immensely complex information system is required for even a moderately sized industrial enterprise, and argues that it is necessary to put the various facets of control together into a fully integrated system of control.

Flamholtz et al (1985), argues the need to develop an integrative organisational control model.

Miesing et al (1984), argues that a formal planning and control system requires an integrated approach, and attempts to describe how components of strategic planning can be integrated into the management system.

Lawrence and Lorsch (1967), imply that there is a need for integrated control and argue that a new management job is required, namely "The Integrator".

3.6 Computer assisted control

This section examines the use and application of computer systems to support business control.

3.6.1 Computer systems and control elements

Computer systems are extensively used by industry to assist various activities, many of these activities interact with and indeed support control loops or elements thereof.

In section 3.3, various business control functions were mentioned including financial/cash flow control, new product introduction control and production control. Each of these control functions are supported by a standard computer system, they include financial ledgers (general/purchase/sales), project control systems and MRP II (Manufacturing Resources Planning) systems respectively.

It follows therefore that many computer systems have in fact been developed to assist business control elements. A particular computer system would normally support elements from numerous control loops.

In section 3.5, it was argued that an integrated approach to business control is required. Such an approach involves rapid and voluminous data processing, and for this reason will generally be dependant upon the use of computer systems for complete application. This is supported by Boyce (1967) and Williams (1986).

3.6.2 Control loop interactions, re-examined

This section is based upon three arguments already made within this chapter, namely that control loops are formed by the flow of control information through five control elements, that control loops interact both vertically and horizontally across organisational functions, and that computer systems interact with and indeed support control loops or elements thereof.

If two control loops are supported by separate computer systems and horizontally interact via an information flow, then it follows that linking the two computer systems in order to support the information flow will result in computer assisted control loop interaction.

It follows therefore that control loop interactions form the basis for determining the interaction required between computer systems. The interaction constitutes an information flow of two types. The first type involves control information which includes plans, budgets, standards, actuals, directives and comparisons. The second type involves activity support information, which can be defined as data required to perform the activity. An example of this is the process planning activity which requires product definition data.

3.6.3 Systems integration to support integrated control

Integrated control across a business, as already stated relies on the capture, flow and feedback of vast amounts of data. Traditionally, such activities were performed manually and consumed large amounts of time. Recent developments in systems integration means that many of the above processes can be computer assisted and in some cases completely automated, thus greatly assisting the process of integrated business control. An example of systems integration to support integrated business control is shown in Figure (13).

The diagram shows how the integration of three systems provides a means of automatically closing two control loops by automating the information flow.

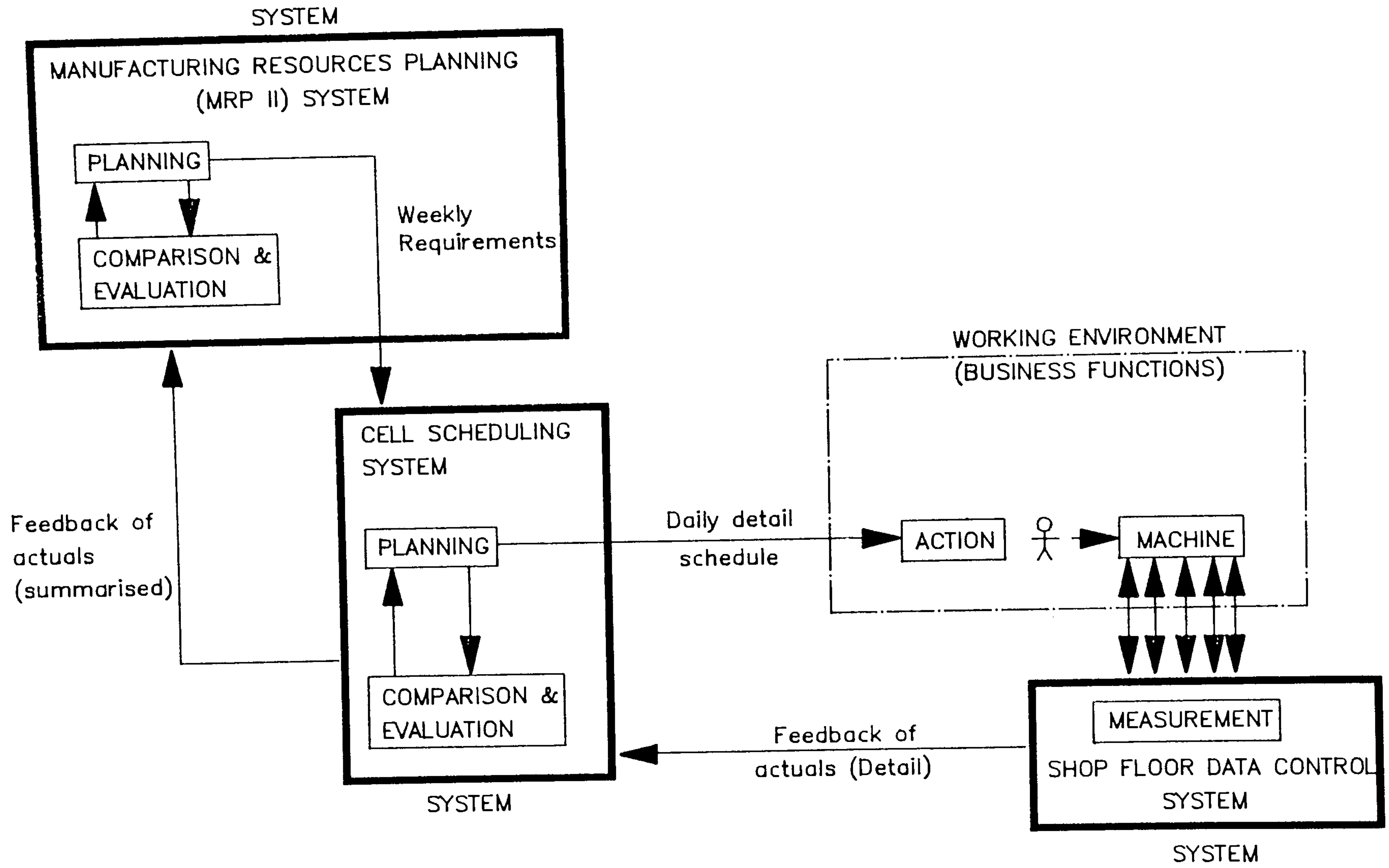


Figure (13): Systems integration to support integrated control

4. CIM AND INTEGRATED CONTROL

This chapter examines the relationship between CIM and integrated control, and its application within a manufacturing business environment.

4.1 Introduction

In chapter three, it was argued that the process of business control and the management role has become less effective over a period of years, and that a major concern of a business should be exercising effective control in an integrated business wide manner. Furthermore, it was shown that computer systems can be used to support various business control elements and that system integration can be used to assist the closing of control loops. From these arguments it can be seen that the development of integrated systems is capable of supporting the process of business control. It is this, the relationship between CIM and control, that forms the main subject of this chapter.

4.2 Discussion of the relationship between CIM and control

This section examines the scope of the relationship between CIM and control.

4.2.1 Systems integration (CIM phase 3) and integrated control

A relationship between CIM phase 3 and integrated control has been developed from both a CIM and control stand point.

In chapter 2.0, it was explained that CIM phase 3 is concerned with the integration of computer systems into the business environment, resulting in systems being an integral part of the overall business process. It was argued that this requires an examination of the environmental business elements in order to develop an optimum relationship and fit.

One particular aspect of fit, is that of achieving unity between the controls of the system and those of the process environment. It is important that integrated system networks have the appropriate interface, data management and timing controls to fully support the overall business process. The importance of data management as an integration and control tool is discussed by Johnson (1986), and the need to examine control requirements during systems integration is supported by Ekong (1987).

In chapter three, it was argued that effective integrated business control can be greatly assisted by integrating computer systems. It was demonstrated that such systems integration would support the flow of control information and aid the closing of control loops.

Both Agrawal (1987) and Patel (1988), demonstrate the requirements and benefits of integrating a Management Information System (MIS) to an advanced process control system. They discuss the need for developing a control hierarchy to examine the control information flows in relation to control loop response times.

It can therefore be seen that there is a strong relationship between systems integration and integrated control.

A less obvious relationship between integrated systems and control exists based on the effects one has on the other. Jones and Webb (1987), found that CIM can fundamentally affect business control; they argue that integration of information and control systems changes the way control is exercised. The fundamental change that takes place is that the control process itself is automated, changing the managerial role from that of active involvement to passive monitoring as automatic control is developed, requiring much less inter-personnel activities. Consequently, the managers function becomes a servicing one, ensuring that the resources are there to carry out the work so that standards and plans are met - this they compare to a plane flying on auto-pilot. Finally, they suggest that managers will take a more strategic role and become more involved in the planning element of the control loop leaving the rest of the control loop to automated integrated systems.

Although Jones and Webb have raised a pertinent point, it is unclear what caused these changes; it would have been useful had they differentiated between the changes caused by automatic control systems and those from pure systems integration.

The effect of pure systems integration on the control problem fall into three areas.

Firstly, the way control is exercised will fundamentally change, that is, the exercising of control will be much less inter-personnel. A worker may receive weekly plans straight to his/her computer and have his or her work content measured and fed back through automatic means. An example scenario of this is an operator on the shop floor.

> An operator may receive a "work-to-list" from the cell controller system identifying his or her work schedule. The operator then picks up his work packet box containing process plan, raw material, tooling, NC programs, setting sheets and batch card comprising batch identification bar code. The operator enters the bar code into a shop floor data control system and begins work. The shop floor data control system interrogates the CNC machine control unit, measures performance and through an integrated network feeds the actual performance data back to the cell controller system.

Secondly, assuming that computer systems have been fully implemented and systems integration complete, the control loop may indeed be characterised by that shown in Figure (14). The managers role as far as the control loop is concerned will focus on the planning element and will change from that of active involvement to passive monitoring [Jones and Webb (1987)]. Once this has developed the manager will adopt a more strategic role.

A Delphi study performed by Glen (1985), examines the strategic and structural implications of CIM; they found that businesses would be involved in a shift from short term tactical planning to long term strategic planning, and forecast the integration of manufacturing into long term strategic planning. The findings from the Delphi study are detailed in Appendix (D).

Thirdly, a control loop supported by integrated systems should take significantly less time to close than one which is performed manually. This alone may well impact on the type of control exercised; systems providing control in batch will have the opportunity to change to on-line control if the requirements are such.

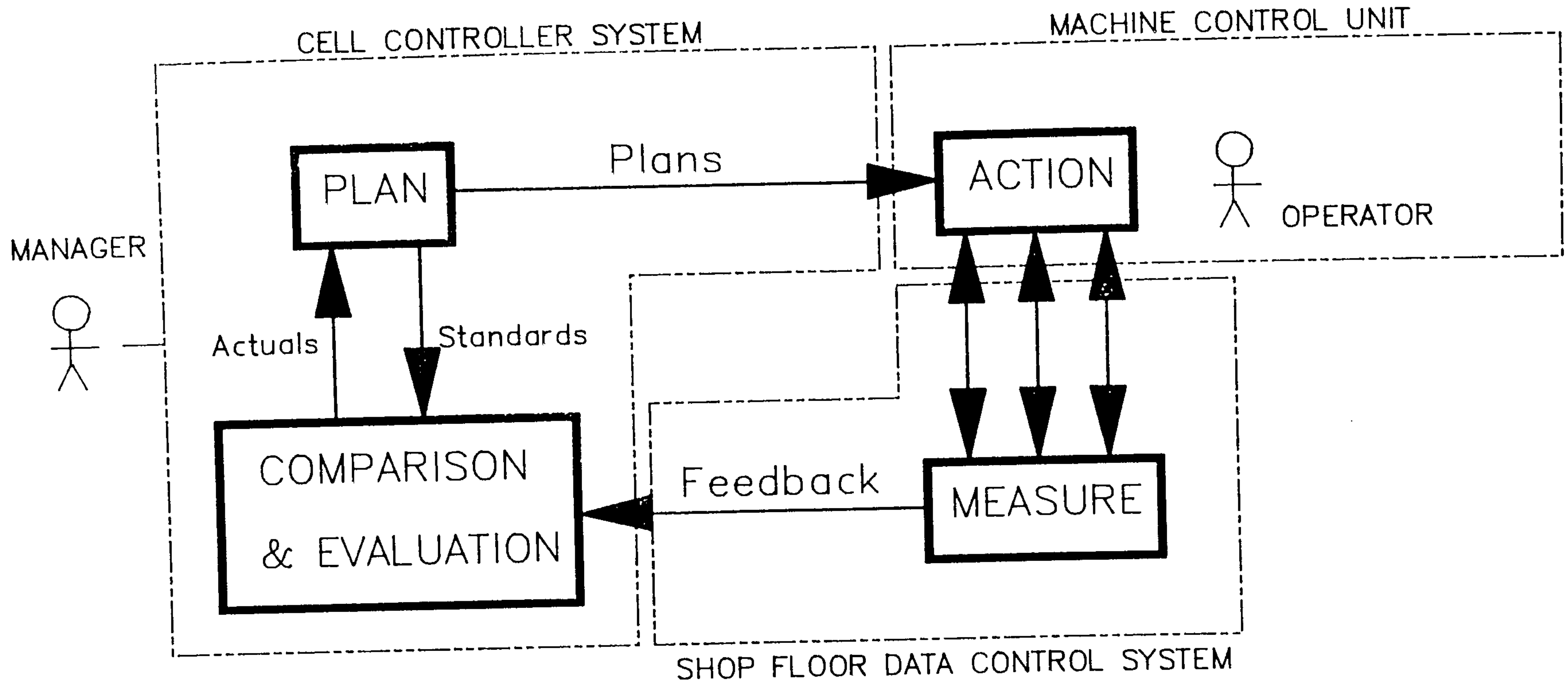


Figure (14): Control loop supported by computer systems

4.2.2 Business integration (CIM phase 4) and business control

A relationship between CIM phase 4 and business control has again been developed from both a CIM and control standpoint.

In chapter 2.0, it was explained that CIM phase 4 is concerned with the integration of the main business elements to include organisation, functions/processes, information, control, people, business strategy, decision making and computer systems. It was argued that these elements need integrating in a mutually supportive and controlled manner to ensure all the organisations various infrastructures have an optimum integrated configuration to maximise the efficiency of the business. One particular aspect of this integrated configuration is that of achieving unity between the various controls of the business elements, such that all controls are underpinned to ensure attainment of organisational objectives.

In chapter 3.0, it was shown using an entity relationship model that there is a rather complex relationship between the elements of a business. In particular the model drawn shows that the control element has a relationship with various other business elements. The chapter goes on to describe the multitude of vertical and horizontal control loop interactions across an organisation, the specific need for an integrated hierarchy of planning, and argues that a fully integrated approach to control is needed to achieve effective control.

It can therefore be seen that there is indeed a strong relationship between business integration and business control.

The relationship between the integration of a business and business control has been discussed by Helming and Vasile (1987) and Lawrence and Lorsch (1967). Helming and Vasile state that hierarchical control for a business often has a substantial impact on the structure of an organisation and that integration becomes real and personal as organisational structures change, including the re-alignment of personnel, their responsibilities, and organisational boundaries, to co-incide with the decomposed hierarchical control levels. Lawrence and Lorsch argue that in order to manage and control a business an "integrator" managerial role is required to ensure the effective co-ordination and control of all the major functional departments. They performed a study of ten organisations in three distinctly different industries and found there was a close correlation between the effectiveness of integration and company growth and profits.

Another type of relationship between business integration and business control exists based on the effect one has on the other. The level of business integration will change both the emphasis of business control required and the way business control is exercised. This can be shown using a manufacturing facilities layout scenario.

The integration of shop floor manufacturing facilities and functions to create a cell based structure changes both the emphasis and mechanism of manufacturing control. The manufacturing routings become much shorter resulting in less work in progress (WIP) and reduced emphasis on controlling WIP against that of a functional machine layout. The scale of the production control problems are much reduced, due to simplified work scheduling and machine loading, increased possibility of machine operator flexibility, standardisation of manufacturing routings, employee satisfaction and job enrichment and more efficient use of machine tools.

4.2.3 Key business process control and systems integration control

In chapter 2.0, it was argued that CIM phase 3 is concerned with developing a business environment in which systems can be regarded as an integral part of the business processes or functions. In such an environment, systems would be subject to the same business element relationships as those of the functions they support. For example, the systems would interact with people, process information, support the process of decision making and be coordinated by the same control mechanism as that of the function.

In chapter 3.0, it was argued that all business processes or functions are underpinned by specific control requirements. For example, the design process is underpinned by the New Product Introduction (NPI) control mechanism.

By taking these arguments and applying them to a particular scenario, it can be demonstrated that business process control can be supported by controlled systems integration. This scenario is illustrated in Figure (15).

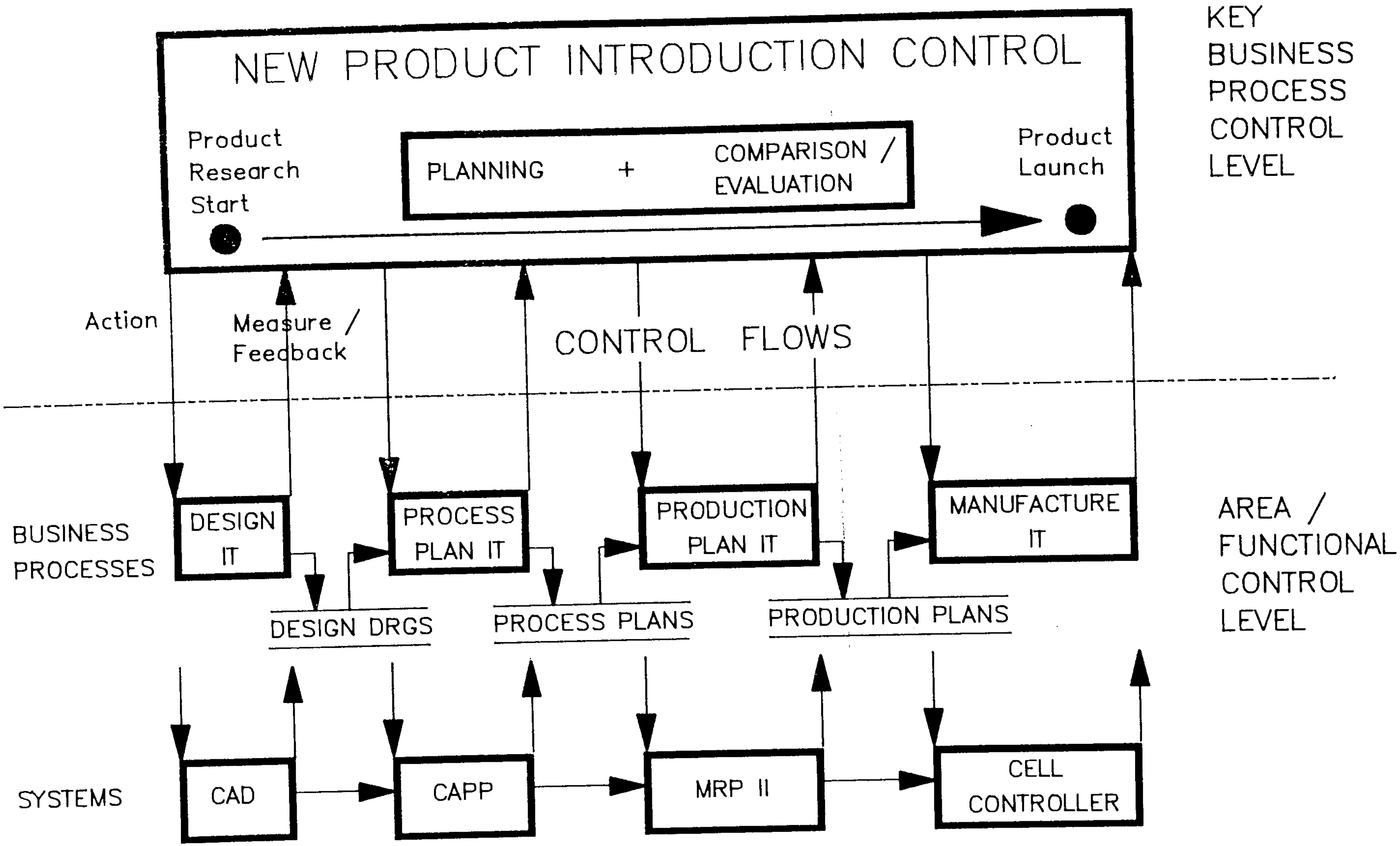


Figure (15): Key business process control and systems integration control

The four business processes shown, that is, design, process planning, production planning and manufacturing are underpinned by a key business process control mechanism, namely New Product Introduction (NPI) control. This NPI control is responsible for planning, co-ordinating and controlling the four functions in a sychronised manner to ensure the introduction of a new product is performed to plan. To achieve the plan, the four elements of control need some consideration. The NPI control mechanism performs the planning exercise and forwards actions down to each business process. Once the process has performed its work schedule, it measures and feeds the actual work done back to the NPI control mechanism, where comparison and evaluation of plans against actuals is performed to aid replanning.

Each of the functions shown are assisted by a computer system, for example:

Function	System used
Design	CAD - Computer Aided Design
Process planning	CAPP - Computer Aided Process Planning
Production Planning	MRP II - Manufacturing Resources Planning
Manufacturing	Cell Controller

Each of the functions are linked by a data flow. Designers produce design drawings which are forwarded to process planners, who produce process plans which are forwarded to production planners, who produce production plans which are forwarded to manufacturing who manufacture the product. As each of the functions are supported by a computer system, it follows that the data flow actually flows between the systems. The timing and control of this information flow should in fact coincide with the overall plans and actions for new product introduction. As many of the support systems have some degree of local control associated with its particular business function. It follows that the new product introduction control mechanism could in fact interact with the systems themselves, thus integrating the controls of the various systems, with the control of the key business process. This would result in the key business process control mechanism being responsible for the integration of the various system.

4.2.4 Summary and introduction to case study

This section has argued that there is a multi-facetted relationship between CIM and integrated control, which varies depending upon the particular view of CIM and control taken. It has been argued that a ralationship specifically exists between systems integration (CIM phase 3) and integrated control, business integration (CIM phase 4) and business control , and key business process control and systems integration.

The relationship between CIM and business control has been examined as part of an industrial case study, involving Lucas Aerospace (Engine Systems Division). The remaining part of this chapter discusses the industrial case study and its findings.

4.3 Lucas Aerospace industrial case studies

Some of the arguments within this dissertation are supported, by way of example through the application of industrial case studies. All case studies are based at Lucas Aerospace (Engine Systems Division). This section provides some background information relating to the company.

4.3.1 Introduction

The individual case studies are based at Lucas Aerospace (ESD), and in particular the divisional design, development and manufacturing facility at Shaftmoor lane, Hall Green, Birmingham. The industrial complex at Shaftmoor lane is fairly typical of a medium sized batch manufacturing company involved in the manufacture of sophisticated and precision machined components.

4.3.2 Market and products

The engine systems division of Lucas Aerospace is a mature manufacturer of systems and equipment for both civil and military gas turbine engine market sectors. The company supplies fuel pumps, fuel management systems and a range of ancilliary equipment such as cryogenic cooling engines for the aerospace and defence industries.

Traditionally, the component composition of engine management systems along with fuel pumps were purely hydromechanical, however the recent advancement in electronics has witnessed the inclusion of more electronic components, particular for the control systems.

The fuel management systems are purpose designed to a very high performance specification for use on a particular type of engine. The system or unit is engineered, developed and then tested in an iterative sense until it meets the high performance specifications, delivering fuel at a desire rate in a controlled and safe manner under varying physical conditions. The unit must also be mounted onto the engine, usually in a very small complex space envelope, and be designed to have the minimum possible weight. The fuel management systems are very high quality engineered units containing many precision machined components and mechanisms, many of which are unique to particular units.

The Aerospace market during the past twenty five years has been slowly contracting which has inturn resulted in a fierce competitive environment. The market place is demanding a single standard on price, quality and delivery, together with fixed term and price contracts with damaging penalty clauses for lateness. The aerospace customers are demanding shorter lead times, improved responsiveness to specification change, reduced product weight, higher quality products, minimum product price and improved product/customer support. The markets are increasingly being influenced by the governments of the various nations, who insist on equal market sharing. An aerospace or defence contract is usually apportioned to particular countries which involves the setting up of multi-national teaming agreements.

4.3.3 Manufacturing facility

The manufacturing facility of Lucas Aerospace, engine systems division is spread across four sites. The divisional site is based in Hall Green, Birmingham and is involved in full design, development, prototype manufacture and testing of all products. It is also involved in the production manufacture of a certain range of products. The Huyton, Liverpool facility is a pure production facility for a particular range of products. The Honiley site in Warwickshire is an engine test centre, and the Marston Green, Birmingham facility is involved in the repair and overhaul of the products, and in-service support.

The divisional site in Birmingham is responsible for the introduction of new products and have full design authority. Much of the new product introduction process is project orientated.

Engine systems division has a wide range of modern flexible machine tools situated at two main sites, Birmingham and Liverpool. The Birmingham factory contains full facilities and expertise to provide 'prototype to production' manufacture, including assembly and test facilities incorporating computer controlled test rigs.

As previously stated most fuel management systems are purpose designed for use on one particular type of engine. This normally means small production runs for the unit spread over a number of years.

A typical unit may have hundreds of components structured on a five to eight levelled Bill Of Materials (BOM). Traditionally a large proportion of these components were made in-house, however during the last ten years the percentage of bought out components has grown rapidly. It has been agreed that engine systems division should manufacture the high added value items and buy-in or sub contract the lower value items. Such a batch manufacturing environment lends itself to the philosophy of MRP II (Manufacturing Resources Planning) for manufacturing planning and control, and is supported by a cellular factory layout based on product groupings.

4.3.4 Case studies

The case studies have been performed at the divisional site in Birmingham; they all relate to the development and integration of systems and the integration of business elements in support of achieving effective business control

There are four case studies discussed within this dissertation, all of which are very closely related.

Case study 1. Section 4.4, discusses the application of a project control system plus organisational structure changes for New Product Introduction (NPI) control.

Case study 2. Section 4.5, discusses the application of an MRP II system plus organisational structure changes for manufacturing operations control.

Case study 3. Chapter 8.0, discusses the development of a CIM design methodology for CIM, which is based on a five level control hierarchy.

Case study 4. Chapter 9.0, discusses the development of a systems integration architecture for establishing CIM and effective business control.

4.4 Industrial Case Study 1 - New Product Introduction (NPI) control

This section discusses the findings from industrial case study 1, which focusses on the application of a Project Control System (PCS) and structural organisation changes to achieve effective New Product Introduction (NPI) control. It will be argued that the adoption of an integrated project control model (system) and the project matrix organisation structure can be considered useful mechanisms for providing effective control to the somewhat complex key business process - New Product Introduction (NPI), through the development of a synergistic relationship between control and integration (CIM).

It will be shown that an integrated project control model can be devised in such a way that it automates the closing of control loops by integrating its controls with the local controls of the functional computer systems, and that the adoption of the project matrix organisations structure supports some of the NPI control requirements and provides a degree of business element integration.

4.4.1 Introduction

One of the most critical and important processes of a manufacturing business is bringing new products to market. The process normally spans product inception to product launch and can take a few weeks to tens of years depending on the type of product. It is stressed that controlling this process is both critical to the success of the company and constitutes a formidable task, which can be assisted through computer application.

4.4.2 The New Product Introduction (NPI) process

The introduction and development of new products is a complex process involving the synchronised interaction of many functions within a business. Each function is responsible for performing a network of activities, all of which consume company resources such as labour, money, functional facilities and time. The time taken to introduce a new product varies depending upon the nature of the business, the type of product and market requirements. Within Lucas Aerospace the time taken normally varies between 9-18 months depending on the product requirements.

At Lucas Aerospace the functions involved in new product introduction are listed in Table (4). The sequence of the key processes shown in Table (4) is a very important factor in controlling the overall process and reducing product introduction leadtimes. The process sequence adopted at Lucas Aerospace is shown in Figure (16). It can be seen from the diagram that parallel working is exploited using a project team/matrix structure which helps to reduce leadtimes.

The aerospace products involve large development costs which, depending on the terms of the contract, maybe funded by the customer or, more often than not funded by Lucas, who then ammortise the costs against the product price over the production period. In most cases the customer imposes a time penalty clause, such that each week of lateness results in a fixed charge.

The introduction and development of a new product requires the co-ordination of a great number of separate activities over a long time thus producing many control problems.

4.4.3 Control problems associated with NPI

New product introduction as previously explained is a complex process involving the interaction of numerous business activities and the consumption of key company resources. Due to the scope of the process and the various parameters involved it can be argued that there are many inherent control problems which require particular attention if effective NPI control is to be sought. This argument is supported by Garside (1988), Johnson (1986), Moore (1987) and the findings from the industrial case study.

The control problems associated with NPI at Lucas Aerospace can be summarised as follows:

- the immense number of inter-related activities, which are performed by different resource types and have varying leadtimes and resource consumption rates, result in a complex scheduling task if performed manually;

KEY PROCESSES	FUNCTIONS / DEPARTMENTS
* Win new contracts	* Sales and Marketing
* Manage Commercial aspect of contract	* Commercial contracts
* Manage project team	* Project leading / management
* Conceptual design	* Performance / Simulation / Reliability
* Full design	* Designs
* Plan method of manufacture	* Manufacturing planning
* Plan production of prototype	* Production planning & control
* manufacture prototype	* Manufacturing cell No 4
* Develop product	* Development

Table (4): New product introduction processes and functions

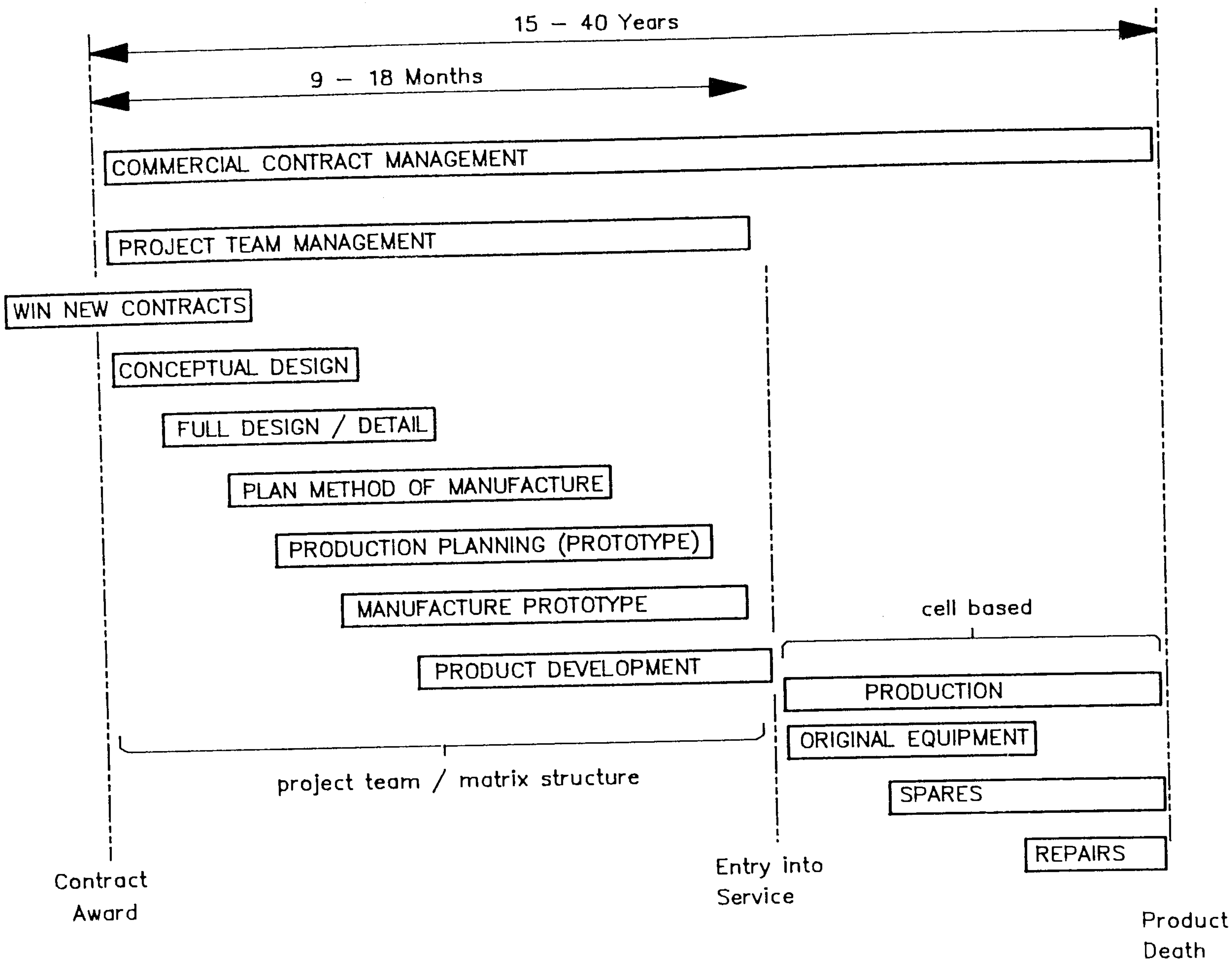


Figure (16): New product introduction process sequence

- the physical dispersion of these activities across the business results in a somewhat difficult co-ordination task;

- determining the status of a project relies on the gathering of vasts amounts of information from various functions within the business. Much of the status information required is stored in people's heads and computer systems and often requires inter personnel communication and system interrogation. Such information gathering would itself consume an appreciable amount of human resource and has proven to be a laborious and formidable task;

- any difficulties or problems encountered with the NPI schedule invariably become visible at a late stage in their development, by which time the problems are more severe and difficult to solve. In some cases problems only become visible when they critically affect the business;

- the NPI process is very dynamic and iterative; a product normally undergoes numerous design changes and consequently takes on many product builds during the development process. Such a change orientated dynamic environment complicates the control process;

- the inflexibility of labour due to the highly technical and specialised nature of roles, results in people having to contribute/participate in more than one project concurrently. In this multi project environment resource scheduling and control proves to be a difficult task;

- the NPI control loop is invariably incomplete; planning and actioning is performed but the feeding back of actuals (ie time taken, costs incurred and resources used) is either not performed, curtailed or grossly summarised. In such an environment effective NPI control is rendered extremely difficult. As actuals are not fed back, variance analysis cannot be performed, which in turn means that re-planning to bring the NPI process back on schedule is more difficult and the planners/estimators have no basis for improving future estimates;

- the accountabilities and responsibilities associated with the introduction of a new product are split. No one person is responsible for planning and controlling the profits of a product. Each person involved has conflicting loyalties;

- the current MRP II system is not flexible enough to effectively control development work. In many cases no process plans exist. Bills of material are only partial and in some cases drawings are not available, only sketches. Engineering personnel have no visibility over the prototype manufacturing process;

- functional engineers, for whatever reason, are not always involved in the generations of project estimates. This results in project plans being imposed on them; such incidents invariably result in a lack of commitment to the project plan.

Whilst the above control problems were found at Lucas Aerospace; they may well be typical of those problems faced by many medium sized batch manufacturing companies.

4.4.4 Requirements for effective NPI control

Chapter 3.0, examined the meaning of control and argued that a control mechanism consists of a number of inter-related closed control loops, each of which are involved in controlling a set of parameters within a specific environment. Thus to establish the requirements for effective NPI control, one must first examine the control loop and the parameters which need controlling. As discussed in chapter 3.0, the control loop comprises five key elements, namely 'planning', 'actioning', 'measurement of actuals', 'feedback' and 'comparison and evaluation'.

The NPI control mechanism must fully support all five control elements.

The parameters which need controlling are generally common across many industrial project or contract based developments and include function or process, quality, resource consumption, money and time. To put this into context, the control task is concerned with performing a function or process, to a quality specification, over a pre-determined period of time, within a particular budget, and at or below a given resource consumption rate.

In order to achieve this level of control, one must consider each of the control elements in turn.

4.4.4.1 Planning

The use of a standard planning technique to assist in the breakdown of the overall process into a workable plan of activity schedules is of primary importance [Pessemier and Root (1973), Dusenbury (1967), Wong (1964), Butler (1973) and Buggie (1982)]. Many standard planning techniques are used including bar charts (Gantt charts), Project Evaluation and Review Technique (PERT) and Criticial Path Analysis (CPA). The choice of the planning technique depends very much on the function/process control required.

At Lucas Aerospace the planning requirements are comprehensive and include the following:

- to decompose the function/process into smaller, more manageable elements of work (ie activities) such that estimates of lead times, cost and resource consumption may be more readily made;

- to show the interdependency of activities so that the consequences in the delay of one activity may be shown against others, and ultimately the whole plan. This necessitates the use of network analysis;

- to perform time analysis using forward and backward runs to determine, earliest and latest start and finish dates for each activity, any critical paths through the network and any timing problems, eg negative floats;

- to perform resource analysis across a multi project environment for all the activities producing resource graphs which show for each resource type, the resource requirement against time and any resource problems, eg resource overloads;

- to perform activity scheduling against fixed time and fixed resource across a multi project environment to produce detailed gantt charts showing scheduled dates and critical paths;

- to perform cost analysis and budgetary control, comparing actual costs against estimates and budgets, and producing cost graphs showing planned and actual costs against time and work performed. This cost data to be summarised and used to monitor and control against the overall profit plan;

- to perform 'what if' planning to evaluate alternatives and possible changes without affecting current working plans;

From examining the above rather detailed planning requirements, it can be seen why a computer assisted standard planning technique was realised as being an essential requirement for NPI control. The use of computer assisted techniques for project planning and CPA applications is supported and further discussed by Sawyer (1983), Vincent (1988) and Scobby (1989).

4.4.4.2 Actioning

The actioning of the work according to plan to be performed through the use of 'work to lists'. The work to lists to include scheduled times, estimated spend and estimated resource consumption for each item of work.

4.4.4.3 Measurement and Feedback

The measurement and feedback of actual work done is of primary importance and constitutes a major requirement. At Lucas Aerospace this control element has traditionally been grossly neglected resulting in anything but the required level of control for NPI. The reason for this was traced back to the problem of gathering vasts amounts of information from the various functions within the business. Upon examination of this information, it was found that much of it is actually stored in the various functional computer systems. This resulted in one common requirement, the automatic measurement of actual work done, followed by the feedback of that information to the computer assisted standard planning technique.

The use of systems integration to close the NPI control loop is discussed and further developed in section 4.4.5.

4.4.4.5 Comparison and evaluation

The comparison and evaluation of actual work done against their corresponding planned values is of critical importance if effective NPI control is to be achieved. This function maybe termed variance analysis.

Exception reports should be produced identifying activities that have not started, but should have; not finished, but should have; started late or finished late; consumed too much resources depleting the load of remaining resources available or incurred a combination of actual and committed cost that exceeds the estimated cost.

Such occurrences may affect the overall plan and therefore need evaluating to determine their impact. This would normally result in re-planning.

Other requirements for effective NPI control cover more the socio-technical aspects. The socio-technical problems identified in section 4.4.3, necessitate the following requirements:

- the personnel involved in the NPI process to be brought together to form a project team. This logically brings the various activities closer together resulting in a simpler co-ordination task and improved communication between members of the team. This project team approach to NPI is more commonly known as the project matrix organisation and is discussed further in section 4.4.6;

- commitment to the project plan must be gained from all project team members. This can only be achieved if they have been involved in the generation of project estimates and subsequently the 'signing off' of the plan prior to the actioning of any work to lists;

- the responsibilities and accountabilities of personnel associated with NPI needs to be clear and commonly known. It was decided that:

  - the Project Leader would be responsible for the day to day running of the project, the co-ordination of the project team and the achievement of the products functional, technical and quality specification in accordance with the plan;

  - the Programme Manager would be responsible for satisfying the customers needs in terms of product functionality, price and delivery whilst producing a profit plan and ensuring its achievement.

In order to achieve effective NPI control an integrated Project Control System (PCS) is required which supports the requirements outlined for each of the control elements, and a project matrix organisation is required which supports the soci-technical requirements outlined above.

Both of the above requirements include particularly important aspects of business integration, these aspects are examined in the following sections, namely 4.4.5 and 4.4.6.

4.4.5 Integrated project control model

In 4.2.3 it was argued, by way of example that a relationship exists between CIM and control. In short, it was argued that business process control is responsible for specifying the required level of integration between the various functional systems. The example key business process used was New Products Introduction (NPI). NPI was then adopted as the core subject of industrial case study 1. The case study concentrates on examining the control required for NPI and the application of an integrated project control system. The findings from the study further develop the relationship between CIM and control.

A model of the integrated project control system required to control NPI at Lucas Aerospace is shown in Figure (17). The model takes on an input/ouput format, the inputs on the far left flow across into the project control system and the functions listed, use those inputs in producing the required outputs on the far right. The model is based on

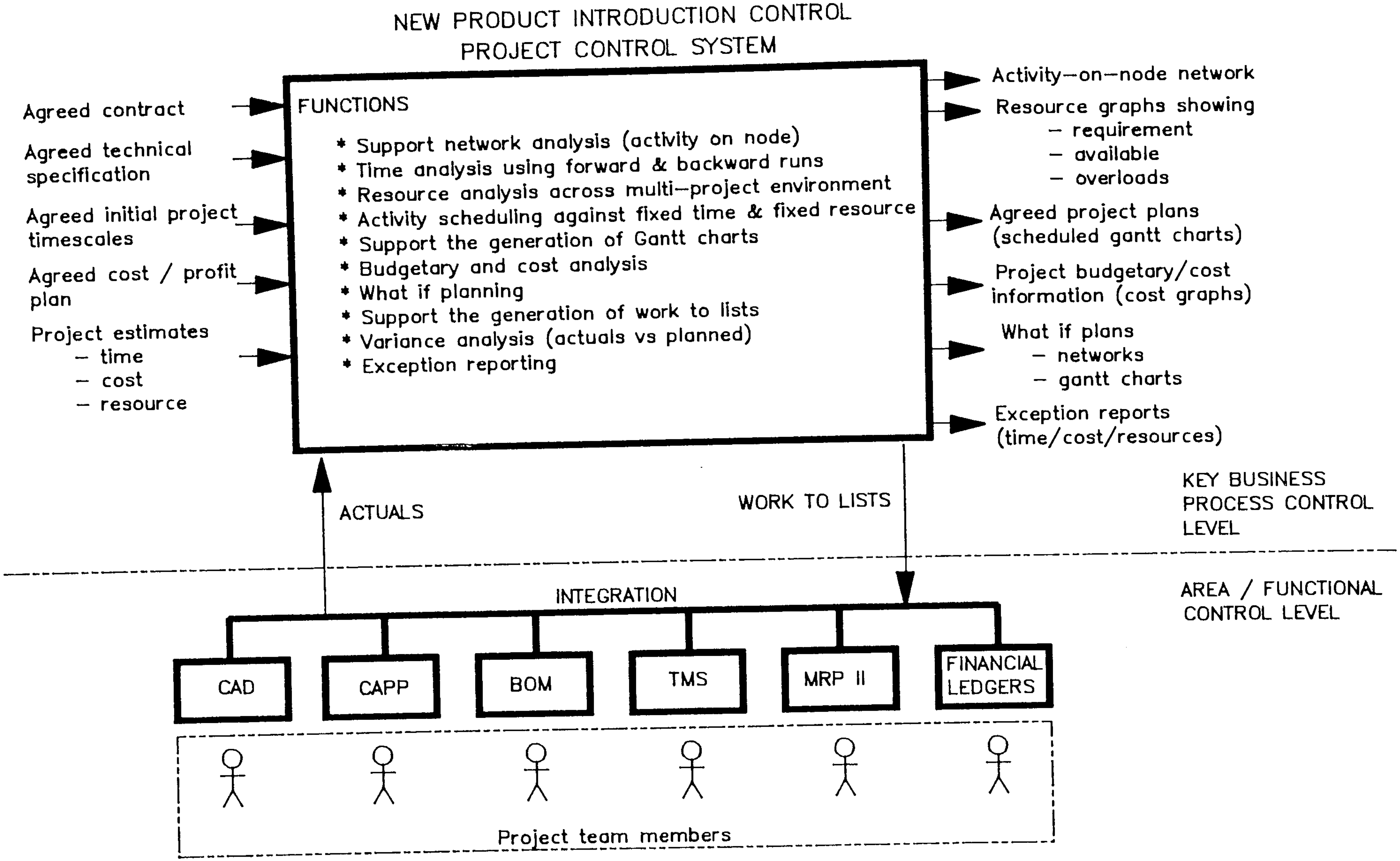


Figure (17): Integrated project control model (overview) the requirements examined in the previous section. The lower part of the model shows the integration required between the project control system and the functional computer systems to support the automation of the control elements, 'measure and feedback'. This as explained earlier suggests the use of systems integration to close the control loop.

The relationship between the project control system and the functional computer systems is, however, much more than just a data link. A more developed relationship can be demonstrated by an example, refer to Figure (18). The diagram shows three control levels. Control level 2 is the key business process control level, involved in the control of NPI through the application of a project control system, control level 3 is the area or functional control level, involved in the control of various new product introduction functions which is performed using an Engineering Database Management System (EDMS), and level 4 is the operational level involved in various functional operational activities.

The role of an EDMS is to provide a controlled working environment, where all engineering data including drawings, NC files, process plans, bills of materials, engineering documentation and reports, part related information, and all change, issue and release notes are controlled throughout their inter-related lifecycles.

The Project Control System (PCS), in planning the NPI process, breaks it down into lower level activities, for example design product, produce bill of materials, process plan part and production plan parts. The activities are supported or assisted by the following computer systems respectively, namely CAD/CAM (Computer Aided Design/Manufacture), BOM (Bill of Materials), CAPP (Computer Aided Process Planning) and MRPII (Manufacturing Resources Planning).

Planning, as argued in chapter 3.0, is hierarchical. To illustrate this, two plans (gantt charts) have been shown, one at a high level showing the global processes for NPI and one at a lower level showing a more detailed plan for the product design activities. This lower level plan can be broken down again to plan the design/draughting of each individual part. However, part based activity planning using a PCS is generally considered too detailed at Lucas Aerospace. These more detailed plans identifying individual activities against a part maybe contained within an Engineering Data Management System (EDMS), which manages the work and information flow

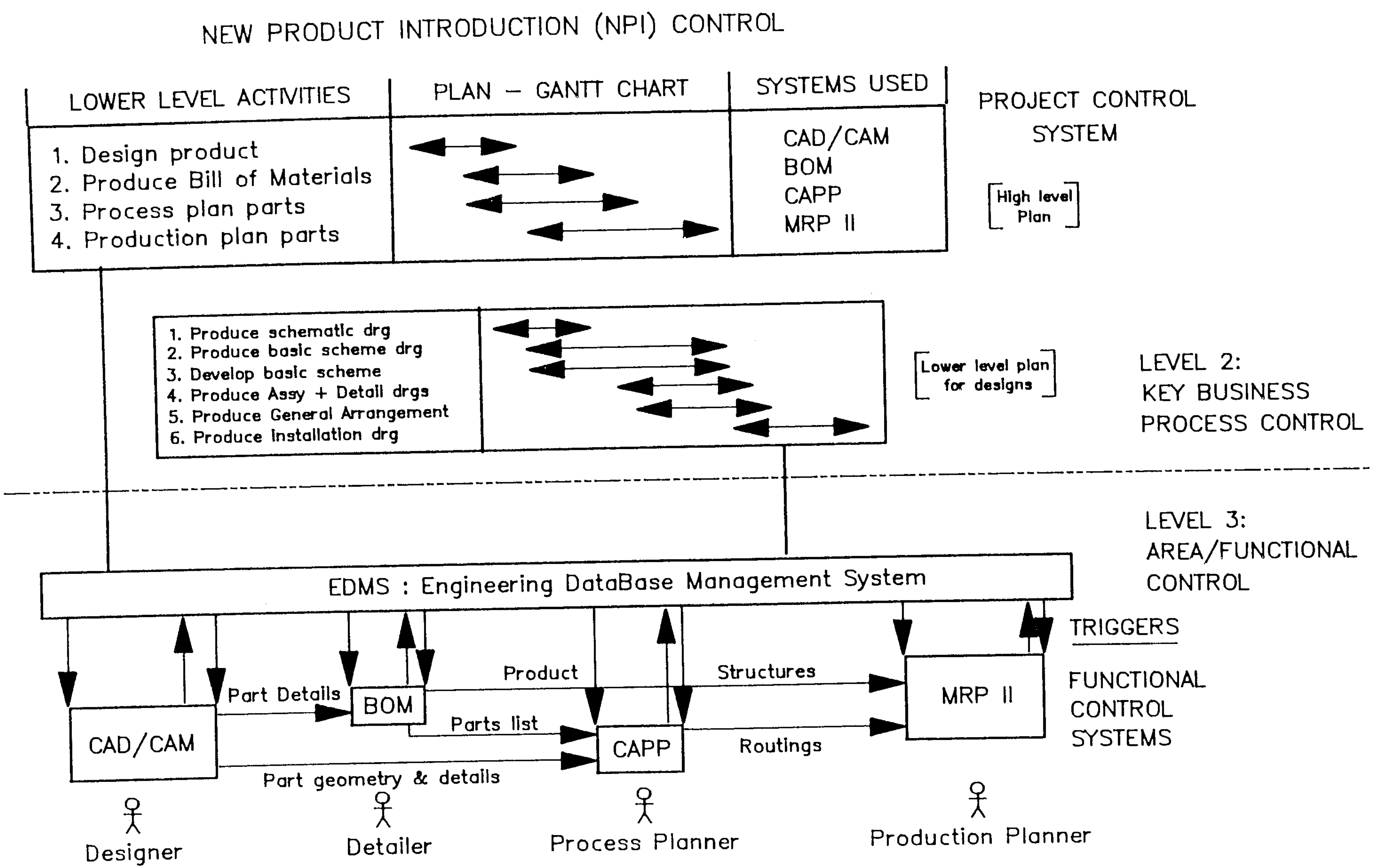


Figure (18): Integrated project control model (detail) through the various engineering systems. Normally these lower level plans would be forwarded to the persons concerned who would be actioned to perform the activities, and any activity status information gathering exercise would result in interpersonnel communication and system interrogation. These procedures will, however, change with the adoption of the proposed systems integration and control concept.

Most functional computer systems have some degree of local control. This being the case, it can be argued that the lower level control (plans) from the project control system should be integrated with the local control of the functional computer system in such a way that actioning of plans and the measurement and feedback of status information (actuals) is automatic and synchronised. This degree of integration can be provided through EDMS.

This is explained in more detail in the following scenario.

> The project control system produces a detailed design in line with the contracts major milestones. The detail plan is forwarded to the Engineering Data Management System (EDMS) where it is held. A designer logs onto CAD/CAM and windows in EDMS to check his or her work to list for that week and begins work. As the designer is working, certain activities are monitored automatically within the CAD/CAM local control, which triggers status flags within EDMS. This work can be used to indicate the progress of the designer's work. The CAD/CAM local control system then automatically updates the detail plan within EDMS, which is inturn fed back to update the project control system.
>
> A typical example is shown in Table (5).

It can be shown that the integration of the project control system with the EDMS system and the local control of the CAD/CAM system provides automatic means for the actioning and the measurement/feedback of actuals. If this degree of integration was adopted across the various functional computer systems, it would provide the basis for a more developed relationship between CIM and control. This developed relationship is based on the transaction chain control concept.

ACTIVITY	INDICATION
* Allocation of a drawing No. from drg register	Design has not been started
* The approval of a design – Entering of initials	Design completed and approved at issue X
* Drawings copied from Designers personal library to main public library	Design ready for use
* Completion of drg issue column/field	Design issued
* Drawing copied from main public library to designers personal library	Design undergoing change

Table (5): Activity monitoring

4.4.5.1 Transaction chain control concept

In Figure (18), it was shown that an information flow exists both vertically between the project control system and the functional systems, and horizontally between the various functional systems. The vertical flows normally include project work actions and work status feedback, whilst the horizontal flows normally comprise information which is produced by one functional system and required by another. The information flows should tie up with the NPI plans, such that all the information required by a system is present prior to the start of the next work packet. This can be done automatically.

The scenario given in the previous section can be extended to explain this.

> The status information fedback from the CAD/CAM local control system to the project control system states that a detail design is complete and ready for issue. This in turn invokes the interface software to forward the detail design (part geometry and details) to the CAPP system, such that the information is available for the process planner to begin his or her next work packet.
>
> If this concept was adopted across all of the New Product Introduction (NPI) processes, then it would provide a means of controlling NPI functions, NPI information flows, NPI support systems and systems integration, in a synchronised manner with automatic closing of the control loops.

This concept has been named "Transaction Chain Control Concept" due to its chaining of transactions to gain control.

Adopting the above concept would greatly contribute to solving many of the new product introduction (NPI) problems encountered by Lucas Aerospace (ESD) and numerous other businesses.

Lucas Aerospace have adopted an integrated project control system and are currently pro-actively involved in the development of the integration philosophy.

Other authors are developing similar views surrounding NPI, integration and control. Johnson (1986), argues that ordinary project management tools, whether computer based or not, do not provide adequate control unless the manager has been extraordinarily diligent in keeping the status of the project current. He further argues that in order to be effective, project management, must be integral with daily operations, reflect actual conditions and keep management up-to-date on the status of the project at all times. Garside (1986), argues that a project appraisal and control mechanism is responsible for integrating the New Product Introduction (NPI) activities. Both authors support the need to more closely integrate Project Control System into the NPI process, but do not identify the methods or concepts needed to do so.

4.4.5.2 NPI systems integration framework

The integrated project control model to support and control the new product introduction process, as discussed within this chapter, is based to a certain degree on both vertical and horizontal integration . In such an environment a need exists for a systems integration framework to support and control the required level of integration. At Lucas Aerospace (ESD) the need for such a systems integration framework was soon realised and a conceptual framework was developed.

The systems integration framework is shown in Figure (19); the procedure is based on 6 triggers.

At trigger 1, work to lists are produced from the detailed project plans and forwarded to the local control environment of the CAD/CAM system under a particular user-id. A user logs on to the CAD/CAM system and queries the work to list file, which contains the actions for which he or she is responsible. The user then designs the part. Once the user has completed the part design and it has been checked and approved, trigger 2 is executed which updates the work to lists file and feeds back status information to update the detail project plans.

> Nb: Trigger 2 may be executed by the transferring of the part design from the users personal CAD library to the public library from which issuing is performed.

At trigger 3, the interface and communication control suite of software is invoked, which extracts the part geometry and details form the CAD/CAM

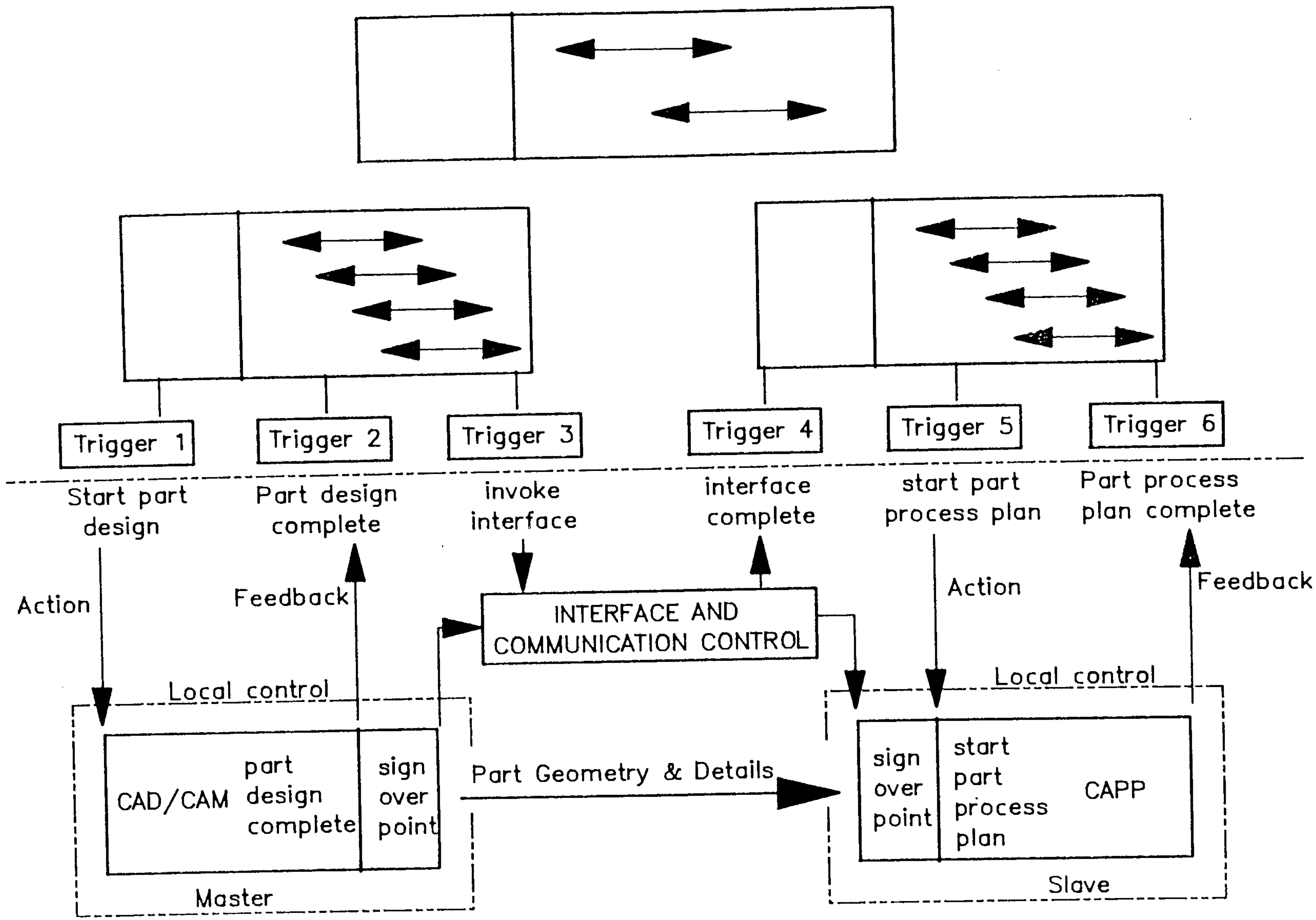


Figure (19): Systems integration framework system and transfers the information to the CAPP system where it is unloaded. Once the interface is complete, trigger 4 is executed which feeds back status information to the detail project plan. Trigger 5 and 6 are similar to trigger 1 and 2 except that the functions and systems are different.

It was decided that the systems integration framework should be adopted right across the NPI process, such that total control can be gained.
This integration framework is further developed in chapter 9., where a standard procedure is developed, together with a standard intersystem communication and control model.

4.4.6 Project matrix organisation

In section 4.4.4, the requirements for effective NPI control at Lucas Aerospace (ESD) were examined. In particular a set of requirements were established to solve some of the socio-technical problems outlined in the previous section. The requirements all centred around the work, organisational and authority relationships surrounding the NPI functions, and after some discussion a potential solution was developed, that being, the adoption of the project matrix organisation structure.

Matrix organisation for development projects is widely practiced throughout the batch manufacturing industry. Advocates of the project matrix organisation include Vincent (1988), Huggins (1986), Garside (1988), Meredith (1987) and Radford and Richardson (1987), to name a few.

The above authors all discuss the potential advantages of such a matrix organisation structure against that of a functional/departmental structure. However, if insufficient time and consideration is given to the organisational structural change, then divided loyalty may result.

Butler (1973), studied at some length the potential organisational conflict associated with project management in functional organisations.
Other studies highlighting the matrix management problems associated with dual authority have been examined by Robey (1982) and Daft and Lengel (1986).

The benefits from adopting project matrix organisation can be summarised as follows, namely improved communication between project team members, improved visibility, tighter control of the development project, more focussed responsibilities are built around the needs of the project, easier recognition of potential problems, cross fertilisation of ideas and promotes parallel working. The benefits could be considered to stem from the integrative components found within the project matrix organisation. In effect a portion of the business elements have been integrated into a mini organisation. The mini organisation together with its integrated environment creates much less of a control problem than that associated with traditional functional/departmental structure. This is due to the following:

- personnel from the various engineering functions are brought together within a project team, this results in improved inter-personnel communication and general visibility;

- the project team accountabilities are normally better defined, and the authority relationship hierarchy has a reduced number of levels and width resulting in shorter lines of communication and control;

- the problems normally encountered in closing the control loops are greatly reduced, and the time taken to close them, significantly shorter;

- problem solving and decision making can be performed on a consensus basis;

- control loop interactions across engineering related functional boudaries are greatly reduced and maybe almost eliminated. The majority of these should infact take place within the project team.

It follows that adopting a project matrix organisation involves the integration of various business elements, which provide an environment which is conducive to the application of effective business control.

4.5 Industrial case study 2 - Manufacturing Operations (MO) control

This section discusses the findings from industrial case study 2, which focusses on the application of an MRP II (Manufacture Resources Planning) system and structural organisational changes to achieve effective manufacturing operations control.

It will be argued that the adoption of an integrated manufacturing operations control model (system) together with a cellular factory organisation structure, can be considered useful mechanisms for providing effective control to the somewhat complex key business process, Manufacturing Operations (MO), through the development of a synergistic relationship between control and integration (CIM).

It will be shown that current MRP II systems consist of an integrated suite of software modules which assist the various business functions, provide support for the various manufacturing operations control elements and aid the necessary closing of the control loops. It will also be shown that the adoption of the cellular factory organisation structure involves the integration of various production related business elements, which provide an environment which is conducive to the application of effective business control.

4.5.1 Introduction

One of the most critical and important processes of a manufacturing business is ensuring on time delivery of products to the customer. The process normally spans order entry to despatch of goods and can take a few hours to tens of weeks depending on the type of product. It is stressed that controlling this process is both critical to the success of the company and constitutes a formidable task, which can be assisted through computer application.

4.5.2 Manufacturing operations control and the development of MRP

Manufacturing Operations (MO), is a complex business process involving the synchronised inter-action of many business functions. The scope of the process begins with the inception of a product demand and covers the generation and management of purchase and production orders right through production and assembly to despatch and invoicing. The functions involved in the key business process "manufacturing operations" at Lucas Aerospace (ESD) can be seen in Table (6).

Over the last two decades there have been tremendous developments surrounding the use of computerised information based tools to assist the various manufacturing functions. These developments have stemmed from the production scheduling problems and have consequently been targetted at the production planning and control functions. Orlickly (1975), Plossl (1973) and Wight (1974/1981), stand out as some of the principal pioneers in these efforts to modernise and computerise the production planning and control functions. MRP (Material Requirements Planning) was one of the first computerised procedures which significantly improved the way things were done.

MRP is a computational technique that converts the master schedule for end products into a detailed schedule for raw materials and components used in the end product. The detail schedule identifies the quantities of each raw material and component items. It also states when each item should be ordered and delivered in order to meet the master schedule for the end products. Since MRP was first implemented, many additional improvements in production planning and control have been introduced by taking advantage of the data processing and computational powers surrounding computer technology.

Wight (1981), defines four classes of MRP user ranging from class D, where the MRP computational technique is working in the data processing department only, to class A, where closed loop MRP is used as an integrated production planning and control systems incorporating capacity planning, shop floor control, etc. Wight concludes that there are four steps in the evolution of MRP.

