COMPUTER INTEGRATED MANUFACTURING CONTROL

by

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SUMMARY

Many manufacturing companies have long endured the problems associated with the presence of 'islands of automation'. Due to rapid computerisation, 'islands' such as Computer-Aided Design (CAD), Computer-Aided Manufacturing (CAM), Flexible Manufacturing Systems (FMS) and Material Requirement Planning (MRP), have emerged, and with a lack of co-ordination, often lead to inefficient performance of the overall system. The main objective of Computer-Integrated Manufacturing (CIM) technology is to form a cohesive network between these islands.

Unfortunately, a commonly used approach - the centralised system approach, has imposed major technical constraints and design complication on development strategies. As a consequence, small companies have experienced difficulties in participating in CIM technology.

The research described in this thesis has aimed to examine alternative approaches to CIM system design. Based on previous research and experimentation, the cellular system approach, which has existed in the form of manufacturing layouts, has been found to simplify the complexity of an integrated manufacturing system, leading to better control and far higher system flexibility.

Based on the cellular principle, some central management functions have also been distributed to smaller cells within the system. This concept is known, specifically, as distributed planning and control.

Through the development of an embryo cellular CIM system, the influence of both the cellular principle and the distribution methodology have been evaluated. Based on the evidence obtained, it has been concluded that distributed planning and control methodology can greatly enhance cellular features within an integrated system. Both the cellular system approach and the distributed control concept will therefore make significant contributions to the design of future CIM systems, particularly systems designed with respect to small company requirements.

KEY WORDS: CIM, MRP, DISTRIBUTED MRP, DISTRIBUTED CONTROL

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CHAPTER 1 INTRODUCTION

There are an increasing number of companies, particularly in manufacturing industry, that are benefiting from the combination of traditional areas in manufacturing such as sales order processing, product design, process planning, production planning, inventory control and actual manufacturing processes into a single integrated environment with the aid of the latest advances in information technology, communications, automated manufacturing and electronic sensor devices. These areas are usually regarded as 'islands of automation', and the result of integrating these 'islands' is generally known as Computer- Integrated Manufacturing (CIM). The benefits which could be gained by CIM include improved overall efficiency, improved productivity and quality, better customer service, lower manufacturing costs and increased profits. Such advantages have attracted many leading manufacturing firms and academic researchers to investigate the latest technology.

1.1 RISE OF 'ISLANDS OF AUTOMATION'

Isolated 'functional islands' in manufacturing existed in the form of functional departments long before the introduction of computers and Advanced Manufacturing Technology (AMT). Rapid developments in modern manufacturing and computing technology have attracted many companies to introduce these newly available technologies into their existing production environment. Thus, industrial automation has apparently taken off without adequate initial cross-linked planning and control being taken into account. This fragmented approach has inevitably converted these computerised 'functional islands' into 'islands of automation'.

Some of these common islands, according to Gauderon [1986], include Computer-Aided Design (CAD), Computer-Aided Manufacturing (CAM), Master Production Scheduling (MPS), Material Requirement Planning (MRP), Group Technology (GT), Flexible Manufacturing System (FMS), Computer-Aided Process Planning (CAPP), Bill-Of- Material (BOM), Work-In-Progress (WIP) monitoring and Sales Order Processing (SOP). Because of the lack of suitable co-ordination between these islands, their performance has been somewhat disappointing.

Common problems which have been associated with these prevailing 'islands of automation' can readily be found in many manufacturing companies. Typical problems such as as duplication and inaccuracy of information, high inventory costs, long manufacturing throughput time, lack of communication between departments, low productivity and high manufacturing costs have highlighted the general need for an ultimate integrated system.

'One of the greatest opportunities for gaining an international competitive edge lies in integrating the elements of product manufacturing to bring them closer to a continuous automated process'. This advice was given in a report by Ingersoll [Ingersoll Engineers 1985] - a highly respectable company in the field of manufacturing consultancy. However melodramatic it may sound, 'Modernise or Fossilise' and 'Innovate or Liquidate' are apt warnings to companies that have not yet drawn up manufacturing strategies for total integration. These warnings, to people who are in managerial positions in manufacturing, implies that unless their competitiveness in associated market sectors can be increased through integration, sooner or later, they will go out of business. As a result, integration projects of varying size and types have commenced all over the world, and Computer-Integrated Manufacturing (CIM) is generally regarded as the ultimate total solution for integration.

1.2 BENEFITS OF INTEGRATED MANUFACTURING

Manufacturing integration is defined as a process of linking different control systems and management elements together by means of techniques such as system design, software and hardware interface, as well as modelling so that information and common resources can be shared by more than one system component without unnecessary duplication. A main intention of integrated manufacturing is that all these system components are serving a common company objective [Kochan 1985].

In contrast to problems which are associated with the existence of 'islands of automation', the improvements that integrated manufacturing would possibly bring, according to Small [1985] and Wills [1984], include reduced inventory, less waste and better control over quality, improved productivity, lower personnel management and administrative costs, more efficient use of machinery, lower occupancy costs for manufacturing facilities, improved dynamic response and flexibility of the overall system, as well as faster response to market changes. These improvements can be achieved in an integrated environment because of efficient interactions between system elements, which ensure the flow of information, its accuracy and as a consequence, integrity.

1.3 COMPUTER-INTEGRATED MANUFACTURING (CIM)

Computer-Integrated Manufacturing (CIM) is generally regarded as an ultimate totalling technology which leads to a manless factory environment and total automation [Kops 1980]. According to Ingersoll Engineers, there is a difference between integrated manufacturing and CIM in that the former is a business strategy whilst the latter is an enabling technology which could be adopted to achieve integrated manufacturing.

At the present moment, CIM is still relatively new when compared to other well established technologies in manufacturing. It is therefore too early to expect individuals to have a common and thorough understanding of CIM. As a consequence, a number of discrete projects which were only dedicated to some specific area of CIM have emerged. Indeed, most of these projects have been concerned only with partial integration in automation and production management. For example, Computer-Aided Design (CAD) has been integrated with Computer-Aided Manufacturing (CAM); Finite Element (FE) and 3-D solid modelling have been integrated with CAM; Computer-Aided Process Planning (CAPP) has been integrated with Production Control; MRP, BOM, MPS, inventory control and Work-In-Progress (WIP) have been integrated to form Computer Aided Production Management (CAPM).

The approach of partial integration, though, would still lead to a complete CIM system eventually. It may take much longer and more difficulties may be encountered because of the lack of integrated links between them. The most likely consequence of this approach being the creation of separate 'islands of automation' which could gradually increase in size but, nevertheless, remain independent.

1.4 PROBLEMS IN CIM DEVELOPMENT

The integration of different isolated system components has led to a number of technical, designing and conceptual problems within overall system control and management. The biggest problem has not come from the technical side, but from insufficient and inconsistent understanding of the concept of integration.

To begin with, there are a number of different CIM definitions available. The fact that CIM is relatively new and in addition, that the technology is very extensive has made it virtually too complicated for easy understanding - let alone efficient system planning and implementation. There is evidence that the direction of CIM development has already been in great divergence [LeClair 1984] and hence the progress has been slow [Phillipson 1986].

Most CIM projects are based on a rather primitive centralised view, despite involving only partial integration. The centralised approach will inevitably lead to a simple 'all embracing' strategy. In fact, this generally accepted centralised and 'all embracing' approach may not be the most suitable method to design an extremely complex and dynamic CIM system. The consequence of this is that CIM remains a possible technology only for the big companies [Hamilton 1984, Burhcer 1985] and, as yet, smaller firms have not been able to participate.

The author has attempted to seek an alternative system approach which would avoid the potential problems associated with the traditional methods, and which improves the flexibility and efficiency of the CIM system design in order to permit its implementation by smaller companies.

CHAPTER 2 DEVELOPMENTS IN CIM

This chapter attempts to describe some of the latest developments in CIM and illustrates examples of its installation in different manufacturing industries. A number of CIM projects which have adopted different system approaches will also be examined. It is hoped that from the observations of these current developments together with the examination of existing installations, the divergence of CIM system design approach and its implementation approaches can be highlighted.

2.1 CIM DEFINITIONS

As mentioned in Chapter One, CIM is a relatively new concept as well as a juvenile technology, and hence a common understanding of CIM has not yet been reached. As a result, many different CIM definitions have been proclaimed by individuals from different backgrounds. Some of these definitions are quoted as follows :

"CIM is a pervasive management strategy, and their development represents a conscious long-term implementation of strategic, operational and tactical plans to achieve high productivity and efficiency in plant operations." [Manchuk 1984]

"CIM is the business philosophy that will eliminate the piece- meal approaches attempted in the past. Good communications across the whole company are needed to develop alternative designs that can be evaluated and accepted through the creation of a common database vocabulary." [Glenney 1985]

"CIM is the complete integration of all functional areas in the company into an interactive computer system. These areas, from engineering and manufacturing to marketing and administration, have traditionally been insulated from each other." [Ingersoll Engineers 1985]

"A series of interrelated activities and operations involving the design, material selection planning, production, Quality Assurance (QA), management, and marketing of discrete consumer and durable goods." [Bunce 1985]

"CIM is the phased implementation of the integration of automated and non-automated systems into the manufacture of a product. It is an amalgam of Computer Aided Engineering (CAE) and drafting (CAD), CAM, engineering, FMS, tooling and quality support system, in-process gauging and automated final inspection, automated storage and materials handling and operations control within a business information system." [Baxter 1985c]

"Different functional areas like engineering, manufacturing, marketing and administration have traditionally been insulated from each other; the need for bi-directional flows has led to the concept of CIM." [Saul 1985]

"A typical FMS is a computer intensive environment in which the functions of manufacturing, material handling, tool management, shop floor scheduling, quality assurance and workpiece accounting are integrated; these functions are all involved in CIM along with marketing, design and distribution, only on a much grander scale." [Saul 1985]

Kochan [1985] defines CIM as a system which includes every activity right from the receipt of a customer order; until the same order is completed in shop floor and the production control manager is informed of its status.

"CIM is suggested as a single complete environment to house everything in a new level of technology - CAD, robotics, FMS, MRP and decision support systems." [LeClair 1984]

2.1.1 COMMENTS ON CIM DEFINITIONS

Boaden [1986b] in his published article stated that "CIM means different things to different people". This is certainly true when one could realise just how broad CIM can be. There is, in reality, more than one way in which CIM can be defined and constructed.

For the purpose of easy analysis, CIM definitions can be broadly divided into ten categories according to Boaden and Dale [1986b] :

(1) the computerisation of the main functions of an organisation;

(2) a philosophy or tool for strategic management;

(3) viewing the organisation as part of a total business unit;

(4) an exercise in information management;

(5) a computer system running from a single database;

(6) a closed loop feedback system for an organisation;

(7) a system to enable a better response by the organisation to market situations;

(8) an integrated CAD/CAM system;

(9) the use of the most advanced manufacturing technology;

(10) a system with its biggest impact on people.

Boaden and Dale have further combined these categories to form three general classes, namely class A, B and C, which are explained as follows :

(A) total organisation definitions (Categories 1, 2, 3);

(B) information systems definitions (Categories 4, 5, 6, 7);

(C) single facet definitions (Categories 8, 9, 10).

In a survey of articles and books about CIM, which was carried out by Boaden and Dale [1986b], a proportion of each category to each of the three classes can be summarised as in Figure 2.1. It gives a breakdown of definition by class and category. The perception in this figure is that Category 1, 3, 8 and 9 have been most popular. This reflects that most people's understanding of CIM is concentrated on these four categories, which subsequently belong to Class-A (Categories 1, 3) and Class- C (Categories 8, 9) respectively.

2.1.2 MAIN REASONS FOR THE EXISTENCE OF DIFFERENT CIM DEFINITIONS

According to Appleton [1984], there are three widely diverse viewpoints of CIM within a manufacturing enterprise. These viewpoints are known as the user view, the technology view and the enterprise view (see illustration in figure 2.2). The user viewpoint defines the demand for information. It is determined by the enterprise's market environment and its various product and business life cycles. The technology

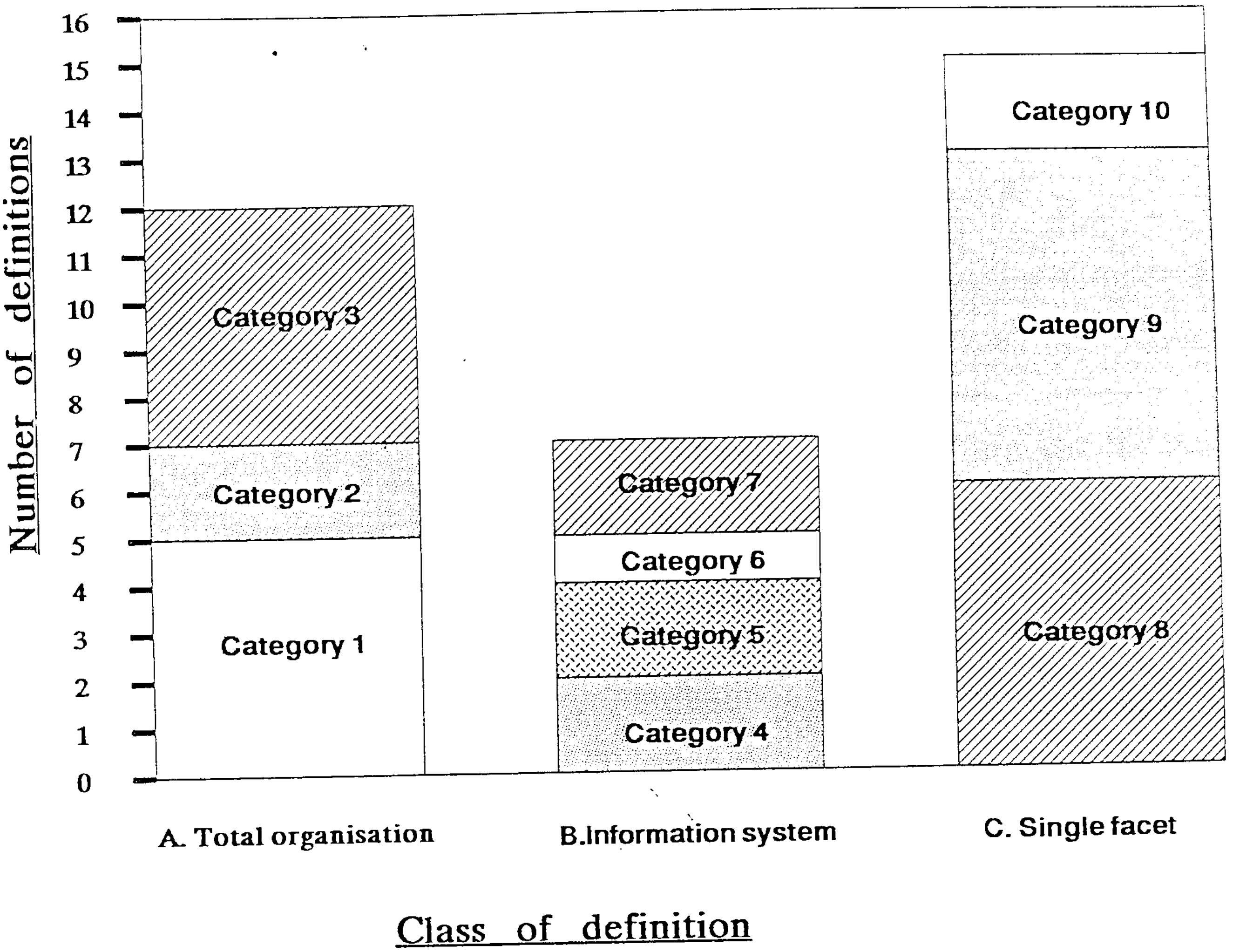


Figure 2.1 Three classes of CIM definition (Boaden 86b)

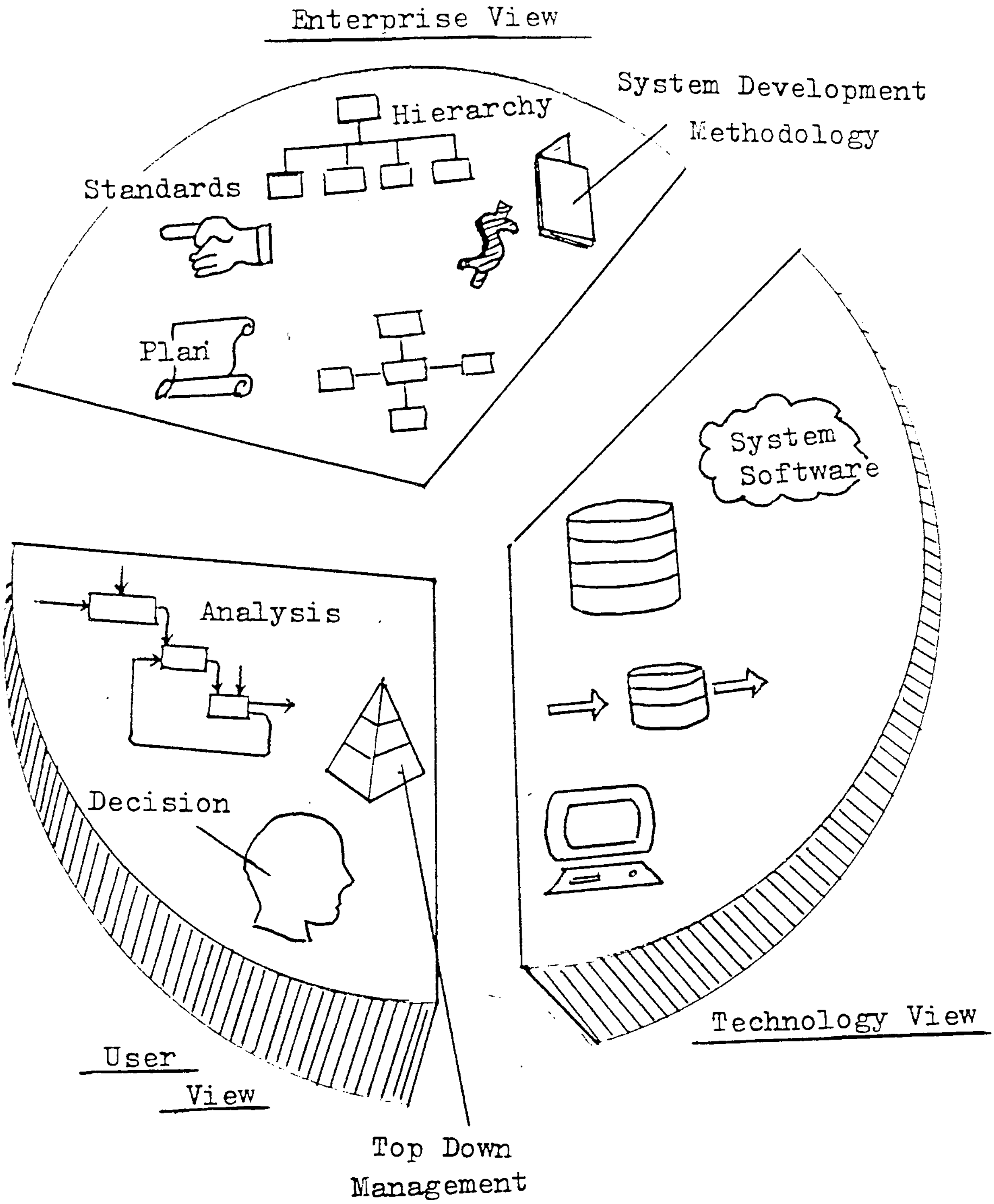


Figure 2.2 The 3 - Dimensions of CIM view
(Appleton 84)

view, which is created by pressure of the providers of technology, considers the supply of information. The last viewpoint is the enterprise view of CIM. It provides a control structure that can maintain alignment between the dynamic user and the technology view, while at the same time providing for the integration and consistency required by the enterprise as a whole.

The enterprise view of CIM contains planning and project management procedures, system and data standards, budgeting and performance controls, as well as organisational responsibilities. A system can not be called a CIM system without an enterprise view that defines what will be shared, why, and how they will be integrated. While the first and second dimensions of CIM are relatively simple to understand, the third is not. It is mainly because of the divergence of the third CIM dimension which has given rise to a lot of different CIM definitions.

The Class-C category of CIM definitions presents a rather narrow and controversial view. It has the advantage of simplifying a would-be complex CIM structure, but is in itself restricted only to a technologically orientated image of CIM.

The Class-B category represents a wider view of CIM; it is however, still relatively limited to the emphasis of use of a competent information system.

The Class-A category comes closer to the author's view of CIM, which is described in more detail in the following sections.

2.1.3 CONCLUSION OF CIM DEFINITIONS

The CIM definitions given in the first section of this chapter have, for the greater part, somewhat imposed a fixed layout of the system. In order to permit more companies, especially those of a small or medium size, to participate in manufacturing integration, the CIM definition has to provide some degree of flexibility in terms of system layout. It must also be simplified and probably is best derived from first principles of integration - a view that has been widely supported by specialists in this field [Yeomans 1986]. Such a definition should not confine CIM only to an elite group of big enterprises.

Fundamentally speaking, CIM is a business philosophy rather than a specific system or set of applications. It uses the advances in computers, information technologies, 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.

The emphasis of such definition is on the integration of data and flow of information. The major role of computers is to support this view so that it can be achieved efficiently. It is therefore perfectly feasible if some parts of the system are manually driven without the use of any computer system.

The principal objective of such a CIM system is to process, link and transfer relevant information associated with different parts of the system in the most proficient way. This information flow is vital during the process of transforming customer demands, product design details and materials into saleable products. The benefits of implementing a CIM system include reduced production cost, a shorter manufacturing lead times, a lower inventory and improved overall system performance. These benefits can only be ensured with the aid of an (or several) accurately contemplated database system, whose main function is to maintain the security, accessibility, integrity and accuracy of data in the most optimal method.

The implication of such a definition is that CIM should not be restricted by the sophistication of computer hardware and software. On the contrary, CIM can indeed exist in many different forms since the needs of each company can differ greatly. This view is supported by Waterbury [1985] who warned that there is no ready-to-run CIM system available.

2.2 RELATED CIM PROJECTS AND STAGE OF DEVELOPMENT

As mentioned in the previous section, no common specification of CIM has yet been agreed. Large manufacturing companies who are engaged in CIM development projects have shown much diversity in their approach of system design and implementation. System specifications for hardware, interfacing techniques, data communications, or even the basic definition and coverage of a CIM system are generally incongruous in these projects. Most of these companies have an imminent priority to design and build a CIM system for their own use with the shortest pay-back period in mind. As a consequence, a very diverse and dispersed effort in both short-term as well as long-term planning for CIM development is commonplace.

According to Burcher [1985] and Powell [1986], most CIM projects have concentrated on CADCAM integration, shop floor automation, FMS, automated assembly, Computer Numerical Control (CNC) and Direct Numerical Control (DNC). The major reason for this is because these areas have appeared to be directly associated with the actual manufacturing processes, with cost reduction as their first priority.

These CIM projects have generally favoured a popular 'think big', 'start big' and 'centralise' philosophy in their system development. They have embraced almost everything in their integration plans - a huge database management system, CAD and CAM, GT, FMS, CNC, DNC, and MRP. On the other hand, these elements are often poorly linked and can not accomplish the stipulations in a true integration environment and degraded performance is inevitably the consequence. This approach can generally be described as an oversized centralised system method which embraces virtually every existing 'island' onto a huge common ground.

The intention of following paragraphs is to provide some good examples of how CIM systems have been developed and implemented in some well known companies. At the end of this chapter, the different system approaches in these examples will be compared, evaluated and summarised.

2.2.1 CURRENT CIM PROJECTS

In Europe, one of the well known CIM projects is the internationally co-operated programme known as ESPRIT (European Strategic Program for Research in Information Technology). The project aims to advance the productivity of manufacturing plants through developing software for the automation of the production process, reducing human intervention and delays and relaying data automatically captured from within the plant. The ultimate goal of the ESPRIT programme is to develop an agreed architectural definition of control systems for integrated manufacture in order to enable anyone to write compatible software.

Various companies and universities throughout Europe have taken part in the ESPRIT programme which comprises many different but co-ordinated projects. Figure 2.3 [Yeomans 1985] illustrates the scope of the CIM definition given by the ESPRIT-CIM group.

'Progress is good but not fast enough' is the comment from Phillipson [1986] on these ESPRIT-CIM projects. He has recently written a report on the current state of European initiative on CIM. Further details relating to some of the important ESPRIT projects are to be found in his paper.

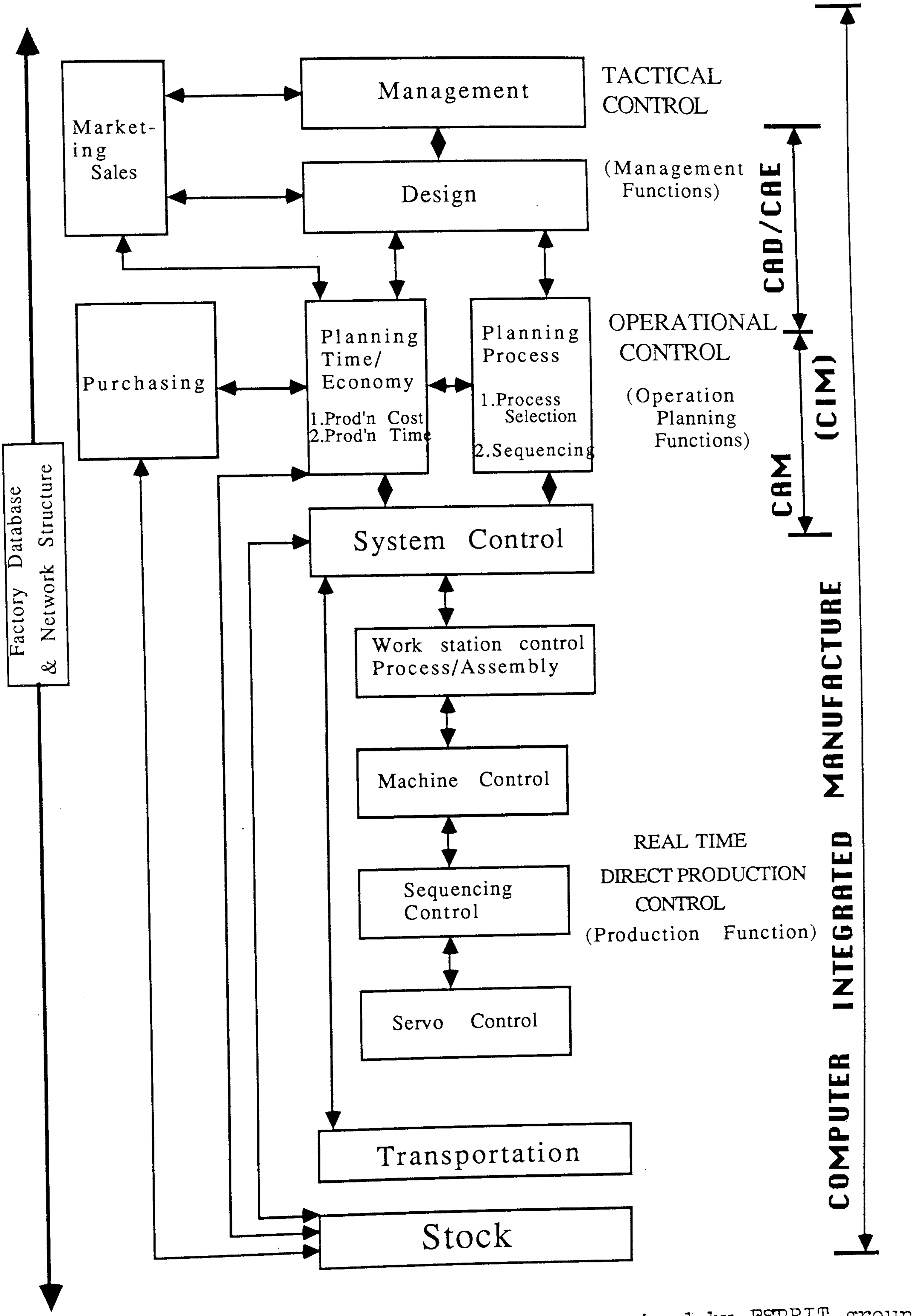


Figure 2.3 Reference model of CIM perceived by ESPRIT group

The first phase of the ESPRIT programme has produced some generic rules for CIM system design which are not specific for any particular application [Hartley 1985]. These rules are used to help build an overall framework which includes models and guidelines to create a CIM system through the use of multi-vendor systems. Control interfaces for different CAD and CAM systems are also included so that these can be linked to other CAE and Production Planning functions. In addition, optical sensors are designed to complement some FMS machining control [Phillipson 1986, Kochan 1984].

The second phase of the ESPRIT's CIM programme, currently being supported by a number of European companies, is the use of rules produced in the first phase to construct a so called 'Demonstrator' model. Separate demonstrators will be built to perform different parts of the ESPRIT programme. They will also be used to validate the rules and theories which have been developed in the first phase.

The emphasis of these ESPRIT projects has been on the use of advanced techniques to improve and handle individual parts of a CIM model which has been generally agreed and understood. Little effort has been made to study the requirement of a basic system design approach; a partially or completely centralised view is still dominant. If these projects are continued with the present system strategy, the end product will certainly be a very huge and sophisticated computer-based system. This will give little opportunity to small companies to share the potential benefits of integration.

In addition to ESPRIT, DEC, Perkins, Rolls Royce, Jaguar, Austin Rover and Vauxhall in the U.K. are other well known companies concerned with CIM development [Baxter 1985a, 1985b, Rooks 1985, Wyman 1986]. With the exception of DEC and Perkin, Rolls Royce, Jaguar, Austin Rover and Vauxhall all happen to be car manufacturers. They have implemented CIM technology mainly because very suitable conditions for CIM application exist within their operations. The major benefits achieved by CIM act as very strong driving forces to these companies. CIM projects conducted within these companies are, inevitably, somewhat specific to their own requirements. Interestingly enough, many of these companies concentrate on various intelligent robots and machining cells. This is probably due to the intention to automate their car manufacturing lines which would require an extremely high level of automation.

DEC, on the other hand, is aiming to produce more generic CIM components for their potential customers. Their CIM components range from machine communication, and the use of LAN, to the installation of a completely distributed information processing system. DEC has recently opened a 'European Competence Centre' in Munich [Baxter 1985b], which represents an investment of about $5.5 M. The main objective for this centre is to display to its customers their latest CIM achievements. They have some eighteen such CIM centres around the world. Figure 2.4 displays a simplified overview of a manufacturing management system which is defined by DEC. DEC has attracted a lot of attention to its Clonmel factory in Eire, which is operated as a 'living' example of CIM to DEC's customers. The factory was designed from first principles using their CIM strategy, and has implemented the concept of 'work cell'. This concept closely resembles the highly successful cellular system which is widely employed in Japan's manufacturing.

It is believed that CIM has been the main development strategy in Japan's manufacturing industry. This is, however, not the case according to some recent reports on the current trend of manufacturing in Japan.

First of all, the Japanese do not seem to have the same definition and understanding of CIM as other countries who are also involved in CIM system development projects. According to the two reports [Hartley 1985, Powell 1986] on the Japanese CIM system development, their progress has been slow. One comment made in this report is that "CIM is still in the future for Japan".

The Japanese have made significant advances in their manufacturing industry since late 70's [Lee 1985]. The introduction of FMS has virtually made them the leading country in manufacturing. The Japanese are still very committed to continuing further development and application of FMS on a wider context. The fields of application are now expanding to small mid-volume and large mid-variety production from mid-volume mid- variety production. These applications have occurred in four directions, and are illustrated in figure 2.5 [Powell 1986].

General speaking, in addition to the area of machining, the Japanese have aimed to incorporate the very well received FMS technologies into other industries such as plastic forming, clothing, food and drink, as well as measuring and assembly. At the same time, they reduce the size of a traditional FMS into smaller constituents which are called Flexible Manufacturing Cells (FMC). The latest development trend is to extensively employ the recent successful Local-Area-Network (LAN) technology to facilitate the automated communications between FMS and FMC in order to achieve the goal of a 'manless factory' more cost effectively.

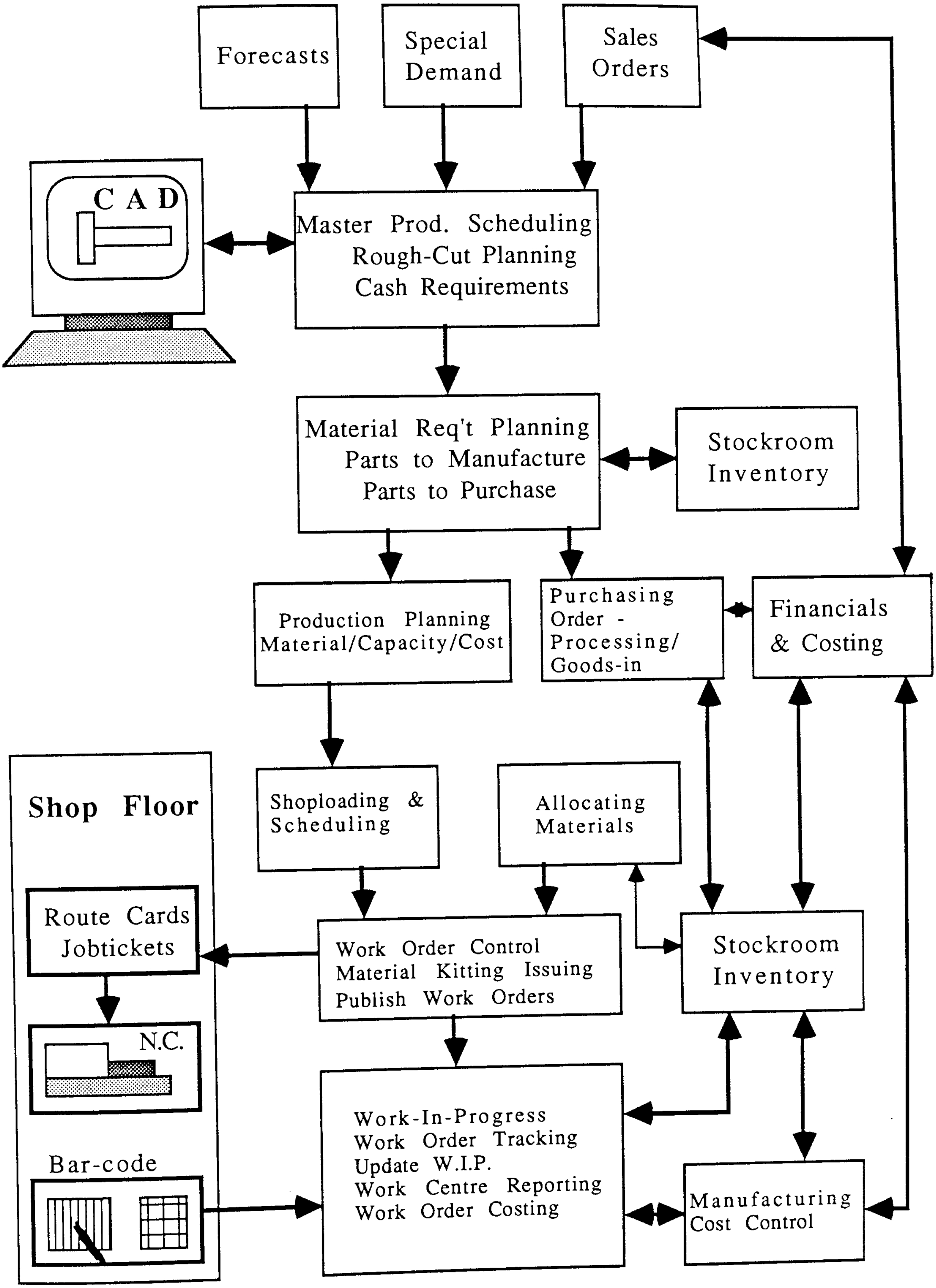


Figure 2.4 Scope of a Manufacturing Control System by DEC

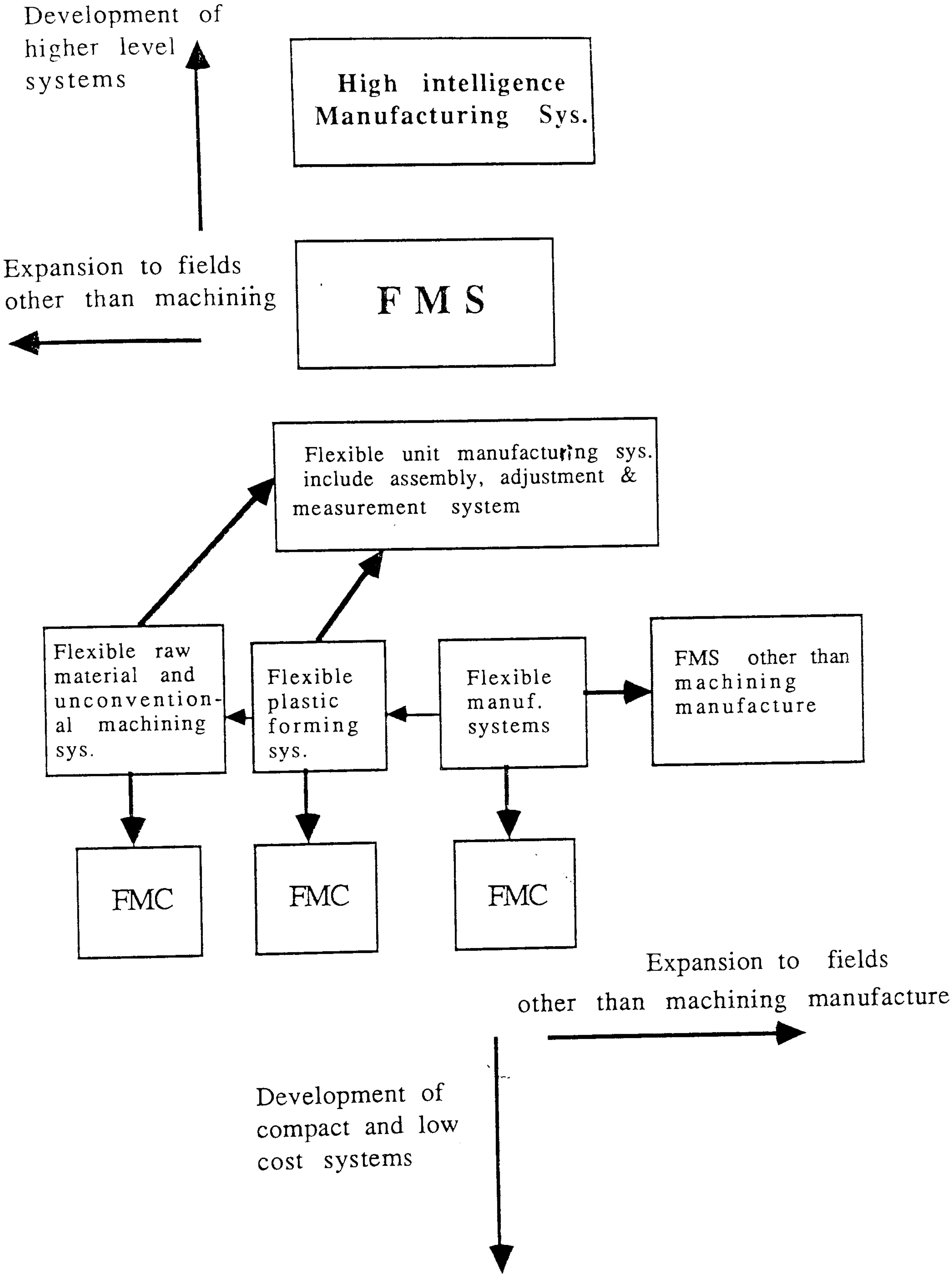


Figure 2.5 The four directions of FMS development

A FMC encompasses more sophisticated features than just those usually contained in a conventional machining cell. In comparison, A FMC may include such additional features as sophisticated monitoring abilililies, bigger data bank storage, extensive use of microcomputers and Local-Area-Network (LAN) systems, and distribution of control from host computer to smaller computers.

The Japanese, in fact, have considered CIM but have their own understanding of the concept. Their ideal CIM system has focused on the co-ordination of CAD, CAE, CAM, FMS and other related production activities [Powell 1986]. This is, comparatively, a narrower view of CIM but one which has greatly influenced their direction of CIM development. They have a strong belief that CIM is simply the addition of CAD and CAM into their FMS systems. Within their present CIM definition, few management functions exist and this may be largely due to the difference in their culture compared to other western industrial nations. The Japanese have a relatively simple loyalty to their employers based on traditional values. Broadly speaking, they are loyal to those who are in higher ranking within the company hierarchy [Mortimer 1986], as such, view management as less important when compared to the actual manufacturing processes.

Relatively well known companies in Japan who have been involved in integrated manufacturing development include Toshiba, Okuma, Fujitsu and Hitachi [Hartley 1985]. Fujitsu, for example, is developing an integrated manufacturing system for computer manufacture where most sections are presently in use. Figure 2.6 illustrates Fujitsu's concept of an integrated system. It has shown clearly that considerably more effort has been put into the design and manufacturing side, and relatively little emphasis has been given to areas such as production management. Toshiba and Okuma, on the other hand, have only been able to prepare a definite and clear plan for CIM development, whilst Hitachi is using their FMS-based technology as a starting point for total integration.

Because of the difference in culture, the Japanese's version of CIM may well be justified even though their overall emphasis is on aspects of manufacturing processes rather than on manufacturing management.

Some of the main features in their FMS and FMC development are well worth examining, such as the emphasis of a cellular manufacturing approach and the extensive use of Local-Area- Network (LAN) systems. Their FMS and FMC systems can be regarded as the ultimate result of the use of the cellular manufacturing approach to the fullest extent. The LAN systems, on the other hand, serve mainly as

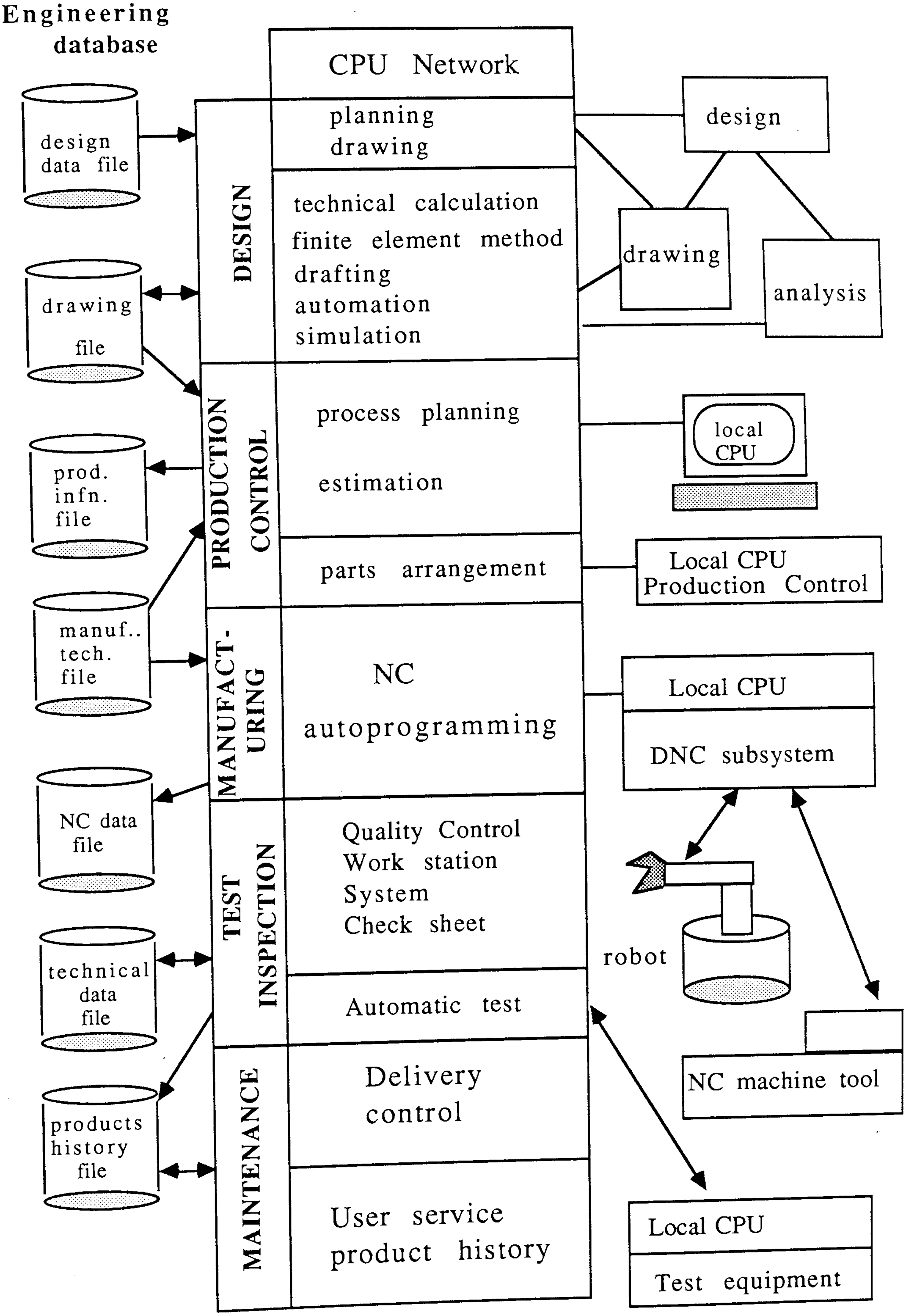


Figure 2.6 An Integrated System defined by Fujitsu

integration links between smaller computer systems. It is therefore believed that the Japanese can easily convert their existing FMS and FMC methodology into a basic CIM system based on the definition earlier in this chapter.

The Japanese are also currently seeking to develop the so-called 'fifth generation' computer which will be capable of very fast intelligent processing. Should they succeed in this task, it will undoubtedly be an enormous impact on their development of integrated systems as well as cellular manufacturing.