Step 1 - MRP

As previously stated this is a computational technique that converts the master schedule for end products into a detailed schedule for the raw materials and components used in the end products.

Step 2 - MRP and priority planning

In step 1, the master production schedule ignored the limitations

MANUFACTURING OPERATIONS	
MAIN PROCESSES	**FUNCTIONS**
* Order entry & acknowledgement * Factory level planning – Rough cut capacity planning – Agree master production schedule – Inventory control * Material requirements planning * Capacity requirements planning * Order issueing & control – Purchased items – Made in items	Factory Planning & Control
* Procurement of purchased goods	Procurement (Purchasing)
* Cellular manufacture of made in items – Cellular production planning – Cellular scheduling/sequencing – Shop floor data collection – Assembly & test – Quality control	Cell based Manufacture
* Receiving of goods * Stores issueing & control * Despatch of goods	Stores Control

Table (6): Typical Manufacturing Operations functions imposed by 'plan' capacity and other constraints. It caused the MRP processor to generate schedules and requirements that could not be accomplished by the factory. To overcome these problems, the MRP system began to incorporate capacity requirements planning (CRP) and order release planning (ORP) into their computations.

Step 3 - Closed loop MRP

This in itself is an integrated system and performs Material Requirements Planning (MRP), Capacity Requirements Planning (CRP), Order Requirements Planning (ORP) and Shop Floor Data Control (SFDC). It is called closed loop MRP as it provides feedback from vendors and the production shop regarding order status throughout the implementation of the production plan.

Step 4 - MRP II - Manufacturing Resources Planning

This from a simplistic standpoint involves a link between the closed loop MRP systems and the financial systems of the company. MRP II posesses two basic characteristics which go beyond closed loop MRP. It is an operational and financial system and has a simulation (ie "what if") facility.

The operational and financial system aspects makes MRP II a company wide system concerned with various facets of the business, it specifically addresses the requirements for effective manufacturing and is used widely across industry for this purpose.

In support of this, a 1984 MORI survey performed in collaboration with Ingersoll Engineers reported that out of the one hundred and eleven manufacturing companies consulted, some 86% of them already have some form of MRP system installed. Lucas Aerospace (ESD) are currently using the IBM COPICS (Communications Orientated Production and Inventory Control System) MRP II system.

The current MRP II systems represent a tremendous development from the first MRP systems. From a control standpoint, the key MRP development took place when MRP step 3 was achieved. It was at this step that the necessity to close the manufacturing operations control loop was realised.

Lucas Aerospace developed their own closed manufacturing operations control loop procedures; it is shown in Figure (20).

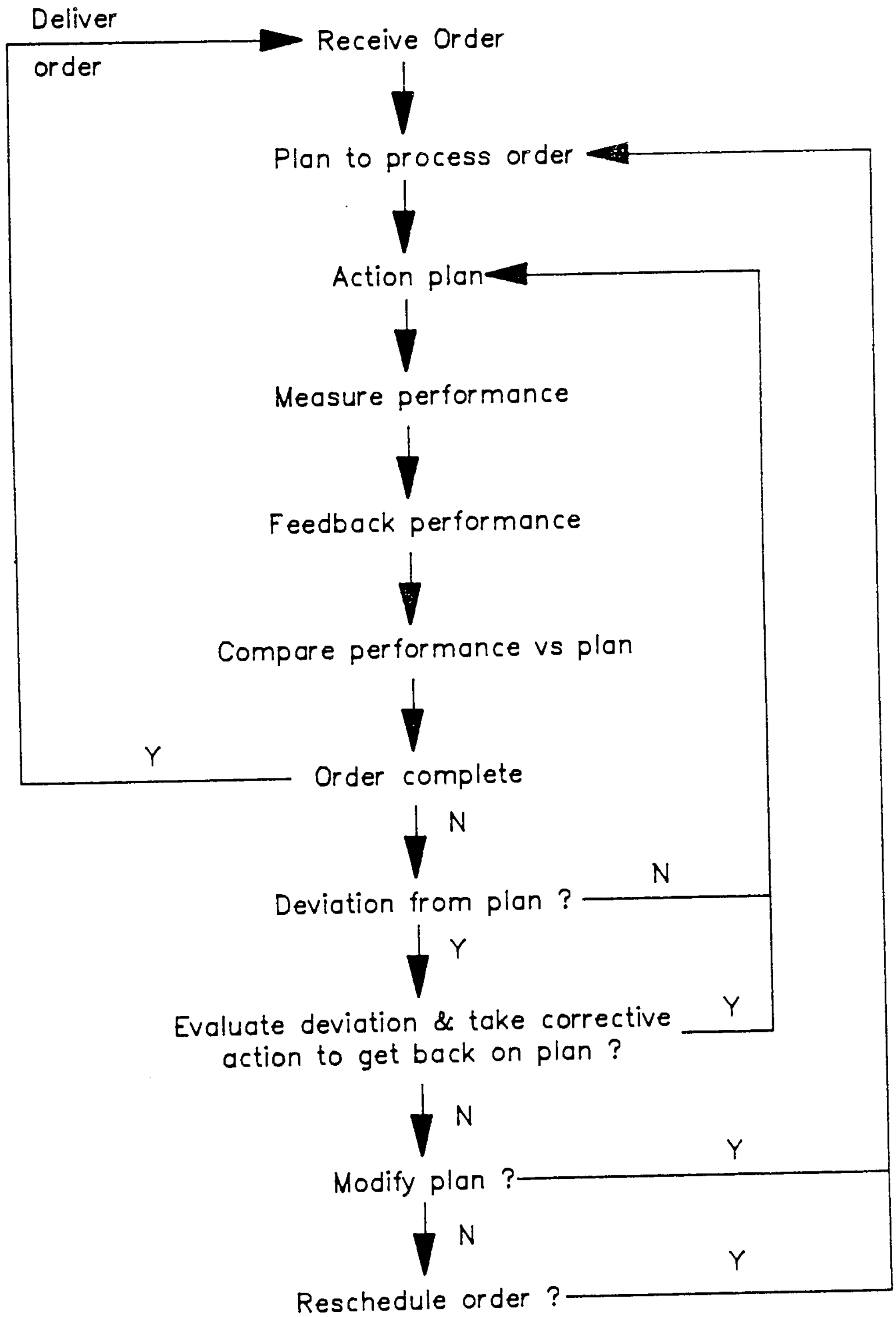


Figure (20): A closed loop control system for manufacturing operations

The importance of closing the MRP control loop and the application of an MRP II system to support integrated order processing is examined in the following section.

4.5.3 Integrated Manufacturing Operations model using MRP II

In 4.2.3, it was argued by way of example that a relationship exists between CIM and control. In short, it was argued that business process control is responsible for specifying the required level of integration between the various functional systems to close necessary control loops. Case study 2, has concentrated on examining the current application of the IBM MRPII system (COPICS) for manufacturing operations control, and how its integrative nature can assist the closing of control loops.

A model of the integrated MRP II system (COPICS) to control manufacturing operations at Lucas is shown in Figure (21). It can be seen that the model supports the main processes involved in manufacturing operations as shown in Table (6), Section 4.5.2.

The model comprises 3 control levels. Control level 2, is the key business control level involved in the overall control of manufacturing operations and includes high level functions such as forecasting, order book control and master planning against long term product requirements. Control level 3, is the area/functional control level involved in the control of various manufacturing functions. Control level 4, is the operational control level directly involved in the cellular planning and control of parts sourcing in accordance with the overall production plan. The model illustrates four physically separate systems. Level 2 and 3 are supported by a tailored version of the IBM integrated MRP II system (COPICS) and a payroll system. Level 4 is supported primarily by a cell control system and a physically separate COPICS module, namely Shop Floor Data Control (SFDC).

The manufacturing operations control procedure illustrated by the model can be summarised as follows.

Firm and speculative product demand is received and entered into the order book. A master schedule is created and maintained to identify end product requirements and to assist in the planning of production/manufacturing

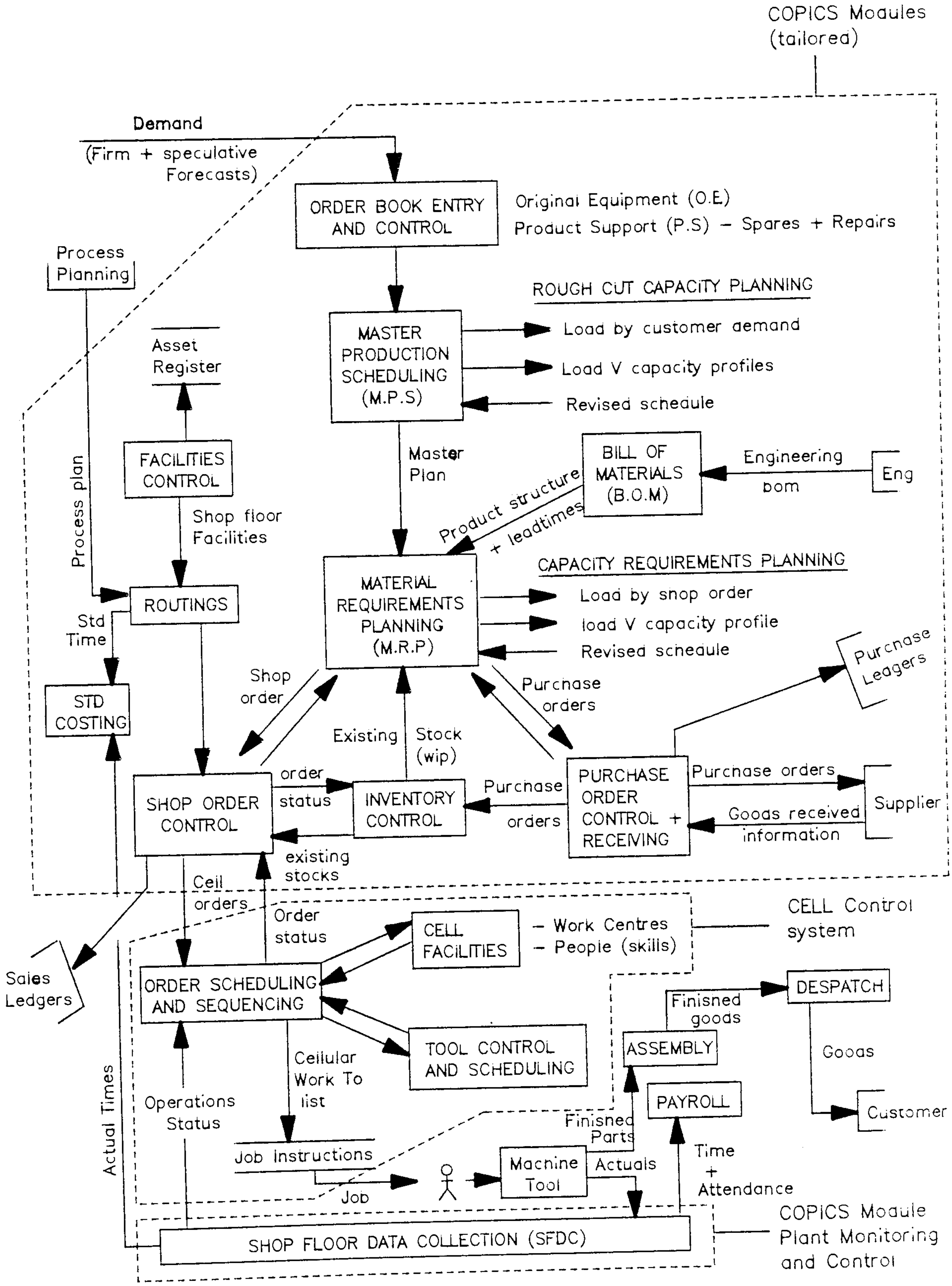


Figure (21): An integrated MRPII system (COPICS) model resources, where load versus capacity profiles are produced (sometimes referred to as "Rough Cut Capacity Planning"). At this particular point, master scheduling simulation may be performed to evaluate "what if' situations. The master schedule for end products is converted into a detailed schedule for raw material and components via an MRP run, which involves exploding the end product requirements down through the product structure to determine gross requirements for components and raw materials and the allocation of existing stock against gross requirements to produce net requirements. A workable detailed schedule which produces favourable load versus capacity profiles is generated, sometimes referred to as "Capacity Requirement Planning (CRP). At this particular point, detailed scheduling maybe performed to evaluate "what if" situations. The detail schedule identifies the quantities of each raw material and component item, and states when each item should be ordered and delivered. Purchase orders are raised, forwarded to supplies and subsequently, goods are received and entered into stores. Shop orders are raised and forwarded to the cell control system which schedules and sequences the orders across the work centres in accordance with the routing or process plan. Work is performed and monitored by the Shop Floor Data Control system (SFDC), which feeds work actuals and status back to the cell control system, which it uses to reschedule and sequence orders. Similarly, work actuals and status information is fedback to update shop order and inventory control which subsequently updates the order book.

All systems are integrated, and support the closing of various control loops. Figure (22), attempts to show in a simplistic manner how control loops are closed through systems integration.

The integrated nature of the COPICS MRP II system modules and its system integration with the cell control system and the Shop Floor Data Control (SFDC) system provides support for the various manufacturing operations control elements and the necessary closing of the control loops.

4.5.4 Cellular factory organisation

At Lucas Aerospace (ESD) a cellular factory organisation structure has been in existence for a number of years. The manufacturing cells have been designed in accordance with the principles of Group Technology (GT).

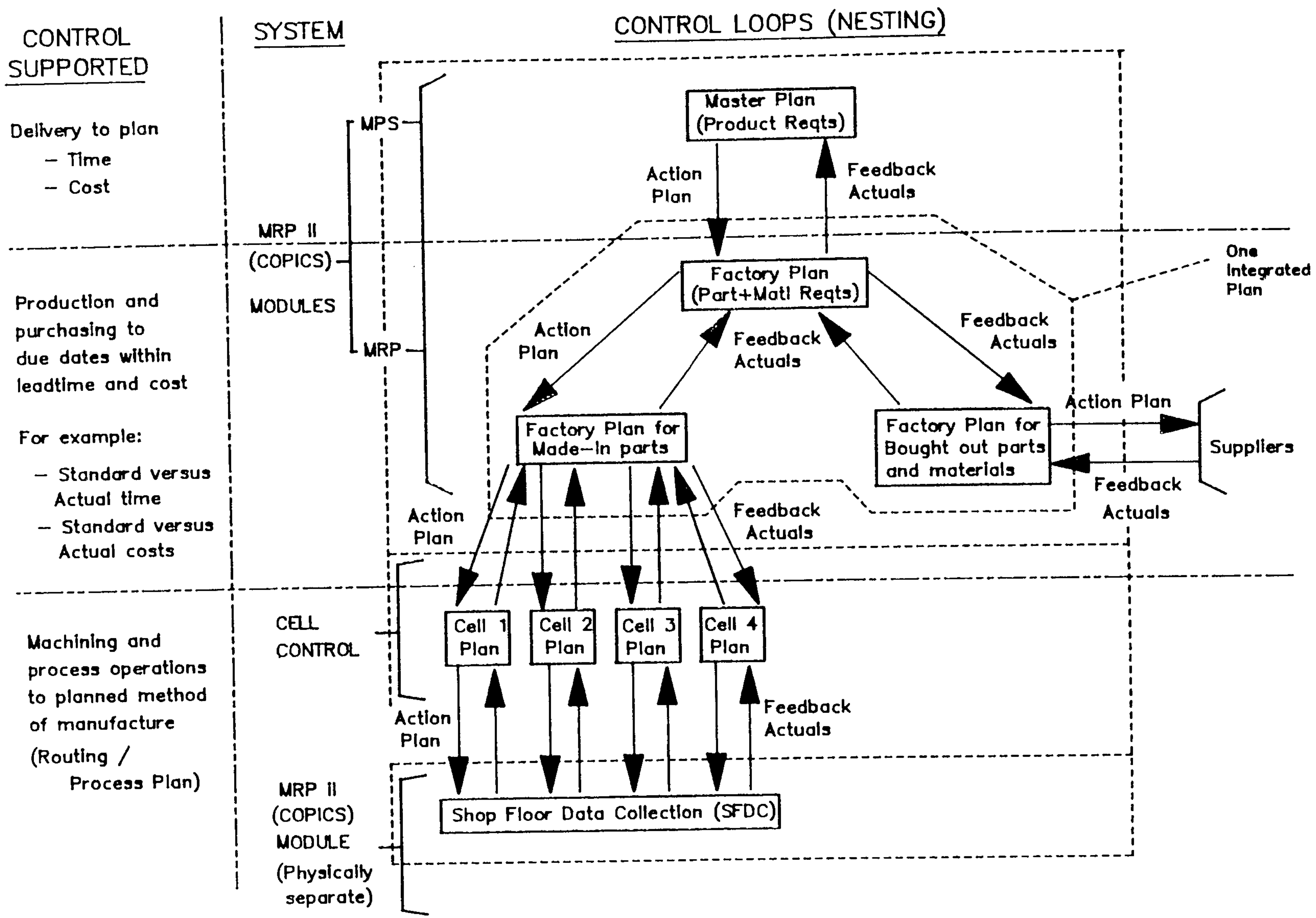


Figure (22): Systems integration to close manufacturing operations control loops

Group Technology (GT), can be defined as a manufacturing philosophy in which similar parts are identified and grouped to take advantage of their similarities in design and manufacturing. The process can be summarised as follows; parts are classified using a parts coding and classification method, those which are similar are grouped into part families. This enables the engineer, during the product definition/engineering process to use standard and "similar to" part designs, parts lists, process plans, and NC programmes, rather than re-inventing the wheel. From the shop floor standpoint, machine tools and processes are then arranged into GT manufacturing cells to support the manufacture of particular part families.

The manufacturing cells can be considered autonomous mini factories which comprise the necessary facilities and resources to translate raw material into finished parts or products.

The adoption of the cellular factory organisation in accordance with the principles of GT for manufacturing is widely practiced throughout the batch manufacturing and mass production industry. Advocates of the cellular factory organisation includes Hyer et al (1984), Vernadat (1986), Groover and Zimmers (1984), Sawyer (1983) and Dumollen and Santen (1983).

The above authors all discuss the potential benefits/advantages of such a GT cellular organisation structure against that of a functional/process factory layout. They suggest that the benefits to be gained from adopting the GT cellular organisation are as follows:

- reduction in setting times (69%);
- simplified production planning and control;
- reduction is throughput time (70%);
- reduction is production shop floor space (20%);
- reduction is raw material inventory (42%);
- reduction in work in progress inventory (62%);
- reduction in finished good inventory (60%);
- reduction in overdue orders (82%);
- reduction in Scrap (45%).

It is suggested that the above benefits, are to some degree attributable to the new integrative components found within the GT cellular factory organisation.

Love (1988), argues that cell based structures are derived from the division of manufacturing systems and that the benefits stem mainly from simplification.

It is the authors contention that cell based structures are a result of dividing a manufacturing facility into a series of tightly integrated and indeed simplified manufacturing cells. The process of division actually reduces the required integration scope and thus provides an environment in which tighter integration is achievable. In effect a portion of the business elements have been integrated into a mini factory. The mini factory together with its integrated environment creates much less of a control problem than that associated with the traditional functional/process factory layout. This is due to the following:

- personnel are able to focus their attention on a much reduced production scope (ie parts, facilities and processes etc, which are allocated to their particular cell). By doing this they are able to develop a better understanding and appreciation of the production elements involved;

- personnel from the various production related disciplines are brought together within the cell to work together as small production teams; this results in improved inter-personnel communication and visibility;

- the cell authority relationships are normally better defined and the hierarchy invariably has a reduced number of levels and width resulting in shorter lines of communication and control;

- problem solving and decision making can be performed on a consensus basis;

- the problems normally encountered in closing control loops are greatly reduced and the time taken to close them are significantly shorter;

- control loop interactions across production related functional boundaries are greatly reduced and maybe almost eliminated. The majority of these should in fact take place within the cell.

Adopting a cellular factory organisation involves the integration of various production related business elements which provide an environment which is conducive to the application of effective business control.

The business redesign consideration surrounding business integration and control are further examined in chapter 5.0.

4.6 New Product Introduction (NPI), Manufacturing Operations (MO) and CIM

This section discusses the relationship between New Product Introduction, Manufacturing Operations and CIM . It will be argued that two key business processes, namely NPI and MO, constitute two key driving forces within a manufacturing business, exhibit facets which are very similar and represent two key control subjects underpinning a manufacturing business. It will be shown that an integrated model spanning both NPI and MO can be developed to illustrate the core requirement for business control upon which the philosophy of CIM can be based.

4.6.1 NPI, MO and their similarities - from a control standpoint

New Product Introduction (NPI) and Manufacturing Operations (MO) have many similar facets.

As defined by the author, both NPI and MO are key business processes and are consequently positioned within a control hierarchy at level 2 - the key business process control level. Both involve the synchronised execution of numerous activities within a business, the interaction of various business functions, and the consumption of key company resources. They are both involved in activities relating to a product and are therefore related through the product lifecycle. NPI covers product inception through to the establishment of an agreed product definition and the success of the first production run. MO covers the full production cycle, from order inception through manufacturing planning, the production and delivery of original equipment, and spares and repairs right through to the products death.

In section 4.4 and 4.5, it was argued that both NPI and MO are responsible for, and associated with, the integration of various business elements. Furthermore, it was argued that both are associated with various computer systems which support and assist control elements, and via systems integration help close the various control loops. Also both maybe associated with organisation restructuring which distils the business functions into smaller units which are closely integrated and conducive to the application of effective business control. Examples of which include matrix or project organisation and GT cellular organisation.

All value added work should be capable of being tied back to a product in one of two phases, either during the introduction and definition of a new product or during the manufacturing operations associated with a product.

The two processes constitute two main driving forces within a manufacturing business and consequently represents two important control subjects, underpinning a business.

4.6.2 NPI and MO integrated business control model

In the previous section it was shown that NPI and MO have many similarities, one in particular focussed on their inter-relationships through the product lifecycle. This section further develops this relationship by examining the links between their two respective support systems "Project Control" and "Manufacturing Resources Planning (MRPII)".

Both the systems are very similar in their functions. They are both involved in planning the execution of activities in line with customer end date requirements, planning and controlling the use of resources including time, money, personnel and facilities, scheduling and controlling work actioning and the measurement and evaluation of actual work done against plan.

Traditionally Project Control Systems (PCS), have supported the product life cycle up to the point of the first production run, at which point MRP II takes over. However, PCS's are increasingly being used to plan and control the whole product life cycle. This is usually performed at a more summarised level than that of MRP II.

At Lucas Aerospace the programme plan for a contract or product covers the production of all original equipment (O.E). In fact, the planned dates are forwarded to the MRP II system from PCS, and status information is fed back. All this is currently performed manually.

The link between Project Control Systems (PCS) and MRP II systems can be developed much further to provide mutual benefit.

Other authors who have examined the relationship between PCS's and MRP II systems, include Robson (1988), Anon1 (1989) and Scobby (1989). Robson

(1988), argues that PCS's can be tailored to act as a production planning tool and discusses such an application at Ingersol-Rand. Anonl (1989), argues that PCS's have far greater functionality than typical MRP II based Rough Cut Capacity planning (RCCP), and Master Production Scheduling (MPS) modules. She argues the need to integrate project control systems to MRP II systems to overcome some of the weaknesses of MRP II systems. For example, MRP II systems typically ignore pre and post production activities, have poor graphical reporting and have a poor "what if" facility. Scobby (1989), in a similar vein discusses the integration of a PCS (Artemis) with an MRP II system (COPICS) to assist the planning and control of the NASA space shuttle programme. Scobby discusses the important link between the bill of tasks in the PCS and the bill of materials in the MRP II system.

It is contended that the relationship and integration between PCS's and MRP II systems should be further examined and developed. The integration could provide a platform upon which integrated business control could be based. A concept chart illustrating this is shown in Figure (23).

4.7 Summary

This chapter has focussed on developing and exposing the relationship between CIM and integrated control in relation to two key business processes, namely new product introduction and manufacturing operations.

It has been shown that there is a multi-facetted relationship between CIM and control which varies depending on the particular view of CIM and control taken.

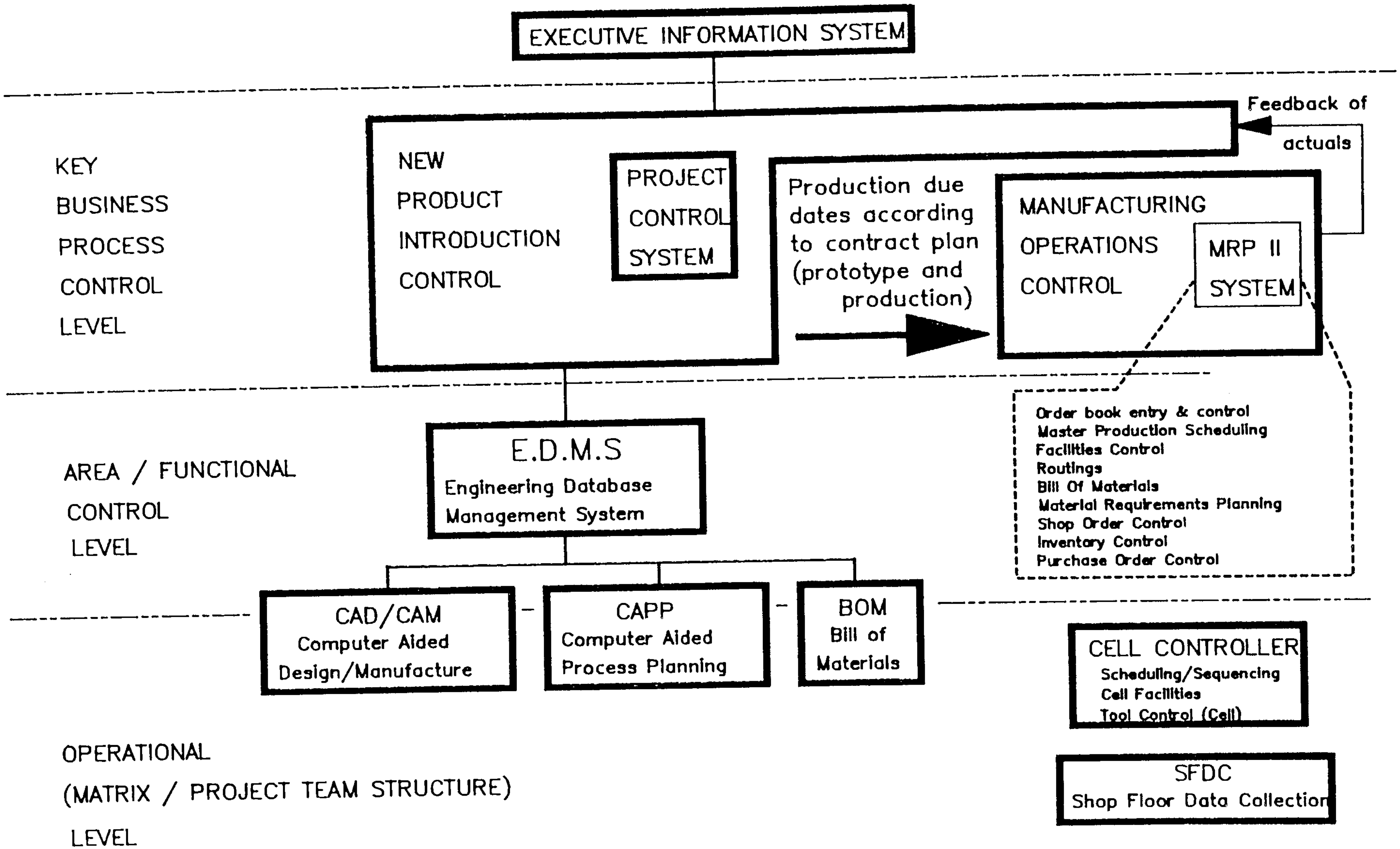


Figure (23): NPI and MO integrated business control model

5. BUSINESS REDESIGN CONSIDERATIONS

This chapter examines the degree of business redesign required during the development of an integrated business environment. It will be argued that a business can be considered to be made up of eight business elements and that business redesign it concerned with redefining the occurrence of these elements and their associated relationships. It will be shown that the developing view of business integration (CIM-phase 4), is resulting in a greater degree of change to both business elements and their relationships, which inturn calls for more business redesign to ensure a optimum environment is achieved.

It will also be shown that there is a wide span of criteria which one needs to consider during a business redesign exercise, which may result in a multi-mode business configuration, that is, a business which has different structures, cultures, mechanisms and beliefs across the various departments.

A common set of changes will be predicted for the structural transformations, coordination and control mechanism and power and political process.

5.1 Introduction

Prior to performing business redesign, one must firstly examine and understand the make up of a business and its workings. The study of organisations has been approached from roughly three perspectives namely the individual, the organisation and its form, and the interactions of systems within the organisation.

In order to effectively redesign a business all three perspectives need examining. One particular method of doing this is to examine the elements of a business and their inter-relationships.

5.2 The key business elements and their relationship

This section examines the elements of a business and their relationship.

5.2.1 The proposed key business elements

A business can be considered to be made up of a large number of elements, all of which are arranged in a certain configuration to ensure effective contribution to business objectives. Although the configuration of these elements will vary depending on the type of business considered, its operating policies and various influencing environmental factors, the actual elements themselves should in fact remain generally consistent.

This can be shown to be true using business models proposed by Handy (1987) and Peters et al (1982). Handy (1987), developed a business model based on six key business elements. They include the following :

- 'people', the people within the organisation;
- 'systems and procedures', the procedures for doing work;
- 'work structures', the organisation structure showing formal reporting relationships and roles/tasks;
- 'goals', the clear goals of an organisation;
- 'culture', the values and beliefs of an organisation;
- 'technology', the technology associated with the business.

Peters et al (1982), developed a business model based on seven key business elements, all of which begin with the letter 'S'. He suggests that an examination of an organisation must take the seven elements into account:

- 'structure', the organisation structure showing formal reporting relationship;
- 'strategy', the business strategy;
- 'systems', the formal/informal procedures for doing work;
- 'style', the style of the organisation;
- 'staff', the people within the organisation;
- 'skills', the skills of the organisation and its attributes;
- 'super ordinate goals', the guiding beliefs or fundamental values of the organisation.

Both business element lists tend to have been based on studies associated with natural sciences, organisational theory and cybernetics. This has resulted in models which consequently fail to show the total elemental view of a business. For example, both lists fail to mention business control, business functions/processes, information and computer systems. Such omissions imply that little or no consideration has been given to the fact that a typical business comprises a wide range of business functions/processes, all of which need controlling, involve the generation of information, and are invariably supported by computer systems. It should be noted that in chapters 3 and 4, it was argued that control should be considered a major element of any business, that information is a key business asset and that computer systems should be regarded as an integral part of the business functions they support.

The element lists include two control related elements, namely "strategy" and "goals" , but these only address a relatively small part of business control. They are only concerned with the planning stage of control and by their nature are positioned at or near the top of a control hierarchy. They should therefore be replaced with the element "control", which covers all stages required in closing control loops and applies to all levels within a business.

Information is widely viewed as a key business asset and deliverable. During new product introduction large amounts of effort and time is consumed generating key information, such as product specification reports, product drawings, bill of materials, process plans and production plans etc. It follows therefore that information should be considered a key business element. The element lists proposed do not specifically include information, however it is probable that they have included information as a subset of the element "systems". It is the authors contention however, that "systems" or work procedures could be considered a subset of the element "information", as they are developed in order to create, update and process information.

It can be shown therefore that the element lists proposed by Peters et al and Handy, fall short of providing a holistic model of the business elements.

For the purpose of examining business redesign issues associated with business integration (CIM phase 4) and control, the more physical business elements should be included, as mentioned above.

In chapter 3, it was argued that to achieve effective business control one must examine and develop an optimum relationship between control and other business elements. The suggested business elements included control, business functions, information, management and operational workers and decisions. The chapter also argued the important role computer systems have in performing effective control.

It follows therefore that the primary business elements should include the following :

- 'control', closed loop control across the business;
- 'functions/processes', processes performed by the business;
- 'decisions', decisions made by the business;
- 'information', information created, processed and managed by the business;
- 'people (skills)', people employed by the business;
- 'computer systems', computer systems used by the business;
- 'organisation structure', structure of formal reporting relationships;
- 'business culture', the guiding beliefs and fundamental values of the organisation.

The element list supports the business models proposed by Peters et al and Handy, but further develops the models to encompass the more physical business elements. A model of the elements, showing the business as a circle, can be seen in Figure (24).

It is the authors contention that business redesign in pursuit of CIM, should include a detailed examination of all eight business elements. Failure to do so, by focussing on the elements proposed by Handy or Peters et al, for example, is likely to result in limiting models of the business and ultimately a less than optimum redesign.

5.2.2 Their relationship

The relationships between business elements is one of the primary discussion areas associated with the study of organisational theory. It

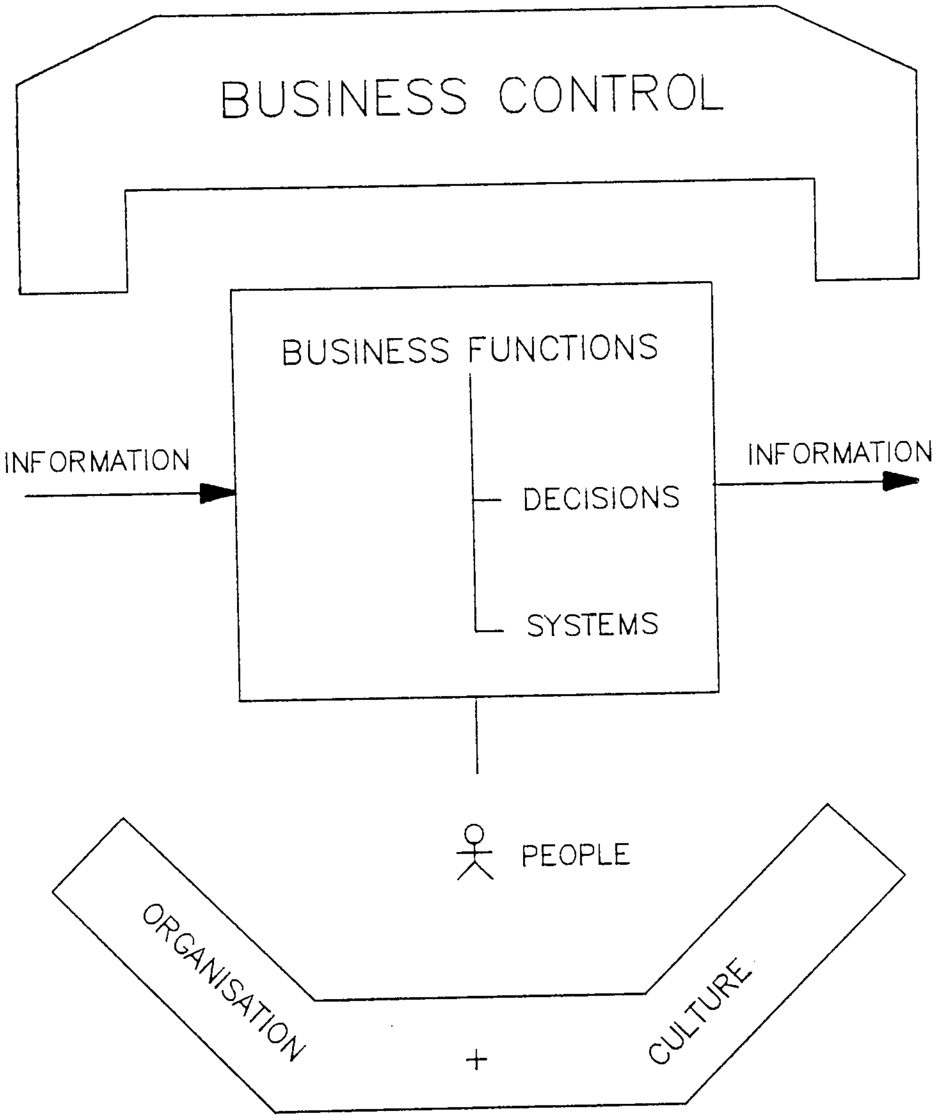


Figure (24): Business element model

is generally accepted that business element relationships constitute a major determining factor in the development of business structures. Emery (1969), Woodward (1965), Mintzberg (1979), Galbraith (1977), Handy (1987) and Eilon (1979), all discuss the important association between business subunits/elements and their interaction/inter-relationships, in organisational design.

A multitude of relationships exist between the various business elements. Figure (25), attempts to illustrate these relationships using an 'entity-relationship' diagram, taken from a structured analysis techniques. The eight boxes and the inter-linking lines shown represent the business elements and the relationships between them. Each line has a relationship number for identification. Relationship R1010, can be defined as follows:

- a person maybe responsible for managing one or more business functions/processes;
- a business function/process is managed by a person.

A full definition of all the relationships is given in Appendix (E).

It can be seen that there is a complex array of relationships. However the relationship diagram only shows one occurrence of each entity, where as in a real organisation the occurrence would be considerably greater. For example, Lucas Aerospace (ESD) comprises the following approximate element numbers:

- 5 levels of control comprising thousands of control loops;
- 100 distinct business functions employing 1800 people;
- 20 different functional computer systems;
- millions of decisions;
- vast amount of information.

There are generally two types of element relationship, the first, between two like elements, and the second, between two unlike elements. Relationship type 1, is concerned with the development of business element vertical structures. For example, element 5 (person) may have a managerial relationship with another person resulting in a management hierarchy. Relationship type 2, is concerned with the development of business element horizontal structures, that is, the development of working environments.

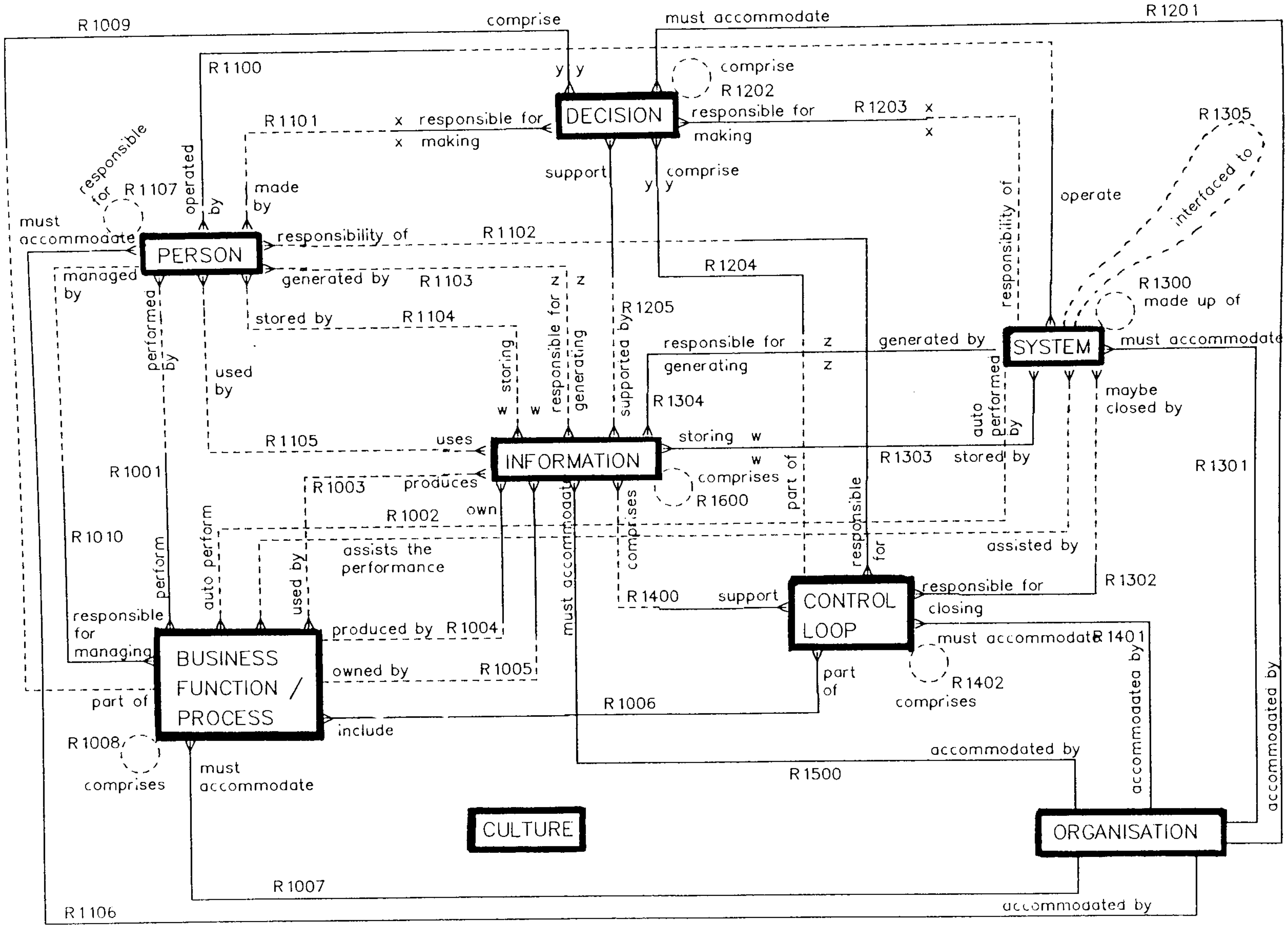


Figure (25): Business element - entity relationship diagram

5.2.3 Business redesign defined

Redesigning a business involves a study of 'organisation theory', which is primarily concerned with the occurrences of business elements and the relationships between them. It normally follows that the greater the scope of business redesign, the greater the study.

It has been argued that a business is made up of eight primary business elements and an array of inter-element relationships.

It follows therefore that business redesign is concerned with redefining the occurrences of the eight business elements and their associated relationships.

5.3 The need for business redesign

This section examines the need for business redesign during the development of an integrated environment. It will be argued that the developing view of CIM, is resulting in a greater degree of change to both business elements and their relationship, which inturn calls for more business redesign to ensure an optimum environment is achieved.

5.3.1 Introduction

In accordance with the general definition of business redesign given in the previous section. It can be shown that business redesign maybe initiated by any activity which results in a change to the various occurrences of the business elements and/or their relationship. This section examines the business redesign considerations associated with CIM phase 3 (systems and their integration), the adoption of effective integrated business control and total business integration (CIM Phase 4).

5.3.2 CIM PHASE 3 (Systems and their integration)

In section 2.5, it was argued that CIM phase 3 is concerned with the integration of computer systems into the business environment, resulting in systems being an integral part of the overall business process. This can only be achieved when certain environmental business elements have been examined to ensure an optimum fit is developed.

When systems are developed and integrated the various business elements may require changing. The key issue is which elements need changing, if any, and to what extent. Various differing views have been proposed by numerous authors. Some suggest that the application and integration of computer systems do not necessitate the changing of various organisational elements. Simon (1977), contended that computer systems would not change the basic hierarchical nature of organisations. Johnson (1986), in a similar vein, develops an approach for overlaying CIM onto an existing factory without having to perform changes, implying that CIM can be applied with little or no business redesign. Dearden (1983), argues that computer systems will not change the role of top management.

Other authors suggest that CIM should be accompanied by organisation redesign, but differ when discussing which business elements are liable to change and the kind of change that is likely to take place.

Leavitt and Whisler (1958), argue that information systems would alter dramatically the shape of organisations and the nature of managerial jobs. They argue that organisations would recentralise, levels of middle management would disappear and a top management elite would emerge. Similarly, Leifer and Mcdonnough (1985), found that departments using computer based systems were likely to be more centralised and perceive less environmental uncertainty than those departments not computer based. On the other hand Robey (1977), argues that within uncertain departments, computing appeared to support a decentralised organisation structure. Bessant and Lamming (1987), argue that systems integration results in shorter hierarchies and greater vertical integration in the organisation structure.

Various other authors have focussed on specific aspects of organisation redesign. Tushman and Nadler (1978), based on the traditional 'data' view of organisation design [refer to Davis and Munro (1977)- Electronic Data Processing (EDP)], develop the view of organisations as information processing systems. They suggest that organisation design is associated with the fit or match between information processing requirements facing an organisation and the information processing capacity of its structure. They argue that computer systems affect the information processing capacity of the organisation. Similarly, Simon (1977) and Galbraith (1977), view organisations as decision making centres, where information is used to reduce the task uncertainty. They argue that computer systems affect information processing, which inturn affects the organisations decision making flows.

Handy (1987), argues that an organisation is more effective when there is a match between the organisation structure and the business culture. He argues that the application of systems technology requires an examination of the business culture to ensure this match is achieved.

Barley (1986), argues that the introduction of computer based systems affect the skills and competence of the people.

Foster and Flynn (1984), found that the development of integrated systems resulted in changes to organisational communications, organisational hierarchy and task performance / structure.

Hartland-Swann (1986), argues that industrial computing and integration should consider all parts of an information system and not just the computer based aspects. He specifically mentions the need to consider, how the function is performed at present, the manual procedures that will still be needed in the future, the organisation structure, and the skills/training needs of the people.

Glen (1985), argues that it is imperative that management explicitly address the strategic and structural changes needed to fully exploit the transition to CIM. Glen argues that CIM alters and changes the various workflows, the decision making flows, the communication flows, and the authority flows within an organisation.

Jones and Webb (1987), argue that a CIM system requires different control and organisational systems to those traditionally found; they state that the whole logic of information flow is integrative rather than subdivided and function based, and that structure has to mirror this flow if conflicts are not to arise.

From examining the above, it can be seen that there is a multifarious and often conflicting view as to how computer systems and their integration can affect an organisation.

It can be shown that the implementation and integration of key business systems requires some degree of change to all the elements of a business including control, functions / processes, information, decisions, organisation structure, people and business culture. The reasoning behind this is as follows.

Business functions or processes are likely to change quite considerably. During the business analysis stage the processes will have been examined in some depth, many will be targetted for improvement or simplification, whilst others will become computer assisted or automated and invariably undergo change. Those processes assisted or automated by the computer systems will undoubtedly affect the the remaining manual processes, particularly if there is a conscious effort to achieve an optimum fit between the computer system and its environment.

With integrated systems the process of re-keying in data is normally eliminated as referential integrity of data is maintained across the various integrated systems using the master-slave theory. Similarly, the information structure and flow will almost certainly change. Various information will be electronically held within the system which may in fact change its flow through the particular functions. In the case of systems integration, the information flow is normally automated, this would invariably change the information structures which flows across the business.

It follows that peoples roles would change to support the process and information structure and flow changes, resulting in both the creation of new roles and the changing and removal of existing. Such changes in peoples roles may necessitate the need for new skills or indeed skill changes; this invariably leads to the retraining of existing employees.

The implementation and integration of computer systems, as argued in chapter 3.0 and demonstrated in chapter 4.0, is likely to result in considerable change to the business control processes. Computer systems often perform specific controls, capture and provide information which supports the control process, and through integration support the closing and interaction of control loops. In effect integrated computer systems are liable to result in a total redesign of business controls, many of which are likely to be computerised and automated. In chapter 4, it was argued that effective integrated business control is increasingly having to rely on the implementation of CIM (systems integration) for complete application.

Decisions are in fact directly linked to business processes and controls, and rely on the availability of certain information to support the decision making process. As already explained, systems and their integration are certain to change the processes to which they are targetted, the information flow and structure and business control. Many systems actually automate various decision processes and provide decision support information. It follows therefore that the decision process will change. The degree of change however depends on the application systems installed and their integration scope.

As already argued, the development of systems and their integration are capable of subjecting change to business functions, control, information flow and structure and people including their roles and skills. Such changes would almost certainly necessitate the need to change the organisation structure to ensure an optimum fit between the various business elements is achieved. This can be shown using an example.

At Lucas Aerospace an integrated CAPP (Computer Aided Process Planning) system was implemented. The design of the system is integrated and brings together four key processes which were previously performed separately and manually. They included 'process planning', which was involved in defining how the part was to be manufactured, 'industrial engineering', which was involved in establishing the standard time it takes to produce a part in accordance with the specified method of manufacture, 'tool design', which was involved in the specification of the necessary tooling, and 'NC programming', which was involved in writing all necessary NC programs using APT (Automatic Programmed Tooling).

Due to the integrative nature of the CAPP system and its effect on both process, control, information and people, it was decided that the four processes should be integrated and renamed 'Manufacturing Engineering' The long term aim for each manufacturing engineer is to be appropriately skilled to perform all four processes. Thus, it can be argued that the installation of an integrated system may well result in business structural changes.

It has been shown that the development and integration of systems results in the need to change various business elements. Such changes are capable of creating a different environment within the business and are likely to result in changes to the business culture.

It can be concluded therefore, that Simon, Johnson and Dearden fail to recognise the importance of redesigning a business in line with the application and integration of computer systems, and that the other authors all focus on specific aspects of business redesign and fail to show the totality of redesign required.

5.3.3 Effective business control

In chapter 3.0, it was argued that a fully integrated approach to business control is needed, one where the establishment of control functions to support control loops is performed with close consideration to the associated business elements. This associativity between control and business elements has been examined in section 5.2, where it was found that the "control" business element has a relationship with all seven key business elements. The adoption of the fully integrated approach to business control will invariably result in changes to the various business elements. Such changes will require some degree of business redesign to ensure an optimum control environment is achieved.

Numerous authors including Boyce (1967), Flamholtz et al (1985), Meredith (1987), Baker and Koppel (1987), Jones and Webb (1987) and Helming and Vasile (1987), discuss the impact of control on various aspects of an organisation. Boyce (1967) argues that the organisation structure will play a very big part in the success or otherwise of business control. Flamholtz et al (1985) and Meredith (1987), whilst discussing organisation and strategic control, extend this view by discussing the importance of developing both the organisation structure and business culture in line with business control. In contrast Jones and Webb (1987), whilst examining the effect new systems technology is likely to have on control, suggest that the automating of the control process will in fact change business functions and the management role.

Baker and Koppel (1987) and Helming and Vasile (1987), extend the view given by Jones and Webb (1987). Baker and Koppel, during a discussion on control issues, suggest that if an organisation is out of control, it may be a serious error to jump to the conclusion that more formal controls are needed. Instead, they suggest that the problem may well be due to the organisation not functioning as an integrated system and that an examination of the business functions, peoples roles and a restructuring of the organisation may well be the answer. Similarly Helming and Vasile, in describing a supervisor control system for the manufacturing enterprise suggest that the hierarchical control approach for an enterprise often has a substantial impact on the structure to suit re-alignment of personnel, their roles and responsibilities, and associated functions.

It can be seen that the above authors differ somewhat when specifying the likely impact of business control on various aspects of an organisation, and that none of the authors have considered the effects of business control on decisions, information and systems.

In chapter 3.0, it was argued that decisions are an integral part of a control loop and maybe present, in one form or another, in all control elements. In chapter 4.0, it was argued that control of key business processes can be considerably improved by adopting the transaction chain control concept, which uses systems integration to support the closing and interaction of control loops by automating the flow of control information. It follows therefore that control is likely to impact business decisions, information and systems.

It can be concluded that the above authors have not considered the full effects of business control on the organisation as they have failed to consider the likely impact on decisions, information and systems.

It follows that if a business is planning to re-institute various controls across on organisation, then one should examine the:

- "business function" responsible for carrying out the control;
- roles and responsibilities of the "person" who actually performs the control process;
- control "information" required to close the control loops;
- control "decisions" required;
- "systems" used to support the control process, that is:
  - provide decision support information;
  - assist the planning control element;

- assist the closing and interaction of control loops;
- "organisation structures" and their ability to provide an effective support framework for the other seven business elements;
- 'organisation culture' and its effect on the coordination and control mechanism, the peoples views and values and the political and power processes within the business.

To achieve effective business control, one must consider all the above points in a collective sense.

5.3.4 CIM PHASE 4 (Total business element integration)

CIM phase 4 is concerned with the integration of the various elements within a business, such that all the business elements are considered equally and collectively during the integration design process.

Section 5.3, has argued the need to examine and change various business elements under the banner of partial business redesign when developing and integrating 'systems', and re-instituting effective business 'control'. The type of business redesign discussed was concerned with the changing of the various environmental business elements in order to achieve an optimum fit between the particular element and its surrounding environment.

Total business element integration on the other hand, is aimed at optimising the business in a global sense and consequently does not focus on any specific element. It follows, that if the development and integration of systems and the re-institution of effective control, representing just two out of the eight business elements), can result in the need for business elemental redesign, then an exercise which develops and integrates all eight business elements would result in the need for a greater degree of business redesign.

Examples of total business element integration have been discussed in both the case studies outlined in chapter 4.0. Case study 1, involved the development of an integrated Project Control System (PCS) to control New Product Introduction (NPI), and case study 2, the development of an integrated MRP II system to control the manufacturing operations process.

In case study 1, as discussed in section 4.4.6, the project matrix organisation structure was adopted to solve some of the socio-technical problems centred around the work, organisational and authority relationships surrounding the new product introduction process. The resulting structure consisted of various project teams established to perform various business functions in a tightly integrated way.

The project matrix organisation involved:

- directly changing the organisation structure from that of a functional bias to that of matrix;

- bringing together various business functions, which had traditionally been performed separately, to form a closely integrated mini organisation. The lower level activities of each function were re-arranged, thus decaying the traditional functional boundaries;

- bringing together people from various business functions to work together in a mutually supportive way. As activities were re-arranged the scope of peoples roles expanded promoting flexibility of labour;

- changing and simplifying the various controls and procedures used. As the functional span of control reduced to that of the project team, the control loop interaction across inter-functional boundaries was greatly reduced, and the time to close a control loop was shortened. The planning and comparison/evaluation control elements were redesigned to be more of a concensus activity;

- restructuring the information flow across the organisation from one that spanned various functions to one that focused specifically on the information flow within the project team. The restructuring considerably reduced the scope of the information flow. Some information flow was eliminated as members of the team became better informed due to their close proximity of working;

- re-aligning decision responsibility from a functional orientation to that of the project team, such realignment promoted decision making on a consensus basis;

- restructuring the physical systems architecture to suit the project matrix structure. This involved changing the access and authority configurations within each system from that of a functional/role basis to that of project team;

- changing the business culture such that people are willing to work together as a tightly knit team with shared values, and able to accept the structural power change from that of a functional predominence to that of project.

It can be seen that the changes to the business elements and business redesign levels associated with such total business element integration as project matrix structuring are quite considerable.

In case study 2, as discussed in section 4.5.4, the cellular factory organisation structure was adopted. The resulting structure consisted of various manufacturing cells which were capable of transforming raw material into finished parts or products. Each cell was considered to be a tightly integrated mini factory. The business element changes and level of business redesign are comparable with those discussed above for the project matrix organisation.

It follows therefore that there is a need to change the various business elements in line with the adoption of business integration (CIM Phase 4).

5.3.5 Conclusion

The developing view of CIM is demanding a greater degree of change to both business elements and their relationships, which in turn calls for more business redesign to ensure an optimum environment is achieved. It can be concluded that business redesign is mandatory when implementing CIM.

5.4 The criteria governing business redesign

This section examines the criteria one needs to consider during a business redesign exercise. It will be argued that there are many factors and issues capable of influencing both business elements and their relationships. One particular issue discussed is the degree of differentiation and integration required across the business.

5.4.1 The wide span of criteria

The functioning of an organisation, its performance and improvement have been the central concern of numerous studies relating to organisational theory. In particular, various authors have endeavoured to recognise the multiplicity of factors impinging on organisational effectiveness and design. The key business elements proposed in section 5.2, provide a useful framework upon which a more detailed examination can be made of the various factors. Suprisingly, there seems to be no agreed set of primary factors, moreover various authors who are known for their contribution to organisation theory have infact adopted differing views on the importance of these factors.

Handy (1987), suggests that an effective organisation is one where an appropriate match is made between the organisations structure and culture. Woodward (1965), on the other hand, argues that technology is a major determinant of organisational design, and that those organisations whose structures are in line with the norm for their technology are the most effective.

Tushman and Nadler (1978), propose that different organisation structures have different capacities for effective information processing, and argue that organisations will be more effective when there is a match between the information processing requirements facing the organisation and its structure.

Flamholtz et al (1985), on the other hand, discusses the importance of matching control mechanisms with both organisation structure and culture. Similarly, Jaeger and Baliga (1985), in their discussion on control systems and strategic adoption, highlight the importance of business control and suggest the type of control systems needed within an organisation should be examined. They suggest two control system types, namely 'cultural' or 'bureaucratic'.

Handy (1987), from a different viewpoint, suggests that the first two questions that the designer of an organisation must ask him or herself are, how much diversity and uniformity?, and what kind?. He adds, organisations as they grow, come up against the diversity and uniformity pressures again and again, but the problem remains of recognising these pressures in the design of both the organisation structure and culture.

There are in fact numerous studies which examine various aspects of business elements and their effect on organisational design, of which the aforementioned are just a handful. One could develop an argument that their exists a determining factor or relationship associated with each of the eight key business elements. This is not surprising when one examines in more depth the entity relationship model drawing in Figure (25), which illustrates the eight key elements of a business.

The criteria one needs to consider during business redesign should include the factors which influence the choice of business element type and their degree of influence. Such a list of factors and an examination of their degree of influence should be developed for each of the eight key business elements. It is important to note the wide span of criteria one needs to examine during a business redesign exercise.

The criteria span can be summarised to include the relationships or matches between business elements (Note : if one considers eight elements as suggested, then there are a total of fifty six possible relationships), the factors affecting the choice of business element type and its configuration and the degree of influence a factor has on given elements.

The wide span of criteria can be demonstrated by examining literature from two authors, namely Mintzberg (1983) and Galbraith (1977). Both of whom, have studied in some depth the design of organisations.

Mintzberg (1983), provided a useful set of parameters one should consider when redesigning or restructuring an organisation. He suggests that there are five parts of an organisation, five control and coordination mechanisms, nine design parameters in four sets and six situation factors. All of which can be put together to form various organisation configurations. The parameters indentified by Mintzberg are shown in Table (7).

Galbraith (1977), provided a conceptual framework for organisation design, refer to Figure (26).

5.4.2 Integration and differentiation factors affecting business elements and its design

In the previous section it was demonstrated that there is a wide span of criteria governing business redesign. A study of all such criteria is outside the scope of this thesis, however, readers interested in taking a total view of organisational design should examine the literature from the following authors including Lawrence and Lorsch (1967), Galbraith (1977), Robey (1982), Mintzberg (1983), Woodward (1965), Simon (1977), Daft and Lengel (1986) and Handy (1987). In line with the subject of this thesis, it is however important to examine the integration and differentiation factors which influence the organisational elements and consequently the design of a business.

An important phenomenon affecting the design of an organisation is the degree of differentiation and integration needed to optimise business performance. This phenomena stems from studies performed by Galbraith (1977), regarding the "division of labour" and "task structuring". Division of labour is based on the premise that the task of an organisation has to be divided into subtasks and each subtask has to be assigned to an individual. It was established that the subtask differential across a business was indeed very large and that a differential of individuals would be required having different skills to provide the high level of subtask performance required. This is generally regarded as the key contributing factor to the development of the

5 parts of an organisation:

- strategic apex
- technostructure
- support staff
- middle line
- operating core

5 control and coordinating mechanisms:

- mutual adjustment
- direct supervision
- standardisation of work processes
- standardisation of output
- standardisation of skills and knowledge

9 design parameters:

Set 1. Design of position:

- job specialisation
- behaviour formalisation
- training and indoctrination

Set 2. Design the superstructure

- unit grouping
- unit size

Set 3. Fleshing out the superstructure with lateral linkages

- planning and control
- liaison device

Set 4. Establish the degree of decentralisation for decision making

- vertical decentralisation
- horizontal decentralisation

6 situation factors :

- age of organisation
- size of organisation
- technical system (input to output process)
- environment
- power (extend control and internal power needs)
- fashion (structure of the day)

Table (7): Mintzberg's organisational design parameters

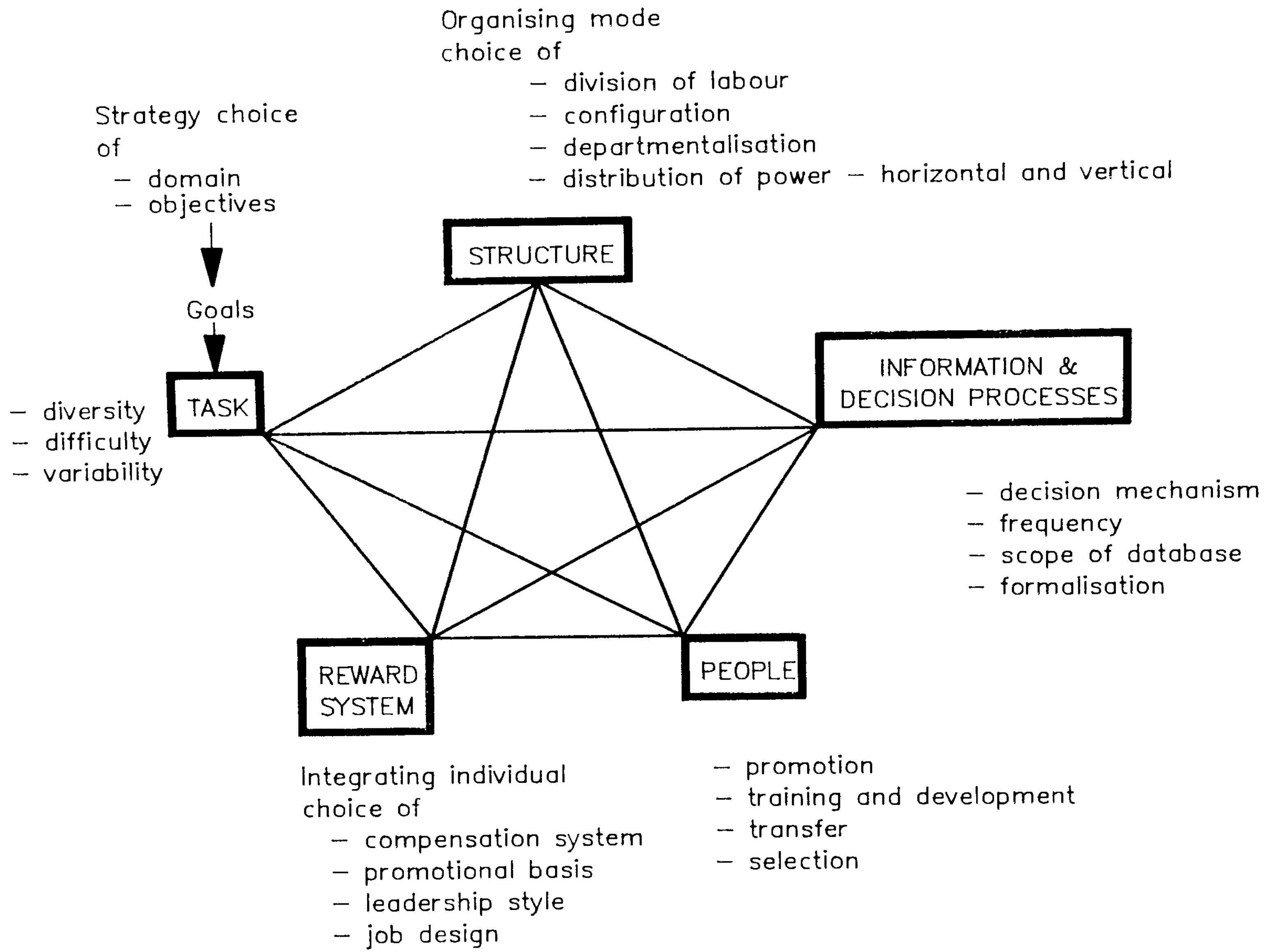


Figure (26): Galbraith's conceptual framework of organisation design and policyvariables traditional functional business structures.

Galbraith highlighted a significant problem with the design of functional structures to optimise subtask performance, that being, the cross functional coordination problem of ensuring the whole task is done. Gailbraith argues that a business needs to adopt task, role, structure and control differentiation to cover the different subtasks within a business, but needs the equivalent amount of integration to ensure the whole task is done. The problem facing the differentiated organisation is how to obtain overall task integration among departments without reducing the differentiation that leads to effective subtask performance. Galbraith argues that this can be achieved by introducing "integrating roles". Examples of these include general manager, marketing manager, project manager, product manager and materials manager. Such integrating roles are normally supported by an organisation structure change incorporating product based and project matrix structures. As explained in Chapter 4.0, such structures by integrating the various business elements can indeed improve the performance and contribution of tasks by:

- improving interpersonal communication and general visibility;
- shortening line of communication and control;
- reducing the time taken to close control loops;
- promoting consensual decision making;
- reducing control loop interactions;
- developing more shared values and common behaviour attitude;
- shortening the information flow lines;
- developing a broad understanding of related functions.

A further development of these structures involves improving the flexibility of Labour by sub task integration. This should be accompanied by an examination and tradeoff between the associated benefits of subtask performance as a result of subtask differentiation, and the benefits of overall task control/performance as a result of the above eight conditions.

A similar tradeoff between integration and differentiation is required with the business element "control". From a business wide coordination point of view a centralised control and decision making capability performed by one man would be ideal. However, such centralisation, in anything but very small firms, is just impractical due to the scope of knowledge and information required and potential decision making frequency.

It is the author's contention that control and decision making should be decentralised and devolved to the level where the decision or control is performed resulting in widespread lateral differentiation. However, in order to achieve effective business wide coordination and control, the various differentiated controls and decisions are then vertically integrated up through the business levels, as discussed in chapter 3.0.

Similar examples of differentiation/integration tradeoffs should be applied to each of the eight business elements to ensure an effective business structure.

5.5 Future expectations surrounding business redesign

From examining the business redesign criteria outlined in section 5.4, it is possible to predict the likely changes that (CIM) will have on an organisation. This section discusses, the potential business structural transformation, the changes in relation to the businesses coordinating and control mechanism, and the likely adaptation required to the power and political system within an organisation. A common set of changes can be predicted for each. It will be argued that a multi-mode business configuration will result.

5.5.1 Structural transformations

Prior to examining the likely transformations, it is pertinent to define the structural aspects of an organisation. Structure, in this context describes the allocation of tasks and responsibilities to individuals and departments throughout the organisation and designates formal reporting relationships, including the number of levels in the hierarchy and the span of control of managers. Structure also identifies the grouping together of individuals into departments and grouping of departments into the total organisation, and includes the design of systems to ensure effective communications, coordination, control and integration of effort in both vertical and horizontal directions.

The effect of business integration on the business structures has already been discussed to some degree in chapter 4.0. There it was demonstrated in both the Lucas industrial case studies that CIM and control can in fact result in structural transformations. The structural transformations associated with both case studies stemmed from the creation of new roles, changing of existing roles, redefinition of authority relationships, creation of new tasks/procedures, changing of existing task/procedures, reallocation of formal responsibility and the restructuring of tasks/procedures.

In both cases, the size of authority, in terms of head count reduced, whilst the span of authority in terms of task/process variety increased. This resulted in smaller working groups comprising a wide range of discipline capable of covering a much wider task/process span. Various existing roles merged, thus expanding the task/process range of a role whilst reducing the total number of different roles. Widening of the process span brought about the need for broader jobs, with diverse skills which cross traditional functional or operational boundaries. Small working groups performed these tasks in a collaborative way with no real recognition of the boundaries. To all intents and purposes the boundaries had been decayed. The adoption of small multi disciplinary working groups greatly increased the flow of lateral communication and in turn created a new basis for decision making, that is concensus decision making. It was found that much of the operational decision making would be better performed by the working group on a concensus basis. This is not surprising as management theory suggests that decision making should be performed as near as possible to the environment in which the effects of the decisions are felt, that is, the operational level. The decisional responsibility is also undergoing change, as more computer systems take over the responsibility for decision making. The devolvement and computerisation of decision making will permit the flattening of the organisation hierarchy as levels of middle management are removed. The integrative requirements from the Lucas industrial case studies resulted in the establishment of the project matrix structure for the engineering tasks and Group Technology (GT) cellular structure for the production environment.

From examining the findings of the Lucas industrial case studies, it follows that CIM (business integration) will affect the structures within a business in various ways.

- pre-production functional structures to be replaced by small multi-disciplinary working groups encouraging a collaborative team approach with a move towards social integration. The matrix structure will become common place with developments towards adhocratic structuring;

  Note the word 'adhocratic' has been taken from Mintzberg (1983) work on organisation structures - for further discussion refer to section 5.5.4

- functional shop floor layout to be replaced by a more product orientated or part-grouped continuous flow manufacturing technique, eg. product/Group Technology (GT) flow line or GT Cellular structure;

- organisation hierarchies to become flatter and wider as middle management layers are removed;

- functional boundaries will decay as the collaborative team approach develops;

- demarcation of functions and roles will be reduced as functional tasks become integrated within the team-based working groups, and roles take on a greater task span promoting flexibility of labour and demanding increased skill variety;

- the communication structure will need to be realigned to support the much increased lateral communication flow. The predominant hierarchical and vertical communication structure will develop into an elaborate lateral network. communication will also become less formal as functional boundaries decay and social integration develops;

- organisations will shift from a focus on vertical management (functional bias) to a focus on lateral management (process bias) as wide process spanning working groups develop;

- the adoption of Management Information Systems (MIS) and Decision Support Systems (DSS), permits managers to spend more time performing prime tasks rather than routine. The amount of time in decisional roles decreases, whilst the amount of time monitoring information and performing long term planning activities increases. The role of managers to become less fragmented and crisis orientated;

- structures of relative hierarchical position lose their traditional grip on the organisation as hierarchy of position is replaced by hierarchy of integration competency. Functional roles to lose some of their power to integration roles;

- devolvement of decision making down through the layers of the business to the various small working groups will take place. The decisions will be positioned at the operational layer of the business where the effects of the decisions are felt.

- Business Systems and Information Technology (IT) departments to be regarded as more important influential functions which have a significant impact on the business structures and strategic direction.

  NOTE: At Lucas Aerospace the Business Systems manager sits on the executive board

It is important to note that the above organisational changes did not span the whole Lucas Aerospace business, they were most prevalent in design engineering, production engineering and manufacturing. It follows therefore that businesses are likely to develop a multi-mode organisational form. Such multi-mode organisational forms are emerging at Lucas Aerospace.

The strategic planning, personnel-training, maintenance, finance and administration functions are all centralised, whereas all the new product introduction processes are distributed into the various project teams, and manufacturing processes into distributed manufacturing cells. Finance and administration functions have a mechanistic or bureaucratic structure, whereas new product introduction project teams are adopting a more organic structure based on mutual adjustment. Some cellular manufacturing roles are expanding their scope, promoting flexibility of labour whilst certain administration roles are narrow and specific.

The emergence of multi-mode organisational forms is a by product of a problem defined by Galbraith (1977), the problem of obtaining overall task integration among departments without reducing the differentiation that leads to effective subtask performance.

Other studies examining the effects of CIM on the organisation structure have been performed by Foster and Flyn (1984), Leavitt and Whisler (1958), Simon (1977) and Jones and Webb (1987). Foster and Flyn (1984), performed a study on the effect of information technology based systems (CIM) on the organisational form and function within General Motors. They found that there were three main changes including redefinition of organisational communications, changes in the uses and purposes of organisational hierarchy and changes in task performance and task structure. The findings from the study support in many ways the findings from the Lucas industrial case studies, however, it is evidently a preliminary study as it fails to mention the changes to the organisational form or structure. Leavitt and Whisler (1958) and Simon (1977), argue that the development of information technology and systems would result in the recentralisation of decisions and organisations. It can be seen that this argument directly conflicts with the findings of the Lucas industrial case study. It is the author's contention that organisations will not recentralise and that decisions will in fact undergo devolution. This is supported by Er (1987), Jones and Webb (1987), Robey (1981) and Glen (1985).

Leavitt and Whisler (1958), also argue that levels of middle management will be eliminated followed by the development of a top management elite. The findings from the industrial case study suggests that as middle management layers are eliminated, lateral integration roles will be developed which support a lateral management matrix structure. These developments, together with the adoption of management information and decision support systems and indeed the devolvement of decision making should infact result in a reduced power and role differential between the hierarchical layers of an organisation . It follows therefore that a top management elite would be unlikely to form.

Jones and Webb (1987), performed a study to establish the effect of CIM on the various organisation structures, the study was undertaken at two engineering companies based in the north-east of England. The study suggests that a slimmer flatter organisation hierarchy with added flexibility is developing and that a simpler and smaller management structure is emerging. The findings from the above study support those from the Lucas industrial case studies with two exceptions. Firstly, Jones and Webb state that a slimmer flatter hierarchy is developing. This can be considered a contradictory statement, the flattening of an organisation hierarchy will lead to a wider hierarchy, not slimmer. The wider hierarchy will result from the integration of the various levels of function into one project based (matrix structure) level. Secondly, Jones and Webb argue that the management structure will become simpler and smaller. This is in fact only partly true, the management structure will become smaller as middle management are removed, but the management structure will become more complex not simpler. A team based adhocratic structure relies to a large degree on the matrix structure which can be problematic and lead to 'dual line reporting' conflicts, see Butler (1973).

This section has examined and predicted the likely changes that CIM will have on the internal structuring of an organisation. CIM is also likely to affect the external structures of a business within its industrial sector. This is outside the scope of this thesis. For further reading refer to Glen (1985), who was involved in a 'Delphi' study designed to identify the strategic and structural consequences of CIM adoption. A summary of the study results can be seen in Appendix (D).

5.5.2 Co-ordinating and control mechanism change

This section examines the changes to the coordination and control mechanism as a result of CIM (business integration) developments.

A coordination and control mechanism can be described as the means of coordinating and controlling tasks within an organisation. The choice of mechanism is very much dependent upon specific task features, including task variablility and span, task complexity, task information processing requirements and task inter-relativity. It follows therefore, that there is a close relationship between the organisation structure and its coordinating and control mechanism. The organisation structure is concerned with the way in which its labour is divided into distinct tasks, and the coordination and control mechanism is concerned with the achievement of coordination and control among these tasks. It can be seen therefore, that the relationship between organisation structure and its coordinating and control mechanism is particularly important during business redesign.

In chapter 4.0, the two industrial case studies examined the effects of CIM and integrated control on the various business structures and mechanisms. It was shown that the changes to the coordination and control mechanism changes stemmed from the application of computer systems to perform particular control tasks, the integration of computer systems to automate the closing of control loops and organisation integration, resulting in the formation of smaller working groups, for example, project teams and manufacturing cells.

In both cases the application and integration of information and control systems changed the way control was exercised. The fundamental change was that certain elements within the control process itself was automated, resulting in a reduction in the time taken to close the control loops. This had an effect of changing the managers role from that of active involvement to passive monitoring and the authority relationship between the manager and subordinate. On the one hand, the degree of inter-personnel contact reduced as the computer system developed into an important Management Information System (MIS), whilst on the other hand, it increased due to the formation of smaller working groups (project teams and manufacturing cells).

The formation of smaller working groups, resulted in quite significant changes to the coordination mechanism. The working groups, whilst supporting the existing divisions of labour structure, provide a conducive environment for the task of coordination. The new project/cell manager is in fact a full-time integrator and works very closely with the project team/cell engineers [Lawrence and Lorsch (1967)].

Based on the findings from the industrial case study, a new developing integrated business environment is likely to result in the following changes to the coordinating and control mechanism:

- direct supervision being replaced by voluntary collaboration as concensual planning is exercised;

- control of the work increasingly being left in the hands of the doers;
- coordination and control tasks increasingly becoming a functional responsibility of computer systems and systems integration;
- enforced discipline being replaced by self discipline;
- mutual adjustment, coordination and control developing among colleagues, as the underlying culture changes from one of 'role' to one of 'task'.

The above changes suggest that both formal/bureaucratic and cultural coordinating and control mechanisms are likely to exist in developing CIM environments. The development and integration of computer systems within the various functions of a business would develop formal controls, whilst the organisational integration associated with project teams and cellular structures would promote the adoption of cultural controls.

It is evident that Lucas Aerospace is undergoing a coordination mechanism transformation from that of a predominant 'direct supervision' and 'standardisation' mechanism, based on bureaucratic control systems, to one of 'mutual adjustment' based on cultural control systems. The coordination and control mechanism in use within the various departments vary quite considerably. At one end of the scale, departments are based on bureaucratic mechanisms, whilst at the other end of the scale, departments are based on cultural mechanisms.

For further reading on coordination and control mechanisms, examine works from the following authors, namely Daft and Lengel (1986), Jaeger and Baliga (1985), Tushman and Nadler (1978), Mintzberg (1979), Galbraith (1977) and Mintzberg (1983).

5.5.3 Changes to power and political processes

In order to examine the power and political process changes influenced by the adoption of CIM (business integration), one needs to define the meaning of power and politics in an organisational context.

Power can be defined as the ability of one person or function in an organisation to influence other persons or functions to carry out orders, or perform a task they would not otherwise have done. Organisational politics is the actual behaviour used to acquire, develop and use power and other means to obtain a preferred outcome when there is uncertainty, disagreement or conflict surrounding the choice.

The distribution of power within the organisation is largely affected by structural transformations. For example, at Lucas Aerospace the adoption of the project matrix structure for New Product Introduction (NPI) created a new power structure. The existing functional managers lost some of their power to the newly formed project leaders/managers. The functional managers role changed emphasis from that of a line manager, actively involved in a new product introduction process to that of resources planning/personnel manager. The project teams soon became regarded as highly knowledgeable groups with a great span of experience, which subsequently led to their increase in power.

A similar kind of power structure change took place with the establishment of manufacturing cells. As the cells became more autonomous so the devolvement of power became more progressive. At present the cells are viewed as separate autonomous business units or mini factories. The cell manager can be considered to be a mini factory manager. The existing production manager for the site began to play a much more strategic role with emphasis on customer delivery targets, high level factory planning, production performance measures and long term investment plans.

The above two examples of power structure changes are attributed to the structural changes implemented as part of a CIM endeavour. They both have one thing in common, that being the establishment of a new powerful integration role, that is, the project manager and cell manager. The high power of integration roles is discussed by Lawrence and Lorsch (1967), Handy (1987) and Mintzberg (1983).

Another major change to the power structure is taking place due to the growing importance of computer systems. As already stated in section 5.5.1 the recognition of the importance of computer systems at Lucas Aerospace has gained the business systems manager a place on the business executive board and a direct responsibility link to the general manager. It is envisaged that as more and more computer systems are developed and installed to assist and computerise various business functions their importance will indeed grow. In say five years time the performance and control of a business will rely heavily on the implementation and integration of computers. At this point in the future the knowledge of computer systems generally held by key staff will have dramatically increased and the role of the business systems manager will be significantly more powerful than those of current times.

Computer systems can in fact indirectly possess power and be used as a political weapon. The computer system currently being implemented at Lucas Aerospace, namely that of an integrated Engineering Database Management System (EDMS) will define the way work is organised and performed, by establishing the operating environment for processes, procedures and communication channels. The system set up will define the operating framework for numerous personnel and guide them through the various stages of their work in a controlled manner. Furthermore, the integration of such systems across the business will expand the scope of this power across the functional boundaries. At Lucas Aerospace, systems are set up to ensure the conformance to predefined procedures and can be used politically in this way to ensure a desired outcome.

The adoption of CIM is also changing the basis upon which power is derived. The primary factor determining the power of a person has traditionally been their hierarchical position within the organisation. It is now, more so based on the knowledge, experience and performance of an individual or function. The power of a role or function is not as strongly influenced by its perceived direct contribution towards the attainment of organisational objectives as was the case some ten to twenty years ago. For example, the role of support functions like personnel and business systems have a developing power structure. This is due to the greater perceived importance of personnel management and training, and computer systems implementation and integration.

Finally, the degree of political behaviour will increase as CIM develops. This can be deduced from the following. Certain factors associated with the development of CIM, for example environmental change, increased technological implementation and inter-dependence between functions, all result in increased task uncertainty. Task uncertainty, as previously stated, is the key cause for political behaviour. Assuming such political behaviour is undesirable one should increase the amount of information available to reduce the task uncertainty. The inverse relationship between uncertainty and information is argued by Galbraith (1973), Tushman and Nadler (1978), Daft and Lengel (1986) and Daft (1986).

5.5.4 The Business configurations for CIM (Business Integration)

This section examines the five business configurations defined by Mintzberg (1983) and suggests the transformations required to support CIM. The five configurations together with their environmental attributes can be seen in Table (8). In order to understand the table, the reader should examine Mintzberg's book, namely "Structures in Fives" (1983).

The configuration of Lucas Aerospace (Engine Systems Division) is currently a composite of all five, which is really what one would expect of a mature medium sized business. The fact is that various parts of the organisation adopt different configurations. However, even this is not wholly true, for example, the engineering department which I would consider to be reasonably well integrated does not conform wholly to one configuration. Although the primary configuration is 'Adhocracy', there are various segments which adopt other configurations. For example, there is a significant amount of action planning and some top down decision making, which denotes the use of 'Machine Bureaucracy'. On the other hand direct supervision is still used in part, which involves the use of 'Simple Structure' configuration. It is the authors contention that the composite configuration for Lucas Aerospace (ESD) will be increasingly based on the 'Adhocracy' as CIM develops.

5.5.5 Summary

It has been shown in section 5.5 that CIM , can result in a great deal of business redesign including changes to the organisational structures, the coordination and control mechanism and the power and political process. A common set of changes have been predicted for each of the above, which result in a multi-mode business configuration.

	Simple Structure	Machine Bureaucracy	Professional Bureaucracy	Divisionalized Form	Adhocracy
Key coordinating mechanism	Direct supervision	Standardization of work	Standardization of skills	Standardization of outputs	Mutual adjustment
Key part of organization	Strategic apex	Technostructure	Operating core	Middle line	Support staff (with operating core in Op. Ad.)
Design parameters:					
Specialization of jobs	Little specialization	*Much horizontal and vertical specialization*	*Much horizontal specialization*	Some horizontal and vertical specialization (between divisions and HQ)	*Much horizontal specialization*
Training and indoctrination	Little training and indoctrination	Little training and indoctrination	*Much training and indoctrination*	Some training and indoctrination (of division managers)	Much training
Formalization of behavior, bureaucratic/organic	Little formalization, *organic*	*Much formalization, bureaucratic*	Little formalization, *bureaucratic*	Much formalization (within divisions), bureaucratic	Little formalization, *organic*
Grouping	Usually functional	*Usually functional*	Functional and market	*Market*	*Functional and market*
Unit size	Large	Large at bottom, small elsewhere	Large at bottom, small elsewhere	Large (at top)	*Small throughout*
Planning and control systems	Little planning and control	Action planning	Little planning and control	*Much performance control*	Limited action planning (esp. in Adm. Ad.)
Liaison devices	Few liaison devices	Few liaison devices	Liaison devices in administration	Few liaison devices	*Many liaison devices throughout*
Decentralization	*Centralization*	*Limited horizontal decentralization*	*Horizontal and vertical decentralization*	*Limited vertical decentralization*	*Selective decentralization*
Functioning:					
Strategic apex	All administrative work	Fine-tuning, coordination of functions, conflict resolution	External liaison, conflict resolution	Strategic portfolio, performance control	External liaison, conflict resolution, work balancing, project monitoring
Operating core	Informal work with little discretion	Routine, formalized work with little discretion	Skilled, standardized work with much individual autonomy	Tendency to formalize owing to divisionalization	Truncated (in Adm. Ad.) or merged with administration to do informal project work (in Op. Ad.)
Middle line	Insignificant	Elaborated and differentiated; conflict resolution, staff liaison, support of vertical flows	Controlled by professionals; much mutual adjustment	Formalization of division strategy, managing operations	Extensive but blurred with staff; involved in project work
Technostructure	None	Elaborated to formalize work	Little	Elaborated at HQ for performance control	Small and blurred within middle in project work
Support staff	Small	Often elaborated to reduce uncertainty	Elaborated to support professionals; Mach. Bur. structure	Split between HQ and divisions	Highly elaborated (esp. in Adm. Ad.) but blurred within middle in project work
Flow of authority	Significant from top	Significant throughout	Insignificant (except in support staff)	Significant throughout	Insignificant
Flow of regulated system	Insignificant	Significant throughout	Insignificant (except in support staff)	Significant throughout	Insignificant
Flow of informal communication	Significant	Discouraged	Significant in administration	Some between HQ and divisions	Significant throughout
Work constellations	None	Insignificant, esp. at lower levels	Some in administration	Insignificant	Significant throughout (esp. in Adm. Ad.)
Flow of decision making	Top-down	Top-down	Bottom-up	Differentiated between HQ and divisions	Mixed, all levels
Situational factors					
Age and size	Typically young and small (first stage)	Typically old and large (second stage)	Varies	Typically old and very large (third stage)	Typically young (Op. Ad.)
Technical system	Simple, not regulating	Regulating but not automated, not sophisticated	Not regulating or sophisticated	Divisible, otherwise typically like Mach. Bur.	Very sophisticated, often automated (in Adm. Ad.); not regulating or sophisticated (in Op. Ad.)
Environment	Simple and dynamic; sometimes hostile	Simple and stable	Complex and stable	Relatively simple and stable; diversified markets (esp. products and services)	Complex and dynamic; sometimes disparate (in Adm. Ad.)
Power	Chief executive control; often owner-managed; not fashionable	Technocratic and sometimes external control; not fashionable	Professional operator control; fashionable	Middle-line control; fashionable (esp. in industry)	Expert control; very fashionable

*Italic type designates key design parameters.

Table (8): Mintzberg's dimensions of the five configurations

6. CIM DESIGN METHODOLOGY AND THE IMPORTANCE OF CONTROL

This chapter examines various aspects of a CIM design methodology and identifies numerous knowledge gaps in current methodology thinking. It will be argued that the importance of developing the right methodology for CIM design is becoming increasingly important and that such a methodology relies on particular attention being given to business control requirements, which seem to be poorly defined in current methodologies. It will be concluded that adopting such a control based CIM design methodology should result in a totally automated and controlled business environment, in which all departments of an organisation are able to work together in a reasonably integrated and controlled manner, towards common business goals.

6.1 Introduction

In chapter 3.0, it was argued that business control and the management role have become less effective over a period of years, and that a major concern of a business should be exercising effective control in a fully integrated manner to ensure all functions of a business are working together in a mutually supportive way. It was subsequently argued, in chapter 4.0, that there is a close developing relationship between CIM and control, which implies that effective integrated business control is increasingly having to rely on the implementation of the CIM philosophy for complete application.

From these arguments it can be deduced that the CIM philosophy can be applied in such a way that the resulting CIM design is capable of supporting integrated business control. It is this, CIM design and its methodology, that forms the main subject of this chapter.

6.2 Methodology versus technology - a general discussion

This section examines the role of methodology and technology during a CIM introduction.

In chapter 2.0, it was argued that the meaning of CIM as perceived in industry, is undergoing a gradual transformation through four phases. It was shown that during the early to mid 1980's, the meaning of CIM fell into phase 1, and then towards the late 1980's a gradual shift witnessed the movement of CIM through phase 2, into phase 3. Whilst the current view predominantly focusses on phase 3, there is a developing tendency underlying the subject of CIM. During this transition period, the emphasis of CIM has changed from that of a predominantly technological bias to that more involved in the methodology surrounding CIM applications.

During the 1970's and early 1980's many of the CIM developments throughout industry adopted single facet systems technology (CIM phase 1), such developments included the implementation of Material Requirements Planning (MRP) and Computer Aided Design (CAD) systems. These systems were often implemented to fit into existing procedures in piecemeal fashion with little or no consideration given to environmental changes. It can be said that many of the CIM phase 1 developments focussed on the application of technology to an existing standardised and often outdated environment. Towards the mid 1980's industry had not realised the benefits expected from such CIM phase 1 investments; the cause of which was attributed to the method of CIM application used [Ingersoll Engineers (1985), Schwendinger (1984), Rolls (1985) and Newman (1985)].

From 1985 onwards the emphasis of CIM began to change, industry on the whole started to discover that the real benefits from CIM may be more fully realised when the business environment is changed to take full advantage of the computer technology being implemented. Such changes as suggested in chapter 2.0, fall into two categories. Category one, focuses on simplifying and optimising the process prior to computerisation and integration such that CIM is applied to best practice. Category two is concerned with tailoring the environmental elements, such as control procedures, processes, people's roles, information flows and organisation structures to create an optimum working relationship between the computer system and its environment.

The requirements for such changes together with some examples were examined in chapter 4.0 and 5.0, which witnessed its entry into phase 3 - "the integration of systems into its surrounding business environment".

Also from the mid 1980's industry began to realize the real importance of getting the CIM planning, design and implementation methodology right.

Various authors began to recommend changes and introduce new ideas to the CIM methodology to improve the effectiveness of CIM implementations. Examples of these changes include:

- developing the CIM strategy on the back of the business or corporate strategy to ensure they are mutually supportive [Vogel (1987), Branco (1986), Rzevski (1987), Chuah (1989) and Ingersoll Engineers (1986)];

- changing financial investment appraisal methods from traditional techniques including payback and Discounted Cash Flows (DCF's) to the use of more strategic justification methods like Critical Success Factors (CSF's) [Kaplan (1986), Sibbald (1987) and Punwani (1985)];

- increasing the level of communications across the business to develop a supportive workforce who share common goals, and who are wholly committed [Soest and Wallace (1988), Welter (1986) and Oden and Bibeau (1986);

- increasing emphasis on the management of change process [Daughters (1986), Rzevski (1988) and Ingersoll Engineers (1986)];

- defining a new role, that of a CIM champion or integrator to develop, coordinate and drive the CIM plans from inception through to full implementation [Rzevski (1988), Branco (1986) and Various (1986)].

From examining the above literature, it can be seen that the importance of CIM methodology has been rising, whilst the concern regarding the technology has been diminishing. It is widely agreed that a substantial amount of the technology required to support CIM developments is currently available.

It follows therefore that establishing the correct CIM methodology can be considered a key requirement in developing effective CIM environments.

6.3 Discussion of CIM methodologies

This section examines a wide range of CIM methodologies and discusses their features and relative similarities/differences.

The issues relating to the development of a CIM methodology and plan are widely documented. Many CIM advocates discuss the important factors and follow up by proposing an approach to CIM. It should be noted however, that although the subject has been discussed widely, there does not seem to be a standard accepted approach. Firstly the various authors differ on what they should call a method for developing a CIM business environment. Some authors view it as a 'CIM strategy' [Ingersoll Engineers (1986), Rzevski (1988), Punwani (1985), Elavia (1987) and Branco (1986)], whilst others, view it as simply 'planning for CIM' or 'CIM implementation steps' [Schwendinger (1984), Vogel (1987), Hales (1984) and Chuah (1989)].

The scope of the methodology also differs depending on the particular view of the author. Some authors begin by defining the strategic framework for CIM and follow on through the business analysis and design phase, but stop at the start of the implementation plan [Branco (1986), Vernadat (1986) and Rolls (1985)]. Other authors have a tendency to develop the implementation plan further by discussing specific systems implementation steps [Elavia (1987), Ingersoll Engineers (1986) and Punwani (1985)].

The main objective normally associated with the adoption of CIM is to improve business performance, this invariably includes reducing operating costs, reducing new product introduction leadtimes, improving product reliability and performance, improving quality, reducing inventory and so on. It can be seen therefore, that the CIM objectives should directly relate to the strategic business objectives. Whilst some authors have recognised this, and have included steps in their CIM methodology to link these objectives [Chuah (1989), Punwani (1985), Branco (1986), Stark (1984), Vernadat (1986), and Ingersoll Engineers (1986),], others perhaps don't perceive the need and have omitted it [Reisch (1987), Vogel (1987) and Rolls (1985)].

Although most of the methodologies reviewed support a top-down 'As-Is' and 'To-Be' analysis phase followed by a bottom-up implementation, very few of them recognise the importance of managing the transformation of the business from the 'As-Is' to the 'To-Be' state. Only Rzevski (1988) and

Chuah (1989), both in recent articles, mention the importance of managing change during the development of a CIM environment.

An important element of any CIM development plan is justifying the CIM investment. Suprisingly, various CIM methodologies do not include CIM justification as a defined development step [Chuah (1989), Reisch (1987), Rolls (1985), Vernadat (1986) and Hales (1984). Furthermore, the methodologies that do include CIM justification, differ with regard to their positioning of the CIM justification task within the sequence of activities and in their justification method used. An example of this can be seen by examining the methodologies proposed by the following authors, namely [Schwendinger (1984), Vogel (1987), Elavia (1987), Rzevski (1987) and Branco (1986)].

Many of the CIM methodologies have been developed from a different standpoint with particular emphasis on a given subject domain, which consequently focusses the readers attention on specific and often different aspects of the methodology. Such methodologies are usually limiting and likely to misinform the reader. Various authors have developed CIM methodologies which fall into this category including Branco (1986), Vogel (1987) and Vernadat (1986).

Branco (1986), focusses on the strategic management approach to CIM, which concentrates on laying a good CIM foundation. Branco emphasizes the need to establish a 'single-focus' for manufacturing, perform a detail examination of the corporate business strategy, develop a corporate vision for the business and establish corporate and manufacturing critical success factors (CSF's). Branco then poorly defines the CIM analysis and design phase by failing to mention the development of business, functional and information 'as-is' or 'to-be' models, which are considered by many to be the core part of any CIM methodology.

Vogel (1987), takes a completely opposite approach to Branco and focusses on the modelling and design aspects of a CIM methodology. Vogel concentrates his attention on developing business models, developing CIM functional models and the creation of a logical and physical CIM architecture which provides the framework for the detailed design of CIM modules. In contrast to Branco, Vogel then fails to mention the strategic management aspects of a CIM endeavour.

Vernadat (1986), takes a different approach to developing CIM by actually incorporating into the CIM methodology an element of CIM, namely Group Technology (G.T). Vernadat argues that group technology must be applied over all of the CIM system definitions, design, implementation and operation phases.

> " Group Technology can be defined as a manufacturing philosophy in which parts are classified and coded into part families to take advantage of their similarities in design and manufacturing. "

It can be deduced that group technology can only be applied to those CIM system elements which are part based. Clearly it would be inappropriate to apply group technology to the following CIM system elements, namely project control, payroll, financial ledgers, asset register and office systems. It follows therefore that the CIM methodology proposed by Vernadat is in fact misleading.

From the above it can be concluded that some current CIM methodologies can be seen as conflicting, incomplete and misleading.

6.4 Gaps in current CIM methodologies

This section examines further the various documented CIM methodologies and identifies numerous gaps in the current thinking. The gaps relate to either the omission of specific CIM development steps or the failure to consider certain influencing factors during the execution of the CIM development plan. Many of the arguments within this section are supported by a CIM methodology literature review which is documented in Appendix (F).

6.4.1 Control related knowledge gaps

This section identifies and discusses various control related knowledge gaps associated with current CIM methodologies.

In chapter 4.0, it was recognised that effective business control is increasingly having to rely on the implementation of the CIM philosophy for complete application. A business model was developed integrating the New Product Introduction (NPI) process with Manufacturing Operations (MO), to provide the framework for total business control It was subsequently argued that this model provides the basis upon which the philosophy of CIM could be based. In summary, chapter 4.0 demonstrated, using industrial case studies, that CIM can be designed and developed to support the integrated control requirements of a business.

The effectiveness of such a CIM design to support business control would depend totally on the business control requirements identified and the way in which they are accommodated within the CIM system. It follows therefore that a key determining factor, during the development of CIM, is the degree to which the CIM methodology considers the effects and requirements of control.

Control is likely to impact all aspects of a CIM methodology, right from recognising the business need for CIM through to the implementation of business redesign changes. Those aspects of particular concern include the following:

- 1. CIM objective definition;
- 2. CIM business analysis;
- 3. CIM system design;
- 4. CIM system architecture;
- 5. CIM business redesign.

<u>6.4.1.1 CIM objective definition</u>

The defining of CIM objectives is normally one of the first steps undertaken in a CIM development plan. The CIM objectives as agreed in the previous section should directly relate to the business strategic objectives. A control based CIM methodology should have its CIM objectives broken down into their constituent business control objectives, so that the important business controls can be identified right from the start. The relevance of doing this is best demonstrated with a scenario.

> Company 'A', a typical medium sized batch manufacturing firm has in recent years invested heavily in manufacturing plant, but found that its main problem is its inability to respond to changing product requirements, which in turn is causing a loss of market share. Company 'A', therefore defines its main strategic business objective

as, " to be more responsive to the changing product requirements of the customer ", which is subsequently adopted as the core CIM objective. The CIM objective is then broken down into its constituent business control objectives, one of which is to improve the controls of the New Product Introduction (NPI) process. NPI control is then broken down into its constituent control elements including project control, engineering change control, modifications control, drawing control, product configuration control and so on. The result of this process is a clear focus on the important business controls that one needs to consider during the CIM project.

The CIM methodology literature review, showed that out of 24 proposed CIM methodologies, 50 percent (12 authors) discuss the need to examine the business strategy and use it as a backcloth for CIM, but none include the detailing of control objectives during the CIM objective definition stage, and none develop a technique (network chart) to tie the CIM objectives to the business control objectives.

6.4.1.2 CIM business analysis

CIM business analysis is an exercise in which the business is examined in order to develop an understanding of the functions, information and procedures used. It typically involves the development of 'as-is' and 'to-be' business models, which focus on the functional and information requirements of the business. This typical view of business analysis however, fails to provide effective means for examining the control requirements associated with business functions and information.

The 'as-is' business modelling method should be capable of identifying functional and data control problems caused by omitted or badly performed control elements, open control loops and poorly specified control loop nesting. Similarly, the 'to-be' business analysis method should be capable of modelling the desired control requirements.

The CIM methodology literature review, showed that out of 24 proposed CIM methodologies, 71 percent (17 authors) discuss the importance of analysing business functions and information during the business analysis stage, but only 21 percent (5 authors) state that business controls should be examined. None of the five authors, [Elavia (1987), Schwendinger (1984), Vogel (1987), Jenster (1987) and Rushton (1985)] define an analysis method which specifically examines business controls, as previously defined.

6.4.1.3 CIM system design

CIM system design is perhaps the most important stage of a CIM development, it typically involves the development of a systems infrastructure model for the business. The model normally illustrates all CIM system elements selected, their positioning within the business and the various system interfaces required.

The widely adopted CIM system design process is based on the detailed examination of the 'to-be' functional and information business models. The core criteria for specifying CIM system elements are the processes and the data input and output requirements, whilst the criteria for defining system interfaces are the system data models and the data flow charts.

The adoption of the control based CIM system, as supported within this thesis, follows a different design process and results in a systems infrastructure model which is capable of illustrating how it supports the various business controls.

The development of the argument that supports this control based CIM system design process is as follows.

In chapter 3.0, it was argued that systems are often used to support specific controls, some of which represent individual control elements others complete control loops. It was further argued that if two systems support individual control elements which are either part of the same control loop or part of two individual control loops related through control loop nesting, then a control loop interaction is developed between them. It was shown that these control loop interactions form the basis for determining the integration requirements between systems.

Also in chapter 3.0, it was shown that control levels are a result of control loop nesting and are capable of providing a useful technique for modelling horizontal and vertical control loop interactions. Furthermore it was shown that control hierarchies can be used to study and examine control requirements and indeed other business elements including business functions, functional control, manufacturing systems, computer hardware and response times.

In chapter 4.0, it was demonstrated that a control hierarchy together with its various levels can be effectively used to model numerous business elements associated with:

- New Product Introduction (NPI) control;
- Manufacturing Operations (MO) control.

Furthermore it was shown that control hierarchies are very useful at modelling the systems integration requirements to support specific business controls.

From examining these two approaches it can be argued that the traditional view of integration is limiting. The traditional view of integration focusses mainly on the functional information flow between two systems, where as the control based view focusses on the flows related to control loop interactions. The control loop is capable of interacting in three different ways which causes three different inter system flows, namely functional information, control information and transaction triggers which trigger the execution of certain processes (refer back to chapter 4.0, for the transaction chain control concept).

It follows therefore that the method for designing a CIM system should accommodate the above mentioned control based approach, and therefore should use the modelling capability of control hierarchies.

The CIM methodology literature review showed that out of the 24 proposed CIM methodologies, none in fact, base the definition of CIM system elements and systems integration on control requirements and control loop interactions, and only one author [Vernadat (1986)] uses the control hierarchy to support the modelling of business elements. Vernadat (1986) however, only uses the control hierarchy to model control systems; no use of it is made to model system integration and business control requirements.

It can be said that none of the CIM methodologies reviewed, perform CIM system design using the previously defined control based approach.

6.4.1.4 CIM system architecture

The CIM system architecture is a more physical view of the CIM system, it generally involves establishing system processing and data modelling rules, the systems integration procedures and the computing standards. The traditional issues discussed at this stage include:

- the type of system processing configuration required, that is, whether it should be centralised, distributed or a mix of both;

- the type of system processing setup required, that is, whether it should be time-sharing, on-line, real-time or batch;

- the type of system data model required, that is, whether it should be a large central database, a number of distributed databases or a mix of both;

- the procedures and methods associated with systems integration, together with data mapping requirements between systems.

- the computing standards that should be adopted associated with hardware, database, operating system, network and languages etc;

A control based CIM system architecture should discuss other issues associated with the development of a systems integration environment which supports control loop interactions.

A control based CIM system architecture should be capable of supporting the transaction chain control concept, as defined in chapter 4.0, section 4.4.5.1, and should include the development of a systems integration framework based on that defined in section 4.4.5.2. The systems integration framework should develop a standard systems integration model and procedure which formalises and standardises the interface mechanism thus eliminating the creation of adhoc interfaces, and develops a single standard interface control mechanism which supports the various control loop interactions.

In chapter 5.0, it was argued that the co-ordination and control mechanism has a close relationship with the organisation structure.

Bearing in mind that the systems integration architecture is responsible for developing an integrated systems environment that supports control loop interactions, it follows therefore, that a control based CIM system should have a physical architectural form that supports the organisation structure.

Although many CIM advocates discuss the general points mentioned above including system processing configuration and type, data modelling, interfacing procedures and computing standards. None of the CIM methodologies examined, discuss the development of a systems integration control framework or indeed stress the importance of matching the CIM system architecture to the organisation structure by examining the business co-ordination and control mechanism..

6.4.1.5 CIM business redesign

In chapter 5.0, it was argued that the developing view of CIM is resulting in a greater degree of business redesign, and that CIM can result in a significant change to the various business structures, coordinating and control mechanisms and the power and political process.

A control based CIM design would, by its very nature, significantly affect the coordinating and control mechanisms within a business . A CIM methodology should therefore provide the necessary stages to model the changes to these mechanisms. At Lucas Aerospace, it was decided that business control scenarios would be demonstrated using system prototypes and walkthroughs. Such methods provided a means of agreeing and signing off business controls prior to full system implementation.

None of the CIM methodologies examined include any kind of system prototyping or system walkthrough methods for modelling the changes to the business procedures.

From examining the above, it can be concluded that current CIM methodologies have various knowledge gaps as they fail to consider important business control issues.

6.4.2 Other knowledge gaps

This section identifies and discusses other knowledge gaps associated with current CIM methodologies. The knowledge gaps of particular concern appertain to the following:

- 1. initiation of a business wide and employee supported approach;
- 2. development of an integrated strategy network;
- 3. business analysis approach;
- 4. standard structured systems analysis techniques;
- 5. management of change process.

6.4.2.1 Initiation of a business wide and employee supported approach

It can be seen that this thesis is developing a holistic business view of both CIM and control. Chapter 2.0, suggested that CIM is undergoing a transformation through four phases, the fourth one being - 'total business integration'. In chapter 3.0, it was argued that a fully integrated business wide approach to control is required. A requirement for a total business approach to both CIM and integrated control was demonstrated in chapter 4.0, using two industrial case studies. Both studies illustrated the far reaching effects of implementing business integration (CIM). Chapter 5.0, then examined the wide ranging degree of business redesign required to support business integration.

A total business wide view of CIM requires a business wide approach to ensure that all areas of the organisation are involved in the overall process, and that support and commitment is gained from everyone. Gaining support and commitment is primarily concerned with developing a business wide realisation that business integration (CIM) represents the target for which the business is striving [Gunn (1986), Oden and Bibeau (1986), Soest and Wallace (1988), Rzevski (1987), Branco (1986) and Henry (1986)].

Gunn (1986), argues that the realisation and determination by a company's management that CIM must ultimately be achieved constitutes a major requirement. This argument is further developed by Oden and Bibeau (1986), who suggest that the CIM initiation phase should include an involvement program for all employees, where the necessary support and commitment is developed through numerous meetings and communications.

Various authors advocate that an informed employee is normally a more committed employee. Although this is true, once the employees realise the degree of technological and organisational change which normally follows such business integration endeavours, they will undoubtedly feel anxious and insecure. Various studies have shown that employees in this position are apprehensive, threatened by the advent of change and often feel that job losses are inevitable.

It is very important to nullify those feelings especially when their support is required. This can be achieved in various ways.

Soest and Wallace (1988), suggest that CIM planning should include a focus on a 'team approach', this they argue is best achieved by changing the corporate culture and developing a clear statement of the company's value system. They suggest that this would set the course for the company, establish a common direction, guide the actions of individuals within the organisations, promote a united feeling across the workforce and help people feel part of the overall process of change.

Rzevski (1987), in a similar vein argues that one of the greatest obstacles to remove during CIM planning is the resistance to change felt by individuals. He argues that the most difficult task is to initiate and sustain a change. To effectively solve this problem, he deems it necessary to create a culture that respects and supports change.

Oden and Bibeau (1986) tackled the CIM initiation phase in a slightly different way; they suggest that one of the first activities undertaken should be the documenting of the corporate philosophy. This they argue will provide a single thread to tie together the various functions across the business and should result in a shared vision of the company's future. Other authors, namely Branco (1986) and Henry (1986), suggest similar ways of promoting a business wide and employee supported approach to business integration.

It can be seen that there are indeed various ways to initiate a business wide approach to integration. Unfortunately there is no evidence to suggest which of the above mentioned methods is more successful. The success of a particular method may well depend upon the type of business to which it is applied. The important thing is that all the above authors recognise the importance of developing a business environment in which the organisation as a whole is fully supportive and committed to the business change to improve business performance. This constitutes the first key step towards the development of a successful CIM endeavour.

The steps taken at Lucas Aerospace to develop a business wide and fully supported approach to CIM are detailed in chapter eight.

The CIM methodology literature review produced the following results:

- 42% of the authors state that CIM should involve all business functions;

- 50% of the authors highlight the importance of gaining support and commitment from all employees;

- 21% of the authors discuss the need to develop a team approach across the business;

- 29% of the authors stress the need to consider the required cultural charges during the development of a CIM environment;

- 24% of the authors discuss the possible resistance to change and advocate the development of a proactive environment to change;

- 21% of the authors discuss the appointment of a CIM-champion to lead such a CIM endeavour;

- 71% of the authors highlight the need to form a multi-disciplinary team to drive forward the CIM endeavour;

- 8% of the authors discuss the formation of a corporate philosophy to guide the employees of the company;

- 8% of the authors stress the importance of developing a shared vision and shared values during the development of a CIM environment;

- 17% of the authors highlight the need for establishing a single focus for the company to encourage a company wide movement towards CIM;

- 19% of the the authors stress the importance of establishing a steering group/CIM executive board group to co-ordinate the CIM endeavour;

- 25% of the authors discuss the use of critical success factors (CSF's) during CIM investment appraisal;

- 59% of the authors stress the importance of training/education during a CIM endeavour.

The above thirteen points are considered to be supportive of the business wide and employee supported approach to CIM discussed in Section 6.4.2 The results generally depict a rather poor understanding of the business approach required for (CIM).

6.4.2.2 Development of an integrated strategy network

In the previous section various methods were introduced to promote a business wide and employee supported approach to integration. One such method was that of focussing on the corporate business strategy to provide a single focus for the business, and ensuring the alignment of all activity in support of it. Such a focus helps to create a shared vision of the business direction and provides a common datum from which all business changes can be underpinned. It is contended that a detailed examination of the business strategy is indeed a crucial process towards the success of a business integration (CIM) endeavour.

This view is held by various authors including Rzevski (1987), Punwani (1985), King and Long (1986), Stark (1984), Branco (1986), Chuah (1989), Murphy (1983) and Orne and Hanifin (1984). The various authors tend to emphasize different relational focuses between CIM and the business strategy.

Branco (1986), argues that any successful CIM effort must be built on a solid foundation directly related to the corporate business strategy. He contends that the most difficult task facing a company interested in CIM is getting started, that is, laying the foundations for justification and implementation. He suggests that the solution to the dilemma is the establishment of a single focus, a corporate business strategy.

Murphy (1983), suggests that CIM is becoming the core of any operations strategy and demonstrates how the business operations strategy is used to establish operational performances criteria, which is subsequently used to aid the selection of the appropriate CIM technology via a CIM opportunity matrix.

Chuah (1989), on the other hand argues that CIM, as well as being an operations issue, is a strategic decision. He stresses that CIM investments can be justified against either operational performance or long term strategies requirements. He adds that companies considering CIM should start by looking at how to integrate strategic thinking into the execution of operations policy.

The other remaining authors develop a similar relationship to that being suggested by Branco and Chuah.

Although the authors mentioned above, support the need to examine the business strategy during a CIM endeavour, none of them define the underpinning mechanisms which tie the CIM strategy back to the business strategy.

NB: The CIM methodology literature review, which examined some twenty four CIM methodologies produced the same result.

The reason for wanting to do this can be explained as follows. It is generally agreed that the commitment required to develop a CIM environment should be top-down, that is, from the top senior executives down to the various operational workers. It is important that the senior executive and managers are fully aware of the need for CIM and agree unanimously and unequivocally of its immense capability to improve business performance. This process or task can be more readily achieved if the CIM manager or 'champion', is capable of relating the CIM business changes to the strategic business objectives. This would help justify the CIM investment on strategic grounds and provide a means for establishing CIM element priorities.

One particular method for doing this, which was adopted at Lucas Aerospace, is the development of an integrated strategy network. The network has listed on the far left, the key CIM elements together with their associated business controls, and on the far right, the business goals followed by the strategic objectives and main business controls.

Numerous lines are drawn linking each CIM element to a number of business controls and strategic objectives, which are in turn linked to various business goals. The network provides a visual representation of how the CIM elements support the business goals. At Lucas Aerospace this method proved to be very effective.

It is argued that a CIM methodology should include in its initial preliminary phase a process that is similar to that used at Lucas Aerospace, that is, the development of a strategic network chart.

The CIM methodology literature review revealed that although a significant number of authors stress the importance of examining the business strategy during preliminary CIM planning, none propose a method of linking the CIM elements to specific business strategies or goals. The integrated strategy network is examined in more depth in chapter eight.

6.4.2.3 Business analysis approach

It is generally agreed that one of the most important activities during a CIM methodology is the business analysis step. There are two important aspects of business analysis the developed approach taken and the standard structured technique used.

The structured technique provides the analyst with a set of tools and techniques for analysing business functions and their associated information flows. It does however, fall short of providing a method for high level business analysis, function and information simplification and optimisation, and organisational change analysis. It can be deduced therefore, that it is the approach or methodology that surrounds the business analysis which requires greatest attention.

It is accepted that the methodology for business integration (CIM) should include a function and information model of the business in both its "AS-IS" and "TO-BE" state. This normally includes a hierarchy of data flow charts which illustrate the business processes and their relative information flow. The processes are decomposed level by level into more detail until the process is sufficiently defined. Although the need to develop an "AS-IS" and "TO-BE" business model is accepted [Branco (1986), Elavia (1987), Schwendinger (1984) and Vernadat (1986)], the author has been unable, during his comprehensive literature search, to find any techniques for taking the "AS-IS" model and then through simplification and optimisation create the "TO-BE" model. This is a crucial element which should be a constituent part of the overall methodology.

At Lucas Aerospace an approach was developed for business analysis which takes the "AS-IS" model and produces a "TO-BE" model. The approach is hierarchical and adopts a top-down "AS-IS" breakdown technique, followed by a bottom-up "TO-BE" summarising technique. An important point about the approach is it provided a systematic way of modelling certain aspects of business redesign at Lucas Aerospace. It would seem that such an approach should be constituent part of any business integration (CIM) methodology.

The CIM methodology literature review revealed that although a number of authors stress the importance of developing "AS-IS" and "TO-BE" business analysis models , none propose a method of creating the "TO-BE" models from the "AS-IS" models.

6.4.2.4 Standard structured systems analysis techniques

A business integration (CIM) endeavour as demonstrated in Chapter 5.0 normally results in a considerable amount of business redesign, including changes to all seven business elements. Such changes are normally the result of extensive business analysis and modelling, most of which should be performed using standard structured analysis techniques.

Over the years many graphical and semi-graphical techniques have been developed and used to assist people in examining and modelling business elements. For example:

- decision trees have proven to be very useful in analysing the effects of composite decision structures;

- flow charts have been employed to model business procedures;

- hierarchy charts have been adopted to model the decomposition of hierarchical relationships within business. An example of this includes a typical organisation hierarchy chart;

- input/output (I/O) analysis charts have proven to be useful in analysing the general input and ouput flow of processes;

- data flow charts are widely used to model the data flows between processes;

- entity/relationship charts are increasingly being used to assist the modelling of data structures in relation to entities.

It is widely accepted that such techniques greatly improve the business analysis process [Gane and Sarson (1983), Mackulak (1984), Hughes and Baines (1985), Hughes and Maull (1985), Yeomens (1987), Ridgway and Downey (1989), Baines and Culquhoun (1989) and Wood and Johnson (1989)].

There are a multitude of structured analysis techniques currently being used across industry. The more commonly adopted techniques include Jackson, Yourdon, Gane and Sarson, SSADM, CACI, GRAI, DE MARCO, IDEF and Multiview. Until recently all these techniques were performed manually using purpose designed stencils. Now, various computer vendors have developed computer systems to support and assist specific techniques. Such developments have led to a further improvement in the tools available to analyse business elements and their relationships. Examples of computer assisted structured analysis tools, or more commonly known as CASE (Computer Aided Systems Engineering) tools includes:

- Prokit workbench [McDonnell Douglas information systems];
- Information engineering workbench (IEW) [Arthur Young (IES)];
- Sun CASE tool [Sun microsystems];
- Oracle Case tool (Oracle);
- IDEF case tool.

Prior to selecting a CASE tool, one must firstly decide on the most appropriate structured analysis technique. Various authors have examined the use of such techniques as an aid in analysing the business elements and their relationships. They include Ridgway and Downey (1989), Baines and Hughes (1985) and Wood and Johnson (1989), all of whom support the use of different techniques.

All CIM development projects should adopt a standard structured systems analysis technique together with the appropriate CASE tool.

At Lucas Aerospace the CIM development projects adopted both the ORACLE and IDEF case tool. The Lucas Aerospace CIM methodology and analysis tools and techniques will be discussed in chapter eight.

The CIM methodology literature review revealed that although a third of the authors support the use of standard structured analysis techniques, none in fact discuss the use of CASE tools.

6.4.2.5 Management of change process

In chapter 5.0, it was argued that the developing view of CIM (business integration) relies on a considerable amount of business redesign which invariably generates some resistance to change from business personnel. Earlier in this chapter it was argued that the resistance to change can be tempered to some degree by developing the right change management process. The management of change process has been examined by various authors, however only a small proportion of them actually identify the constituent steps. A stepped management of change process is developed by each of the following authors, Laird (1989), Plant (1986) and Daughters (1986).

Laird (1989), argues that there are seven steps to technology change:

1. keep up to date with developments;
2. obtain good advice;
3. inform personnel;
4. purchase well known equipment;
5. careful selection of the team;
6. train personnel;
7. introduce at suitable pace.

Steps 1, 2 and 4 are not in themselves important management of change issues, moreover they are guideline elements that need to be considered when selecting and purchasing new technology. Laird's seven steps also fail to mention key issues, such as, the need to change the ways and attitudes of personnel, such that they respect and are committed to change, and the importance of changing the perception of change from that of a threat to that of an opportunity.

Plant (1986), argues that there are six key steps for successful implementation of change:

1. help individuals or groups face up to change;
2. communicate well;
3. gain total commitment to the change;
4. ensure early involvement;
5. change perception of change from a threat to an opportunity;
6. avoid over-organising.

Plant has focussed primarily on ways to develop a positive attitude and perception of change, thereby improving commitment. He fails however, to discuss the implementation issues associated with change management, for example, no mention is made of speed of implementation or personnel training requirements. It can also be argued that steps 2 and 4 are support elements for the other steps.

Daughters (1986), argues that the process of change has five stages, refer to Table (9). It can be seen that Daughters, focusses on the actual steps and their sequence and fails to sufficiently define the key issues associated with each step.

Each of the above authors whilst covering various important points, fail to cover the total picture. More attention should be given to the development of the "management of change" process to ensure effective implementation of the changes associated with CIM.

The CIM methodology literature review showed that out of the twenty four CIM methodologies reviewed, seven (29 percent) state the importance of managing the process of change during a CIM endeavour, but none in fact, actually attempt to define a management of change process.

6.5 Summary, and the importance of control

This chapter has focussed on the issues and requirements of a CIM design methodology. It has been argued that the emphasis of CIM has changed from that of a predominantly technological bias, to that mainly involved in the methodology surrounding CIM applications. This it argued, was due to the developing realisation that establishing the correct CIM methodology

Aston University

Content has been removed for copyright reasons

Table (9): Management of change process [Daughters (1986)] constitutes a key requirement in developing effective CIM environments. An examination of numerous documented CIM methodologies concluded that current CIM design methodologies are often conflicting, incomplete and misleading. Moreover, an extensive literature review, found that there are various gaps in current CIM methodologies, many of which relate to business control issues.

It was subsequently argued that a CIM design methodology should include the necessary steps to fill the knowledge gaps, and in particular address the control issues. Such a CIM design methodology would be capable of developing a totally automated controlled business environment, in which all departments of an organisation are able to work together in a reasonably integrated and controlled manner, towards common business goals. It is the authors contention that this is the main business objective for implementing CIM.

It is therefore concluded that control is a key determining factor in the development of an effective CIM design methodology.

The following chapter examines the specific effects of control on a CIM design methodology. Chapter eight, then develops a complete CIM design methodology which addresses both the control and approach related gaps.

7. THE EFFECTS OF CONTROL ON A CIM DESIGN METHODOLOGY

This chapter examines the effects of control on a CIM design methodology. It will be shown that a control based CIM design methodology is different in many ways to that of the traditional approach. Both approaches will be contrasted to highlight the differences.

It will be argued that the basis of the CIM design will change from that of a traditional view, where the integration requirements are based on the information input/output requirements of the various functions, to one where the integration is based on control loop interactions. Furthermore, it will be argued that such a control based methodology will require significant changes to the business analysis technique, resulting in the application of a control hierarchy as the core of the CIM design.

7.1 Introduction

In chapter 6.0, a literature review found that there are various gaps in current CIM methodologies, many of which relate to business control issues. It was argued that a CIM design methodology should include the necessary steps to fill these knowledge gaps, and in particular address the control issues. Chapter 7.0, examines these control issues and discusses the effects they are likely to have on a CIM design methodology.

7.2 Changes to the fundamental basis of CIM design

Traditionally, CIM systems and their elements have been perceived as computer based tools which assist particular functions by processing information. Consequently, the design of CIM systems has been largely based on the functional requirements of the business and the information input, output and storage requirements of each business function. The functional and information requirements were used as the basis for specifying the required CIM system elements, examples of which include, Computer Aided Design (CAD), Computer Aided Process Planning (CAPP) and Material Resources PLanning (MRP II). Integration was viewed purely as a means of transferring functional information across the business between different CIM system elements.

A control based CIM system design can be perceived differently, in this case the computer based tools are employed to assist specific business controls, which they themselves comprise business functions and information flows. The business functions and functional information flows are mapped onto specific control elements, which in turn form control loops. Taking this approach, the specifying of CIM system elements is based on control requirements and their constituent functions and information. Integration in this case is viewed as the transferring of control, functional and transaction based information between different CIM system elements to support control loop interactions.

This fundamental change to the basis of CIM system design can be shown by constructing a simple model of a typical business environment in which all eight business elements are present, and then overlaying the CIM system design focus of both the traditional and control based approach. This is illustrated in Figure (27).

The basis upon which the integration requirements are defined change considerably. As already stated the traditional view of CIM system design bases its integration requirements on functional information flows between systems, this is illustrated in Figure (28), and can be explained as follows.

> Figure (28), represents a simplified data flow chart which is made up of nine business functions 'F1' to 'F9' and thirteen data flows 'D1' to 'D13'. Systems analysis results in the specification of system 'A', to assist the performing of functions 'F1' to 'F4' and processing of data 'D1' to 'D7', and system 'B', to assist the performing of functions 'F5' to 'F9' and the processing of data 'D8' to 'D13'. Overlaying the system scoping lines on top of the data flow chart, as shown in Figure (29), reveals the inter system data flows 'D4','D6' and 'D7'. The inter system information boundary line is marked with three *'s.

Once the inter system flows have been defined, further analysis would need to be performed to understand under what conditions these interfaces are to be executed, i.e, the timing of the interface and the rules that apply.

The control based view of CIM system design bases its integration requirements on the transferring of control, functional and transaction

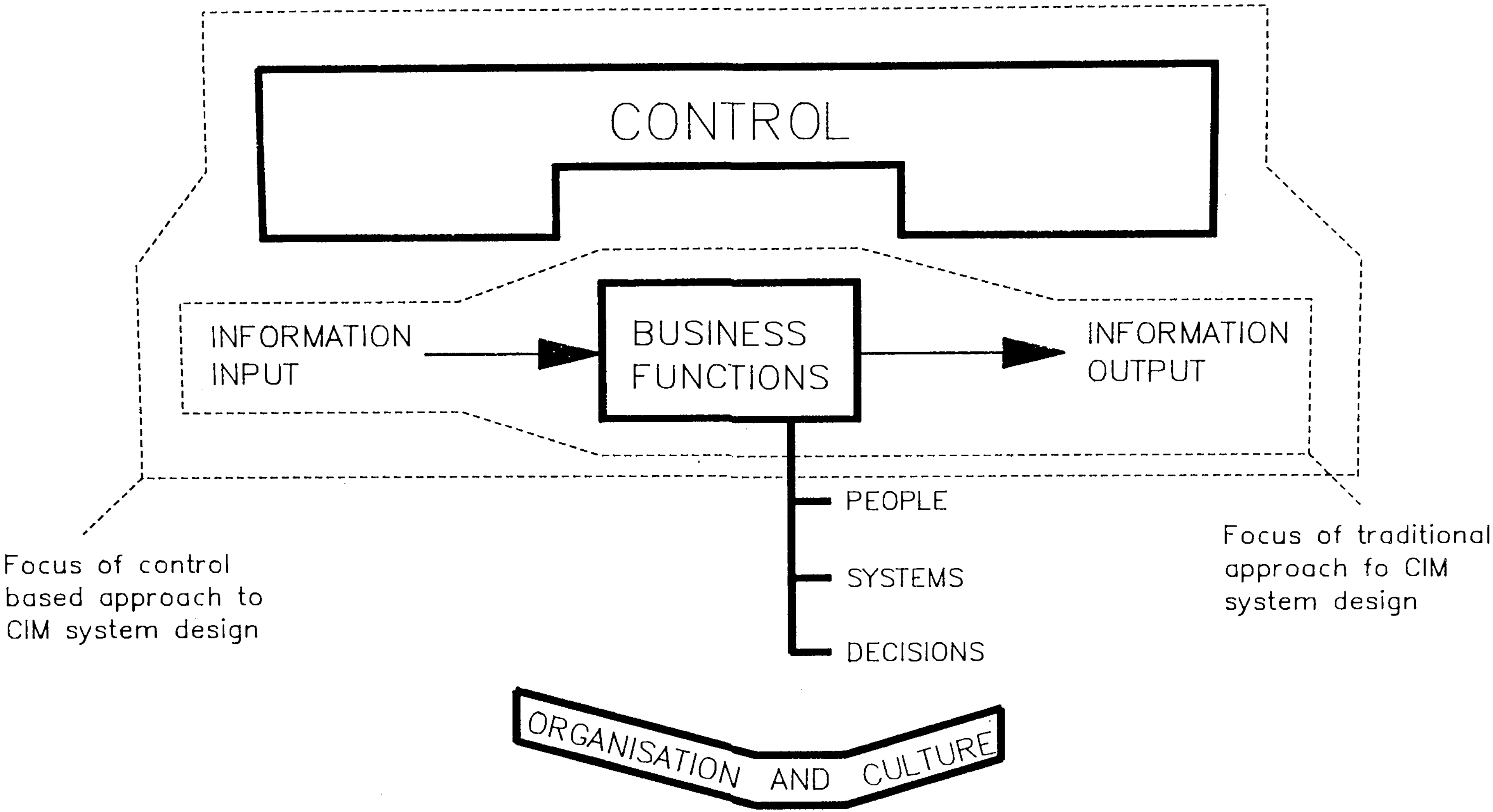


Figure (27): Focus of CIM system design – Control vs traditional approach

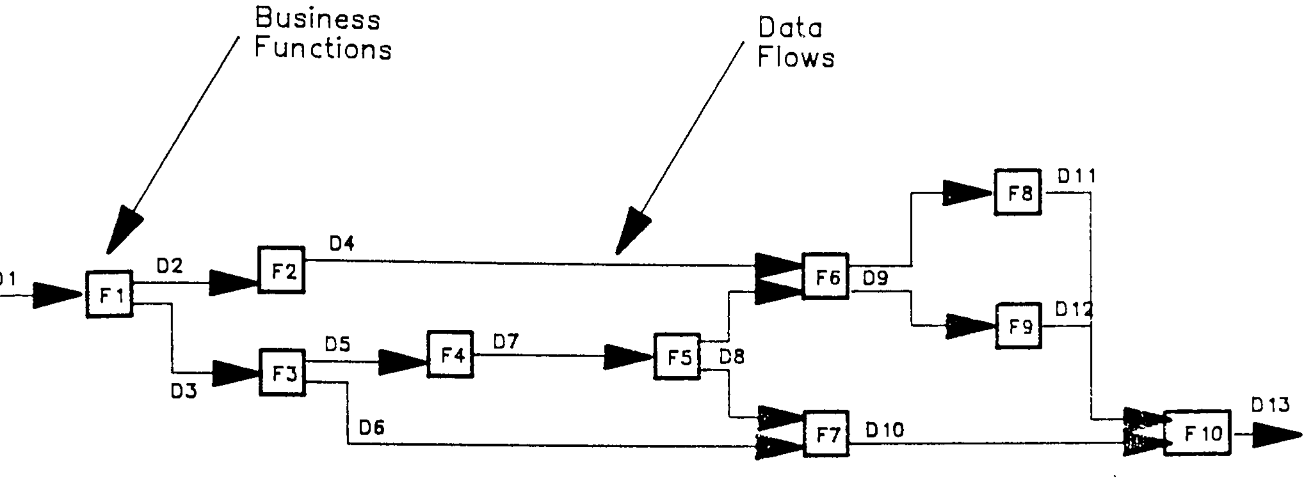


Figure (28): Simplified data flow chart

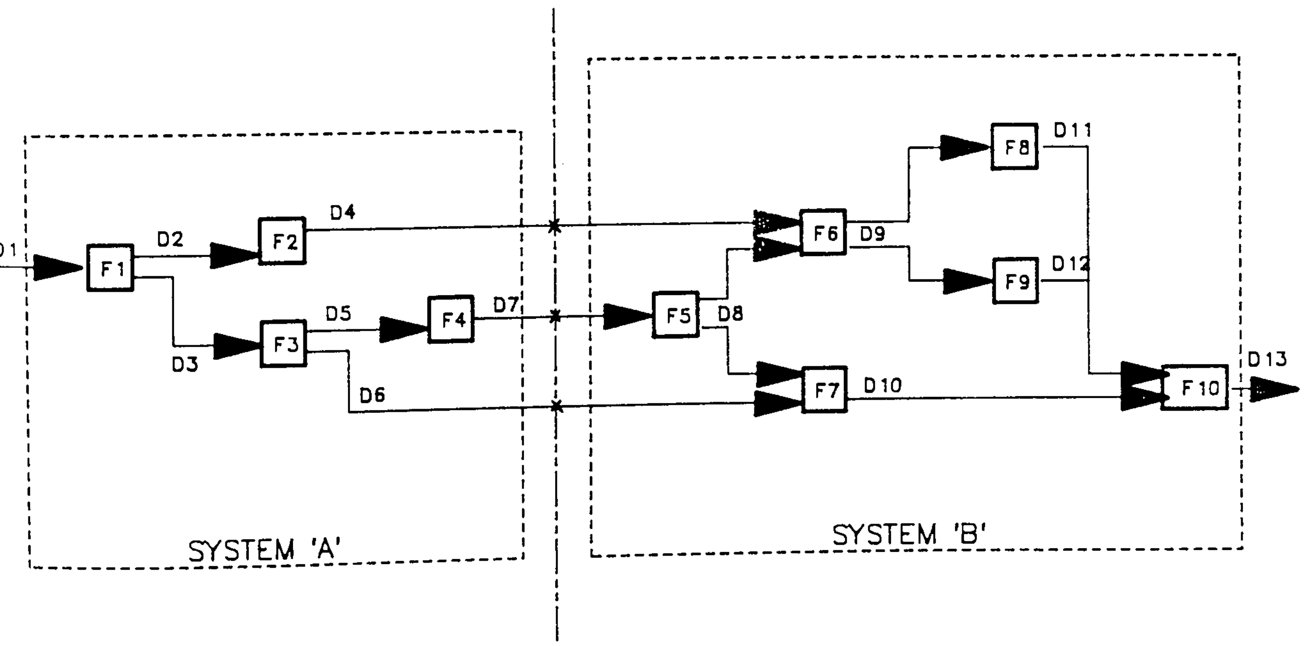


Figure (29): Intersystem data flows

based information between different CIM system elements to support control loop interactions. The control loop interactions can be classified into three types, namely 1. control loop closing, 2. control loop nesting and 3. control loop inter-chaining.