ICAM, which stands for Integrated Computer Aided Manufacturing, is a U.S. Air Force-sponsored program. The project was intended to improve state-of-the-art manufacturing automation [Banerjee 1986]. There are many projects present under ICAM. Each project is conducted by a coalition of companies under the guidance of a prime contractor who plans to implement the results. Although all project results remain within the public domain, the results come under the For Early Domestic Dissemination (FEDD) for the duration of two years following the completion. One such project is known as Conceptual Design of Computer Integrated Manufacturing [Cooke 1985]. Its aim was to establish a conceptual framework for the Factory of the Future (FOF). It was headed by Vought Corp., Dallas, and involved a coalition of fifteen companies. Another example, is a project called Integrated Information Support System (IISS). It was intended to develop a technology for accessing and managing databases which were distributed on various vendor equipment with different DBMSs.

Computer Aided Manufacturing-International (CAM-I) of the U.S. has started a CIM project called Advanced Factory Management System (AFMS) [Casey 1987, Wills 1984]. AFMS has defined a hierarchical control architecture and distributed asset management system for the factory. This architecture covers all aspects of shop floor activities both in a semi-automated and automated environment, and describes all external interfaces.

2.2.2 MAP AND TOP STANDARDS

It was General Motors (GM) in the U.S. who first introduced the idea of establishing a standard for factory floor communications in 1980. This is known as the Manufacturing Automation Protocols (MAP) [Cheshire 1986]. In addition to MAP which was mainly designed for manufacturing environment, TOP (Technical Office Protocols) has also been introduced for use in Office Automation.

MAP is a broadband communication network system, and its seven layers of communication are based on the Open Systems Interconnection (OSI) model [Houten 1986]. Figure 2.7 illustrates the seven-layered structure of MAP. Each of these layers takes control of a particular attribute of computer communication.

MAP has been regarded as a crucial element in CIM development because of its very promising features which include automatic signal conversion and sophisticated multi-disciplinary network control [Deadman 1986, Dwyer 1985]. However, since its first appearance, MAP has received serious criticism and has countless technical problems. According to Cheshire [1986] and Cornwell [1985], the OSI model only defines functions but not how those functions are to be implemented, and thus does not define what the optimum protocols are. Hence, compliance with the model does not ensure that systems can communicate. In addition, Houten [1986] and Warnecke [1985] suggest that while layer one to layer five can be expected to be fairly consistent from various hardware suppliers, layer six and layer seven, which are the 'Presentation layer' and 'Application layer' respectively, have created enormous areas of inconsistency.

Among those companies who are not yet convinced that MAP will be the ultimate standard in computer system communication is DEC, who in fact has responded by hitting out against the independent standard MAP without reservation [Olsen 1987]. Houten [1986] also fears that the present version of MAP will only support communication functions but not the rest of the required monitoring and control facilities. This problem will become extremely serious when thousands of MAP believers and MAP hardware suppliers try to solve these problems by setting up their own standards. At present, the latest version of MAP V.3 is still full of potential problems and is, itself, not fully compatible with the previous version.

In conclusion, although the emergence of both MAP and TOP has raised the hope that a universal standard in hardware communications as well as in automatic data conversions can be finally agreed, there have been number of furious conflicts about the MAP's standard. It is believed a number of vigorous tests for MAP have to be carried out before the final version can be fully accepted [Cornwell 1985]. At the moment, and probably in the near future, the relative costs of TOP and MAP are still too high to be justified by their inconsistent performance. This is certainly unsatisfactory news for smaller companies who want to get involved in manufacturing integration.

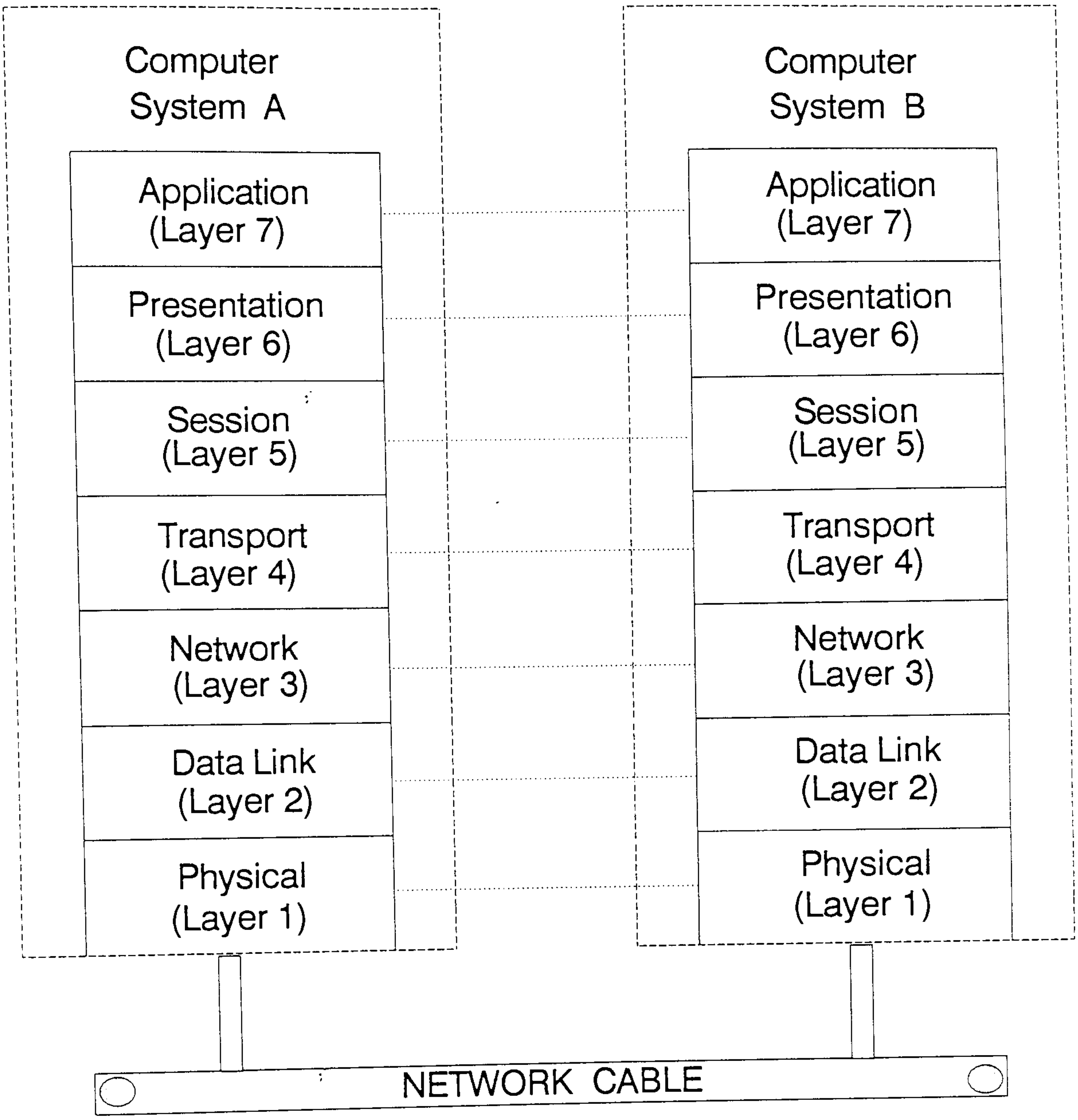


Figure 2.7 7 layers used in MAP standard

2.3 TREND OF CURRENT CIM DEVELOPMENT

Referring to the previous section, it seems that the West and the East have different attitudes and a different understanding of CIM. This view is also supported by Smalley [1986] and Meyer [1985]. The West's view of integration is concerned with the total integration which comprises CAD/CAM, CAE, Robotics, CAPM and information systems. On the other hand, the East, notably represented by Japan, is more restricted in its integration scope. Strictly speaking, the Japanese's view of integration is confined only to their FMS systems enhanced by cellular features.

Some conclusions can be drawn by comparing the essence of these many CIM projects which have been mentioned above :

(1) many of these projects have adopted a centralised approach; a huge common database is used for storing shared data and information [Bryce 1985, Melkanoff 1984];

(2) many systems concentrate on integrating shop floor automation [Burcher 1985];

(3) some developments have begun by establishing a CIM skeleton and master reference based on first principles [Baxter 1985a];

(4) some companies are more interested in integrating their existing systems, whilst others are incorporating new elements into their existing systems [Biles 1984, Salzman 1984];

(5) most of these projects are huge, and are, consequently, both time consuming and capitals intensive. They are also technically very complicated [Gerry 1986];

(6) many systems are too specific in application and functionality for a particular company, whilst on the other hand their broad structure has almost covered every related activity regardless of actual needs [Boaden 1986, Meredith 1984];

(7) different standards in hardware and software communications are still used [Gettelman 1982, Cornwell 1985].

These conclusions have caused major concerns for smaller manufacturing companies. The fact that most of these systems are so complicated and expensive makes it difficult for these companies to decide whether they should commit themselves to integration. In addition, the search for a more effective and more flexible design approach for integration systems still remains. In the next chapter, various system approaches which have been used in present CIM projects will be examined in greater depth. Their advantages and drawbacks will also be elaborated upon.

CHAPTER 3 APPROACHES USED IN CIM SYSTEM DESIGN AND IMPLEMENTATION

In Chapter 2, the current status of CIM developments has been briefly discussed. Some conclusions have also been made based on the system approaches within in these CIM projects.

According to Salzman [1984], these different approaches can be generally grouped into two main global types. The essence of the first global approach is to build an integrated system from existing system elements, whilst the second approach is to build an integrated system from first principles.

3.1 GLOBAL SYSTEM APPROACH ONE - A CIM SYSTEM IS BUILT FROM EXISTING SYSTEM ELEMENTS

In this approach, an integrated system will be built from the existing elements and functions in a specific application environment. The major advantage of this approach is that the least possible interruption to existing manufacturing routines will occur [Timm 1981]. This global approach has been used in many CIM projects of all sizes, ranging from the preliminary stage of single-function integration, through the intermediate stage of multi-function integration, and to the final stage of ultimate total integration.

3.1.1 SINGLE FUNCTION INTEGRATION - ISLAND OF AUTOMATION

The first type of integration is known as single-function integration. In fact, they are sometimes regarded as 'islands of automation'. As explained in Chapter 1, the term 'islands of automation' has emerged as a result of rapid manufacturing automation. As technologies have grown, swiftly, but in an isolated mode, the co-ordination between them is insufficient and are sometimes virtually non-existent. These technologies include manufacturing, information and computing. When these technologies continue to grow, they are isolated from one another in terms of functionality and data sharing.

Most of these 'islands of automation' derived originally from single functions or processes. These single functions have undergone rapid and severe automation - becoming 'islands' themselves. They are usually smaller in size and have fewer operations within themselves. Examples of these 'functional islands' are CAD, CAM, MRP, NC, CNC, ROBOTICS and CAPP. Although these islands are isolated from one another in terms of information flow, they themselves represent a limited degree of integration. Indeed they can be considered as the lowest degree of integration in comparison to the ultimate integration - CIM.

As described above, most of these functional areas were originated from individual key processes such as drafting, stock control, machining and process-route planning. During rapid computerisation, other activities have also merged into these processes with the the final products emerging as the notorious functional islands.

For example, CAD is itself an integration of design, drafting and database (storing geometric data) [Groover 1984].

CAM is an integration of the process of geometric data generation, NC data programming, verification of cutting paths, as well as the final machining process [Groover 1984].

MRP has combined the functions of Bill-Of-Materials (BOM) and conventional inventory control, with data from forecasting, sales orders and shop-floor WIP, into a single system which performs major planning for net material requirements [Callarman 1986, Blackstone 1985].

Although all these functional islands - CAD, CAM, MRP and CAPP, can be viewed as stand-alone functions as they are literally isolated from one another with very little communication or data sharing, they represent some degree of integration [Gott 1984, Willer 1984]. In fact, they are often regarded as essential elements for a conventional CIM system.

The essence of the system approach mentioned here is that automation islands are actually end-products of the preliminary integration. Within a single island, data is maintained and shared by similar activities. Very often, the presence of a self-contained common database is not unusual. This central database within each island is responsible for the provision of data to all activities embraced within that island. However, there is very little co-ordination between these islands in terms of operations and data sharing, making the full benefits of integration difficult to achieve.

In order to illustrate the role of central databases in these single-function integration processes, some of the examples mentioned above are examined. In CAD, for example, the geometric data generated from design processes is stored in a central database so that the same data could be used for the design of a new product.

In CAM, the geometric profile which has been defined for a component part will serve as an input for the NC data generation process. The output NC code will then be verified for its subsequent cutting paths before actual machining operations take place. In this example, a single database could be used for all processes.

Inside MRP, a central data bank is used to hold all information associated with stock transactions such as on-hand inventory management, on-order information and free stock allocation. The results generated during the MRP process are also stored in that data bank so that they can be accessed by other functions such as Purchasing, Capacity Planning and Shop Scheduling. The same data bank can also be used to serve other conventional stock control activities such as material issue, shortage allocation, parts receipt and possibly re-order point management. Figure 3.1 shows a typical layout of such an integrated system.

3.1.2 MULTI-FUNCTIONS INTEGRATION - PARTIAL INTEGRATION

A step forward from single-function integration is the multi- function integration. This is the result of combining some of the single islands together to improve data communication and data accuracy. Examples of such integration include Flexible Manufacturing System (FMS), Computer-Aided Engineering (CAE) and Computer-Aided Production Management (CAPM). They represent a medium degree of integration in relation to the ultimate total integration.

This multi-function integration can be regarded as a logical progression from the original 'islands of automation'. As the application environment itself becomes bigger and more sophisticated, demand for a higher degree of integration becomes more severe. Thus, some existing islands are further combined into a single integrated system so that more common resources can be shared [Weatherall 1984]. Strictly speaking, the resulting integrated system is merely a bigger 'island' itself but consists of a greater number of activities.

For example, FMS is the integration of NC, CNC, Group Technology (GT), ROBOTICS, Automated Guided Vehicle (AGV) and production scheduling rules. CAE is the integration of CAD, CAM and other design-orientated computing processes such as 3-D modelling and finite-element system. CAPM has integrated

Island of function

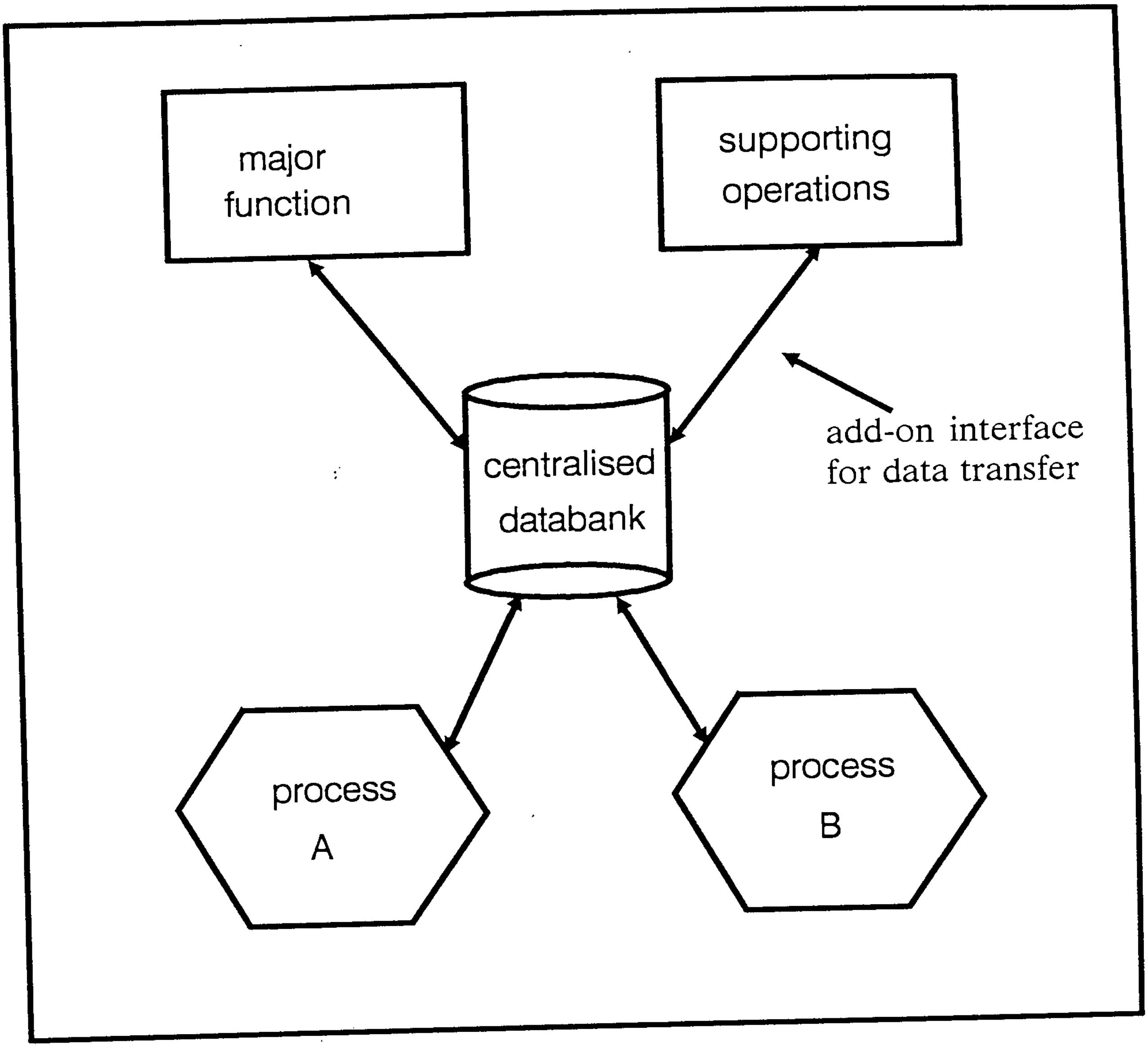


Figure 3.1 Layout of an integrated functional island

most of the functions in production planning and control, including MRP and MPS, as well as those in shop floor scheduling, shop floor documentation and sales order processing.

These enlarged islands are formed more or less in the same way as those single-function integrations. Here, existing systems are bound together using suitable interfaces. Functions which have been merged into a bigger island can communicate with one another where a reasonable degree of data sharing and data access is ensured. However, it must be noted that this system approach is comparatively passive because the links between these functions are only designed in at a later stage. The original design of these individual functions did not accommodate any data link for integration.

As in single-function integration, the centralised database strategy is also popular in this second group of integrated systems. System elements in multi-function integration communicate by using a central database through which all data transactions are carried out and all resulting data is stored [Biles 1984]. Figure 3.2 shows a typical layout of such an integrated system in which it is formed by two separate functional islands, an individual function and a centralised database.

3.1.3. TOTAL INTEGRATION

Total integration is often regarded as the ultimate solution to integration problems. Indeed a lot of CIM definitions have implied the need for such integration. Although the size and the number of activities included in total integration is enormous, the system approach probably is no different to those used in previous integrations. Very often, because of the commitment in finance and time that is required, only very big companies are able to afford this ultimate degree of integration.

The reason why many big companies prefer the first global type of integration approach has already been referred to in Chapter Two. Most of these companies have aimed to achieve the maximum benefit of computer integration in order to improve their competitiveness. On the other hand they have remained reluctant to disrupt the existing system whilst the process of integration is being implemented. The first type of system approach which focuses on integration of existing systems is therefore more appealing to them.

The other possible explanation is that most of these companies already possessed highly sophisticated machining processes, production planning, control, engineering

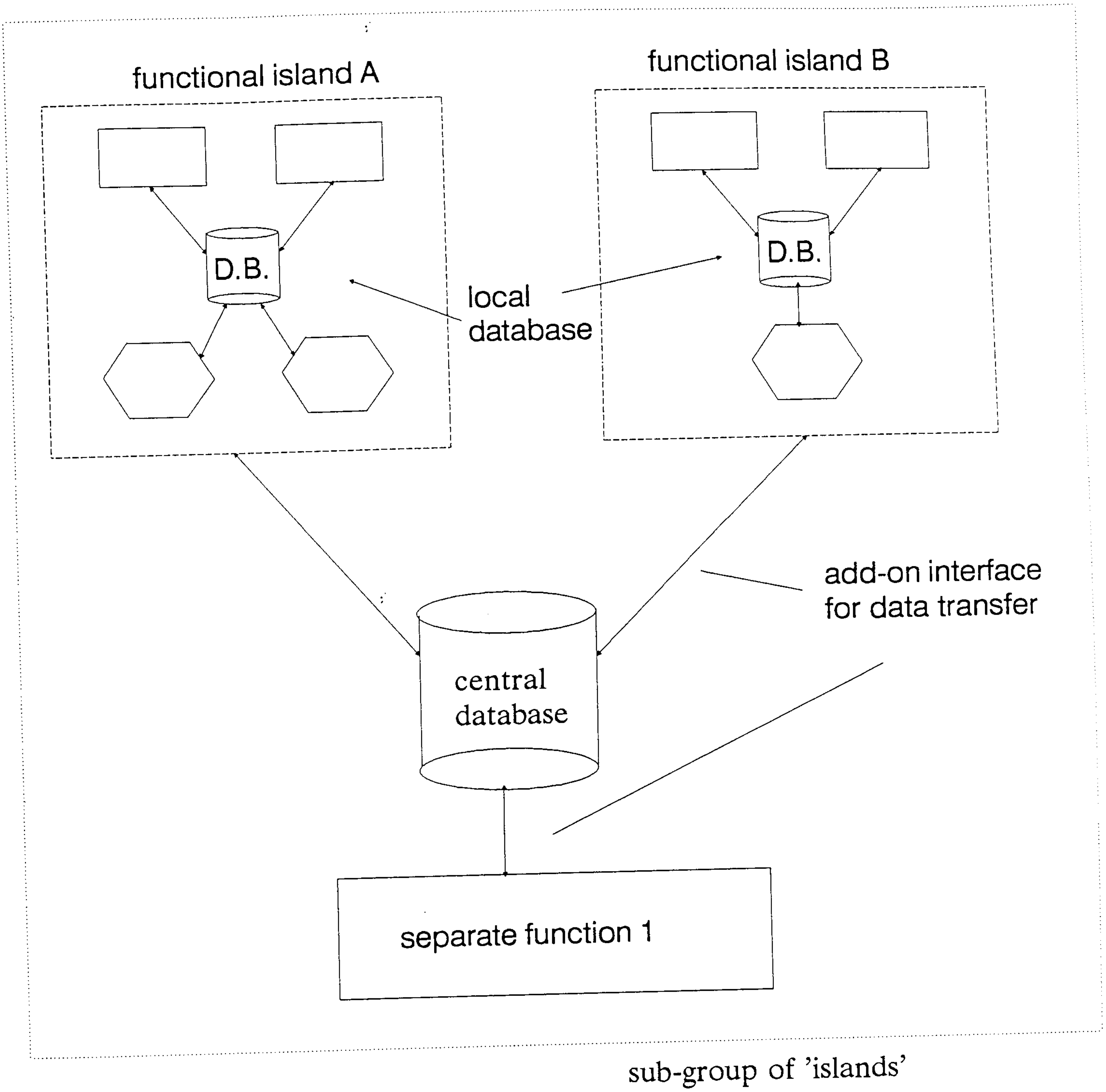


Figure 3.2 Layout of a group of functional - islands

design, administrative and financial systems. As a result of this, they own a number of 'automation islands' and it is therefore quite natural that they want to avoid radical modifications of these existing 'islands'.

In order to ensure minimum disruption of their existing systems, these companies have inevitably adopted an integration approach which only concentrates on linking existing elements. As a consequence, direct and indirect interfacing techniques have been used throughout for hardware and data communications between these system elements.

Islands such as CAD, CAM, MRP, MPS, sales order processing, CAPP, FMS and AMT may initially be combined together to form sub- integration groups, and these sub-groups are then linked to form the total system. Alternatively, these elements can be integrated into a single system using a single step. Whichever method is undertaken, the use of a centralised database for achieving integration is inevitable. This is similar to the other two types of integration patterns mentioned in previous paragraphs. Central data links between 'islands' and sub-groups are designed only after the latter have come into existence.

In fact, a total integrated system may be sometimes formed by combining the previous two types of integration, as is demonstrated in Figure 3.3. Represented in this figure, is the final integrated system formed by sub-group 1 (approach in 3.1.1), islands C,D and E (approach in 3.1.2), as well as some individual functions.

3.1.4 CONCLUSIONS

The characteristics of the first global system approach is that, while existing systems are linked, little or no modification is necessary to the systems themselves. Hardware and software interfaces have to be developed to serve as a passive communication media between elements of the integrated system. Finally, the centralised approach, which includes the use of a central database, has been applied throughout to support the integration.

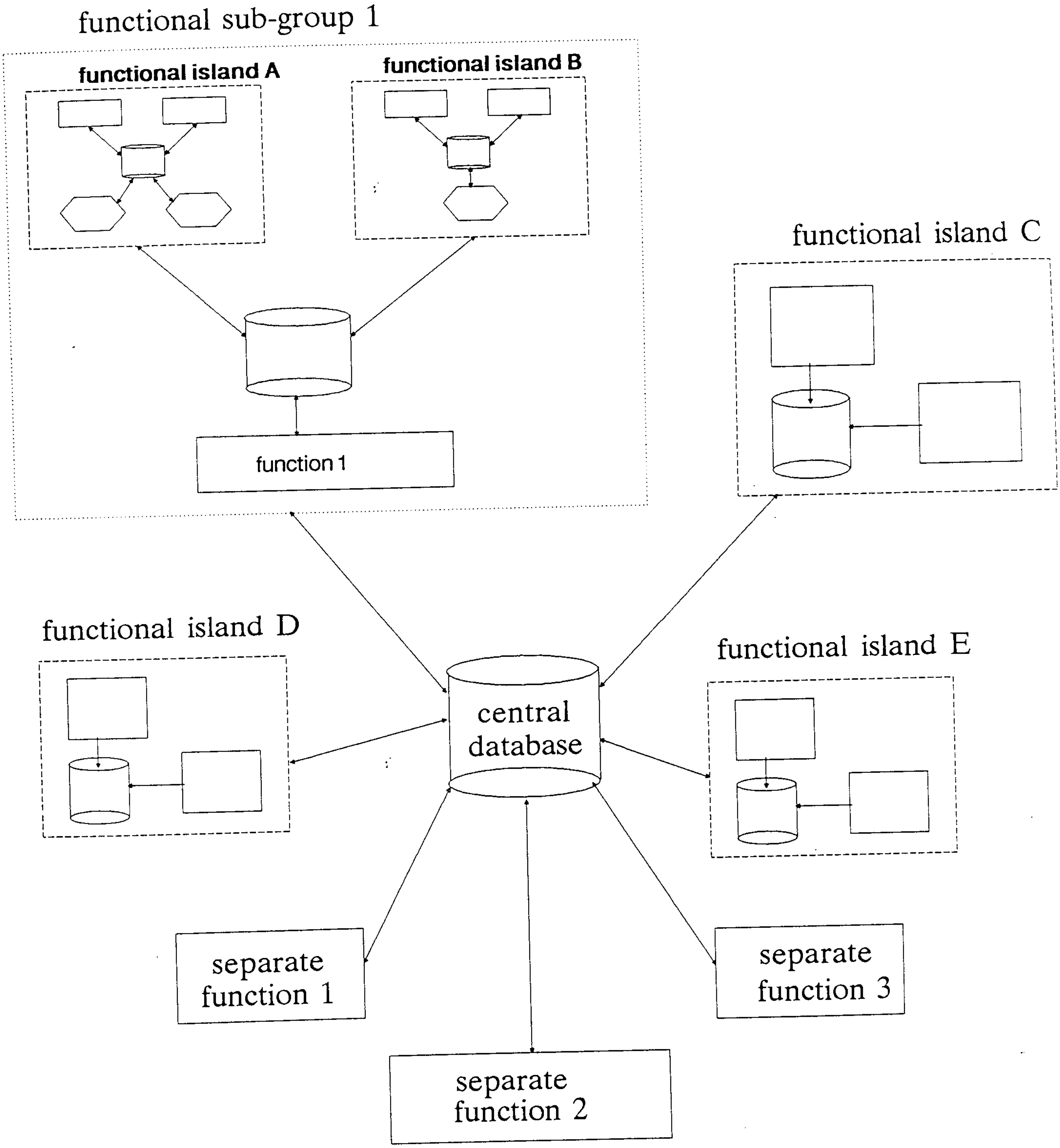


Figure 3.3 Layout of a total integrated system

3.2. GLOBAL SYSTEM APPROACH TWO - A CIM SYSTEM IS BUILT FROM FIRST PRINCIPLES

The second major type of global system approach which has been employed by companies for CIM system design is to develop an integrated system from first principles.

The main characteristic of this type of approach is that integration links between system elements are designed and embedded into the system elements themselves, which differs remarkedly from the first approach.

Figure 3.4 demonstrates the principle of this global system approach. The size of an integrated system using this approach may vary from company to company. From the literature search, a centralised database is again always commonplace for overall data storage and data communications [Canada 1986, Staley 1982, Timmer 1985].

Comparatively, this global approach is more suitable for a conceptually innovative system such as CIM, as data links between its elements are best designed at the initial stage. However, because this system approach requires a considerable amount of modification or even complete re-development of existing systems, it is therefore less attractive in comparison to other available system approaches.

To some extent, figure 3.4 looks similar to figure 3.3, as they are both based on a centralised database. The notable difference between them is the data links present in the two systems. In figure 3.4, direct data links for communication are available for system modules, rather than compulsorily through the central database as shown in the other figure. These direct hardware and data links allow efficient communications between system elements through the central database. Only the second global approach will support these direct data links which are developed during the initial system design.

On the other hand, both global system approaches face the same hardware interfacing problems. The use of different computers and peripherals from various vendors is still commonplace and causes complex interface problems. These problems should be solved when a recognised version of MAP and TOP is eventually available at affordable prices.

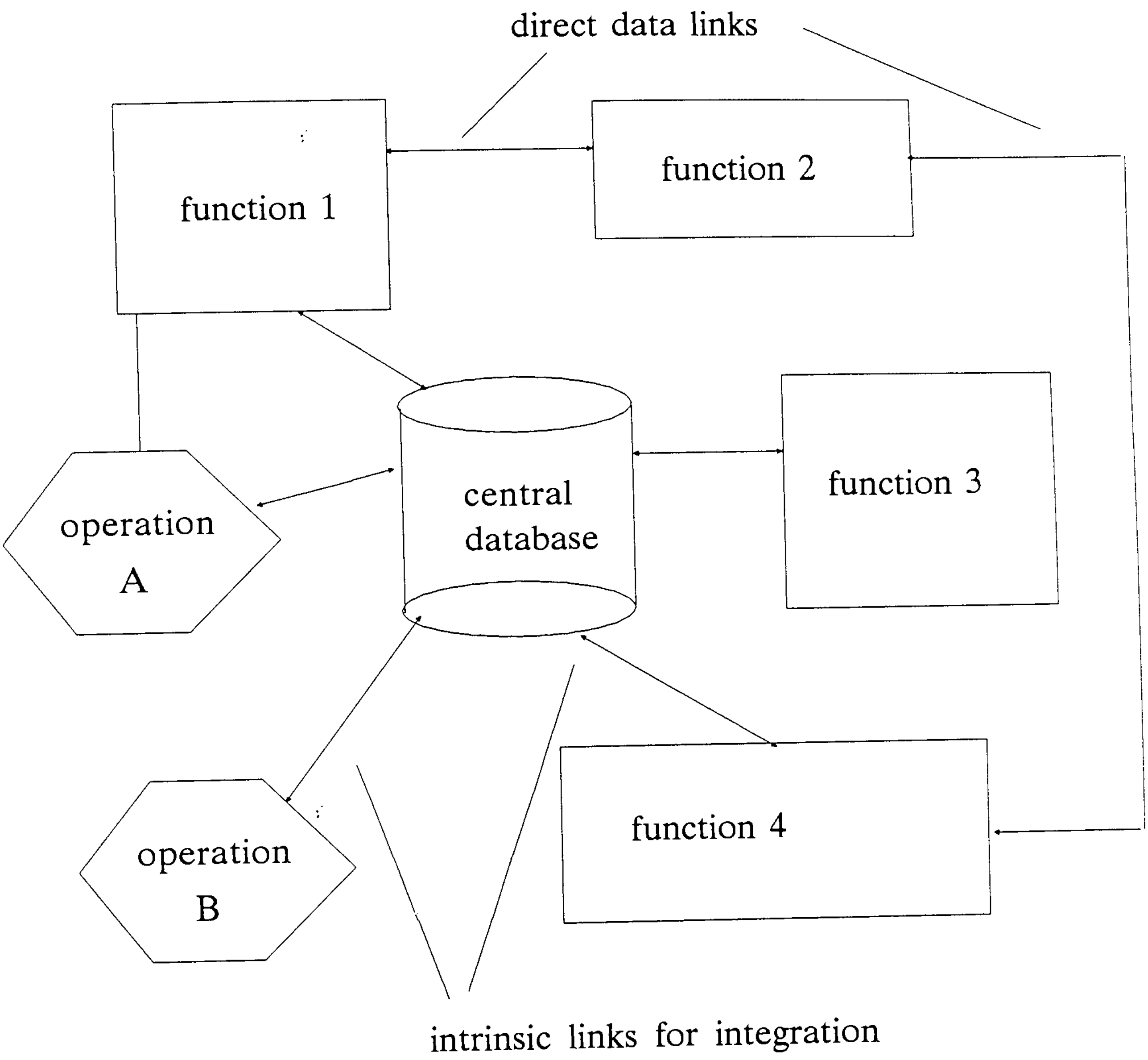


Figure 3.4 System approach 2 - a CIM system built from first principles

3.3 DISCUSSION

The first global system approach introduced in this chapter focuses on integrating existing 'islands of automation' or functions by using suitable hardware and software interfaces. The likely emergence of standard industrial hardware communication, MAP, has encouraged the public acceptance of the former system approach, as it was designed to link different makes of computing equipment and machinery. The size of integration under this system approach may range from single- function integration and multi-function integration to, eventually, the ultimate total integration. Regardless of the size of integration, the presence of a centralised database is a dominant feature.

On the other hand, the second global system approach requires integration links for a CIM system to be designed from first principles, which are best embedded into system elements when they are first developed. Consequently, essential integration features such as data sharing and data integrity become inherent characteristics. Although it is a different system approach from the first type, literature has suggested that the use of a centralised database is also common.

In short, both system approaches, though different in principle, agree that a central database should be used for data sharing and control. There are obvious reasons why the centralised database method has generally been used in most integrated system design. Often, it is believed that a centralised common database is the simplest method to provide important data processing functions which are required in a CIM system [Groover 1986]. These functions include storing common data for all system modules, updating dynamic files, monitoring data transactions, and finally reducing possible data duplication.

It is probably true to say that a centralised database can provide all these essential data processing facilities, which will be examined in greater detail in the next chapter. On the other hand, its use has laid serious restrictions on flexibility of an integrated system in terms of design, implementation and operation. In addition, there may be other database approaches other than the centralised database method which can be used more efficiently in an integration environment.

In the next chapter, examination will be made of such a centralised approach looking at its merits and drawbacks with respect to designing an integrated system.

CHAPTER 4 DISCUSSION OF THE IMPLICATIONS OF A CENTRALISED APPROACH TO CIM

In Chapter 3, various common system approaches used in many present CIM projects have been examined. The conclusions drawn at the end of the chapter clarifies that these system approaches can be clustered into two main global brackets. The first global approach is to build an integrated system by associating existing system elements, whilst the second global approach is to build the system from first principles. It has been suggested that the second approach should be used for CIM development in order to accomplish its benefits to the fullest extent. Nonetheless, the concept of using a centralised common database which will inevitably lead to the development of a centralised attitude towards total system design, is undoubtedly the foremost methodology employed to achieve data integration.

In this chapter, the implications of using a centralised methodology will be analysed in detail. Advantages and disadvantages of such a methodology will also be discussed. Finally, a conclusion that an alternative system approach should be investigated will be reached.

4.1 ADVANTAGES OF A CENTRALISED SYSTEM APPROACH

4.1.1 FEW MODIFICATIONS REQUIRED ON EXISTING SYSTEM MODULES

The essence of a centralised system approach is its use of a central common database through which all required data processing functions for an integrated system are provided. Relatively speaking, this is a very straight forward concept to use for integrated systems [Adachi 1985, Groover 1986]. Existing system elements do not therefore require drastic modifications in order to communicate with the common database, however, interfaces may possibly be required to act as data links.

4.1.2 SIMPLER INFORMATION FLOW

A central common database, theoretically, stores all required data for systems which are connected to it. The procedures of operation and maintenance of such a database is relatively simple [Huges 1985], as there is only one physical location in which all data transactions and updating are taking place. Software data links which are essential for communications between system modules and the database need not be very sophisticated. All involved modules recognise exactly where the information required is held.

In such a set up, all data retrieval and updating is done in the central system. The number of direct information links between modules, in this case, is very few.

If, for example, there is a new product needed by a customer, the Sales Processing module within the system module first checks from the central database if the product concerned is among existing products. If not, it will then issue a design request for that product with details provided by the customer. Again, such details are stored in the common database, which will then be accessed by the Product Design module in its subsequent operations. Because any data transaction virtually has to be done through the common database, it has been suggested [Hartland 1986] that the most suitable application environment is the one in which few direct data communications between system modules are required.

4.1.3 SIMPLER SYSTEM CONFIGURATION

An integrated system in which design is based on the centralised methodology will have a much simpler, though restricted, system configuration. Configuration of a system is defined as a process in which recognition and interrelationships are outlined for all involved hardware and software modules.

In the system, each module reads data from, and writes data back to, the common database in which all data is stored. Few data links are maintained directly between modules themselves. Location of all associated data files and the various types of communication facilities between system elements are rather inflexible. Configuration of such a system should therefore be relatively straight forward [Scharbach 1984].

In centralised integration, a major link exists between a functional module and the common database. The main function of such a data link is to convert data requests originated from a system module into a suitable data format before it reaches the common database. Consequently, a system module can be amalgamated into the main system with relative ease, provided its associated data is supported by the common database.

The implication of using a central database is that little flexibility in system configuration can be provided during implementation [Witte 1986]. All system modules are implemented in the way they were first designed, and tailoring of the system would normally require extraordinary effort and substantial modification.

4.1.4 HOMOGENEOUS DATA LINK, DATA FORMAT AND INFORMATION RETRIEVAL PROCEDURES

In a centralised system, all required information is stored in a common database. Most data retrieval is done through some data links using consistent procedures. Those data formats which are not readily compatible with the central database will undergo a format conversion routine so that they can be processed [White 1982]. The standardisation of data link, data format and data retrieval procedures should be applied to each of the involved system modules. Once this is done, communications can be maintained through the central database, and as a result, the actual work which would be required to in design these modules for the integrated system should be relatively simple.

4.1.5 FEWER USER MODIFICATIONS AFTER SYSTEM IMPLEMENTATION

As implied in previous sections, only limited flexibility is provided for by a centralised system during configuration. In general, the system only performs what it was designed for and, as such, little modification is required which leads to less confusion. As a consequence, the system would probably require only a few modifications by the user before it can be used, as the entire system is designed with a specific format in mind.

In case of future expansion or other system changes, there is little the user can do except to call upon the original system vendor. Indeed, many users favour this approach because often it avoids user involvement in terms of major system maintenance and system updates.

4.2 DISADVANTAGES

4.2.1 LACK OF SYSTEM FLEXIBILITY

The manufacturing environment is often very demanding in which, there may not be a variation only in product demands from time to time but where, the overall strategy of manufacture may have to alter. Certain company decisions and activities such as how customers orders should be converted into work orders; the control of requirement of various materials; monitoring of shop floor work orders; the recording and collection of costing factors; planning of the required capacity to satisfy the demands; deciding the priority of orders; organising the optimum route of information flow between system elements; and how altering the overall system response to vigorous changes in the market, are all dedicated to a greater extent by manufacturing strategy.

All these activities generally function fairly steadily in a stable business environment. Unfortunately, it is very difficult to maintain steady conditions in modern manufacturing due to swift changes in available technologies and acute competition. Typical manufacturing factors such as customer demand, product specifications, addition of new machineries and control techniques, shop floor capacity, total material requirements and order delivery status change almost everyday.

As the prime objective of CIM is to integrate all the above activities into a single effective operational environment, adequate tailoring flexibility therefore should be provided to permit users to modify or to re-configure the installed system with some degrees of freedom. This system flexibility is designed to absorb changes. The more vigorous the changes, the greater the need to allow the user to manipulate the system. Such a system must also be flexible so that different parts of the system can be tailored to satisfy needs of differing companies.

The difficulties of designing a universal integrated system have been mentioned in previous chapters, and hence an integrated system should therefore be designed with an open system architecture [Boaden 1986a, Weston 1986]. This allows future technological changes such as faster computers and equipment, more sophisticated network system, more versatile hand-held terminals or light-pen devices for shop-floor data collection, and bigger database storage systems to be deployed to enhance the existing system. In addition, new management techniques can also be introduced.

The same flexibility should also be applied to introducing new manufacturing control and management techniques that could be available in the future. These techniques include methods of material control, line balancing, production planning, work centres scheduling and budget control. The system should provide the flexibility required to implement these without disruption to the overall integration doctrine.

Using the centralised approach in designing a CIM system would almost certainly impose huge restrictions when introducing new system aspects. This is mainly because of the system highly rigid structure and primitive design. A centralised system is therefore easy to design but difficult to modify after it is installed and operated.

The use of a central common database heightens the restrictions of the system despite its simple appearance. The purpose of such a common database is to provide data from one single source to all system elements. A typical centralised CIM system will contain all information required for its system modules which have to be specified during initial system configuration. Any addition or replacement of new elements into the existing system is very difficult as the original common database design does not readily accommodate these new comers.

As mentioned earlier, a tremendous amount of work and expertise is almost certainly required if a common database is to be expanded or modified [Timm 1981]. More importantly, a centralised system approach will not usually allow an end user to implement any modifications but he or she is restricted to following the designed routines once the system has been installed. On the contrary, an ideal CIM system should provide an appropriate degree of flexibility for future expansion, modification, and even system re-configuration which will be required in a dynamic manufacturing environment.

4.2.2 LACK OF SYSTEM OPERATION EFFICIENCY

As very few direct information links exist between different parts of a centralised CIM system, the continuity of information flow is sometimes prolonged by the need for data to be fed via the central database. Consequently, the overall system operation efficiency may be degraded sometimes [Purcheck 1985].

An ideal system approach therefore should allow direct information links to be designed for those system elements requiring this facility which should be embedded into the system modules themselves so that they are transparent from the user's point of view. This allows a more efficient flow of information between vital system elements without the possibility of delay caused by the central database.

4.2.3 IMMENSE COST FOR REQUIRED HARDWARE AND DATABASE SYSTEM

Computer systems used in a centralised CIM system have to be very powerful in order to support crucial control of all concerned activities [Hodgson 1986, Milacic 1982]. Requirements of the amount of computer memory, processing speed, upgrade flexibility and associated massive data storage device are very substantial as a consequence. Costs of acquiring and maintaining all this computing equipment are formidable.

In addition to the requirements of powerful computing equipment, the cost of developing and supporting a centralised common database is an extravagant task because of its extensive coverage and the complexity of its internal structure [Pipes 1986]. System changes which may need to be implemented will also lead to very expensive and laborious modifications of the database system.

4.2.4 EXTENSIVE DEVELOPMENT TIME AND FINANCIAL COMMITMENT

An average estimation for installing a full MRP system successfully before it is functional can be as long as five to seven years [Fisher 1981, Anderson 1982]. Although this figure was quoted in the early 1980s, situations have not changed much since. It is only natural to assume that it would take even longer to develop and implement a CIM system. If unexpected problems such as personnel turnover, technical and system changes, user-environment changes and market changes are all to be taken into consideration during the development, then the time and financial commitments for such a complete centralised CIM system will be enormous. This is certainly not good news to smaller users or those whose applications are simpler.

As the major drawback of the centralised system approach is the lack of system flexibility, this will worsen the above commitments if changes are to be made after the system has been developed and implemented. An ideal system approach for CIM should provide security for time and cost spent against possible future system modifications.

It is more than likely that the development of a centralised CIM system must be dependent on external expertise because of its extensive coverage and technical complexity. The system will then be supplied as a turn-key system to the end user, and as mentioned earlier, a turn-key integrated system, although offering on one hand little user involvement will, on the other hand, cost enormously if the system is to be tailored in the future. In other words, once the company has started using such a system, it is dependent for maintenance and expansion on the original vendor.

4.2.5 CLUSTERED MANAGEMENT RESPONSIBILITY

Decisions such as material procurements, part inventory policy, capacity planning and production scheduling for the shop floor are made by central management. These responsibilities remain as part of the central management in a centralised integrated system. All such relevant decisions will have to be made centrally by vital system modules within the central management.

In fact, not only have shop floor decisions to be made, but other co-ordinated planning and control activities also have to be carried out within central management following integration. Generally speaking, central system modules can easily be overloaded and, certainly, the resulting planning and control will not be as efficient as one would expect in a true integrated system.

The centralised management approach has long received general criticism [Slautterback 1984, Burbidge 1983] as an efficient management technique. It is often referred to as inflexible, ineffective, and poorly associated with subsequent management levels below it such as those on the shop floor. An ideal approach for integration therefore should allow some central management responsibilities to be taken where most suitable - including the shop floor.

4.2.6 TECHNICAL PROBLEMS IN SYSTEM HARDWARE AND SOFTWARE

There are a number of potential problems associated with the development of a centralised CIM system. These problems can be grouped under several headings such as software, hardware, communications and database design.

4.2.6.1 SOFTWARE

In a centralised CIM system, all required information is maintained in a central database to which system software modules are attached. Each of these modules, though designed to execute a specific function, has to relate to all its data which is stored in the common database during processing. After processing has been completed, all this data will be relayed back to the database. Consequently, a degraded processing speed and poor software efficiency can easily occur [Barash 1980].

This problem is highlighted when the loads for other modules which operate concurrently are examined. For example, the MRP module has to handle all existing product requirements for every customer order at any one time; the Capacity Requirement Planning module has to calculate the capacity plan for all available work stations; and even machine loading analysis and work-to-list scheduling has to be done for all concerned machines concurrently.