7.2.1 Control loop closing

Control loop closing is used to define inter-system 'control information' flows (systems integration) which support the closing of control loops. The standard control loop is shown in Figure (30), which illustrates the five key control elements. An example, which illustrates closing of the control loop through systems integration is shown in Figure (31). The example control loop closing is described as follows.

> The Manufacturing Resources Planning (MRP II) system is run daily and produces a foremans book of all the jobs to be done in each manufacturing cell. The foremans book is forwarded to the Cell Leader, who inturn actions the work to his subordinate operational workers. The operational workers book their start time and finish time into a Shop Floor Data Collection (SFDC) system using bar codes and a wander. At the end of each day the SFDC system feeds the actual bookings back to the MRP II system, such that the standards can be compared against the actuals followed by evaluation and replanning/planning.

In the example shown in Figure (31), the closing of the control loop is achieved by integrating two systems namely MRP II and SFDC systems. It can however, take up to three integrated systems to close a control loop. This would apply when the work activity itself is actually supported by a computer system [refer to Figure (31)]. The information flows required to close a control loop can flow both vertically and horizontally.

7.2.2 Control loop nesting

Control loop nesting is used to define inter-system 'control information' flows (systems integration) that support the closing of control loops when the planning element is hierarchically levelled and supported by two systems. Standard control loop nesting is shown in Figure (32), which

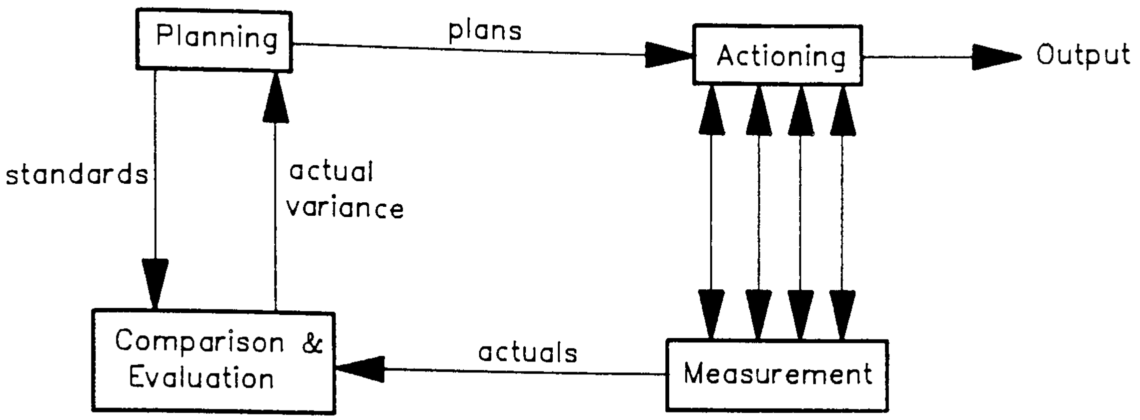


Figure (30): Standard control loop closing

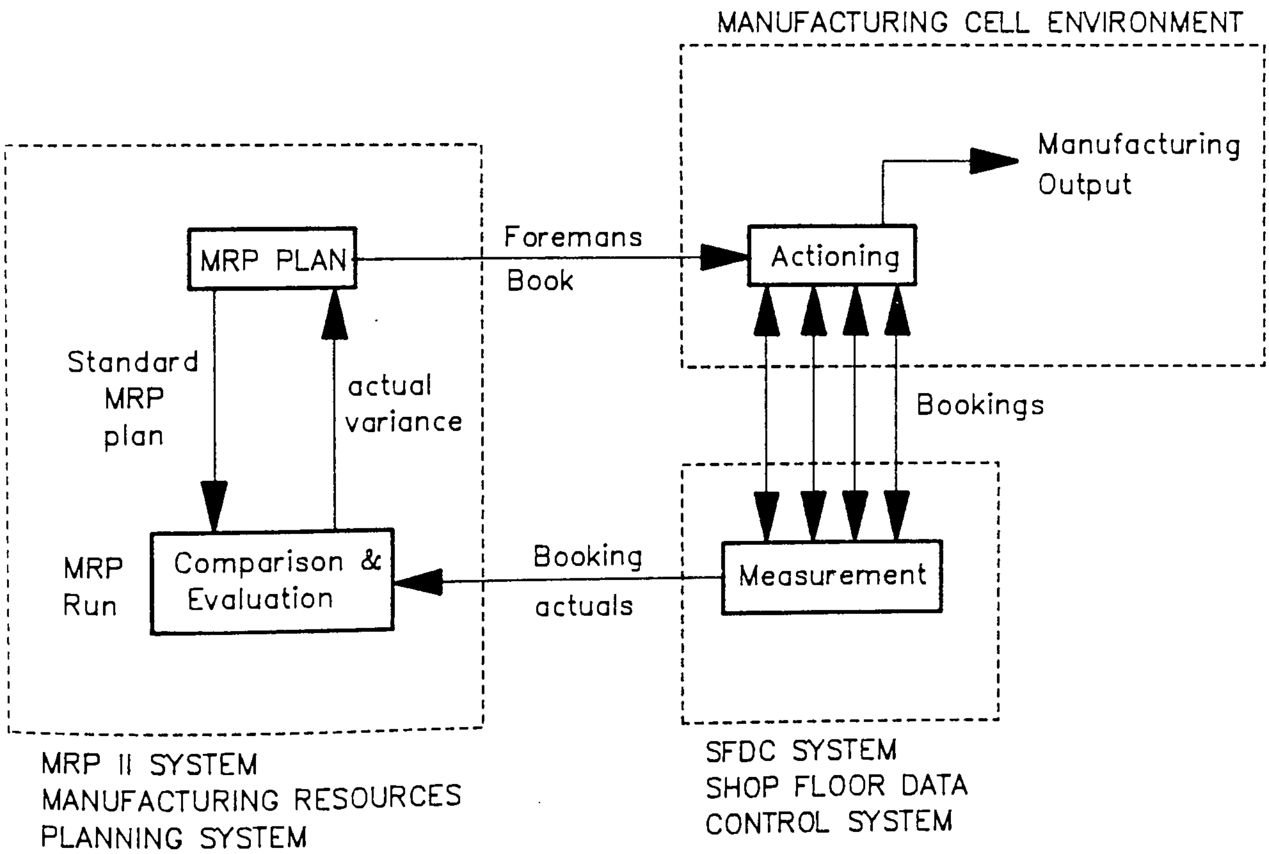


Figure (31): Systems integration to support control loop closing

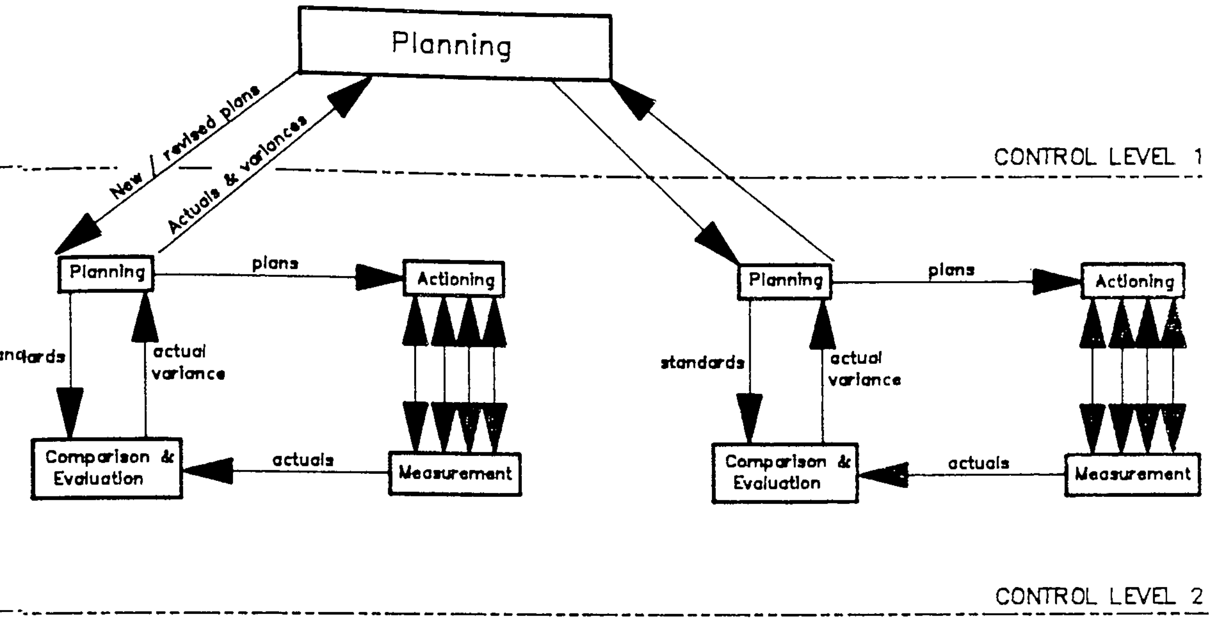


Figure (32): Standard control loop nesting

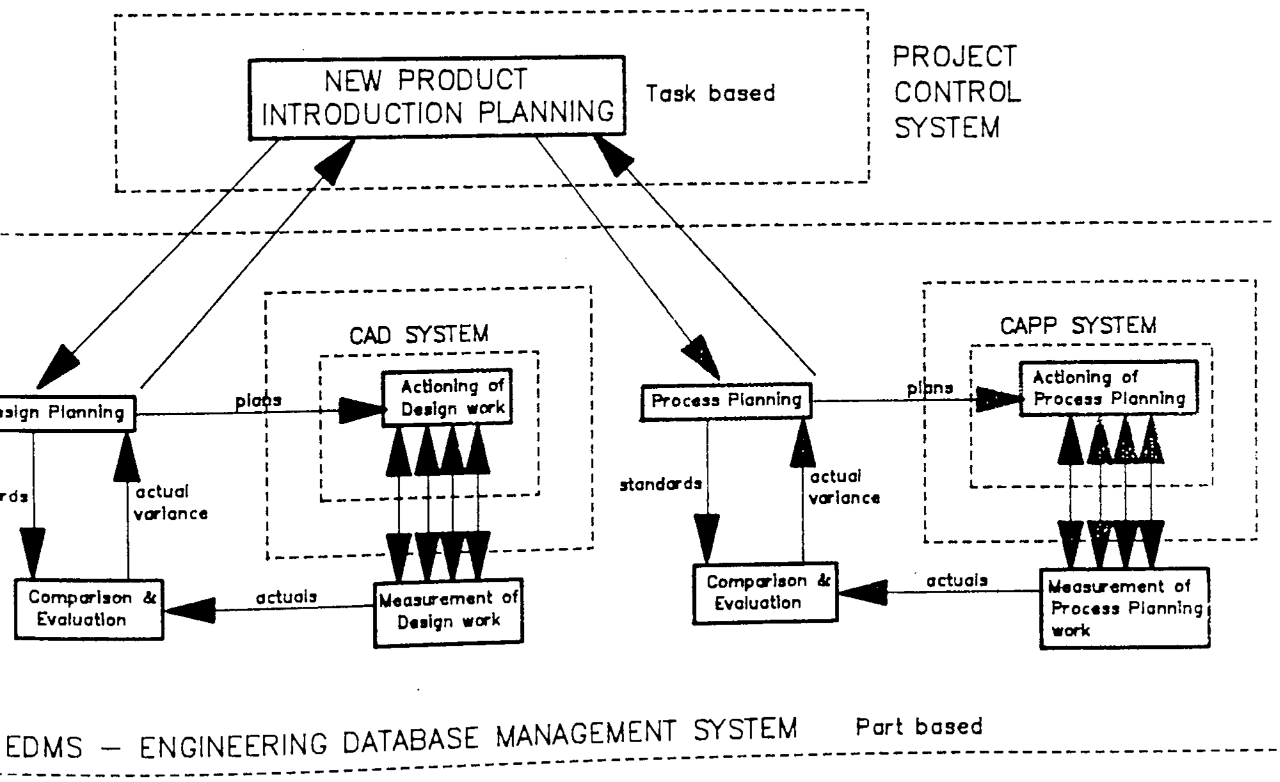


Figure (33): Systems integration to support control loop nesting illustrates how the planning element of two lower level control loops are linked to a single higher level planning element. An example, which illustrates control loop nesting through systems integration is shown in Figure (33). The example control loop nesting is described as follows.

> The Project Control System (PCS), produces a pure 'task' based plan for introducing a new product. These high level plans are forwarded to the Engineering Database Management System (EDMS), which takes these high level plans and breaks them down into more detail, resulting in the creation of part based plans. The EDMS then actions these lower level plans by sending a work request to a specific user i.d on the Computer Aided Design (CAD) system. The designer receives the work request and begins work. Once the design is complete the drawing is transferred from the 'in-work' space on CAD to the 'controlled' space (which can be anywhere on the network) under the direction of the EDMS. The EDMS logs the date of transfer and compare this date to the planned date. This subsequently results in the EDMS detail plans being reviewed. Summarised information regarding actuals dates and variances are then fed back to the PCS which uses the information to update the high level new product introduction plans.
>
> NB: A similar planning and control flow exists between the Project Control System (PCS) and the Computer Aided Process Planning (CAPP) system.

In the above example, refer to Figure (33), control loop nesting is achieved by integrating four systems, namely PCS, EDMS, CAD and CAPP system.

7.2.3 Control loop inter-chaining

Control loop inter-chaining is used to define inter-system 'functional information' flows (systems integration) that provide the necessary input information for action elements. Standard control loop inter-chaining is shown in Figure (34), which illustrates how the action element of one control loop can be linked to the action control element of another. An example, which illustrates control loop inter-chaining through systems integration is shown in Figure (35). The example control inter-chaining

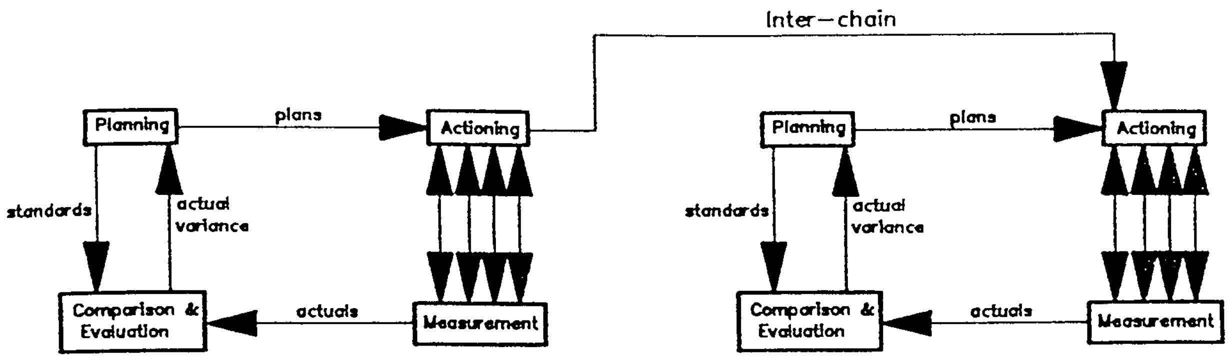


Figure (34): Standard control loop inter-chaining

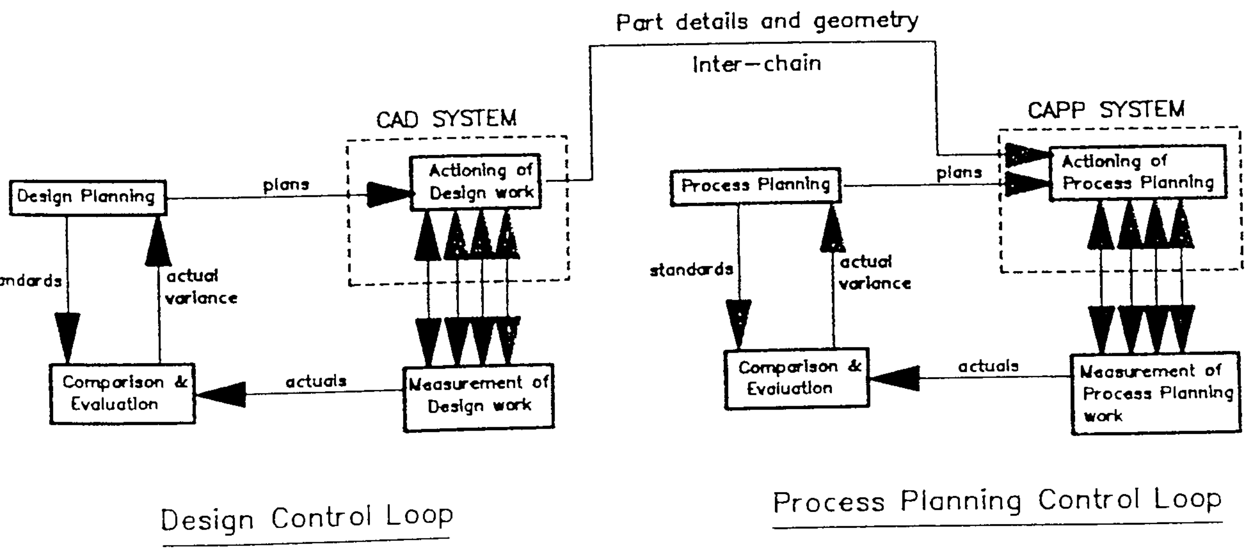


Figure (35): Systems integration to support control loop inter-chaining is described as follows.

A designer on CAD completes a drawing and gets it approved, once the drawing status is changed from 'in-work' to 'approve', the part details are extracted from the drawing (CAD database) and forwarded to CAPP which has a specific input requirement for that information.

In the above example, refer to Figure (35), control loop inter-chaining is achieved by integrating two systems, namely CAD and CAPP system.

7.2.4 Transaction information flows

The three types of control loop interaction as defined above have only considered two types of information flow, that is, control and functional information. The third type of information flow is of the transaction type which can be viewed not actually as information but as process integration because the flow is used to trigger a process.

Transaction information flows are based on the transaction chain control concept, as described in chapter 4.0, and can be present in both control loop nesting and control loop inter-chaining. It can be described by examining in more depth the example in Figure (35), where systems integration is used to support control loop inter-chaining.

The following scenario is used to explain transaction information flows.

NB: The EDMS as shown in Figure (33), is used as the drawing management system and as a controlling medium for the systems integration process.

A designer on CAD completes a drawing which is currently held within the 'in-work' area on CAD and gets the drawing approval note signed. Once the drawing is approved, the designers initials are entered into the 'approved by' field on the CAD drawing. This triggers two transactions, both of which are transparent to the user.

The first transaction transfers information from CAD to EDMS, which triggers a process within EDMS to transfer the drawing from the 'in-work' area on the local CAD station, to a controlled 'approved' area on the central CAD database, and subsequently updates the drawing status from 'in-work' to ' approved'.

The second transaction extracts part details from the CAD drawing and forwards this information to EDMS in a specified format which in turn sends this information to the CAPP system in a controlled way.

In both cases the transaction flow is from the CAD system to the EDMS system using its open programmable callable interface, and is used to trigger the execution of a process on the EDMS, rather like logging onto the EDMS and performing the process through manual execution.

At Lucas Aerospace, it is envisaged that transaction based information flows between systems will exceed any other kind of integration.

NB: It is suggested that all systems which are used to control business flows and procedures should have an open callable programmable interface.

The traditional view of CIM system design which uses functional and information flow analysis to specify inter-system information flows (systems integration) does not lend itself to the specifying of transaction based information flows.

7.2.5 System structuring

An important issue when defining a CIM system infrastructure is to understand how systems are related and structured. The traditional data and functional approach to CIM system design does not assist the process of establishing a systems structure, the only type of system relationship it develops is when two systems process the same functional information. The control based view of CIM system design establishes a control relationship between systems, which can be used to specify control related system structuring. It is based primarily on vertical control information flows between systems, where one system can be classified as the 'controller' system, (normally the higher level one), and the other system can be classified as the 'controlled' system, (normally the lower level one). This is developed through the control loop nesting.

7.2.6 Summary

There is a significant fundamental change to the basis of CIM system design, when comparing the traditional view with that of the control based view. It can be shown that the basis of CIM system design will change from that of a traditional view, where the CIM elements and their integration are largely based on the functional requirements of the business, to one where the CIM system elements and their integration are based primarily on control loop requirements and their interactions. The basis of the CIM system design would therefore be derived from control loop closing, control loop nesting and control loop inter-chaining requirements, the transaction chain control process integration requirements and the control related system structuring requirements.

7.3 Control hierarchy and its effects on CIM design

This section examines the application of a control hierarchy as the core of the CIM design process and discusses various aspects of such a control based design approach. This structured control based CIM design will then be contrasted with the unformalised design of the traditional approach.

7.3.1 Introduction and CIM design process discussion

In the previous section, it was shown that the control based view of CIM system design bases its integration requirements on the transferring of control, functional and transaction based information between different CIM system elements to support control loop interactions.

In chapter three, it was argued that levelled control hierarchies are capable of representing and analysing the complexity of control loops and their interactions across business functions in a real organisation.

It follows therefore, that levelled control hierarchies can be used to model and represent the integration requirements for CIM.

An examination of the control loop interactions, as discussed in section 7.2, shows that the control levels of the hierarchy have, in effect, been used to model specific business elements including control elements, information flows, business functions and computer systems. This can be seen in Figure (36), which shows how control levels can be used to structure CIM systems and model the various control loop interactions. The diagram can be explained as follows.

> The project control system which is responsible for new product introduction control is situated at control level 'A', where it produces task based plans which are forwarded to the EDM system situated at control level 'B'. The EDM system translates these task based plans into more detailed part based plans which forward actions to the CAD and CAPP system situated at control level 'C'. The integration requirements between these systems are represented by the control loop interactions shown. Control loop nesting exists between the project control system and the EDM system. Control loop closing exists between the EDM system and both the CAD and CAPP system. Control loop inter-chaining exists between the CAD and CAPP system, which supports the flow of part details, and a transaction information flow exists between the EDM system and the CAD system to trigger the execution of the CAD to CAPP part details interface. Finally, it can be seen that the system structuring is based on the control loop interactions between the systems.

An important stage of a CIM design is the construction of CIM business infrastructures to model the business elements and their positioning within the organisation. A particularly eminent one, is the CIM system infrastructure, which illustrates the CIM system elements, their positioning within the business and their integration requirements. Such infrastructure models provide a graphical means of illustrating the CIM system design for a business. It can be seen that the control hierarchy shown in Figure (36), is capable of representing the CIM system infrastructure.

The traditional view of CIM does not develop a method for constructing these CIM business infrastructures. In fact, the extensive literature review, performed by the author, revealed that no CIM design structuring method is commonly supported. Instead, the various CIM advocates propose CIM concept charts, CIM system interface charts and CIM system architecture charts. CIM concept charts illustrate the elements of CIM [McDonnell Douglas (1986), Cowan (1987), ICL (1986) and Vernadat (1986)]. CIM system interface charts illustrate the elements of CIM and their

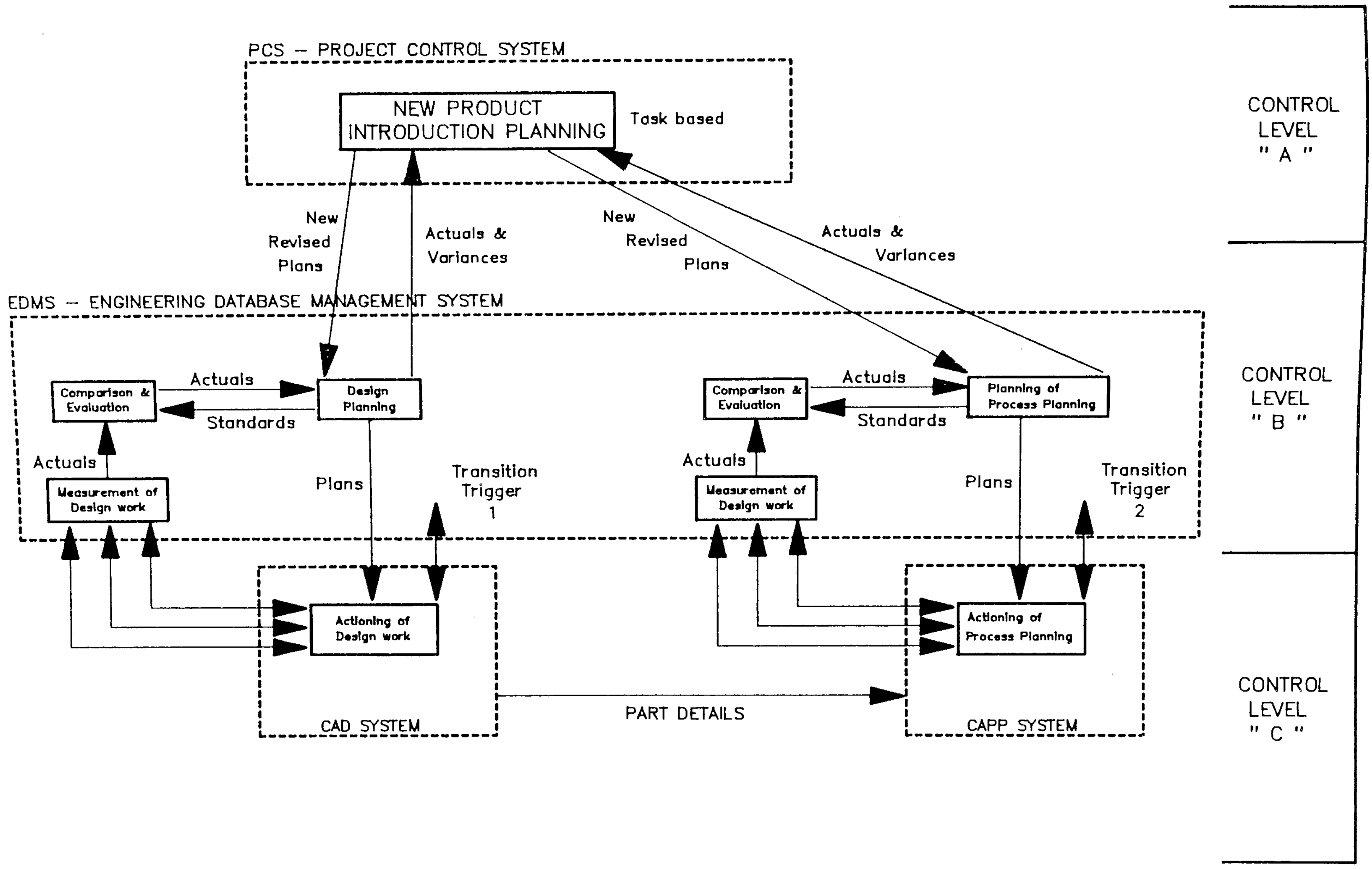


Figure (36): Control hierarchy levels, control loop interactions and system structuring interfaces [Reisch (1987), Rawlinson (1987), Cowan (1987) and Spur and Specht (1987)]. CIM system architecture charts display a logical and often levelled view of system elements and various attributes, for example level number, computer hardware type, functions and sometimes response time [Hearn and Weald (1987), Vernadat (1986) and Rzevski (1988)].

The above three chart types do not construct CIM business infrastructures, that is, none of the references examined attempt to link these charts to other business infrastructures, not even the organisation structure. Furthermore, the three charts should in fact be directly related as they are all views of the same fundamental CIM system design, but none of the references highlight this.

It can be seen that the control hierarchy has a large role to play in the CIM design process. As already shown a control hierarchy is capable of representing and analysing control loops and their interactions, which when related to systems is capable of illustrating the integration requirements between systems and their structuring within the business (CIM system infrastructure). Furthermore the control hierarchy has shown that it is capable of modelling various business elements including control elements, systems, information and processes.

It therefore seems reasonable to suggest, that control hierarchies could be used to illustrate the various CIM business infrastructures and model the business inter-element relationships. The use of control hierarchies for this purpose will be examined in the following section.

7.3.2 The hierarchical modelling of business elements

The use of control hierarchies to model business elements and their relationships is in fact supported by many authors. They include Kluchar (1987), Parnaby (1987), CIM Task Force (1988), Helming and Vasile (1987) and Vernadat (1986).

Kluchar (1987), develops a six level control hierarchy pyramid for a process steel making company. The pyramid is numbered bottom up 0 - 5 and illustrates the following elements, namely control systems, computer hardware and system application.

Parnaby (1987), illustrates a four level control hierarchy for manufacturing systems. The hierarchy is numbered top down 1 - 4 and illustrates business modular groupings, business functions, system elements and suitable computing equipment.

CIM task force (1988), proposes a four level control hierarchy for CIM. The hierarchy has four levels, namely business level, module level, cell level and work unit level. The elements illustrated, include nature of decisions, planning horizons, control cycle time frame and importance of decisions.

Helming and Vasile (1987), develops a five level control hierarchy to support hierarchical decomposition of manufacturing control. The hierarchy illustrates the following elements including management staff (personnel), business functions and computer systems.

Vernadat (1986), illustrates a five level control hierarchy to support a computer control systems architecture. The hierarchy has five levels, numbered bottom up, namely company, plant, job shop (cell), station and process. The hierarchy only models the type of computers used at each level.

It can be seen from examining the proposed control hierarchies that it is possible to model a significant number of different business elements and relate them together by classifying them within the same control level. Although there is no set pattern as to which business elements are considered more suitable for control hierarchy representation, the above five control hierarchies do collectively attempt to model six out of the eight key business elements.

In summary the five authors have shown that it is possible to hierarchically model business elements using control hierarchies.

7.3.3 Control hierarchy application review and CIM design

The application of control hierarchies across industry to model business elements has been developing for a number of years. Their original application within the process industry for illustrating control systems and devices is now fully established and common place. It can be shown that the application scope of control hierarchies is developing, but that a major proportion still focusses on production related aspects of a business. This is in fact supported by a control hierarchy literature review, which examined how control hierarchies are used across industry, including their application and design characteristics.

The literature review addressed fifteen control hierarchies and established criteria relating to the number of levels and numbering conventions, modelling scope of the control hierarchies, control hierarchy application type, business elements supported and response time for each level.

The control hierarchy literature review analysis criteria and results can be found in Appendix (G). The literature review results can be summarised as follows:

- the average number of levels is 4 to 5;

- no standard numbering convention prevails;

- the modelling scope of the various control hierarchies are focussed on production related activities, some 80% of the hierarchies are production related. Only one hierarchy was considered to assess the various business functions equally;

- the type of application the control hierarchies have been targetted at varied between production processes, computer systems, control and pure academic.

- the business elements supported by the hierarchy include:
    - 60% support the "control" element;
    - 87% support the "process/function" elements;
    - 13% support the "information" element;
    - 60% support the "systems" element;
    - 13% support the "people" element;
    - 7% support the "decision" element.

  The majority of control hierarchies focussed on the control, process/function and system business elements;

- 33% of the hierarchies identify the response time of each control level;

It can be concluded from the above results that although control hierarchies used across industry tend to focus on specific business elements within a production related environment, the actual type of application, (the primary focus of the control hierarchy) does in fact vary.

Given the evidence that control hierarchies are widely used for modelling business processes, controls and systems (refer to literature review), it follows that with the correct design the control hierarchy could be used to represent the CIM business infrastructures for the main business elements.

In order to maximise this modelling capability the control hierarchy design including its methodology should be developed with due consideration given to the business element modelling characteristics of the control hierarchy levels.

This approach for CIM system design was adopted at Lucas Aerospace and resulted in a detailed examination of control hierarchy design criteria including an investigation into control level characteristics for six out of the eight key business elements excluding business culture and organisation.

The above examination, resulted in the development of a control hierarchy design methodology including a list of design rules and a control level characteristics examination report for six of the business elements. The methodology and report is detailed in chapter eight, where a full CIM design methodology is proposed based on the developing control view of CIM.

The above methodology was used at Lucas Aerospace to develop a five level control hierarchy, which is detailed in the following section.

7.3.4 Proposed control hierarchy

The proposed control hierarchy model developed at Lucas Aerospace is illustrated in Figure (37), where it is drawn as a pyramid to represent the hierarchical nature of the business. The control hierarchy has five control levels which are numbered top down. Each Level can be defined as follows.

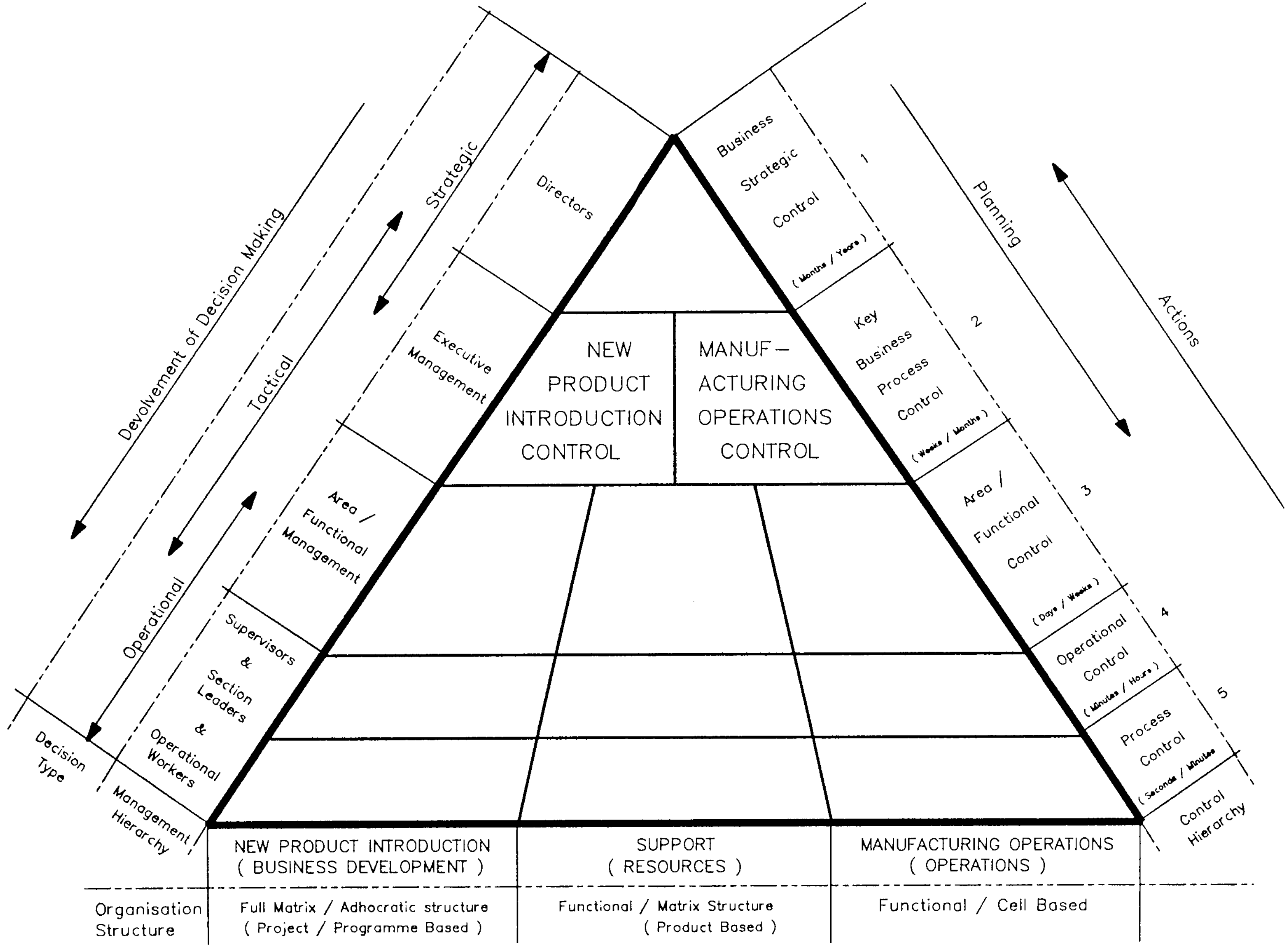


Figure (37): Control hierarchy model (Lucas Aerospace)

Level 1, is primarily involved with the development of corporate and strategic plans, which set the goals and the direction for the company. It follows that activities of this kind are long term and therefore the control level has a control response time of months or even years. Such activities are not departmental based, but are in fact business wide and are therefore performed by an executive board of directors. The decisions at this level are purely strategic.

Level 2, represents the primary driving processes of the business, and as shown include two, namely New Product Introduction (NPI) and Manufacturing Operations (MO). These two key business processes, as argued in chapter four, provide the focal point for coordinated and integrated business control through the adoption of the transaction chain control concept. This means that level two of the control hierarchy can be considered to be the logical control centre, for it is this level that controls all work done within the business at levels three, four and five. Control activities of this kind are medium to long term and therefore the control level has a control response time of weeks or months. The decisions at this level are a mixture of strategic and tactical.

The new product introduction process and manufacturing operations process are performed by the Business Development core group and the Operations core group respectively. Both core groups are supported by a Resources core group, which has a pure supporting role associated with financial accounting and control, personnel and training, business systems, quality control and administration.

Level three, is mainly involved with departmental or functional activities across the business, which directly or indirectly support one of the two key business processes. Functional control of this kind is short to medium term and therefore the control level has a response time of days to weeks. The decisions at this level are a mixture of tactical and operational. The level three activities can be grouped together under one of the three core groups mentioned earlier, namely Business Development, Operations or Resources. In fact levels three, four and five are also subject to this core group grouping.

Level four, is involved with the operational work of the business, that is, the various activities associated with the day to day work. The control of these activities are very much short term and therefore the control level has a response time of minutes to hours. The decisions at this level are purely operational.

Level five, is involved with the bottom level processes of the operational activities. Such activities are mainly associated with the shop floor manufacturing operations of the business, and are therefore mainly found within the Operations core group. The control of these processes is very much an ongoing concern, the control level therefore has a response time of fractions of a second to seconds or even minutes. The decisions at this level are of the bottom level operational kind.

The proposed control hierarchy suggests that the organisation structure for the three core groups, namely Business Development, Resources and Operations, should be full matrix and adhocratic structure, functional and matrix, and functional and cell based, respectively.

The control hierarchy would provide a useful means for analysing the control requirements of a business and represent the required control loops and their interactions. The control hierarchy would also provide the core platform for the development of CIM business infrastructures and the basis from which the CIM concept charts, CIM systems integration charts and CIM architecture charts can be developed.

In section 4.3, it was established that Lucas Aerospace is typical of a medium sized batch manufacturing company, involved in the design, development and manufacture of sophisticated and precision machined mechanical components. It is the authors contention therefore, that the business model is not just applicable to Lucas Aerospace, but is equally representative of any medium sized batch manufacturing company.

The control hierarchy has been successfully adopted at Lucas Aerospace and is examined further in chapter eight, where its application as the core of CIM design is discussed with examples.

7.3.5 Summary

This section has shown that a levelled control hierarchy can be used to analyse and represent the integration requirements for CIM, by modelling the various control loop interactions and CIM system structures.

Furthermore, it was argued that the application of a control hierarchy can be extended to model the CIM business infrastructures due to its capability of modelling various business elements.

To conclude, it can be argued that a control hierarchy can be used as the core of CIM design, which is not supported by traditional CIM designs.

7.4 Changes to CIM design methodology

This section examines the methodology differences that are likely to exist when contrasting the traditional CIM system design approach with that of the control based approach.

Developing the right methodology for CIM, as argued in chapter six is a very important stage and is likely to be the main contributing factor to the success or otherwise of the CIM project. In effect the methodology sets the framework within which the CIM environment is developed.

In the previous sections, it was shown that there are fundamental differences to the basis of CIM design, when comparing the control based view with that of the traditional view. These changes must be built into the CIM methodology to ensure the required CIM design is established. Such changes are likely to have a significant affect on the methodology and result in a change of focus from that of a functional bias to that based on control. The changes can be best described by examining a typical traditional CIM methodology, refer to Table (10).

From examining the control related gaps in chapter six and the changes to the basis of CIM design as discussed in the previous sections, changes can be predicted to the following:

- CIM objective definition;
- business analysis;
- CIM business model appraisal technique;
- CIM opportunity evaluation technique;
- CIM system and architecture design;
- CIM implementation plan;
- project team skills.

Steps

1. Develop CIM plan.

2. Define CIM objectives.

3. Conduct 'AS-IS' analysis and formulate 'AS-IS' functional models.

4. Fully appraise 'AS-IS' functional model.

5. Conduct 'TO-BE' analysis and formulate 'TO-BE' functional models.

6. Evaluate opportunities for CIM.

7. Develop 'TO-BE' CIM system design.

8. Create a CIM architecture.

9. Produce a CIM implementation plan.

10. Implement plan.

NB: The methodology has been derived from the CIM methodology literature review.

Table (10). Traditional CIM methodology

7.4.1 CIM objective definition

The defined CIM objectives (refer to step 2, Table (10),) should be broken down into their constituent business control objectives so that the important business controls can be identified right from the start. This involves the decomposition of CIM objectives into supportive business controls which they themselves can be further decomposed into more detailed controls. The traditional approach to CIM would therefore have a list of CIM objectives, where as the control based approach would also have a list of associated business controls.

7.4.2 Business analysis

CIM business analysis is an exercise in which the business is examined in order to develop a clear and detailed understanding of the processes, controls, information and procedures used. It typically involves the development of 'AS-IS' and 'TO-BE' business models.

The traditional view of CIM business analysis is generally function and information oriented and typically involves the development of functional and data business models [refer to methodology steps 3, 4 and 5, Table (10)]. It follows that the methodology and analysis tools are also function and information oriented.

The control based view of CIM business analysis involves the development of business models, which examine business controls, functions and information.

The key differences between the traditional and control based view of CIM business analysis can be summarised as follows.

The control based CIM methodology supports the use of process purpose and control analysis charts which identify the objectives of the process, the important controls used, the key outputs from the processes and the associated decisions made. Traditional methodologies tend not to use these charts.

Traditional CIM methodologies use levelled data flow charts to model the information flows between processes. Such charts do not provide the necessary means for analysing process and information controls. The control based CIM methodology adopts a process flow analysis technique known as IDEF (0), which models the information flows, processes and identifies the resources used and process controls.

The control based CIM methodology supports the use of control loop nesting charts and closed control loop charts, both of which assist in the specification of control and integration requirements as outline in section 7.2. The various types of control loop interactions to be analysed and represented using control hierarchies.

The top level business analysis charts, which examine the various business elements to be overlayed onto control hierarchies to represent CIM business infrastructures.

It can be seen that there are significant differences between the traditional and control CIM business analysis techniques

The control based CIM methodology steps and analysis tools are examined further in chapter eight, where a complete CIM methodology is developed based on the practical work performed at Lucas Aerospace.

7.4.3 CIM business model appraisal technique

The appraisal technique used for 'AS-IS' business models (refer to step 4, Table (10), should be developed to include the necessary steps for business control.

Traditional appraisal techniques focus on the functional and information 'AS-IS' analysis charts, and normally include the following checks:

- simplify and rationalise as far as possible all functions and information flows;

- check that all functions add value to the product, eliminate any non value adding activities (NVA's);

- ensure all information flows are necessary, check for multiple instances of the same data and establish master and slave instances.

Appraisal techniques for control based CIM should include the following:

- ensure that all control loops are closed;
- simplify and rationalise control, avoid control for control sake;
- ensure the time taken to close a control loop matches the required response time of the activity.

7.4.4 CIM opportunity evaluation technique

The method used for evaluating CIM opportunities (refer to step 6, Table (10), should be extended such that it considers the benefits of achieving effective control.

Traditional methods for evaluating CIM opportunities have focussed on investment appraisal techniques like discounted cash flow analysis and more strategic evaluation techniques which use critical success factors (CSF's) as the basis for CIM investment

A control based CIM system design should be evaluated using an investment appraisal technique which also considers the benefits to be gained by achieving effective control. One such technique developed at Lucas Aerospace involves the use of a checklist of critical control success factors (CCSF's), which experience suggests is necessary for success.

These CCSF's would be derived from the business control objectives specified at the start of the project.

7.4.5 CIM system design

In section 7.2, it was shown that the basis of CIM system design will change from that of a traditional view, where the CIM elements and their integration are largely based on the functional requirements of the business, to one where the CIM system elements and their integration are based primarily on control loop requirements and their interactions.

In section 7.3, it was shown that the control hierarchy is capable of analysing and representing the complexity of control loops and their interactions.

It follows therefore that the CIM system design, refer to step 7, Table (10), should adopt a methodology that involves the development of a control hierarchy to model the CIM system integration requirements and the CIM business infrastructures.

7.4.6 CIM system architecture design

The design of a CIM system architecture, refer to step 8, Table (10), should be such that it accommodates a standard systems integration control framework and develops an architectural form which supports the coordination and control mechanism and matches the organisation structure.

The standard systems integration control framework should adopt a standard systems integration model and procedure, which is supported by a standard inter-system communication and control system, which in turn includes a transaction log for logging interface transactions, a register for indexing data and systems and a standard set of interface software. Such an architecture is necessary to provide the data management and control functions to support the overall business control requirements.

The logical design of a CIM system architectural form should be based on the proposed five level control hierarchy, due to its ability to analyse and represent control loop interactions, and model CIM business infrastructures. The control hierarchy provides a common platform for modelling various business elements including in particular business control requirements, CIM systems and their integration, the business functions and organisational structures.

An architecture based on the above was developed at Lucas Aerospace and is detailed in chapter 9.0.

7.4.7 CIM implementation plan

The CIM implementation plan, refer to step 10, Table (10), should reflect the relative importance of the business controls. The implementation sequence of the various CIM elements and their integration should be scheduled to support the primary business controls first. For example, if a control loop has been identified as the main priority and three integrated systems are required to close it, then an implementation plan should be developed to establish the three integrated systems first.

Traditional CIM implementation plans tend not to disclose their reasoning behind the schedule of events.

7.4.8 Project team skills

The skills of the project team need to be expanded to cater for the control related changes to the CIM methodology.

A control based CIM project team need additional skills to those required of a traditional CIM project team. They include the following:

- a good understanding of the business and the controls that are used to help ensure achievement of business objectives;

- a basic knowledge of control theory including an appreciation of control elements, control loops and their response times,and control loop nesting;

- a good working knowledge of control oriented business analysis techniques including IDEF (0) process flow analysis, control loop requirement charts (including control loop nesting) and process purpose and control analysis charts.

- an understanding of control hierarchy applications and its use as the core of CIM design.

7.5 CIM design review and summary

The design of traditional CIM systems has been largely based on the functional requirements of the business and the information input, output and storage requirements of each business function. The functional and information requirements were used as the basis for specifying the required CIM system elements. Integration was viewed purely as a means of transferring functional information across the business between different CIM system elements.

This traditional CIM design has consequently resulted in a design methodology which supports an approach and analysis tools that focus on the functional and information aspects of a business.

The design of control based CIM systems can be based on the control requirements of the business and the functions and information associated with these controls. Taking this approach, the specification of CIM system elements is based on business control requirements and their associated functions and information. Integration in this case is viewed as the transferring of control, functional and transaction based information between different CIM system elements to support control loop interactions.

This control based CIM design requires a design methodology which supports a control based approach to CIM, with the necessary analysis tools that focus on the control requirements of the business and are capable of relating this control to business functions and information.

It has been shown within this chapter that the basis of CIM and the design methodology required for a control based CIM system design is significantly different to that of the traditional view.

A control based CIM system design views its various elements as control systems employed to control specific areas within the business. The system design is based on the transaction chain control concept, which provides the capability of developing a totally automated controlled business environment, in which all departments of an organisation are able to work together in a reasonably integrated and controlled manner, towards common business goals. Integration requirements, as already argued, are therefore based on the various horizontal and vertical control loop interactions. As far as the author is aware, this control based view of CIM is unique, and has only been applied to Lucas Aerospace.

A control based CIM system design methodology adopts a significantly different and indeed new approach to business analysis, which focusses on the controls of the business. A five level control hierarchy is proposed as the core of the CIM design, which provides a particularly useful medium for illustrating the CIM business infrastructures. Such an application of the control hierarchy extends its use into new areas and aids the development of a unique methodology for CIM

A full CIM design methodology has been developed at Lucas Aerospace based on the findings of this research. The methodology is examined in full in the following chapter, chapter eight.

8. PROPOSED CIM DESIGN METHODOLOGY

This chapter identifies the various requirements associated with the development of a CIM design methodology and establishes a detailed unique approach and method for achieving an integrated and controlled business environment.

Introduction and industrial case study

This thesis has shown that there is a mutually supportive relationship between CIM and business control, which can be used as the basis for developing a fully integrated and controlled business.

Chapter six argued that the importance of developing the right methodology for CIM is becoming more apparent and that current methodologies have various knowledge gaps due to their failure to consider aspects of business control. Chapter seven subsequently examined these aspects of control and proposed various changes to the basis of CIM design and the methodology used.

This chapter develops a CIM design methodology that fills the knowledge gaps identified in chapter six, and adopts the control related changes associated with the basis of CIM design and methodology used, as identified in chapter seven.

The proposed CIM design methodology was developed by the author and successfully applied to Lucas Aerospace.

8.2 CIM design methodology requirements

This section, based on the findings within chapter 6.0 and 7.0, lists the requirements associated with the development of a CIM design methodology.

The requirements are based on the control related knowledge gaps (section 6.4.1), the other knowledge gaps (section 6.4.2) and the whole of chapter seven, which discusses the affects of control on a CIM design methodology.

The requirements are as follows.

1. A business wide and employee supported approach should be adopted to ensure that all areas of the organisation are involved in the overall process, and that support and commitment is gained from everyone.

2. An integrated strategy network should be developed which links each CIM element to a number of business controls and strategic objectives, which are in turn linked to various business goals. Such a network provides a visual representation of how the CIM elements support the business goals, which in turn helps to justify the CIM investment on strategic grounds and provides a means for establishing CIM element priorities.

3. During the development of the integrated strategy network, the CIM objectives should be broken down into their related primary business control objectives, which they themselves can be further decomposed into more detailed controls. The result of this process is a clear focus on the important business controls that need to be considered during the development of CIM environment.

4. The CIM business analysis technique should involve the development of 'AS-IS' and 'TO-BE' business models, which are capable of examining the control requirements associated with business functions and information. A CIM business analysis methodology should include the steps and analysis tools highlighted in section 7.4.2.

5. The CIM business analysis methodology should adopt an approach which takes the 'AS-IS' business models and then through simplification, optimisation and various appraisal checks, creates the 'TO-BE' business models.

   NB: The appraisal checks should include those associated with business controls.

6. The CIM business analysis methodology should adopt a standard structured systems analysis technique together with appropriate Computer Aided Systems Engineering (CASE) tools.

7. The method used for evaluating CIM opportunities should be extended

such that it considers the benefits of achieving effective control. The use of Critical Control Success Factors (CCSF's) is required.

8. CIM system design should base its integration requirements on the transferring of control, functional and transaction based information between different CIM system elements to support the three main control loop interactions, namely control loop closing, control loop nesting and control loop inter-chaining. The system design methodology should include steps which provide an effective means of examining the various control loop interactions.

   NB: Transaction based information flows which support process integration should be based on the transaction chain control concept, refer back to chapter four.

9. A five level control hierarchy should be used as the core of a CIM system design due to its capability to effectively model various business elements and its application as the core platform for the development of CIM business infrastructures.

10. System prototyping and walkthroughs should be adopted to demonstrate the operational aspects of the system and in particular the coordination and control mechanism changes.

    NB: System prototyping and walkthroughs typically involve 'walking' the user 'through' a proposed environmental change, using some form of modelling or demonstration means.

11. The control hierarchy to be used as the basis for the development of a CIM system architecture due to its ability to analyse and represent systems integration requirements and model CIM business infrastructures.

12. The methodology for establishing a CIM system architecture should include the necessary analysis steps to develop a standard systems integration control framework.

13. The CIM implementation plan should be developed after due consideration has been given to the important business control

requirements, such that the various CIM elements and their integration can be scheduled to support the primary business controls first.

The remaining requirements affect all stages of a CIM design methodology.

14. The project team members should have the understanding and necessary skills to carry out a methodology which has been based on the above requirements.

15. A 'management of change' process should be established, which provides a set of guidelines to ensure effective implementation of the CIM system.

8.3 The approach

Prior to developing a detailed CIM design methodology, an examination of the business is required to establish the most appropriate high level CIM approach, from which the methodology can be derived.

The CIM approach established for Lucas Aerospace is illustrated in Figure (38). The figure shows two distinct boxes, one representing "where the company is now", that is the 'AS-IS' case and the second, the "most effective integrated business", that being the 'TO-BE' case. Due to the fact that Lucas is a mature business with a considerable investment in computing technology and manufacturing facilities, one could argue that the only process required is to integrate, as identified by following 'Route 1'. However this route is based on various assumptions, namely that the:

- business is effectively controlled;
- organisation is optimum;
- business functions are in the most simplified and effective form;
- processes, procedures and roles are value adding and optimally performed;
- information used across the business is accurate, timely and readily interpretable;
- computer systems effectively support the business functions.

It was decided that these assumptions could not be made and that an

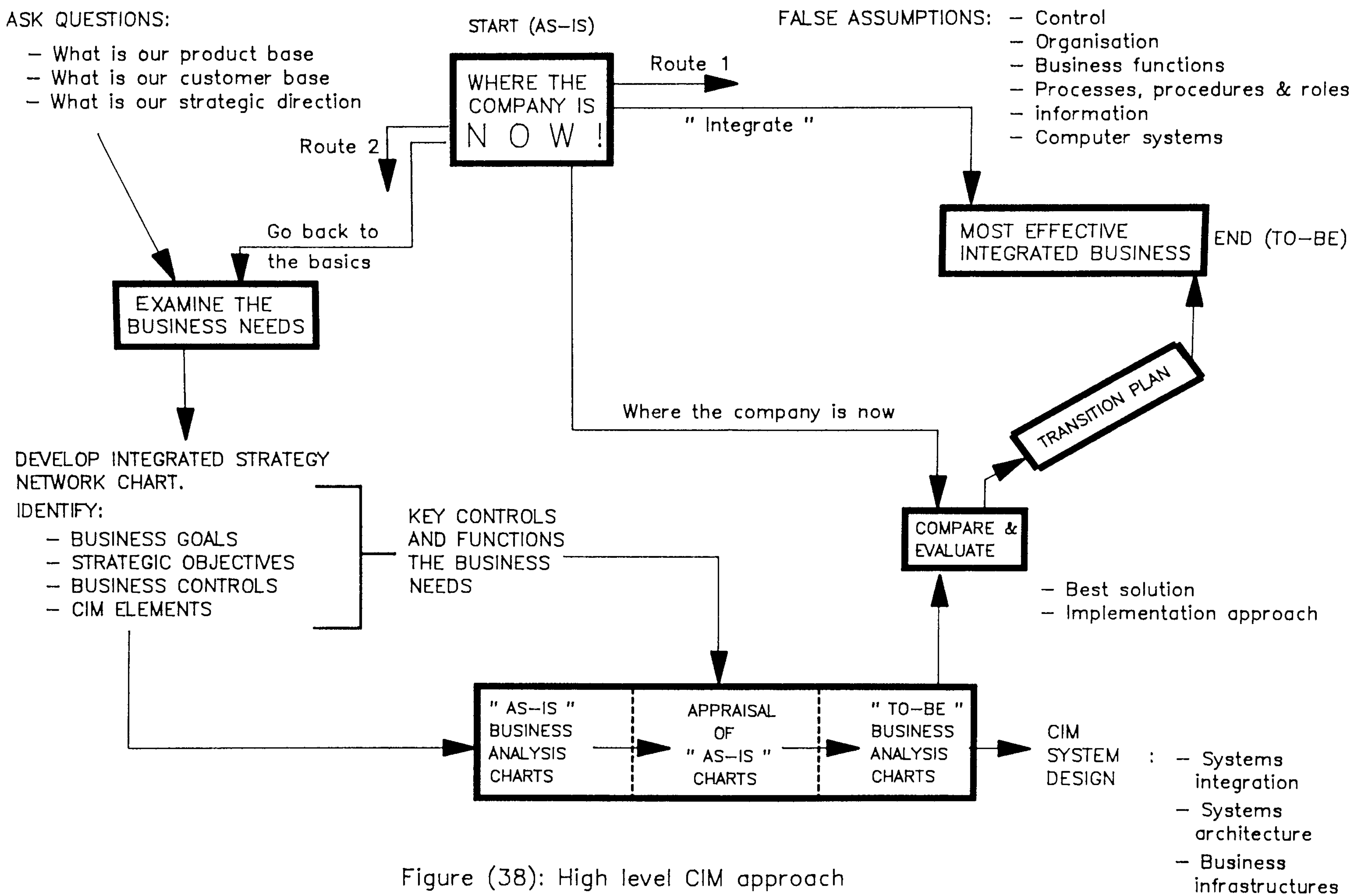


Figure (38): High level CIM approach

examination of the various business aspects should be performed. This meant following 'Route 2', which involved going back to the basics and establishing the answers to the following questions:

- Why are we here?
- What is our product base?
- What is our customer base?
- What is our strategic direction?

From these, the business needs are examined and subsequently a network chart is drawn which identifies the business goals, strategies, primary controls and CIM elements. The network chart is used to identify key functions which are subsequently used to build models of "where we need to be". The optimised business model of "where we need to be" is then compared with "where we are now", any constraining factors are identified and considered, the variance between the two models is evaluated to determine the best solution. Finally from this a transition plan is developed.

Such an approach provides the basis from which a CIM design methodology can be derived, which is capable of supporting the development of the most effective integrated business, and is capable of linking the CIM elements back to the business goals. The approach, although specifically developed for Lucas Aerospace, should be equally applicable to any medium sized mature batch manufacturing company involved in the design, development and manufacture of complex sophisticated products.

8.4 Methodology defined

This section discusses the CIM design methodology adopted at Lucas Aerospace, which was derived from the high level CIM approach (refer to section 8.3), and incorporates the methodology requirements reviewed in section 8.2.

8.4.1 The method - overview

The method used at Lucas Aerospace to develop an effective integrated environment comprises the following steps.

1. Develop a phased CIM plan and gain full senior executive commitment.

2. Develop a business wide and employee supported approach to CIM.

3. Identify and examine the strategic requirements of the business and establish an integrated strategy network chart.

4. Provide business models of where the business is now (AS-IS business models).

5. Identify and examine problems, inefficiencies and any non value added activities associated with current procedures and fully appraise 'AS-IS' business models.

6. Provide business models of where the business needs to be. (TO-BE business models)

7. Identify CIM system elements and provide a CIM system infrastructure model. (Must illustrate current and proposed system elements).

8. Develop systems integration architecture. (Must illustrate current and proposed system hardware/networks).

9. Determine implementation approach; against each CIM element make build, buy or modify decision.

10. Develop a phased transition plan to take the business from its 'AS-IS' state to its 'TO-BE' state.

11. Provide full cost/benefit analysis and investment appraisals.

12. Implement transition plan and monitor.

The sequence of the above steps are diagrammatically represented in Figure (39).