Because of the amount of data which has to be processed , the design of software therefore becomes more complicated if a reasonable efficiency is desired. This results in longer software development and debugging time, a bigger program source code, slower processing response, as well as difficult software modification and maintenance. In general, software modules in a centralised CIM system are more sophisticated, larger in size, less flexible, and much harder to maintain and update.

4.2.6.2 HARDWARE

'Hardware' in this context includes all computing equipment and periherals, but excludes shop floor machinery such as CNC machines and robots. The problems associated with hardware generally arise from the required interfaces, data storage devices, communications equipment and the actual power performance of the computer.

Ideally, all computing hardware should be supplied by a single vendor. In practice, however, this is rarely the case because of the varying costs, specifications and performance of hardware offered by different suppliers. Unfortunately, different hardware manufacturers use incompatible protocols for hardware communications and this has created many problems. Computing equipment from different vendors can only be integrated through the use of an added-in hardware interfaces [Pye 1986].

Data storage devices are generally a magnetic winchester disk. The capacity of the disk is dependent on its physical size, its density the magnetic material, and most importantly the sophistication and precision of its disk drive controller. In a centralised CIM system, the common database is enormous and can, therefore, only be supported by very fast and large hard disks which are very expensive.

In a centralised system, dumb terminals (VDUs) are connected to the host computer which is generally a mainframe computer and a common database is attached through suitable cables. This is the simplest method available to download a required program and its associated data within a multi-user environment. However, these VDUs do not normally have their own data storage device nor their own processing power - they are merely working as if they were windows to the central computer and database.

Although this method of linking many terminals to one single central computer offers several users access to a very powerful computer, if there are too many tasks running simultaneously, it causes the performance of the central computer and its data disk drives to be degraded substantially [Barash 1980].

Because of the general lack of system flexibility in a centralised system, the total requirement of computing power and data storage capacity has to be planned very carefully during the design stage. Once the complete system is installed and running, it is extremely difficult then to make any significant changes.

4.2.6.3 COMMUNICATIONS BETWEEN FUNCTIONS

As mentioned in the previous section, VDUs are connected to a central mainframe computer for interactive processing - this being the simplest way to permit multi-user facilities. However, this method is regarded by some as a rather inefficient way of operating a computerised system [Banarjee 1986]. There are several reasons behind this argument.

In a centralised environment, it is very likely that often more than one terminal is used to access data or a software module at any one time, inevitably causes interference. The degree of interference will depend on the system used, its original system design and probably also its characteristics of file handling including file locking and record locking which are considered to be the crucial functions.

The number of terminals that are logged onto the system can slow down the processing speed quite drastically and give unsteady and unpredictable system performance [Cheung 1987].

A lot of data in a typical manufacturing environment is actually only used for specific functions. Ideally, this data should be grouped and dedicated only to those functions. Indeed it can be localised and kept in a separate database dedicated to that function, or even processed locally by its own computer. Unfortunately, normal dumb terminals do not support either local processing or a local database. All information must be retrieved from the common database and processed in the central computer, this has greatly reduced the efficiency of the system.

As the cost of stand-alone microcomputers has dropped dramatically in recent years, whilst their power has increased, it is worth using them instead of normal terminals. These machines have their own processors and separate data storage hard disks. Hence, dedicated data groups and even software programs can be downloaded into these machines and processed locally.

4.2.6.4 DATABASE DESIGN

The main objective of having a common database is that all data can be stored there for subsequent use. Types of data stored include dynamic, static, shared or unique data. As mentioned in the previous section, often data in the common database is only for a specific function. Consequently, a competent, sophisticated and well designed database management system has to be used to maintain overall performance of information retrieval.

Because specifications of required hardware and structure of database must be defined during the initial system configuration, a central common database is usually inflexible [Hewitt 1982]. Ideally, a database should provide some flexibility for future changes. The design of such a central common database system with flexibility, however, is technically extremely difficult and costly.

Other factors which may make the design and maintenance of a huge common database difficult are described as follows :

(1) processing and maintenance of different types of data, which are for specific use is inefficient if it is stored in a single location;

(2) the design and implementation of a huge common database is very costly, error sensitive and time consuming;

(3) data integrity and security can be a serious problem because of the size of the database;

(4) it takes considerable time to analyse, summarise, and convert existing data to the acceptable format required by the central database;

(5) the size of the database makes possible modification, expansion and maintenance extremely difficult, and this probably can only be done by the people who originally designed and implemented it.

4.3 CONCLUSIONS

There are certain advantages to be gained when using a centralised approach and a common database in a CIM system. On the other hand, potential problems and difficulties as mentioned above do seem to overwhelmingly outweigh the available advantages. The net result is not satisfactory after comparing all its advantages and disadvantages, especially if the system is designed with smaller companies in mind.

The biggest restriction is the lack of system flexibility which is an essential aspect for smaller systems. The inflexible centralised and 'all-embracing' methodology makes the justification of using such an approach unsuitable for smaller companies. As a consequence, only larger companies can afford to consider implementing a centralised CIM approach.

Whilst discussing the advantages and drawbacks of the centralised system approach, several features emerged that should exist in an ideal alternative approach. In general, this system approach should simplify the design of an integrated system and provide greater flexibility in terms of user requirements and operation efficiency. Therefore, the use of such an alternative approach should reduce or eliminate those problems caused by the centralised approach. In the next chapter, suggestions will be made for a better system approach towards a smaller CIM system design.

CHAPTER 5 AN ALTERNATIVE SYSTEM APPROACH - CELLULAR CONCEPT IN CIM SYSTEM DESIGN

In the last chapter, the advantages and disadvantages of the favourite centralised system approach were discussed. Although this system approach is used in a large number of CIM projects, there have been major drawbacks with such an approach, and this renders it highly unsuitable for smaller integrated systems development within some companies.

The conclusion drawn at the end of last chapter indicates that the centralised system approach requires the use of a central and common database, and influences the overall strategy for the management and planning of various production activities. The biggest drawback of this approach is its lack of system flexibility. In general, a centralised system provides few alternatives for individual tailoring, system configuration, future modifications as well as end user involvement.

In order to bring CIM or similar integration technology into smaller companies, an alternative system approach which would provide more system and user flexibility must be considered. In this chapter, a relatively new design concept for CIM system is introduced. It is known as the cellular approach for CIM system. The aim of this chapter is therefore to explore the characteristics and merits of using such an approach for CIM system design, and to explain why it will be more appropriate for use in smaller systems. Finally, the improved system flexibilities and the capability of being modified by the user which are two of the critical advantages offered by a cellular based integration system are also discussed.

5.1 GENERAL BACKGROUND OF CELLULAR MANUFACTURING

5.1.1 GROUP TECHNOLOGY

The term 'cellular manufacturing' was derived from the application of Group Technology (GT) to the design of a manufacturing system. GT is a manufacturing philosophy in which similar parts are identified and grouped together to take advantage of their similarities in manufacturing and design [Groover 1984]. These parts are arranged into part families, and each family will possess similar design and process characteristics. Hence, the manufacturing requirements for each member of a given part family is similar, resulting in better planning and control of those parts. In general, the overall manufacturing efficiency is also greatly improved. This efficiency is achieved in the form of reduced set-up times, lower parts and work-in-progress inventories, better scheduling, improved tooling control, as well as standardisation of parts, subassemblies and manufacturing processes.

In order to extend the application of GT further, GT production cells are established. Each GT cell is responsible for the production of one or several product families. Usually, a GT cell would possess sufficient production resources to carry out all the required operations for producing products allocated to that particular cell.

5.1.2 FLEXIBLE MANUFACTURING SYSTEMS AND FLEXIBLE MANUFACTURING CELLS

In recent years, Flexible Manufacturing System (FMS) represents a technically more sophisticated implementation of the cellular principle [Love and Lung, 1986]. These systems are characterised by their ability to completely manufacture a 'family' of components, assemblies, or finished products. Another example is Flexible Manufacturing Cell (FMC) which is the smaller version of FMS. It characteristically resembles the FMS but is technically simpler and physically smaller. In fact, an FMS may consist of one or more FMCs in its location. FMS and FMC are two typical representations of the application of GT and have been proved to be very successful in automated manufacturing [Hartley 1986] [Gregory 1983].

These FMS, FMC and other production cells can be collectively regarded as manufacturing cells. Each of which, in general, should enclose all the machining facilities required to complete the production of some allocated product groups.

5.1.3 BENEFITS OF CELLULAR MANUFACTURING

Some major benefits, such as the improved throughput time and reduced work-in-progress, have been reported by Black [1983] as a result of applying cellular concepts. The main reason that these benefits are achieved with the cellular approach is because it simplifies the complex nature of manufacturing control. Hence, problems areas can be identified readily and adequate solutions can be recommended to rectify these problems.

In general, the adoption of cellular principle in CIM system design should also provide the same benefits as in cellular manufacturing. In addition, it will also lead to the decentralisation of some major control functions which are carried out solely by some central system modules.

Traditionally, the cellular view has been restricted to ordinary machining processes and some basic shop floor activities only. In order to extend the principle of cellular view even further, it must be applied more broadly to other management functions as well. Here, a cell is defined more generally as an independent or semi-independent unit which has retained its own local facilities, systems, control and data required to perform its allocated tasks. It may receive or transmit information from or to other cells in the same system [Love and Lung, 1986]. Figure 5.1 illustrates the characteristics of a cell defined in this context.

In order to design a CIM system using the cellular approach, it is necessary to analyse all the elements and their associated information path within the system. As a consequence, a full picture of the entire system can be re-established incorporating the new cellular methodology.

5.2 APPLICATION OF CELLULAR CONCEPT TO CIM SYSTEM DESIGN

5.2.1 TYPICAL ELEMENTS IN A CIM SYSTEM

As discussed in Chapter 2, some definitions of CIM aim to cover almost every single activity within a company. Indeed, one can literally argue that CIM should include everything that is related to manufacturing. Nonetheless, there are some functions which are relatively more important than the others. These functions include Sales Order Processing (SOP), order acknowledgement, invoicing, Master Production Scheduling (MPS), Material Requirements Planning (MRP), Capacity Requirement Planning (CRP), CAD techniques (3-D solid modelling, Finite Element Analysis and Computer Aided Drafting), FMS, FMC, Robotics, NC, CNC, Computer Aided Manufacturing (CAM), Quality Control (QC), Work-In-Progress (WIP) Monitoring, inventory control, purchasing, job costing, forecasting, ledgering, budgeting and financial reports.

As described in Chapter 1, all these system elements are often regarded as 'islands of automation', especially if they traditionally operate in an isolated mode. Some of these

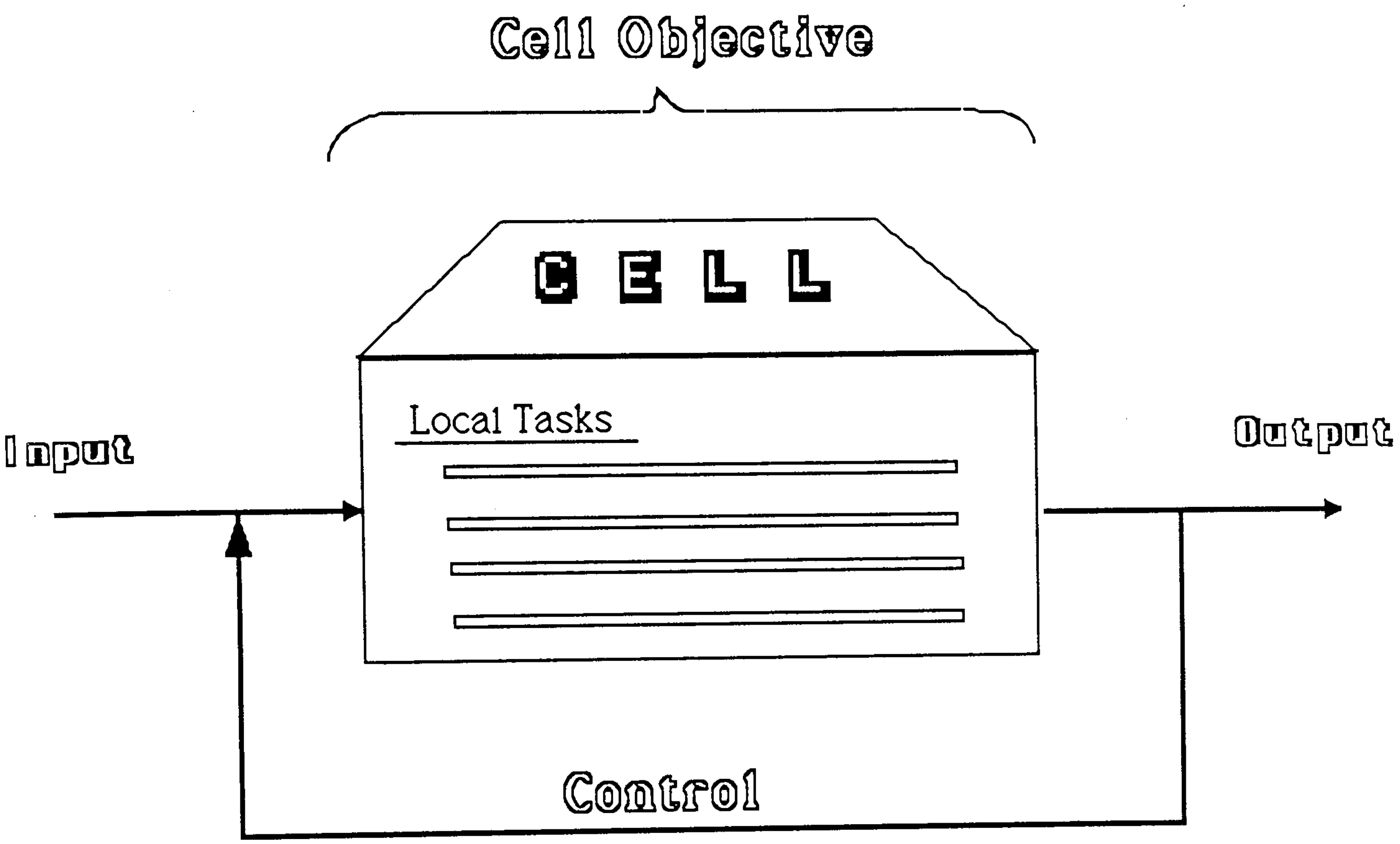


Figure 5.1 Characteristics of a cell

system elements, however, can be logically grouped to form some major functional areas.

5.2.2 MAIN FUNCTIONAL AREAS

According to the characteristics of each system element, five major functional areas or groups can be formed, namely :

(1) Customer Service;
(2) Design Engineering;
(3) Planning;
(4) Manufacturing & Control;
(5) Finance and Administration;

'Customer Service' contains all activities which are undertaken to satisfy various customer requirements. These requirements include order processing, customer enquiry, quotation, order entry and control, order verification, delivery date estimation, general product search as well as final product shipments.

'Design Engineering' includes all the facilities which are required to complete the design of a new product, or the modification of an existing product. Typical facilities may contain Computer Aided Design (3-D modelling, finite element analysis) and Drafting, Computer-Aided Process Planning (CAPP), Bill of Material (BOM) generator and N.C. data generator.

'Planning' encompasses all the planning activities which are needed to produce a final production schedule. MPS, MRP, CRP, rough cut planning, purchasing, inventory control, material inspection and 'what-if' simulation are all typical elements in this group.

'Manufacturing and Control' consists of machine scheduling, Work- In-Progress (WIP) monitoring, Quality Control (Q.C.), job costing, and the actual fabrication processes such as milling, turning, CNC, NC and even DNC.

'Finance and Administration' is self explanatory. Typical elements include sales ledgering, purchase ledgering, nominal ledgering, payroll, budgeting, general cost control, forecasting, invoicing and financial reports analysis.

The formation of these major functional groups in a typical manufacturing firm was supported by Smolik [1983] and Corke [1977]. Figure 5.2 and Figure 5.3, which are extracted from their publications, illustrate clearly their view of a manufacturing system. Although neither of the diagrams has labelled the actual divisions of the five functional groups, all the essential system elements, however, are present in both system layouts. In general, any typical manufacturing system can indeed be represented by these five functional groups.

5.2.3 CELLULAR VIEW TO THESE FIVE MAJOR FUNCTIONAL AREAS

In a centralised CIM system, all these five functional groups can be considered to be linked through a common database and a host mainframe computer. Figure 5.4 illustrates such a view in a simplified fashion.

The main disadvantages of the centralised approach were already discussed in the last two chapters. In general, the lack of system flexibility is found to be the biggest problem with respect to such an approach. As the degree of flexibility provided in an integrated system is the most crucial factor in smaller systems development, the centralised approach is therefore not particularly suitable for small companies.

As defined earlier, any system unit that processes its input information and transfer its output information to another unit for further action is regarded as a cell. The five major functional groups in a typical CIM set up can be viewed as five semi-independent cells, namely the Customer Cell, Design Cell, Planning Cell, Manufacture and Control Cell, as well as the Finance and Administration Cell. Figure 5.5 illustrates the key information flow between the five functional cells.

On the contrary, Figure 5.6 demonstrate a simple configuration of a cellular CIM system. Apart from a localised database which is now attached to each major functional cell, the layout of this cellular system looks very similar to the centralised system shown in Figure 5.4. In Figure 5.6, each functional cell may have its own computer and database, which is then subsequently linked through the use of a local-area-network (LAN) system.

Figure 5.2 A comprehensive factory data system (Smolik 83)

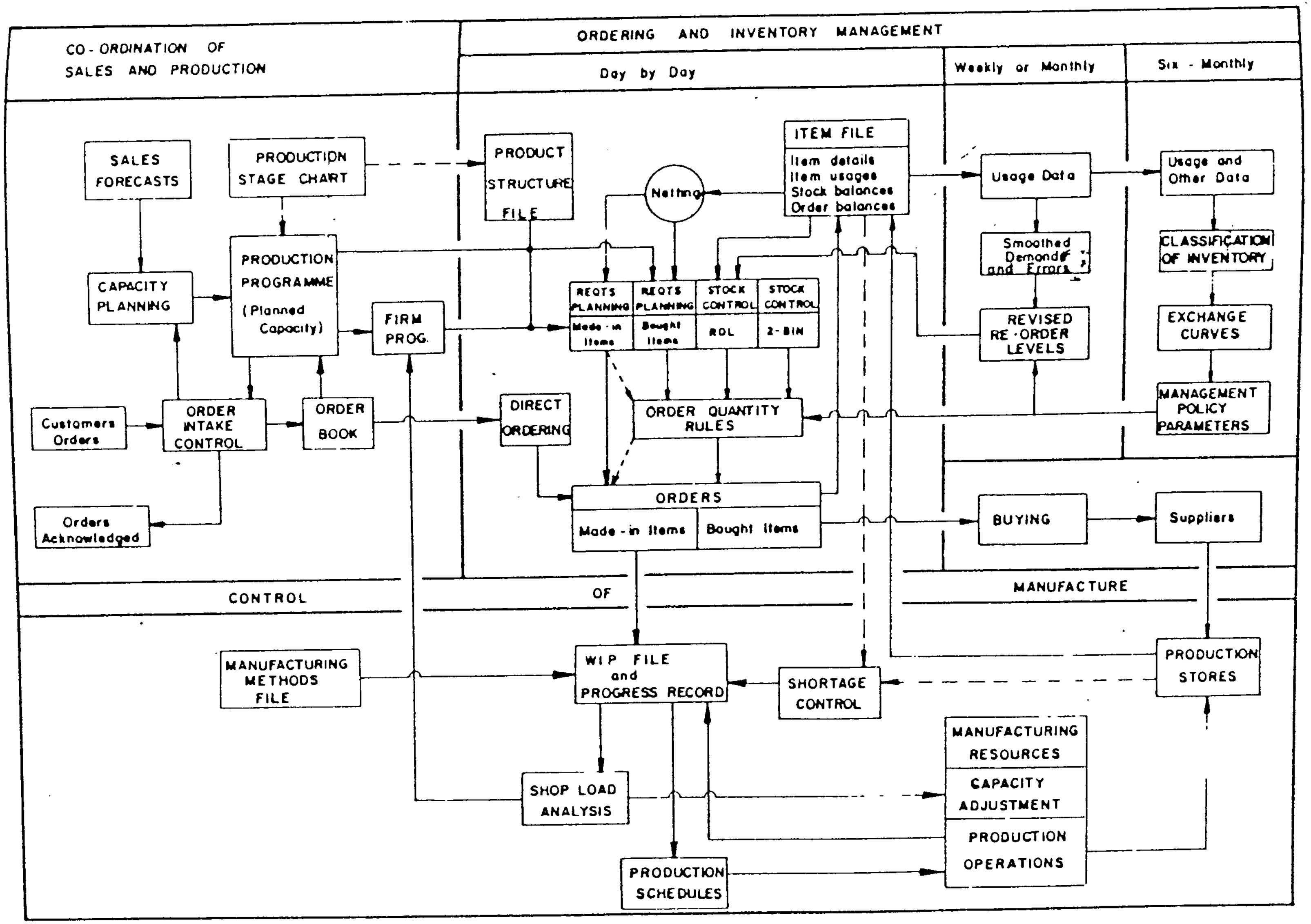


Figure 5.3 Production Control flow chart (Corke 77)

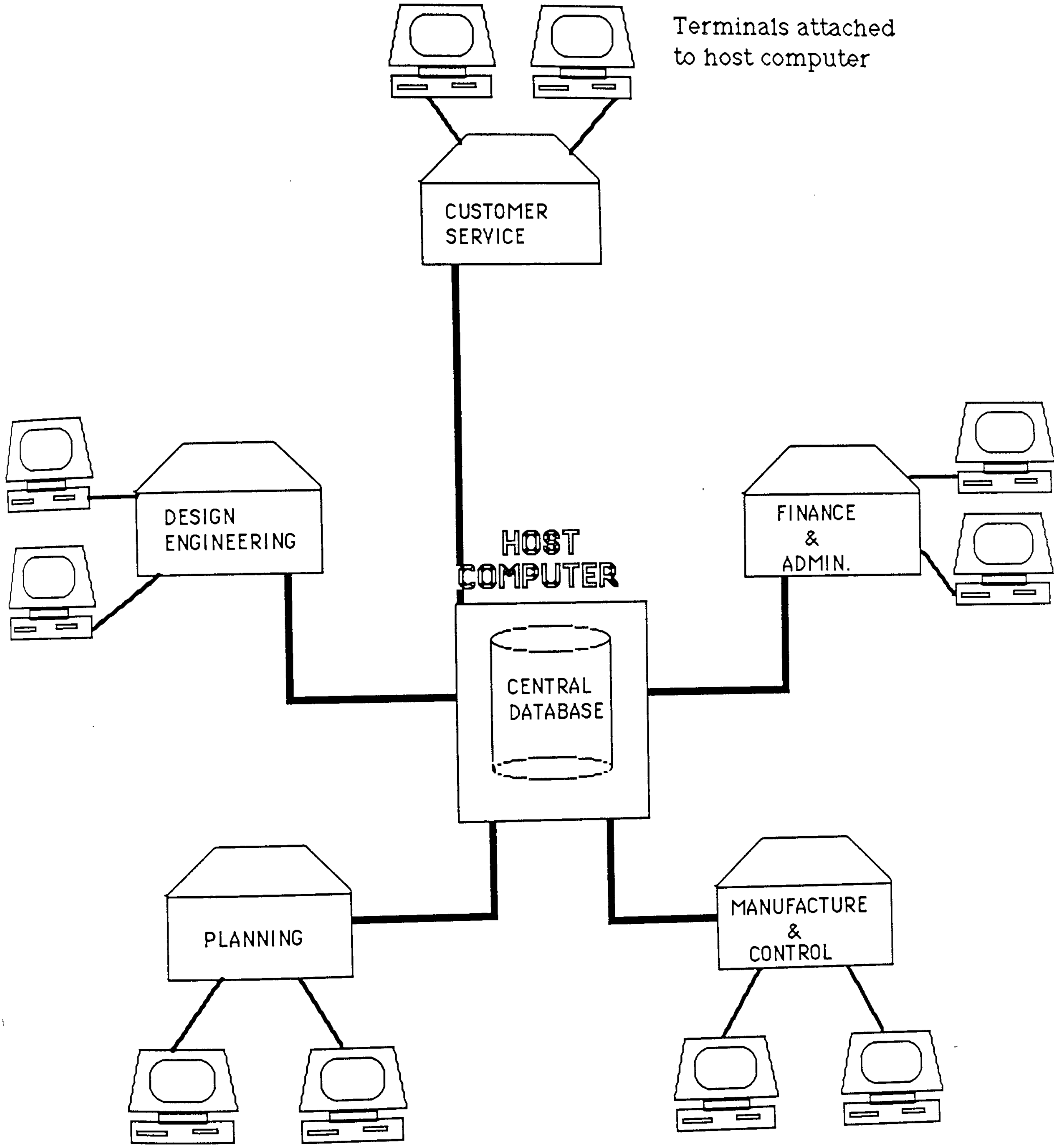


Figure 5.4 Use of a central host computer and a common database in a centralised CIM system

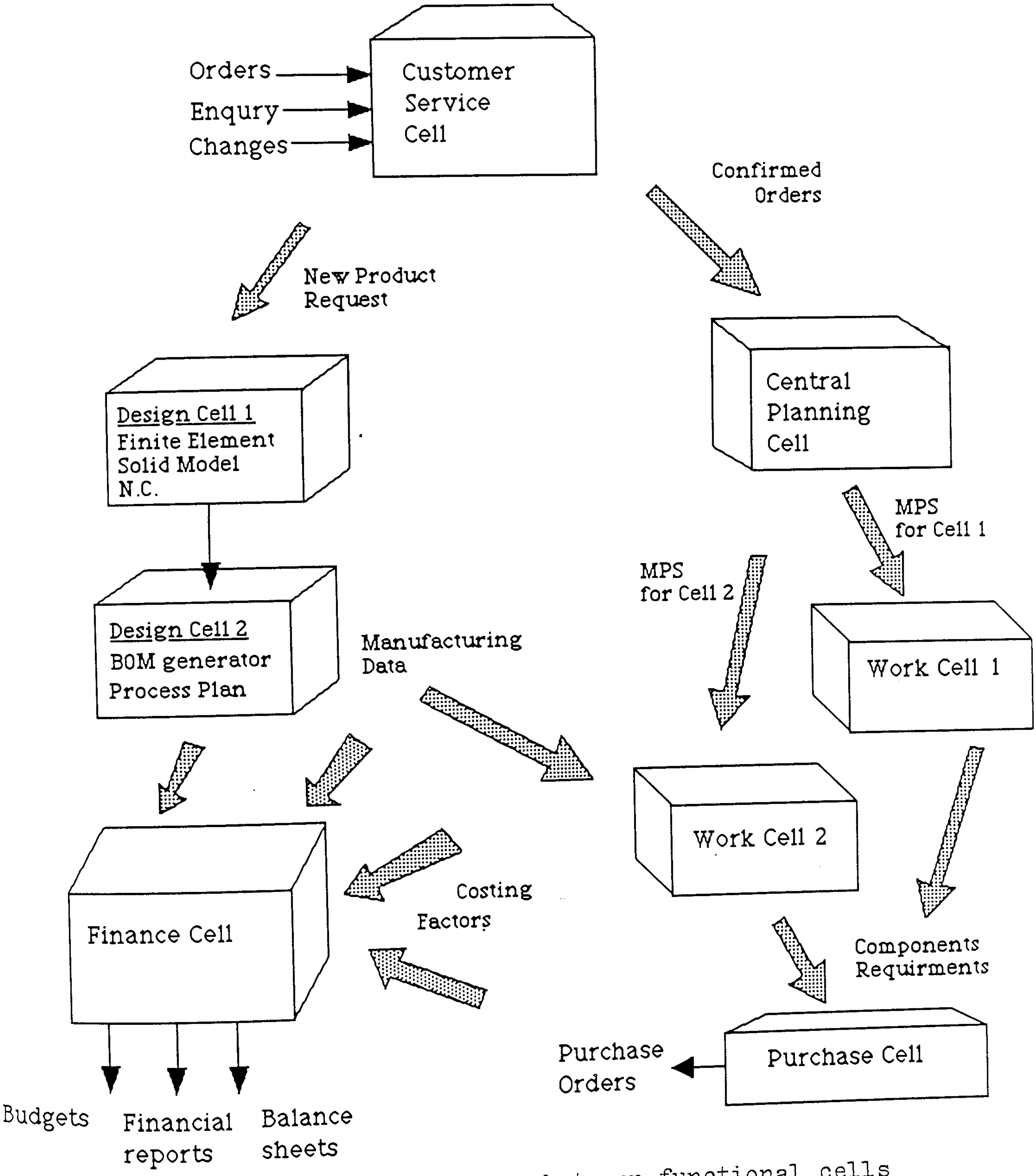


Figure 5.5 Information flow between functional cells

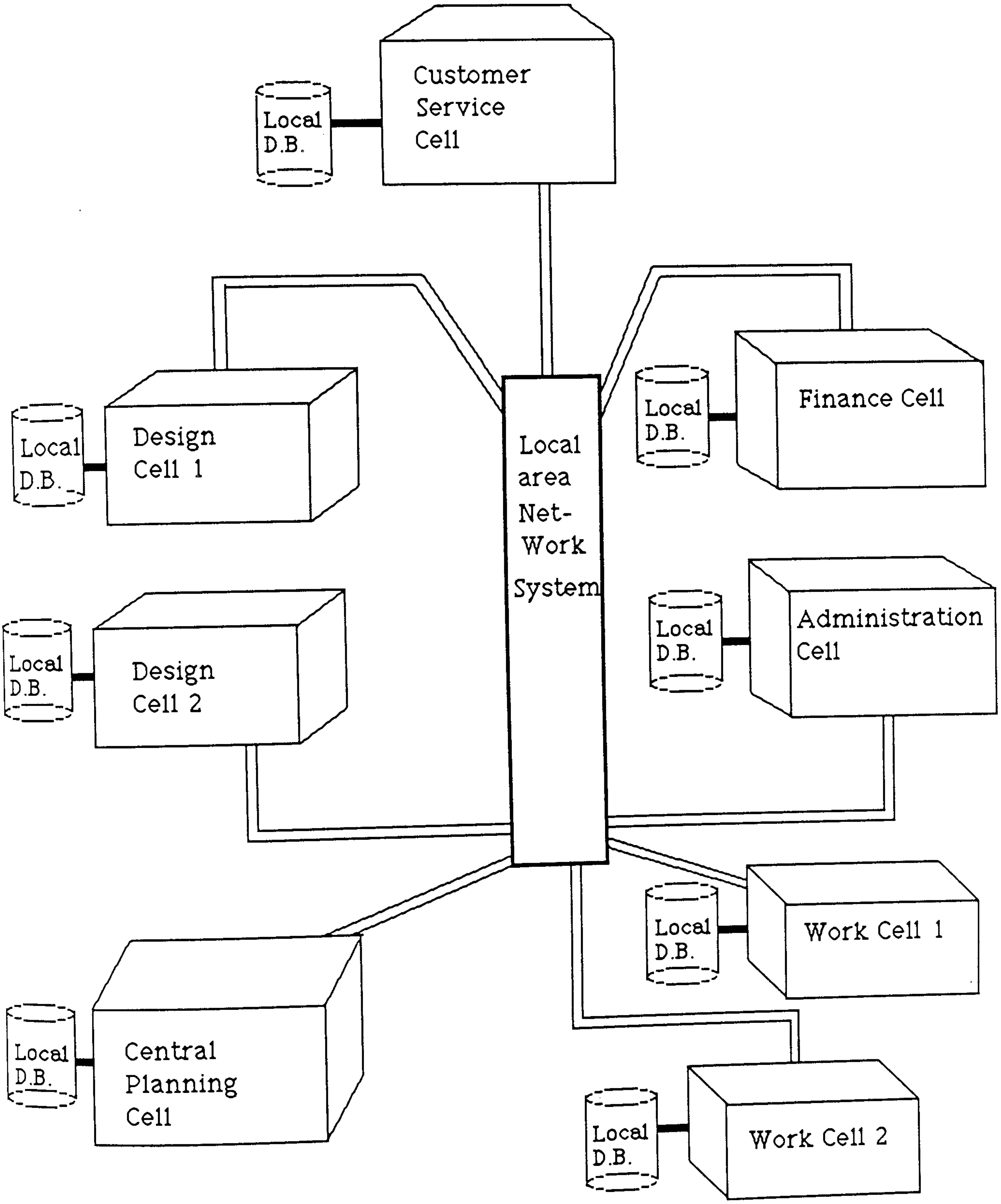


Figure 5.6 A simple view of cellular CIM system configuration

5.3 DISCUSSION ON POTENTIAL BENEFITS OF USING CELLULAR SYSTEM APPROACH

In contrast to the centralised approach, the use of cellular concept in CIM system design and implementation can avoid or eliminate some of the difficulties previously encountered.

In general, problems such as the lack of system flexibility, the oversized common database, the prolonged development time, the requirement of very powerful computer hardware and software systems, and a huge financial commitment, are commonplace with the centralised system approach [Timm 1981] [Wemmerlov 1987].

5.3.1 INCREASED SYSTEM FLEXIBILITY FOR MODIFICATIONS

The concept that a CIM system can be constructed by combining a number of semi-independent cells will increase the overall system flexibility. The resulting system therefore can be configured in any specific way to suit particular applications.

For example, the system shown in Figure 5.7 consists of some functional modules which are appropriate for a 'Job Type' production environment. In 'Job Type' manufacturing, the volume of production is generally small and the customer order is seldom repeated. Fewer planning and control modules therefore are required in such an environment.

On the other hand, Figure 5.8 represents a cellular system layout for a 'Batch Type' production environment. This time, the modules contained in the system are notably different from those in a 'Job Type' production environment. This is mainly because their needs are incongruous. The figure illustrates customer orders, and forecast demands are entered as major inputs into the system. There are generally more planning and control modules in a 'Batch' production environment as 'Mixed Products' production is commonplace.

By comparing the two differing situations, one can realise that a MPS cell is unsuitable in a 'Job' production environment as there is no requirement for forecasting or a long term sales order book. Instead, a Critical Path Analysis (CPA) module or a Project Management module would probably be more valuable. On the other hand, both the MPS cell and MRP cell are absolutely essential in a 'Batch' production situation, as there is a greater variety of parts, and the scheduling of materials and machine capacities is always more complicated.

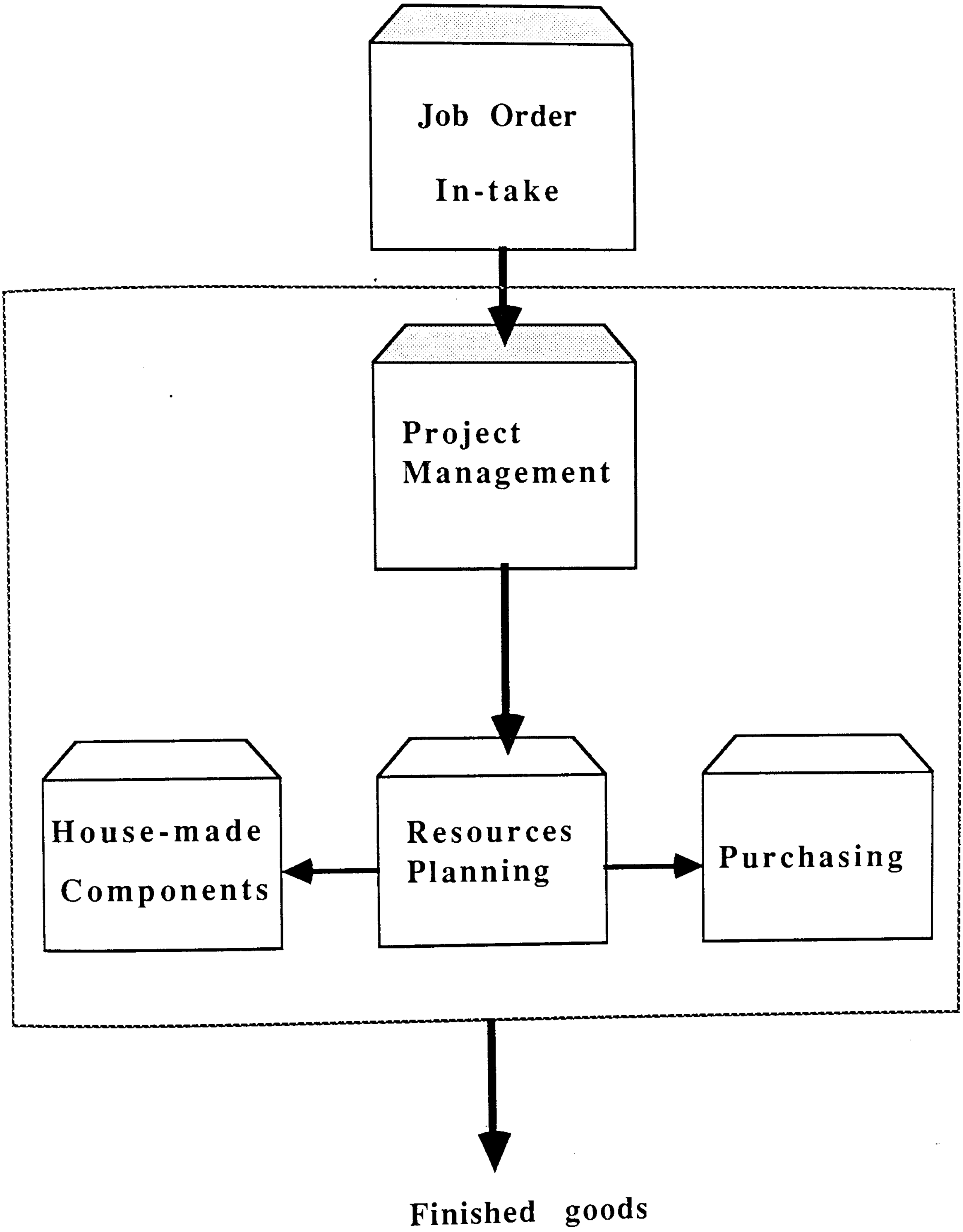


Figure 5.7 Cell modules in a 'Job Type' production system

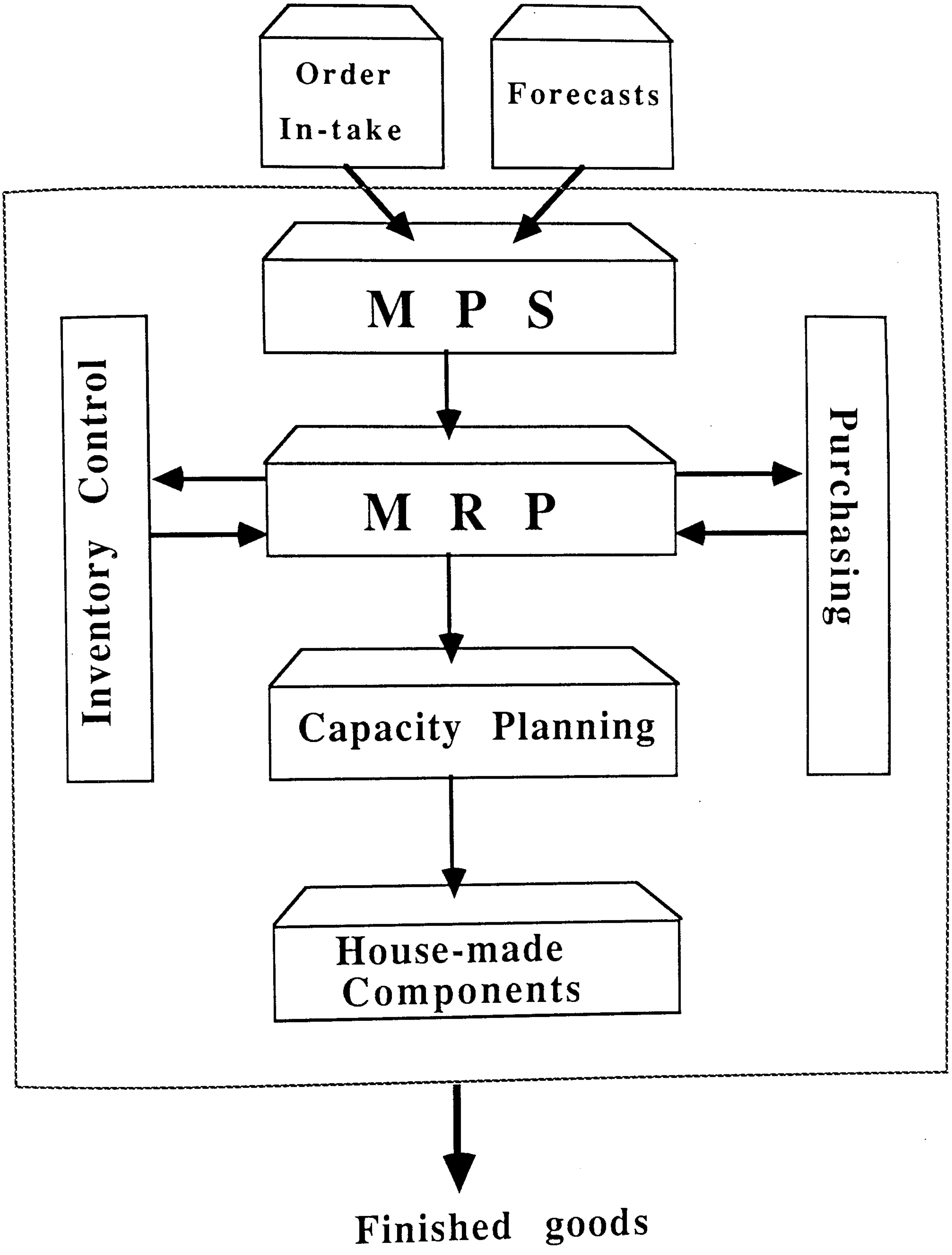


Figure 5.8 Cell modules in a 'Batch Type' production system

Assuming all the system modules are compatible to the system because of the cellular design, the two figures do show how relatively easy it can be to modify the system configuration in order to meet various requirements. A larger manufacturing company can therefore use both system layouts to address different internal production requirements.

A CIM system designed using the cellular approach would therefore offer a good degree of system flexibility throughout, and this is essential in a dynamic manufacturing environment. The cellular approach will permit the whole system, or part of it, to be tailored to meet differing requirements and specifications so occur in a particular application environment.

Figure 5.9 illustrates how a flexible cellular system can be formed by combining suitable inputs and outputs of different system cells. This concept will permit the system to be modified easily in order to adopt new technical and managerial innovations.

Figure 5.10 also illustrates how a new functional module, which is called Cell-2A, can be introduced into the existing system without upsetting the rest of the system and its original information flow.

5.3.2 SIMPLIFIED STRUCTURES OF INDIVIDUAL CELLS

The cellular approach permits the huge and complicated CIM system philosophy to be considered as a simpler system consisting of a number of small semi-independent cells. The resulting system, in theory, is much easier to implement and control. Thus, the understanding of an integrated system will be much improved, and the personnel involved in designing, installing, maintaining and operating such a system can interact more easily with its component parts.

In a cellular CIM system, each cell can be analysed separately - focusing on its specific objectives, functions and data. This not only divides the total design effort into smaller, more manageable groups, but also permits all required training to be simpler and more accurately addressed. In addition, each cell can be documented separately so that software and data maintenance can be carried out without ambiguity.

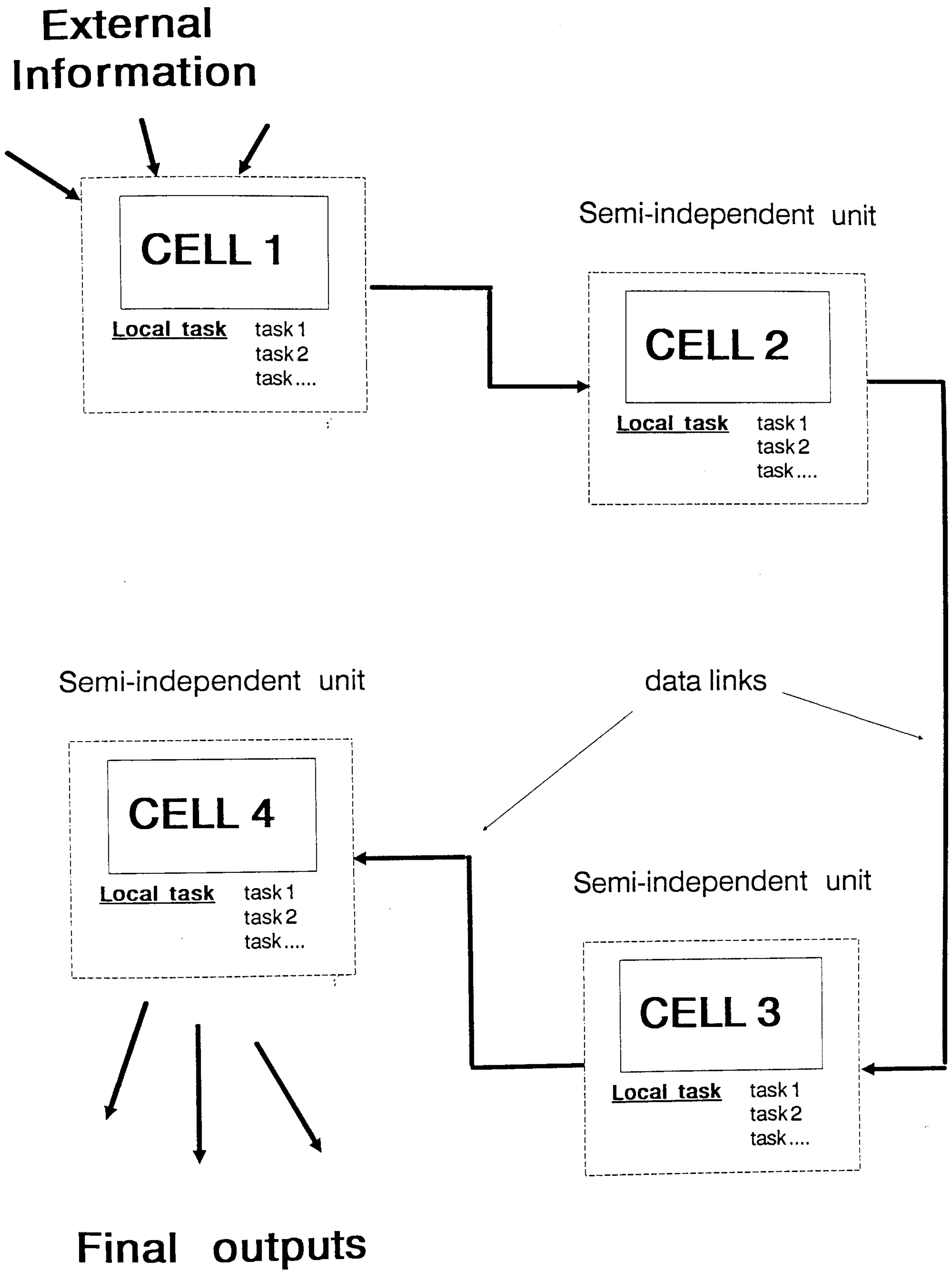


Figure 5.9 The formation of a flexible cellular integrated system

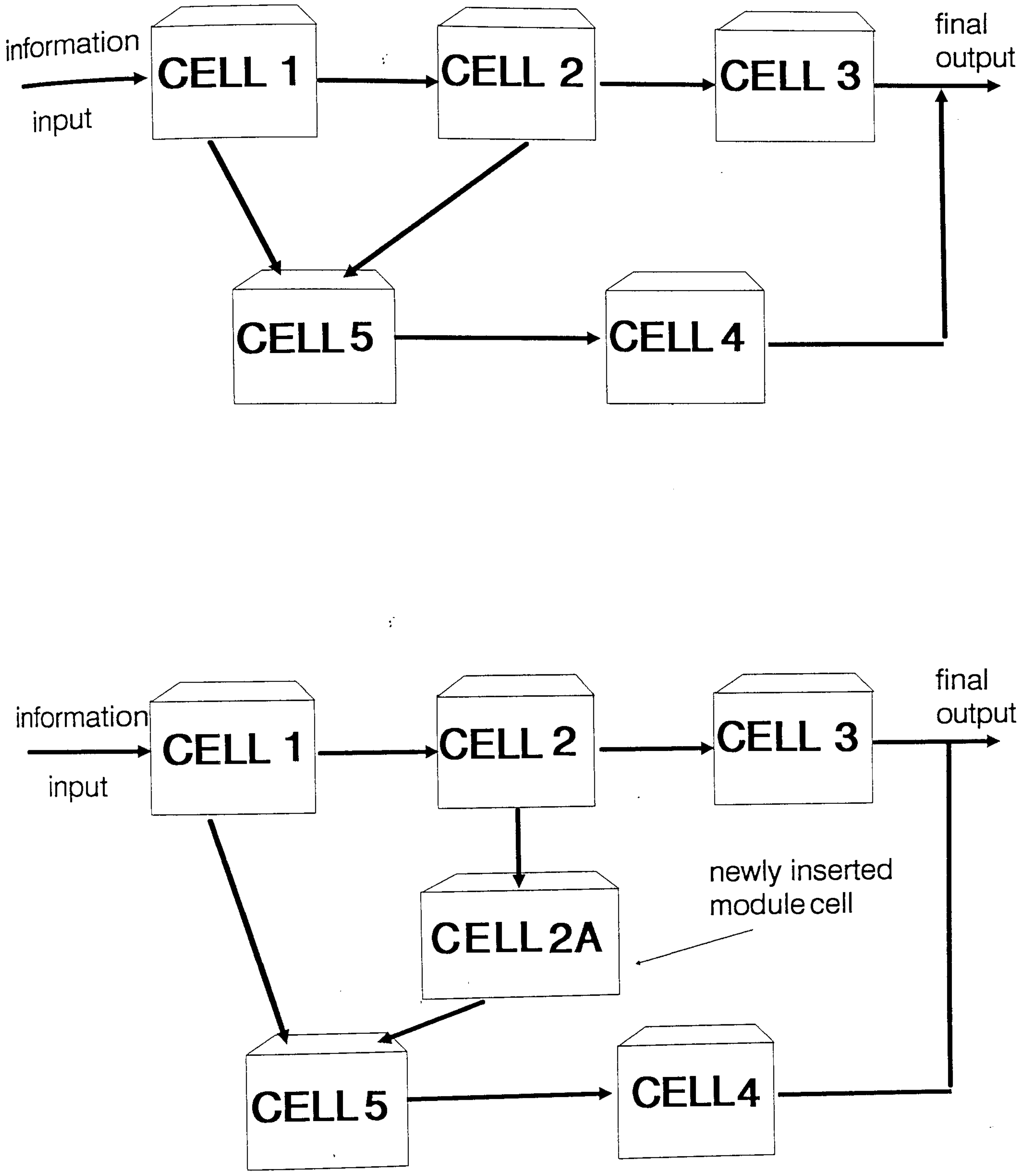


Figure 5.10 Demonstration of the flexibility of a cellular integrated system

In general, the following benefits are likely to be achieved as a consequence of the simplicity of the cellular approach :

(1) shorter time for software development and overall system design;

(2) easier system configuration or re-configuration;

(3) appropriate training can be systematically organised;

(4) system and data maintenance is simpler;

(5) more internal staff can be involved with the development of the system.

5.3.3 IMPROVED TIME COMMITMENT IN SYSTEM DEVELOPMENT

With the adoption of the cellular principle, most of the necessary steps in the overall system development, including system design, software development, database preparation and final system installation can be carried out more efficiently in smaller more manageable sections. Consequently, the total development time required would be comparatively shorter and as a result, the total cost so incurred should be reduced.

Time and cost are the two most important factors in any system development and once they have been accommodated a certain degree of assurance, smaller companies could be encouraged to participate in CIM with greater confidence. Thus, the feasible reduction in both development time and cost achieved by adopting the cellular view would undoubtedly appeal to smaller manufacturing firms.

5.3.4 HARDWARE AND SOFTWARE REQUIREMENTS

As described in earlier sections, two of the merits of using the cellular system approach would be the improved simplicity in CIM integration principle and the unambiguous definition of each individual functional cell. This will lead to a clearer specification with respect to hardware and software required in a cellular CIM system.

With the adoption of the cellular system approach, more specific objectives, functions, data and interrelationships can be established for each software module in the system -

thus ensuring reduced development time and cost. In addition, the reduction in the reduced amount of data handling permits software complexity to be reduced.

With the centralised approach, the structure of a common database is usually very complicated. The use of smaller and local databases to support either a single cell or a group of specific cells, with the aid of LAN, on the other hand, will drastically reduce the size of necessary data storage devices as well as the level of sophistication of the individual database structures. The speed of accessing a particular piece of data in a local database would also be significantly improved.

Figure 5.11 illustrates the use of smaller computers and local databases to serve one or a group of functional cells. Communication between these cells is maintained via a LAN system. In the diagram, a microcomputer is used in the MPS cell, whilst a mini-computer is used for all functional cells concerned with parts and materials planning which include MRP, inventory control, and purchasing. The micro and the mini-computer, as well as the laser printer, are all connected to a LAN system. Data from the MPS cell can be archived, through the LAN system, by the MRP cell. Calculated results are then transferred to its local database for subsequent use in the capacity planning and shop scheduling modules. Some resulted data is also transferred to, and maintained in, the local database in the Purchasing Cell.

The figure illustrates only one particular configuration, out of the possible many, and it shows that different sizes and makes of computers can be connected through the LAN system for data integration.

Although each system cell is a semi-independent unit and has its own local computer and database, it must be pointed out that it is different from 'island of automation' which appears to be similar. A cellular CIM system will have taken into account the overall objectives for integration during the design stage of individual units (cells). This is therefore different from just placing them together as in the case of a centralised CIM system.

Each software module has to be designed with a certain format for data inputs and outputs. This ensures the overall system will be compatible when these modules are linked together in the system configuration. They can be tested separately during the development stage. When all these modules have been integrated in the final stage, the whole system can then be tested for its data compatibility and integration capability. This software development approach is sometimes regarded as 'modular

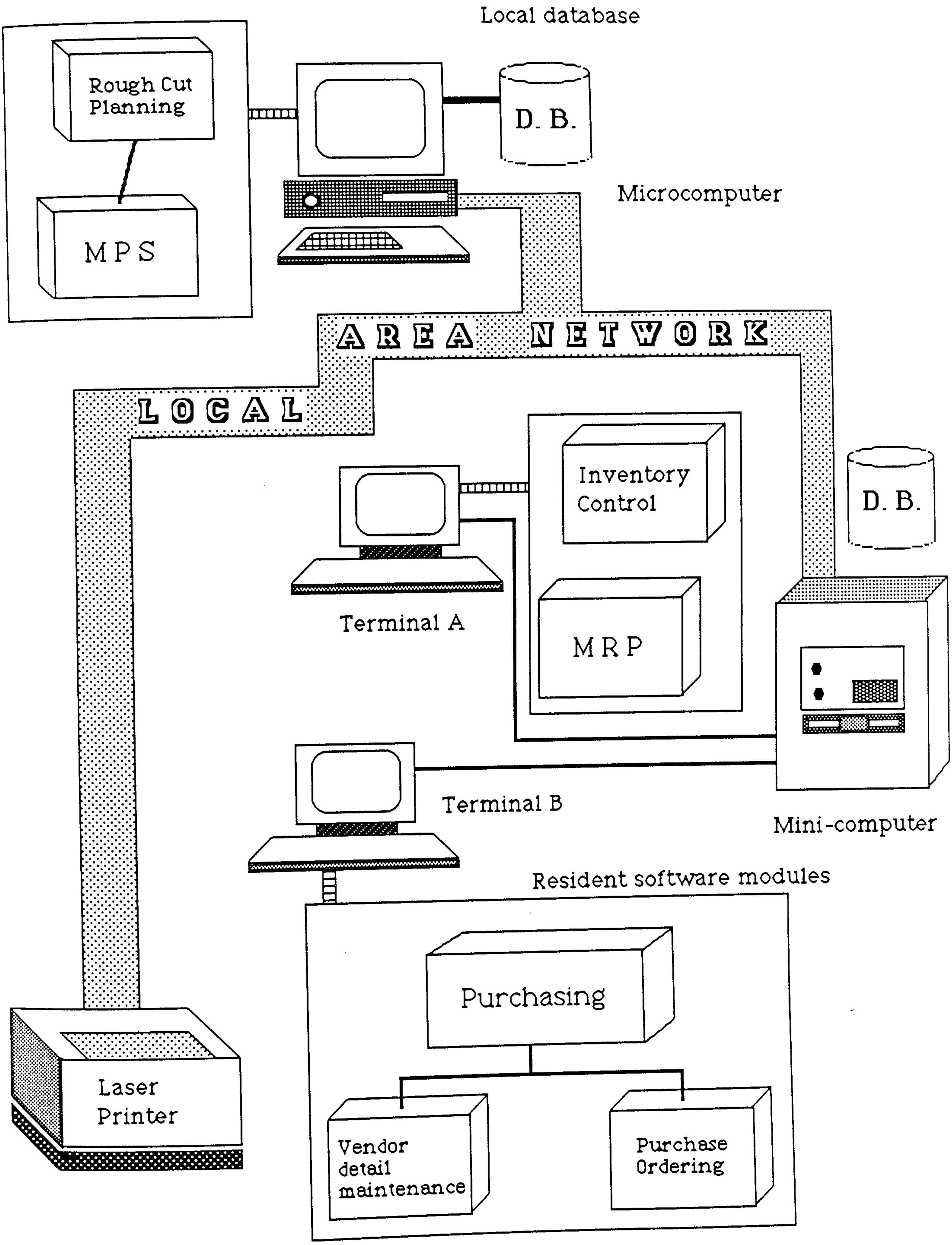


Figure 5.11 Use of a smaller computer to serve a group of cells

programming' in system terms. The use of this method provides the advantage of rectifying causes of error in each single software module at early stage.

Figure 5.12 shows that a number of cells with similar data input/output formats have been linked to achieve the desired information flow. These cells can be tested separately provided suitable information is fed through them. At the final stage, the complete system can then be tested by entering suitable data into the first cell in the chain, and results are collected and examined from the last cell in the chain.

5.3.5 MORE SPECIFIC TRAINING

In a centralised CIM system, because all elements are consolidated into a single huge system, specific training has been extremely difficult. As the entire system is so extensive, it is very hard to recognise the parts of the system which would need more training than the others.

On the contrary, more specific training can be organised for a cellular CIM system since the entire system is made up of many individual independent and semi-independent cells. More specific and correlated training can be prepared for the right parts of the system. In addition, the improved system legibility offers users an easier understanding of its internal architecture.

Generally speaking, the capability of addressing precise training to different parts of the system will ensure a high degree of internal staff involvement.

5.3.6 IMPROVED FINANCIAL IMPLICATIONS

Costs that are incurred in designing, setting up and running a CIM system may consist of the following major factors :

(1) hardware and software costs;
(2) system development costs;
(3) system implementation costs;
(4) system modification costs;
(5) system verification costs;
(5) system maintenance costs;
(6) operation costs;

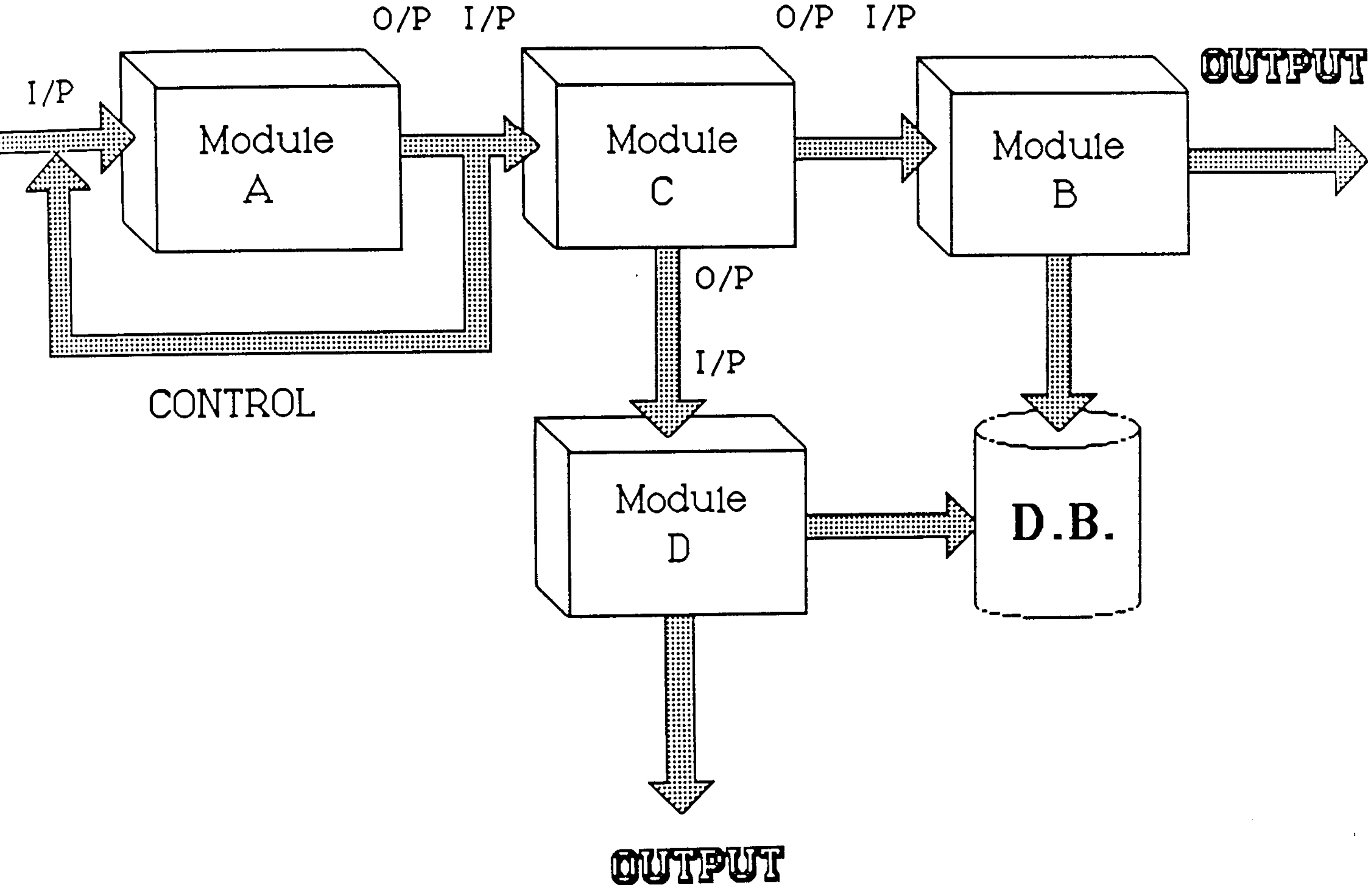


Figure 5.12 The standard IN/OUT formats of each cell module

(7) management and training costs.

All these costs, in theory, can be reduced because of the benefits gained by using the cellular approach. As mentioned in previous sections, the potential benefits of adopting a cellular principle in designing an integrated system may include the increased system flexibility and simplicity, use of less powerful computers, reduced software sophistication, clearer defined objective for each cell, reduced length of development time, easier and simpler system maintenance, precise training, more effective planning and control, easier system modification to reflect changes, and the ability to tailor the cells for individual needs. As a result, the total system cost will be reduced and the system will be more flexible.

5.3.7 SHARED MANAGEMENT RESPONSIBILITIES

Of all the potential advantages to be gained when using the cellular approach, the shortened throughput time and the improved work-in-progress inventory [Love and Lung, 1986] are relatively more significant. These result from the improved user involvement and management accountability in each cell. However, the single most important aspect of a cellular approach is its capability to simplify the nature of a manufacturing control system. Many of the traditional control functions such as material planning and capacity scheduling can now be performed and monitored in each cell individually.

By implementing the cellular approach, management problems associated with the centralised system are considerably reduced. These problems are summarised as follows :

(1) great responsibility is imposed on a small group of executives, and any error of judgement could have significant repercussions in perhaps all areas of operations;

(2) the barrier between decision makers and those who execute their orders is traditionally too wide, hence, problems in communications leading to, subsequently, inappropriate actions with, perhaps disastrous results, are not uncommon;

(3) the accountability for overall performance is generally poor because of the barriers between top management and lower levels in the company hierarchy;

(4) activities on the shop floor are usually such that people in top management do not easily recognise the coherent problems. Consequently, from time to time,

unrealistic decisions may be made which are impossible for the shop floor to follow. For example, one of these typical problem is the unrealistic master production schedule generated by the production control department.

Indeed, the application of the cellular concept has simplified what used to be a very cumbersome system. It also reduces some common problems and restrictions encountered in CIM system development. Further use of the cellular method within management and control facilities in an integrated system will lead to a new management technique known as the distributed planning and control being feasible. This new concept will be used to complement the characteristics already provided by a cellular integrated system. Further details about this relatively new management concept will be discussed in the next chapter.

CHAPTER 6 COMPARISON OF A CELLULAR CIM SYSTEM TO A CENTRALISED CIM SYSTEM

In the last chapter, the prospective benefits of using the cellular system approach in CIM design were discussed. This chapter is to elaborate this concept and to compare it with the centralised system methodology which has been widely adopted in CIM system development. The comparison will be done in terms of respective system concepts, and communications between each system element.

6.1 CIM ELEMENTS AND MAIN FUNCTIONAL AREAS

As mentioned in the last chapter, there are often five major distinguishable functional areas which can be located in any typical manufacturing company. These are Customer Service, Design Engineering, Planning, Manufacturing and Control, as well as Finance and Administration. These functional groups exist in an integrated system regardless of the system approach used.

Each of these major functional groups comprises several elements and sub-systems. In general, these various elements operate in a specific operation sequence within each functional group. They are also usually arranged in appropriate top-down hierarchies.

6.2 A CENTRALISED APPROACH OF CIM ELEMENTS / FUNCTIONS INTERACTIONS

In a CIM system which is based on the centralised methodology, each functional area retrieves from, and stores all its data in, a centralised common database. The result is, although all elements share information as required in an integration environment, they have to continuously refer to a common central database for retrieving and updating relevant data.

Very often, a group of separate elements may have already been combined to form bigger functional groups before the total integration plan is commenced (see Chapter 3). These integrated functional groups, together with other remaining automation islands, are finally linked together to complete the integration.

Although these small integrated groups exist as self-contained units, they have in fact adopted the centralised system methodology for elements within them on a smaller scale. In addition, there may be already separate databases currently used along with some of these groups. Apparently, these systems resemble those units within a cellular system defined in earlier chapters, although they actually illustrate typical characteristics of a centralised systems. Figure 6.1 shows an example of the configuration of such a system. In this diagram, there are three preliminary integrated groups, namely group A, group B and group C. Each of these groups has its own database whilst the system status is still in the process of partial integration. However, no direct data links are established between them. Communications between each of these groups have to be done through the overall central common database in the system.

Figure 6.2 demonstrates a different configuration for a CIM system based on a similar centralised philosophy. In this diagram, two previously integrated groups and three stand-alone islands are integrated through the use of an overall central database.

When comparison is made between figures 6.1 and 6.2, the characteristics of centralised system methodology is dominant in both examples. Indeed, in a centralised system, it does not matter whether system elements in the existing functional groups have been already previously integrated, or if separate local databases have been used, they are still regarded as separate entities. Communications between them have to be done through a superseding central common database.

6.3 A CELLULAR VIEW OF INTERACTIONS BETWEEN CIM ELEMENTS

In a cellular CIM system based on the second global system approach, all its elements should be designed from first principles. Although these elements are joined together to form semi-independent cells, all the required fundamental data links for data access between cells and local databases are readily available. In short, although these cells have been assigned to different quite specific duties, and although they work separately, the embedded data links allow them to transfer data directly to other destination cells through the LAN system. This method therefore is radically different from a centralised system in which data is always stored in a central and common database. Details of the difference will be discussed in greater depth later in this chapter.

In general, characteristics of a cellular CIM system's elements can be summarised as follows :

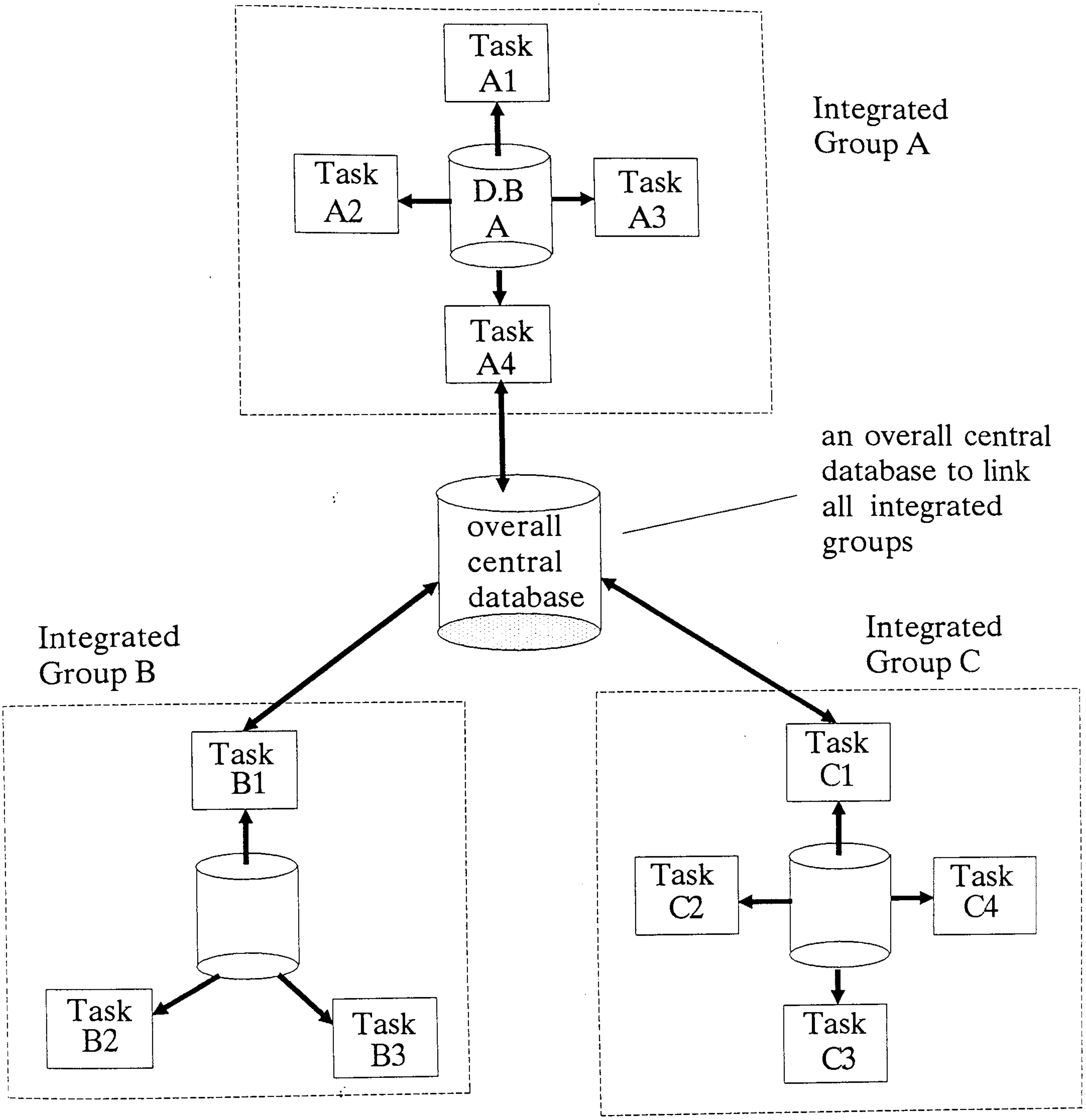


Figure 6.1 The use of an overall central database to link smaller separate database

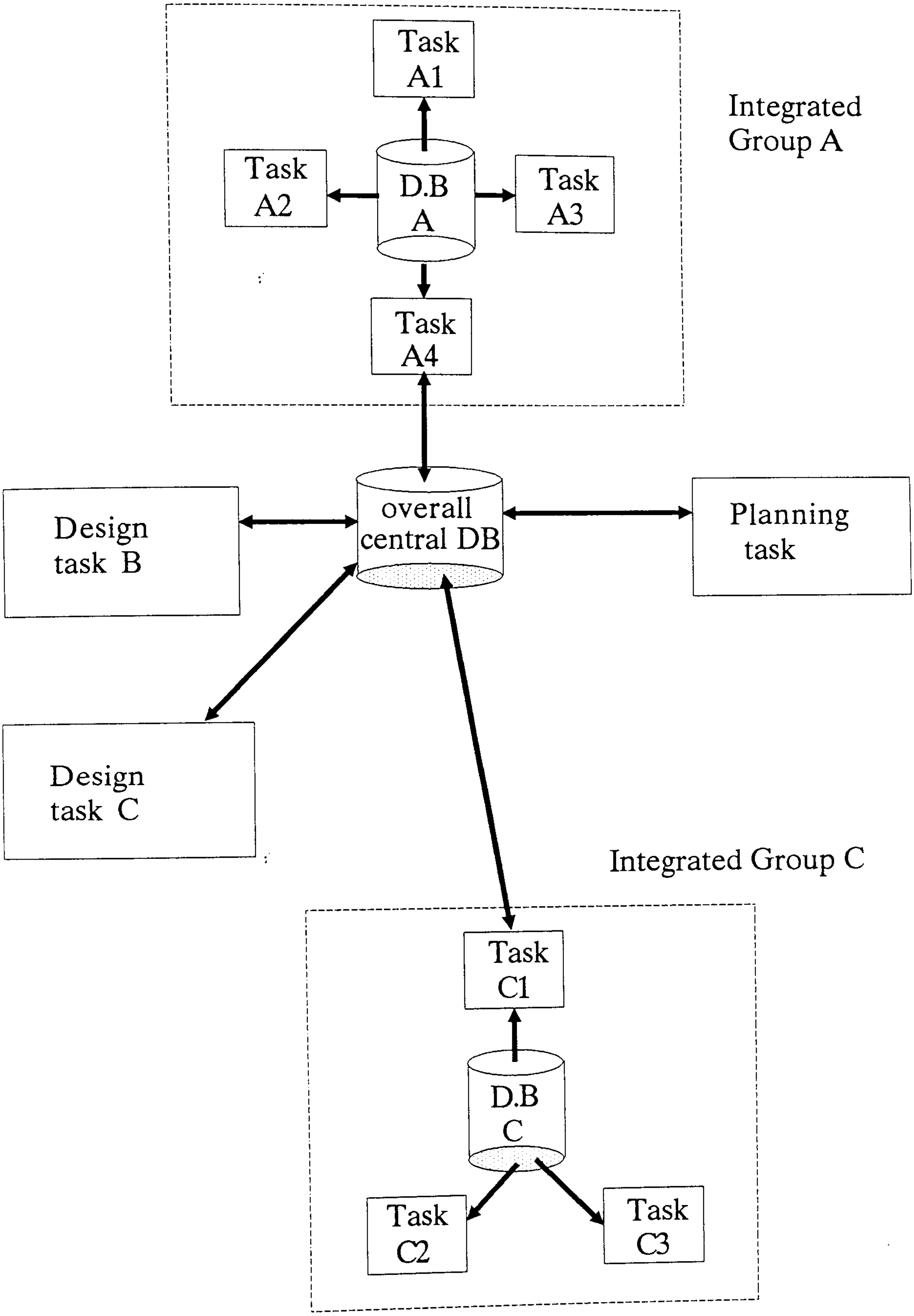


Figure 6.2 Layout of a centralised CIM system

(1) similar activities (such as those in Customer Enquiry and Sales department) are grouped together to form a functional cell;

(2) sub-cells may be further defined within each of these functional cells, in which job allocations can be defined more specifically;

(3) smaller separate database systems are widely used to serve only local functions in the individual cells. Data can also be retrieved from a local database by other cells, provided such links are already embedded in the latter;

(4) each cell or sub-cell, or a mix of them, can be served by a local computer;

Figure 6.3 illustrates the co-existence of main functional cells (from now on also known as central cells), sub-cells, and finally work cells. The arrows indicate the directions of key information flow which usually begin with some central cells, then to sub-cells, and finish at work cells which are located at the bottom of the overall hierarchy of the structure.

Further analysis shows that the data stored in a local database can be divided into two main groups, namely local data and shared data [Lung, 1986]. Data which is generated and used only for functions within a cell is termed local data. Data which does not only support local functions but will also be used by other correlated cells is called shared data. Both groups of data can be physically situated in a local database. It is then attached to a cell which is considered to be the most appropriate 'owner' or prime user of that database. Figure 6.4 illustrates the interrelationships between cells, sub-cells, local database, local data and shared data in a cellular CIM system. Note that all system cells in the diagram are connected to a LAN system for direct information transfer.

Ideally, in a cellular CIM system, each cell normally works with its localised computer and database, and will retrieve data from other databases via the LAN system only when necessary.

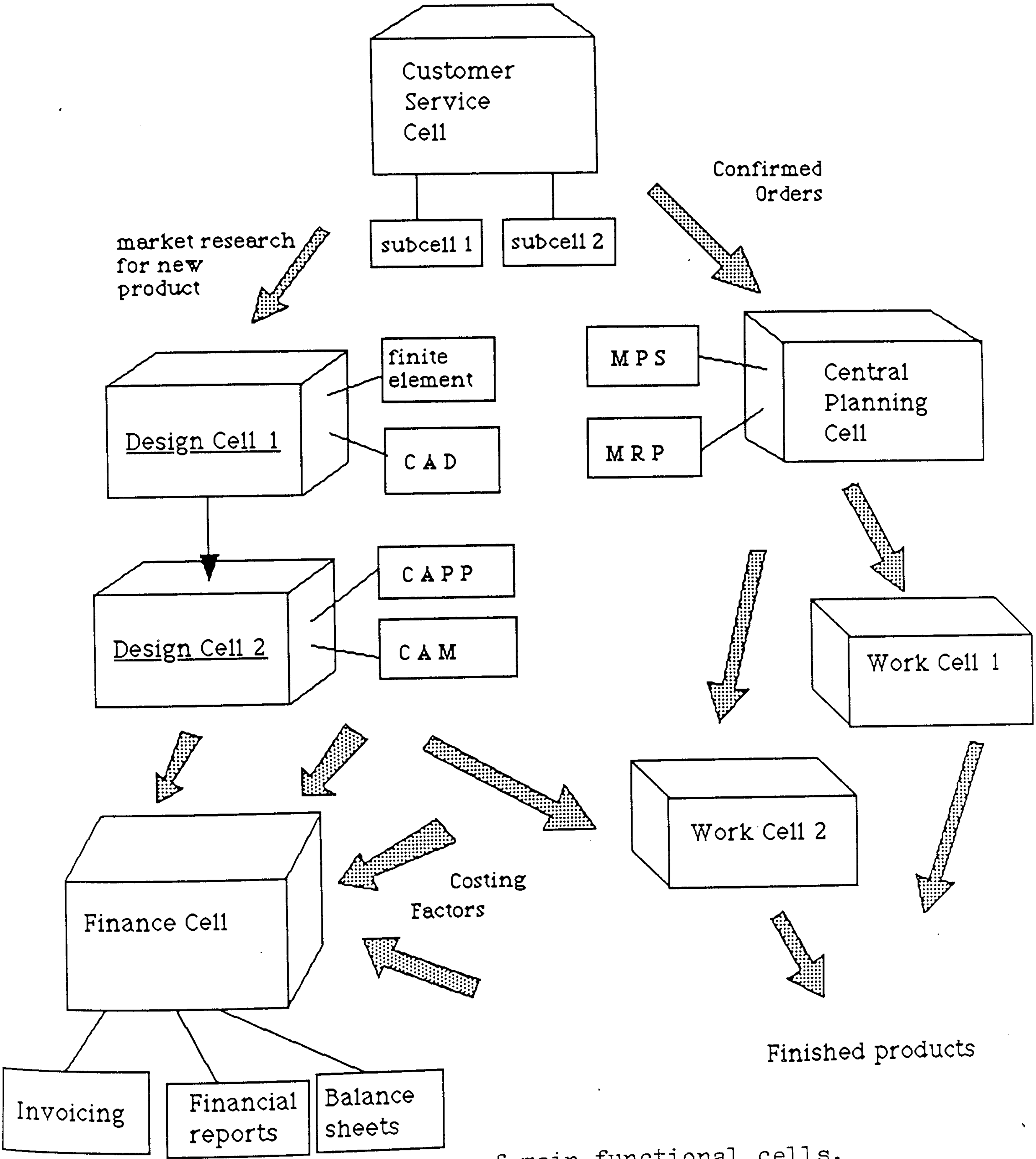


Figure 6.3 Co-existence of main functional cells, sub-cells and work cells

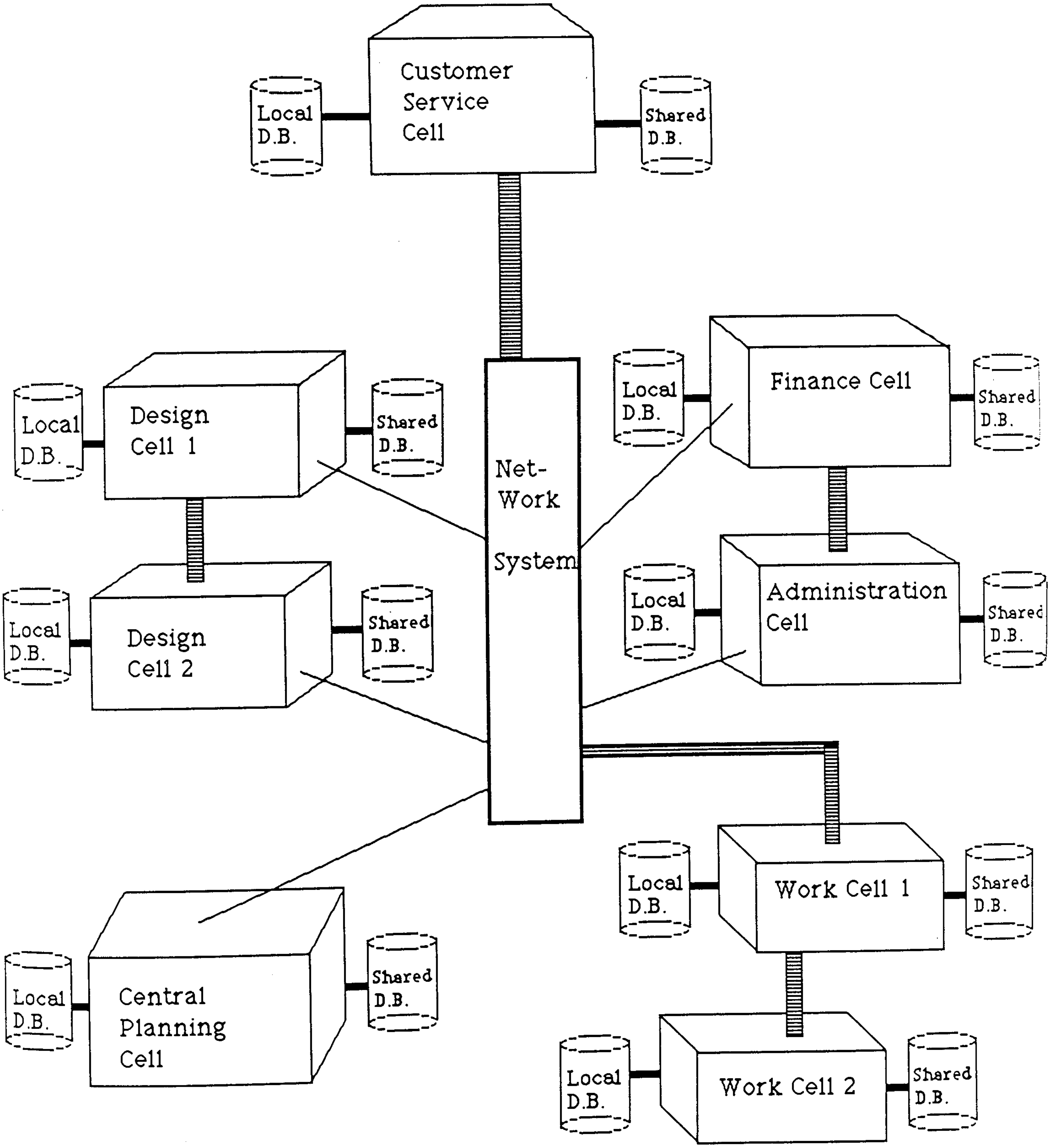


Figure 6.4 The linking of main cells, sub-cells and local databases through a LAN system

6.4 IMPLICATIONS OF DESIGNING A CIM SYSTEM USING THE CELLULAR CONCEPT

Referring to Figure 6.3 and Figure 6.4 in the previous section, theoretically, the cellular design methodology can be applied to every part of a CIM system leading to the concept that a complete CIM system can be formed by a group of inter-linked cells and sub-cells. Because of the restricted physical size of each cell and its reduced amount of associated data, the functions in a cell are more controllable and yet flexible. As a consequence, a traditional CIM system can be greatly simplified in terms of system design, database structure, software complexity, system implementation and configuration, system maintenance and data accuracy.

With the use of cellular approach, the rigid structure of a centralised system can now be replaced by a highly flexible structured system which is essentially made up of a number of semi-independent but inter-connected cells. Each cell is, up to some degree, capable of being tailored for specific requirements. In addition, each cell also has its own control and a self-contained database. Integration can be achieved through links between these separate cells.

6.4.1 HIERARCHY OF SUB-CELLS

Figure 6.5 and Figure 6.6 demonstrate two of the many possible combinations for cell interrelationships. These relationships can be specified during the initial system configuration.

In the first figure, a Customer Cell consisting of sub-cells such as {Product Search}, {Customer order verification} and {Order Acknowledgement}, is illustrated. There are then further defined cells within some sub-cells. For example, {Delivery Date Estimation} and {Delivery Date and Quantity Confirmation} are contained in the sub-cell {Quantity and Delivery Verification}. Likewise in the second example, many sub-cells have been defined within the Design cell. Each of them has been assigned specific design activities. Note that a local database is always used to support functions within each major cell.

There may be different hierarchies of cells defined for differing application environments, depending on what activities are to be achieved and the level of control required.

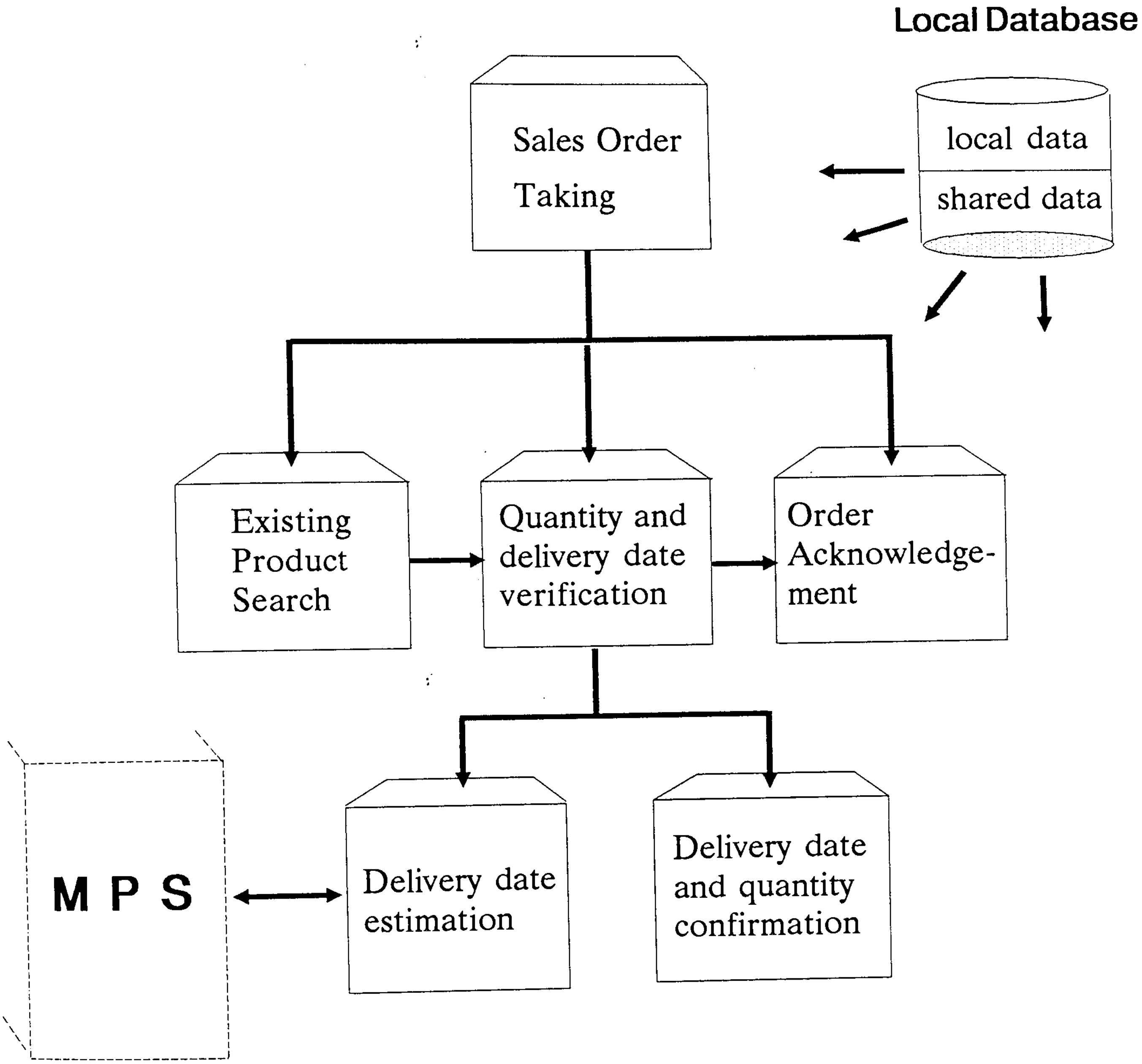


Figure 6.5 Example of main cell and sub-cells relationship in Sales Order Taking

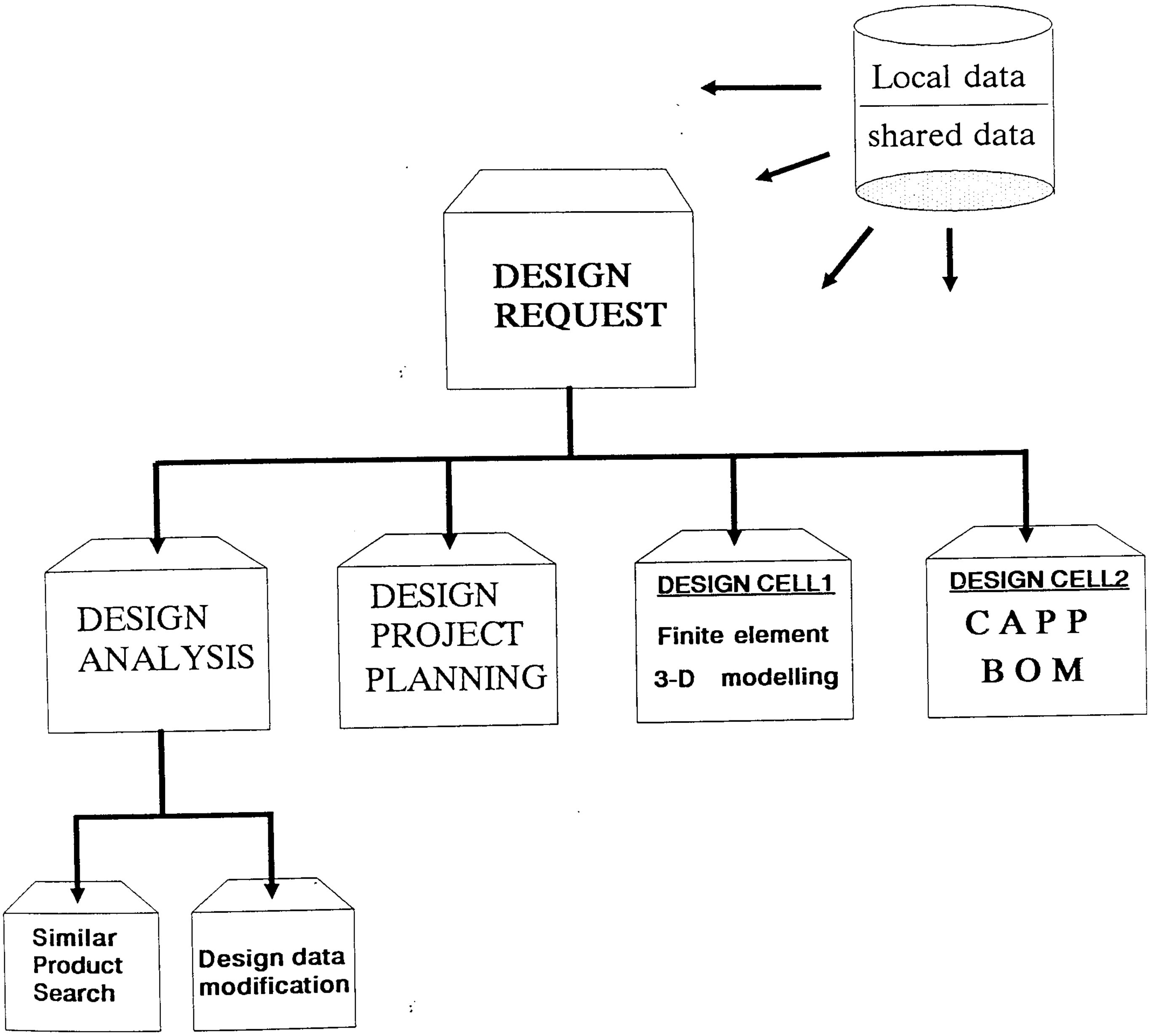


Figure 6.6 Example of main cell and sub-cells relationship in Design

Each cell or sub-cell must have a clearly defined set of objectives, local tasks, and, possibly, a local dedicated computer and database for its own use.