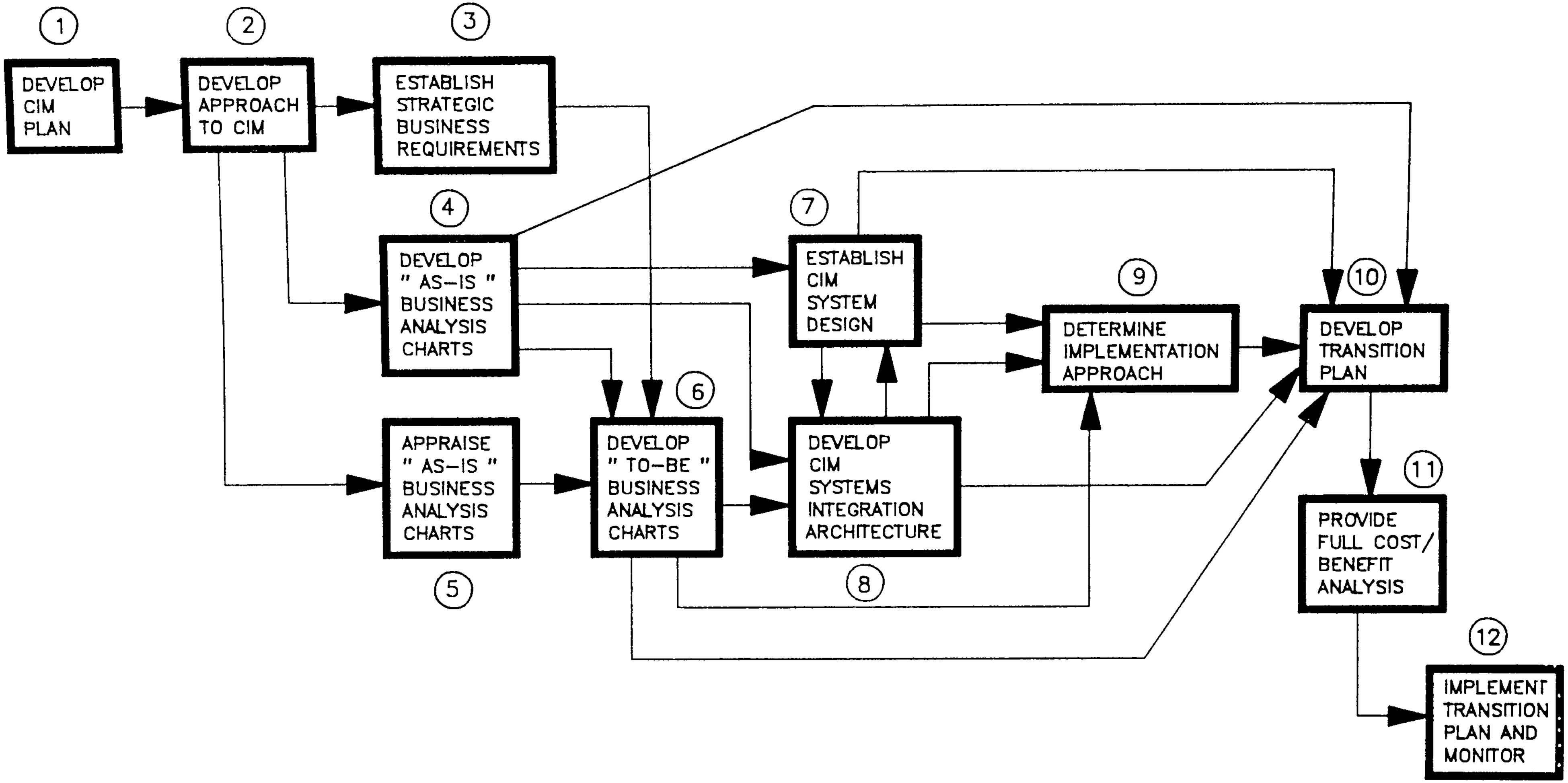


Figure (39): A 12 step CIM design methodology

8.4.2 The detailed methodology

Each of the steps are now broken down into more detail.

Step 1 : Develop a phased CIM plan and gain full senior executive commitment.

1.1 General Manager to provide a letter of commitment to CIM, which is disseminated to all senior managers.

1.2 A CIM Manager to be appointed, who reports directly to the general manager (commonly referred to as CIM champion)

1.3 Provide a terms of reference for the CIM project, to include the following:

- introduction and background;
- objectives;
- scope;
- method, checkpoints and deliverables;
- phased time plan;
- resource requirements;
- reporting structure and frequency.

1.4 Provide a CIM policy statement to ensure the project will be clear on issues such as:

- stability of organisation;
- cost of computing as percentage of sales;
- priority areas within the business;
- expenditure plans/budgets;
- devolution of decision making;
- system data to be owned by the users;
- return on effort (investment appraisal);
- internal and external constraints.

1.5 Establish a CIM board of executive comprising senior business executives from all areas of the business. At Lucas Aerospace the following senior managers were on the CIM board, namely the:

- Divisional General Manager (Chairman);

- Manufacturing Operations Manager;
- Business Development Manager;
- Finance Manager;
- Quality Manager;
- CIM Manager (Business Systems Manager).

Their main role is to define the CIM objectives, determine or clarify policy points, help establish and agree CIM plan, review business issues, agree priorities, review progress against plans and objectives, help resolve conflicts and problems, steer CIM project and signoff project deliverables at each checkpoint.

The CIM Executive to be convened quarterly. Meetings may be called on a more frequent basis to resolve important problems, conflicts or concerns.

1.6 Establish a middle management steering group to review tactical and operational issues during business analysis, guide the project team towards the attainment of project deliverables, resolve concerns and conflicts, discuss and agree resourcing levels, prioritise monthly activities and review/agree business analysis charts and procedures.

At Lucas Aerospace the steering group was made up of various 'user' middle management, project team and project leaders and system development managers. The CIM manager was appointed the role of steering group chairman. The steering group to meet monthly, other non scheduled meetings can be held to address important issues.

1.7 Establish a multi-skilled CIM development team. The project team members should have the necessary understanding to undertake a control oriented CIM development, as specified in methodology requirement 14, section 8.2.

The team members should have:

- a good understanding of the business activities and the controls that are used to help ensure achievement of business objectives;

- a basic knowledge of business control including an appreciation of control elements, control loops and their response times,and control loop nesting;

- some experience of using a standard structured analysis methodology including a good working knowledge of:

  - control oriented business analysis techniques including IDEF (0) process flow analysis, control loop requirement charts (including control loop nesting) and process purpose and control analysis charts;

  - data modelling using a standard entity-relationship chart and data dictionary.

  NB: Lucas Aerospace adopted the CACI data modelling standard;

- an understanding of control hierarchy applications and its use as the core of CIM design;

NB: The necessary training should be given to the team members prior to project launch.

1.8 Select project management technique and standard structured analysis methodology to be adopted.

Lucas Aerospace adopted the Project Manager Workbench (PMW) system for project managing the CIM project. The standard structured analysis methodologies selected to include the following:

- IDEF (0) for:
  - levelled process flow analysis;
  - process hierarchy;

- CACI for:
  - data modelling (entity-relationship charts);
  - data dictionary;

- Lucas developed standards for:
  - documentation standards;
  - interview note sheets;
  - presentation standards;
  - process purpose analysis and control charts;
  - control loop charts.

Lucas employed the Design/IDEF Computer Aided Systems Engineering (CASE) tool to support the IDEF (0) technique, and the Oracle CASE tool to support the CACI technique and provide a data dictionary.

NB: The adoption of a standard structured technique and CASE tool was established as methodology requirement 6, refer to section 8.2.

1.9 The CIM executive (chaired by Divisional General Manager) to agree CIM plan and launch project.

<u>Step 2</u> : Develop a business wide and employee supported approach to CIM.

Steps 1.1, 1.2, 1.4, 1.5, 1.6, 1.7 and 1.9, all contribute towards the development of a business wide and employee supported approach.

2.1 Demonstrate the support and commitment of the senior executive and management towards the achievement of CIM by getting the:

- General Manager to disseminate a communications note to all employees expressing the importance of CIM and the need for everyones support;

- CIM Executive to pin various CIM communication sheets on the communications board;

- various departmental managers to discuss the plans for CIM with their subordinates.

2.2 Develop a business wide understanding of the importance of CIM and develop the perception of change from that of a threat to that of an opportunity. This can be achieved by:

- emphasizing the need for change to improve business performance;

- putting all employees through a structured course of seminars and videos, which discuss the need for CIM and portray business change as an opportunity;

- discussing the issue of job security with employees.

- emphasizing that employees will be retrained wherever required.

2.3 Emphasize that support and commitment is required by all and develop a business wide team approach.

2.4 Through meetings, communications and seminars, develop a single focus on CIM and a shared vision of the company's future.

NB: The development of a business wide and employee supported approach to CIM was identified as a CIM design methodology knowledge gap in chapter six, and was subsequently established as methodology requirement 1., see section 8.2.

<u>Step 3</u> - Establish and examine the strategic requirements of the business.

3.1 Examine in some detail the strategic plan for the business.

Identify and examine the:

- business goals/objectives (ROCE, profit growth and positive cashflow);

- current position of company, to include market share, customer base, product mix, product technology and external factors;

- customer ratings of Lucas Aerospace against competitors;

- Strengths, Weaknesses, Opportunities and Threats (SWOT analysis).

3.2 Develop an integrated strategy network chart for the business. The network chart to include the following column headings:

- business goals;
- business strategic objectives;
- detailed business objectives (CIM objectives);
- business controls;
- CIM elements.

The network chart is drawn by starting with a list of the business goals on the far right. Each major core group of the business then establishes it's various strategic objectives which contribute towards the business goals. Links are drawn connecting the various strategic objectives to each of the business goals. Each of the strategies are then examined and a list of detailed business objectives (CIM objectives) are identified for each; again links are drawn. A similar process is then performed linking various business controls to the detailed business objectives. Once a business control list has been established, CIM elements are identified which support the business controls, which in turn support the detailed business objectives, strategic objectives and ultimately help achieve the business goals. An example network chart is illustrated in Figure (40) which focuses on the engineering core group.

3.3 Discuss and agree the strategy network chart with the user group and the executive committee.

NB: The development of a integrated strategy network chart was identified as a CIM design methodology knowledge gap in chapter six and required methodology change in chapter seven, and was subsequently established as methodology requirement 2., refer to section 8.2.

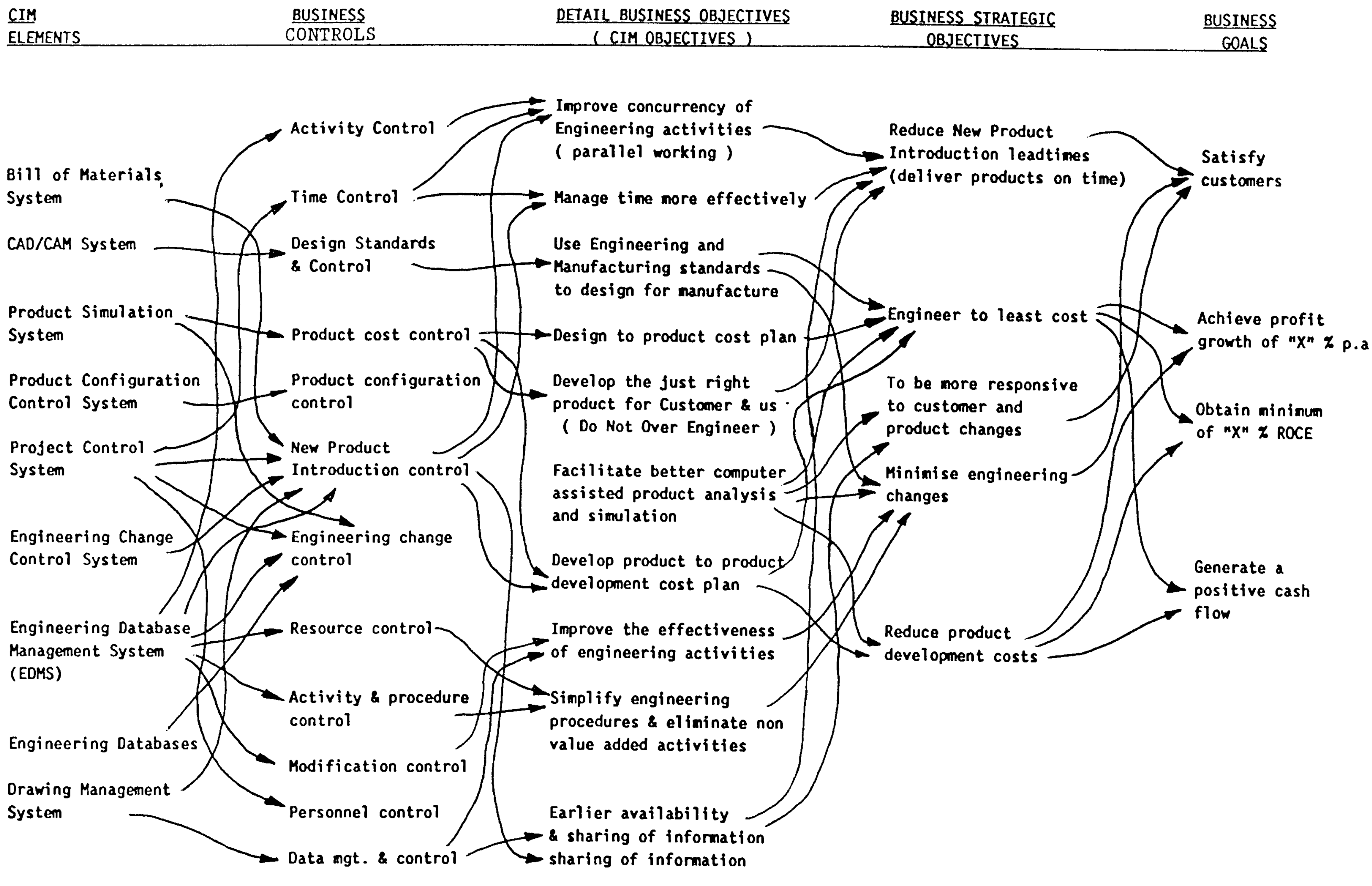


Figure (40): Integrated strategy network chart

Steps 4, 5 and 6 are all a subset of business analysis, and are therefore discussed collectively.

In chapter six, it was argued that the business analysis step is one of the most important activities during a CIM development, and involves the establishment of both 'AS-IS' and 'TO-BE' business analysis charts. It was also argued that an approach should be developed, which is capable of taking the 'AS-IS' model, and through simplification and optimisation, create the 'TO-BE' model. This was subsequently established as methodology requirement 5., refer to section 8.2.

Steps 4, 5 and 6 can be defined as follows:

4. provide business models of where the business is now (AS-IS);
5. perform a full appraisal of the 'AS-IS' business models;
6. provide business models of where the business needs to be (TO-BE).

At Lucas Aerospace, such an approach was developed. The approach is hierarchical and adopts a top-down 'AS-IS' breakdown technique, followed by a bottom-up 'TO-BE' summarising technique. The approach is shown in Figure (41) and flows from left to right.

A business analysis model of the business in its 'AS-IS' state is produced and subsequently hierarchically broken down, level by level, into more detail. During the breakdown the levelled business models are examined; any problems, inefficiencies, illogicalities, etc., are noted. Once the hierarchical breakdown is complete, the business models are fully appraised. All but the bottom business models are disregarded, which in effect removes any reference to the existing 'AS-IS' business structure. This bottom level set of business models illustrates the business processes, controls and information required but has no control, functional or data structures.

The next step is to perform a bottom-up summarising process for business models to develop the "TO-BE" control, functional and data structures. As the summarising up takes place the business controls, functions and information are grouped to provide simplified and optimum structures.

NB: An important point about the approach is it provides a systematic way of modelling certain aspects of business redesign.

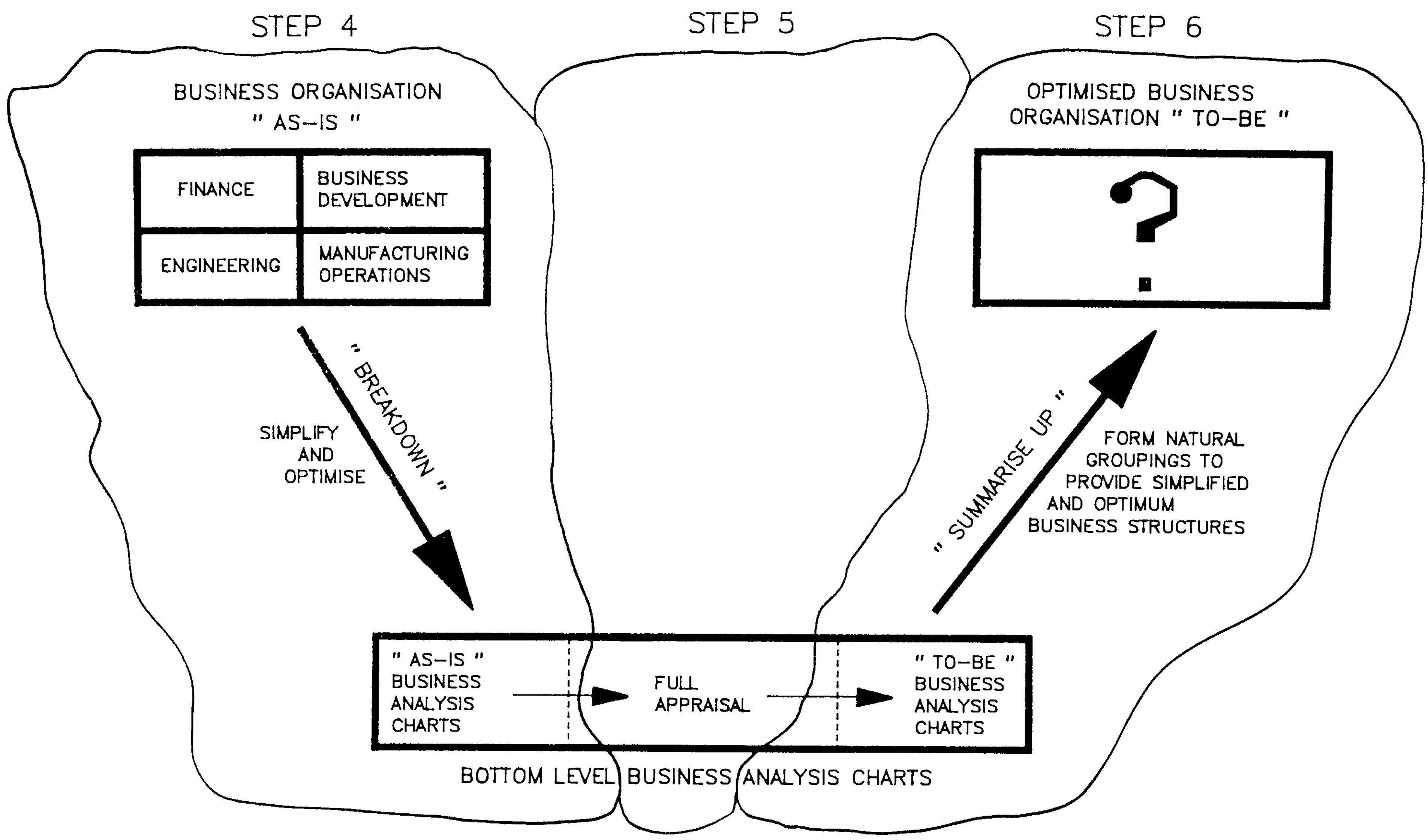


Figure (41): Business analysis approach

The three steps can be detailed as follows.

Step 4 - Provide business models of where the business is now ('AS-IS').

4.1 Provide a standard interview list of questions for each business function.

- What are the functions main objectives and purpose?
- What business control requirements are associated with the function?
- What are the outputs?
- What are the processes to create the outputs?
- What inputs are required for each of the processes?
- What are the information requirements of each function?
- What main decisions are made?
- What systems are currently used?

4.2 Interview functional managers/personnel and ask questions from standard list of questions.

Perform a top down business analysis exercise and produce hierarchically based (levelled) business analysis charts including:

- process purpose and control analysis charts;
- process hierarchy chart (several levels);
- data models (entity-relationship charts);
- control loop nesting and closed control loop charts;
- IDEF (0) process flow analysis charts;
- data dictionary;
- interview records.

NB: The above process should adopt the standard structured analysis techniques agreed during step 1. Examples of the above charts can be seen in Appendix (H).

Step 4.2, supports the control based business analysis steps illustrated in Table (10), refer to section 7.4. Such business analysis was subsequently established as methodology requirement 4., refer to section 8.2.

4.3 During the interviews identify any problems or inefficiencies, both internal to the function and between it and any others. Identify data ownership and establish sign over points.

4.4 Provide an 'AS-IS' business analysis report and gain approval from the functional manager/personnel, the middle management user group and the CIM executive committee.

Step 5 - Perform full appraisal of 'AS-IS' business analysis charts.

5.1 Ensure that all control loops are capable of being closed and that they can be tied back to the business control objectives defined on the integrated strategy network chart;

5.2 Simplify and rationalise control loops, avoid control for control sake;

5.3 Ensure the time taken to close a control loop matches the required response time of the activity;

5.4 Ensure that all business functions support business control requirements and business objectives;

5.5 Simplify and rationalise as far as possible all functions and information flows;

5.6 Check that all functions add value to the product, eliminate any non value adding activities (NVA's), and ensure all information flows are necessary;

5.7 Check for multiple instances of the same data and establish master and slave instances;

5.8 Provide an appraisal report for the 'AS-IS' business models.

NB: The above appraisal technique was identified as a required CIM methodology change in chapter seven, and was subsequently established as methodology requirement 5., refer to section 8.2.

Step 6 - Provide business models of where the business needs to be ('TO-BE').

6.1 Examine the various 'AS-IS' business analysis charts (refer back to step 4.2) and review the findings from the full appraisal (refer back to step 5);

6.2 Identify the required changes to the 'AS-IS' business analysis charts, which have resulted from the full appraisal, and establish a set of fully appraised 'TO-BE' bottom level business analysis charts;

6.3 Summarise up the 'AS-IS' business analysis charts to form natural groupings of:

- control loops which are closed, support the necessary control loop interactions and meet the business control requirements of the business;

- processes which support the control requirements, optimise the use of resources, improve performance, reduce level of integration and form natural signover points;

- data which support the process and control requirements, conform to data ownership principles, simplify data flows, adopts master-slave relationship for different instances of the same data and form natural databases that support the business information needs.

6.4 The 'TO-BE' hierarchically levelled business analysis charts to be approved by:

- the functional managers/personnel;
- the middle management user group;
- the CIM committee.

Step 7 - Establish a CIM system design.

7.1 Develop a levelled control hierarchy for the business, which is capable of effectively modelling the various business infrastructures and organisation.

At Lucas Aerospace, a five levelled control hierarchy was developed, refer to Figure (37), chapter 7, section 7.5.4.

7.2 Examine the 'TO-BE' business analysis charts in their 'summarised up' form and overlay the various business elements onto the control hierarchy in order to develop various business infrastructures.

Summarised views of the Lucas Aerospace business infrastructures are shown in Figures (42) to (47).

NB: The development and adoption of the control hierarchy as the core of the CIM system design, was identified as a required CIM methodology change in chapter seven, and was subsequently established as methodology requirement 9., refer to section 8.2.

7.3 Examine the 'TO-BE' business analysis charts and identify the CIM system elements required. Cross reference the identified CIM system elements with those listed on the integrated strategy network. At Lucas Aerospace, twenty two CIM elements were identified including:

1. Office systems
2. Project Control System (PCS)
3. Project team matrix structure
4. CAD/CAM (Computer Aided Design/Manufacture)
5. CAE (Computer Aided Engineering)
6. EDMS (Engineering Database Management System)
7. GT (Group Technology)
8. CAPP (Computer Aided Process Planning)
9. TMS (Tool Management System)
10. AMH (Automated Materials Handling)
11. CAM (Computer Aided Manufacturing)

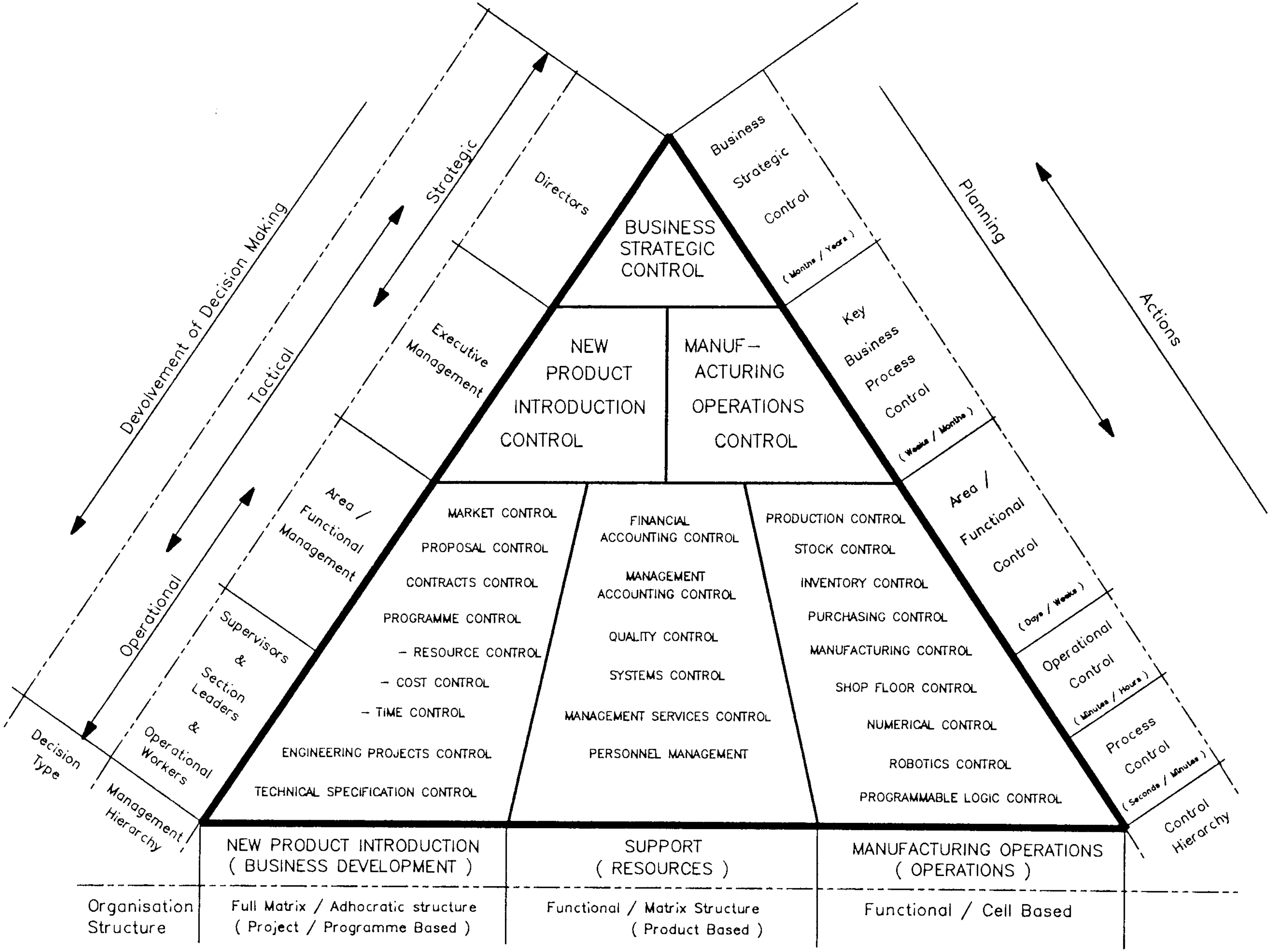


Figure (42): Business control requirements model

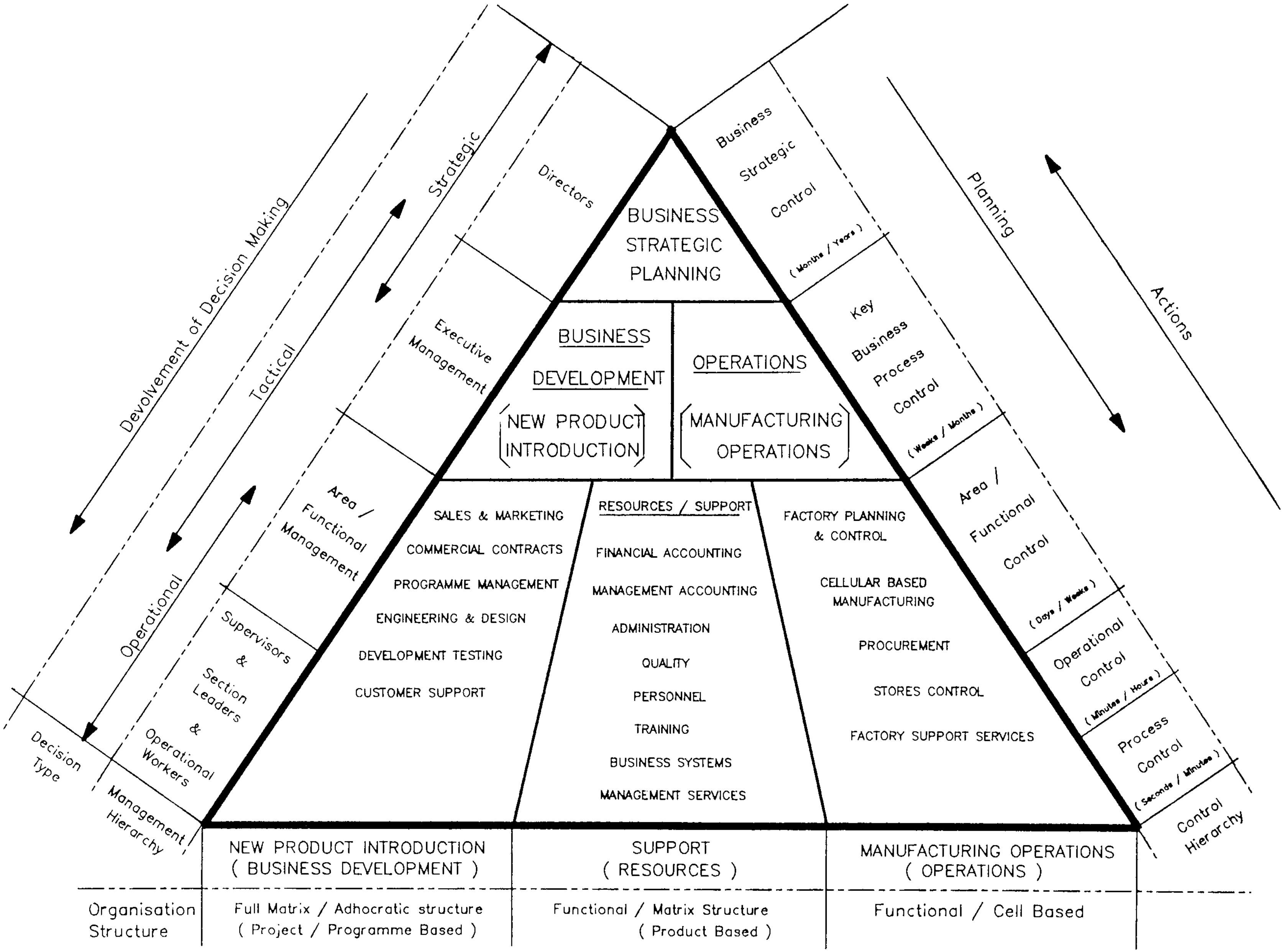


Figure (43): Business functions / processes model

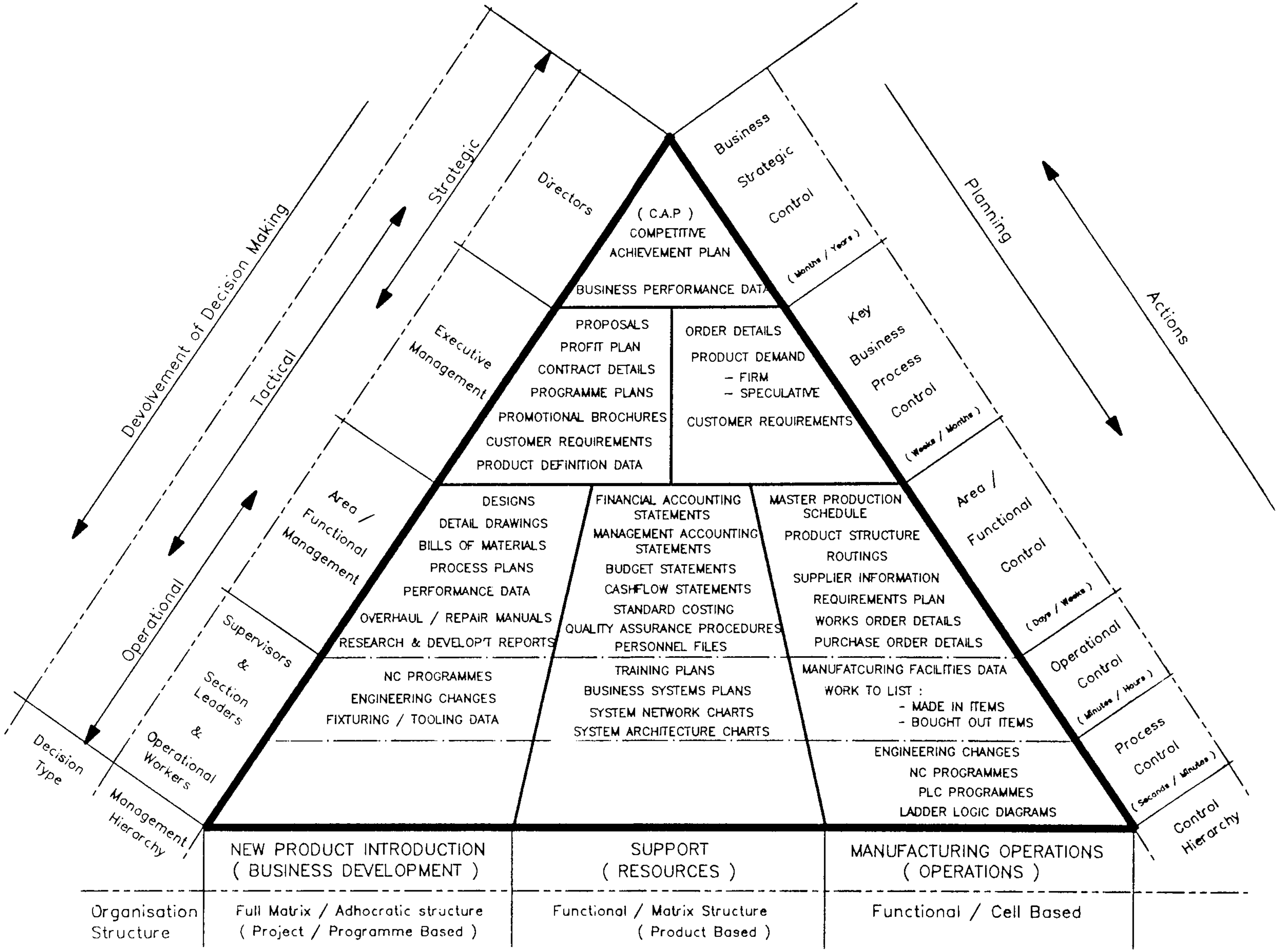


Figure (44): Business information model

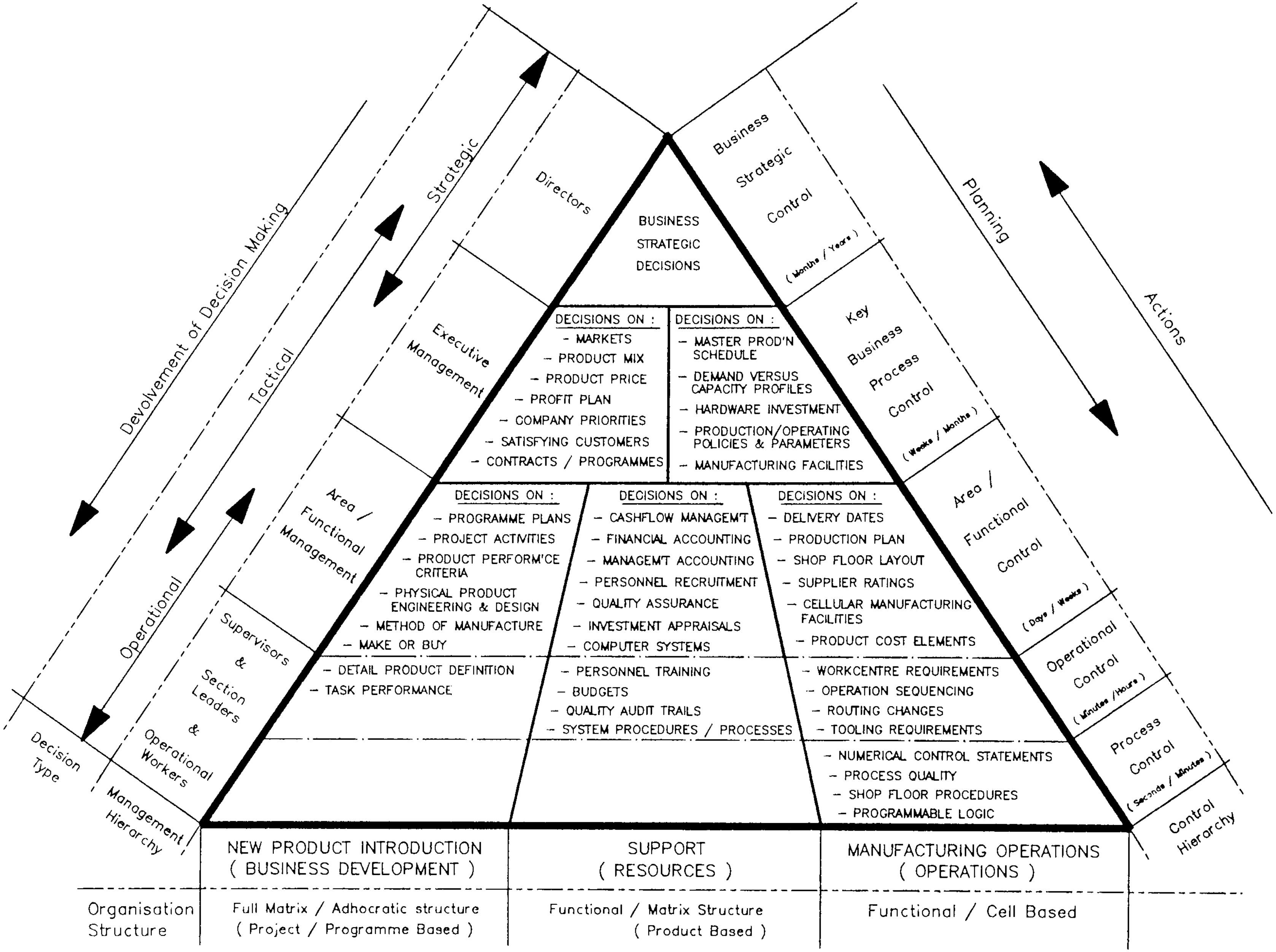


Figure (45): Business decision model

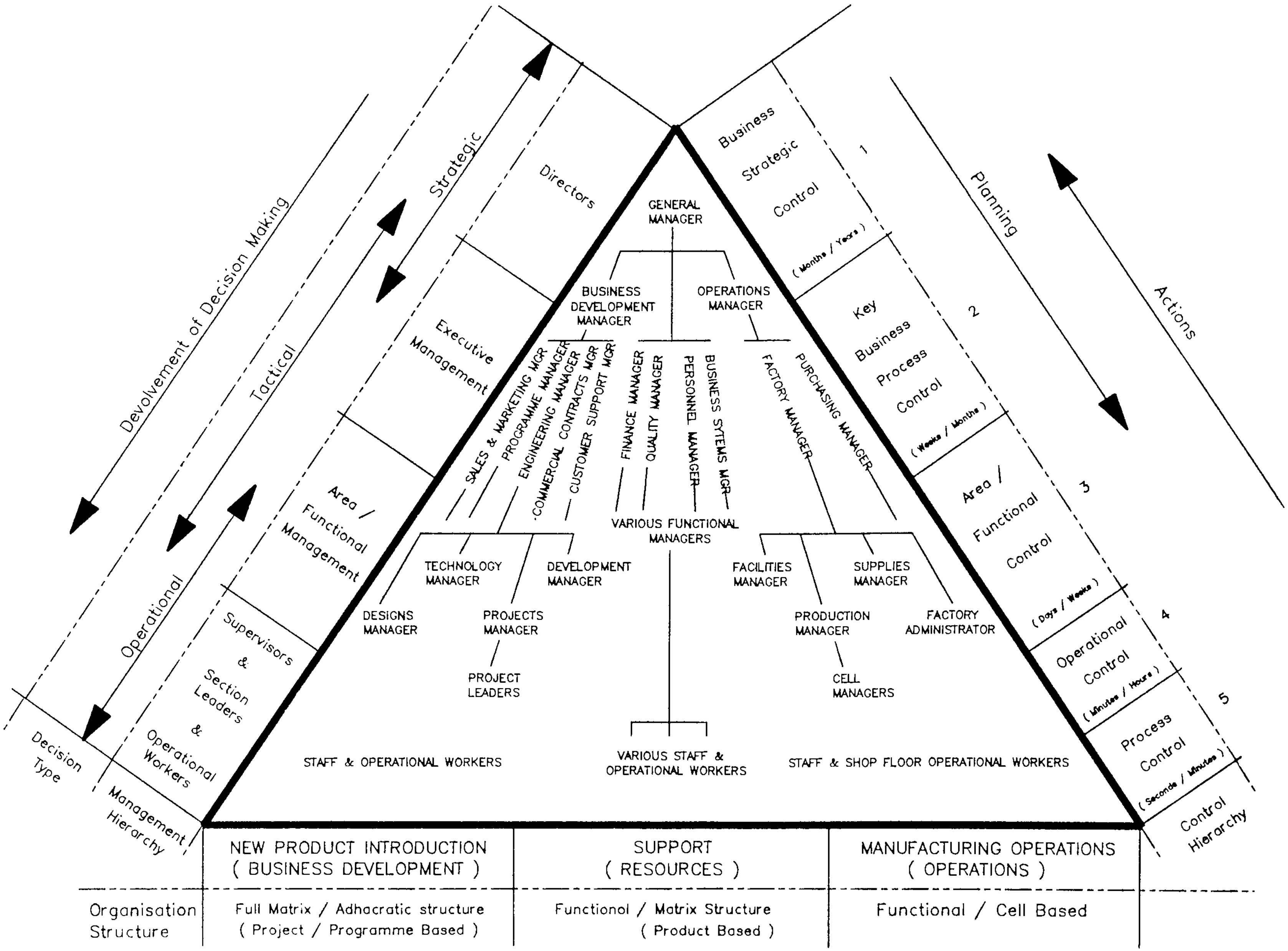


Figure (46): Business people model

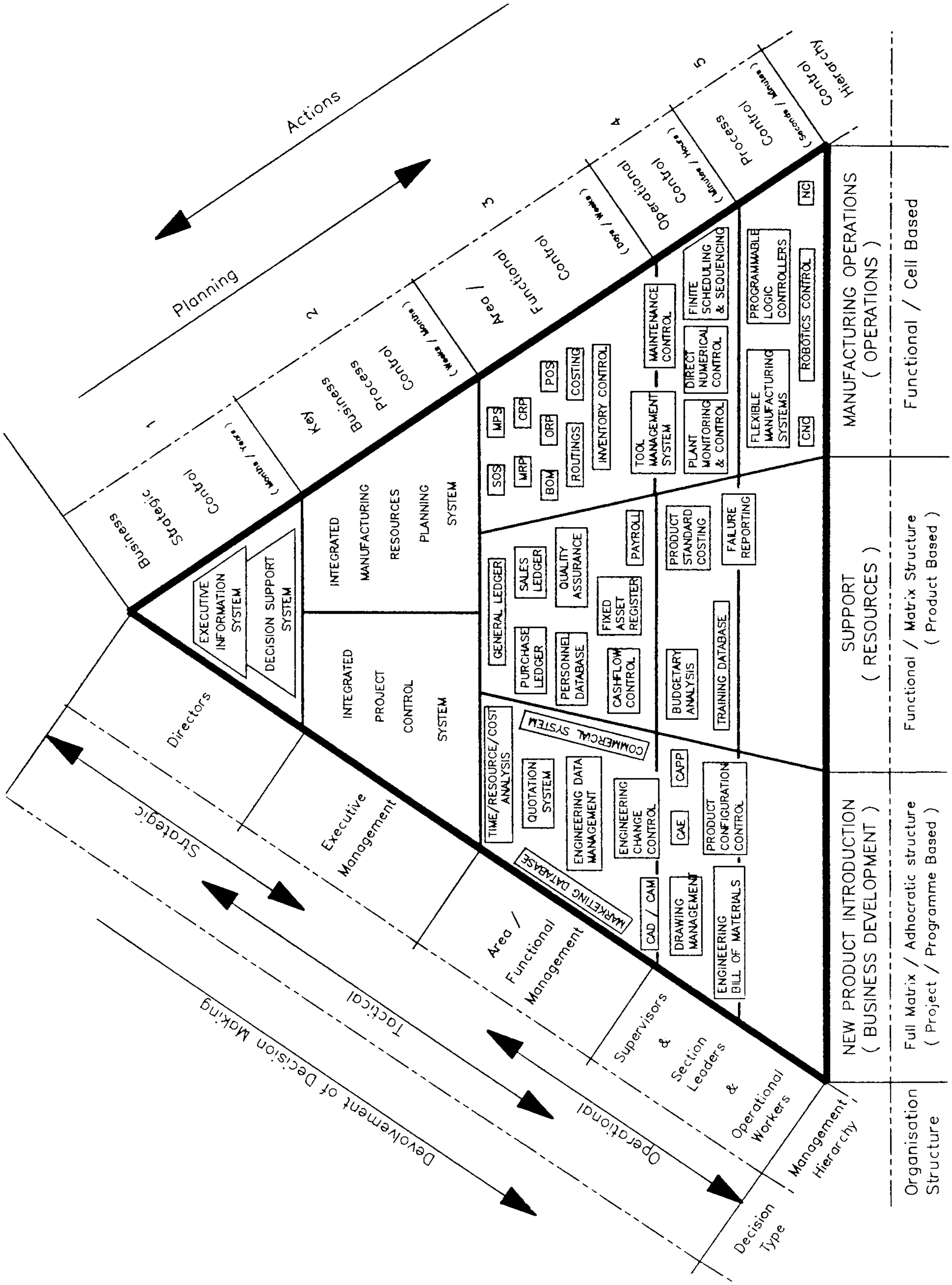


Figure (47): CIM systems infrastructure model

12. Robotics
13. Cell Management
14. JIT (Just In Time)
15. MRPII (Manufacturing Resources Planning)
16. Factory simulation
17. SFDC (Shop Floor Data Collection
18. Financial ledgers
19. Computing technology
20. Invoicing
21. Payroll
22. Fixed asset register

NB: for more discussion on CIM system elements, refer to Appendix (C).

7.4 Provide a CIM systems infrastructure model of the defined CIM system elements using the five level control hierarchy. At Lucas Aerospace, such a model was drawn illustrating the twenty two systems, refer to Figure (47).

7.5 Overlay on top of the IDEF (0) process flow analysis charts the scoping lines for each system. Clearly establish the controls performed by the system, the processes the system supports and the input and output information flowing through the systems. Break the business data models (entity/relationship charts) down into the data models for each system.

7.6 Examine system overlayed IDEF (0) process flow analysis charts, closed control loop charts and control loop nesting charts, and establish control loop interactions. Using the control loop interactions, define system integration requirements (refer to chapter 7, section 7.2).

NB: The above systems integration definition technique was identified as a required CIM methodology change in chapter seven, and was subsequently established as methodology requirement 8., refer to section 8.2.

7.7 Provide a CIM systems integration model of all integration requirements. At Lucas Aerospace, such a model was drawn illustrating the systems integration requirements, refer to Figure (48). Thirty different integration links are numbered. An examination of the dataflow for each integration link is provided in Appendix (I).

7.8 Examine the CIM systems integration model and define the hierarchical control relationship between the systems by investigating the control loop interactions and the transaction chain control concept (refer back to chapter 4, section 4.4.5).

7.9 Obtain full approval for the CIM system design from the:

- the functional managers/personnel;
- the middle management user group;
- the CIM committee.

7.10 Provide a system requirements definition report, to include the following topics:

- system structure and scope;
- system control and functionality requirements;
- information outputs, inputs and information processing requirements;
- user operating environment;
- data requirements to include database record structures;
- user interface;
- integration requirements;
- security, archive and back up, growth path.

7.10 Obtain full approval for the systems requirements definition report.

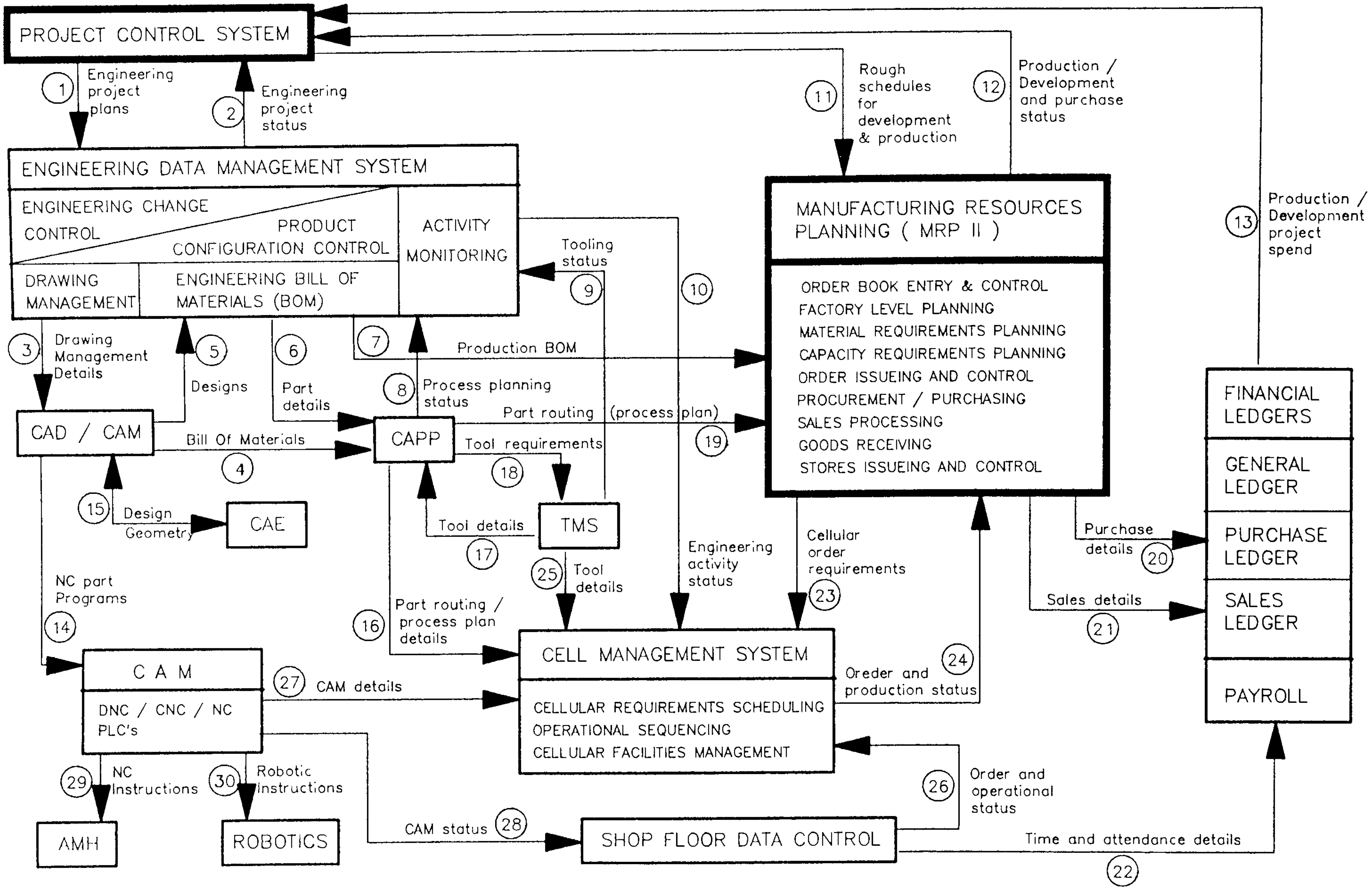


Figure (48): Key CIM system interfaces

Step 8 - Provide a CIM systems integration architecture report.

Note: This step is not concerned with selecting actual hardware, moreover it is aimed at developing a systems integration architectural framework which will help to ensure that all system implemented are capable of communicating and fit into the business infrastructure in an optimum fashion.

8.1 Develop a standard systems integration control framework. The emphasis is on data management and control. Develop standard interfacing procedures and a standard intersystem communication and control mechanism. Consider the requirements relating to:

- data trail auditability through transaction logging;
- assured data communications;
- data copy management.

Refer to section 9.2 for a more detailed discussion.

NB: The above standard systems integration control framework was identified as a required CIM methodology change in chapter seven, and was subsequently established as methodology requirement 12., refer to section 8.2.

8.2 Establish a set of system/computing standards towards an open systems architecture. For example, it was decided that a particular core group within Lucas Aerospace should adopt the following standards, namely:

- ORACLE relational database;
- UNIX operating system;
- Ethernet network IEEE 8802.3;
- distributed hardware using local servers.

8.3 Develop an architectural form which is based on the control hierarchy and supports the system configuration, control form requirements, organisational form and system extendability and modularity considerations.

NB: The use of the control hierarchy as the basis for the systems architecture was identified as a required CIM methodology change in chapter seven, and was subsequently established as methodology requirement 11., refer to section 8.2.

8.4 Provide a report outlining the required systems integration architecture, to include the findings from steps 8.1, 8.2 and 8.3 and a systems architecture chart. The chart shows both the current and proposed architecture. The proposed systems architecture chart is discussed in detail, and indeed illustrated in chapter nine.

8.5 Obtain full approval for the systems integration architecture report.

Step 9 - Determine implementation approach (build, buy or modify).

9.1 Contrast the AS-IS models with the TO-BE models and identify where differences occur.

9.2 Make the 'build, buy or modify' decision by looking at the differences and establishing how each difference can be resolved, that is, by developing the necessary software in house, by purchasing new software packages, or by redesign and modification of existing procedures or software.

9.3 Identify system options and establish the preferred suppliers for hardware and software.

9.4 Obtain quotations from preferred suppliers.

9.5 Obtain full approval for the implementation approach.

Step 10 - Develop a transition plan to take the business from the AS-IS state to the TO-BE state.

10.1 Determine the order of implementation paying particular attention to early payback, prioritised business control needs, success and the modular building block approach.

NB: The need to consider business control needs during the development of an transition plan was argued in chapter seven, and established as methodology requirement 13., in section 8.2.

10.2 Examine and survey the desired timescales and service levels required in the business with the ability to absorb the rate of change. Examine the bridging required to support the various business activities during the process of change.

NB: The need to consider the management of change process during the development of a transition plan was argued in chapter seven, and established as methodology requirement 15., in section 8.2.

10.3 Define the resource requirement and gain full commitment.

10.4 Provide a transition plan, gain widespread agreement and publish agreed plan.

Step 11 - Provide full cost/benefit analysis and investment appraisals.

It should be noted that the determination of cost and benefit should be an ongoing process throughout all the steps. The process also continues during and after the implementation as the perceived cost/benefit is monitored and plans altered.

11.1 Determine the costs for each of the projects, associated with resources, hardware, software, support and consultancy.

11.2 Determine the benefits associated with each project in a qualitative sense.

Note: Use critical control success factors (CCSF), which support both business strategies and business goals

11.3 Determine the financial benefits associated with each project.

11.4 Determine the availability of capital during the lifetime of the project. Establish the payback, internal rates of return (IRR), net present value (NPV) and payback for the various projects. At Lucas Aerospace a standard set of investment appraisal documents are used.

11.5 Establish the optimum timing of investments by using and changing the transition plan to improve cashflow.

11.6 Obtain financial agreement to the investment proposals.

<u>Step 12</u> - Implement transition plan and monitor.

Following a business executive decision to proceed, the process of implementation can begin. Although the bulk of the detailed work is done, it is vital that the user areas control the development, and own the data and the systems.

12.1 Identify the methods, techniques and standards that will be used to develop the procedures and computer systems.

12.2 Establish the user groups that will own and validate the developing procedures/systems.

12.3 Review the implementation plan and key check points.

12.4 Establish the procedures for systems development.

12.5 Implement procedures according to plan.

12.6 Examine the developing system at regular intervals to prove the design and confirm that the cost/benefit expectations are being achieved.

(Post implementation review).

9. DEVELOPMENT OF A CIM (SYSTEMS INTEGRATION) ARCHITECTURE

This chapter examines the requirements associated with the development of a CIM systems integration architecture. It will be argued that the development of such an architecture should include the establishment of a standard systems integration environment and a specific architectural configuration. A large proportion of this research was based on work performed at Lucas Aerospace (ESD).

9.1 Introduction

In chapter 5.0, it was argued that the development of effective integrated systems should be accompanied by business redesign to ensure an optimum fit into the business environment is achieved. One aspect of fit, included the matching of the coordination and control mechanism with the organisation structure.

In chapter 6.0 and 7.0, it was argued that current CIM system design methodologies have numerous gaps due to their failure to consider aspects of business control. It was subsequently argued that a control based CIM system design methodology should be capable of developing a CIM system architecture which is based on the standard systems integration framework, as defined in chapter 4.0, and whose architectural form is based on a five level control hierarchy due to its ability to analyse and represent system integration requirements and model CIM business infrastructures.

This chapter examines the development of a system integration architecture with particular consideration being given to the above points. The chapter comprises three main parts. The first, examines the impact of the transaction chain control concept from chapter 4.0 and further develops the standard systems integration control framework based on research work performed at Lucas Aerospace. The second, investigates the impact of the organisation and its constituent business elements on the form of the systems integration architecture required. The third, proposes a distributed hierarchical systems integration architecture.

9.2 Standard systems integration control framework

9.2.1 Introduction

In chapter 4.0, the transaction chain control concept was developed to provide automatic means for closing control loops. The concept is based on the chaining of transactions through the use of triggers tied into vertical and horizontal control loop interactions, which they themselves are supported by systems integration. To support such an environment a systems integration framework was proposed based on the recurrence of four triggers. This section further develops this system integration framework.

A typical manufacturing company embarking on a (CIM) development programme should consider the application of standards in the following areas:

- standard systems integration procedure;
- standard intersystems communications and control system;
- standard systems integration control framework;
- system/computing standards.

9.2.2 Standard Systems integration model and procedure.

The systems integration framework diagram shown in chapter 4.0, refer to Figure (19), only illustrates two functional systems, namely CAD/CAM and CAPP. In a manufacturing company the number of systems and indeed integration requirements would be significantly greater. At the time of performing this research, Lucas Aerospace had installed twenty five computer systems running on fourteen computers (excluding P.C's and workstations) spread across three sites. This in turn resulted in thirty system interfaces being required.

A standard systems integration model and procedure should be developed for business environments which require numerous system interfaces, to promote conformity of interface mechanism, eliminate the creation of adhoc interfaces and enable the development of a single standard interface control mechanism for supporting the various control loop interactions. Such a model and procedure was developed at Lucas Aerospace (ESD) and is shown in Figure (49). The model shown reflects the environment during New Product Introduction. The general workings of the model have already been

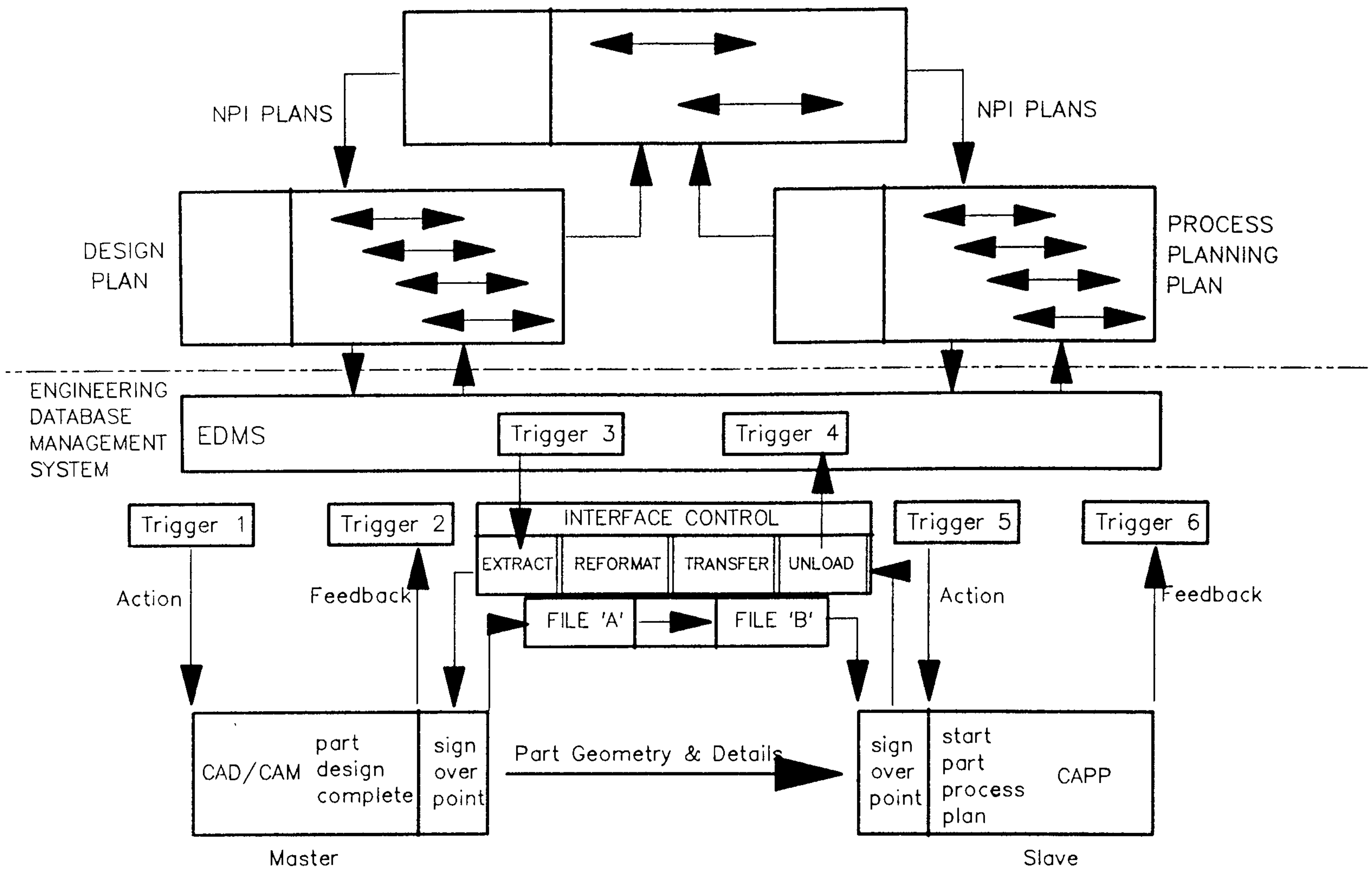


Figure (49): Standard systems integration model and procedure explained in chapter 4.0, therefore the focus will be on the interface control procedure concerning triggers 3 and 4.

The standard interface control procedure has seven steps, they are as follows.

NB: The procedure is based on two systems installed on different hardware.

1. Once the EDMS (Engineering Database Management System) is informed that a part design is complete, trigger 2 automatically logs the part number and executes trigger 3, which invokes the interface software.

2a. The "Data Extract" software module is invoked which reads the CAD/CAM files and extracts the part records for the selected part(s). A check is performed to ensure the part records extracted are for the right part.

2b. The part records are written to File 'A' where a check is performed to ensure they are complete and accurate.
N.B: the data format of File 'A' is similar to the format held within the CAD/CAM system.

3. Once the 'Data Extract" software module has completed its checking, it invokes the 'Data Reformat' software module which reads the CAD/CAM part records from File 'A' and reconfigures them into the data format required within the CAPP system and subsequently writes the data to File 'B'.
N.B: This reconfiguration would normally include the deletion of unwanted data fields, reformatting of data fields, renaming of data fields and the dynamic insertion of new data fields.

Finally, a check is performed to ensure the data reconfiguration is successful and that data File 'B' is complete and accurate.

4. Once the 'Data Reformat' software module has completed its checking, it invokes the 'Data Transfer' software module which purely transfers File 'B' down the communication line to the hardware platform which is supporting the CAPP system.

5. The 'Data Unload' software module is invoked which reads File 'B' on the CAPP hardware and updates the CAPP system database. A check is performed to ensure the CAPP system part data files have accepted the data correctly and that the data is complete and accurate.

6. An interface summary record is produced which may be accessed to check the success or failure of the interface. If failure has occurred then the record should identify the point at which failure took place and provide an error message describing why the failure took place.

7. Once the interface software is complete trigger 4 is executed which feeds back status information to the EDMS (Engineering Database Management System), which executes other triggers.

It should be noted that the integration of system should be accompanied by an examination of the master/slave theory. The master/slave theory states that any changes/updates to the data must take place on the master data, which is inturn reflected in the slave data through interfacing. Changes should not be made directly to the slave data, unless referential integrity is not required. The theory includes identifying and differentiating between creators and users of data, and determining which instance of the data is master and which instances slave.

In the example given in Figure (49), the part geometry and details are created by designers on the CAD/CAM system and used by process planners on the CAPP system. Therefore, the data instance on the CAD/CAM system is master and the associated data instance on the CAPP system slave. This in fact means that any changes/updates to the data should be made on the CAD/CAM system which inturn through the interface mechanism updates the CAPP system. It would be correct to prohibit changes to the part geometry/details data on the CAPP system.

It was decided that the above procedure should be used as a standard platform for all systems integration within Lucas Aerospace.

Any manufacturing company embarking on a systems integration development programme should consider establishing a standard systems integration procedure.

9.2.3 Standard intersystem communication and control system

The agreement of the standard procedure at Lucas Aerospace was followed by further investigations associated with data trail auditability and the method of intersystem communication across various hardware platforms.

The investigations resulted in the identification of the following requirements including a transaction logging mechanism, a central register of systems and data, and a standard interface software. This subsequently led to the required development of a standard intersystem communication and control systems.

9.2.3.1 Transaction Log

The proposed approach to systems integration would inherently experience many information processing transactions between systems each day. In order to manage data effectively in such a dynamic environment, it is suggested that a transaction log is required. This would be responsible for logging each of the individual transactions performed during an interface. The example interface shown in Figure (49) would typically require logging at:

- the start of the interface (ie at trigger 3);
- the completion of the 'Data Extract" software;
- the completion of the 'Data Reformat' software;
- the completion of the 'Data Transfer' software;
- the completion of the 'Data Unload' software and;
- the finish of the interface (ie at trigger 4).

Such logging would provide full data trail auditability. If the interface proves to be successful then only the start and finish log is kept. The log would store important data management information regarding the various transactions. Typically this would include start date and time, transmitting and receiving systems, the information type, unit, part number(s), the initiator, the success/failure details of each transaction and the finish date and time.

9.2.3.2 Register

In a typical manufacturing business environment, there are numerous computer systems and a vast amount of data flow. The need for a co-ordination and monitoring system to define/monitor the system configuration and important data flow milestones is seen to be of paramount importance. The 'Register' is required to provide knowledge of all routes between transmitting and receiving systems, such that the only required information is, what to send, where to send it and when. All three pieces of information are identified by the first stage of the interface procedure during transaction chaining. The register also provides an access path to, or a storage medium for, specified business control information required by the project control or the manufacturing operations control system, in order to close control Loops. Such information would include part status, order status and task status.

At Lucas Aerospace it is perceived that the register would infact be relationally linked to the Engineering Database Management System (EDMS) and the cell control systems, because it is these that are responsible for the triggering of interfaces.

9.2.3.3 Standard interface software

To promote conformity of the interface mechanism, it is suggested that the interface software structure adopted should be, as far as possible, standardised. It was decided that for inter-functional system interfacing, the following should be specified and written by Lucas personnel, including data reformat software, file 'A', data transfer software and file 'B'. The 'data extract' and 'data unload' software may require consultation with the particular system vendors depending on source code licencing agreements.

9.2.4 The proposed Standard System integration control framework

The proposed framework is illustrated in Figure (50); it is based on the systems implemented at Lucas Aerospace. The illustration represents a "logical" view of the framework. Such a framework should be equally applicable to any medium sized batch manufacturing Company.

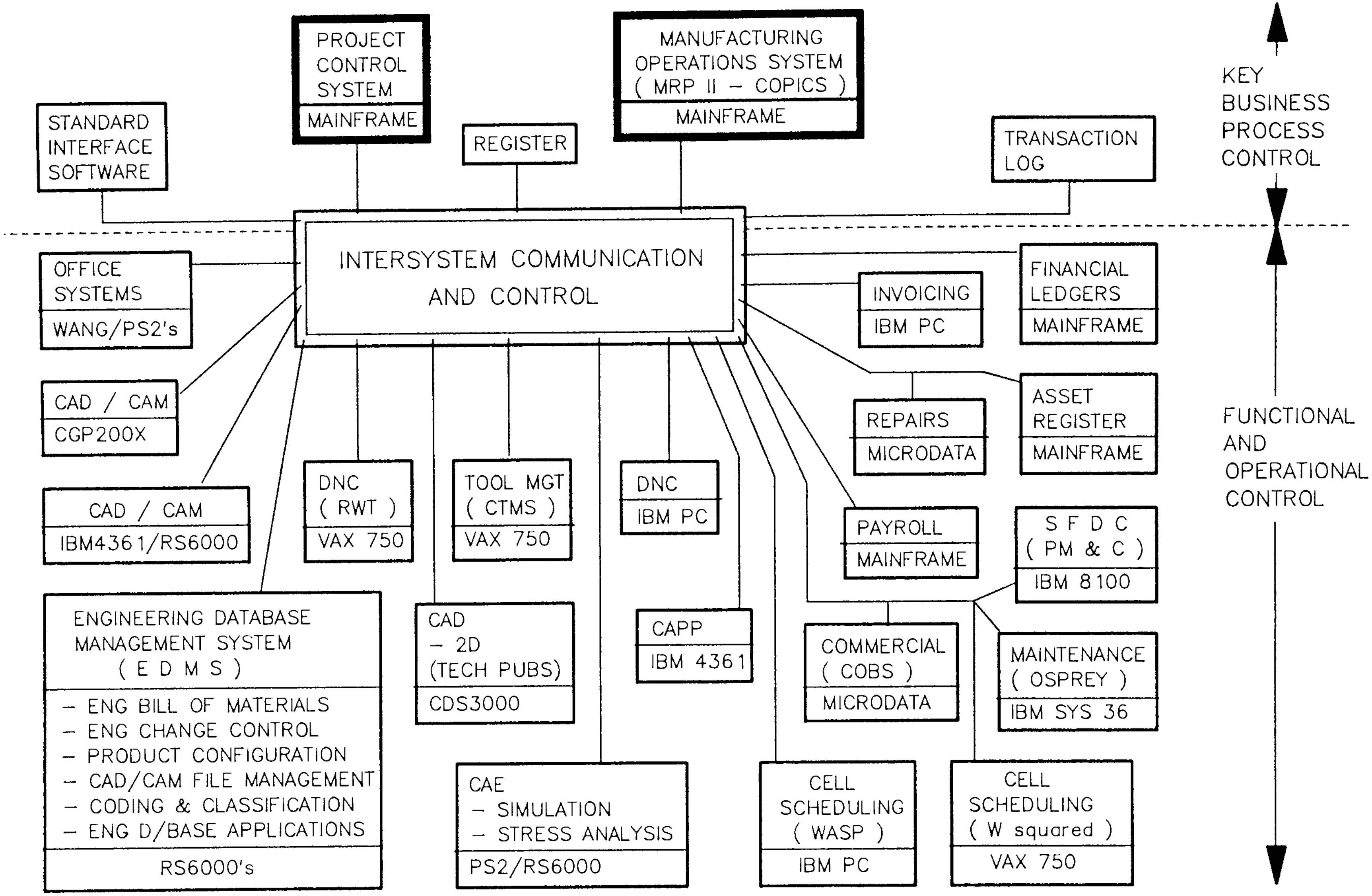


Figure (50): Proposed standard systems integration control framework

9.2.5 System/Computing Standards towards an open Systems Architecture

Section 9.2, has so far discussed the need for a standard intersystem communication and control environment focussing on the conceptual and procedural elements of systems integration. Beneath this there are other standards one should consider relating to the system hardware and software. This section examines such standards and stresses their importance towards achieving an open systems architecture.

Traditionally some companies have selected systems applications based purely on system functionality with little or no consideration being given to its operating environment, that is, the operating system it runs under, the data management/storage method (database schema), the hardware it sits on and the network (protocols) the system supports.

Such developments have resulted in a rather complex systems environment where a multitude of different system elements exist, many of which are incompatible and unable to co-exist in an integrated environment. On the other hand other companies who have realised the importance of systems integration have been forced to choose particular systems which are compatible with those that currently exist even though they maybe functionally inferior to others on the market.

Lucas Aerospace has infact been subject to both the above routes resulting in a total of twenty five computer systems running on fourteen computers (eight different makes excluding PC's and Workstations) spread across three sites. This has resulted in the use of various operating systems, databases and networks. Lucas Aerospace has realised that systems integration towards CIM in such an environment is both technically demanding and expensive, and is therefore currently involved in a major systems redesign and development exercise to create the aforementioned open systems operating environment. The proposed architecture is illustrated in the following section.

A development which is helping the above situation is the establishment and adoption of system and computing standards. Various organisations, committees and working groups are developing computer standards such that various devices are compatible and able to work together in an integrated environment. It is widely accepted that the establishment of such standards is very important in improving the progress towards CIM.

Various computing standards are emerging, Open Systems Interconnection (OSI), which is an international standard for the exchange of information among open systems is now widely supported. It has been developed by ISO (International Standards Organisation) and CCITT (Consultative Committee on International Telephony and Telegraphy) to facilitate open communications among a wide variety of heterogeneous products independent of their suppliers, and to free users from being confined to a single vendors proprietary solution. OSI comprises a reference model, a set of service definitions and a set of protocol specifications. The reference model is made up of 7 layers. OSI is already receiving widespread endorsement in the user community. MAP (Manufacturing Automation Protocol) and TOP (Technical Office Protocol) are two highly publicised, user driven, product functional specifications dictating the use of OSI protocols.

Various open system vendor groups are backing the development of a standard multi user and multi tasking operating system, namely Unix. Similarly, various relational database vendors now support the SEQUEL (SQL) Structured Query Language.

The National Institute of Science and Technology, the United State Air Force (USAF) and Boeing are currently developing a standard graphics data exchange specification to enable CAD systems to digitally exchange graphics data directly. The new standard PDES (Product Data Exchange Standard) will supercede IGES (Initial Graphics Exchange Specification). The PDES standard is currently examining data structure standards for all types of engineering data including Bill of Materials (BOM) and engineering change control conventions. PDES has recently changed its name to "Product Data Exchange through STEP", where STEP is a standard for the exchange of product model data.

During the development of a systems integration architecture one should examine the various standards and make the appropriate selections to maximise the openness of the systems environment. At Lucas Aerospace the following standards have been selected:

- OSI reference model [Ethernet (TCP-IP) IEEE 8802.3 and Token Ring IEEE 8802.5];
- ORACLE Relational Database Management System (RDBMS), plus SQL;
- Unix operating system;
- PDES (IGES) data exchange standard.

9.3 The influencing factors affecting choice of architectural form

9.3.1 Introduction

It was argued in Chapter 5.0, that the development of effective integrated systems should be accompanied by a certain amount of business redesign to ensure an optimum fit into the business environment is achieved. One particular aspect of systems integration is the architectural form upon which the interfacing is performed.

This section examines the impact of the organisation and its various constituent business elements on the form of the architecture required.

9.3.2 System configuration

One factor which has a significant impact on the architectural form is the particular type of system configuration adopted. There are two aspects associated with this, the system processing configuration and system database configuration.

Various authors have examined the above configurations and arrived at differing conclusions. Many support the development of a central database [Britton and Hammer (1984), Windsor and Nestman (1984), Lee and Mosier (1984) and Reisch (1987)].

Britton and Hammer (1984), stress that one of the key factors for consideration during a CIM development is optimising data integrity. They argue that the advent of the Data Base Management System (DBMS) has provided a means of achieving optimum data integrity through the use of a centrally configured DBMS, that is, a corporate database.

Windsor and Nestman (1984), argue the need for a central Relational Database Management System (RDBMS) supporting an array of multi-subject databases. They state that the development of such a central RDBMS promotes the designing of a stable, non redundant and well structured integrated database which provides for simpler and cleaner control of both data processing and product control.

Lee and Mosier (1984) argue that the development of integrated system should be the subject of a modular approach and subsequently states that this is best achieved by having a distributed 'data' processing configuration with both a central main database and local mass storage support at each of the distributed processors. They point out that the problem with a totally distributed configuration, is getting the various discrete systems to talk to one another, and the problem with a totally centralised configuration, is the long processing response times and high system operational costs. They argue that a modular approach is capable of taking the better points from both the configurations and thus alleviating the above mentioned problems.

The approach the authors seem to be suggesting would result in an environment in which the data would be considered both centralised and distributed. The data would be housed on a central computer but pulled down to the local distributed systems where the data would be stored in a local database and locally processed. Once the processing is complete the local systems then forward the information back to the central database. This concept of having both local and centralised databases has been developed to solve engineering and design system problems, where local processing is of paramount importance. Although this concept is well suited to CAD/CAM and CAE system applications, it is naive to suggest its application on a global business scale.

All the above mentioned authors support the development of a centralised database to assist systems integration and suggest various advantages in doing so. It is important to point out that none of the authors consider the problems and difficulties associated with a central database configuration. A one sided view has been given which fails to construct a coherent argument.

The concept of a central corporate database is idealistic and indeed problematic, from a data integrity point of view a central corporate database is ideal as there would be little or no data redundancy and no need for integration due to the fact that all the required data can be accessed from a central point. However, even though these benefits do seem attractive, one should consider the related problems. Such an environment relies heavily on the development of a very large database which would almost certainly need to be housed on a large machine, for example a supermini or even a mainframe. Such a large computer would require a significant investment and the provision of a substantial systems development and operations support team. One of the key factors why this approach is unacceptable is the fact that if the central computer breaks down then all the system applications lose their database.

Another consideration is that large central computers are generally unable to provide the kind of processing response that the various system applications require. It is suggested that this would be true even if the processing was distributed and the central database was just used as a data repository and management medium, as the amount of input/output (I/O) required by the central computer to support the typically high volume data flow to and from the central database may infact outstrip the capabilities of the computer and again result in response time problems.

In contrast other authors support the development of a distributed systems architecture [Rzevski (1987), Suski and Rodd (1986), Hearn and Weald (1987), Hewitt (1982), Groover and Wiginton (1986) and Ranky (1986)].

Rzevski (1987), discusses the concept of a CIM system architecture and examines the various types of architectural configuration required for a CIM development. He argues that a centralised architecture is only really applicable to small organisations and that with large companies the development of a centralised database system results in various problems. He suggests that the performance of a centralised system is usually inadequate, with slow processing and poor response times, which invariably results in a system which is unable to meet the processing requirements of certain business functions. He adds that a centralised database is very expensive, time consuming and is likely to lead to undesirable rigidity.

Rzevski, states that the main advantage of distributed configurations is that it offers the possibility of locating system components where their effectiveness can be maximised. He goes on to examine two types of distributed architectures including hierarchical and network, and claims that such configurations offer an excellent basis for evolutionary incremental development of a CIM system. Such configurations provide ease of extendability and a multi-levelled simultaneous processing capability.

Suski and rodd (1986), examine the application of a distributed computer system configuration within the process industry. They argue that such an application is well suited, and suggest that the structure of the distributed systems architecture should be hierarchical to permit the required hierarchical distribution of functionality.

Each of the remaining authors including Hearn and Weald (1987), Hewitt (1982), Groover and Wiginton (1986) and Ranky (1986) echo a similar view to that which has been put forward by both Rzevski, and Suski and Rodd.

A distributed systems architecture is considered the most appropriate for CIM due to the following:

- a distributed computing architecture allows successive decomposition of the process control problem into more manageable elements;

- distribution provides the ability to exploit graded processing capability, that is, match the computer processing to its environment. For example, the processing requirements for a production control system running nightly batch update is significantly different to that of an on-line process control application;

- distribution permits a modular approach to implementation where low cost investments can result in a proof-of-principle prototype before incurring large investments;

- it is generally less costly to distribute the intelligence in smaller computers than to centralise intelligence in high-performance central computers;

- distributed systems have an inherent characteristic of fault isolation, such that, if part of the system fails the remainder can continue to operate;

- distributed systems support extensibility, that is, the ability to add functionality without major systems redesign.

There is, however, a dilemma facing CIM system architects, on the one hand a distributed processing environment is required to reap the previously noted advantages, but on the other, a centralised database is ideal due to its integrated nature and supreme data integrity. A hybrid architecture is required, which incorporates varying levels of centralisation and distribution within an agreed framework of computing standards.

For the reasons expressed, a distributed processing environment is required, one in which small groups of system applications which require close integration are housed on mid-range machines. In such an environment a key concern is the data integrity and data integration problem, which is normally encountered within distributed environments. Such concerns can be eroded through the adoption of a "logical" central data management function which manages the data across the distributed network. This in effect forms the basis of the architecture developed at Lucas Aerospace. The standard intersystem communication and control system, which is explained in 9.2.7 provides the required central data management function.

As already stated the advent of the Database Management System (DBMS), has provided a significant achievement for data management, the "Relational" schema can now be considered a standard. At Lucas it has been decided that "ORACLE" is the agreed Relational Database Management System RDBMS. Many DBMS suppliers are actively involved in expanding their data management capability across various hardware. ORACLE is in fact capable of doing this now in a limited way. Such research is currently underway to develop a truly Distributed RDBMS, that is, a DRDBMS.

A true distributed RDBMS with referential data integrity across various tables on separate hardware would be capable of harnessing the data integrity/integration benefits from a centralised database configuration within a fully distributed environment. The distributed RDBMS uses a central "logical" data model as a means of ensuring data integrity across the various computers.

It is interesting to note that various research projects within the United States are underway to develop a distributed database and integration system across distributed heterogeneous databases. The projects include:

- Multi-base sponsored by DARPA and the US Navy;
- Integrated Information Support System (IISS) sponsored by US Airforce;
- Integrated manufacturing distributed database administration system (IMDAS) sponsored by NBS;
- Integrated Design Support Systems (IDSS) sponsored by US Airforce.

The views of Lee and Mosier (1984), should also be adopted, where data is stored both centrally and locally. This, as previously stated is ideal for the CAD/CAM/CAE environment and has been adopted at Lucas Aerospace. This has be termed a "central to local downloading configuration"

In summary it is argued that, the optimum system architecture configuration for CIM will include:

- a distributed processing environment which matches the processing requirements of the various functions with that supported by the computer system;

- a controlled number of physically separate, but logically integrated relational databases which are truly distributed and controlled by a central data management system through a central "logical" data model;

- a central to local downloading configuration within certain areas of the business eg CAD/CAM/CAE.

9.3.3 Control form requirement

Another factor which has a considerable impact on the architectural structure for systems integration is the particular form of control required across the business.

The important multi-facetted relationship between CIM and control has been examined and developed throughout this thesis. It has been shown that key business process controls such as New Product Introduction (NPI) and Manufacturing Operations (MO), can be improved by using systems to support the actual control functions and integrating these systems to support the the various control loop interactions.

In chapter 4.0 and 7.0, it was argued that a CIM environment supporting systems and their integration should be configured based on control loop interaction requirements. It follows therefore that the architectural form for both systems integration and business control should be mutually supportive.

In chapter 7.0, it was shown that the business control requirements can be best modelled by a levelled control hierarchy. In particular a five level control hierarchy was developed at Lucas Aerospace and subsequently used to model various business elements including control requirements and functions, systems and information flow, etc. (refer to chapter 7.0). The systems integration architecture should directly overlay on top of the business control hierarchy to ensure the systems are configured to support the various control functions, to provide an optimum support framework for the closing of control loops and control loop interactions and to ensure the distributed processing requirements of the system match the distributed control processing requirements.

The systems integration architectural form proposed by the author provides a total business view based on the control requirements of a medium sized batch manufacturing company. The architectural form is based on the five level control hierarchy as shown in chapter 7.0.

9.3.4 Organisational form

In chapter 5.0, it was suggested that a business comprises eight key elements, all of which are very closely related. The organisational form in concerned within optimising the other elements through organisational redesign to optimise the business. As explained, the organisational form should accommodate the various business structures, including:

- control hierarchy (levelled);
- function/process hierarchy;
- people/authority hierarchy;
- information flow structure;
- decision structure;
- systems hierarchy/architecture.

As shown in the business element relationship model (refer to chapter 5.0), systems have a one to many relationship with each of the other business elements, it follows therefore that the above six business structures must be related.

In chapter 5.0, it was shown that the primary business structure is the control hierarchy as it is this which provides a controlled framework for all work done, such that all functions/processes contribute effectively towards the attainment of business objectives. As argued in chapters 7.0 the other business elements can be successfully modelled on top of the control hierarchy. The organisational form should therefore be based on the five level hierarchical structure, refer to Figure (37), chapter 7.0.

9.3.5 Architectural development and extendability considerations

During the design of a systems integration architecture, it is important to consider the overall system development process, its propensity to change and ease of extendability. It is widely accepted that the development of systems integration towards CIM is an evolutionary process, which is best achieved through the adoption of a modular approach. This is due to the fact that a modular approach is capable of supporting a progressive investment programme where initial capital outlay and personnel committment is limited. Such a programme may infact provide a basis for self funding, i.e, the benefits from each system module could be used to fuel further module investments. The modular approach also supports the building block approach, which supports a step by step bottom up implementation where investment is made upon proven levels of system modules, and each incremental step adds value to the business process. The modular approach also supports a development environment in which systems are able to evolve as technology advances.

Such a modular approach as previously shown in this chapter, relies on the development of a distributed systems environment where system modules can be developed in a "stand-alone" mode, but with due consideration to the overall integration requirements. As argued in section 9.2, this kind of "stand alone" integrated system development requires the establishment of a standard systems integration control framework in which various computing standards have been agreed.

A modular systems integrated development within a distributed environment provides a very cost effective and flexible approach to future systems expansion where system modules are free to utilise new technologies one at a time and where new systems modules can be added with minimum disruption to the existing system network.

It follows, that to support a systems architecture which is effectively developed, flexible and extendable, one needs to consider the development of a modular approach, together with a distributed systems environment.

9.3.6 Summary discussion of factors and choice of architectural form

From examining the various discussions within this section, it can be argued that the architectural form best suited for the integration of systems toward CIM should be based on a distributed and hierarchical configuration. In particular the system architecture should be based on the 5 level control hierarchy [refer to Figure (37), chapter 7.0] and support a distributed processing environment where there is a controlled number of physically separate, but logically integrated relational databases which are controlled by a central data management system through a central "logical" data model, and are truly distributed. The system architecture should also be capable of supporting a "central to local downloading" configuration within certain areas of the business, for example CAD/CAM/CAE, and be capable of being developed in a modular way.

Adopting a distributed and hierarchical system architectural form based on the above, would result in:

- a business where the systems are configured to support the various control functions and provide an optimum support framework for the closing of control loops;

- an architecture where the distributed processing requirements of the systems match the distributed control processing requirements, and permit the successive decomposition of the control problem into more manageable elements;

- a multi-levelled simultaneous graded processing capability can be fully exploited in which system components can be located where their effectiveness can be maximised;

- an environment which offers an excellent basis for evolutionary incremental development of a CIM system, thus providing ease of extendability and the ability to add functionally without major system redesign;

- a robust overall system which has an inherent characteristic of fault isolation, such that if part of the system fails, the remainder can continue to operate;

- an environment in which the data is well integrated promoting referential data integrity across the various physically distributed but logically integrated databases, through the use of a data management system which incorporates the master-slave relationship;

- a systems architecture which is capable of being effectively supported within the organisation form, such that an optimum fit can be achieved with the various business element structures;

- the possibility of adopting a progressive investment programme where the initial capital outlay and personal committment is limited.

9.4 The proposed distributed hierarchical systems integration architecture

This section proposes a schematic view of a distributed hierarchical systems integration architecture. It is based on development work performed at Lucas Aerospace and incorporates the architectural requirements previously discussed within the chapter. Figure (51) illustrates a five level architecture specific to Lucas Aerospace. It is suggested that such an architecture could apply globally to any batch manufacturing industry.

The two networks shown in Figure (51) include Ethernet to ISO Standard IEEE 8802.3 and Token Ring to ISO standard 8802.5. It should be noted that the use of the protocol (MAP) is being considered for the shop floor communications.

The schematic shown fails to show the true hierarchical nature of the architecture, therefore a separate diagram has been drawn to illustrate this feature. Refer to Figure (52).

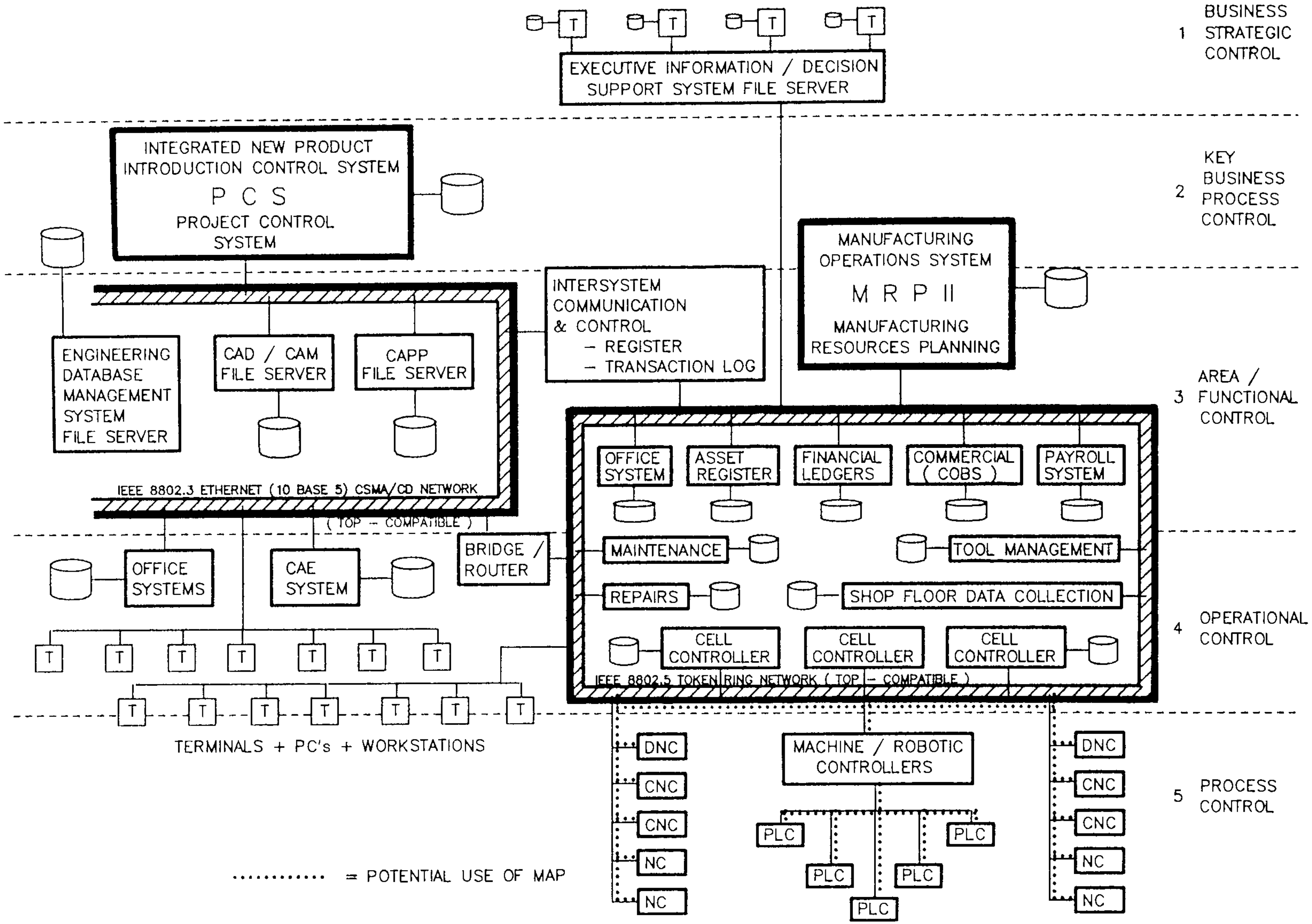


Figure (51): Schematic of proposed hierarchical distributed systems architecture

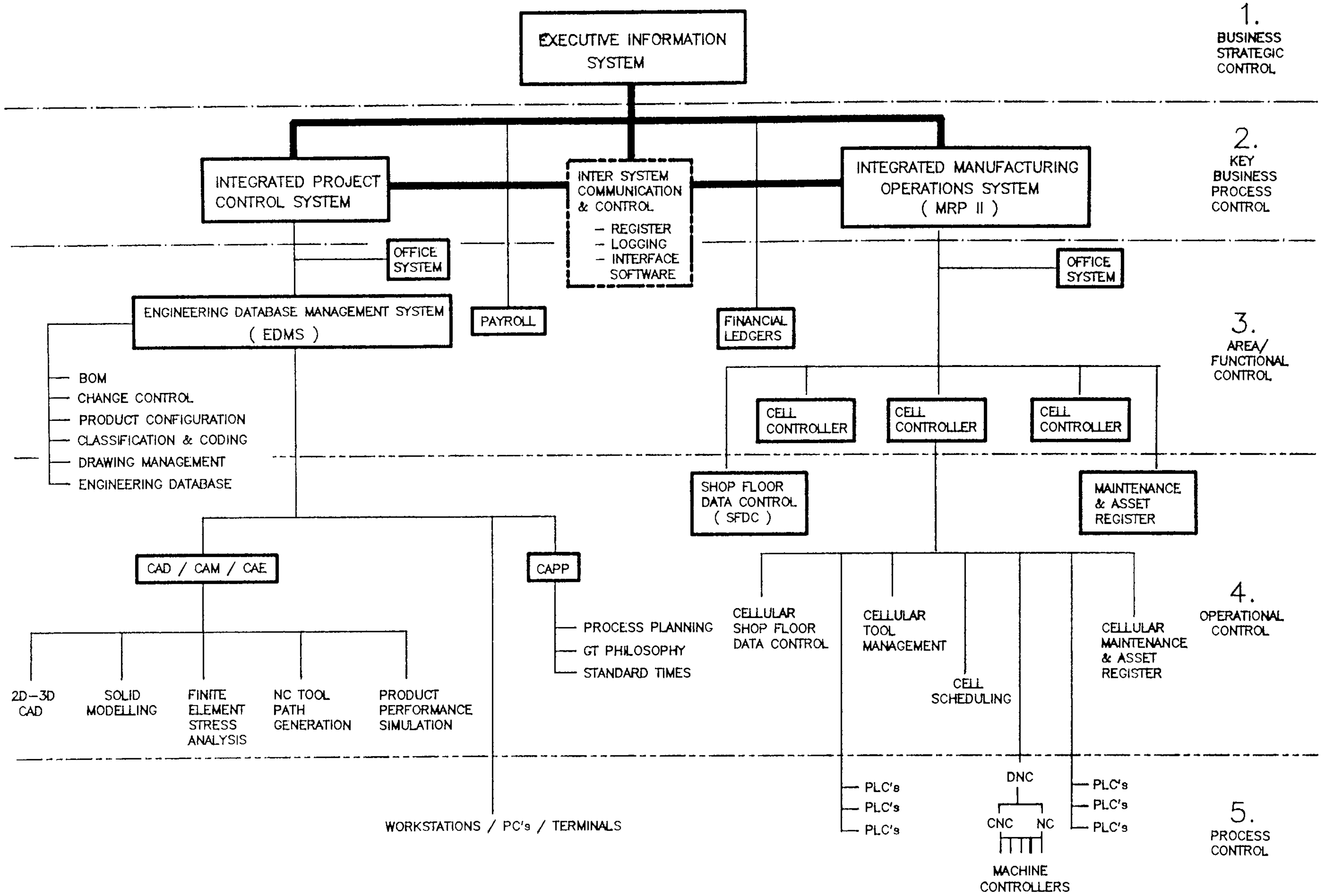


Figure (52): Hierarchical view of systems integration architecture

10. CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

10.1 Conclusion

It is generally recognised that the recent developments in advanced manufacturing and computing technology have resulted in the formation of functional 'islands of automation', and created a business environment which has focussed areas of excellence, and poor overall efficiency, co-ordination and control. Computer Integrated Manufacturing (CIM) has been introduced in order to improve this situation. However, from the literature search on CIM, the various perceptions of CIM, although developing, are primarily concerned with the information flow between these islands and in some cases their inter-functional procedures. This current view of CIM (CIM phase three) has a very narrow integration scope, resulting in mere linked islands of automation, the effect of which has little improvement in the overall business co-ordination and control process.

It follows that a more developed and holistic view of CIM should be established, one which involves a wider integration scope, reflects the current and future requirements of manufacturing industry, considers the likely effects on the organisation and moreover, is capable of developing an effectively co-ordinated and controlled manufacturing business. Such a view of CIM has to be derived from the fundamental principles and objectives of integrated manufacturing. The view proposed in this thesis, is one where the integration scope goes beyond that of physical computer systems to include the integration of various business elements including "control". This view of CIM is classified as CIM phase four, and concentrates on developing a totally integrated business environment which is capable of achieving effective control. Such an expanded integration scope results in more business elemental change and consequently a greater degree of business redesign.

The adoption of this holistic and control based view of CIM (CIM phase four) will result in significant changes to the basis of CIM design. Traditionally, the design of CIM systems has been largely based on the functional requirements of a business and the information processing needs of each function. Such CIM system designs have resulted in methodologies which adopt analysis tools and techniques that focus on the functional and information modelling aspects of a business.

In contrast, a CIM system that supports the above holistic view, perceives its various elements as control systems employed to control specific areas within the business. Taking this approach, the specification of CIM system elements is based on business control requirements and their associated functions and information. Systems integration in this case is viewed as the transferring of control, functional and transaction based information between different CIM system elements to support the various control loop interactions, including control loop closing, control loop nesting, control loop inter-chaining and transaction chain control information flows. The system design should be based on the transaction chain control concept (refer to chapter four), which provides a means of gaining control of business wide processes by chaining transactions between the CIM system elements.

A case study demonstrated that there is a mutually supportive and determining relationship between CIM and business control, such that effective integrated business control is having to rely on the implementation of the CIM philosophy for complete application. In particular, it was shown that the development of an integrated model for both New Product Introduction (NPI) and Manufacturing Operations (MO) is capable of providing the basis upon which business control and the CIM philosophy can be developed.

The findings from the literature review on CIM design methodologies, showed that there are numerous gaps in current CIM methodologies, many of which relate to business control issues. A control based CIM system design requires a significantly different design methodology, which includes the necessary steps to fill the knowledge gaps, and in particular address the control issues. Such a methodology was developed, which fills the knowledge gaps discussed in chapter 6.0, and adopts the control related changes proposed in chapter 7.0.

The application of this control based approach to CIM design at Lucas Aerospace, resulted in a unique CIM systems integration architecture. The architecture should include the establishment of a standard systems integration framework and a specific architectural form. Based on case study findings, a typical manufacturing company embarking on a systems integration (CIM) development programme should consider the application of specific standards, to include a standard systems integration control framework and procedure, and specific system/computing standards. Furthermore, the systems architecture configuration for CIM should be based on a 5 level control hierarchy, have distributed processing, have a physically separate but logically integrated relational database, support "central to local" file downloading, have an intersystem communication and control system and be capable of being developed in a modular way.

This research has shown that the relationship between business control and CIM, can be used as the basis for the development of a unique approach and design to CIM, which is capable of developing a totally automated controlled business environment, in which all departments of an organisation are able to work together in a reasonably integrated and controlled manner, towards common business goals. This, it is argued, is the main business objective for implementing CIM.

The findings from this research will have far reaching implications on traditional management strategies and philosophies presently used in manufacturing industry. This approach to CIM will therefore make a significant contribution to the planning, modelling, design and development of future CIM systems.

10.2 Suggestions for further work

10.2.1 Link between PCS and MRP II

In chapter 4.0, both the two key business processes, namely new Product Introduction (NPI) and Manufacturing Operations (MO) were examined. It was argued that these processes can be assisted by a Project Control System (PCS) and a Manufacturing Resources Planning (MRP II) System respectively.

The findings from chapter 4.0, showed that these two processes are very similar in concept as they are both involved in planning work, scheduling critical resources, monitoring actual work done to identify work deviation and replanning. It was also shown that both processes are based on a hierarchy of closed control loops.

An examination at Lucas Aerospace revealed that new product introduction control loops have numerous interactions with those of manufacturing operations. It became increasingly apparent that the transition from NPI to MO is poorly defined and in need of attention.

Various authors have discussed the relationship between NPI and MO by examining the overlap and interaction between Project Control Systems and MRP II systems [Sherpa (1990), Robson (1988), Scobby (1989), Jones (1989), Brooks (1989), Lawrence (1990) and Anonl (1989)]. The interactions examined have focussed on functionality and information, and not on the control loop interactions.

The hierarchical and interacting control loops comprising each of these key processes should be modelled such that a mutually supportive and controlled integrated environment can be developed.

It is contended that the relationship and integration between PCS's and MRP II systems should be further examined and developed. The integration could provide a platform upon which integrated business control could be based. The concept chart illustrating this is shown in Figure (23), section 4.6.

10.2.2 PCS to EDMS; closing the control loop

In chapter 4.0, it was argued that New Product Introduction (NPI) control can be assisted by installing an Project Control System (PCS), which is integrated with an Engineering Database Management System (EDMS) to close the various control loops. An integrated project control model was developed which showed this, refer to section 4.4.5.

NPI control is gained by integrating the PCS at the key business process control level (level 2) with the EDMS at the area/functional control level (level 3). The systems integration supports the flow of control information which closes the control loop. This is illustrated in Figure (53). Although this as a concept is practicable, it must be ensured that the control information exchanged, can be interpreted by both the PCS and the EDMS. This actually means that the control information held within the PCS and EDMS should either have the same unit, or be capable of being converted using factors or relationship data.

The PCS is normally used to develop plans that are "task" based, where as the EDMS monitors activities against "parts". This means that the feedback of part based actuals can only be interpreted by the PCS, if the part based actuals can be related to the higher level tasks. This is complicated by the fact that parts lists are invariably dynamic during the NPI development process and therefore subject to frequent changes. The relationship or factor data would therefore need changing each time the parts list change.

It can be seen that an effective method for automatically closing the control loop between the PCS and the EDMS, using systems integration has not been fully developed; further work is required.

Various authors including Scott (1989), Anon2 (1990), Sherpa (1990), Lawrence (1990), SDRC (1990), Prime (1990), ICL (1990) and Hamilton Hall (1990), all discuss the importance of Engineering Data Management (EDM) and its various functions. Although most of the above references include some form of project monitoring as an EDM function, none of them, as far as the author knows, discuss how a PCS could be integrated with an EDMS to close the NPI process control loops.

It follows therefore, that an examination into how a PCS and an EDMS can be integrated to close NPI control loops automatically should be performed.

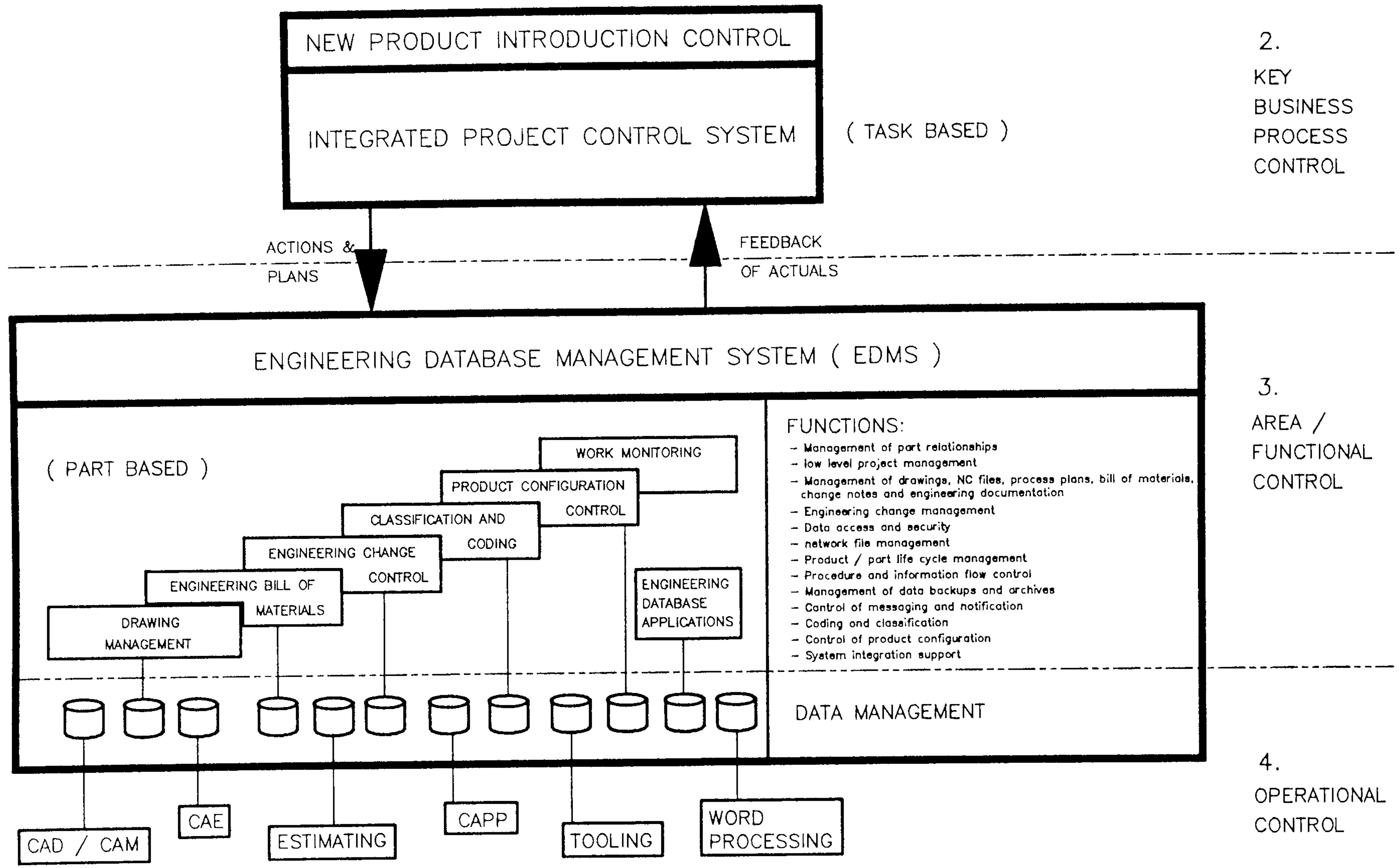


Figure (53): PCS to EDMS - Closing the control loop

10.2.4 Cellular Database Management System (CDMS)

It has been argued that control should be devolved to the level at which the process is performed such that local decision making can be performed. Within the New Product Introduction (NPI) process the recognition of the need for control devolvement has contributed to the conception of the EDMS (Engineering Database Management System), refer to section 10.2.2.

Within Manufacturing Operations (MO), it can be suggested that the same applies. Many medium sized batch manufacturing companies use an MRP II system to control manufacturing operations. This control however, is invariably installed at levels two or three of the control hierarchy. Various authors have examined the MRP II elements and attempted to devolve some of its constituent parts to a lower level. This has been investigated by Love and Barekat (1990), who proposes the introduction of cellular MRP II, and Baker et al (1986) and Gershwin (1986) who propose a levelled hierarchical approach to production planning, scheduling and control.

The above authors have only examined part of the solution, a holistic system is required at level four, which is capable of providing a controlled working environment for all aspects of cellular production. Its function and purpose is similar to that of the EDMS in engineering

Such a cellular system has been termed a CDMS (Cellular Database Management System). The CDMS concept is illustrated in Figure (54), where the four relevant layers are shown. Layer two and three comprise the integrated MRP II system which forwards cellular production requirements to each cell. These plans are acknowledged by the CDMS system, which then performs a low level scheduling and sequencing function to ensure that all cellular resources and information is available to meet the requirements. In effect the CDMS is responsible for achieving a schedule such that everything is available at the right time. The CDMS then ensures the work is performed in a controlled way.

The CDMS is also responsible for closing the various control loops by feeding back the actuals to layer 2/3. This feedback should then be used to automatically replan.

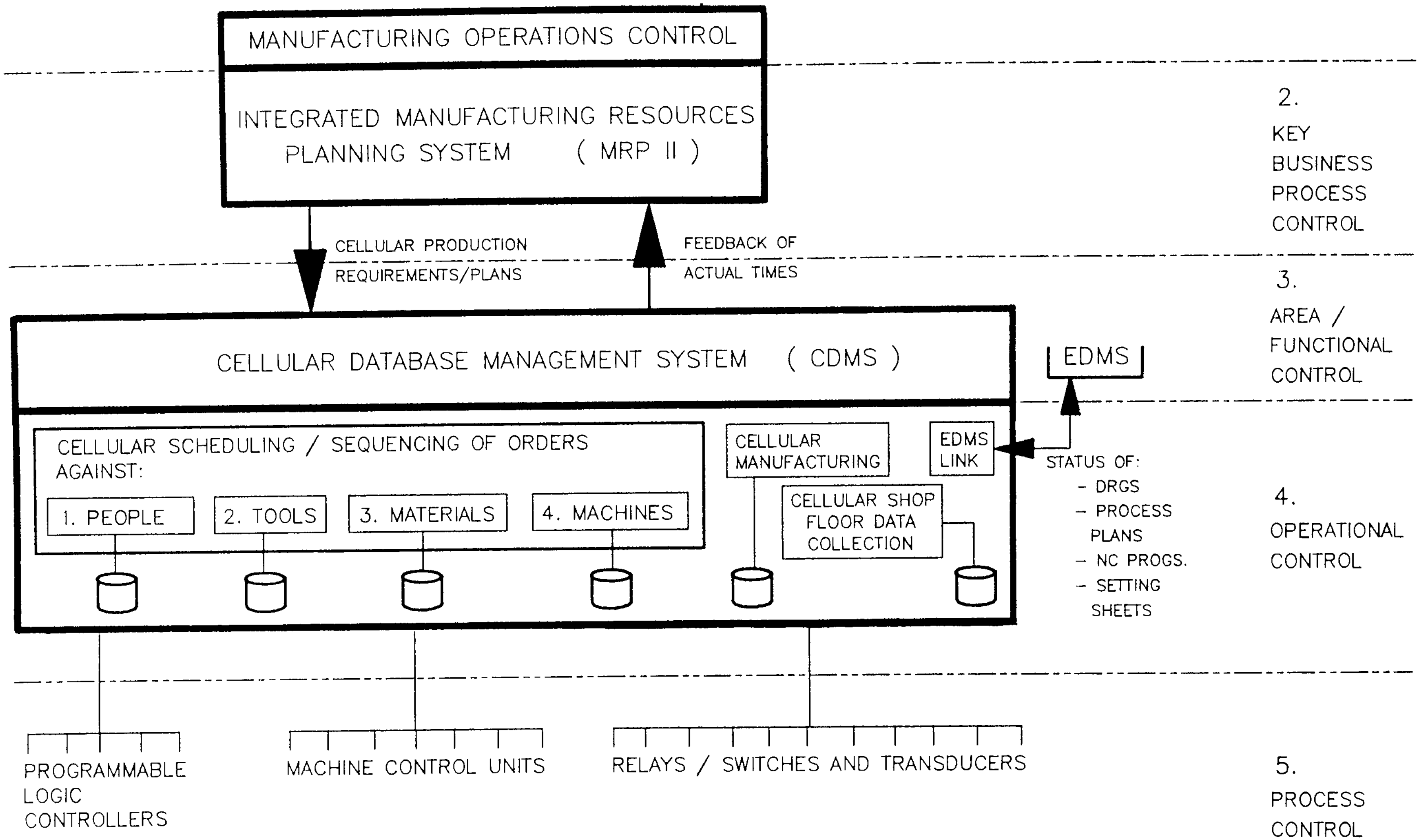


Figure (54): CDMS concept

The concept of CDMS, its positioning within the control hierarchy and functionality, together with its relationship to the cellular production procedures, systems and controls, and its method of triggering replanning automatically, should be considered as a possible area for further research.

APPENDIX

APPENDIX A

CIM DEFINITION LITERATURE REVIEW

This literature review was performed by examining some forty references, all of which discuss the definition of CIM.

The references and definitions are as follows:

1. Alting and Lenau (1986) - CIM is a system in which distributing computing networks and common databases are used for combining and co-ordinating into a harmonic whole, such functions as product design, process planning, scheduling, purchasing, production, inspection, assembly, handling, management and marketing of discrete consumer or producer goods.

2. Reisch (1987) - CIM means linking all levels of the manufacturing process into an integrated information and control network.

3. Ewaldz (1987) - CIM is a combination of the various forms of computer technology put together to satisfy the needs of the individual firm.

4. Rzevski (1988) - CIM is a system whose aim is to add value to a manufacturing business by employing Information Technology (IT) with a view to achieving an effective integration of all planning and control activities within the host manufacturing organisation.

5. Crookhall (1986) - CIM includes all relevant control and information functions in a single interactive and centrally based system.

6. Thomas (1986) - CIM is a unified network of computer systems controlling and/or providing information to the functions of a manufacturing business in an integrated way.

7. Vernadat (1986) - CIM means complete integration of Computer Aided Design (CAD) functions with Computer Aided Manufacturing (CAM) functions with Production Management (PM) functions through Group Technology (GT) principles by means of a central Database Management System (DBMS).

8. Claydon (1985) - CIM is a philosophy which by definition uses a computer or a series of computers to achieve the objectives of integrating the manufacturing process.

To include the following areas:

- CAD
- GT
- MP & C
- AM & H
- CAM
- ROBOTICS

9. Cowan (1987) - CIM is the strategy by which manufacturing organisations bring together technologies and operational functions to optimise business activity from bidding to post delivery service.

10. Arnold & Johansson (1984) - CIM is a strategy, a conceptual methodology to integrate the various physical components to include the requirements of sales, marketing, manufacturing, planning & control, finance, accounting, administration and distribution.

11. Thomas (1986) - CIM is a united network of computer systems for controlling and/or providing information on the functions of a manufacturing business in an integrated way.

12. Hewlett Packard (1986) - CIM is a strategic framework for linking existing technologies and people to manage previously independent activities to achieve a total manufacturing system.

13. Vowler (1987) - CIM is a business strategy involved in taking the whole company and ensuring that it is organised so the information generated can be maximally exploited in the most efficient manner attainable.

14. Dutton (1986) - CIM is a strategy for winning in manufacturing; it is involved in the sharing of manufacturing resources related to information collection, storage, processing and distribution in such a way to optimise the performance of the total enterprise.

15. Meister (1987) - CIM is not a product as such, but a concept that calls for the combination of products, both hardware and software, with specialised capabilities that result in an integrated and interrelated overall process.

16. Mize et al (1985) - CIM is a concept, one which involves the intelligent combination of many technologies.

17. Garrett Turbine (1985) - CIM is the use of computer and information/communication technologies to effectively integrate all of the engineering/design functions, manufacturing plant functions, equipment/process technologies, manufacturing control processes and management functions, necessary to convert raw materials, labour, energy and information into a high quality profitable product within a reasonable amount of time.

18. Dunn (1984) - CIM is not a product but a strategy to enable a company to get the best out of the design, manufacturing and information technologies that are available.

19. Fischer (1986) - CIM is one unified logical system that will tie together the many separate systems that now exist in the typical manufacturing business.

Ingersoll Report (1986):

20. CIM is an information structure supporting the free flow of all information resident in the system to any part of the system as needed.

21. CIM is an amalgam of computer aided engineering and drafting, computer aided engineering, computer aided manufacturing engineering, flexible manufacturing system, tooling and quality support systems, in-process gauging and automated final inspection, automated storage and material handling and operations control within a business information system.

22. CIM is a unified network of computer systems performing and/or controlling the totally integrated functions of business.

23. CIM is the phased implementations of the integration of automated and non automated systems into the manufacture of a product. It is the integration to the maximum level of beneficial usage, to serve both long term profitability and quality of the product.

24. CIM is the organisation of the company so that computer hardware and software capabilities can be used to permit large organisations working on a complex products to achieve the responsiveness of small organisations working on simple products.

25. CIM is a strategy consisting of physical components and conceptual methodology to integrate the components.

26. Ranky (1986) - CIM is concerned with providing computer assistance, control and high level integration/automation at all levels of the manufacturing industries, by linking islands of automation into a distributed processing system.

27. IBM (1987) - CIM essentially means tying together via computer technology, all the various departments in an industrial company, so that they operate smoothly as a single integrated business system.

28. Riesman (1988) - CIM means co-ordinating via computer technology all the departments in an organisation so that they can operate smoothly as a single integrated business unit.

29. Lung (1988) - CIM is a philosophy rather than a specific system or set of applications. It uses the advances in computers, communication standards, information technology and database management systems in order to ensure an efficient flow of information between operations and activities in an enclosed integrated manufacturing environment.

30. Bertain (1987) - CIM is a corporate strategy for survival, it is an overall strategy that includes manufacturing.

31. Canada (1986) - CIM is any computer oriented equipment or system which aids in, or achieves, the automation of a manufacturing enterprise, and is planned to increase, if not eventually complete, integration of the enterprise.

32. Sibbold (1987) - CIM and management, "CIM", is the computer assisted integration of production processes and operations control functions needed for optimal deployment and productive use of the minimum manufacturing resources required to meet specific strategic business objectives.

33. White and Apple (1985) - CIM represents the high level of a computer hierarchy that includes CAD/CAM, CAE, CAPP, MRP, FMS, CNC, DNC, AMH, and AS/RS; it utilises a computer network to link together all functions of an enterprise.

34. Phelps (1986) - CIM is a goal or vision for the total integration of computer automation, networking tools and people to enable overall planning, coordination and decision making for the control of productivity, quality and cost to maximise profitability.

35. Spur and Specht (1987) - CIM can be understood as a dynamic means of rationalisation which by way of the integration of partial measures is directed at the whole factory.

36. Riehn (1987) - CIM is described as the horizontal and vertical integration of an enterprise by optimised movements of material, manufacturing resources and information under computer control.

37. Smith (1984) - CIM is, in the most general case, a colossal logarithm specifying company operating inter-relationships amongst most levels and most departments.

38. Downsland (1986) - CIM system can be defined as systems which bring together the engineering and design, planning, manufacturing and management functions of a company using current computer and equipment technologies in the most effective manner.

39. Gunn (1986) - CIM signifies the appropriate linkages by a carefully structured computerised operating and information management system between formerly separate manufacturing processes/operations and between such organisational functions as product design, manufacturing, engineering, purchasing, production control, quality assurance, etc.

40 Chuah (1989) - CIM should be viewed not just as a manufacturing issue but also as a business strategy which should be considered in the corporate planning and decision making processes; it is an enabling concept of functional integration for all business functions.

41. Little (1988) - CIM is the full integration of all business activities concerned with product design, sales and manufacture.

The literature review findings for the forty one CIM definitions, against the various classes and categories are shown in Table (11).

NB: The answers have been interpreted by examining the CIM definition and the supportive text which accompanies it.

AUTHOR	YEAR	DEFINITION CLASSES SINGLE FACET TYPE	 INFORMATION TECH./SYSTEMS	 TOTAL ORGANSTN	CIM SYSTEM/ NETWORK	 STRATEGY	 PHILOSOPHY
Arnold & Johanson	1984			*		*	
Dunn	1984		*			*	
Smith	1984			*		*	
Garrett Turbine	1985		*	*	*		
White & Apple	1985			*	*		
Mize et al	1985		*				*
Claydon	1985			*			*
Alting & Lenau	1986			*	*		
Gunn	1986		*	*	*		
Crookhall	1986		*		*		
Thomas	1986			*	*		
Vernadat	1986			*	*		
Hewlett-Packard	1986			*		*	
Dutton	1986		*	*		*	
Fischer	1986			*	*		
Ingersoll 1	1986		*		*		
Ingersoll 2	1986		*	*	*		
Ingersoll 3	1986			*	*		
Ingersoll 4	1986				*		
Ingersoll 5	1986						
Ingersoll 6	1986			*		*	
Thomas	1986			*	*		
Ranky	1986			*	*		
Canada	1986			*	*		
Phelps	1986						
Downsland	1986			*	*		
Bertain	1987			*		*	
Riehn	1987			*			
Sibbald	1987						
Reisch	1987	*			*		
Ewaldz	1987		*		*		
Cowan	1987			*		*	
Rzevski	1987		*	*	*		
Vowler	1987			*		*	
Meister	1987			*			*
IBM	1987			*	*		
Spur and Specht	1987			*			
Little	1988			*			
Riesman	1988			*	*		
Lung	1988		*	*			*
Chuah	1989			*		*	
TOTAL		1	11	31	21	9	4

Table (11): CIM definition literature review results

APPENDIX B

CIM CONCEPT CHART LITERATURE REVIEW

This literature review was performed by examining ten references, all of which discuss the elements of CIM and propose CIM concept charts.