6.4.2 LOCAL DATABASE

One very important advantage for using local databases is that the amount of data stored is limited as there is no irrelevant data maintained within its store. Ideally, all data in such a database should support only local activities. Nonetheless, as the number of smaller databases increases, the control software which makes data integration possible must be designed with great care and reasonable flexibility.

A great number of differences can be noted when the localised database approach is compared with the centralised database method in CIM system design. Some of the significant distinctions are as follows :

(1) the amount of data to be handled is less and few data transactions are required, hence an improved system response results;

(2) smaller data storage devices can be used;

(3) a simpler database structure design is required;

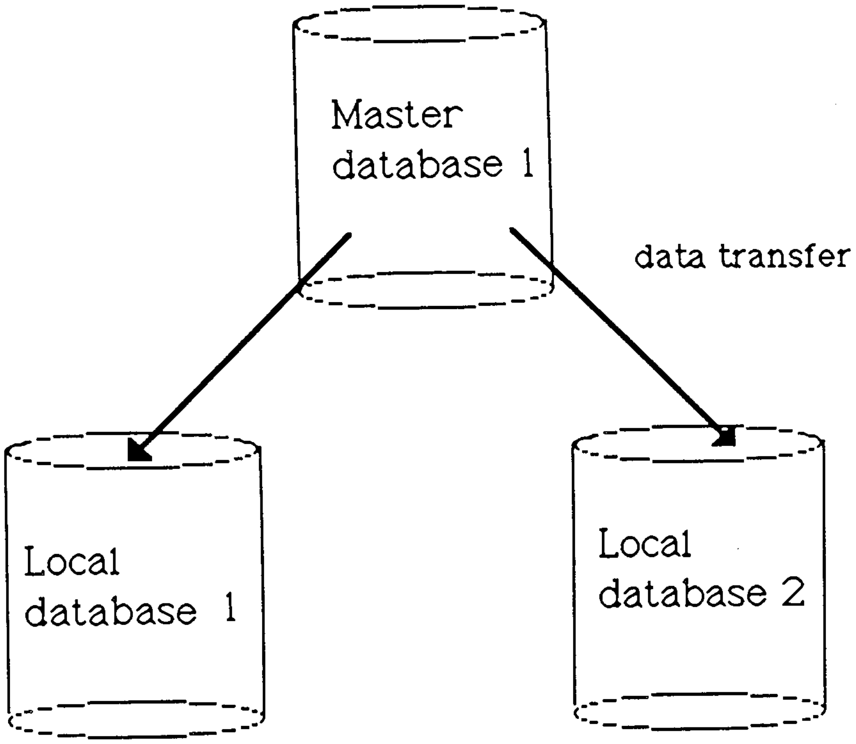
(4) a local database will mainly support local functions, but access of shared data by external cells is possible;

(5) smaller computers can be used.

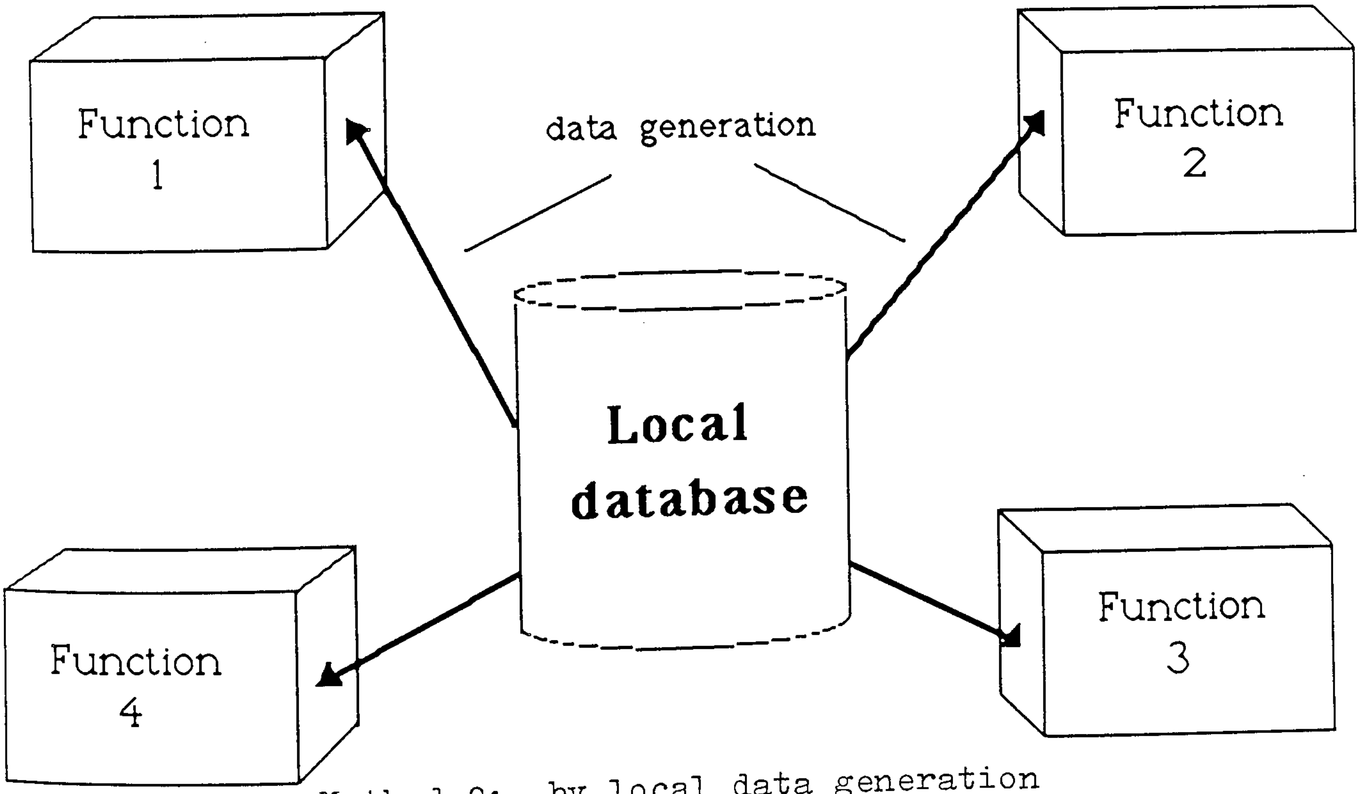
In general, there are two possible methods to prepare data for a local database during the system implementation. One method is to download data from a bigger master database which is usually maintained at a higher system hierarchy. The other method is to generate the required data by local functions in a cell. Figures 6.7 illustrate both methods in which data is prepared for a local database.

6.4.3 LOCAL AREA NETWORK (LAN) FOR COMMUNICATIONS

An integral part of a cellular CIM system is the use of a Local- Area-Network (LAN) system through which a number of computers and separate software modules,



Method 1: by data distribution



Method 2: by local data generation

Figure 6.7 Two methods used in data preparation machines, process controllers, data storage devices, input/output devices and other computer periherals can share information. Suitable interfaces and cables are required to connect these devices to the LAN system.

There are some significant advantages of using LAN for data integration in a cellular integration environment including the following :

(1) different makes of equipment can communicate with each other and share expensive resources, without the need to use complicated hard circuit wiring;

(2) information can be processed locally before it is sent out to subsequent cells via the LAN;

(3) a highly flexible combination of hardware can be used, provided there are suitable interfaces for connection to the LAN;

(4) the actual network configuration can be easily modified to cope with new system changes;

(5) priorities, for different levels of data access, can be assigned to each networked station;

(6) file locking or record locking facilities, as well as assignment of different levels of data security, can be done via the LAN control software .

There are different types of LAN systems for differing requirements. Three of the major types are the 'STAR', 'BUS' and 'RING' topologies. Although the prime purpose of the three systems are almost identical - to pass information between computer work stations. Each type of LAN system may offer various enhanced networking features. This permits the design of an integrated system to be more specific to individual requirements. In addition, different types of LAN systems can be connected together through proper network control software and cables - hence an extensive integrated system is possible, using LAN technology.

6.5 FURTHER ENHANCEMENT OF THE CELLULAR CONCEPT - DISTRIBUTED PLANNING AND CONTROL

6.5.1 MANAGEMENT DECENTRALISATION

Recently, there has been a rather interesting debate about the benefits of decentralisation of management over the traditional centralised approach [Timm 1981, Hewitt 1982, Tyler 1986]. Management decentralisation is often regarded as a management technique which can improve a company's efficiency in term of data processing and responsibility transfer. This approach is usually applicable to administrative and costing areas within a company.

In fact, the idea of decentralisation can be broadly introduced in a cellular CIM system as a supplementary tool to consolidate the cellular concept within the system.

Decentralisation, according to Tyler [1986], is more a management strategy than a management technique. When applied to an integrated manufacturing environment, it permits the traditional central-clustered responsibilities such as production planning, inventory control and machines scheduling to be decentralised and distributed into multiple locations so that more efficient information processing and control is possible. The result of applying a decentralisation approach to a cellular CIM system, as a management strategy, leads to the emergence of a new management concept known as distributed planning and control.

6.5.2 DISTRIBUTED PLANNING AND CONTROL

Distributed planning and control can be regarded as a technique or tool to implement the policy of function-decentralisation in a cellular CIM system. It can not be separated from, and indeed should be viewed as complementary to, the established cellular concept in this thesis. With the application of distributed planning and control, not only will data be distributed from central functions to smaller multiple system units, but some central functions themselves may also be simplified and divided into smaller components which can then be replicated and embedded in several locations.

Figure 6.8 shows a conventional view of how central MPS and MRP interact. Data, required for production scheduling, is first collected and summarised in the MPS cell. It is then transferred to the MRP cell. The central MRP cell works out the gross and

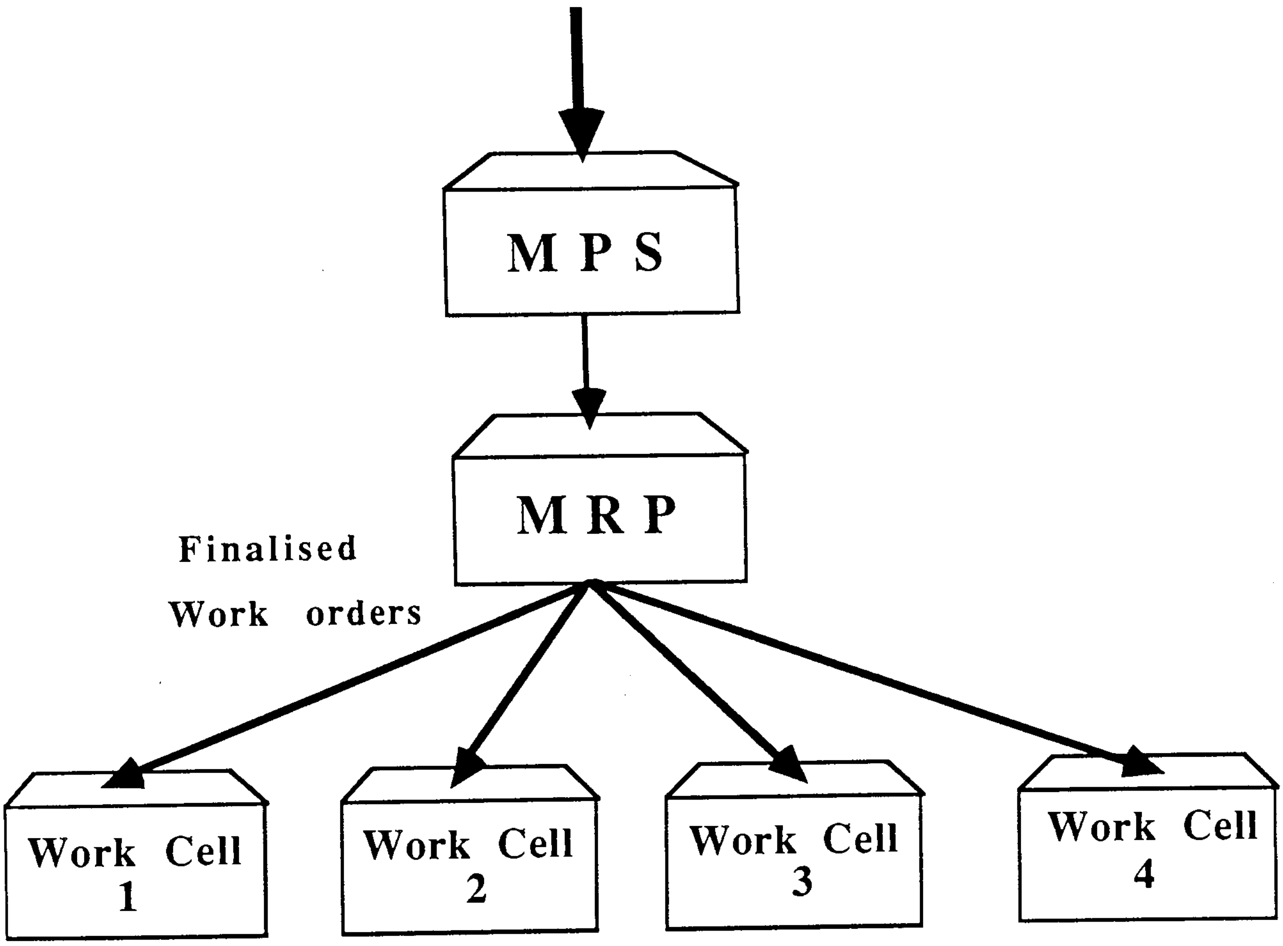


Figure 6.8 A conventional view of a MRP process

net requirements for all subsequent parts concerned. Final work orders are then distributed to the various work centres for appropriate actions.

Figure 6.9 shows similar activities, but with the adoption of the distributed planning and control concept to both the central MPS and MRP modules. The central MPS collects demands for products in a usual manner. It will then, according to pre-specified distribution rules, distributes data to those work cells which are concerned. Subsequent planning, control and management functions are finally carried out locally within those work cells.

When comparing the two figures, a notable characteristic with respect to a distributed system has been illustrated. In such a system, the significance of a central functional module (not any specific one) can be replaced by several smaller but effective local modules. These modules can be duplicated and assigned to more than one physical location in accordance with the initial system configuration. For example, in figure 6.9, the central MRP system has been replaced altogether by four smaller and simpler local MRP modules which themselves can be identical. These MRP modules may look similar to the original central module but will process much smaller amounts of data.

In the next chapter, the tributes of distributed planning and control will be discussed in greater depth. Examples of how this concept can be applied to CIM system design will also be examined.

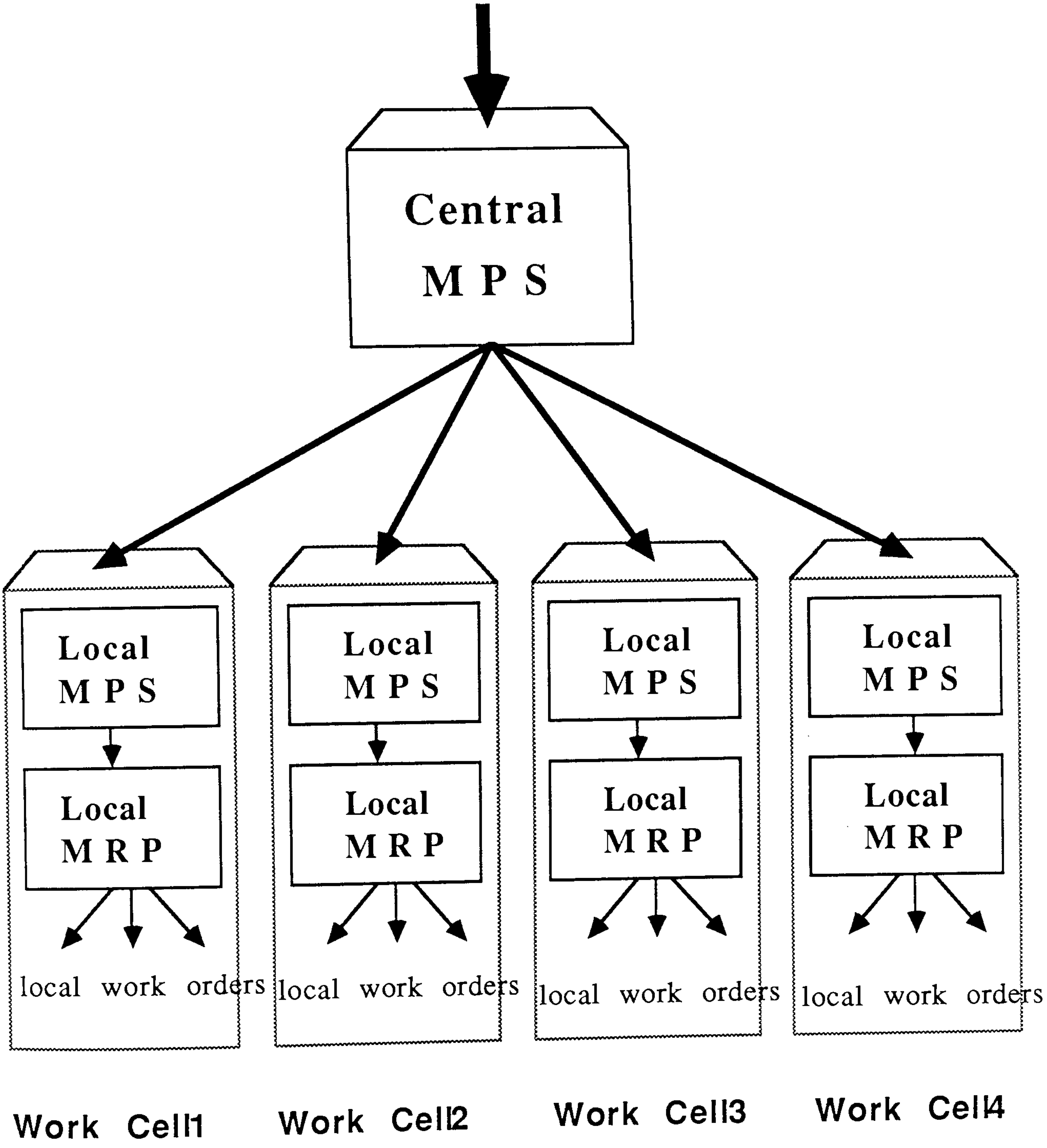


Figure 6.9 The concept of distributed MPS and MRP

CHAPTER 7 DISTRIBUTED PLANNING AND CONTROL IN A CELLULAR CIM SYSTEM

The last chapter compared the significance of a cellular integrated system to a more traditional centralised CIM system, and deduced the implication that further application of the cellular concept can lead to decentralisation of some central management functions. These functions can be merged into other cells which are usually located at the lower strata of a company's hierarchy structure. This is known as the distributed planning and control concept, and will be explained in greater details in this chapter.

Implementing the distributed planning and control methodology, major functions such as MPS, MRP and capacity planning, which used to dominate the central production management, can now be either entirely or partly substituted by some smaller MPS, MRP and capacity planning modules which will be stored in more than one location. These modules will be situated locally in some of the lowest hierarchical units which are regarded as the work cells in this context. The consequence of this approach is to alleviate the heavy burden of the traditional central planning area by shifting the emphasis onto multiple location work cells. Theoretically, this concept should overcome some of the common problems experienced in a number of CIM system development projects which are based on the centralised system approach.

7.1 THE PRINCIPLE OF DISTRIBUTED PLANNING AND CONTROL

Distributed planning and control is a management tool which can be used to assist in attaining a decentralisation management strategy. Relatively speaking, the idea of distribution is not new in the area of information technology. This is where the term 'distributed data processing' has been reasonably well established and has been in use within the data processing departments of some large companies.

In general, 'distributed data processing' can be regarded as a system where many workstations share one or several central processing units (CPUs) [Hawkes 1988]. These CPUs are then linked via a network which permits data to be shared between systems. Consequently, data is distributed and processed separately to improve processing efficiency and speed.

In this context, however, only data is distributed and processed at different workstations. In general, distributed data processing does not normally include distribution of any physical process or function, nor does it imply the distribution of any planning and control responsibilities. In comparison the term, distributed planning and control when referred to in this thesis, has a much broader definition than just ordinary data distribution. With respect to this definition, not only will relevant data be downloaded into smaller computer units, but some of the central functions will also be distributed to smaller cells in the system.

7.1.1. DISTRIBUTION OF CENTRAL FUNCTIONS AND DATA

Based on a cellular CIM system, central functions such as MPS, MRP and capacity planning are all sub-cells within the big planning cell. By applying the distributed planning and control methodology, these central cells can be decentralised so that their normal functions will be distributed to various work cells.

The types of functions and their associated data suitable for distribution depends very much on the individual user's requirements. An ideal cellular system therefore should provide some level of flexibility so that differing distribution plans can be implemented.

In order to illustrate the principle of distributed planning and control, some typical central functions have been chosen for experiment. These functions include MPS, MRP, capacity planning and inventory control. However, the same technique can also be applied to other central functions such as CAD, CAM, purchasing and job costing. This view will be discussed in more depth later in the thesis.

7.1.1.1 DISTRIBUTION CRITERIA

In order to determine whether a specific central function is suitable for distribution, the following data analysis is suggested with respect to that function :

(1) definition of the associated data;

(2) definition of input information required;

(3) definition of the outputs generated by the function, and the destination to which these transferred;

(4) definition of the operations required;

(5) definition of the procedures within the function required to complete the information flow maintained by the system;

(6) definition of the role of the particular function within the system;

(7) definition of the number and availability of data links required.

7.1.1.2 DISTRIBUTION PROCESS

Figure 7.1, 7.2, 7.3 and 7.4 together illustrate the systematic procedures carried out for the decentralisation and distribution of two chosen central functions, namely module X and module Y.

Figure 7.1 shows the interactions between the two central modules X and Y. Figure 7.2 actually zooms into the module X to display more details about its operations.

Figure 7.3 illustrates the actual distribution process in which both functional modules are distributed. In this figure, three different line types are used to indicate the routes of data distribution. For example, key functions contained in the original module X are distributed to work cell A, B and C respectively to form a local module X within each work cell. Similarly, functions in the original module Y are also distributed to these work cells to form local modules Y. Finally, relevant data is distributed from the host database D.B.1 into the three local databases namely DB-A, DB-B and DB-C which are located in the work cells respectively.

In normal circumstances, a machining cell represents a group of machines which have been put together in accordance with the process requirements of a product family, formed by using the GT. technique. A GT machining cell usually possesses all the required operations for an entire product family. The cell does not normally contain any of the traditional central management functions such as MPS, MRP and capacity planning. In this context, however, a work cell will not only possess all the above characteristics, it will also contain some management responsibilities. The types of central function which can be contained in a work cell depends on the individual use's requirements.

Following the distribution, all the operations contained in the original module X and Y should be available in each work cell. Figure 7.4 actually zooms into work cell A to

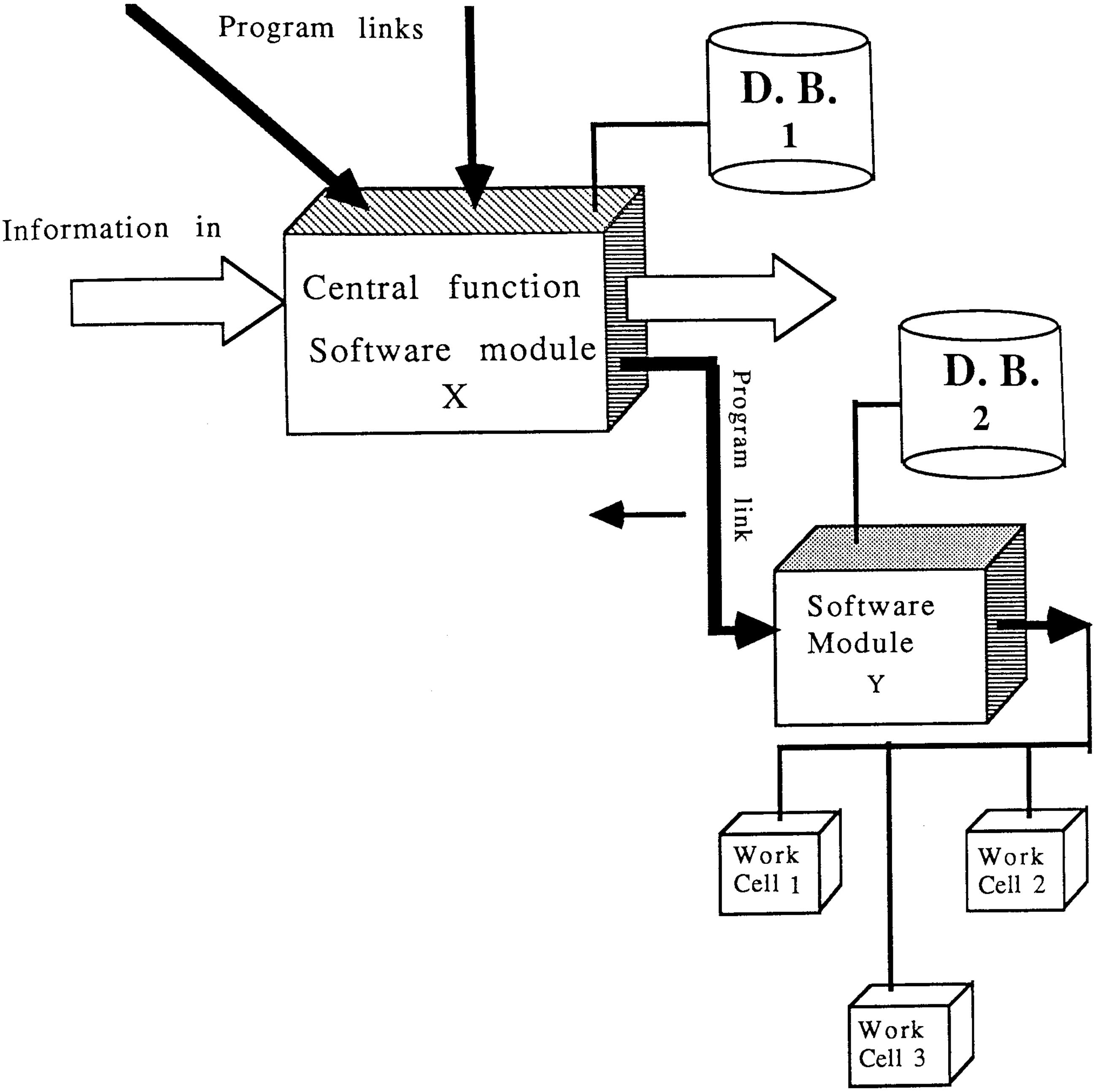


Figure 7.1 Interaction between central module X and module Y

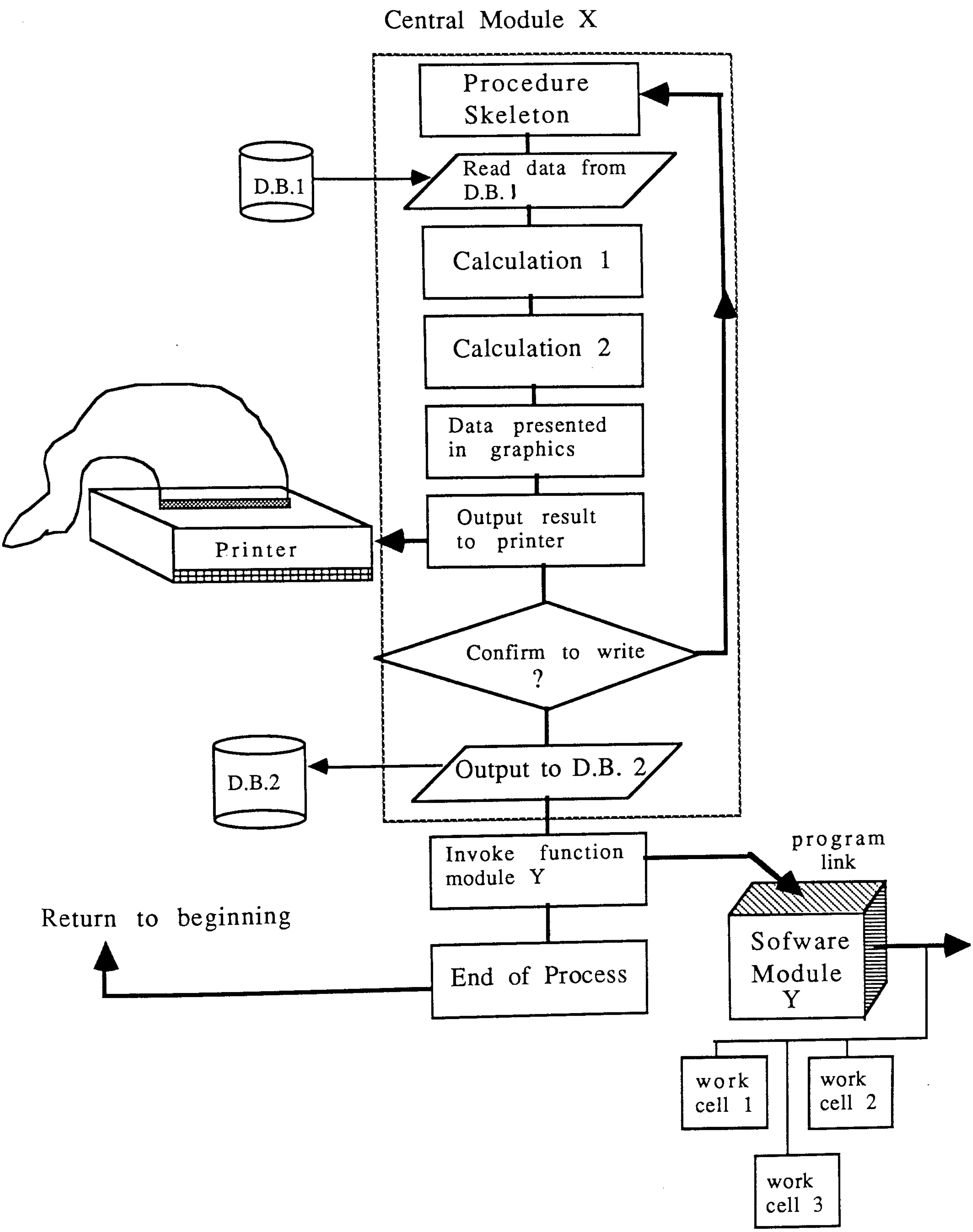


Figure 7.2 Detailed examination of operations in central module X

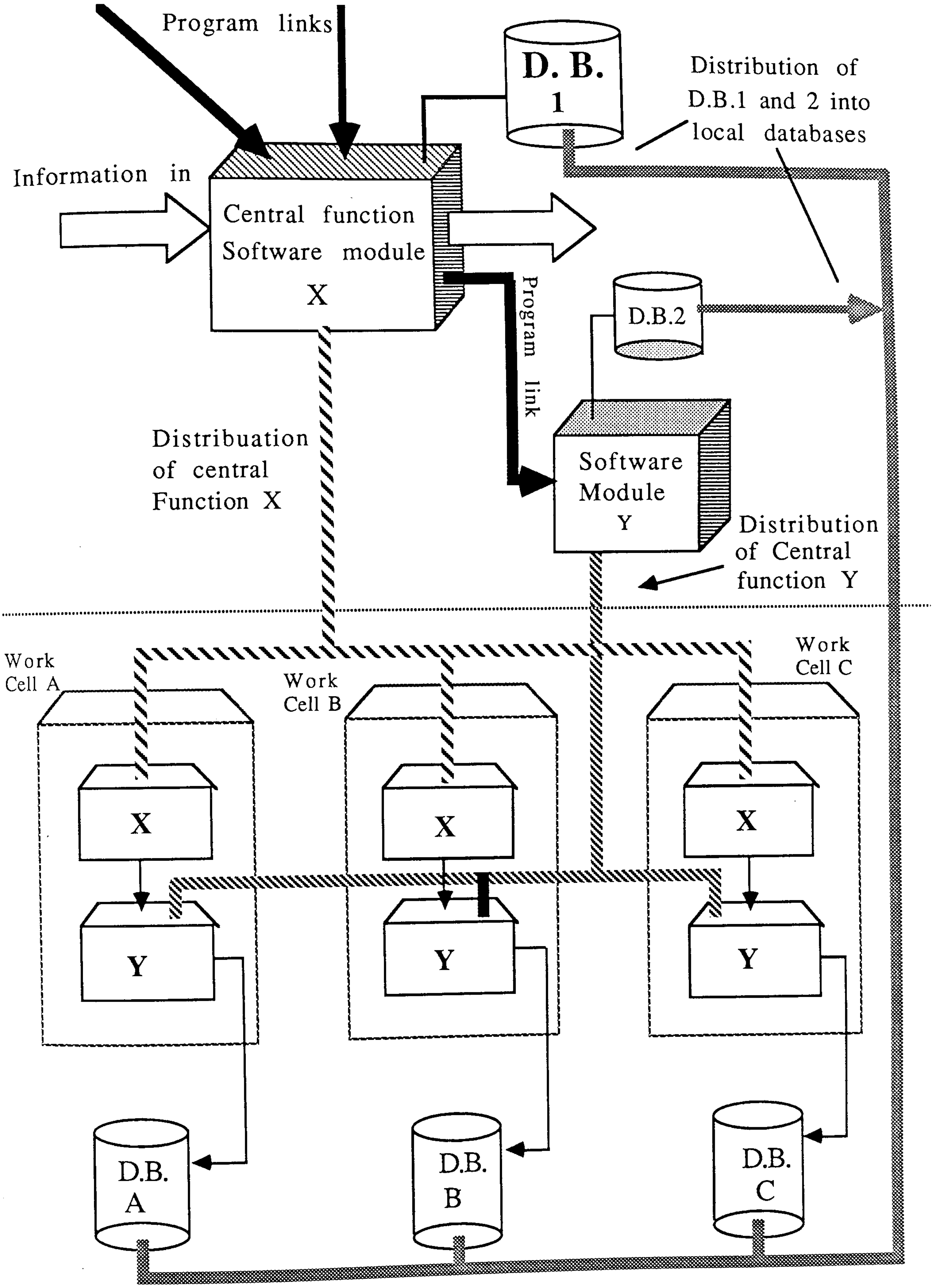


Figure 7.3 Routes of functions and data distribution for module X and module Y

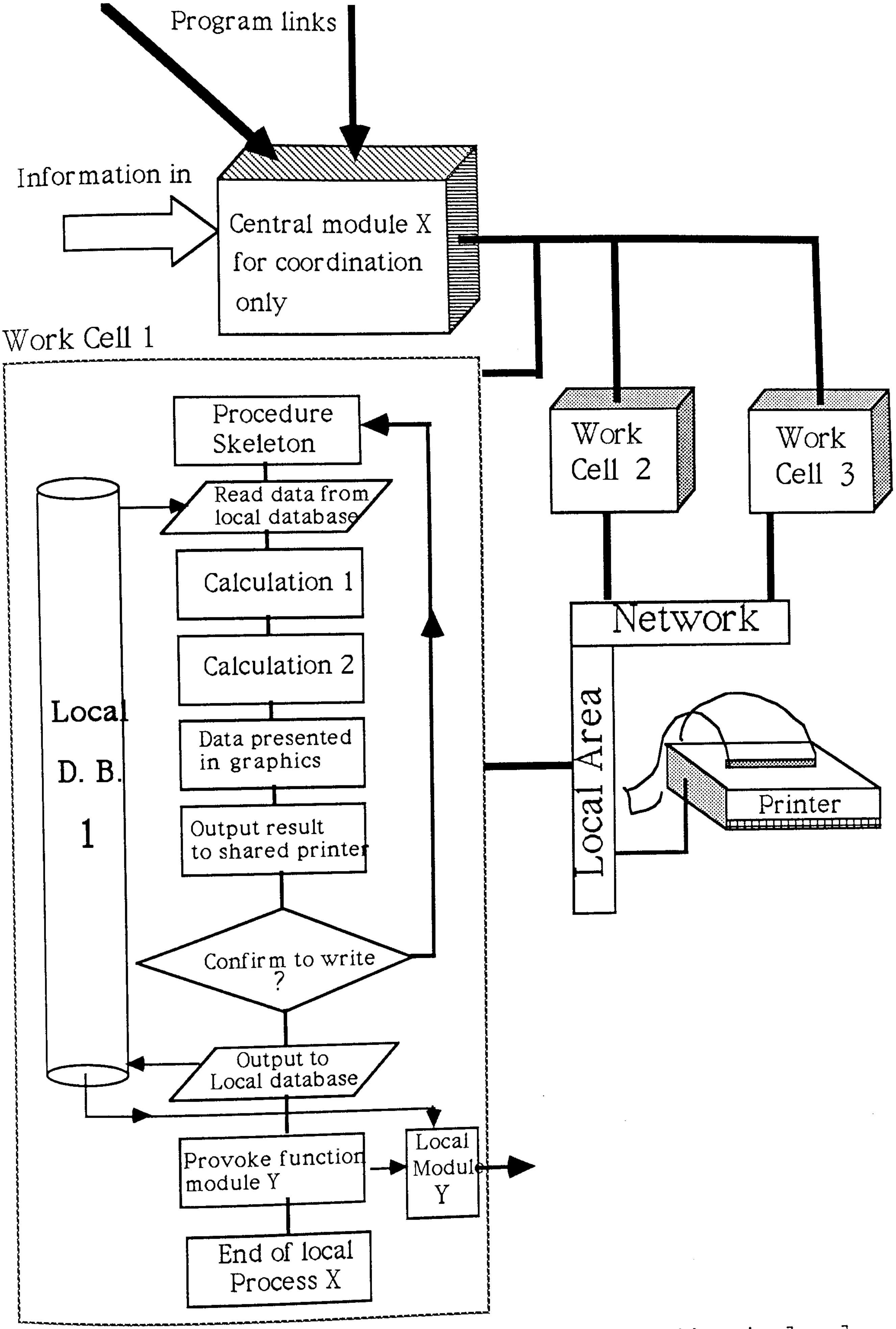


Figure 7.4 Detailed examination of operation in local module X after distribution

display its internal operations. Note that all the functions in the original central module X have been duplicated here. The interactions between these operations remain unchanged, and the data link to the local module Y is also maintained in each work cell.

In this particular example, a central module X still has to be maintained even after the distribution process. Its main function is to act as a co-ordinator to maintain the data links between other central functions and those already distributed to each work cell. In practice, this sort of module should be merged, with others, into in a single operational module called cell supervisor which will be referred to in this chapter.

7.1.1.3 POST DISTRIBUTION

After the distribution process has been completed, each work cell should have sufficient information to work on its own. Transfer of information between separate work cells should be kept to a minimum, and such communication data links should be considered whilst the original system design is conceived.

In general, distributed functions should be smaller and simpler in comparison to their predecessors. They usually possess similar operations and features as their central parental modules, though this may vary within different application environments. In essence, these localised modules should work together in order to replace the original central modules.

Referring to figure 7.4 again, the operations inside the distributed local module X are activated, and its outputs are sent back to the local database DB-A. This largely resembles the similar routine in its parent cell which also transmitted its output back into the database D.B.2. The local module Y is not initiated until all processes in the local module X are complete and the results have been transferred to local DB-A.

Basically, the four diagrams used in this section have outlined a systematic procedure for the distribution process. In order to demonstrate the principle of distributed planning and control in application, an embryo cellular integrated system has been developed. The actual development procedures and some experimental test results obtained from this embryo system will be discussed in the next few chapters.

In relation to the cellular system principle which was introduced earlier in this thesis, the presence of the distributed planning and control concept does not in the least jeopardise the features of a cellular CIM system. Each cell (central or local work cell) continues to operate in a semi-independent mode and the progression of information flow between these cells still remains. In fact, the newly introduced distribution concept will have the effect of improving the overall system flexibility; this is because more management responsibility has been given to the defined work cells and they can be tailored in many different ways according to individual requirements.

7.1.2 FUNCTIONS OF WORK CELL SUPERVISOR

As mentioned earlier, it may sometimes be necessary to retain those central modules, which have undergone the distribution process in their original central positions, as co-ordinators. These co-ordinators will no longer possess their original operations or data. Theoretically, all the remaining central co- ordinators can be merged to form a new management cell called 'work cell supervisor'. The main objective of this cell is to oversee the activities in all work cells.

The functions contained in a work cell supervisor may vary. It depends on each specific system configuration and the amount of management responsibility included in each work cell. Usually, a work cell supervisor must take up the basic role of acting as a chief co-ordinator between the remaining central modules and the available work cells. In general, a work cell supervisor should provide the following facilities :

(1) the interpretation of commands received from other central modules, and distribution of these to the correct work cells;

(2) a summary of information received back from work cells, and transfers it to the central modules concerned;

(3) re-distribution capability, if necessary, the central functions and their data into the newly configured or modified work cells. The distribution process for functions should normally need to be done only once during the initial system configuration;

(4) information transmission from one work cell to another, when there is no direct link between them;

(5) temporary store for data which is neither stored in any of the work cell's local database nor in any central cell's database;

(6) some data-update regulations and rules to which various work cells can refer;

(7) an assessment of the individual performance of each work cell.

7.1.3 OPERATIONAL RELATIONSHIPS BETWEEN WORK CELLS

Although ideally each work cell should be designed to possess all the required facilities to produce one or several complete range of products, it is sometimes more practical to split the production resources into a convenient layout according to the operational requirements of the products.

For example, for a mid-volume and mid-variety manufacturing environment, the layout of available work cells could be arranged in such a way that the production will begin with a reasonable number of component work cells capable of processing different groups of components and parts. The layout then continues with a few subassembly cells which are responsible for the production of the required subassemblies. Finally, the layout will end at only one or two final assembly cells as the process requirements for final assemblies are normally very similar. It is therefore, from the production point of view, more economical and convenient to arrange a common assembly cell for all products. Figure 7.5 illustrates a typical progression of work cells in a typical mid-volume and mid-variety production environment.

The relationships between various work cells are specified during system configuration. It is these relationships that actually determine the progression of information between the work cells. In fact, the operations of various work cells are compiled by following this progression of information established between them. Information therefore will be initially transferred from the first work cell in the chain to the next work cell which is affected. The process will be repeated until the last work cell is reached.

In principle, many of the central functions such as CAD, CAM, MPS, MRP, capacity planning and purchasing can be distributed to a number of work cells. However, it is the distribution of MPS, MRP and their associated data that actually defines the key relationships between the work cells. In order to link the different work cells in relation to their operations, the distributed MPS and MRP will produce three types of output: internal work orders for its local manufactured parts; requests for parts requiring external manufacturing resources from other work cells, and suggested purchase orders for components supplied by outside vendors.