The references include the following:

Ref. No.	Author	Year	CIM concept chart title
1.	McDonnell Douglas	1986	McDonnell Douglas concept of CIM
2	ICL	1986	ICL - CIM elements
3.	Materni and Sepehri	1986	Computer Integrated Manufacturing definition
4.	Vernadat	1986	The CIM concept
5.	Cowan	1987	CASA/SME - Integrated data architecture concept in CIM
6.	Cowan	1987	CIM content - CAD/CAM chart
7.	Schroeder	1987	CADMAC based CIM
8.	Gunn	1986	Computer Integrated Business
9.	Lee and Mosier	1984	Computervision - CAD/CAM database: CIM integrator
10.	Lee and Mosier	1984	General Electric "Factory with a future"

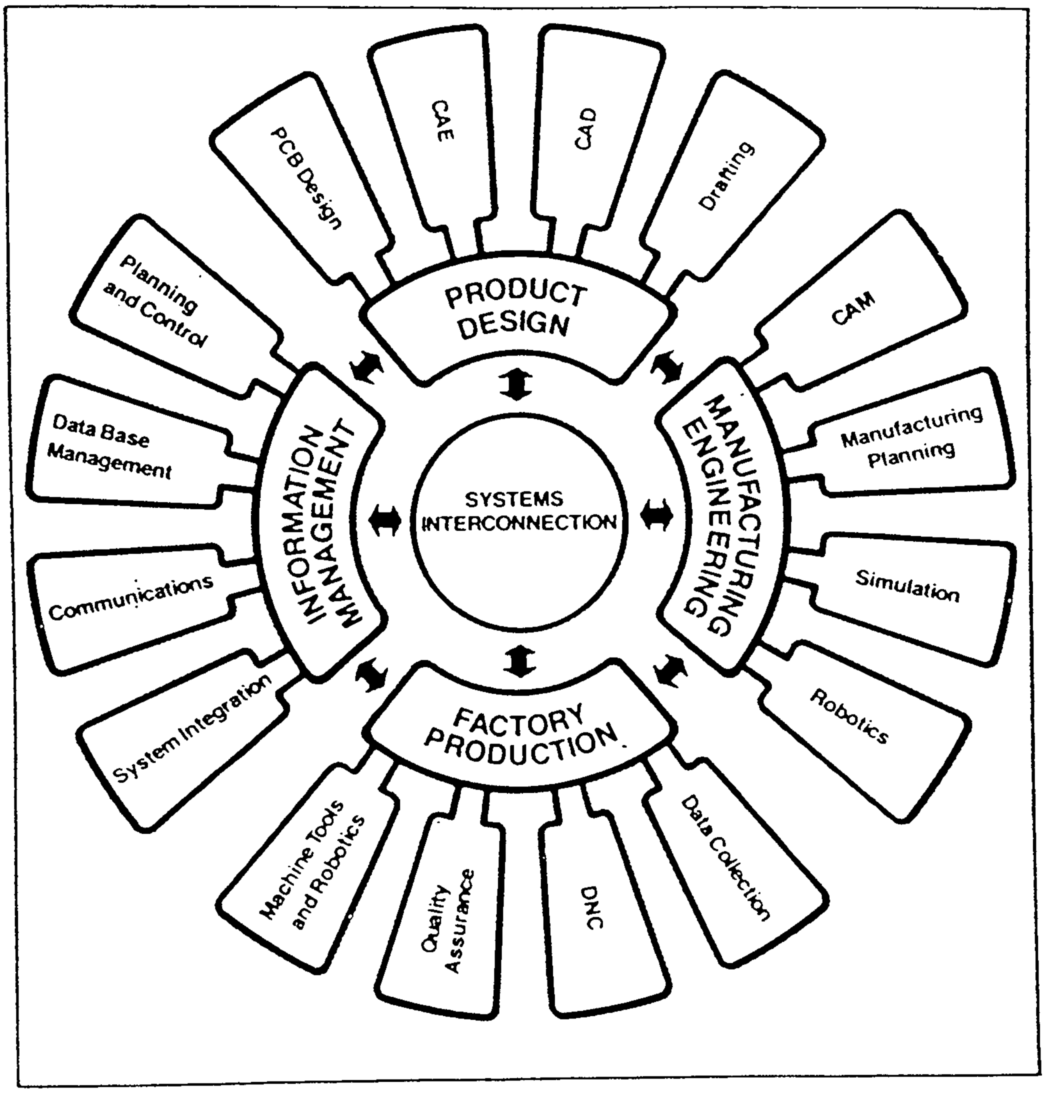


Figure (55): McDonnell Douglas concept of CIM

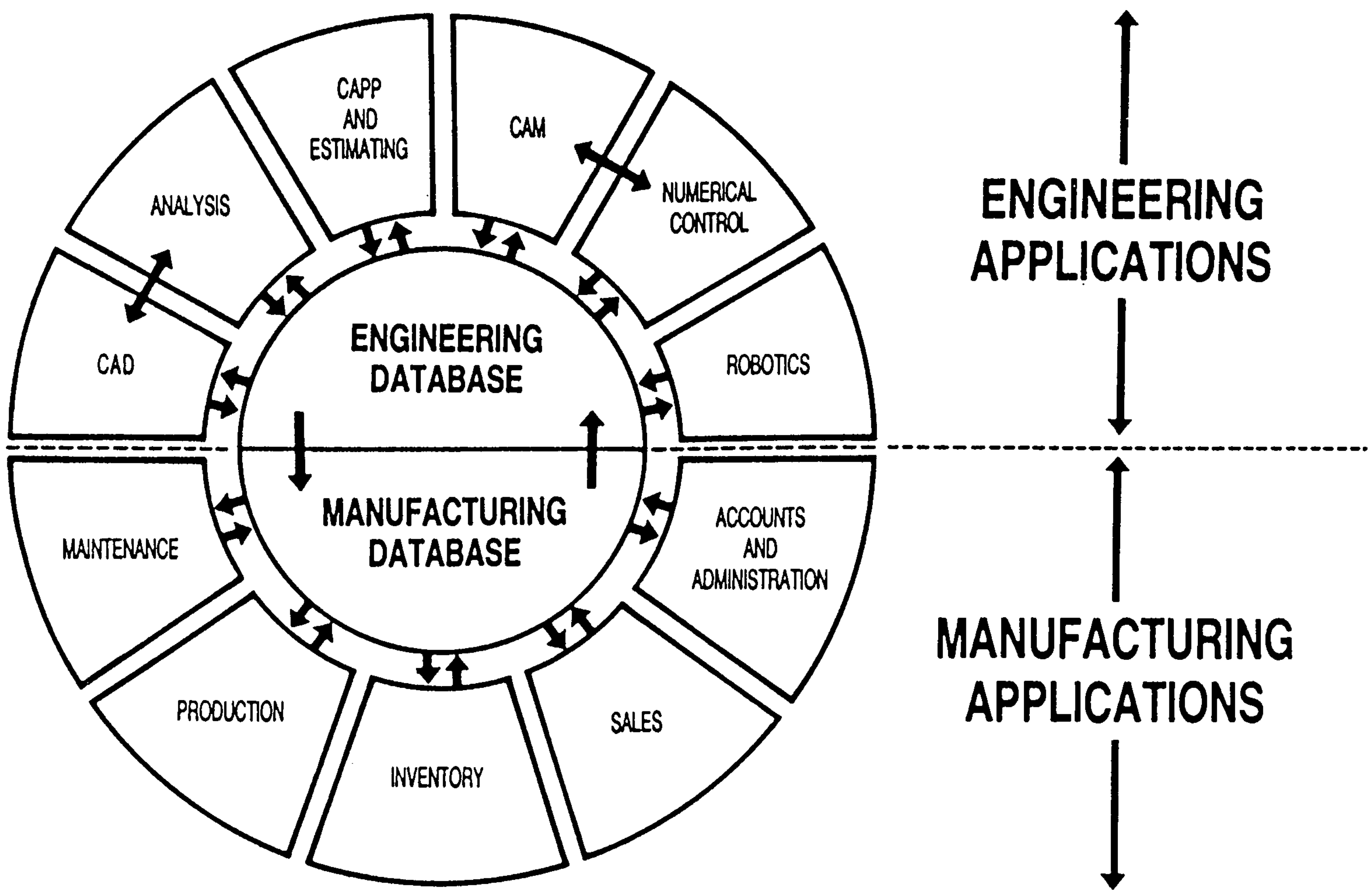


Figure (56): ICL - CIM elements

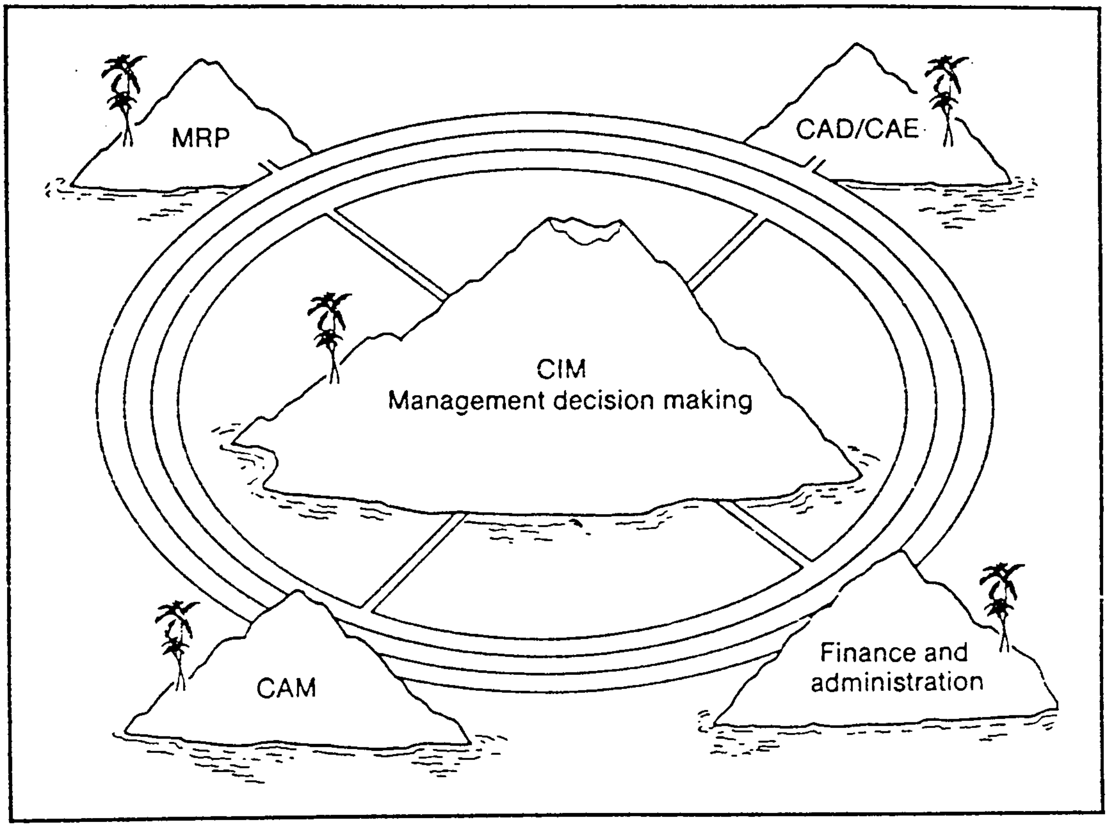


Figure (57): Computer Integrated Manufacturing definition

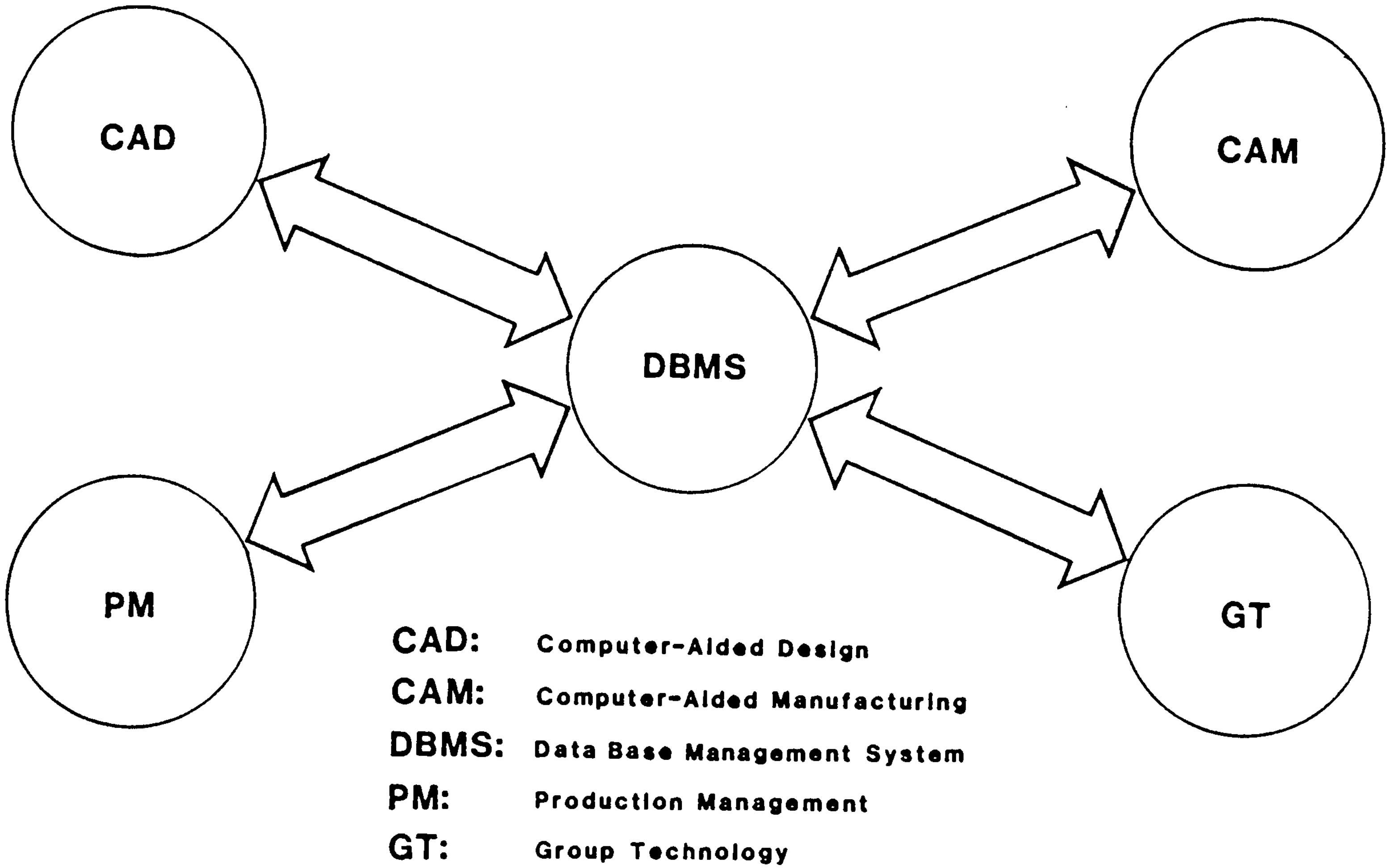


Figure (58): The CIM concept

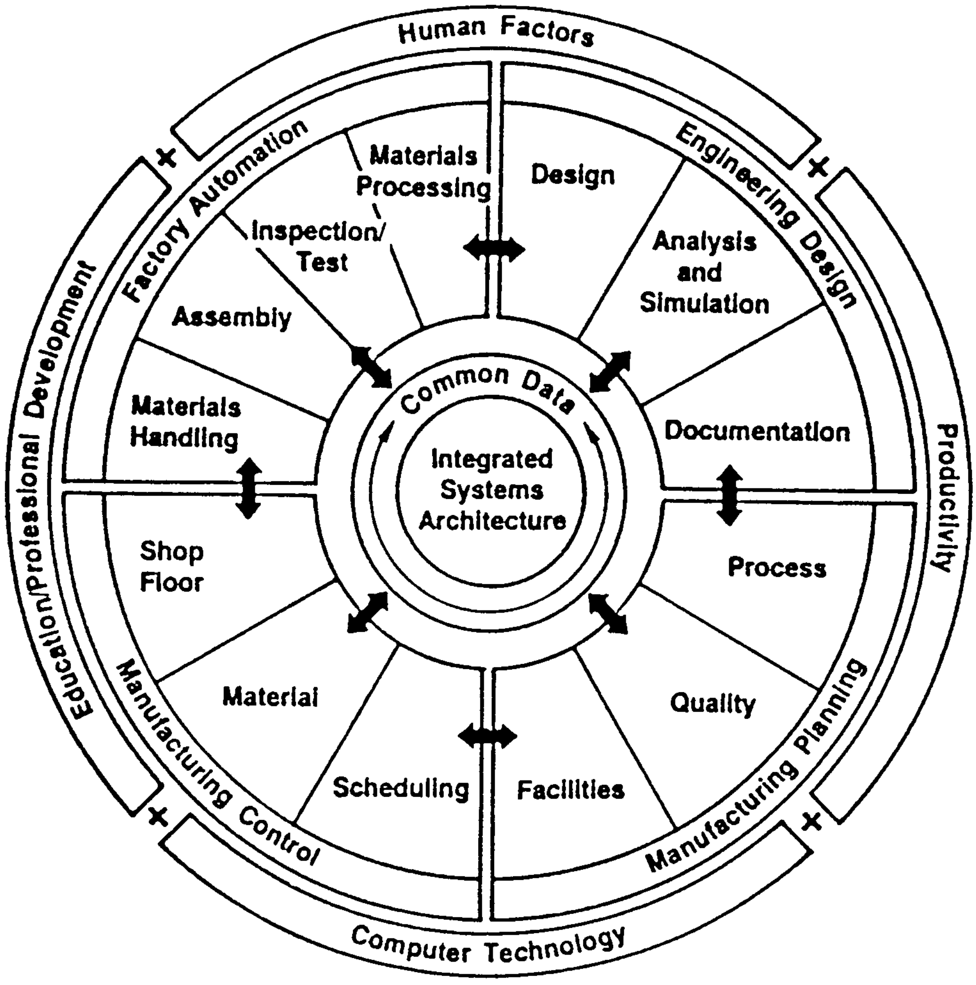


Figure (59): CASA/SME Integrated data architecture concept in CIM

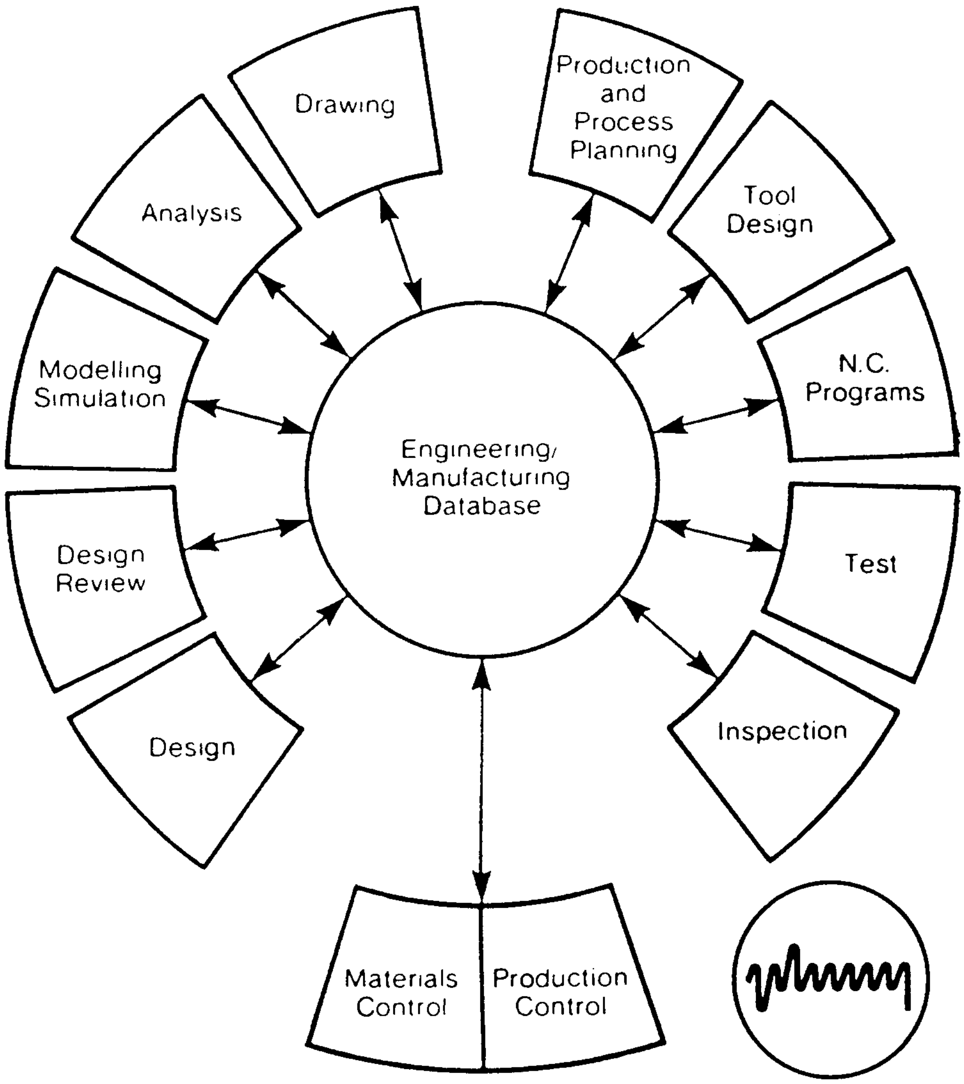


Figure (60): CIM content - CAD/CAM chart

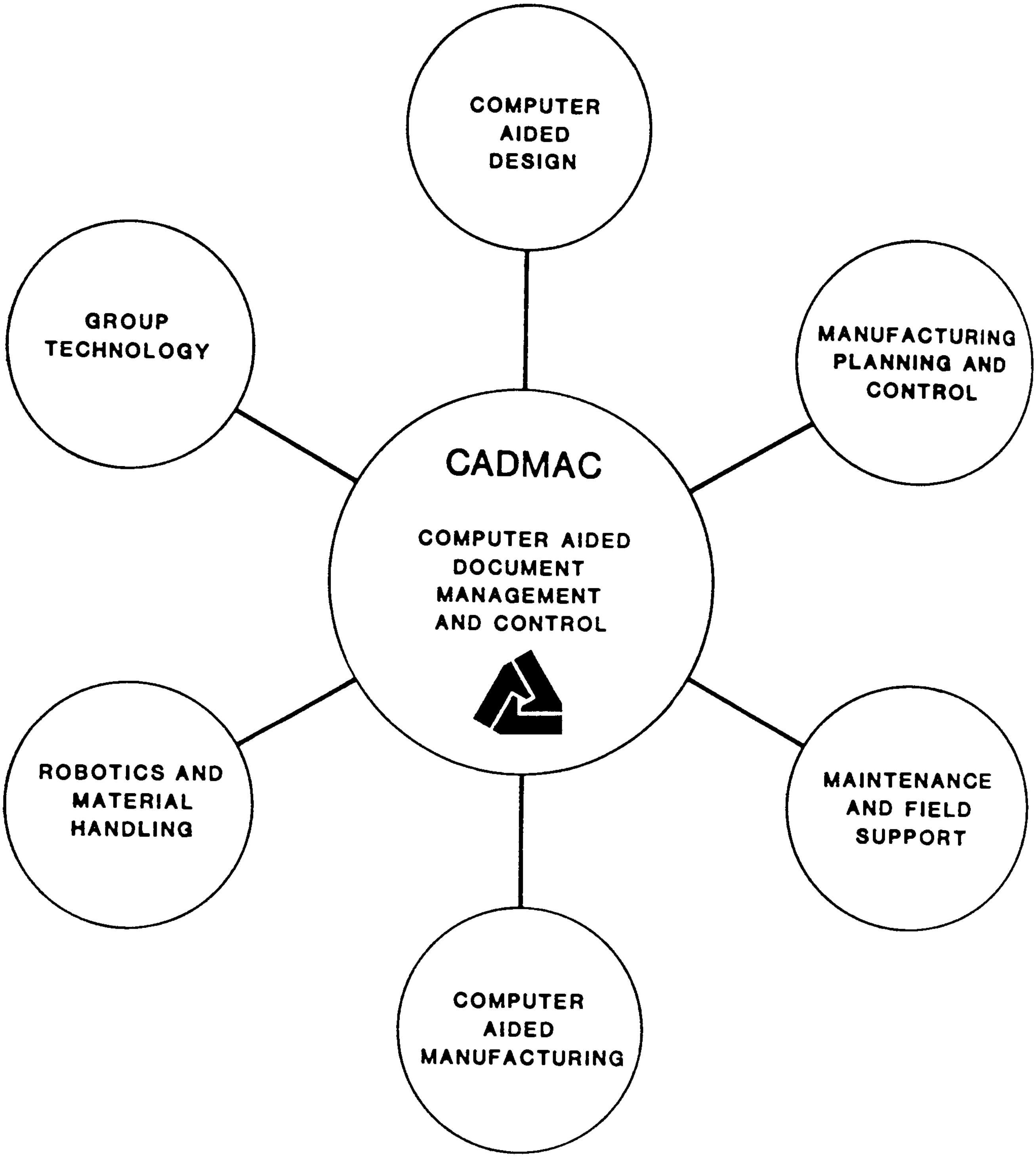
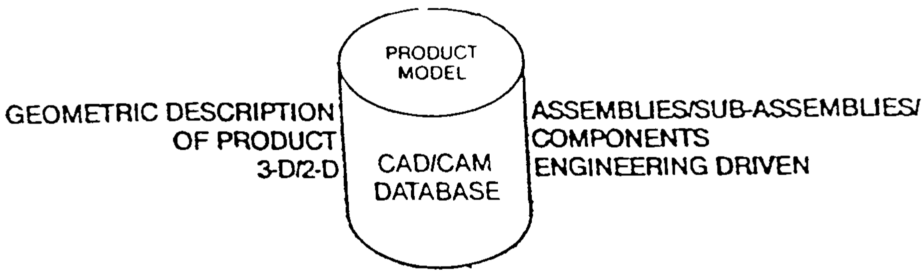


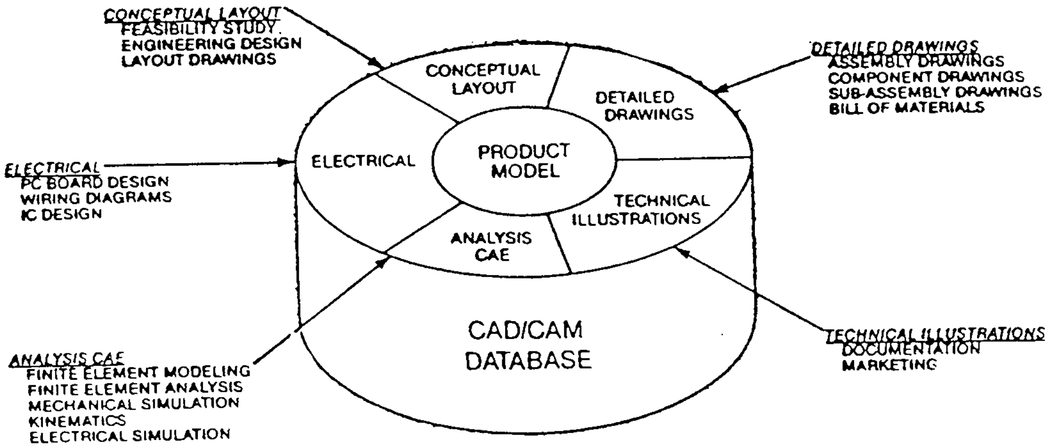
Figure (61): CADMAC based CIM

Illustration has been removed for copyright restrictions

Figure (62): CIM concept chart [Gunn (1986)]



CAD/CAM data base: product model core.



CAD/CAM data base: engineering applications.

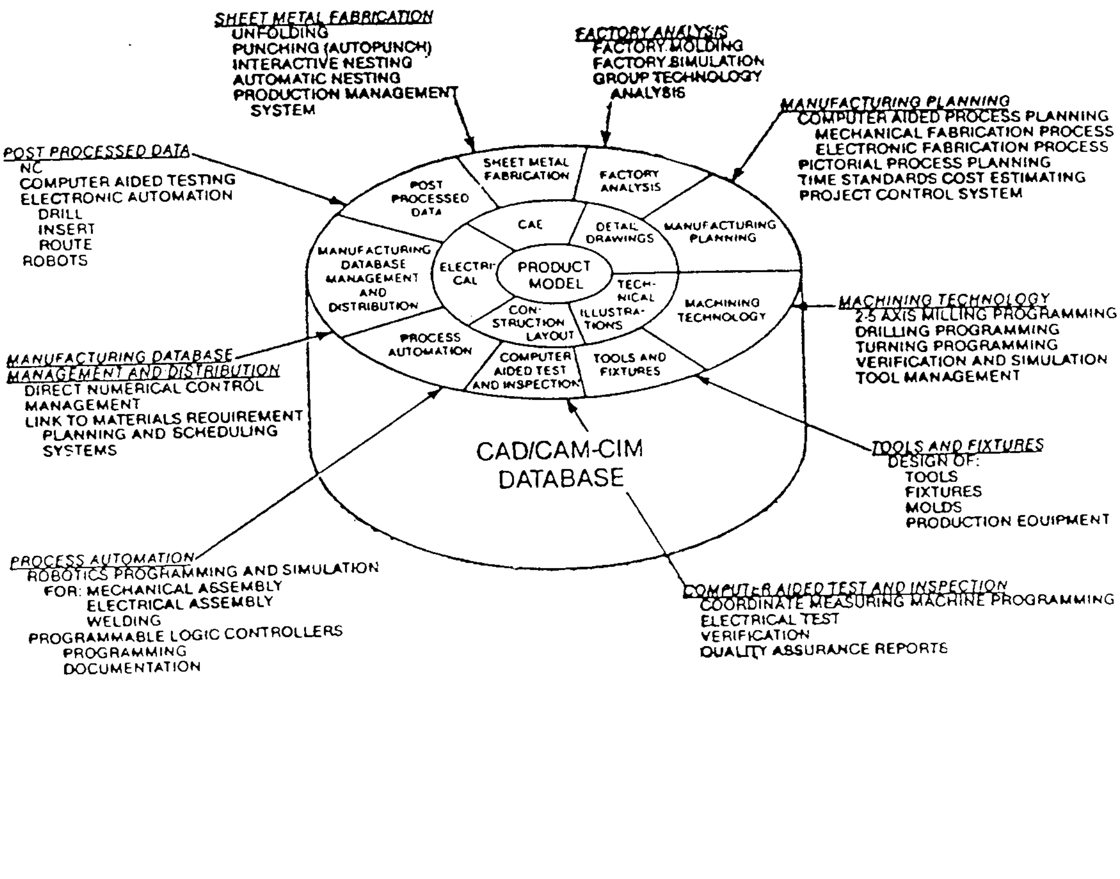


Figure (63): Computervision's CAD/CAM database - CIM integrator

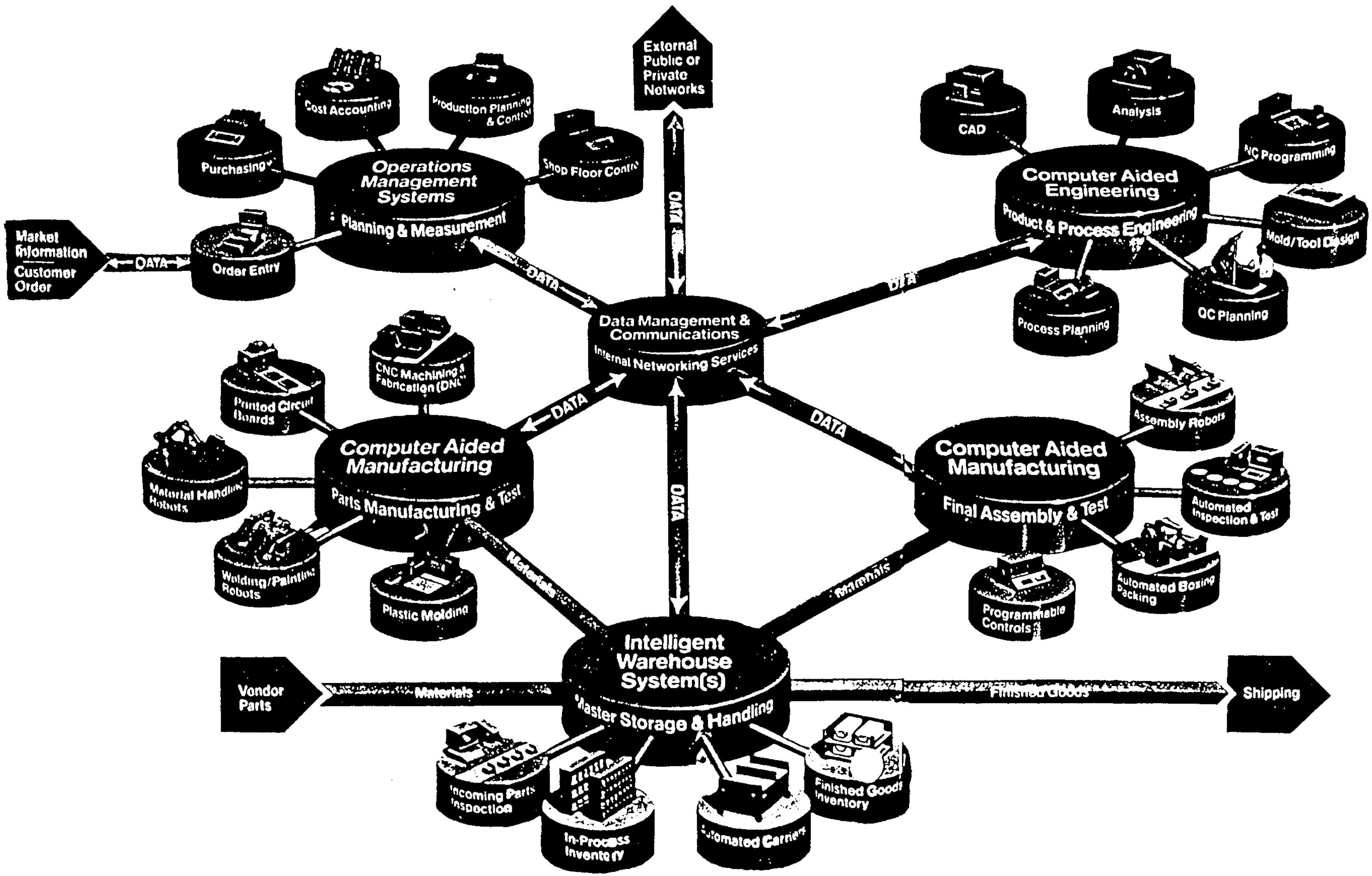


Figure (64): General Electric 'Factory with a future'

APPENDIX C

CIM ELEMENT LITERATURE REVIEW

This CIM element literature review was performed by examining twenty one references, all of which discuss the constituent parts of CIM. The references include the following:

Ref.no	Author	Year	Illustration/table name
1.	Gunn	1986	Establishing a CIM framework
2.	Materna/Sepehri	1986	CIM engine
3.	Vernadat	1986	CIM concept in the 1980's
4.	Reisch	1987	Total CIM concept
5.	Lee/Mosier	1984	CAD/CAM Dbase : CIM integrator
6.	Cowan	1987	Plessey CIM concept
7.	Schroaeder	1987	CADMAC based CIM
8.	Jones	1986	McDonnell Douglas concept of CIM
9.	Harvey	1986	CIM : Factory of the future
10.	P.A. Technology	1986	Integrated manufacture
11.	Owen	1986	Integrated manufacture
12.	Spur/Specht	1987	CIM in future factories
13.	Teicholtz	1984	CIM functions
14.	Willis/Sullivan	1984	Eight Key CIM functions
15.	Manchuk	1984	CIM subsystems/functions
16.	Branco	1986	CIM focus
17.	Elavia	1987	CIM modules
18.	Hales	1984	CIM overview chart
19.	Morgan	1986	An integrated data from CIM concept
20.	Ranky	1986	An overall CIM model
21.	Ingersoll Engineers	1986	The manufacturing information network

The above references were closely examined to see if their perceived view of CIM supports the inclusion of the following elements. The element list was established from a Lucas Aerospace Study; note that each CIM element has been broken up into its main sub elements.

Element List

1. Office Systems to include:
   - WP (Word Processing);
   - spreadsheet packages;
   - DTP (Desk top Publishing);
   - 2D sketching;
   - electronic messaging/mailing;
   - simple database;
   - autofaxing.

2. P.C.S. (Project Control Systems) to perform:
   - CPM (Critical Path Method);
   - time analysis;
   - resource analysis;
   - cost analysis.

3. Project team matrix structure

4. CAD/CAM (Computer Aided Design/Computer Aided manufacture) systems:
   - 2D drafting;
   - $2^1/2$ wire frame;
   - 3D modelling;
   - solids;
   - tool path generation/verification (cutter location file).

5. CAE (Computer Aided Engineering) systems to include:
   - mass properties calculation;
   - finite elements analysis/modelling;
   - product/part simulation.

6. EDMS (Engineering Database Management System)to comprise:
   - Engineering BOM (Bills of Materials);
   - Engineering Change Control (ECC);
   - product configuration control;
   - drawing management;
   - engineering database applications.

7. G.T. (Group Technology) philosophy to include:
   - classification of parts into families;
   - cellular manufacture of part families.

8. CAPP (Computer Assisted Process Planning) to comprise:
   - method of manufacture definition;
   - standard times generation;
   - setting sheets.

9. TMS (Tool Management System) to include:
   - tool selection/ordering/standardisation;
   - tool stores control;
   - tool scheduling.

10. AMH (Automated Material Handling) to include:
    - AS/RS (Automated Storage and Retrieval Systems-Warehousing);
    - conveyor systems;
    - AGV's (Automated Guided Vehicles).

11. CAM (Computer Aided Manufacturing) to include:
    - NC (Numerical Control), CNC (Computer Numerical Control) and DNC (Direct Numerical Control);
    - FMC/S (Flexible Manufacturing Cell/Systems);
    - Process Control (PLC - Programmable Logic Controllers);
    - CAI & T (Computer Aided Inspection & Test);
    - automated assembly.

12. Robotics

13. MRP II (Manufacturing Resources Planning)
    (for subsystems - refer to section 4.5)

14. JIT (Just in Time) philosophy to include:
    - just in time purchase of goods;
    - just in time delivery to customer.

15. Cell Management:
    - cell scheduling/sequence;
    - cell tool management;
    - cell quality control;

16. SFDC (Shop Floor Data Control) - normally part of MRPII system.

17. Factory Simulation (manufacturing systems design simulation).

18. Financial Ledgers to comprise:
   - Purchase Ledger (P.L);
   - Sales Ledger (S.L);
   - General Ledger (G.L).

19. Invoicing

   (maybe part of MRP II system)

20. Payroll

21. Fixed Asset Register

22. Computing technology to include:
   - DBMS (Database Management Systems);
   - operating system;
   - Protocols: (MAP - Manufacturing Automation Protocol);
(TOP - Technical Office Protocol);
(Ethernet/Token Ring/SNA, etc).
   - Fourth Generation Languages (4GL's);
   - computer hardware and software;
   - expert systems;
   - artificial intelligence.

The literature review findings for the above twenty two elements against the pre-stated twenty one references, are as follows. See Table (12)

Nb. The answers have been interpreted by examining the supportive text which accompanies the CIM element illustration.

Proposed Elements \ Reference Number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	TOTAL	%
1	Office Systems							*											*				2	10%
2	Project Control System (PCS)					*				*									*		*		4	19%
3	Project Team Matrix Structure									*									*		*		3	14%
4	CAD/CAM	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	21	100%
5	CAE	*	*		*	*	*		*	*	*		*	*			*	*	*	*	*	*	16	76%
6	EDMS	*				*	*			*	*						*	*	*	*	*		10	45%
7	GT - Part families - Cellular manfg.	*		*		*		*		*	*			*		*	*		*	*			11	52%
8	CAPP	*	*		*	*	*	*	*	*	*		*	*		*	*	*	*	*	*	*	18	86%
9	TMS					*				*				*					*	*			5	24%
10	AMH	*			*			*		*	*		*	*	*		*	*	*	*		*	13	62%
11	CAM	*	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*		*	19	90%
12	Robotics	*			*	*		*	*	*	*			*	*	*	*	*	*			*	14	67%
13	MRP II	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	21	100%
14	JIT	*								*													2	10%
15	Cell Management												*						*				2	10%
16	SFDC	*			*		*		*	*	*	*	*	*		*	*	*	*	*			14	67%
17	Factory Simulation	*				*			*					*		*			*				6	29%
18	Financial Ledgers		*									*			*	*	*	*	*		*	*	9	43%
19	Invoicing														*				*			*	3	14%
20	Payroll																		*		*	*	3	14%
21	Fixed Asset Register																		*		*		2	10%
22	Computing Technology	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	21	100%

Table (12): CIM element literature review results

APPENDIX D

CIM DELPHI STUDY

This appendix highlights the findings and propositions of a Delphi Study on the strategic and structural implications of Computer Integrated Manufacturing (CIM).

Delphi Results

The study focussed on three areas: benefits sought, internal impacts, and external impacts. Panelists were asked to identify the kinds of benefits they expected to result from CIM implementations, the kinds of internal changes that will be needed within their organisations, and, the likely impact of CIM adoption on the particular industry or industries they are familiar with. The following lists identify responses that were agreed to by a majority of the respondents.

Benefits of CIM

Reduced lead times for new product introductions.

Reduced Work in Progress inventories.

Reduced set-up and retooling times.

Lower unit costs for small to medium batch production.

Ability for high volume manufacturers to manufacture parts in the order they will be assembled, thereby reducing inventories.

Reduced costs and improved performance through better integration of design, engineering, and production functions.

Improved quality through automation and better control.

Reduced costs and greater flexibility through tighter integration of activities with suppliers and customers.

Alternative to overseas production.

Greatly increased manufacturing capacity.

Reduced risks of being locked into obsolete product designs.

Reduced plant size due to increased utilisation and reduced inventory needs.

Internal Impacts

Shift from short-term tactical planning to long-term strategic planning.

Development of "in-house" CIM integration capabilities.

Integration of manufacturing into long-term strategic planning.

Shift from emphasis on short-run cost reduction to long-run flexibility benefits.

Very tight integration of design, engineering, production, materials management, and marketing.

Very tight integration of manufacturing and distribution operations with those of suppliers and customers.

Much closer integration of product design and manufacturing activities between divisions.

Shift from a "hardware" to a "software" emphasis in manufacturing.

More companies will attempt to realise "economies of scope" strategies by increasing the range of manufactured products by a given facility.

External Impacts

Manufacturing industries will become more competitive as a result of: shorter product cycles; greater market fragmentation, as firms exploit their capability of producing small batches economically; and entry of new competitors, as very large manufacturing firms expand their product lines in pursuit of "economies of scope" strategies.

Destabilisation of industry structures as:

- industry leaders pursuing high volume/low cost strategies become vulnerable to more flexible and innovative challengers;

- entry costs for design/marketing firms are reduced as CAD systems linked to contract flexible manufacturing plants lowers the cost of new product development;

- increased flexibility lead to "de-maturing" of markets as firms experiment with new product variations;

- exit-costs are reduced as increased manufacturing flexibility allows firms to more easily switch resources to alternative markets.

Proposition 1: Although CIM will be faltering gradual and difficult, it will have significant impact by 1995.

Panel participants were well aware of the technical and financial difficulties inherent in CIM implementations. Most felt that CIM adoption would occur gradually with piecemeal automation being gradually tied together into an integrated system. The speed of adoption depends, they believe on: how quickly common communication standards are adopted, how aggressive computer manufacturers are in developing selling, and servicing CIM systems, and upon the success of high visibility projects, such as GM's Saturn division. Most panelists felt that favourable outcomes are likely in the above areas and that CIM will significantly impact industrial structures by the mid 1990s.

Major technological developments are expected in the areas of machine vision, improved accuracy and speed of robots, tactile sensors, use of artificial intelligence software for robot control and manufacturing expert system development. However, most panelists thought the great impact would come from resolving the problems associated with integrating existing technologies.

Proposition 2: Adoption of CIM will lead to manufacturing strategies to shift from their traditional emphasis on economies of scale to economies of scope.

As firms develop the ability to produce a wider range of products at a given site, and as they greatly reduce the lead times needed to introduce a new or customised product, and as markets become more competitive and unpredictable, firms will shift from their traditional focus on economies of scope. In other words, firms will seek to recoup their enormous investments in CIM by expanding their product lines within a given industry and by diversifying into different but technologically related industries.

A corollary of this proposition, is that divisionalised firms will seek close integration of design and manufacturing operations between divisions, as it becomes less economically feasible to decentralize very expensive and very flexible manufacturing facilities.

While the traditional economy of scale strategy (high volume/standardisation/low cost) will still be appropriate for many situations, many firms who have traditionally relied on this approach will find themselves caught in a pincer squeeze. Pacific Rim competitors with very low labour costs and/or very high capacity manufacturing plants will make it very hard to compete successfully on price. While domestic competitors, following flexibility and continuous innovation strategies, will not only deprive the firm of high-margin segments where differentiation is important, but will also force the firm to innovate more rapidly in order to protect its high volume markets, thereby cutting the size of its production runs.

Faced with these pressures, even firms seeking low cost leadership in their industry, will seek to exploit economies of scope strategies and to build greater flexibility into their manufacturing operations in order to protect their long-run, low cost strategies.

Proposition 3: Very large "super-corporations" will emerge organized around strategic technologies.

In the past firms have organized around industries, markets, and geographical boundaries. In order to make and recoup massive multi-million dollar investments in CIM facilities, manufacturing firms will increasingly organise themselves around strategic technologies. The logical extension of the "economies of scope" strategy is that they will exploit all the major markets and industries which can be supported by a strategic technology.

The merger between General Motors, EDS and Hughes Aircraft is one such example of the development of a huge enterprise organized around strategic technologies. The merger was based on electronic control and manufacturing systems, which can be applied to a variety of industries.

<u>Proposition 4: "Quasi-Firms" will emerge made up of strategic alliances between tightly linked but independent firms.</u>

The drive to lower costs and increase responsiveness will lead to attempts to achieve ever tighter integration between all the elements that make up a product's delivery system. Integration of design with manufacturing, Just-in-Time inventory policies and very high levels of flexibility, all require tight coupling between a firm and its suppliers. Typically, a lead firm will act as a prime contractor and will encourage its suppliers to tie in their administrative and operational systems with those of the firm. In exchange, the suppliers will enjoy long-term contracts. Example of such "quasi-firms" already exist in the construction industry and the aerospace industry.

<u>Proposition 5: Knowledge boutiques will emerge</u>

Relatively small firms made up of very young, highly educated and fanatically motivated individuals will emerge to service larger, more stable, but less entrepreneurial firms. Examples of these kinds of firms already exist in advertising, public relations, product design, television production, and software development.

As manufacturing becomes an increasingly knowledge intensive industry, reliance on such firms is likely to grow enormously.

<u>Proposition 6: The organisation of CIM firms will shift from focus on vertical management to a focus on lateral management.</u>

The traditional organisational structure organises people into semi-permanent departments, linked together through a vertical chain of command. While this system is simple, easy to implement and highly effective during times of relative stability, it has proven to be very weak when it comes to integrating activities across organizational lines. The emphasis in CIM firms will switch to lateral integration of activities. Task forces and teams made up of people from different functional units will be the main organisational unit for achieving integration. Managers will spend much of their time traversing traditional organizational boundaries. The hierarchy as an information conduit will become increasingly obsolete as people are able to utilise informal contacts, electronic mail, and database systems to retrieve and exchange information as they need it.

Proposition 7: CIM firms will shift from a single mode to a multi mode form of organization

Firms tend to be organised around single modes whether it be centralised or decentralised, organised around product or function, mechanistic or organic. In a CIM environment, firms will have to adopt several modes concurrently. The massive investment in technology requires long-term, centralised strategic planning, and the need to integrate design and manufacturing activities between divisions also implies centralisation. However, the firm also faces the need to exploit the flexibility of the technology by attacking high margin segments and it must also be able to respond to the fast changing demands of a fragmented and unstable market place. Consequently, some activities will require a centralised, integrated decision making structure, others will call a decentralised, distributed structure.

Similarly, the conventional wisdom in organizational theory is that as firms face increasingly unstable and dynamic environments, organic structures based on mutual adjustment becomes preferable to highly standardised bureaucratic structure. Yet, the CIM environment, which requires great flexibility, implying an organic structure, also requires rigid standardisation of procedures for the computer integration to be made possible in the first place. Again the effective firm must learn how to adopt different modes of operation according to the specific task required.

Proposition 8: CIM organisations will shift from a low commitment human resource management policy to a high commitment one

High volume, standardised manufacturing has been built around the philosophy of specialisation and control. Tasks were broken down into their smallest component parts; job cycles times were reduced from hours to minutes to seconds; jobs were redefined and redesigned so that they could be performed by the plentiful supply of low paid, unskilled labour. This highly fragmented production system was integrated through two devices, an assembly line and a system of close, top-down supervision. These principles of industrial job design and control have also been applied to large white-collar offices where routine, repetitive work cycles have to be performed. Although these production systems have proven to be remarkably efficient, they have serious flaws. They tend to be inflexible and they tend to generate low commitment and alienation among the work force. As firms become more capital and information intensive, they can no longer afford low commitment human resource strategies. Firms will become increasingly dependent upon fewer people. If they are to be effective, they must design jobs, career structures, and reward systems that encourage high commitment and participation.

APPENDIX E

CIM BUSINESS ELEMENT MODEL - RELATIONSHIP DEFINITIONS

This appendix defines the relationships between the various business elements shown in the business element relationship diagram, Figure (25), chapter 5., section 5.2.2.

RELATIONSHIP NUMBER	RELATIONSHIP DESCRIPTION
R1001	A BUSINESS FUNCTION is PERFORMED BY one or more PERSONS. A PERSON may PERFORM one or more BUSINESS FUNCTIONS.
R1002	A BUSINESS FUNCTION is PERFORMED BY a SYSTEM. A SYSTEM may PERFORM one or more BUSINESS FUNCTIONS.
R1003	A BUSINESS FUNCTION may USE one or more INFORMATION. An INFORMATION may be USED BY one or more BUSINESS FUNCTIONS.
R1004	A BUSINESS FUNCTION may PRODUCE one or more INFORMATION. An INFORMATION is PRODUCED BY a BUSINESS FUNCTION.
R1005	A BUSINESS FUNCTION OWNS one or more INFORMATION. An INFORMATION may be OWNED BY a BUSINESS FUNCTION.
R1006	A BUSINESS FUNCTION is PART OF one or more CONTROL LOOPS. A CONTROL LOOP INCLUDES one or more BUSINESS FUNCTIONS.
R1007	A BUSINESS FUNCTION is ACCOMMODATED BY the ORGANISATION. An ORGANISATION must ACCOMMODATE one or more BUSINESS FUNCTIONS.
R1008	A BUSINESS FUNCTION may COMPRISE one or more BUSINESS FUNCTIONS.
R1009	A BUSINESS FUNCTION may COMPRISE one or more DECISIONS. A DECISION is PART OF a BUSINESS FUNCTION.
R1010	A BUSINESS FUNCTION is MANAGED BY a PERSON. A PERSON may be RESPONSIBLE FOR MANAGING one or more BUSINESS FUNCTION.
R1100	A PERSON may OPERATE one or more SYSTEMS. A SYSTEM is OPERATED BY one or more PERSONS.

R1101 A PERSON may be RESPONSIBLE FOR MAKING one or more DECISIONS.
A DECISION is MADE BY one or more PERSONS.

R1102 A PERSON may be RESPONSIBLE FOR one or more CONTROL LOOPS.
A CONTROL LOOP is the RESPONSIBILITY OF a PERSON.

R1103 A PERSON may be RESPONSIBLE FOR GENERATING one or more INFORMATION.
An INFORMATION is GENERATED BY one or more PERSONS.

R1104 A PERSON may STORE one or more INFORMATION.
An INFORMATION is STORED BY one or more PERSONS.

R1105 A PERSON may USE one or more INFORMATION.
An INFORMATION may be USED BY one or more PERSONS.

R1106 A PERSON is ACCOMMODATED BY an ORGANISATION.
An ORGANISATION most ACCOMMODATE one or more PERSONS.

R1107 A PERSON may be RESPONSIBLE FOR one or more PERSONS.

R1201 A DECISION is ACCOMMODATED BY an ORGANISATION.
An ORGANISATION must ACCOMMODATE one or more DECISIONS.

R1202 A DECISION may COMPRISE one or more DECISIONS.

R1203 A DECISION may be the RESPONSIBILITY OF a SYSTEM.
A SYSTEM may be RESPONSIBLE FOR MAKING one or more DECISION.

R1204 A DECISION is PART OF a CONTROL LOOP.
A CONTROL LOOP may COMPRISE one or more DECISIONS.

R1205 A DECISION is SUPPORTED BY one or more INFORMATION.
An INFORMATION may SUPPORT ONE or more DECISIONS.

R1300 A SYSTEM may be MADE UP OF one or more SYSTEMS.

R1301 A SYSTEM is ACCOMMODATED BY an ORGANISATION.
An ORGANISATION MUST ACCOMMODATE one or more SYSTEMS.

R1302 A SYSTEM may be RESPONSIBLE FOR CLOSING one or more CONTROL LOOPS.
A CONTROL LOOP may be CLOSED BY a SYSTEM.

R1303 A SYSTEM STORES one or more INFORMATION.
An INFORMATION is STORED BY one or more SYSTEMS.

R1304 A SYSTEM is RESPONSIBLE FOR GENERATING one or more INFORMATION.
An INFORMATION is GENERATED BY a SYSTEM.

R1305 A SYSTEM may be INTERFACED TO one or more SYSTEMS.

R1400 A CONTROL LOOP COMPRISES one or more INFORMATION.
An INFORMATION may SUPPORT one or more CONTROL LOOPS.

R1401 A CONTROL LOOP is ACCOMMODATED BY an ORGANISATION.
An ORGANISATION must ACCOMMODATE one or more CONTROL LOOPS.

R1402 A CONTROL LOOP may COMPRISE one or more CONTROL LOOPS.

R1500 An ORGANISATION must ACCOMMODATE one or more INFORMATION.
An INFORMATION is ACCOMMODATED BY an ORGANISATION.

R1600 An INFORMATION may COMPRISE one or more INFORMATION.

APPENDIX F

CIM METHODOLOGY LITERATURE REVIEW

This literature review was performed by examining twenty four references, all of which discuss aspects relating to the development of a CIM methodology. The references include the following:-

Ref.No	Author	Year	Title of Reference
1.	Murphy	1983	Developing a CIM strategy and plan.
2.	Stark	1984	Successful identification of a CIM strategy and successful implementation of a CIM solution.
3.	Hales	1984	How small firms can approach, benefit from CIM systems.
4.	Schwendinger	1984	Do your homework before you modernise the factory.
5.	Punwani	1985	CIM business strategy case study for an aerospace organisation.
6.	Rolls	1985	The CIM debate.
7.	Ingersol Engineers	1985	Integrated manufacturing.
8.	Rushton	1985	Developing a CIM strategy.
9.	Branco	1986	Laying the CIM foundation. A structured strategy based methodology.
10.	Gunn	1986	CIM - A management perspective.
11.	Henry	1986	In preparation for CIM.
12.	Oden & Bibeau	1986	Involving all employees in CIM.
13.	Harvey	1986	CIM: strategies for success.
14.	King and Long	1986	Transitioning from tactical to strategic planning in CIM.
15.	Vernadat	1986	Key technologies for successful manufacturing integration CIM.
16.	Jenster	1987	Using critical success factors in planning.
17.	Elavia	1987	Where do I start with CIM?
18.	Greenwood	1987	CIM and You.
19.	Reisch	1987	The position of internal logistics in factory automation and total CIM concept.
20.	Vogel	1987	Strategic planning for CIM implementation.
21.	Rzevski	1987	From business plan to CIM strategy.
22.	Moyes	1987	CIM, a realistic approach.

23.	Harrower	1988	Successful systems management in manufacturing.
24.	Chuah	1989	CIM development - A strategic management issue.

Survey Analysis Criteria

1. Is a business wide approach to CIM supported, one which:

   1.1 involves all business areas;
   1.2 gains support and commitment from all employees;
   1.3 develops a team approach;
   1.4 considers the required cultural changes.
   1.5 develops a pro-active response to business change;
   1.6 appoints a CIM champion;
   1.7 forms a multi-disciplinary team;
   1.8 establishes a corporate philosophy;
   1.9 develops a shared vision and shared values;
   1.10 establishes a single focus;
   1.11 establishes a steering group/CIM executive committee;
   1.12 supports the use of critical success factors;
   1.13 recognises the importance of training/education.

2. Is CIM cross referenced back to the business strategy, such that it:

   2.1 supports the direct underpinning of CIM opportunities back to the business strategy elements, that is, the business strategy is used as a backcloth for CIM;

   2.2 supports the need to develop a network chart to tie the CIM objectives to the primary business and business control objectives.

3. Does the business analysis technique:

   3.1 recognise the importance of analysing business functions and information;

3.2 recognise the importance of examining the business controls;

3.3 establish business analysis models for both the AS-IS state and the TO-BE state;

3.4 develop an approach that takes the AS-IS model and produces the TO-BE model.

4. Is business element modelling supported by the development of levelled control hierarchies;

5. Does the CIM system design base the definition of CIM system elements and systems integration on control requirements and control loop interactions;

6. Does the CIM system architecture support the development of a systems integration control framework (refer to chapter 9).

7. Is the CIM analysis and design stages structured , such that it:

7.1 recognises the need to use standard structured analysis techniques;

7.2 supports the IDEF standard.

7.3 supports the use of Computer Assisted Software Engineering (CASE) tools.

8. Recognises the importance of the management of change process during a CIM endeavour.

9. Is system prototyping or system walkthrough methods used for modelling the changes to the business procedures.

The findings form the CIM methodology literature review can be seen in Table (13)

Ref No / Criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		TOTAL	%
1.1	*		*				*				*	*	*				*			*	*			*		10	41.67
1.2		*			*	*	*		*	*		*		*		*	*				*			*		12	50.00
1.3					*											*	*		*			*				5	20.83
1.4							*				*	*		*				*			*			*		7	29.17
1.5		*					*				*	*		*							*			*		7	29.17
1.6							*	*	*								*				*					5	20.83
1.7	*	*	*		*	*	*	*			*	*	*	*			*	*	*		*	*	*			17	70.83
1.8									*			*														2	8.33
1.9											*													*		2	8.33
1.10					*				*			*											*			4	16.67
1.11			*		*		*					*		*	*	*										7	29.17
1.12			*	*	*				*							*					*					6	25.00
1.13	*	*	*		*		*	*	*	*		*	*	*			*			*	*					14	58.33
2.1	*	*		*	*				*	*			*	*		*					*		*	*		12	50.00
2.2																											
3.1		*	*	*	*	*	*	*			*	*		*	*	*	*		*	*	*			*		17	70.83
3.2				*			*	*								*	*									5	20.83
3.3			*	*											*					*						4	16.67
3.4																											
4															*											1	4.17
5																											
6																											
7.1				*	*		*							*	*		*	*				*				8	33.33
7.2				*											*											2	8.33
7.3																											
8		*			*		*				*			*			*				*					7	29.17
9																											
10																											

Table (13): CIM methodology literature review results

APPENDIX G

CONTROL HIERARCHY LITERATURE REVIEW

This literature review was performed by examining fifteen references, all of which discuss levels of control and their business characteristics. The references include the following:

Control Hierarchy No	Author	Date	Control Hierarchy Title
1.	Rembold et al	1986	Hierarchical Computer Control.
2.	Vernadat	1986	Computer Control System Architecture.
3.	Groppetti	1987	CIM Reference Model.
4.	Rzevski	1987	Hierarchical CIM Architecture.
5.	Helming/Vasile	1987	Manufacturing Control Hierarchy.
6.	Kluchar	1987	Genuine Control/Production Hierarchy.
7.	CIM task force	1988	Business Control Levels/Hierarchy.
8.	Parnaby	1987	Manufacturing Systems Architecture Level.
9.	Rhodes	1984	Control Levels.
10.	Ekong	1987	Factory of the Future Architecture.
11.	Metzger & McCarthy	1986	Plant Control Hierarchy.
12.	Williams	1986	Industrial Control Hierarchy.
13.	O'Grady	1986	CAMI Factory Management Control Hierarchy.
14.	Furlain et al	1983	NBS Planning and Control Hierarchy.
15.	O'Grady	1986	Planning and Control Hierarchy.

The above references were closely examined to establish the business characteristics for each control hierarchy. This process was performed by checking each control hierarchy against a standard analysis criteria list.

Survey Analysis Criteria

1. No of levels supported.

2. Numbering of levels is:
   - A. top down;
   - B. bottom up;
   - C. no numbering.

3. Control hierarchy modelling scope is:

   - A. primarily production related;
   - B. mainly production related, some discussion of other business processes/systems;
   - C. generally an equal assessment of business functions;
   - D. not related to business functions.

4. Type of control hierarchy application is:

   - A. production process related within:
     - A1. process industry;
     - A2. general manufacturing industry;
   - B. manufacturing computer systems related;
   - C. control related;
   - D. pure academic.

5. Business elements supported (excluding business culture and organisation structure):

   - control;
   - process/functions;
   - information;
   - systems;
   - people.

6. Identify the response time for each level.

The findings from the control hierarchy literature review can be seen in Table (14).

Survey Analysis Criteria / Control Hierarchy Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Comments
1. Number of levels supported	4	5	5	4	5	6	4	4	3	5	6	5	4	5	4	Average = 4/5
2. Type of numbering convention	A	B	C	B	C	B	C	A	A	C	B	B	C	C	C	Various
3. Control Hierarchy modelling scope	A	B	B	B	A	A	D	C	D	B	A	A	A	A	B	Mainly Production Related
4. Type of control hierarchy application	A2	B	B	C	A2	A1	D	B	C	A2	D	A1	D	D	D	Various
5. Business elements supported:																
- Control	*	*	-	*	-	-	-	*	*	*	*	-	*	*	-	9/15 = 60%
- Processes/Functions	*	*	*	*	*	*	-	*	*	*	-	*	*	*	*	13/15 = 87%
- Information	*	-	-	-	-	-	-	*	-	-	-	-	-	-	-	2/15 = 13%
- Systems	*	*	*	*	*	*	-	*	-	*	-	-	-	-	*	9/15 = 60%
- People	*	-	-	-	-	-	-	-	*	-	-	-	-	-	-	2/15 = 13%
- Decision	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	1/15 = 7%
6. Response time for each level	*	*	-	-	-	-	*	*	*	-	-	-	-	-	-	5/15 = 33%

Table (14): Control hierarchy literature review results

1. Rembold et al (1986)

Figure 65. HIERARCHICAL COMPUTER CONTROL

People: Functions: Control: Systems: Response Time: Information:	Corporate management/executive personnel. Forecasting, marketing, competitive analysis. Strategic planning, business operation. Large central computer. Weekly basis. Simulation models, control schemes and summarised data from: - sales; - purchasing; - finance; - manufacturing operations.	1 CORPORATE CONTROL LEVEL
Control: Functions: People: Systems: Response Time:	Management of plant and manufacturing system. Order scheduling, production release, order tracking, production status reporting. Middle management. Several mini computers and micros. Daily basis/several hours.	2 PLANT CONTROL LEVEL
Control: Systems: Functions: Response Time:	To supervise and control production runs and quality activities. A number of mini/micro computers: Monitoring/supervising several machine tools, scanning process inputs from sensors, counting and evaluation of critical parameters, data reduction, limited control of process. Continuous/real time.	3 PLANT FLOOR CONTROL LEVEL
Control:	Real time controller for machines.	4 MACHINE CONTROL LEVEL

2. Vernadat (1986)

Figure 66. COMPUTER CONTROL SYSTEM ARCHITECTURE FOR CIM

Control: Functions: Systems: Response Time:	Corporate management. Forecasting, customer order processing, billing, accounting, personnel management. Mainframe computers/powerful databases. Months to years.	5 COMPANY LEVEL
Control: Functions: Systems: Response Time:	Medium term management. Plant inventory control, production planning, material requirements planning, production scheduling, process planning. MRP, CAD/CAE, CAPP. Weeks to months.	4 PLANT LEVEL
Control: Functions: Systems: Response Time:	Short term process management functions at the Cell level. (Control of several groups of machines). Job scheduling, job dispatching, job monitoring, quality control, cost monitoring. Mini/super mini computers. Hours to days.	3 JOB SHOP LEVEL (CELL)
Control: Functions: Systems: Response Time:	Process supervision. Giving orders to processes at level 1, and monitoring the process, DNC control, machine loading/unloading, robot and machine collision avoidance. Micro and mini computers, DNC. Seconds to minutes.	2 STATION LEVEL
Control: Functions: Systems: Response Time:	Machine/process control. Control of NC machine tools, robots, co-ordinate measuring machine and welding/assembly processes. Micro-computer based: programmable logic controllers, machine controllers and micro-processors. Real time (milli seconds to seconds).	1 PROCESS LEVEL

3. Groppetti (1986)

Figure 67. CIM REFERENCE MODEL

Systems:	CAD, general CAM, office information system, MRP II.	STRATEGIC LEVEL
Functions: Systems:	Scheduling of shop floor, shop floor decision making. Expert system (scheduling), system emulator and simulator.	TACTICAL LEVEL
Functions: Systems:	Collect aggregated data from cell controllers and take tactical decisions. Shop controller.	SHOP OPERATION LEVEL
Systems:	Cell controller, transport systems.	CELL OPERATION LEVEL
Systems:	Computer Numerical Control (CNC), Programmable Logic Controller (PLC), Automated Guided Vehicles (AGV's), Numerical Control (NC).	EXECUTION LEVEL

4. Rzevski (1987)

Figure 68. HIERARCHICAL CIM ARCHITECTURE

Control:	Plans and controls an entire manufacturing operation	4 CIM SYSTEM LEVEL
Control: Functions: Systems:	Co-ordinating the various operations. Flexible manufacturing cells. Production line, accounting, computer aided design, business planning. CAD.	3 CIM SUB SYSTEM LEVEL
Control:	Planning and controlling the operation of a collection of manufacturing work stations organised into: - flexible manufacturing cell; - production line section.	2 CIM CELL LEVEL
Control:	Controlling a single manufacturing work station (machine tool, robot arm or conveyor).	1 CIM MODULE LEVEL

5. Vasile (1987)

Figure 69. MANUFACTURING CONTROL HIERARCHY

Systems: Function:	Corporate divisional computer, corporate CAD computer. Corporate management.	CORPORATE MANAGEMENT LEVEL
Systems: Function:	Plant computer, SMCS (Supervisory Manufacturing Control System. Plant management.	PLANT STAFF MANAGEMENT LEVEL
Systems: Functions:	Line computers. Line management to include materials, operations, manufacturing engineering, quality control, finance.	LINE MANAGEMENT LEVEL
Systems: Functions:	Area computers. Area supervision to include production and inventory control, assembly, test, receiving, warehouse, shipping, distribution.	AREA SUPERVISOR LEVEL
Systems: Functions:	Production resource control systems. Material handling, tools, decision support, shop floor control, work station management, preventative maintenance, data collection.	PRODUCTION RESOURCES LEVEL

6. Kluchar (1987)

Figure 70. GENERAL CONTROL/PRODUCTION HIERARCHY

Systems:	CIM, MRP, Payroll, CAD/CAM, CAPP, large mainframe computer (corporate host).	LEVEL 5
Functions: Systems:	Scheduling, receiving, shipping. MRP, Small mainframe computer, large mini computer (plant host).	LEVEL 4
Functions: Systems:	Data collection, time and attendance, order tracking, inventory, activity reporting. Mini supervisory computers, data collection systems, machine monitoring, inventory control systems, process instrumentation systems, graphic systems.	LEVEL 3
Systems:	Process computers controlling area networks, application software, communications, interface and networks, protocol software, menu driven software, graphics, local area networks, dedicated networks, special interfaces, mini computers.	LEVEL 2
Systems:	Local control systems, Programme logic controllers (PLC's), CNC, micro processors, relay panels, real time control programs, ladder logic, relay logic, micro programs.	LEVEL 1
Systems: Function: Systems:	Sensors. Provides basic inputs to all levels of control and information systems. Machine data entry stations, limit switches, current transformers, pressure transducers, bar code readers.	LEVEL 0

7. Lucas group CIM task force (1988)

Figure 71. BUSINESS CONTROL LEVELS/HIERARCHY

Nature of decisions: Planning horizons: Control cycle time frame: Importance of decisions:	Strategic. 1 - 5 years. Year/month. Great in business terms.	BUSINESS LEVEL
Nature of decisions: Planning horizons: Control cycle time frame: Importance of decision:	Strategic/operational. 1 - 18 months. Week/day. Balance between strategic and operational.	MODULE LEVEL
Nature of decision: Planning horizons: Control cycle time frame: Importance of decision:	Operational. 1 - 6 weeks. Hour/minute. Very low in business terms.	CELL LEVEL
Nature of decision: Planning horizons: Control cycle time frame: Importance of decision:	Functional. 4 - 26 hours. Seconds (real time). Very high in detailed operational and quality terms.	WORK UNIT LEVEL

8. Parnaby (1987)

Figure 72. MANUFACTURING SYSTEMS ARCHITECTURE LEVELS

Control: Functions: Systems: Information:	Executive business control. Business ratio monitoring and integration of product group performance. Networked personal/mini computer, intelligent terminals linked to mainframe word processors and multi-user facilities Product group performance ratios.	1 BUSINESS UNIT LEVEL
Control: Functions: Systems: Information:	Business planning. Overall stock control, sales distribution overall factory scheduling, product design CAD, MRP I or MRP II, product costing systems, mainframe, networked mini. Sales/market/product database, sales distribution information.	2 PRODUCT GROUP LEVEL
Control: Functions: Systems: Information:	Production control. Local production planning, local work in progress control, bottleneck planning, cell ratio monitoring. Cellular control system to support production routes, process capabilities, tool management, maintenance control, cell scheduling, electronic office system, word-processing, multi-user facilities, administration. Cell database.	3 CELL LEVEL
Control: Functions: Systems:	Material flow control. Dedicated control and monitoring of materials, machines and processes. Micro-processor based instrumentation, process control systems, machine control systems, local stock control, local kanban card control, conveyor sequencing, robot control, mini computers, dedicated micro's and programmable logic controllers.	4 ELEMENT LEVEL

9. Rhodes (1984)

Figure 73. CONTROL LEVELS

Control/ Functions:	Set aim of business, identify basic resources to achieve aim, monitor overall performance.	1 STRATEGIC LEVEL
People:	Directors and top management.	
Response Time:	Months/years.	
Control/ Functions:	Set operational aims for activities, allocate resources to activities and co-ordinate their use, maintain performance of activities.	2 TACTICAL LEVEL
People:	Functional management.	
Response Time:	Weeks/months.	
Control/ Functions:	Plan effective use of resources in relation to activities to meet operational aims.	3 OPERATION LEVEL
Response Time:	Days/weeks.	