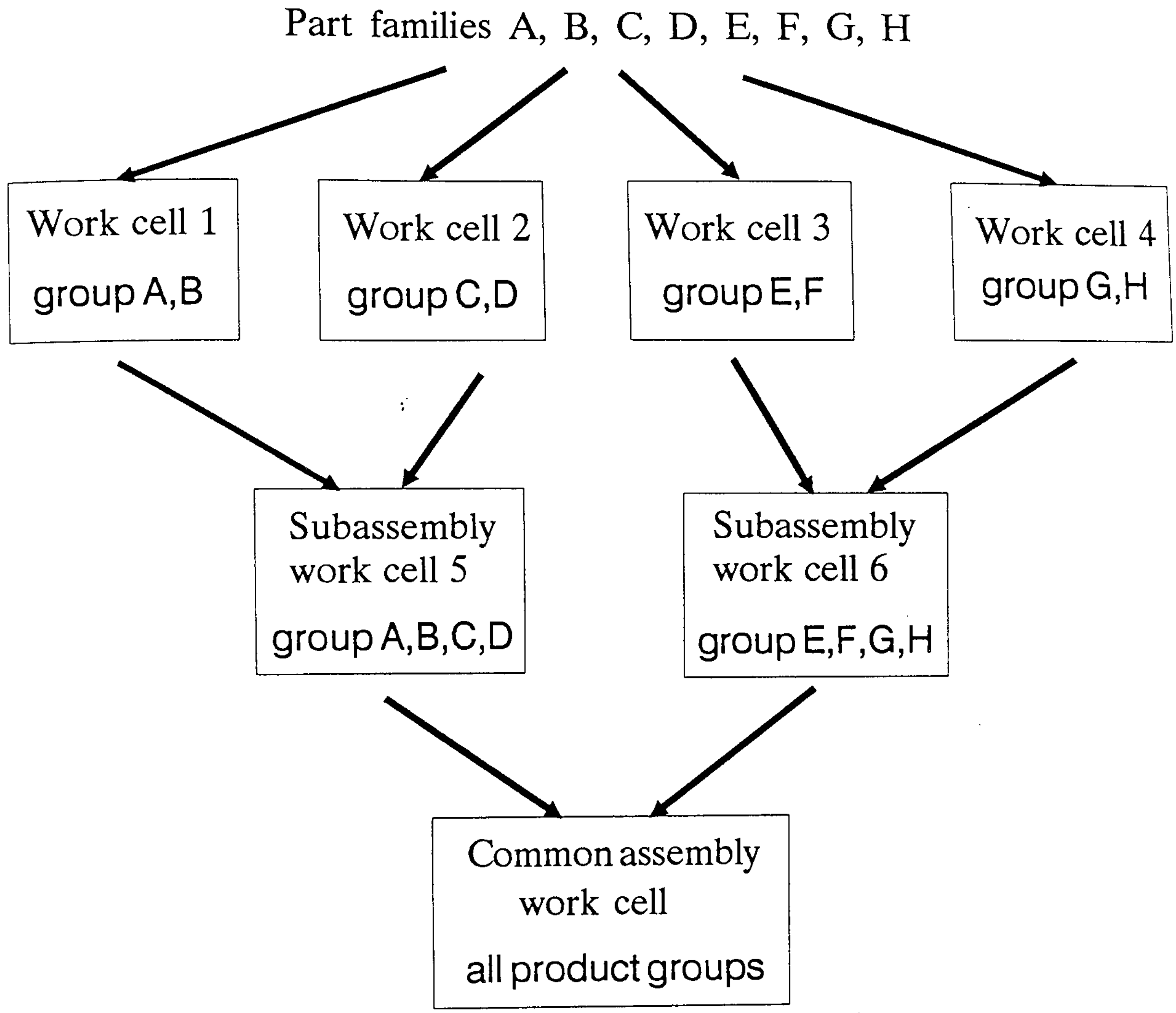


Figure 7.5 Logical progress of work cell layouts

These outputs generated from each work cell together form a closed loop relationship which connects all the concerned work cells by the external part-requests. The desired progression of information between them must be carefully defined so that the looping will not be ambiguous.

Figure 7.6 illustrates a particular set up which consists of three work cells. Note that the three outputs generated in each work cell are used to link the work cells together. These outputs are the internal work orders, external part-requests and purchased part-requests. In the figure, the same module X and module Y used in previous examples are used here again.

In this particular set up, relevant data is first distributed from the central production scheduling module to the three work cells. The distributed data is then stored in the local database in each work cell. Because of the defined relationships, module X and module Y in work cell 3 will first be executed. The three outputs are then subsequently generated during the operations. Its external part requests will be transferred to work cell 2. Local operations then begin in work cell 2 in order to generate the three outputs. Similarly, the external part requests so generated in work cell 2 will be transferred to work cell 1 which is the last cell in the chain. This process is repeated until all operations in the three work cells have been completed. All purchase requests are transferred to the central Purchase cell for further action.

Although normally it is the distributed MPS and MRP which form the major data links between work cells, it is theoretically possible to localise most of the central functions with the distributed control concept. The ultimate result will be the presence of interrelated company cells operating along with one another in the same company. It must be noted, however, that some central functions are by nature more suitable for distribution than others, and detailed analyses must be always carried out prior to any distribution plans being implemented.

Figure 7.7 shows a similar set up to that in Figure 7.6. In this figure, module X and Y is replaced generally by local planning. The relationships between the three work cells are also slightly different. Work cell 3, in this case, is a common assembly cell. Its external part requests therefore will be transferred not only to work cell 2 but also to work cell 1 because of the routing. This figure actually illustrates a common set up for a cellular CIM system, in which subsequent part orders are generated from a common assembly work cell.

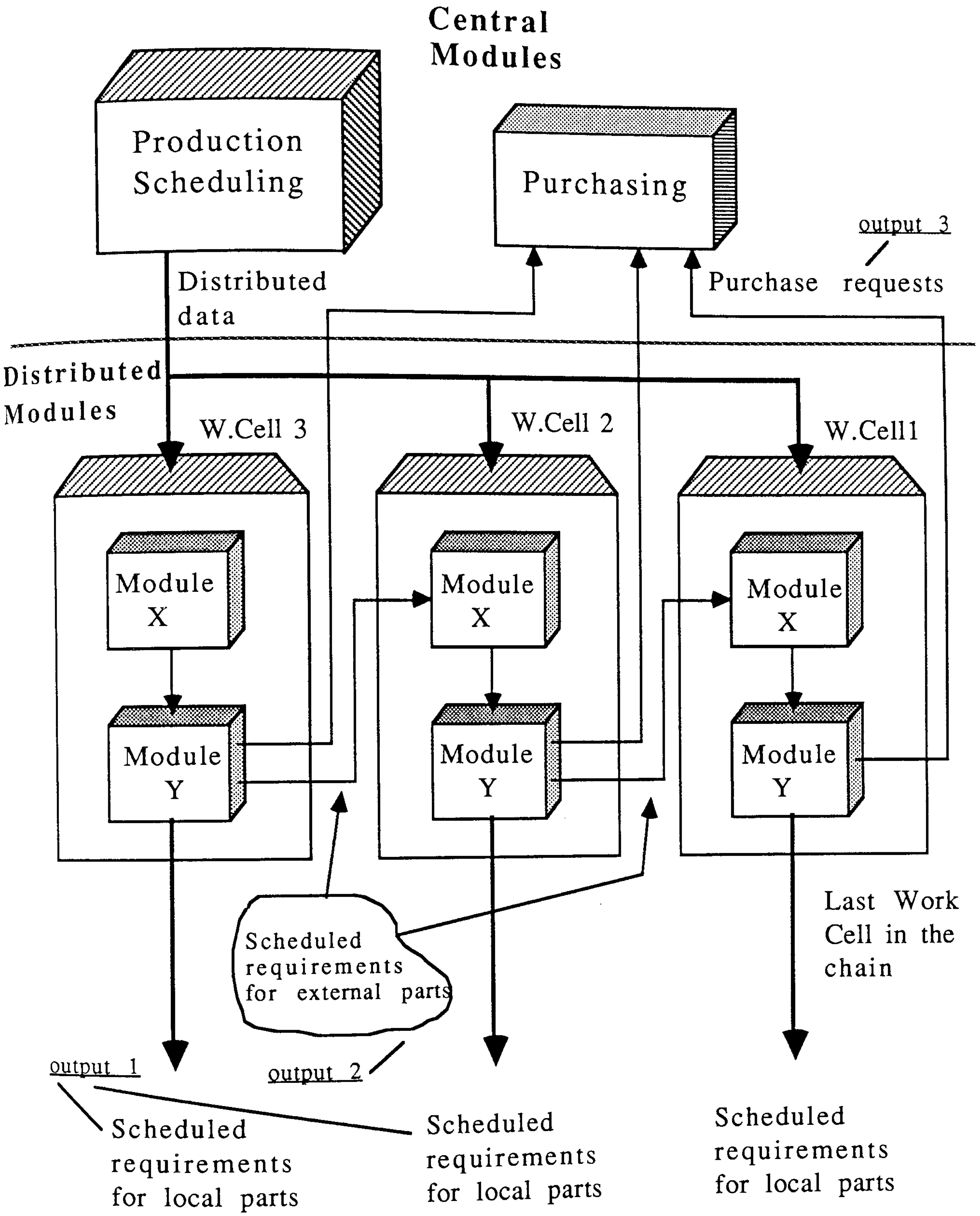


Figure 7.6 Interactions between central modules and distributed local modules in work cells

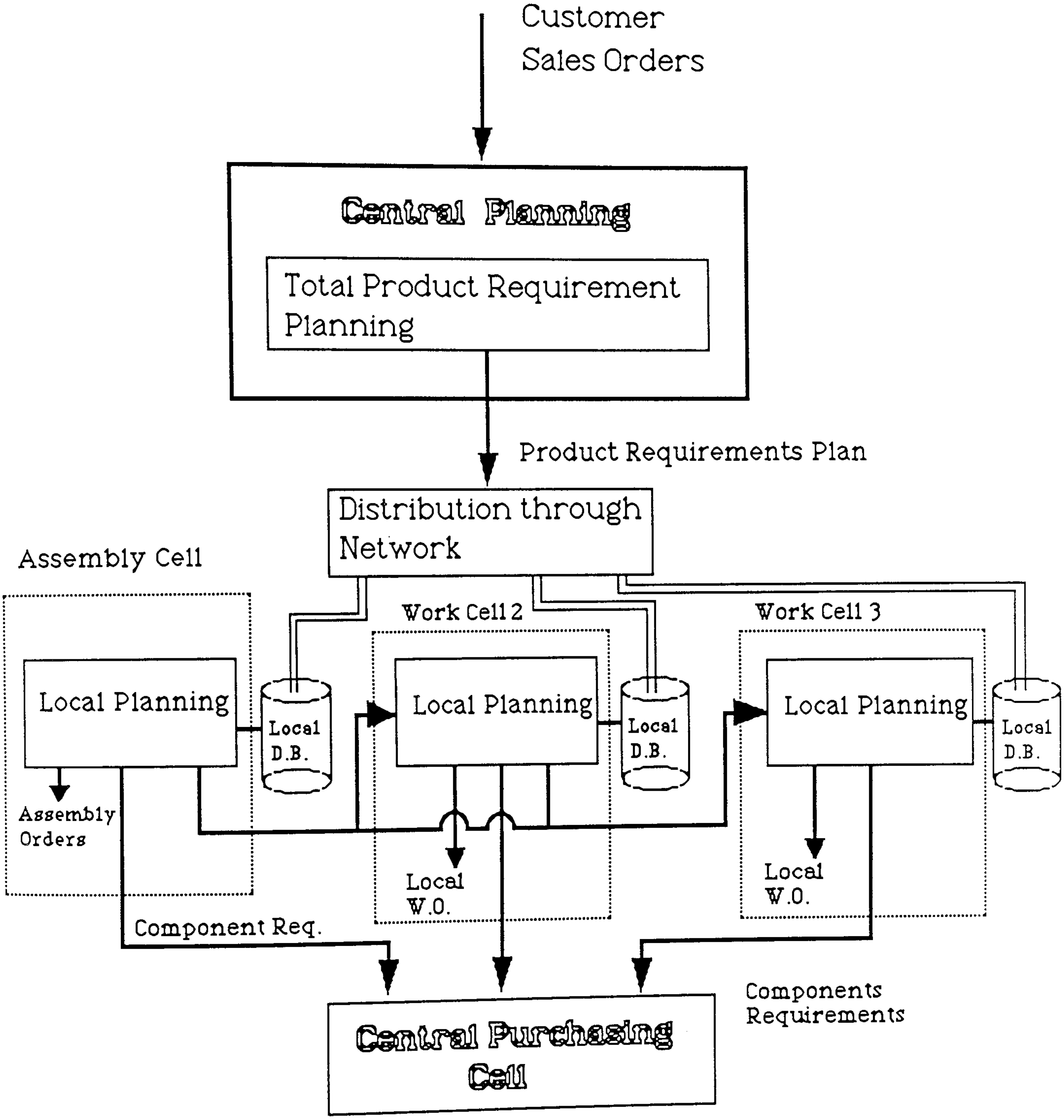


Figure 7.7 Interrelationships between local planning modules and central planning modules

7.1.4 LOCAL TASKS, OBJECTIVES AND STORAGE IN A WORK CELL

The constitution of a work cell is very similar to an ordinary machining cell, as they were both derived from the GT principle. With the adoption of distributed planning and control concept, a work cell will be much different in the way that it has more responsibility for management decisions. This is usually not found in an ordinary GT machining cell.

7.1.4.1 LOCAL TASKS AND OBJECTIVES

In theory, each work cell is responsible for its performance against its allocated tasks and prime objectives. Only at a specified interval will the performance of each work cell be reviewed and assessed by other central cells in order to obtain system optimisation. It is therefore important to have a self- monitoring module in each work cell so that smooth operations can be ensured. Real-time closed-loop data links can be used to provide instant feedback from work cells to central cells if such a decision is justified.

Prime objectives which can be considered in a work cell include the following :

(1) to achieve a specified percentage of utilisation of local resources. This may include a reduced set-up time and total lead time;

(2) to monitor incurred costs as a self-contained independent cost centre;

(3) to meet a customer's particular demands - priority rules may have to applied to expedite the urgent orders.

In addition to local objectives, there are a number of local tasks which may be contained in a work cell. Some of the essential functions are displayed in Table 7.1.

Some of these local functions come from the distribution of central cells. The actual number of these distributed functions depend very much on individual system configurations. As a consequence, not all work cells will necessarily possess the same functions and hence the local objectives. They may vary from work cell to work cell because of differing requirements and application environments.

Local Task contained in a Work Cell

Planning and Control activities	**Actual fabrication processes**
Inventory control	FMS, FMC
MPS	DNC, CNC, NC
MRP	Ordinary machinery
Capacity planning	Automated machinery
Shop scheduling	Robotics
WIP minitoring	
Job costing	
What-If analysis	
Quality control	

Table 7.1

7.1.4.2 LOCAL DATABASE

In theory, a work cell is characterised by the presence of a self-contained local database. It will support only the local activities occurring within a particular work cell. Apart from the initial data distribution and the necessary communications with other work cells, the database itself is almost a self- sufficient unit. Figure 7.8 shows the possible content of a localised database in a work cell.

In general, the system elements contained in a work cell can be divided into three main groups : control tasks, local planning activities and local manufacture. Figure 7.9 illustrates the interactions between these elements and the local database.

Each individual work cell, after the initial data distribution process, is totally flexible and self-sufficient in its decision making responsibilities. It is not in any way restricted to a pre-defined frequency of running its own tasks and hence its data update. In theory, a work cell should be able to freely exercise its local modules as frequently as required. It would not normally require the consent from other cells, nor would it cause interference to operations in other cells. This facility ensures that each work cell can always work to the optimum strategy on data updating and management in accordance with its actual requirements.

7.1.5 DATA ACCOUNTABILITY

Data accountability will be greatly improved in a distributed planning and control environment because of the characteristics of localised data processing, operations and management. In a distributed environment, the amount of information to be processed at any one time is much reduced and the definition of a data group is much more clearly defined. Finally, because the database in a work cell mainly supports just local functions, the number of routes for necessary information flow to modules in other cells is largely reduced.

Each work cell, once the central master production schedule has been distributed, can go its separate way to perform its own assigned tasks. The cell therefore is not only able to plan for a realistic schedule using its resources, it also can monitor all the internal processes so that satisfactory results can be obtained.

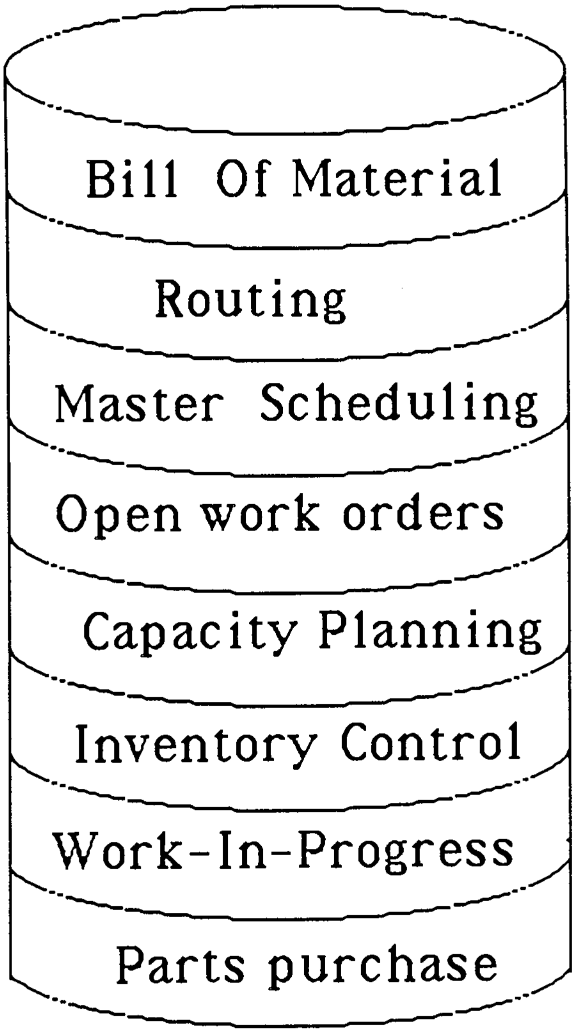


Figure 7.8 Content of a local database in a work cell

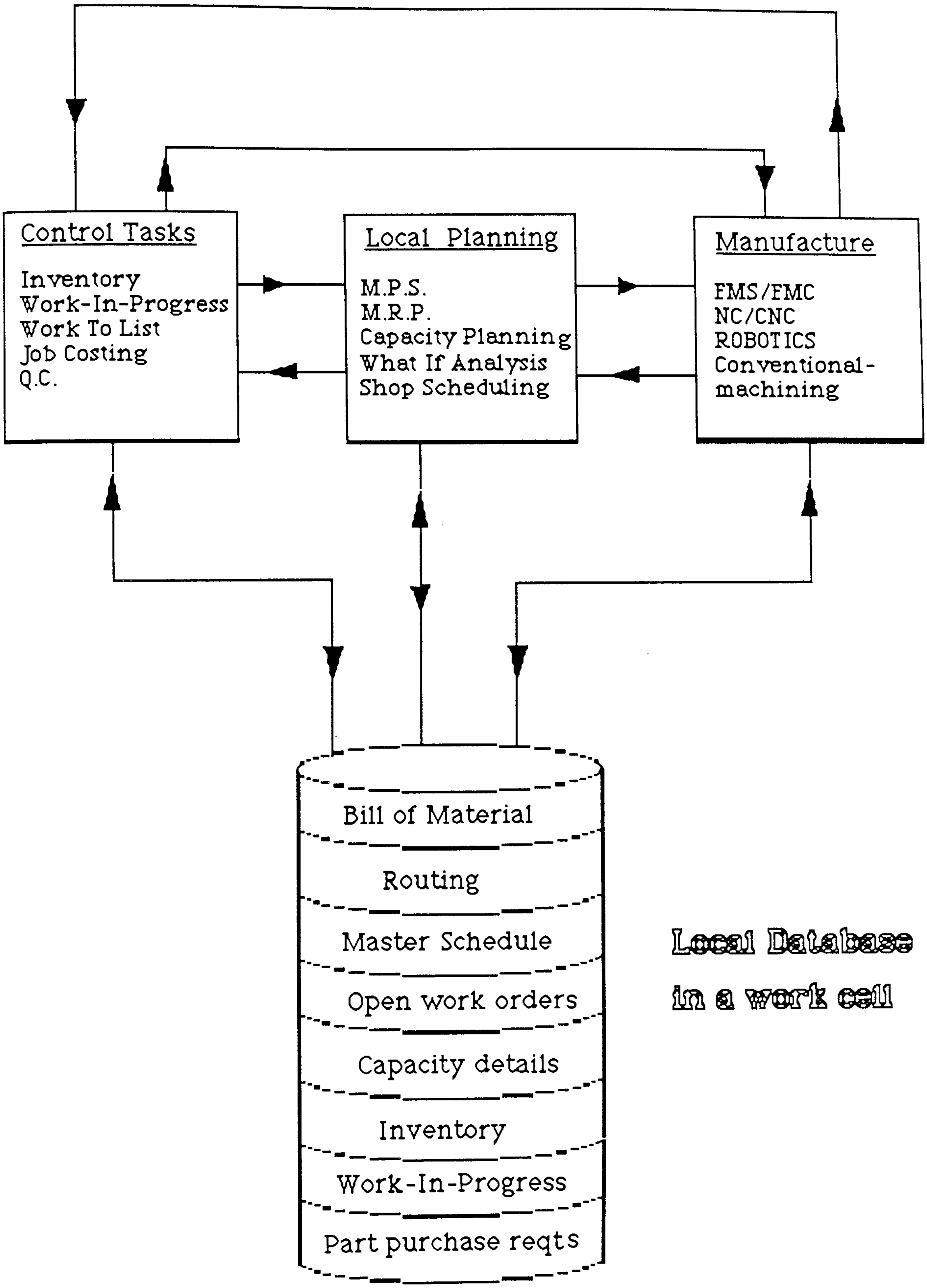


Figure 7.9 Interactions between local activities and local database in a work cell

7.2 POTENTIAL BENEFITS OF DISTRIBUTED PLANNING AND CONTROL

There are a great number of benefits that are likely to result from adopting the distribution strategy. Some of these benefits are suggested as follows :

(1) improved efficiency in system control;

(2) further enhancement of the system flexibility in a cellular system;

(3) faster localised data processing;

(4) improved response to new decisions or order changes;

(5) capability of simplifying and rationalising complex tasks in an integration environment, and reducing the amount of data in process at any one time;

(6) the link between management and shop floor can be improved;

(7) data accountability can be improved within each system unit.

The concept of distributed planning and control allows shop floor personnel to take part in making management decisions closely related to their area of work. This could greatly reduce the traditional barrier between the central management and the shop floor management. In addition, central management would no longer be burdened with all the detailed planning. Each work cell would have to make decisions of its own in order to cope with changes.

Accuracy of data is also improved as a consequence of frequent data updates and adjustments. This is possible because of the improved processing speed and the smaller amount of associated data within each work cell.

Although the complexity of the design of software modules in a work cell does not only depend on the amount of data to be processed, it is still greatly reduced for the above reasons. In general, because the local software modules in each work cell only have to handle a limited amount of data, they should be easier to design, as well as more efficient to implement and operate. Because of the similarities of these local software modules, standardisation of programming is also possible.

The major advantage of applying the distribution concept is greatly improved system flexibility. The concept makes the introduction of new functions into an existing work cell relatively easy. For example, new management approaches can be implemented by a particular work cell when required. These new management approaches could include material control, and manufacturing simulation techniques.

A simple demonstration is given in figure 7.10, in which a new simulation module is introduced to replace the existing one in a work cell. The newly implemented module will be compatible with the rest of the system, so long as its design has the embedded data links.

The use of local database in each work cell provides potential benefits which include faster data retrieval, more efficient data management and maintenance, better data accountability, use of smaller data-storage devices and simpler individual database structure design.

7.3 INSTALLATION IN PRACTICE

In previous sections, the characteristics of the distributed planning and control concept as well as its role in a cellular CIM system have been discussed. An example was used to explain how such a distribution approach can be applied to two central planning modules X and Y.

In this section, module X and Y are substituted by two common central functions known as MPS and MRP respectively. The purpose of this is to examine the logical procedure for distributing a specific central function - MRP in this case - from the initial stages when it is analysed, until it has been decentralised, distributed and implemented in a work cell.

Figure 7.11 demonstrates a conventional view of the interaction between a MPS module (MPS Cell) and a MRP module (MRP Cell). The MPS cell gathers all product demands and produces a time-phased gross requirement table. The MRP cell then calculates the net requirements and the corresponding dates for delivery of these parts and components which are required to satisfy the demands. Capacity planning is then carried out to analyse the potential load on each work centre at different periods. Results are then used in a simulation module in which the entire schedule can be verified for its reality. The sequential operations in the MPS, MRP and capacity planning modules will be repeated until final results are satisfactory. Subsequently,

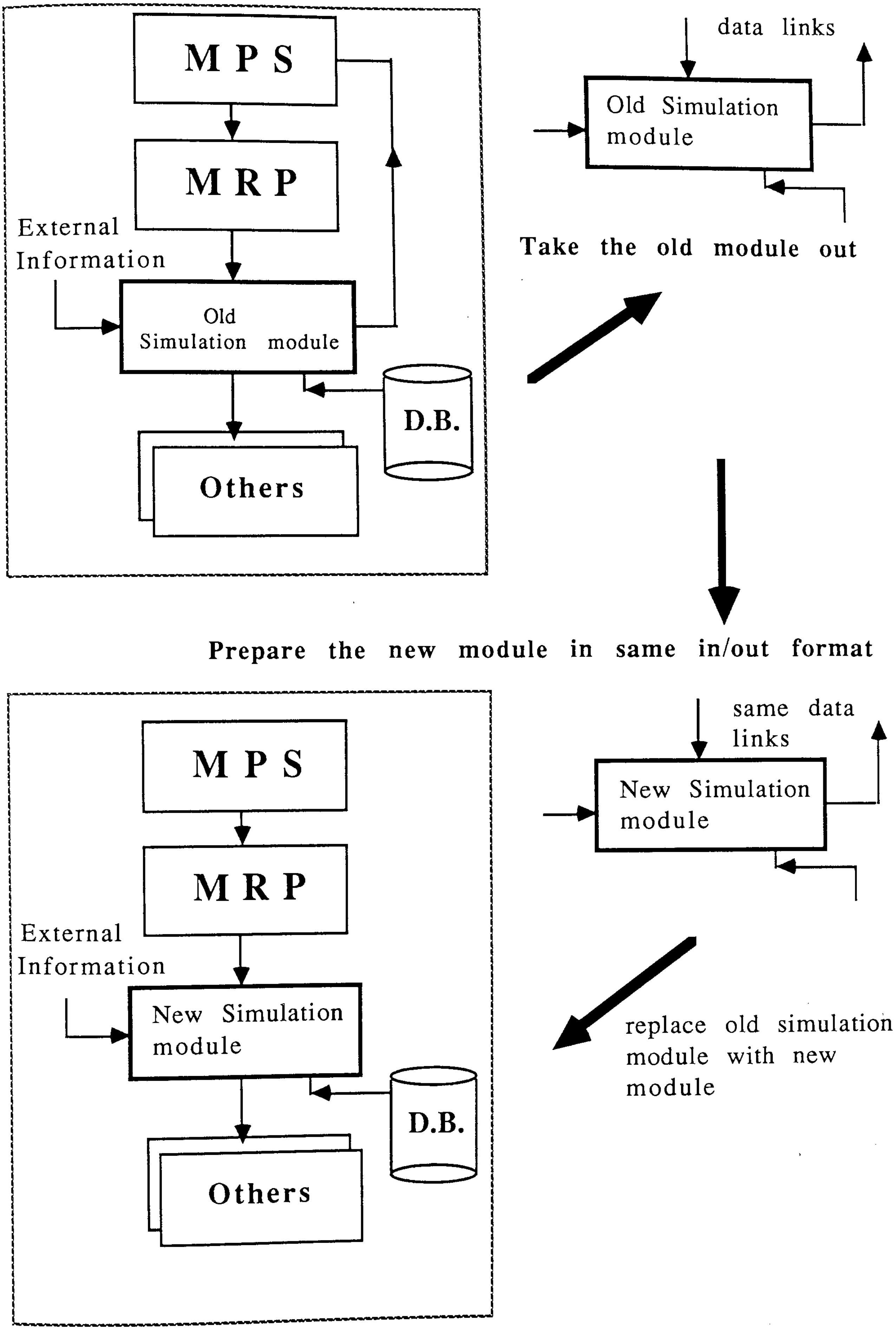


Figure 7.10 Substitution of a simulation module in a work cell

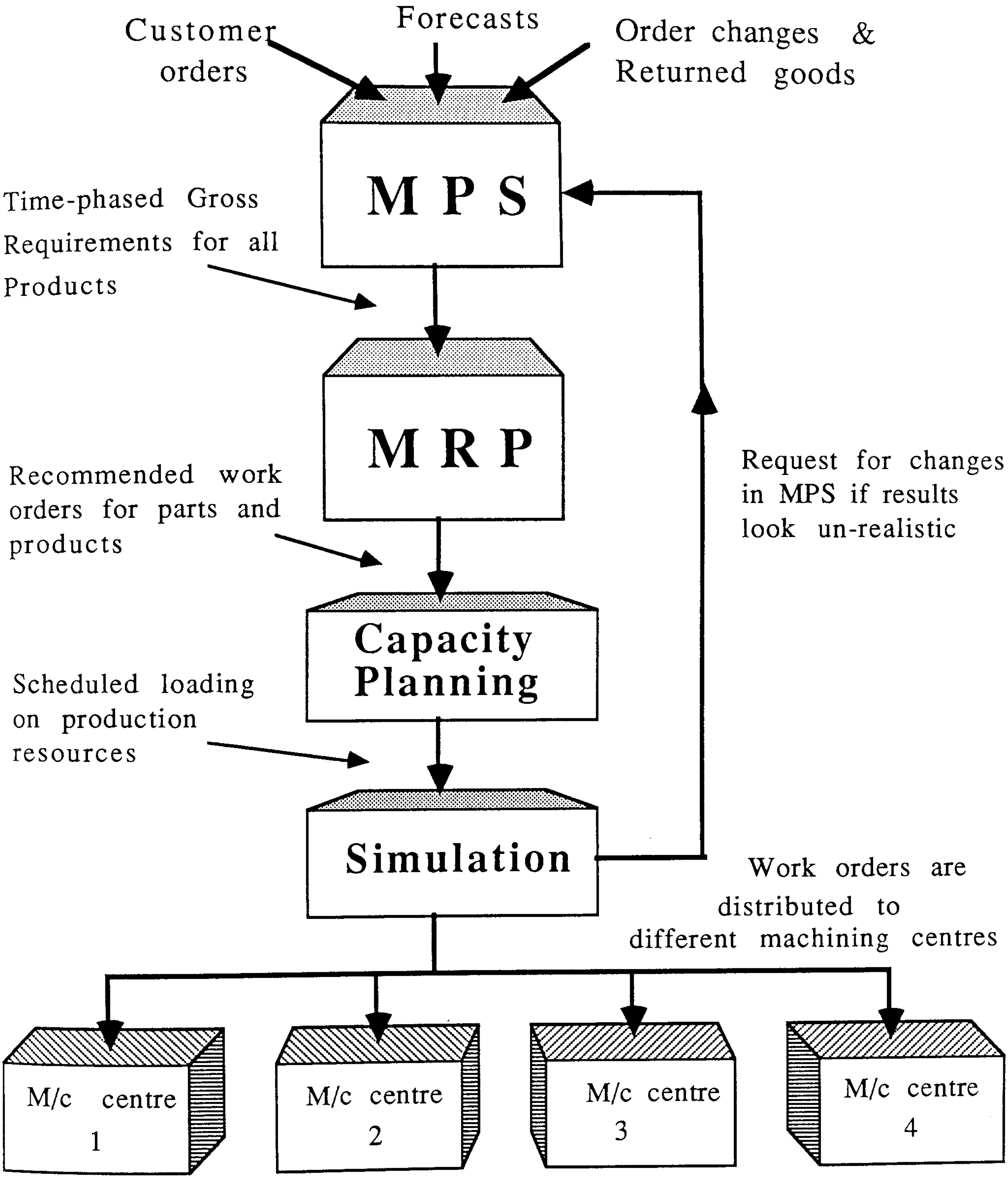


Figure 7.11 A conventional view of MRP process

recommended work orders for parts, subassemblies and products are generated and issued to various work centres. In addition, recommended purchase orders for bought-out components are also transferred to the central Purchase Cell.

7.3.1 ANALYSIS PRIOR TO DISTRIBUTION

In order to distribute the MPS, MRP and the capacity planning functions into work cells efficiently, the following aspects must be examined prior to any distribution process :

(1) the IN and OUT data formats and the information links of the function concerned;

(2) its role in the overall CIM hierarchical structure;

(3) functions and objectives in each cell;

(4) specifications of product group allocations;

(5) the development of a central co-ordinator to maintain data transfer between central cells and work cells following distribution;

(6) the compatibility of a distributed function in the destination work cell;

(7) data links between work cells for direct communication after distribution has occurred.

7.3.2 ACTUAL DISTRIBUTION PROCEDURES

If the results from the above analysis is satisfactory, then the actual distribution process may commence. The logical procedures to distribute a central function together with its data are explained in the following steps :

(1) analyse the software modules contained in the MPS cell and the MRP cell, so that their actual operations, data requirements, related data files and essential data links can be identified;

(2) check the compatibility of each function in the MPS and the MRP cell which is to be distributed;

(3) install local MPS and MRP modules in destination work cells. There are two ways of doing it :

  a) modify existing software modules in the two central cells so that they can be used in a local work cell. The modified modules are then transferred into the dedicated computer of each work cell;
  b) develop new software modules for local MPS and MRP process with references to the original modules. These new software modules are then stored in each work cell's local computer;

(4) distribute relevant data groups into appropriate local databases. This should be done after the local MPS and MRP software modules have been properly installed;

(5) develop data links between work cells which are necessary for these newly installed local modules. These data links should be designed before the distribution process.

After the above procedures have been completed, the original central MPS and MRP cells are now be functionally substituted by their corresponding local modules in each work cell.

7.3.3 OPERATIONS OF LOCALISED MPS AND MRP WITHIN A WORK CELL

Figure 7.12 illustrates the operations of the local MPS and MRP modules in a work cell. In this figure, all customer orders and forecast demands are first analysed by the central MPS cell which acts mainly as a co-ordinator. The results are then distributed to the suitable work cells in accordance with their pre-specified product group assignments. Once this is done, the local modules of a work cell will take full control over the remaining subsequent operations. Local MPS, MRP, capacity planning and simulation modules work together in the same sequence as before distribution, except that these operations are now carried out in each work cell locally instead of at a central location.

After the central MPS data has been distributed to a work cell, the local MPS module will first consolidate this data by combining it with other essential data to form a

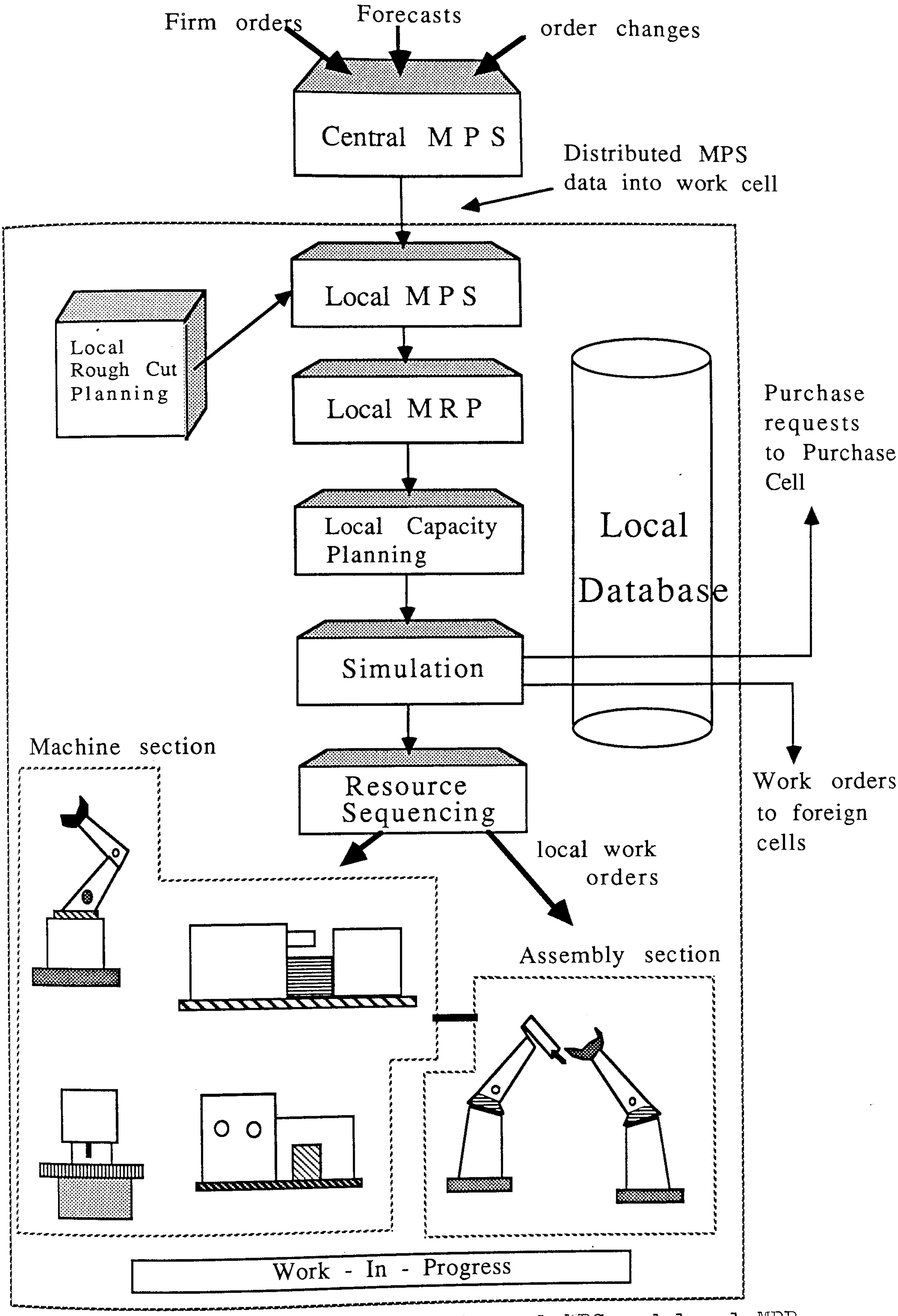


Figure 7.12 Operations of local MPS and local MRP modules in a work cell

localised MPS file. This file is then used by the local MRP module in order to complete the calculation for the actual material requirements. Final results generated in a local MRP module include suggested work orders for local parts, suggested orders for external parts which are made in other work cells, and suggested purchase orders for bought-out components.

Local work orders are monitored by the local WIP module within that work cell. Work orders for parts or subassemblies which require extra resources from other work cells will be transferred, through the established data links, via the LAN, and finally to the appropriate destination work cells where those resources are provided.

As before, these work orders which have been transferred to a new work cell will be combined with the distributed MPS data already in that cell. Local MRP is then activated to produce the three types of orders for that cell. Similar processes will be repeated in each work cell until all external works orders have been generated and properly received. This relationship between the work cells has formed a chained reaction which stops at a final work cell.

Although it is possible to transfer the finalised MPS information from each work cell to the central MPS co-ordinator as feedback, it will increase the complexity of the overall system and hence reduce the intended flexibility and data accountability in a work cell. One method which can be used to diminish the significance of this feedback loop is to apply Rough Cut Capacity Planning along with the central MPS before its data is distributed. This reduces the chance that potential bottleneck resources in various work cells will be overloaded.

Some technical constraints in relation to the practical application of the distributed planning and control concept into a cellular integrated system will be discussed along with the development of an embryo cellular system in the next few chapters.

7.4 THE DECENTRALISATION CONCEPT APPLIED THROUGHOUT A CELLULAR CIM SYSTEM

It is relatively innovative to consider the cellular concept with respect to design of a CIM system. It is equally new to suggest that the application of the cellular approach will ultimately lead to the decentralisation and distribution of certain central planning and control functions.

Because of its infancy, the distribution concept, when first applied, may seem less suitable for some central functions. These functions may include sales order processing, CAD and purchasing. Other functions, which by nature are more suitable, may include MPS, MRP and capacity planning.

An interesting point to note is if most of the essential central functions such as MPS, MRP, capacity planning, purchasing, shop scheduling, quality assurance (QA), inventory management, WIP, CAD/CAM and even finance and budgeting are all decentralised and distributed, then each work cell will become self-contained company cells operating in the same company. They can also be regarded as sub-contractors existing side by side within a company. The feasibility of such an idea will be discussed in the final conclusion of the thesis. Figure 7.13 demonstrates the co-existence of three company cells, all having similar features. They are integrated with one another through a local area network system.

7.5 DEVELOPMENT OF AN EMBRYO SYSTEM TO DEMONSTRATE THE CELLULAR SYSTEM APPROACH AND THE DISTRIBUTED CONTROL CONCEPT

The proposed cellular CIM system has a lot to offer smaller firms which may previously have been discouraged by the conventional 'all embracing' and inflexible centralised integration approach. The emergence of cellular technology has simplified the generally formidable and complicated depiction of a CIM system. It converts such a system into a number of smaller, more controllable units. The resulting system is therefore much easier to understand, to design, to maintain, and to operate. In addition, this permits clear objectives to be defined for each unit, hence both development time and cost will be reduced.

With the advanced development of microcomputer technology and information technology, it is feasible to use microcomputers and local-area-network systems to form the technical basis of a cellular CIM system. This is largely because each defined unit within such a system is highly flexible, and its size and associated data limited. Consequently, smaller but powerful microcomputers can be used tactically to achieve the desired total integration philosophy.

The next few chapters will be dedicated to the development of a microcomputer-based embryo cellular integrated system. It was designed to demonstrate the characteristics of cellular philosophy in CIM system design. Practical procedures in implementing the distributed planning and control concept into work cells will also be discussed.

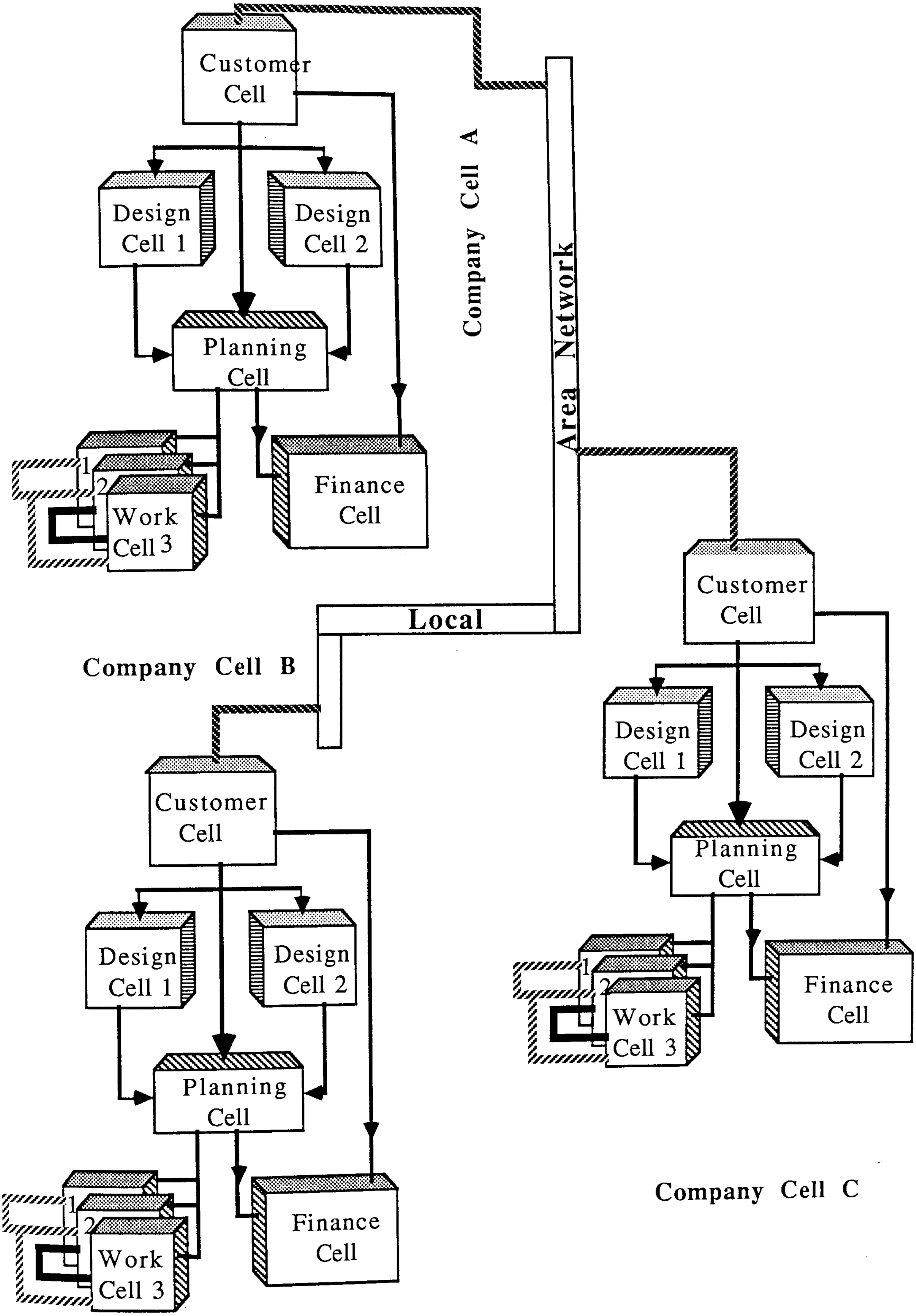


Figure 7.13 Formation of integrated company cells within a company

CHAPTER 8 DEVELOPMENT OF AN EMBRYO CELLULAR CIM SYSTEM - THE INITIAL PREPARATION

As discussed previously, the adoption of a cellular system approach, using localised databases as well as the distributed planning and control concept based on smaller but powerful computers, notably microcomputers, can make a significant contribution towards the design of a CIM system.

This chapter describes the main objectives and the development procedures of an embryo cellular integrated system which is microcomputer based. The chapter will concentrate on the initial preparation of this system development, including hardware and software requirements, as well as the specifications for such a system and its multiple databases.

The next chapter will make an in-depth examination of the system methodology used in the development, including the distributed database structure design.

8.1 OBJECTIVES OF THE EMBRYO SYSTEM DEVELOPMENT

8.1.1 DEFINITION OF THE EMBRYO SYSTEM

The system developed is called an embryo system as its main role is to demonstrate the cellular concept and the attributes of distributed planning and control developed in this thesis. Most of this embryo system's software modules have been developed using a relatively simplistic approach which, nevertheless, forms a significant part of both the cellular system approach and the distributed planning and control technique.

8.1.2 OBJECTIVES OF THE DEVELOPMENT

The main objective of the embryo system development was to test the arguments and proposals which were established earlier in this thesis. The development of these arguments and proposals with reference to various parts of the system can now be verified. The system has been configured and re-configured several times according to pre-defined specifications. Each configuration was accompanied by a comprehensive test run and the results were compared and discussed at length. Conclusions were then drawn based on these results.

The developed embryo system is intended to demonstrate and verify the arguments and hypotheses established in this thesis and can be summarised as follows :

(1) an integrated system such as CIM should be developed from first principles, rather than built from existing systems;

(2) the cellular approach can be applied in order to simplify the complexity of CIM system design;

(3) localised and smaller databases can be used to replace a huge centralised and common database;

(4) the distributed planning and control concept can be a useful technique to help achieve system decentralisation so that central management functions and activities can be carried out more effectively in individual work cells;

(5) the use of LAN and low cost computers such as microcomputers is feasible in a cellular CIM system.

Another important objective of the embryo system development is to establish some design guidelines and systematic procedures for the design and implementation of a cellular integrated system. These guidelines include the structures of databases and data files used, the characteristics and features of each cellular software module, the relationships and communications between different system modules, and the necessary data links that are required between the work cells in a cellular system.

Also, the experience gained during such development will be very valuable for further development of bigger systems, or even the enhancement of the embryo system, itself. There are always unexpected difficulties and problems in hardware, software and communication areas which are not encountered during the design and conceptual stages but appear when the system is actually installed and being used. The embryo system will highlight nature of these problems, and will also provide some useful hints regarding potential solutions. In addition, some suitable development tools, including both hardware and software tools, will most probably be identified during the development process.

The distributed and localised database is an important issue and the embryo system should demonstrate the advantages that the use of such databases can effectively offer compared to a centralised database in a true integration environment. In addition, as the distributed planning and control concept is still in its infancy, it must be evaluated and tested in a purpose-built experimental system model. The embryo system could serve this objective.

The flexibility of system configuration offered by the embryo cellular system allows the optimisation of the most efficient configuration for differing application requirements. It can, therefore, be regarded as a simulation tool prior to the development of a bigger system.

Finally, the experience gained in building such an embryo system, is highly educational in its own right. It can, therefore, undoubtedly be used as a training tool and as a research basis for development of similar projects.

In general, the key objectives of the embryo system development can be summarised as follows :

(1) to prove that the concept of cellular CIM system is feasible, and that smaller computers and smaller databases can be used;

(2) to verify the argument that the cellular approach will simplify the CIM system design and its implementation, and will also improve the flexibility in terms of system configuration;

(3) to evaluate the statement that the distributed planning and control technique should be extensively used to enhance the developed work cells in the shop floor so that the overall system flexibility as well as the individual performance can be improved;

(4) to establish structured guidelines for design which can be used in the development of a bigger system;

(5) to establish some standardised procedures in which system software can be developed;

(6) to prove that the use of distributed local databases would improve the overall system efficiency and data accountability;

(7) to locate unanticipated technical problems which may arise in the form of hardware, software, system communication, even in the design concept itself;

(8) to evaluate the suitability of using a database type programming language in an integration project;

(9) to identify the necessary systems, including software, hardware, and network communication system which would be required in a full scale system development;

(10) to use the embryo system as a simulation tool prior to making any greater commitment;

(11) to use the various features of such an embryo system for training purpose.

The developed embryo system is capable of demonstrating all the above objectives, although emphasis may vary at different stages.

8.2 SPECIFICATIONS OF AN IDEAL MICRO-BASED CELLULAR CIM SYSTEM

There can be a number of features considered in the embryo system development, and the following paragraphs represent some of the important ones which would affect the resulting system.

8.2.1 MULTI-TASKING AND NETWORKING CAPABILITIES

The embryo system should provide both multi-tasking and networking capabilities. The multi-tasking function will allow the user to run several jobs simultaneously on one computer. This is an important issue for such an experimental system as the number of computers to be used is likely to be restricted. In reality, the total cost incurred for the hardware used is always an important criteria for system specification.

From an experimental point of view, the multi-tasking characteristics enable a specific computer to emulate the operations of several work cells, and hence the data interactions between them can be evaluated. Figure 8.1 illustrates a simple

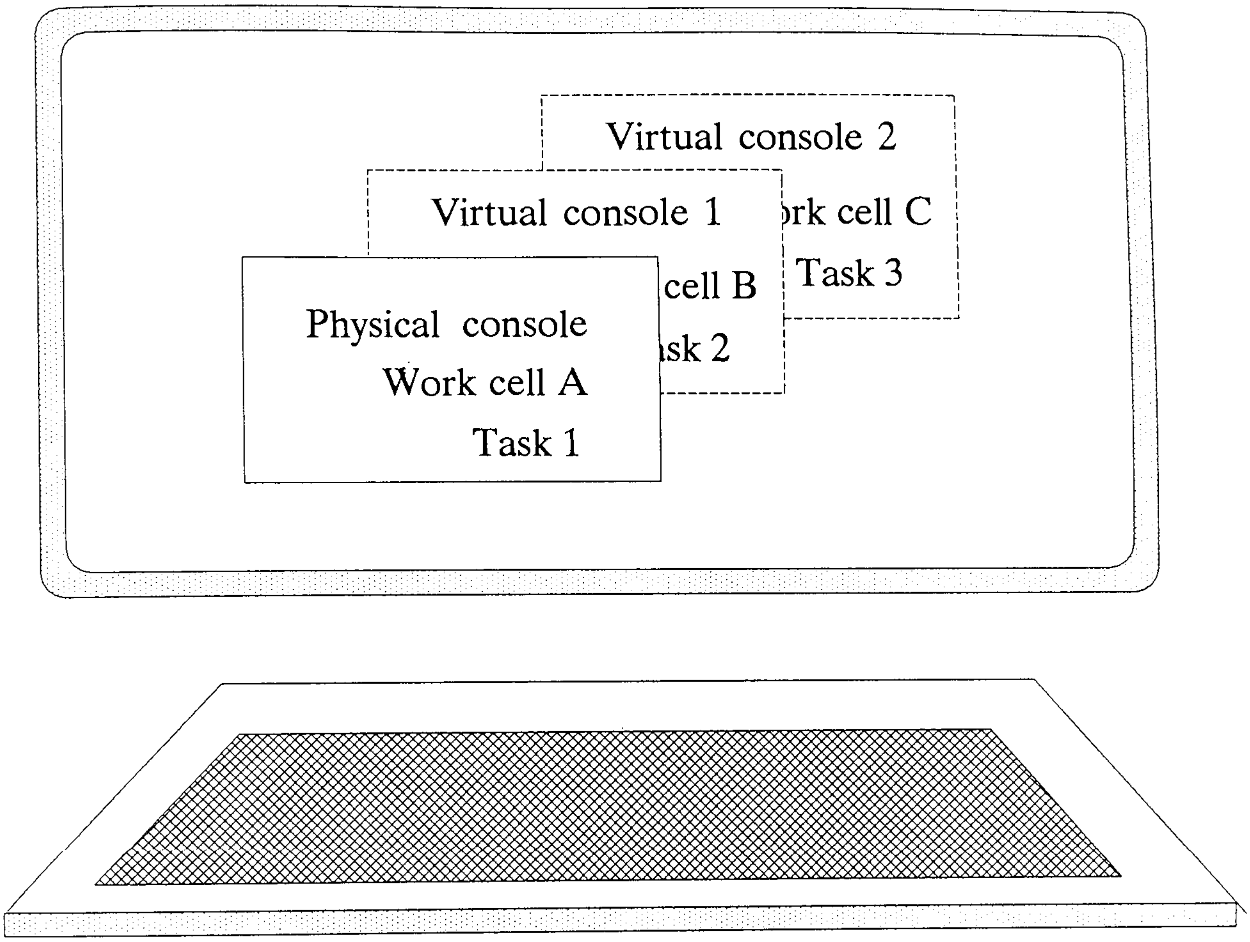


Figure 8.1 A simple view of multi-tasking configuration

configuration of a multi-tasking system, in which each console may represent the control of a separate work cell.

The main advantage of a networked system is that data can be transferred between computers efficiently. It also allows the attached periherals such as printers and plotters to be shared between all computers. This is a very important feature in a cellular CIM system, as it permits the individual microcomputers to be linked to form a larger integrated network, economically.

At the end of the development, some relevant test runs on the embryo system were conducted in order to demonstrate the effect of multi-tasking and networking capabilities on the cellular system principle. Chapter Eleven will explain how the system can be specifically customised in order to demonstrate this.

8.2.2 HARDWARE AND INTERFACING COMPATIBILITY

All the hardware used in the embryo system should provide high compatibility with each other. This will avoid the technical problems of interfacing different makes of computers and periherals, which may have adverse effects on the overall system performance. Ideally, all hardware should be compatible to the LAN system chosen. In practice, this is not often a serious problem because most commercially available hardware and periherals will support more than one common interfacing format as standard.

8.2.3 IDEAL SYSTEM FLEXIBILITY

One very important objective of developing the embryo system was to prove that the final system, when complied with the cellular system principle, would be highly flexible upon implementation and operation.

The ideal system, must have a high level of flexibility in terms of system configuration, system installation, user tailoring and normal system operations. This inevitably will probably give rise to an increased complexity in system software design. The final system therefore must draw a compromise between system design complexity and the level of system flexibility that it can provide.

8.2.4 IDEAL DATABASE SYSTEM DESIGN

Since the use of smaller and localised databases is one of the major considerations in the embryo system, all precautions must be taken into account to ensure that the design of such databases must be compatible with the cellular environment as well as with the concept of distributed planning and control.

Ideally, a highly efficient database management system which would enable all data to be readily accessible within the embryo system, should be installed. Some factors for consideration which could affect the database design in the embryo system are summarised as follows :

(1) the internal structure of each database must allow easy modification for future enhancement;

(2) because of the local database approach, it is inevitable that some data items may be physically present in more than one location. A carefully designed update algorithm is needed to ensure all these duplicated data items are updated at the same time so that data inaccuracy can be eliminated;

(3) the data in/out formats should be kept simple for easy modification;

(4) data fields have to be carefully defined so that they can be used to cover most information within a medium sized company;

(5) the dependence and independence of each data item must be analysed and well defined in the overall database structure;

(6) each data item, data file or database would normally belong to a unique 'owner' according to the extended cellular system concept. This ownership will affect the overall system efficiency and therefore must be planned with great care;

(7) the structure of a database must support easy data transfer between databases situated at different computers. Its format also has to be consistent throughout.

8.2.5 SYSTEM DATA INTEGRITY AND COMPATIBILITY

The way that the software modules in the embryo system would communicate, internally between themselves, or externally with surrounding factors such as users, customers' demands, application environment and management policy, plays an important role in the integrity and the compatibility of the system data.

In general, it has to be recognised that data integrity is not an entity which can be designed separately. It has to be considered at the preliminary stage of total system design, and also at the stage of system implementation. In addition, different data entry and update procedures should be introduced in order to secure the desired levels of system data integrity. Stringent procedures must be applied effectively to interface system modules and users. These procedures may include a systematic data entry sequence and format, comprehensive data error detection, extensive user-fool proof design in data entry and system operations, and finally the appropriate levels of data security.

8.2.6 MAJOR FUNCTIONS IN THE DEVELOPED EMBRYO SYSTEM

Ideally, all major functional cells maintained in some of the previous chapters must be included in the embryo system. These cells are the Customer Service, Design Engineering, Central Planning, Manufacture and Control, as well as the Finance and Administration. Each of these functional cells are represented by a number of relevant software modules.

However, the system will be too complicated if all the intended functions are to be included in the embryo system. On the other hand, the embryo system should contain sufficient software system modules to demonstrate the effect of the cellular principle and the distribution concept. Consequently, it is not necessary at this early stage to develop every single module. The next chapter will give more details of the essential modules which have been developed for the embryo system.

8.3 SELECTION OF SYSTEM HARDWARE

Some considerations were made to select the most suitable hardware and software systems for the embryo system development. The purpose of this section is to explain the criteria used to select the suitable hardware systems for development. It must be pointed out at this stage that although these selection criteria were adhered to, the equipment already existed in the university department did have some influence over the final chosen hardware systems.

8.3.1 HARDWARE REQUIREMENTS AND SELECTION CRITERIA

Each of the following sections represents a different type of hardware system which had to be selected for use in the embryo system development. Each section will first start off with the description of the basic requirements of the system, and then conclude with the hardware system which was actually chosen for use.

8.3.1.1 COMPUTERS AND OPERATING SYSTEM

Since multi-tasking and networking are two very important features in the embryo system, and both features demand a lot of processing power from the microprocessor, the ideal computers must be powerful enough to cope with the loads generated in such an environment. Both 8-bit and 16 bit microcomputers, at the time of development, were very popular. The 16-bit microcomputer is more capable of handling multi-tasking and networking, and therefore this type was chosen.

Colour monitors should also be used. Various types of data can be shown in different colours for easy distinction. These monitors should also provide a reasonable level of screen resolution so that graphics or CAD systems may be operated on these workstations.

At the time of development, two popular operating systems were available for microcomputers. They were known as CP/M and MSDOS respectively. CP/M stands for Control Program for Microprocessor, and MSDOS stands for Micro-Soft Disk Operating System. Unfortunately both operating systems imposed a restriction of usable memory in the computer. With MSDOS operating system, the maximum addressable memory (user memory) is 640 KB, and with CCP/M (Concurrent CP/M) operating system, the maximum memory attainable is up to 1Mb. In general, the bigger the memory a computer can support, the better the system performance.

The developed embryo system consists of three OCTOPUS 16 bit microcomputers, each with 768k RAM. Each computer can handle from one up to six tasks simultaneously under the Concurrent CP/M operating system. All three machines are connected to a local area network system called ARC-NET which allows the three machines to share common periherals and information. Two of the OCTOPUS have a 20 MB Winchester disk and a floppy drive, and the third one only has a single floppy disk drive for data back-up.

All the three computers have a medium resolution colour monitor. These monitors support both text mode and graphics mode, and can therefore be used for CAD and other graphical applications.

The expansion possibilities of the OCTOPUS were considered good, as it incorporates a number of expansion slots which can be used to fit any compatible functional board for future requirements. In fact, each OCTOPUS was already fitted with an IBM emulation board, a network card, a memory expansion board and a graphics board. All these boards can easily be upgraded or replaced if the system does need enhancement or modification in the future.

If the embryo system is properly configured, the two hard disk OCTOPUSes can both act as file servers and requesters, whilst the single floppy machine will only act as a requester. File servers, as their names suggest, would be responsible for supplying data from their local disk drives to those who request the data. A requester is just the opposite; it can only receive information from servers but would not itself send any data. The reason why the third OCTOPUS can only be configured as a requester is due to its single floppy disk drive configuration.
Each 20 MB hard disk was formatted into two partitions, namely drive A and drive B. The floppy drive is referred to as drive C. Consequently, there are four hard disks, altogether. With proper system configuration, one of these four hard disk partitions can be dedicated to the use of the single disk OCTOPUS only, through the LAN. This arrangement has enabled the embryo system virtually to consist of three hard-disk workstations instead of two. Such an arrangement has been proved very useful for development.

8.3.1.2 HARDWARE INTERFACING STANDARDS

Although it was stressed, previously, that the hardware (computers and periherals) used in the embryo system ideally should be compatible, a standard for hardware interfacing is still essential to secure hardware compatibility. For example, the printer and the plotter used in the system had to be connected to the networked computers through interfaces.

The fact that most modern microcomputers and other periherals support both RS232 and Centronic interface standards [Houten 1986] offers a solution to most hardware interfacing problems. For example, most external periherals such as plotters, printers, second display monitors, external disk drives, graphics tablets and digitisers need to be interfaced so that they can receive and transmit data from/to a host computer. This can be done relatively easily by using the serial or the parallel interface, provided a suitable cable is available.

8.3.1.3 LOCAL AREA NETWORK (LAN) SYSTEM

The local area network system is the main core of a micro-based CIM system. There are different forms of local area net-work systems. They differ both in terms of hardware components and the way they are connected. Each type of LAN has its own merits and restrictions.

Although at the time of development, there were few choices for the LAN system because of the computer hardware chosen, the following characteristics of a LAN system must be analysed in order to ensure its compatibility with the development plan :

(1) the maximum number of computers and periherals which are supported by the LAN system;

(2) the maximum versatility of network control system (usually known as network manager) in terms of user definition and system configuration;

(3) the flexibility of the LAN system in terms of installation, expansion and maintenance;

(4) the availability of application software which would operate in that network system;

(5) the support of file locking and record locking facilities;

(6) other physical constraints such as the limitation of the connecting cable length and the effect on the system response when all workstations are in use.

The local-area-network system finally chosen was called ARC-NET. It is a bus-type network which permits up to 128 computers to be connected together through a simple coaxial cable. The length of the cable can be extended up to fifty meters without the use of an 'active hub' which is basically a signal booster.

Figure 8.2 shows the major hardware set-up used in the embryo system. It also illustrates the connection of the three OCTOPUS computers to the ARC-NET LAN system through a coaxial cable. This particular hardware set-up also includes two line printers and one plotter which can be shared.

Full file locking as well as record locking facilities are available in the chosen ARC-NET system, and can be used by any software which is written to support these facilities.

The ARC-NET system provides a high level of flexibility for further expansion since an additional node can be simply connected to the network cable without any adjustment of the existing system. Also, each node can be individually configured as either a requester, a server or both without affecting the rest of the system.

8.3.1.4 OTHER HARDWARE PERIHERALS

There are two high speed dot matrix printers (OK1 84) attached to the embryo system. They can produce a printing speed of up to 200 characters per second (CPS) in draft printing mode, and up to 80 CPS in Near Letter Quality (NLQ) mode. Print paper used is up to 14 inches (132 column) in width.

The high printing speed and the versatility of these printers have two significant effects on the embryo system's performance. Firstly, the computer involved in the printing process will be freed more quickly so that it can be used for other functions. This is especially important if the number of computers is restricted. Secondly, specifications and formats for the different documents and reports are so variable in the embryo system that the use of a versatile printer will greatly improve the overall system's hard-copy making capability.

Other periherals includes an A3 sized digital plotter. It can be used to produce very good engineering drawings and charts. This is particularly useful for CAD or other graphical applications.

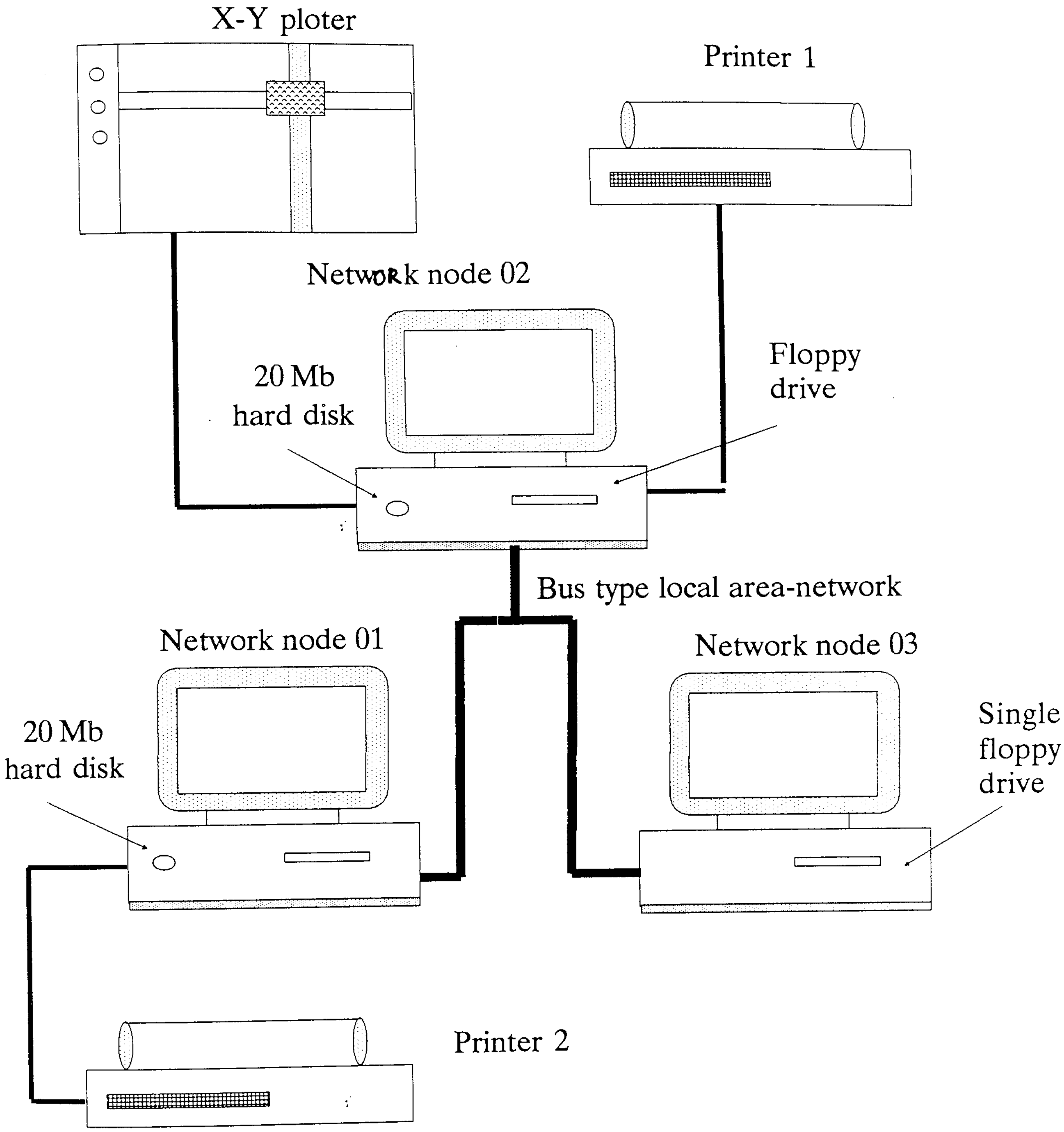


Figure 8.2 The basic hardware used in the embryo system

8.4 SELECTION OF SOFTWARE

The software defined in this context would include the computer operating system, a suitable programming language, and other supporting software tools for the system development.

8.4.1 SOFTWARE REQUIREMENTS AND SELECTION CRITERIA

8.4.1.1 OPERATING SYSTEM (OS)

As mentioned in the last section, there were two major operating systems available for microcomputers at the time of development, namely MSDOS and CP/M. The ideal OS for this development project must support both multi-tasking and networking facilities.

The latest version of CP/M, called CCP/M 4.1, was chosen as the major OS for the OCTOPUS computers used in the development. CCP/M stands for Concurrent CP/M, and CP/M stands for control program for microprocessors. It was developed and supplied by Digital Research.

CCP/M 4.1 is a multi-tasking operating system which can support up to six different programs running simultaneously. Only one task can be performed in the foreground (physical console) and the rest have to be in the background (virtual consoles). This OS is also compatible with certain networking hardware and software systems. The network manager, which is a piece of software full of networking commands and features, can be merged into the CCP/M OS itself and is readily available to users.

Another major advantage of using the CCP/M 4.1 operating system is that it allows the OCTOPUS computer to run both CP/M software and MS-DOS (notably IBM) software. This has proved very useful as some software which was developed for true IBM microcomputers can run without any modification. Standard off-the-shelf packages including LOTUS 1-2-3 (a spreadsheet system) and MLD2 (a CAD system) can be used successfully in this way.

As regards the disk file directory handling, MSDOS and CCP/M are quite different. MSDOS supports the hierarchy of directories, whilst CCP/M supports sixteen fixed partitions of a disk drive. It is not critical at this point as to which approach is better as either approach has not imposed any restriction to the system design concept. Figure 8.3 illustrates the two differing approaches of storing files in a disk.

8.4.1.2 PROGRAMMING LANGUAGES

8.4.1.2.1 REQUIREMENTS

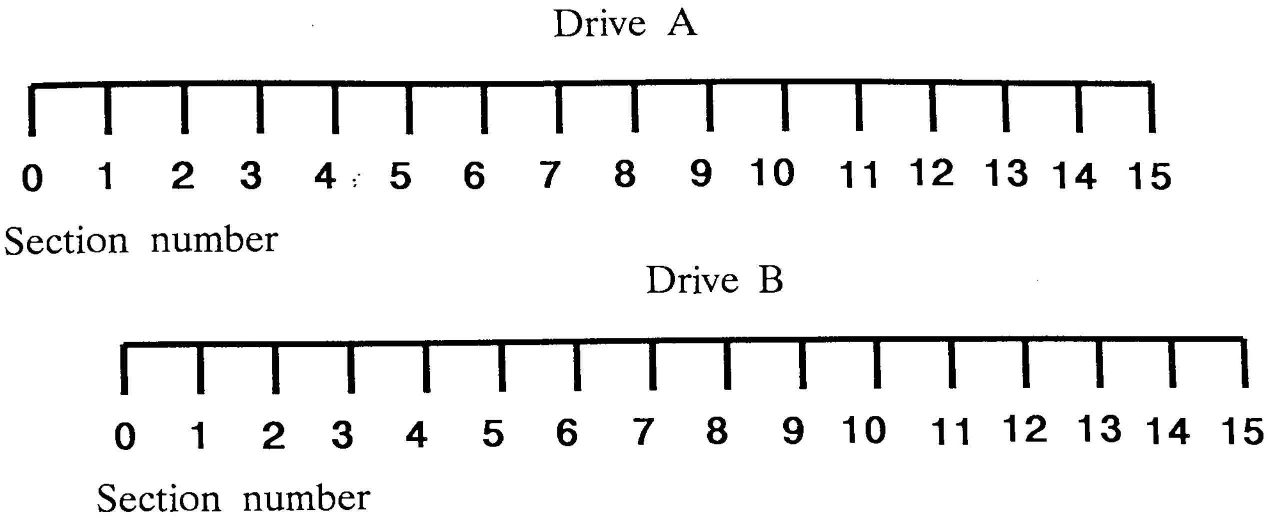
Software development for the embryo system played a very important role in the entire project, as many modules had to be written in order to provide the basic functions specified for the embryo system. The selection of a suitable programming language therefore was critical. Such a programming language would have to provide high flexibility in terms of software development for different applications. It would also have to be portable so that the same programs could be run on different types of computer. This is an important issue as different computers may be added to the network as further expansion takes place. The written program source codes would therefore have to work on these machines without any modification.

The chosen programming language should provide good facilities for data handling, as multiple database systems was the main criteria of the embryo system. The overall performance would be greatly affected if the chosen language is not suitable for data handling. The processing speed of the language can also have a significant effect on the performance of the whole system. Other features including the support of different data formats, easy editing and tailoring of the source codes, and the neatness as well as the structure of the language itself, would also play an important part in the software development.

Some popular programming languages were evaluated for their suitability for the embryo system development. These included BASIC, FORTRAN, PASCAL, and some so called Fourth Generation Language (4GL) which includes dBASE [Catchings 1986], Amber [Naylor 1986] and PC/FOCUS. The 4GLs generally are high level programming languages and can generate required application programs relatively easily and more quickly than the other languages [Catchings 1986, Salama 1986].

8.4.1.2.2 DBASE II AS PROGRAMMING LANGUAGE

CCP/M Directory Handling



MSDOS Directory Handling

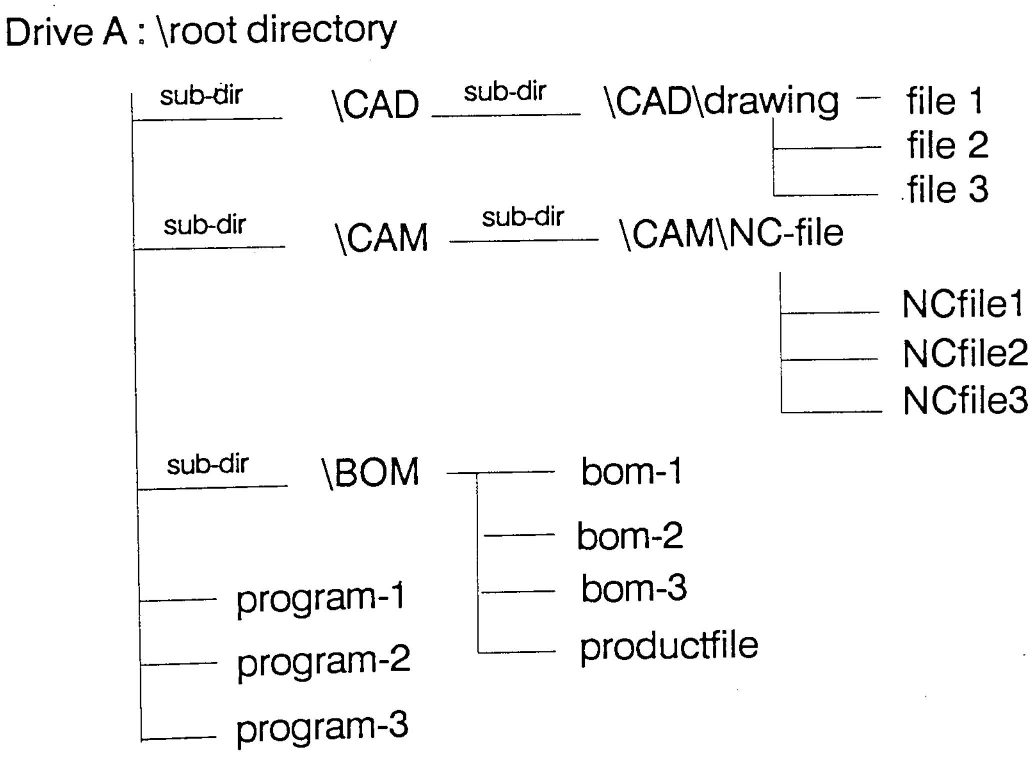


Figure 8.3 Files and directories handling approach in CP/M and MSDOS

From the evaluation, 4GL seemed to be the most suitable language for such an application. The advantage of using 4GL is that it provides an environment in which application programs could be developed much more quickly and more efficiently. In particular, dBASE II was chosen for this purpose. Its portability from one computer to another is extremely good and application programs written in dBASE can run on different machines without any modification.

At the time of development, dBASE II was a very popular database system as well as being a powerful programming language. Later, a more powerful version dBASE III and dBASE III plus, were released. The possibility of upgrading the entire embryo system from dBASE II to the latest dBASE version will be discussed in the final chapter in which recommendations for further development of the system will be suggested.

dBASE is a relational data base management system, and it is also a very flexible query language. It can be used interactively as a ready-to-run software package. On the other hand, its power is demonstrated when it is used as a procedural programming language in which application programs can be generated.

There are many powerful commands in dBASE, each of them is functionally equivalent to a subroutine of similar function in BASIC or FORTRAN languages. For example, commands like DISPLAY ALL FOR CLASS = 'MANUFACTURE' will display all the articles whose classification are 'MANUFACTURE'; REPLACE PRICE WITH PRICE * 0.1 FOR PRICE = $10.00 will select all the present prices which are equal or over $10.00, increase them by 10% of their present value, and then put the new prices back to where the original were stored; LOCATE ALL FOR 'CIM' $TITLE will select all articles which have 'CIM' in their titles.

The non-procedural characteristics of dBASE allows a huge program to be split into several smaller programs which are maintained in a functional relationship. This was particularly useful for the development of the embryo system as its software modules were kept reasonably small and independent but functionally related. In addition, this feature is particularly suitable for menu- driven and modular programming approach which were two main factors in the development of the embryo system.

In general, the use of dBASE II for the embryo system development could provide the following advantages :

(1) the language is easy to use. dBASE was originally designed to manipulate data in a highly complex environment. It is also easy to modify and to debug;

(2) it supports a structured programming technique;

(3) it has a number of simple but effective commands for data archival, data handling and data management;

(4) dBASE supports the cellular concept in which each program can be kept fairly small in size but allows the multi- levelled program execution. For instance, one dBASE program can call in another dBASE sub-program which in turn can call in the third dBASE subroutine. Figure 8.4 demonstrates this multi-levelled program execution in a simplified manner;

(5) dBASE can run almost on every single microcomputer which supports either the CP/M or MSDOS operating system. Latest version of dBASE (dBASE III Plus) can also run on the UNIX operating system. Consequently, the portability of the developed programs between machines should be very good;

(6) a number of compilers are available for dBASE should execution speed poses a problem. Examples of these are Clipper and dB Compiler;

(7) dBASE provides the embryo system with a good chance of integrating other systems which were written in different programming languages, as it supports a good few data IN/OUT formats;

(8) a number of third-party add-on development tools are available for dBASE. For example dB-Graph offers graphics capability for programs written in dBASE. Enhancement of certain features in the embryo system is therefore a possibility;

(9) as dBASE provides a systematic and consistent environment for programming, modules can be written and debugged more quickly and efficiently.

Another important reason for choosing dBASE was that some major systems developed previously in the same department were written in dBASE. The consistency of using dBASE provides the advantage that some of these systems can be modified and integrated into the embryo system. Two of these systems are CAMAC and MCS which will be described in detail later in the chapter.

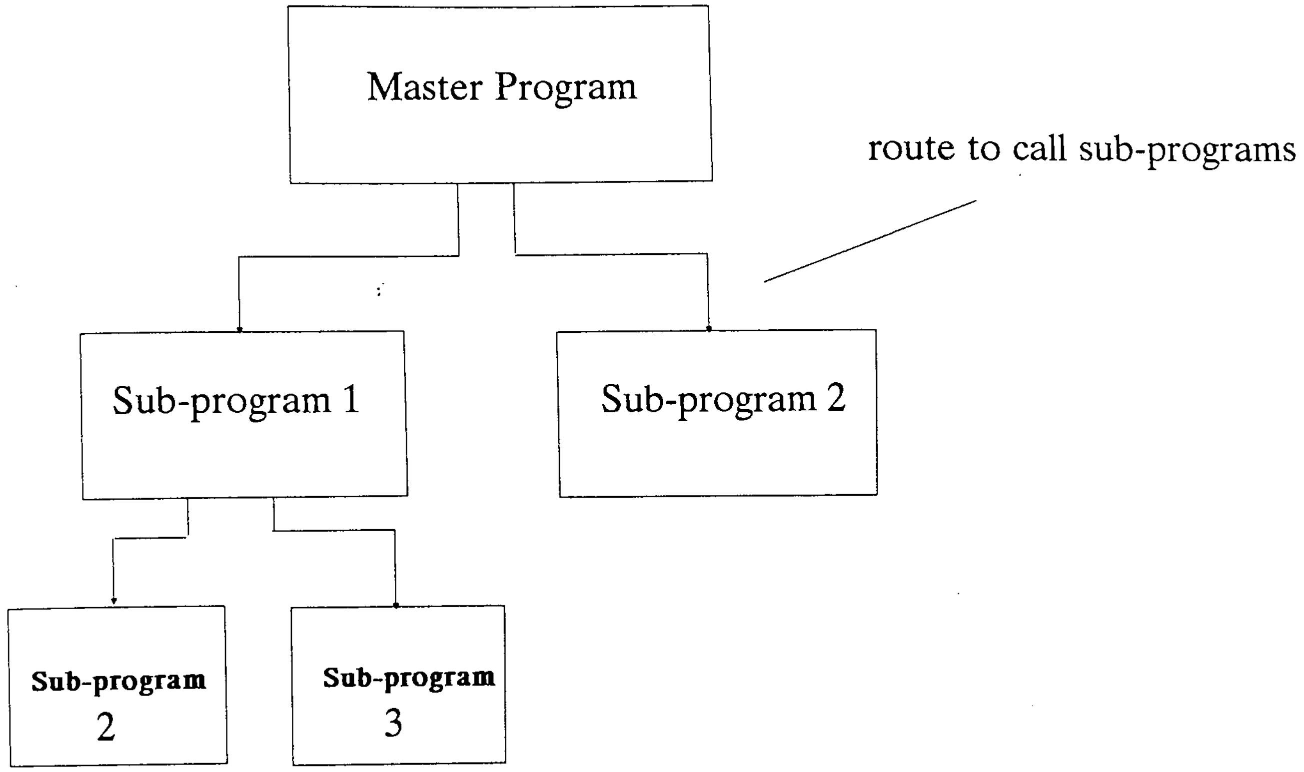


Figure 8.4 Multi-level program control with dBASE language

8.4.1.3 OTHER SUPPORTING SOFTWARE

There were some existing software systems in the department, which could be considered for incorporation into the embryo system. These include a dedicated manufacturing control system developed for a cutting tool company, a 2D drafting system, and a rather sophisticated coding and classification system.

8.4.1.3.1 MANUFACTURING CONTROL SYSTEM (MCS)

MCS stands for Manufacturing Control System. It was developed as part of a 'Teaching Company Scheme'. The system was developed for, and was also totally dedicated to, a medium sized company which produces cutting tools.

As the entire MCS was written in dBASE II, there were a number of useful modules which potentially could be modified and used in the embryo system. Acknowledgement to the author of the MCS is made in this context wherever appropriate.

Figure 8.5 shows the original planned functions of the MCS. Although the system was not completed when its author finished his degree, some existing modules such as the latest start date calculation and the work-in-progress monitoring were modified and used in the embryo CIM system. Other functions, although they could theoretically be incorporated into the embryo system, would have needed heavy modifications and generalisation.

The main objective of for merging some of the MCS's modules into the embryo system is to demonstrate the intended flexibility of the developed system to show that it is possible to integrate other software systems when the required data formats and links are supported.

8.4.1.3.2 CAMAC CLASSIFICATION AND CODING SYSTEM

CAMAC stands for Computer Aided Manufacturing Classification System. It is a component coding and classification system with high system flexibility one which can be easily tailored for use in a new application environment [Love 1986].

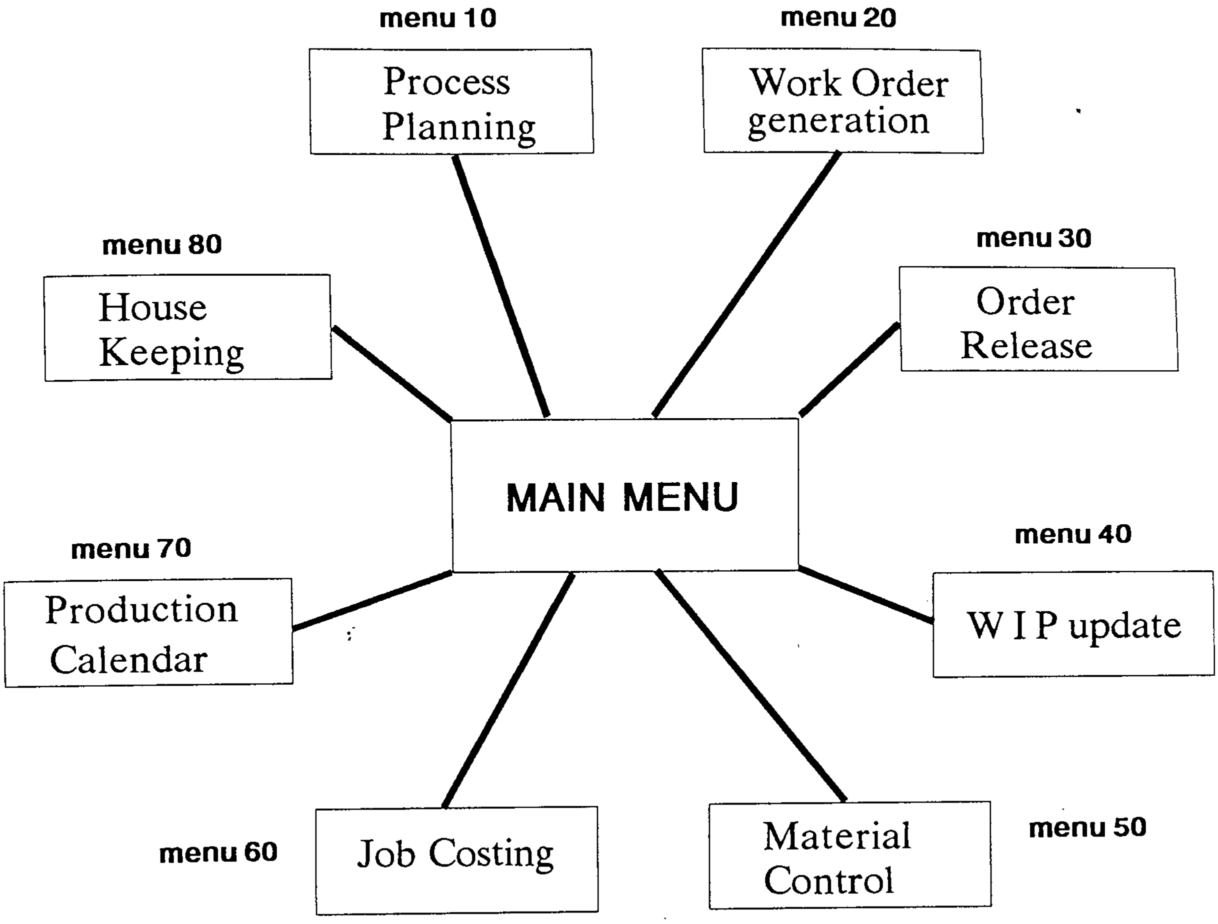


Figure 8.5 Major planned function in the MCS development

The CAMAC system uses a binary code structure to record the characteristics of a component. The binary coding method allows multiple entries in a column whilst a character code is restricted to a single entry. The multiple entry facility allows each code position to be dedicated to a single feature yet provides unambiguous recording of all the possible feature combinations. Thus, although the structure of the code is very simple, its recording capacity is much greater than character codes of a comparable length.

A graphics tablet is used in the system to provide quick data entry and data archival from the computer data base. Different templates can be placed on the graphics tablet so that data for different component families can be readily identified. Figure 8.6 shows an example of such a coding template used for rotational parts [Love 1986].

Since CAMAC can allow information of existing components and products to be located very effectively, the integration of such a coding system into the embryo CIM system will act as a chief bridging module for other design modules such as CAD and CAPP.

As the CAMAC system was mostly written in dBASE, it should be theoretically not too difficult to integrate it into the embryo system.

8.4.1.3.3 OTHER AUXILIARY SOFTWARE PACKAGES

Some 'off-the-shelf' software packages for potential use with the embryo system include SC4 and MLD2.

SC stands for SuperCalc. It is a very advanced electronic spreadsheet package. Spreadsheet packages are established as extremely useful tools with regard to the powerful analytical and mathematical modelling features which they can provide [Rickles 1985].

SC4 can be used as a useful supporting tool for the embryo system, particularly with its data analysis capability and the graphics facilities.

Its capability of storing a value or a formula in each cell makes it an ideal tool for 'what-if' analysis, especially in production planning. In a cellular CIM model, there are many areas which require repetitive calculation for optimum results. Examples include

CLASS	WORKHOLDING CAPABILITY		SPECIAL FEATURE CAPABILITY		MAXIMUM CAPACITY				MACHINING CAPABILITY		FEATURE PRODUCING CAPABILITY									
					Diameter		Length				CYLINDRICAL				PLANE SURFACE FEATURES				HOLE FEATURES	
											External		Internal							
Rotational Components	MATERIAL CROSS SECTION AT LARGEST DIAMETER	Cylindrical Cross Section	GEAR TEETH	Spur Gear Teeth	MAXIMUM DIAMETER	<= 12 mm	MAXIMUM LENGTH	<= 10 mm	MATERIAL TYPE	Cast Iron	BASIC SHAPE	Uniform Outside Surface (inc chamf)	TYPE OF BORE	Blind Bore	PLANE SURFACES	Flat Parallel Component Faces	INTERNAL FEATURES	Internal Slots or Grooves	HOLE DIRECTION & RELATIONSHIP	Holes in a Radial Direction
		Hexagonal Cross Section		Bevel Gear Teeth		> 12 mm <= 25 mm		> 10 mm <= 20 mm		S.G. Iron Meehanite		Stepped from One End		Through Bore		Flats Not Related by Graduation around a Circle		Int. Slots or Grooves Related by Graduation on a Circle		Holes Along the Axis
		Square or Rectangular X Section		Helical Gear Teeth		> 25 mm <= 50 mm		> 20 mm <= 30 mm		Mild Steel		Stepped from the Centre	BASIC SHAPE	Blind bore From One End Only		2 Flats Parallel & Perpendicular to Component Faces		Int. Flat Surfaces Related by Graduation on a Circle		Holes in Other Directions
		Any other Symetrical X Section		Worm and Pinion Gear Teeth		> 50 mm <= 100 mm		> 30 mm <= 50 mm		Medium/High Carbon and Low Alloy Steels		Stepped from Both Ends		Stepped From One End		Flats related by Graduation around a Circle	CAM SURFACES	External Cam Surfaces		Holes Angularly Related
		Non Symetrical X Section	OTHER TEETH	Chain Sprocket Teeth		> 100 mm <= 150 mm		> 50 mm <= 80 mm		High Alloy Steels		Formed Grooves (not V Belt or Oil)		Stepped From Both Ends		Inclined Flat Surfaces		Internal Cam surface Slots or Grooves	TYPE OF HOLE(S)	Plain Holes
		Cams		Ratchet or Clutch Teeth		> 150 mm <= 200 mm		> 80 mm <= 160 mm		Brass Bronze or Copper	POSSIBLE FEATURES	Formed Surfaces	POSSIBLE FEATURES	Centre Drilled End(s)	EXTERNAL GROOVES OR SLOTS Type	Open Ended Slots or Grooves		Spiral Surfaces, Slots or Grooves		Counter-bored &/or Spot-faced Holes
	ADDITIONAL FEATURES	Bent Axis After Machining	BELT DRIVE	Toothed Belt Teeth		> 200 mm <= 300 mm		> 160 mm <= 250 mm		Aluminium Alloys		Standard Screw Threads		Formed Grooves (not Oil)		Enclosed Slots, Grooves, Recesses	OIL GROOVES	Straight Oil Groove(s)		Countersunk Holes
		Bent Axis Before Machining		Vee Belt Groove		> 300 mm <= 450 mm		> 250 mm <= 500 mm		Other Non-Ferrous Metals		Knurled Surfaces		Standard Screw Threads		Radiused Slots or Grooves		Spiral Oil Groove(s)		Threaded Holes
		Eccentric Surfaces or Bores	OTHER FEATURES	Formed Bends Hooks or Eyes		> 450 mm <= 800 mm		> 500 mm <= 1500 mm		Plastics		Short Functional Tapers (not Chamf)		Short Functional Tapers	Direction & Relationship	Slots or Grooves Along the Main Axis		External Oil Groove(s)	SIZE RANGE(S)	<= 12 mm Diameter
		Made up of Segments		Bent Axle Other Than Above		> 800 mm <= 1000 mm		> 1500 mm <= 2000 mm		Other Materials		Long Functional Tapers		Long Functional Tapers		Slots or Grooves Across Face of the Part		Internal Oil Groove(s)		> 12 mm <= 25 mm Diameter
		Cast Moulded or Forged		Welded Assemblies		> 1000 mm		> 2000 mm	H/TREAT	Heat Treatment Required		Special Screw Threads		Special Screw Threads		Slots or Grooves Related by Graduation on Circle		Curved Surface		> 25 mm Diameter

The University of Aston in Birmingham
Department of
Mechanical and Production Engineering

CAMAC SYSTEM for MACHINE TOOLS
ROTATIONAL PARTS

Revision No.
1.0

Date
5th May 84

Drawn
R H Love

Figure 8.6 CAMAC machine tool code for rotational parts (Love 86) capacity planning, latest start date calculation, manufacturing lead time estimation and cost estimation. Possible further work may include incorporating such a useful tool permanently into the embryo system as part of the system. This can be done via its macro language facilities.