10. Ekong (1987)

Figure 74. FACTORY OF THE FUTURE ARCHITECTURE

Mission: Product Focus: Systems:	Strategies/direct. Computer integrated manufacturing. MRP II, CAD/CAM, CAPP, DBMS, resource managements.	FACTORY LEVEL
Mission: Product Focus: Control: Functions: Systems:	Plan/manage. Integrated software. Co-ordinates multiple stations. Production scheduling, quality control analysis, scheduling and planning, cell to cell co-ordination. Large mini computers/small mainframes.	CENTER LEVEL
Mission: Product Focus: Control: Functions: Systems:	Monitor/control. Systems network. Co-ordinates and controls production information between levels. Mainly supervisory and less real time cell management/control of stations. Advanced P.C's, small minis, DNC, cell controller, production monitoring and control system.	CELL LEVEL
Mission: Product Focus: Control: Functions: Systems:	Move manipulate. Robotics. Real-time control of station. Monitoring, collecting, compilation, data retrieval and storage, positioning of mechanically controlled devices. P.C's, board level micros, intelligent I/O devices, drive control systems, CNC.	STATION LEVEL
Mission: Product Focus: Control: Functions: Systems:	Make. Any manufacturing process. Real time control of processes. Actuation/motor control, interface controls to production elements. Relays, starters, solenoids, small PLC's, remote I/O modules, various drive control systems.	MACHINERY/ PROCESS LEVEL

11. Metzger & McCarthy (1986)

Figure 75. PLANT CONTROL HIERARCHY

COMPANY LEVEL MANAGEMENT FUNCTIONS	LEVEL 4B
PLANT LEVEL CO-ORDINATIONS AND FUNCTIONS	LEVEL 4A
AREA CO-ORDINATION AND FUNCTIONS	LEVEL 3B
UNIT CONTROL AND OPERATIONS	LEVEL 3A
DIRECT PROCESS CONTROL AND OPERATION	LEVEL 2
PHYSICAL COMMUNCIATION AND LOCAL DEDICATED CONTROL	LEVEL 1

12. Williams (1986)

Figure 76. INDUSTRIAL CONTROL HIERARCHY

Functions:	Management information level, management data presentation.	LEVEL 4B PLANT GENERAL MANAGEMENT CONTROL
Functions:	Production scheduling and operational management, operational and production supervision, plant operational management.	LEVEL 4A PLANT OPERATION CONTROL
Functions:	Supervisory, intra area co-ordination (shop co-ordinator), area operational management.	LEVEL 3 AREA OPERATION LEVEL
Functions:	Supervisory, DNC, unit operational management.	LEVEL 2 UNIT OPERATION LEVEL
Functions:	CNC, PLC (dedicated).	LEVEL 1 PROCESS CONTROL

Figure 77. FACTORY MANAGEMENT CONTROL HIERARCHY

Control: Functions:	Top level factory management. Determine end item requirements, product structures, process planning, shop capacities/capabilities.	FACTORY CONTROL LEVEL
Control: Functions:	Takes commands from factory control level and determines and commands for the work centre level. Exploding end item production into process operations, scheduling of shop order events.	JOB SHOP LEVEL
Control: Functions:	Takes commands from job shop level and determines commands for the unit/resource level. Scheduling task events.	WORK CENTRE LEVEL
Functions:	Break tasks down into sub-tasks and performs them.	UNIT/ RESOURCE LEVEL

14. Furlain et al (1983)

As defined by: NBS - National Bureau of Standards.
AMRF - Automated Manufacturing Research Facility.

Figure 78. PLANNING AND CONTROL HIERARCHY

Functions:	Long range scheduling and information management, production management, process planning.	FACTORY LEVEL
Control:	Production planning and control.	
Control:	Management and co-ordination of resources and jobs on shop floor.	SHOP LEVEL
Functions:	Classification of parts/group technology, grouping of jobs, cell configuration, allocation of tools/materials to work stations.	
Control:	Schedules and controls jobs through cell.	CELL LEVEL
Functions:	Cellular scheduling of jobs, Schedule of materials and tools within cell.	
Control:	Co-ordinates the activities of workstation	WORK STATION LEVEL
Functions:	Co-ordination of: - robot; - machine tool; - material storage buffer. Arranges/sequences operations.	
Control:	Real time control of machine tool, robot or material handlers.	EQUIPMENT LEVEL

15. O'Grady (1986)

Figure 79. PLANNING AND CONTROL HIERARCHY

Systems:	Computer Aided Process Planning (CAPP), Computer Aided Design (CAD), Master Production Scheduling I (MPS I), Material Requirements Planning (MRP), financial systems.	FACTORY LEVEL
Systems:	Master Production Schedule II (MPS II), on-line scheduling systems.	SHOP LEVEL
Functions:	Schedules and controls cell activity.	CELL LEVEL
Functions:	Controls the equipment.	EQUIPMENT LEVEL

APPENDIX H

BUSINESS ANALYSIS EXAMPLE CHARTS

This appendix comprises example business analysis charts used at Lucas Aerospace. The charts include the following:

- process hierarchy charts;
- process purpose and control analysis charts;
- data models (entity-relationship charts);
- control loop requirements chart;
- IDEF (0) process flow analysis charts;

The above charts were adopted as part of a standard structured analysis technique.

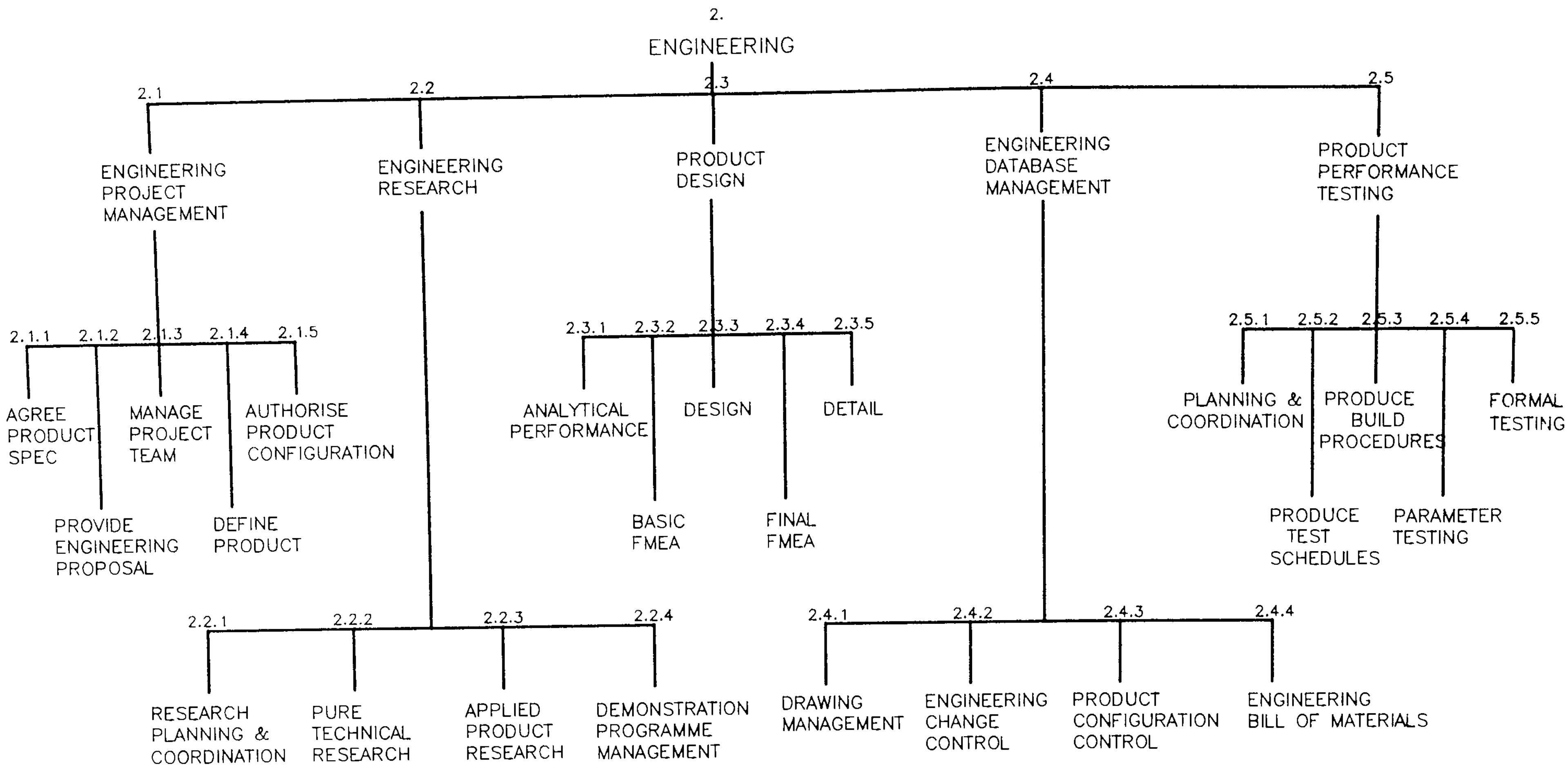


Figure (80): Business analysis chart – Process hierarchy

Figure (8 1): Process purpose and control analysis sheet example
(based on Lucas Aerospace)

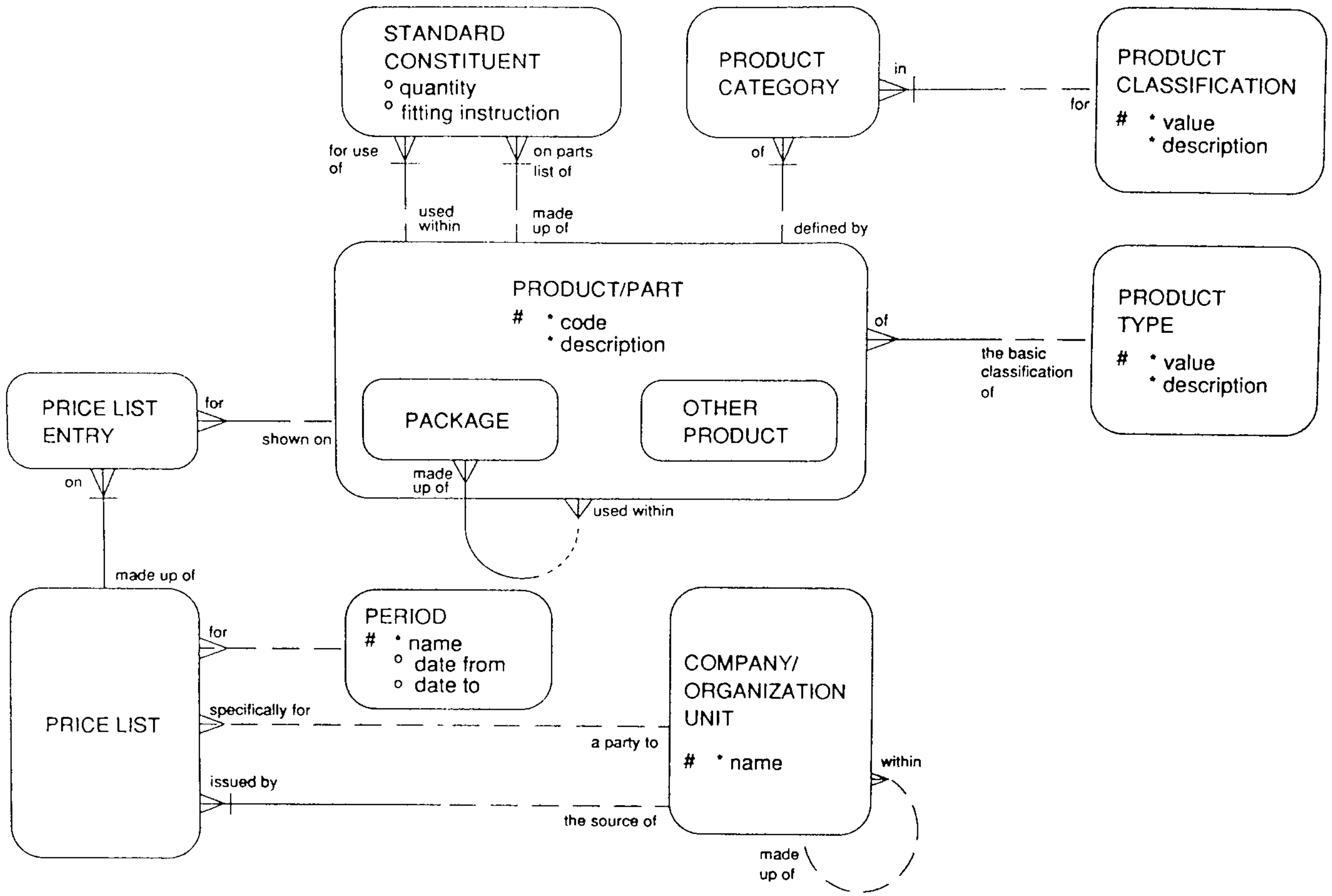


Figure (82): Data model (Entity-Relationship) chart

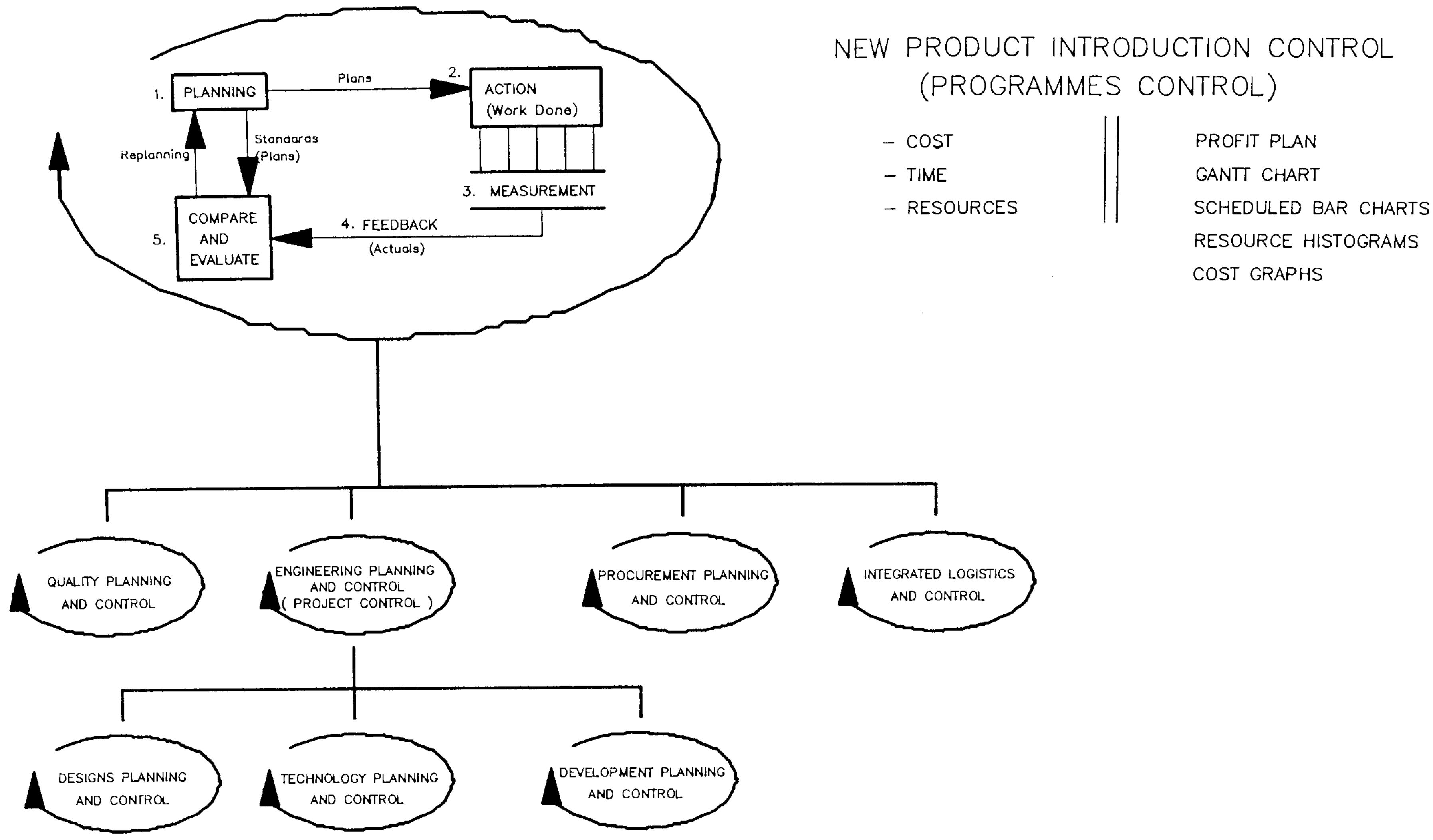


Figure (83): Control loop requirements chart - An example

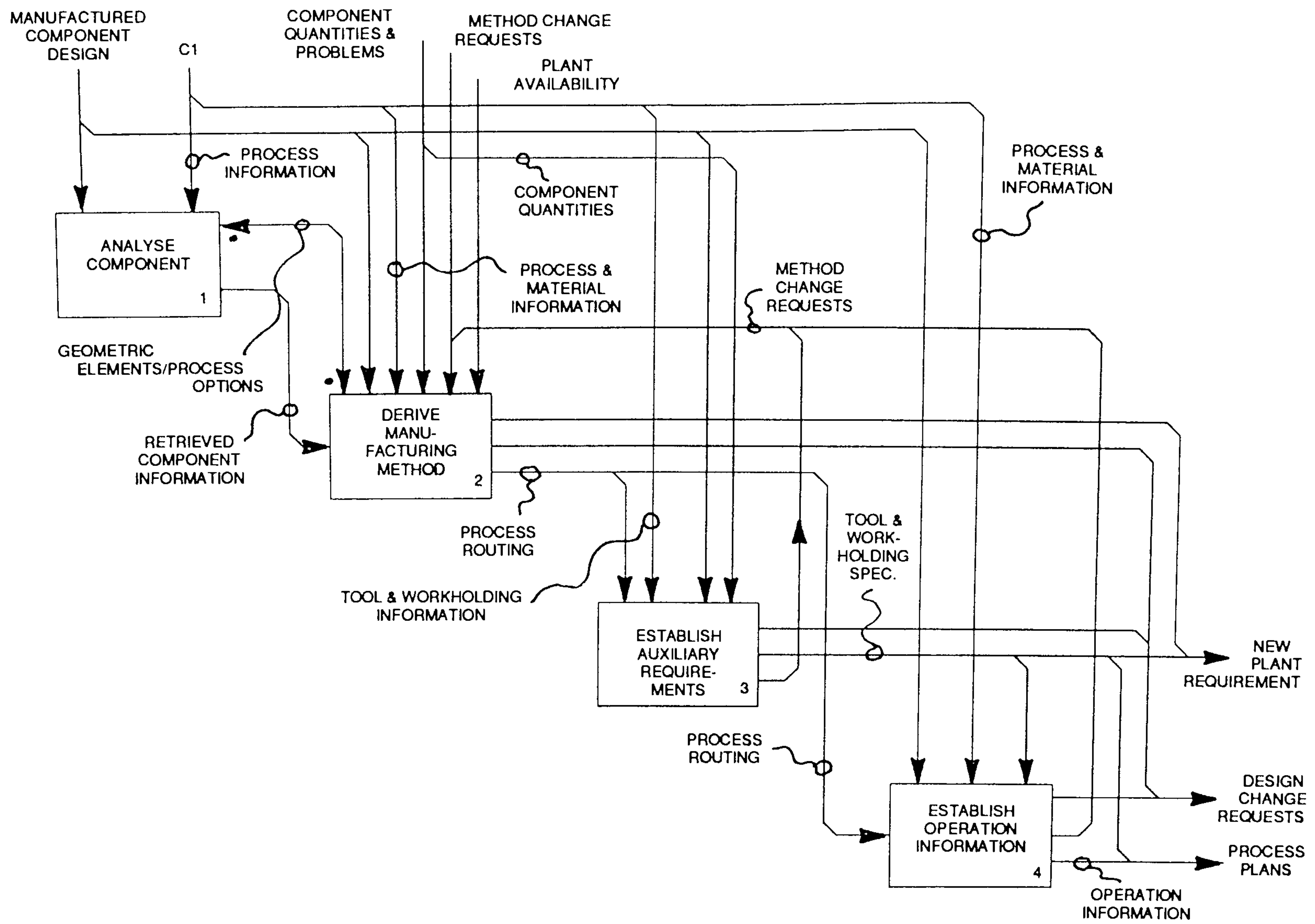


Figure (84): IDEF(0) functional data flow chart

APPENDIX I

CIM SYSTEM INTERFACE EXAMINATION

This Appendix examines the key CIM system interfaces outlined in section 8.4.2, Figure (48).

Interface (1). Project Control System to Engineering Data Management system

Purpose: The project control system passes engineering project information to the EDM system which actions and monitors work within engineering. The EDMS also needs the project information to control access to the various engineering subsystems (for example CAD/CAM, BOM, CAPP etc) and manage the various engineering/change flows.

Information: Project header details, project team members and tasks/activities and due dates/planned expenditure.

Interface (2). Engineering Data Management System to Project Control System

Purpose: To feedback engineering task/activity status to the project control system.

Information: Task/activity status:
- actual duration;
- actual dates;
- actual spend.

Interface (3). Drawing Management - CAD/CAM

Purpose: To manage all aspects of CAD/CAM files, that is access/movement/filing/archive/backup/issue and release.

Information: CAD/CAM control data (see above) and CAD/CAM files.

Interface (4). CAD/CAM system to CAPP system

Purpose: To forward part geometry to the CAPP system where it is used to automatically generate the process plan.

Information: CAD/CAM part geometry file.

Interface (5). CAD/CAM to Engineering Bill of Materials (BOM)

Purpose: To forward the design BOM from the CAD/CAM system to the engineering BOM system.

Information: Design Bill Of Materials (BOM).

Interface (6). Engineering BOM to CAPP system

Purpose: To automatically load part details into the CAPP header.

Information: part details (part no, part description, project, quantity, item type code, raw material specifications, parent and child relationships etc).

Interface (8). CAPP System to EDMS activity monitoring

Purpose: To feedback process planning status information to the central EDMS activity monitoring system.

Information: CAPP file status information, for example, process plan for part XYZ is complete at issue 4, including header, operations and times.

Interface (9). TMS System to EDMS activity monitoring

Purpose: To feedback tooling status information to the central EDMS activity monitoring system.

Information: Tooling information/status.

Interface (10). EDMS activity monitoring system to cell management system

Purpose: To inform the cell management system of the availability/status of engineering product/part definition data.

Information: Engineering activity status.

Interface (11). Project Control System to MRP II System

Purpose: To load high level rough schedules to the MRPII system for development and production manufacturing schedules.

Information: Development and production manufacturing .

Interface (12). MRP II system to Project Control System

Purpose: To feedback production/development manufacturing and purchasing status information to the project control system to support the project control process.

Information: Production/development manufacturing and purchasing status information.

Interface (13). Financial ledgers to Project Control System

Purpose: To feedback actual development/production project spend to the project control system to support the project control process.

Information: Actual production/development project spend.

Interface (14). CAD/CAM System to CAM System

Purpose: To forward NC part programming information to the DNC system.

Information: NC programmes.

Interface (15). CAD/CAM System to CAE System

Purpose: To forward design geometry to CAE system which in turn processes the geometry file, for example, a 3D solid model maybe forwarded to a CAE Finite Element Analysis (FEA) system, which processes the model to determine stress contours.

Information: Geometry models.

Interface (16). CAPP System to Cell Management System

Purpose: To pass process planning information to the cell management system, such that it can schedule manufacturing operations.

Information: Process plan (layout/routing) to include - part no, raw material size, manufacturing location, operations and sequences, tooling data etc.

Interface (17/18). CAPP System - TMS System

Purpose: To exchange tooling information.

Information: Tool details/requirements.

Interface (19). CAPP System to MRP II System

Purpose: To pass process planning information to the product definition database of the MRP II system.

Information: Process plan (layout/routing).

Interface (20). MRP II System to Financial ledgers System

Purpose: To forward purchasing details to the purchasing ledger.

Information: Purchasing details.

Interface (21). MRP II System to Financial ledgers System

Purpose: To forward sales details to the sales ledger.

Information: Sales details.

Interface (22). Shop Floor Data Control System to Financial Ledgers System

Purpose: To forward time and attendance details to the payroll system in order to calculate wages.

Information: Time and attendance details.

Interface (23). MRP II System to Cell Management System

Purpose: To pass the cellular order requirements down to the cell management system.

Information: Cellular order requirements to include order no, part requirements, batch size, due date etc.

Interface (24). Cell Management Systems to MRP II System

Purpose: To feedback production order status back to MRP II system.

Information: Production order status.

Interface (25). TMS System to Cell Management System

Purpose: To forward tooling details to the cell management system such that tool scheduling can be performed.

Information: Tool details, to include operation no, tool No, tool availability, tools in stock and tool ordering load time.

Interface (26). Shop Data Control SFDC System to Cell Management System

Purpose: To feedback order and production operational status to the cell management system to support cellular re-scheduling.

Information: Production order operational status.

Interface (27). CAM System to Cell Management System

Purpose: To forward details of NC programs and their availability to the cell management system to aid cellular scheduling.

Information: CAM details, to include NC programs, setting sheets etc.

Interface (28). CAM System to Shop Floor Data Control (SFDC) System

Purpose: To feedback CAM status information to the SFDC such that it knows production status.

Information: CAM Status, to include NC program operational status.

Interface (29)/(30). CAM System to AMH and Robotic System

Purpose: To forward instructions to material handling/robotic systems.

Information: NC/robotic instructions.

Interface literature review

This literature review was performed by examining four references, all of which discuss system interfaces within CIM. The references include the following:

Ref No.	Author	Year	Reference title
1.	Reisch	1987	The position of internal logistics in factory automation and total CIM concept.
2.	Rowlinson & Sackett	1987	Automation and effective process planning in CIM.
3.	Cowan	1987	Is CIM achievable?
4.	Spur & Specht	1987	Computer Integrated Manufacturing in future factories.

The literature review identifies the system interfaces supported by the above authors; the survey results are shown in Table (15).

It should be noted that the results are those perceived by the author after close examination of the above references.

The results show a rather focussed and limiting view of systems integration within CIM.

	Proposed System Interfaces Reference No	1	2	3	4	TOTALS
1	PCS - EDMS	*		*	*	3
2	EDMS - PCS					-
3	Drawing Mgt - CAD/CAM					-
4	CAD/CAM - CAPP		*	*		2
5	CAD/CAM - Eng BOM			*		1
6	Eng BOM - CAPP			*		1
7	Eng BOM - MRP II	*		*	*	3
8	CAPP - EDMS					-
9	TMS - EDMS					-
10	EDMS - Cell Mgt					-
11	PCS - MRP II					-
12	MRP II - PCS					-
13	Financial Ledger - PCS					-
14	CAD/CAM - CAM	*	*	*	*	4
15	CAD/CAM - CAE					-
16	CAPP - Cell Mgt	*	*	*	*	4
17	CAPP - TMS		*			1
18	TMS - CAPP					-
19	CAPP - MRP II	*	*	*	*	4
20	MRP II - Financial Ledgers					-
21	MRP II - Financial Ledgers					-
22	SFDC - Financial Ledgers					-
23	MRP II - Cell Mgt	*	*		*	3
24	Cell Mgt - MRP II	*			*	2
25	TMS - Cell Mgt		*			1
26	SFDC - Cell Mgt	*		*	*	3
27	CAM - Cell Mgt		*			1
28	CAM - SFDC					-
29	CAM - AMH					-
30	CAM - Robotics					-

Table (15): CIM system interface literature review results

LIST OF REFERENCES

LIST OF REFERENCES

AGRAWAL, S.S. 1987
'Functional requirements for integrating MIS with advanced control', proc. of 6th annual conference of control engineering, Rosemount, IL, USA, 19-21 May 1987, pp 153-158.

ALTING, L. and LENAU, T. 1986
'Integration of engineering functions in the CIM philosophy', proc. of int. symp. on automotive technology and auto with particular ref. on CIM, ISATA 86, Croydon, England.

ANON1 1989
'How to live up to deadlines', industrial computing, May 1989, pp 33-37.

ANON2 1990
'Engineering data control', Industrial computing, Oct. 1990, pp 25-26.

ANNON 1974
'Outline of computerisation in Kawasaki steel corporation', Kawasaki steel corporation, Kabi, Japan, August 1 1974.

APPLETON, D.S. 1985
'The technology of data integration', Datamation, November 1 1985, pp 108-116.

ARNOLD, J.C. and JOHANSSON, H.J. 1984
'Establishing a framework for the analysis and justification of computer integrated manufacturing', conf. proc. of synergy 84, chicago, IL, USA, 13-15 Nov. 1984, pp 29-33.

ARTHUR, W.E. 1986
'Shop floor control- the first step to CIM', CIMTECH conf. proc. CASA (SME), Boston, Massachusettes, March 10-13 1986.

BAINES, R.W. and COLQUOHOUN, G.J. 1989
'The use of the generic IDEFO model to capture process planning functional information', conf. proc of SAMT 89, 20-22 March 1989, Sunderland, pp 8A/4.

BAKER, T.E. et al 1986
'The integration of planning, scheduling, and control for automated manufacturing', proc. of symp. on real time optimisation in automated manufacturing facilities, National Bureau of stds., Gaithersbury, Maryland.

BAKER, W and KOPPEL, P 1987
'Control systems: the key to a productive public sector', OPTIMUM, volume 18-3, pp 7-50.

BARLEY, S.R. 1986
'Technology as an occasion for structuring: Evidence from observations of CT scanners and social order of Radiology departments', Admin. Science, Quarterly 31, 1986, pp 78-108.

BARSAMIAN, J.A. and PATEL, D.J. 1987
'Benefits of integrating MIS with advanced process control', proc. of 6th annual conference of control engineering, Rosemount, IL, USA, 19-21 May 1987.

BELOW, L.J. 1987
'The meaning of integration', proc. of 4th european conf. automated manufacturing, May 1987, pp 345-352.

BENTLEY, T.J. 1984
'Control systems and information Management', Management Services, June 1984, pp 8-13.

BERTAIN, L. 1987
'Reculturing for CIM', a program guide for CIM implementation, Soc. of Manufacturing Eng. Publication Devt. Dept.

BESSANT, J. and LAMMING, R. 1987
'Organisational integration and advanced manf. tech', proc. 4th European conf. Automated Manufacturing, pp 353-364.

BOADEN, R.J. and DALE, B.G. 1986
'What is computer integrated manufacturing ?', IJOPM, 6, 3, 1986, pp 30-37.

BOYCE, R.O. 1967
'Integrated Managerial Controls, a visual approach through integrated MIS', Longmans, Green and Co Ltd.

BRANCO, K. 1986
'Laying the CIM foundation: A structured, strategy based methodology', CIMTECH conf. proc., March 10-13 1986, Boston, Massachusettes.

BRAVOCO, R.R. 1987
'Planning a CIM system using system engineering methods', a program guide for CIM implementation, soc. of manf. Eng. Pubs. Devt. Dept.

BROOKS, B. 1989
'In search of integration', CAD/CAM international, May 1989, pp44-45.

BROSVIC, J. 1984
'Integrated plant management', conf. proc. of synergy 84, Chicago, 12, USA, 13-15 Nov. 1984 pp 123-126.

BRITTON, H.O. and HAMMER, W.E. 1984
'Designers, Users and Managers share responsibility for ensuring CIM system integrity', Industrial Engineering, May 1984.

BUGGIE, F.D. 1982
'Strategies for new product development', long range planning, vol. 15, no. 2, April 1982, pp 22-31.

BUTLER, A.G. 1973
'Project Management: A study in organisational conflict', academy of management journal, March 1973, vol.16/1. pp 84-101.

CANADA, J.R. 1986
'Non traditional method for evaluating CIM opportunities assign weights to intangibles', I.E. March 1986, pp 66-71.

CHUAH, K.B. 1989
'CIM development - A strategic Management issue', conf. proc. of SAMT 89, 20-22 March, 1989, Sunderland, pp 10A/3.

CIM task force report 1988
'Computer Integrated Manufacturing guidelines to good practice', Editor K. Oldham, Issue 1, Sept. 1988.

CLAYDON, B. 1985
'An introduction to computer integrated manufacturing', National materials handling centre conference on paperless systems for distribution and production, 18-19 June 1985, pp 26-46.

COMPUTERVISION LTD 1986
'CAD/CAM database - CIM integrator, Company report.

COWAN, D.A. 1987
'Is CIM achievable', proc. of 4th int. conf. on automated manufacturing, Birmingham, UK, 12-14 May, 1987, pp 115-130.

CROOKHALL, J.R. 1986
'CIM - the optimising technology for the factory of the future', proc. of Int. symp. on Automotive Tech. & Auto. with particular ref. on CIM, ISATA 86, England.

DAFT, R.L. 1986
'Organisation theory and design', 2nd Edition, West publishing Co., 1986.

DAFT, R.L. and LENGEL, R.H. 1986
'Organisational information requirements, media richness and structural design', mgt. science, vol. 32, no. 5, May 1986. pp 554-571.

DAUGHTERS, S.M. 1986
'Manufacturing Management using technology as a vehicle for change', 1st int. conf. on Eng. Mgt: theory and applications, Swansea, 1986, pp 151-159.

DAVIS, G.B. and MUNRO, M.C. 1977
'Determining management information needs: A comparison of methods, MIS quarterly, June 1977, pp 55-66.

DEARSDEN, J. 1983
'Will the computer change the job of top management', Sloan Mgt. Review (USA), Autumn 1983, pp 57-61.

DEMPSEY, P. 1988
'Integration is a key to survival', Integration for success, 23rd European conf. on prod. and inv. control, B'ham 2-4 Nov. 1988 pp 1-13.

DOWNSLAND, W.B. 1986
'Computer integrated manufacture and management science', lst. int. conf. on Eng. Mgt: theory and applications, Swansea, 1986.

DRATCH, R. 1986
'Distributed control makes CIM possible', Robotics Eng. Nov. 1986, pp 6-7.

DUMOLLEN, W.J. and SANTEN, W.P. 1983
'Cellular manufacturing becomes philosophy of Management at Components facility', Industrial Engineer, Nov. 1983.

DUNN, J. 1984
'CIM: A key to the factory of the future', The Engineer, 10 May, 1984.

DUSSENBURY, W. 1967
'CPM for new product introduction', Harvard Bus. rev., July/August 1967, pp 124-139.

DUTTON, P.L. 1986
'In pursuit of CIM', Datamation, Feb 1, 1986, pp 63-66.

EARL, M.J. 1986
'Formulation of information systems (IS) strategies - a practical framework', Information Management in competitive success, state of the art report, Permagon Infotech group, 1986.

EILON, E. 1979
'Management Control' 2nd Ed, Permagon Int. Library.

EKONG, E.S. 1987
'Controls: The bridge to systems integration', 16th. Int. annual prog. controller conf. & exposition proc., Detroit, MI, USA, 7-9 April, 1987. pp 49-57.

ELAVIA, D.E. 1987
'Where do I start with CIM', proc. of 4th Int. conf. on Automated Manfg., Birmingham, U.K., 12-14 May 1987.

EMERY, J.C. 1969
'Organisational planning and control system theory and technology', Macmillan Co.

ER, M.C. 1987
'The impact of information technology on organisations', Journal of Systems Management, Vol. 38, No. 4, Issue No. 310, April 1987.

EWALDZ, D.B. 1987
'Crossing the Bridge to CIM', ISATA 17th. Int. Symp. on Automotive Tech. & Automation proc., Munich, West Germany, 25-30 Oct. 1987.

FISCHER, R. 1986
'Towards an open system', Industrial Computing, May 1986, pp 31-32.

FLAMHOLTZ, E.G. et al 1985
'Towards an integrative framework for organisational control', accounting organisations & society, vol. 10, no. 1, pp 35-50.

FOSTER, L.W. and FLYN, D.M. 1984
'Management Information Technology: Its effects on organisational form and function', MIS Quarterly, December 1984, pp 229-237.

FURLAIN, C.M. et al 1983
'The automated manufacturing research facility of the NBS', proc. computer simulation conference, Vancouver, B.C. 1983.

GALBRAITH, J. 1973
'Designing complex organisations', Addison-Wesley, 1973.

GALBRAITH, J. 1977
'Organisational design', Addison-Wesley, 1977.

GALLIERS, R.D 1986
'Information systems and technology planning with a competitive strategy framework', Information Management in competitive success, state of the art report, Permagon Infotech group, 1986.

GANE, C. and SARSON, T. 1983
'Structured Systems Analysis: Tools & Techniques', Mcauto, McDonnell Douglas, ISBN 0-931096-00-7.

GARSIDE, J. 1988
'Integrated factory of the 1990's', Lucas CAV Ltd.

GARRETT TURBINE 1985
'Formation and workings of a corporate wide CIM Committee at Garrett Corporation', Industrial Engineering, Nov. 1985, pp 75-85.

GERBER, D.L. 1988
'Tomorrows Organisation', Journal of Sys. Mgt., Jan. 1988, pp 33-35.

GERSHWIN, S.B. 1986
'An approach to hierarchical production planning and scheduling', real time optimisation in automated manfg. facilities, proc. of symp., N.B.S., Gaithergburg, Maryland, Sept. 1986.

GIGLIONI, G.B. and BEDEIAM 1974
'A conspectus of mgt. control theory', acad. of mgt. journal, 17(2), 1974, pp 292-305.

GLEN, R.H. 1985
'The CIM revolution: A Delphi Study of the strategic and structural implications of CIM', Int. conf. on Cybernetics and soc. IEEE. proc. Tusson. Arizona, 12-15 Nov. 1985, pp 59-63.

GREENWOOD, F. and GREENWOOD, M. 1987
'CIM and You', Journal of Sys. Mgt., June 1987, pp 39-41.

GROOVER, M.P. and ZIMMERS, E.W. 1984
'CAD/CAM: Computer Aided design and manufacture', Prentice/Hall Int. editors.

GROOVER, M.P. and WIGINTON, J.C. 1986
'CIM and the flexible automated factory of the future', Industrial Engineering, 1986, pp 75-81.

GROPETTI, R. 1987
'On the development of a CIM experimental center', ISATA 17th Int. Symp. on Automotive Tech. & Automation proc., Munich, West Germany, 25-30 Oct 1987.

GUNN, T. 1986
'The CIM Connection', Datamation, Feb. 1st, 1986, pp 51-58.

HAFFENDON, A. 1988
'Towards integration: bridging the straits', Ind. Comp. Supplement, 1988.

HALES, H.L. 1984
'How small firms can approach, benefit from computer-integrated manufacturing systems', Ind. Eng., June 1984, pp 246-257.

HAMILTON HALL 1990
Engineering Database Management technical manual, Hamilton Hall Ltd.

HANDY, C.B. 1987
'Understanding organisations', Third Ed., Penguin business library.

HARNED, J. and HOLLMAN, S.B. 1987
'An approach for solving the CIM Gap problem', PROC of 4th conf. on Automated manfg., B'ham, U.K. , 12-14 May 1987, pp 115-130.

HARTLAND-SWANN, J. 1986
'CIM: Hit or Myth', Ind. Computing, Feb. 1986, pp 22-23.

HARVEY, G. 1986
'Computer Integrated Manufacturing: strategies for success', proc. of Int. symp. on Automotive Tech. & Auto. with particular ref. on CIM, ISATA 86, England.

HARROWER, P. 1988
'Successful mgt. in manfg.', Computers in manfg. conf., olympia London 10-12 May, 1988.

HEARD, E. 1988
'Responsiveness the next battleground', BPICS 23rd European conf. on Prod. and Inv. Control on 'Integration for success', Birmingham 2-4 Nov. 1988.

HEARN, R. and WEALD, W. 1987
'Landrover and istel Ltd. Computer integrated manufacturing a paint shop initiative', ISATA 17th Int. Symp. on Automotive Tech. & Automation proc., Munich, W Germany, 25-30 Oct. 1987.

HELMING, F.W and VASILE, J. 1987
'The key to integration: a supervisory control system for the manufacturing enterprise: proc. of 6th annual conf. of control engineering, Rosemount, IL, USA, 19-21 May 1987, pp 410-418.

HENRY, G.F. 1986
'In preparation for CIM', 36th Electronic compts. conf. proc. IEEE, Electron. Ind. Assoc., Seattle, WA, 5-7 May, 1986, pp 70-78.

HEWITT, D.G. 1982
'Distributed computing in the manufacturing environment', 1982 Fall Industrial Engineering Conf. proc., pp 173-179.

HEWLETT PACKARD 1986
'Europeans must try harder', Industrial Computing, June 86, pp 13-14.

HIATT, W.H. and PETERSON, C.D. 1977
'Reliability analysis of the proposed hierarchical computer control system for large steel manufacturing complexes, report No. 93, Purdue Laboratory for applied Ind. control, Purdue university, West Lafayette, Indiana, sept. 1977.

HOFSTEDE, G. 1978
'The poverty of management control philosophy', Academy of Mgt. Review, 3 (3), 1978, pp 450-461.

HUGHES, D.R. and BAINES, R.W. 1985
'Evolutionary Design of CIM Systems', proc. of 1st, Nat. Conf. on Prod. Research in Advanced Manfg. Tech, University of Nottingham, Sept. 1985 pp 57-63.

HUGHES, D.R. and MAULL, R.S. 1985
'Software - the key to CIM', Effective CAD/CAM 1985, Cambridge, England, 8-10 July, 1985 (Mech. Eng. Pubs, 1985) pp 15-22.

HUGGINS, L.P. 1986
'Computers, Functional integration, and improved competitive strategy', Information strategy: The Executives journal, Spring 1986, pp 17-23.

HYER, N.L. et al 1984
'Formation of Group Technology Cells', Conf. proc. of Synergy 84, Chicago, IL, USA, 13-15 Nov. 1984, pp 151-155.

IBM REPORT 1987
'Computer Integrated Manufacturing: the IBM experience; IBM Findlay Publications'.

ICL Report 1986
'Computer Integrated Manufacturing - The intelligent approach', ICL 1986.

ICL 1990
'Engineering Data Management', technical manual, 1990.

INGERSOL ENGINEERS 1986
'Beware of the hype about MAP',Production Engineer, Dec. 1986, pp 7.

INGERSOL REPORT 1986
'Integrated Manufacture', IFS publications, UK.

JAEGAR, A.M. and BALIGA, B.R. 1985
'Control Systems and Strategic Adaptation: Lessons from the Japanese experience', strategic Mgt. Journal, vol. 6, pp 115-134.

JAHRLING, K 1987
'CIM application in the omega body manufacture K-130', ISATA 17th Int. Symp. on Automotive Tech. & Automotive proc., Munich, West Germany, 25-30 Oct. 1987.

JARVIS, J.W. 1986
'Computer Integrated Manufacturing Technology and status - an overview for management', IEEE. publications - AMI, 1986.

JENSTER, P.V. 1987
'Using Critical Success factors in Planning', Long Range Planning, vol. 20, No. 4, pp 102-109.

JOHNSON, W.S. 1986
'Complex CIM environment require sophisticated mgt. Control', Hard Copy, Dec. 1986, pp 57-58.

JONES, M. 1989
'Building a CIM framework - Engineering data', Industrial Computing, June 1989, pp 34-36.

JONES, A. and WEBB T. 1987
'Introducing Computer Integrated Manufacture', Journal of General Mgt. vol. 12, no. 4, Summer 1987, pp 60-74.

JOYNER, S. 1987
'The organised reqts of modern, automated manufacturing systems', Dept. of Human Sciences, University of Tech., Lougborough, Leicester.

KAPLAN, R.S. 1986
Justifying CIM', Harvard Business Review (USA), Mar/April 1986, (64/2), pp 87 (9 pages).

KING, L.B. and LONG, J.M 1986
'Transitioning from tactical to strategic planning in CIM', proc. of 8th conf. on computer and Ind. Eng., 19-21 March 1986, vol. 11, no. 1-4, pp 266-270.

KLUCHAR, J.E. 1987
'Hierarchical Automation and Control applied in a modern steel making facility', 16th Int. conf. on Automated manfg. B'ham, UK, 12-14 May, 1987 pp 241-254.

KRUSE, G. 1988
'Excellence in manufacturing', Production Eng, April 1988, pp 54-56.

LAIRD, R.J. 1989
'Seven Steps to Tech. change', SAMT 1989, proc. 20-22 March, 1989, Sunderland, UK, 10A/1.

LAWLER, E.E. 1970
'Control Systems in organisations', Handbook of Ind. & Org. Psychology, Rand McNally, Chicago, 1970, pp 1247-1291.

LAWRENCE, A 1990
'Engineering Data Management', Industrial Computing, May 1990, pp 21-24.

LAWRENCE, P.R. and LORSCH, J.W. 1967
'Organisation and environment', Harvard graduate school of business administration, Boston, 1967.

LAWRENCE, P.R. and LORSCH, J.W. 1967
'New Management Job; the integrator', Harvard Bus. Rev., Nov/Dec 1967, vol 45, No. 6 pp 142-151.

LEAVITT H.J. and WHISLER T.L. 1958
'Management in the 1980s', Harvard Business Review, 36, 1958, pp 41-48.

LEE, S.C. and MOSIER, C.T. 1984
'The development of a Computer Integrated Manufacturing System: A modular approach', proc. of the 1984 annual International Industrial Engineering conf., May 1984.

LEFKOWITZ, I. 1977
'Integrated control of industrial system', Phil. Trans. R. Soc. Lond. A. 287, pp 443-465

LEIFER, R. and McDONNAUGH E.F. 1985
'Computerisation as a predominant technology effecting work unit structure', Proc. of sixth annual conf. Information Systems, 1985, pp 238-248.

LITTLE, D. 1988
'Manufacturing Control: Crucial to CIM', Integration for success, the 23rd European conf. on Prod. & Inv. Control, B'ham, 2-4 Nov. 1988, pp 270-277.

LOMAS, I. 1988
'Islands of CIM', Computerised Manufacturing, Feb 1988.

LOVE, D.M. and BAREKAT, M. 1988
'An introduction to the decentralised, distributed MRP philosophy; a solution to control problems in cellular manufacturing systems', 3rd Int. conf. on CAPE, Michigan, June 1-3 1988.

MACKULAK, G.T. 1984
'Planning techniques for CIM', Nat. Productivity Rev., Summer 84. pp 315-333.

MANCHUK, S. 1984
'CIM project may be doomed to failure if key building blocks are missing', Ind. Engineering, July 1984.

MARTIN, J. and MACLURE, C. 1985
'Structured techniques for Computing', Prentice Hall, 1985.

MATERNA, A.T. and SEPEHRI, P.E. 1986
'Integrating Manufacturing Systems using TRW's CIM Data Engine', Industrial Engineering, Oct. 1986, pp 70-80.

McDONNELL DOUGLAS CORP 1986
Production Engineer, April 1986 - pp 22

McDONNELL DOUGLAS CORP 1986
'Computer Integrated Manufacturing report, 1986.

McHUGH, P. 1988
'IS CIM a mirage', Integration for success, 23rd. European conf. on Prod. & Inv. Control, B'ham, 2-4 Nov. 1988, pp 13-14.

McPHERSON, R.F. and WHITE, K.P. 1986
'A management control approach to the manufacturing planning and scheduling problem', real-time optimisation in Automated manufacturing facilities. proc. of a symp. NBS, Gaithergsburg, Maryland, Sept. 86.

MEHTA, A.D. 1987
'Integrating islands of automation is management - not technical problem', Ind. Engineer, Vol. 19, No. 11, Nov. 1987.

MIESING, P. et al 1984
'Integrating planning with mgt.', Long Range Planning, Vol. 17, No. 5, pp 118-134.

MEREDITH, J.R. 1987
'Strategic Control of Factory Automation', Long Range Planning, Vol. 20, No. 6, pp 106-112.

MESAROVIC, M.D. 1970
'Theory of hierarchical Multi level systems', Academic press, New York.

MINTZBERG, H. 1975
'The Managers job, folklore and fact', Harvard Bus. Rev., July-August 1975.

MINTZBERG, H. 1979
'The structuring of organisations', Eagle-wood Cliffs, NJ: Prentice Hall.

MINTZBERG, H. 1983
'Structure in fives: Designing Effective Organisations', P.H.I. Edition.

MEISTER, G.F. 1984
'Management roles and responsibilities in implementing CIM', proc. of the 1984 Computers in Manufacturing conf., San Franscisco, CA, USA, 28-30 Nov. 1984.

METZGER, D.P. and McCARTHY, J.J. 1986
'The challenge of integrating hierarchical control across distributed processors on a plant wide network', proc. of 12th. annual adv. conf, West Laffayette, IN, USA, 15-17 Sept. 1986.

MIZE, J.H. et al 1985
'Information and workings of a corporate-wide CIM committee at Garrett Corporation', Ind. Eng, Nov. 1985, pp 73-80.

MOYES, P. 1987
'CIM - A realistic approach', proc. of 4th Int. Conf. on Automated manfg., B'ham, UK, 12-14 May 1987, pp 125-136.

MOORE, R.A. 1987
'Control of New Product Development in UK companies', European journal of marketing, 18, 6/7, 1987.

MURPHY, A.D. 1983
'Developing a CIM strategy and Plan', 6th ann. conf. on Design Eng, Birmingham, 4-6 October, 1983, pp 25-35.

NA, H.S 1986
'Integration of computerised manufacturing systems', CIMTECH conf. proc., CASA (SME), Boston, Massachusettes, March 10-13 1986.

NEWITT, D.N. et al 1985
'CIM in the semi-process industry: A case study', proc. of 3rd European conf. on Automated manfg. 14-16 May, 1985, B'ham, pp 71-88.

NOREFORS, U.G 1987
Communications around MAP, ISATA 17th, Int. Symp. on Automotive Tech & Automation proc. Munich, W. Germany, 25-30 Oct. 1987.

ODEN, H.W. AND BIBEAU, J.M. 1986
'Involving all employees in CIM', CIMTECH conf. proc., March 10-13, 1986, Boston, Massachusetts, pp 10-39/10-52.

O'GRADY, P.J. and MENON, O. 1986
'A hierarchy of intelligent scheduling and control for Automated manufacturing systems', Real-Time optimisation in automated manfg. facilities. proc. of a symp. NBS, Gaitherburg, Maryland, Sept 86, pp 15-30.

OLSEN, M.E. 1978
'The process of social organisation', Holt Rinehart and Winston, New York, 1978.

ORLICKY, J. 1975
'Material Requirements Planning', NcGraw-Hill Book c, New York, 1975.

ORNE, D.L AND HANIFIN, L.E. 1984
'The interacting roles of international manfg. strategy and CIM' conf. proc. of synergy 84, chicago, IL, USA, 13-15 Nov. 1984, pp 45-49.

OUCHI, W.G. 1977
'The relationship between organisational structure and control', Administration Science Quarterly, 22(1), 1977, pp 95-112

OWEN, W. 1986
'Steamed up about AMT', Industrial Computing, Feb. 1986.

PARNABY, J. 1987
'The need for fundamental changes in UK manufacturing systems' proc. of 4th European conf. automated manufacturing, May 1987, pp 9-22.

P.A TECHNOLOGY, 1986
'Integrated Manufacture - A framework for the application of technology', PA consulting group, 1986.

PESSEMIER, E.A. and ROOT, H.P. 1973
'The dimensions of new product planning', Journal of Marketing, Vol. 37, Jan. 1973, pp 10-18.

PETERS, T. et al 1982
'In search of excellence', Harper and Row, 1982.

PHELPS, H.S. 1986
'Computer integrated manufacturing (CIM) in the process control industry', proc. of 12th ann. adv. conf, West Lafayette, IN USA, 15-17 Sept 86, pp 125-132.

PLANT, R. 1986
'How do we get there'? ISBN 0-00-636873-5

PLOSSL, G.W. 1973
'Manufacturing Control', Reston Publishing Co, Inc, Reston, Va., 1973

PLOSSL, K.R. 1987
'Computer Integrated Manufacturing: The Buzzword and reality', Prod. Engineering, June 1987, pp38-50.

PROJECT STAFF, 1977
'Systems Engineering of Hierarchy Computer Control systems for large steel manufacturing complexes, report no.100, purdue laboratory for applied ind. control, purdue university, west lafayette, Indiana, Sept 1987.

PRIME 1990
'EDM vault - technical manual', Prime U.K Ltd., 1990.

PUNWANI, P.K. 1985
'CIM business strategy case study for an Aerospace Organisation', CASA/SME CIMCON 85 conf., April 1985.

RADFORD, J.D. AND RICHARDSON, D.B. 1987
'The management of manufacturing systems.

RANKIN, W.G. 1987
'Deere's CIM story' proc. 4th European conf. automated manufacturing, May 1987, pp 23-32.

RANKY, P.G 1986
'Computer integrated manufacturing' PHI ISBN 0-13-165655-4, 1986.

ROWLINSON, P.R. and SACKETT, P.J. 1987
'Automation and effective process planning in CIM', proc. of 4th European conf. Automated Manufacturing, May 1987, pp 229-308.

REISCH, D 1987
The position of internal logistics in factory automation and total CIM concept', ISATA, 17th int. symp. on automotive tech & automotive proc. Munich, West Germany 25-30 Oct. 1987.

RIESMAN, L. 1988
'Implementing CIM for the 1990's', integration for success, 23rd European conf. on prod. and inv. control, B'ham, 2-4 Nov 1988.

REMBOLD, U. et al 1986
'Computer integrated manufacturing technology and systems'

RHODES, D. 1984
'Computers, information and manufacturing systems.

RHODES, D. 1984
'Management control for effective corporate planning', long range planning, vol. 17, No. 4 , pp 115-121, 1984.

RIEHN, A. 1987
'Cell level integration provides migration path to CIM' ISATA 17th int. symp. on automotive tech. & auto. proc. Munich, West Germany, 25-30 Oct 1987.

RIDGWAY, K. AND DOWNEY, S. 1989
'A graphical technique for planning the introduction of AMT: The GRAI method; SAMT 89, proc., 20-22 March 1989, pp 2A/2

ROBEY, D. 1977
'Computers and Management structure: Some empirical findings re-examined', Human Relations, 30, 1977, pp 963-976.

ROBEY, D. 1981
'Computer information systems and organisation structure', Communications of the ACM, Vol. 24, No. 1, 1981, pp 24-33.

ROBSON, J. 1988
'Keeping the pumps primed', Ind. Computing, July 1988, pp 27-28.

ROLLS, D. 1985
'The CIM debate', The Engineer, 16 May, 1985

ROWLINSON, P.R. et al 1987
'Automation and effective process planning in CIM', proc. 4th European conf. automated manufacturing May 1987, pp 299-308.

RUSHTON, D. 1985
'Developing a CIM strategy', Ingersoll Engineers, 1985.

RZEVSKI, G. 1987
'The concept of CIM system architecture', proc. 4th, European conf. automated manufacturing, May 1987, pp 365-378.

RZEVSKI, G. 1988
'From business plan to CIM strategy', Industrial Computing, supplement 1988.

SADOWSKI, R. 1986
'Roundtable participants discuss systems integration, trends, strategies, champions, Ind. Eng., Aug. 1986, pp 26-34.

SAVAGE, C.M. 1986
'CIM and management policy: A word to the president', A program guide for CIM implementation, CASA/SME.

SAWYER, J.H.F. 1983
'Critical path analysis', Department of Production Technology and Production Management, University of Aston in Birmingham, 1983.

SCHROEDER, C. 1987
'CADMAC, next step on the path to CIM', proc. of 4th int. conf. on automated manfg. B'ham, UK, 12-14 May 1987, pp 9-41/9-63.

SCHWENDINGER, J. 1984
'Do your homework before you modernise the factory', conf. proc. of synergy 84, chicago, IL, USA 13-15 Nov, 1984, pp 52-56.

SCOBBY, S. 1989
'Mission controlled, Ind. Computing, Aug. 1989, pp 15-18.

SCOTT, D. 1989
' Managing Engineering data', Ind. Computing, Sept. 1989, pp 27-29.

SDRC, 1990
'DMCS- Data Management and Control System', technical manual, SDRC Ltd., 1990.

SHERPA, 1990
' EDM technical manual', Sherpa Ltd., 1990.

SIBBALD, G.W. 1987
'Justification of CIM', a prog. guide for CIM implementation 2nd Ed, SME devt. dept., 1987.

SIMON, H.A. 1976
'Administrative behavior', New York, The Free Press, 1967.

SIMON, H.A. 1977
'The new science of management decisions' prentice-Hall, 1977.

SMITH, J.L. 1984
'CIM - target or philosophy by-product?', 1984 fall, Ind. Eng. conf. procs., pp 32-34

SOEST M.J.V. and WALLACE M.E. 1988
'Up-front planning before CIM', proc. of 6th ann. conf. of control eng., Rosemont, IL, USA, 19-21 May 1987, pp 674, 676.

SPUR, G. AND SPECHT, D. 1987
'Computer integrated manufacturing in future factories', Robotics and CIM Vol. 3, No. 2, 1987, pp 147-155,.

STARK, J. 1984
'Successful identification of a CIM strategy and successful implementation of a CIM solution', conf. proc. of synergy 84, chicago, IL, USA, 13-15 Nov, 1984, pp 127-131.

STAUFFER, R.N. 1987
'Managing the fifth generation enterprise', CIM tech, Feb. 1987, CT-19.

STEVENS, G 1988
'Integrating the supply chain', integration for success, 23rd European conf. on Prod. and Inv. Control, B'ham 2-4 Nov. 1988.

STULCK, S.
'Integrated manufacturing: the human systems perspective', ITP Boston, inc, USA.

SUSKI, G.J. AND RODD, M.G. 1986
'Current and future issues in the design, analysis and implementation of distributed, computer based control systems.

TANNOCK, J.D.T. et al 1987
'Strategies for integrated systems in quality control', proc. 4th European, conf. automated manufacturing, May 1987, pp 213-222.

TUSHMAN, M.L. AND NADLER, D.A. 1978
'Information processing as an integrating concept in organisational design', academy of mgt. rev., July 1978, pp 613-624.

TEICHOLTZ, E. 1984
'CIM", Datamation, Vol 40, March 1984, pp169-174.

THOMAS, G.S. 1986
'The role of systems integrator in CIM', proc. of int. symp. on Automotive Tech & Auto with particular ref. on CIM ISATA 86, Croydon, England.

THOMPSON, J. 1987
'CIM: bringing the islands together', CME, March, 1987, pp 49-52.

THURWATCHER, W.A. 1986
'Simplified integrated manufacturing (SIM): a byword for operational strategy', Ind. Eng., Nov 1986, pp 74-81

VAN SOEST, J.M. 1987
'Up-front planning before CIM', proc. of 6th ann. conf. of control eng., Rosemont, IL, USA, 19-21 May 1987, pp 674, 676.

VARIOUS, 1986
'Roundtable participants discuss systems integration trends, strategies, champions', Ind. Engineering, Aug. 1986, pp 26-34.

VERNADAT, F. 1986
'Key technologies for successful manufacturing integration (CIM)', CIMTECH conf. proc. March 10-13 1986, Boston, Massachusettes pp 5-27/5-47.

VINCENT, G. 1988
'Taming Technology - how to manage a Development project', BIM, PA Technology, ISBN 1-85091-679-9.

VOGEL, S.A. 1987
'Strategies planning for CIM implementation', proc. of 6th ann. conf. of control Eng. Rosemount, IL, USA, 19-21 May 1987, pp 666-673.

VOSS, C.A. 1988
'Integration of JIT and MRP the Japanese experiences', Integration for success, 23rd European conf. on prod. and inv. control, B'ham 2-4 Nov. 1988, pp 209-222.

VOWLER, J. 1987
'Realism dispels CIM Hype', Computer Weekly, Dec 3, 1987, p 30.

WARD, J.M. 1987
'Integrating Information systems into Business strategies', Long Range Planning, Vol. 20/3, No. 103, June 1987.

WELTER, W.R. 1986
'Looking At The Human Side Of Manufacturing Strategy For An Effective CIMS', Ind. Engineering, June 1986, pp 18-21.

WIGHT D.W. 1974
'Production and Inventory management in the computer age', CBI publishing Co. Inc., Boston, 1974.

WIGHT D.W. 1981
'MRP II: Unlocking America's productivity potential', Oliver Wight Ltd. publishing Co. Inc., Williston, UT., 1981.

WILLIAMS, T.J. 1986
'One view of the future of industrial control', Purdue laboratory for applied control, Purdue University, West Lafayette, Indiana, USA, 1986.

WILLIS, R.G. and SULLIVAN, K.H. 1984
'CIM in perspective: Costs, benefits, timing, payback periods are outlined', Industrial Engineering, Vol. 16, No. 2, 1984, pp 28-36.

WINDSOR, J.C. AND NESTMAN, C.H. 1984
'Criteria for the selection of a CIMs database system', 1984 Fall Ind. Eng. conf. proc., pp 154-167.

WHITE, J.A. and APPLE J.M. 1985
'Material handling requirements are altered dramatically by CIM information links', Ind. Engineering, Feb. 1985, pp 36-41.

WONG, Y. 1964
'Critical Path Analysis for new product planning', Journal of marketing, vol.28, Oct 1964 pp 53-59.

WOOD, J.P. AND JOHNSON, P.N. 1989
'A review of the use of SSADM AND IDEF at the University of Warwick', SAMT '89, proc. of conf., 20-22 March 1989, pp 8B/4.

WOODWARD, J. 1965
'Industrial organisations: theory and practice', London Oxford University press.

YEOMENS, R.W. 1987
'Design rules and development guidelines for CIM projects', proc. of 4th European conf. automated manufacturing May 1987, pp 395-412.