SC4's graphics facilities include pie chart, bar chart, line chart and X-Y chart. Since SC4 supports the dBASE data file format, the different types of graphs can be used to display data exported directly from the embryo system.

MLD2 is a two dimensional drafting system. It enables non- professionals who are from any engineering field to produce high quality drawings. MLD2 has all the typical drafting facilities for drawing lines, circles, arcs, rectangles, texts and dimensions. Powerful features such as zoom, rotation, mirroring, parameterised drawing, layering, windowing and hatching. It also allows standard drawings to be stored as library subroutines so that they can be called into any new drawing.

Another powerful feature of MLD2 is its MLL programming language. The use of MLL can enable MLD2 to be tailored for specific uses. It also allows other systems to be integrated with MLD2. For example, MLL can be used to generate a part list based on an final assembly drawing. This part list can then be used by the BOM module in the embryo system. The feasibility of integrating MLD2 to the present embryo system will be discussed in the final chapter.

CHAPTER 9 DESIGN METHODOLOGY EMPLOYED IN THE EMBRYO SYSTEM DEVELOPMENT

Chapter 8 has described the objectives of the development of the micro-based embryo cellular integrated system. Initial preparation prior to the development, including selection of suitable hardware and software, has also been discussed.

This chapter focuses on the design methodology used during the embryo system development. This design methodology covers the overall system design strategy, software module development, database design, an establishment of data communication links and the essence of documentation.

9.1 GENERAL OVERALL DESCRIPTION OF THE DEVELOPED SYSTEM

This section aims to give a general overview of the characteristics and features of the developed embryo system.

9.1.1 MAJOR FUNCTIONS IN THE EMBRYO SYSTEM

As mentioned earlier in this thesis, five major functional areas can be readily identified in most manufacturing firms regardless of their size and nature. These five functional areas are Customer Service, Design Engineering, Planning, Manufacture and Control, as well as Finance and Administration.

Prior to any software development, typical functions covered by each of these five major areas had to be identified. Software modules were then written in accordance with these typical functional modules. The final system is capable of performing these important, selected operations in a similar manner to that expected in a full scale micro-based CIM system. Based on the cellular approach, the embryo system is a total system which is composed of five major functional cells. These five functional cells are identical to the five functional areas as identified earlier, and each of these five cells subsequently consists of sub-cells at appropriate levels.

9.1.2 GENERAL DESCRIPTION OF SYSTEM SOFTWARE MODULES

The embryo system consists of many individual system software modules. These software modules, according to their associated data and functions, can be grouped into one of the five major functional cells described in the last section. All these software modules are located at different operational hierarchies and are accessed through the use of a menu-path structure, from which any specific module or option can be selected.

The menu-path begins with the five functional cells in the system's main menu. Subsequent sub-cells can then be selected from sub-menus. These sub-menus may contain further smaller sub- sub-menus and options. Theoretically, a specific module can either be addressed by following the menu-path hierarchy, or by entering a unique module code which is unambiguous to each available system module. Indeed, if required, a module which is located at the bottom of the menu-path structure can be called by entering its correct module code, even if the user is in the main menu.

There is a local database designated for each of the five functional cells. Such a database will normally only supply data to the local activities within that cell. Data links, which have been embedded in these cells, permit necessary communications via the LAN system so that data integration can be achieved.

9.2 POSSIBLE OPTIONS FOR SYSTEM CONFIGURATION

The embryo system must be configured at the beginning during system installation. This allows the required program modules as well as their associated data files to be copied to the right computers and databases. The system can be configured in a number of different ways, depending on the number of micro- computers available, and the requirements of the application environment in which the system should operate. As mentioned in Chapter 8, up to three OCTOPUS microcomputers are used - hence the embryo system can be configured with either one, two, or three computers in its installation.

Each software module was developed by applying the cellular approach throughout, in which data input, data output and local operations were all clearly defined. In addition, the Structured Design Analysis (SDA) technique as well as modular programming methodology were also employed during software development. Further details about SDA and modular programming will be provided later in the chapter.

After the initial system configuration, a configuration map is maintained by each computer. This map mainly indicates the locations of different functional modules within connected computers. When the system is configured, a module-map and a data file-map are also generated. The location of each software module and each data file is clearly recorded in these two additional system maps.

After the initial configuration, appropriate software modules and data files are automatically transferred to destination computers with hard disks, in accordance with the configuration map, the module-map and the data file-map. After this, each system computer can then be operated freely and separately. Built-in data links and the LAN will ensure that communications between system modules in separate computers are still maintained.

9.3 SYSTEMATIC PROCEDURES FOR THE DESIGN AND IMPLEMENTATION OF THE EMBRYO SYSTEM

9.3.1 GENERAL DEVELOPMENT PROCEDURES OF THE EMBRYO SYSTEM

There were five general phases to which the embryo system referred during its development. These five design phases may be regarded as necessary systematic procedures for any sizeable integrated system development. They are therefore not restricted merely to the embryo system. These five development phases are explained as follows :

(1) Specific system strategy - it may vary according to different environments, requirements and installation policies. This is the methodology to decide what elements are to be included in the system and how the overall system should perform. Although system flexibility is the main theme in the embryo system development, some specific objectives with respect to the above factors must be defined.

(2) An overall architecture which is based on the defined system strategy will be developed as a framework for implementation. For example, activities including standardisation of data communication methods, software development approach, the evaluation of information availability and hence the configuration of data file structures can be specified in this stage. A preliminary installation draft, which includes all the above information with

respect to the embryo system, should be available prior to proceeding to the third stage.

(3) Development of integration software modules - these modules are designed to perform the desired objectives defined in the system strategy. Their formats and interrelationships must be conformed to the overall architecture specified in the second stage. In addition, compatibility of these software modules to the overall system strategy and integration must be emphasised.

(4) Auxiliary aids to implementing CIM system. These aids should provide various services to the development, including program editing, software compatibility analysis, overall system evaluations, and system documentations. The installation of the embryo system should complete in this stage.

(5) Feedback from user, modification and maintenance. These are necessary procedures for the fine tuning of the system so that optimum results can be obtained. Suggestions for further enhancement of the system are also be made in this stage.

Figure 9.1 summarises the five design phases introduced in this section.

9.3.2 SPECIFIC DESIGN REQUIREMENTS FOR SYSTEM MODULES

Whilst the above development procedures outlined the general phases of the embryo system project, this section focuses on the design requirements which are specific to developing the integrated modules in the system. These requirements represent the main characteristics of the embryo system with respect to the cellular and the distribution methodology employed in its design. They can be divided into five groups and are explained as follows :

(1) definition of each functional cell and its modules - each functional cell and its associated modules must be designed to comply with the standardised format of a cell;

(2) definition of cellular and distributed databases - these local databases must support the characteristics of a cellular system as well as the concept of data distribution;

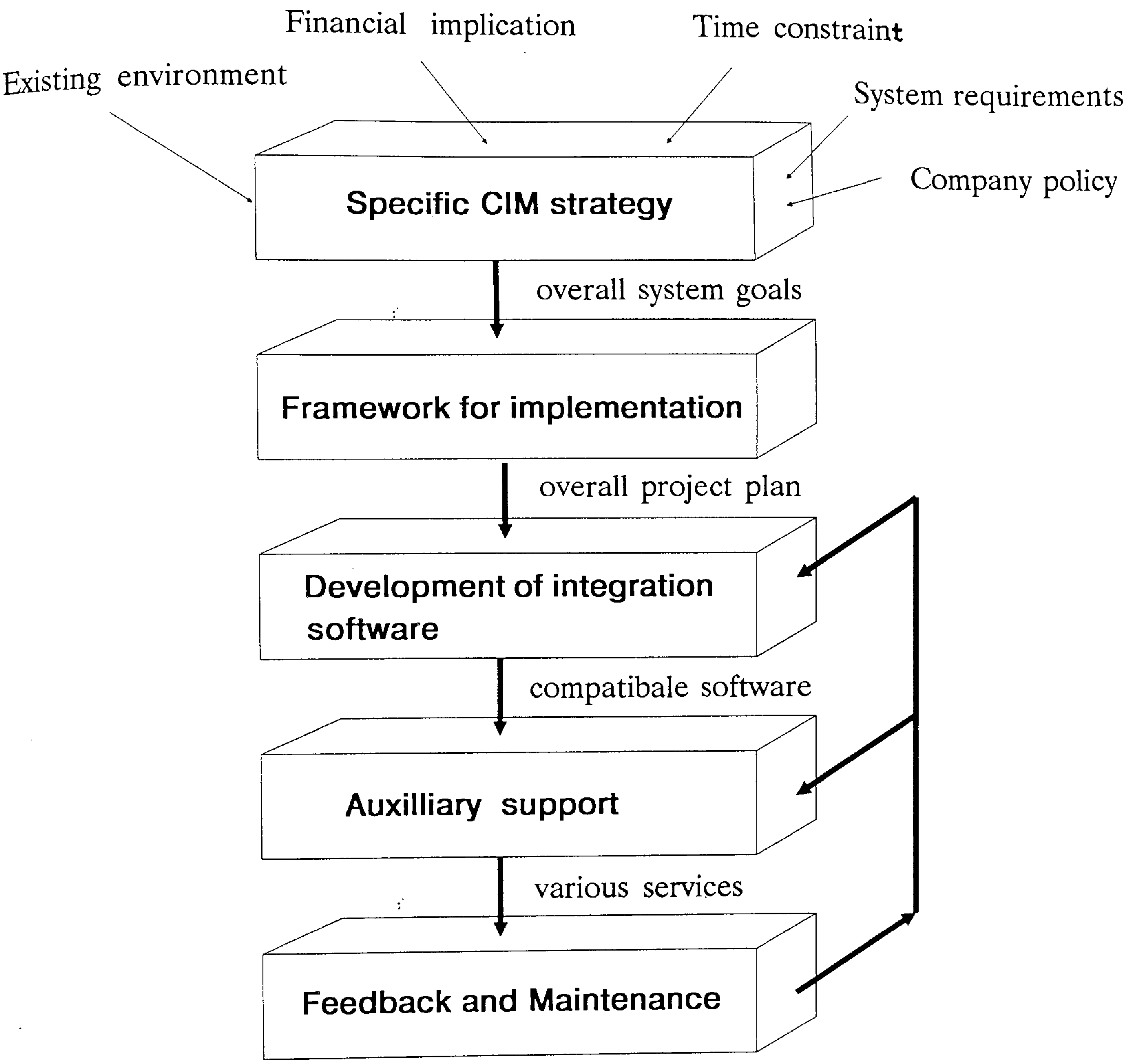


Figure 9.1 Major design procedures for an integrated system development

(3) design of system main menus and sub-menus - a comprehensive menu-path has to be designed to support the desired system flexibility in terms of configuration and operation;

(4) design of work cells using the distributed planning and control concept - this is the most important design requirement as the philosophy of distributed planning and control has to be demonstrated through the capabilities of these work cells;

(5) design of a flexible system configurator - this is to ensure the final embryo system is as flexible as it was intended, hence the configuration of the system can be modified relatively easily.

9.4 DOCUMENTATION REQUIREMENTS

Documentation normally contains user instructions and software operation details and is very important in relation to future technical support, system maintenance, program modification and enhancement of a computer system. The lack of standard and adequate documentations for a extremely complicated CIM system may lead to serious system degradation when trained personnel depart and during development changes and system maintenance.

Some standardised procedures were complied with to produce consistent documentation throughout the embryo system development. Some of this documentation includes the description and instruction for each system module, which clearly displays important data in/out formats, files, variables and program path used in a particular module.

In a large project such as the development of a cellular CIM system, it is always possible that the whole system cannot be completed by one person in the time given. If the project is to be continued or expanded by somebody else in the future, standardised, consistent and comprehensive documentation will enable important information and details to be passed on so that the development can be continued efficiently and accurately.

According to the GEC Software handbook [GEC 1986], ideal system documentation should provide basic information in relation to the system details. This information may include the system parameters, the present system's constraints, comprehensive user instructions, details about the system structure, necessary and relevant tutorial for system operations, and different levels of the system details for appropriate personnel.

In the handbook, there are also some very practical points which may be referred to when preparing the system's documentation. Complying with these procedures will ensure a systematic approach to documentation of the embryo system project. Most documentation written for the embryo system is summarised and enclosed in the appendices of this thesis. For example, the system screen menus and options are shown in Appendix A; help as well as specific user instructions for each module are summarised in Appendix C. Appendix F and G contain print-outs obtained in the two major system test runs.

Program listings for the developed system software, however, have been prepared and bound as a separate user document as it is too bulky to be included in the appendices. This program listing is available in the department for reference. A considerable number of remarks were embedded in the program listings themselves for people who want to modify the programs. These remarks are mostly concerned with specific system parameters and operational characteristics. Program listings of a few essential modules, mainly concerned with distribution and MRP, are enclosed in Appendix H for reference.

9.5 DESIGN OF THE MENU-PATH AND MODULE CODES

All the functions in the embryo system can be accessed through an inter-linked menu system. When the system is first loaded, the main menu will appear on the screen. From the main menu, the user can reach any specific options by either following the menu hierarchy, or entering the option number directly. When a sub- menu is chosen, it may contain further sub-menus or functional options. This menu driven approach has enabled all the available system modules to be arranged in a highly structured hierarchy.

In the menu hierarchy, each system module was assigned with a unique module code. These codes will be used during the system configuration - a process which involves the transferring of the appropriate modules to the correct computers. These module-codes are also used in the menu-path structure in which they are arranged in a logical hierarchy for use.

9.5.1 MAIN MENU AND SUB-MENUS IN THE EMBRYO SYSTEM

The entire embryo system design benefited from dBASE's non- procedural features. Programs written in dBASE can be executed in multi-levels. When a dBASE program is executed, it can call in another dBASE sub-program within it. After the sub-program has finished, the control will be automatically returned to the previous level of program. With dBASE II, a nest of control through sub-programs can be as many as six levels.

As described earlier, the embryo system was made up of a number of individual modules which have been arranged in a menu hierarchy. Each main menu, sub-menu and individual module has been assigned a unique code number within the system. This code always begins with a letter ranging from A to H, indicating the functional cell to which it belong. Each of these letters stands for a major functional group as explained as follows :

FIRST DIGIT OF CODE	FUNCTIONAL GROUP
A	System Configurator
B	Customer Service
C	Design Engineering
D	Planning
E	Manufacture and Control
F	Finance and Administration
G	House keeping
H	Help
M	Miscellaneous

All options in the main menu are represented by only one letter as described above. When an option is chosen, a sub-menu will then appear. This time, each option in the sub-menu is represented by an extra digit in addition to the first letter. This digit ranges from 1 to 9, standing for a different option. There can be as many as nine options to choose from within each sub-menu.

The essence of this module coding approach can be illustrated by a simple example. In the main menu, 'A' stands for the System Configurator. After menu A is chosen, user can then select 'A1' which stands for a sub-menu for file preparation. There are then five further options whose module codes range from 'A11' to 'A15' respectively. Each of these options can either be a sub-menu or a final program module. Figure 9.2

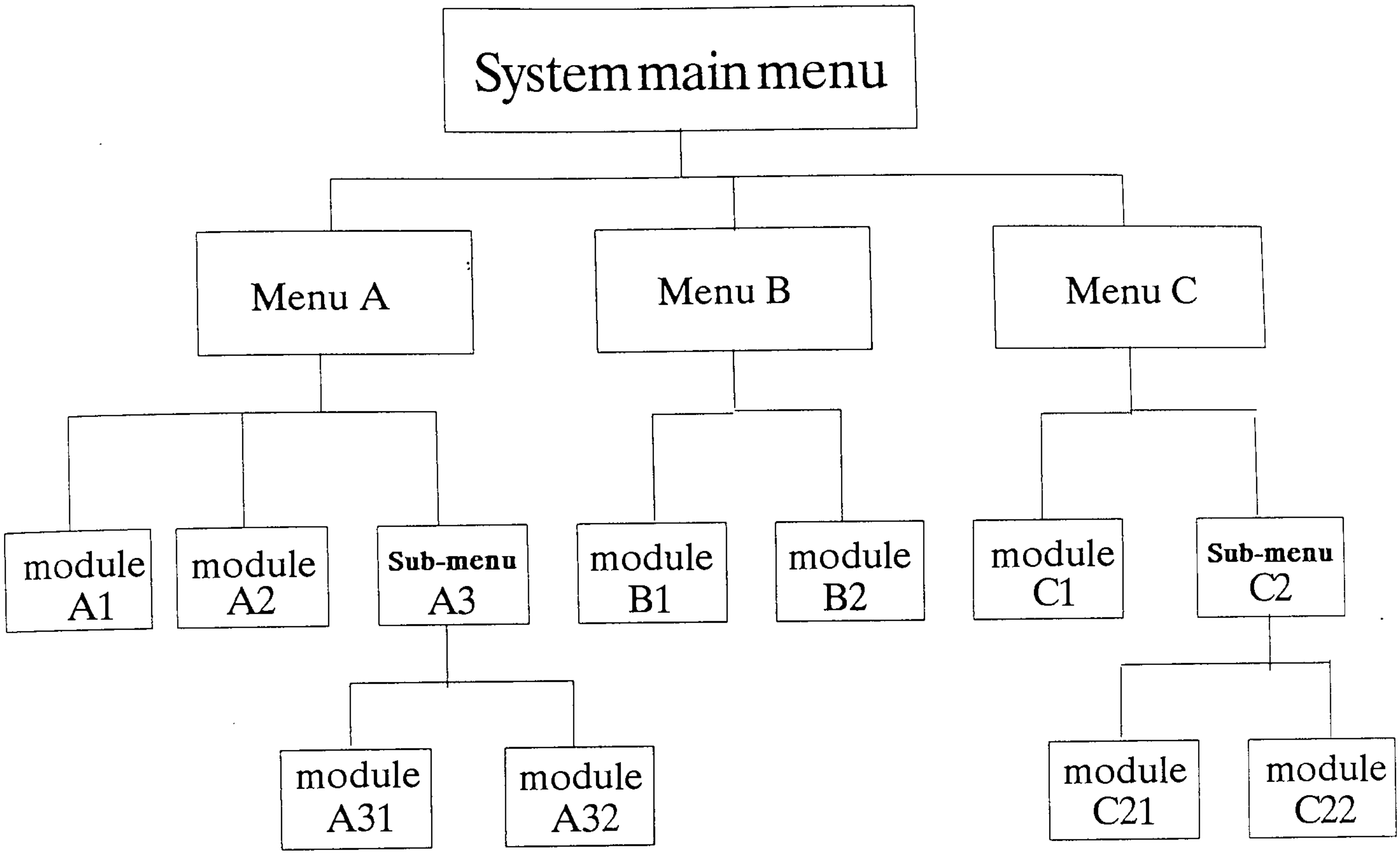


Figure 9.2 The interrelationships between menus and sub-menus in the embryo system

illustrates the interrelationships between the menu and sub-menus within the embryo system.

Another advantage of using this module coding method is that a specific option can be called from anywhere within the system, provided this code is in the current menu path. For example, the user can select option 'C62' to change the overhead cost assignment for a subassembly while he is still in the program 'C11' in which he has just generated new BOM details for a product. This provides the user convenient access to all modules according to a familiarization with the system.

The menu driven approach as well as the module code design method allows many modules in the embryo system to form logical functional cells. This compliments the principle of the cellular system approach emphasised earlier in this thesis - a cellular CIM system is a amalgamation of many semi-independent cells.

9.5.2 PROGRAM NAME DESIGN FOR EACH SYSTEM MODULE

Although each software module in the system always has a code number, it is different from the actual program name assigned to this module which is stored physically in the hard disk. Since the main theme of the embryo system is that the system can be tailored for specific use, different menu-paths therefore can be designed and implemented in different configurations. For example, if the system is to be installed for a company which requires different modules arranged in different menu formats, only the system menu's structures need to be modified so that appropriate module codes can be assigned to those available program modules.

In general, a module's program name itself usually indicates more information than its module code in the system. A program name is made up of 8 characters, maximum. In addition, there are 3 extra characters which can be used as the file extension. This makes the maximum length of a program name up to 11. Consequently, meaningful names can always be assigned to a module for easy identification. For example, the program module whose function is to create a new BOM for a product is actually called 'BOMGEN.PRG'. Its module code in the embryo system, however, is 'C11'. It is through the menu system that 'C11', which is stored in the hard disk, is interpreted as 'BOMGEN.PRG'.

9.6 EMBRYO SYSTEM SOFTWARE DESIGN

This section summarises the particulars which concern with the design of software modules for the embryo system.

9.6.1 IMPLICATIONS OF THE CELLULAR APPROACH AND THE DISTRIBUTION CONCEPT IN SOFTWARE DESIGN

The cellular approach and the distribution concept has imposed a significant influence on the software development for the embryo system, as the main objective of the latter to demonstrate the characteristics of both in an integrated system.

Each software module in the system was designed with some standardised procedure with input/output formats so that the end product would always be compatible with other modules and also with the rest of the system. These procedures include the use a local database for supporting internal activities, the standardisation of program variables and logic design, the identification of shared data for access by other cell modules, and the establishment of essential data-links for data integration. The final embryo system, containing a group of such software modules, should show consistent compatibility with respect to data transfer and operations.

9.6.2 LOGICAL STEPS FOR GOOD SOFTWARE DESIGN

Software is normally regarded as a cluster of commands (a program) which is loaded into the computer memory to perform certain tasks. Software usually is the main core of a system - the design of which would directly influence the overall performance of the system.

Generally speaking, the logical steps of software development include project estimating, requirements analysis, actual software design, structured coding, testing steps and methods, software maintenance, software configuration management and documentation. These concepts constitute a basic skeleton of a software life cycle.

A reputated programming and analytical tool for software design called Structured Design Analysis (SDA) has been applied throughout the embryo system development. The main reason for using SDA technique is to make software programs simpler to write, changeable, flexible, and reusable [Stevens 1981, Mandes 1980].

According to Stevens, SDA is a set of concepts, measurements, and guidelines whose purpose is to reduce the cost of developing and maintaining computer programs. It is a technique for separating functions within a system into relatively independent modules by using a set of design and coding rules.

Since the advantages of structured design rely on modularity, it is compatible with modular programming and top-down development.

9.6.3 INTEGRATION PRINCIPLE IN SOFTWARE DESIGN

As the main objective of the embryo system is to demonstrate how integration can be achieved through the cellular system approach, software modules so developed must therefore communicate with one another when they are merged together in the final system. Hence, some integration principles must be conformed to during the stages of software design and development. Some guidelines to achieve this objective are summarised as follows :

(1) the use of standardised formats for data input and data output;

(2) the use of global and local variables must be clearly defined;

(3) common data items and system parameters should be identified in different software modules;

(4) the relationship of a software module to other system modules must be established before the software is written. This relationship may be expressed in terms of operational sequence, information flow or physical data transaction;

(5) there should be a universal development environment which provides standardised toolings for design, coding, debugging, testing, documentation and configuration. It should support all phases of software development;

(6) the method of data processing and data transaction should be standardised throughout, irrespective of the prime function of the module concerned.

Other elements which would also affect the integration characteristics of the final system include the system disk drives, operating system, LAN features and the limitation of the size of a program supported by the computer.

If all these design guidelines are followed, then the final system should be capable of demonstrating a high degree of system compatibility with respect to data integration.

9.7 TYPE OF SOFTWARE MODULES IN THE EMBRYO SYSTEM

As the main purpose of the embryo system development is to demonstrate the two hypotheses established earlier in the thesis; one being that the cellular system approach can permit simpler system design, and the other that the concept of distributed planning and control concept can make the resulting system more flexible and capable of being tailored by users. As a results, there are two main types of modules in the embryo system, namely the central modules and the local modules respectively.

In general, a central module is one which is positioned at a single central location in relation to the system structure, whilst a local module is one which has been distributed to more than one location. Both types of modules were designed using the cellular and distribution principles. Figure 9.3 shows a simplified view of the interrelationship of central modules and local modules.

9.7.1 CENTRAL SOFTWARE MODULES AND DATA FILE

As mentioned previously, there are five major functional cells in the system. In general, all software modules in these cells are regarded as central modules, except those in the Manufacture and Control Cell, which are duplicated as local modules to various work cells.

A central module is usually responsible for larger amounts of system data. For example, the Customer Service Cell is a central cell consisting of many sub-cells. They are all central modules and are only found at a single location. These modules are responsible for all the data related to the Customer Service Cell. According to the design, modules of a central cell are always grouped together physically. This concept will be explained in the next chapter.

The data files used by these central modules are considered to be central data files.

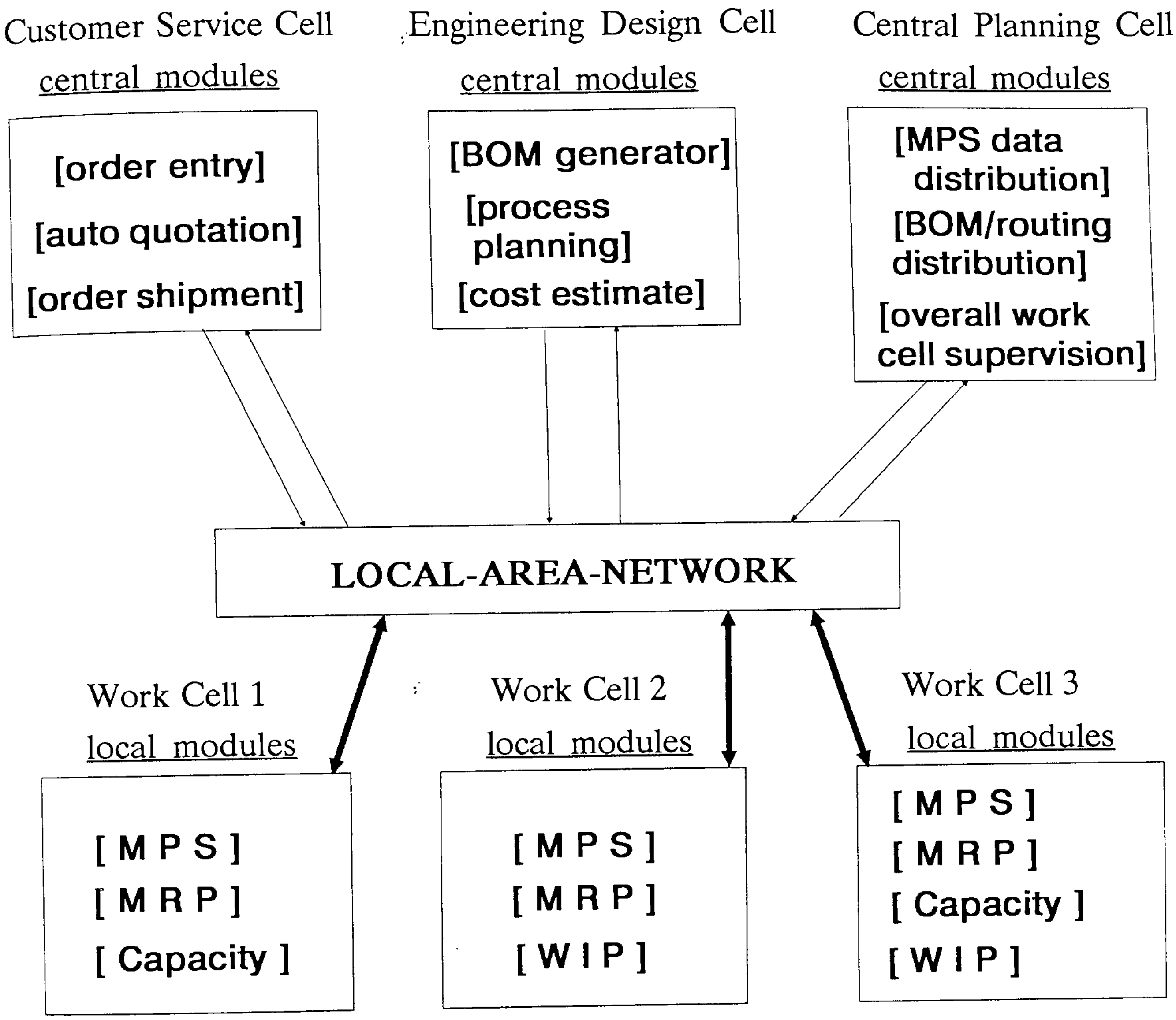


Figure 9.3 Relationships between central modules and local modules

9.7.2 LOCAL SOFTWARE MODULES AND DATA FILES

As Manufacture and Control is the only functional cell in the embryo system which are duplicated and situated at more than one local location - work cells, that all its software modules and data files are regarded as local modules and local files. For example, the modules such as MPS, MRP and capacity planning in a work cell are all regarded as local modules, and hence their data files as local data files.

The distinction of central modules and central files from local modules and local files must be clearly understood as it complements the very important distributed planning and control methodology which the embryo system was developed to demonstrate.

9.8 TYPE OF COMMUNICATIONS IN THE EMBRYO SYSTEM

As software modules in the embryo system are divided into central and local types, communications between these modules are also different. There are five main types of communications within the embryo system :

(1) communications between modules in the same central functional cell, for example, modules in the Customer Service Cell;

(2) communications between modules in different central cells, for example, communications between modules in the Customer Service Cell and the Central Planning Cell;

(3) communications between modules in a work cell, for example, module in a final-assembly work cell;

(4) communications between modules in different work cells, for example, communications between modules in a final- assembly work cell and a component cell;

(5) communications between modules in a central cell and a local work cell, for example, modules in the Central Planning Cell and the final-assembly work cell.

Each type of communication link has certain characteristics, and has a significant influence on the performance of the embryo system.

9.8.1 COMMUNICATIONS BETWEEN MODULES IN A CENTRAL CELL

In order to avoid unnecessary interference in data communication, all software modules of the same functional cell must be stored physically together in the same hard disk. For example, all modules in the Customer Service Cell are stored in Drive A, and all modules in the Central Planning Cell are in Drive B. This approach allows data transfer between modules in the same functional to be done without the LAN system.

To illustrate this, Figure 9.4 shows a particular configuration for the embryo system, in which there are two computers and four hard disks lettered A,B,C and D respectively. In this configuration, all modules of the System Configuration Cell are stored in disk A; modules of the Customer Service Cell and the Design Cell are both stored in B; those of the Central Planning Cell and the Finance Cell are in C; local modules of Work Cell 1 are stored in D, and local modules of Work Cell 2 are stored in disk A.

9.8.2 COMMUNICATIONS BETWEEN MODULES IN DIFFERENT CENTRAL CELLS

When the system was first configured and implemented, a hard disk drive number was given to each central cell and each work cell with respect to the LAN layout. Some system maps were also created to record these drive locations. For example, a Module-Map is used for storing locations of all system modules, whilst a File-Map is used for storing locations of all files. When a central cell wants to transfer data to another central cell, it will first pick up the appropriate drive number for the destination central cell using these system maps, and complete the data transfer via the LAN system.

Figure 9.5 highlights the procedures in this type of communication. Because all the checking routines are done automatically, communication of this sort is transparent from the user's point of view.

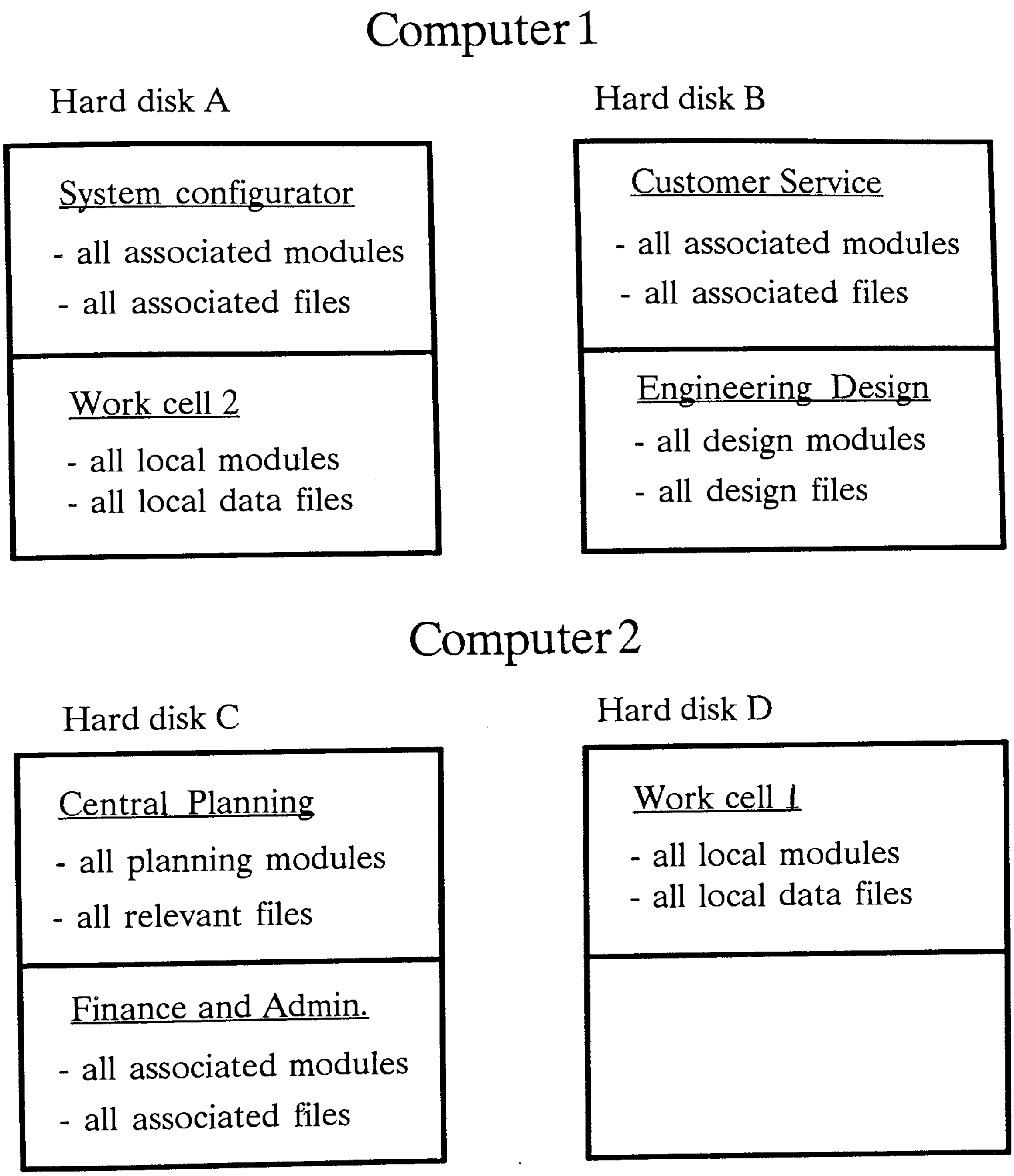


Figure 9.4 Example of a specific system configuration for the embryo system

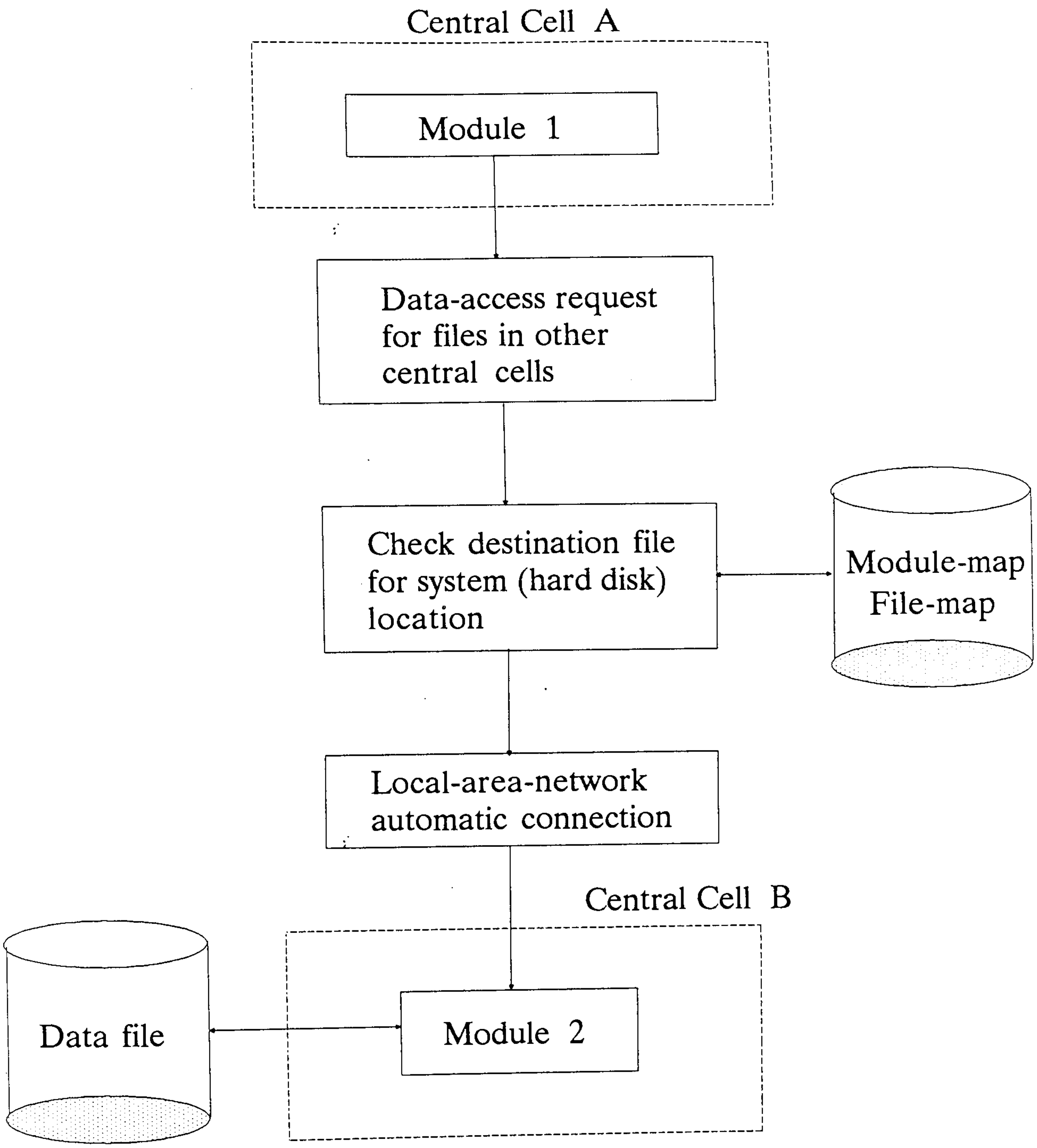


Figure 9.5 Data communication procedures involved between two central cells

9.8.3 COMMUNICATIONS BETWEEN MODULES IN A WORK CELL

The communications between modules within a work cell is done exactly in the same way as in a central cell, hence all the descriptions in Section 9.8.1 apply also to this section.

9.8.4 COMMUNICATIONS BETWEEN MODULES IN DIFFERENT WORK CELLS

In addition to Module-Map and File-Map, a Work-Cell Map was also created when the system was first configured. This map has records the disk locations for work cells in the system, and can be used merely for communications between different work cells.

When a work cell wants to transfer data to another work cell, it will first identify the hard disk location of the destination work cell using the Work-Cell Map. The transfer of data is then completed via the LAN system automatically. Figure 9.6 illustrates the necessary procedures to complete this type of data transfer.

9.8.5 COMMUNICATIONS BETWEEN CENTRAL MODULES AND LOCAL MODULES

The required procedures for this type of data communication is very similar to those described in the previous section. When a central module needs to transfer data to a local module in a work cell, or vice versa, it will first pick up the hard disk location for the destination cell, and complete the data transfer operation via the LAN system.

9.9 IMPLICATIONS OF DIFFERENT MODES OF DATA COMMUNICATION ON SOFTWARE DESIGN

It is important to differentiate the attributes of each of these five types of communication links in the embryo system. The distinctions of the data communications within the system make the demonstration of the distributed planning and control methodology much clearer.

As the characteristics of each type of data communication varies, easier software design and control is possible. In addition, the classification of software modules and their associated data files into different types permits data transactions to be carried out in a networked and integrated environment more systematically and efficiently.

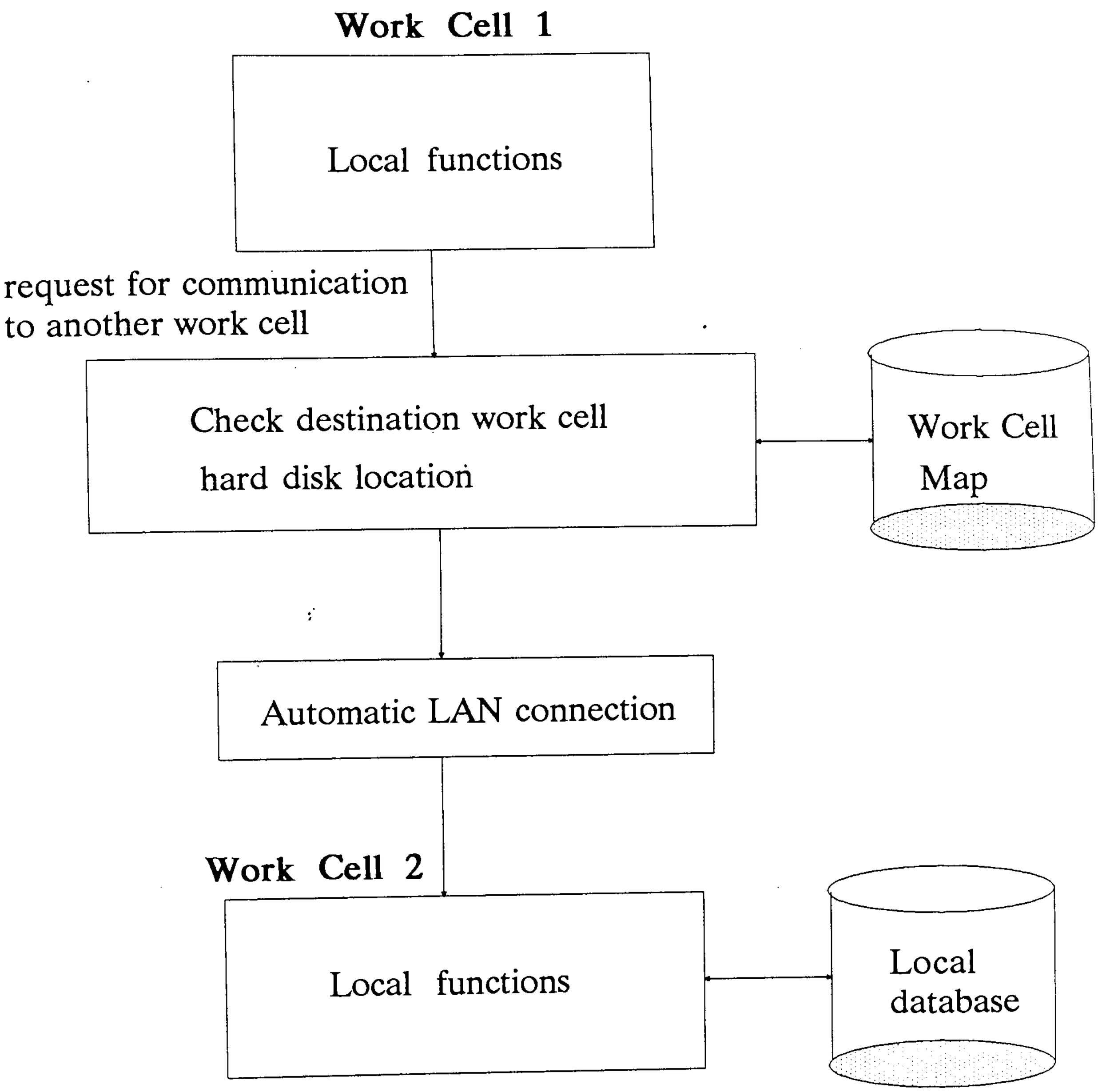


Figure 9.6 Data communication between two work cells

9.10 DESIGN OF THE DATABASE IN THE EMBRYO SYSTEM

9.10.1 DATABASE MANAGEMENT SYSTEM DESIGN (DATABASE STRUCTURE DESIGN AND LOCAL DATABASE)

A database is interrelated data collectively stored together with as little redundancy as possible to serve one or more applications in an optimal fashion [Hirouchi 1984]. A common and controllable approach should be used to add new data, and to modify or retrieve existing data, within the database.

It is important to recognise the role of a database system in the embryo system development, as it forms a major part of the design philosophy - the use of multiple localised database established in this thesis. The design of such databases for system optimisation, with respect to data independence, data redundancy, data integrity, data accessibility, data security, data sharing and overall data transaction efficiency in a distributed environment is a first priority. Evidence quoted by Appleton [1984] supports that a compatible database management system is the key to the success of an integrated system.

According to Melkanoff [1984], a system database must provide some basic functions in relation to the overall system operation. These functions include defining, entering, accessing, communicating, and updating of the necessary information in the system. All these database design criteria were taken into consideration in the embryo system development.

In addition, some specific functional attributes of a database system, according to Britton [1984], would have significant influence on an overall system performance. These functional attributes include data sharing, configuration flexibility, standardisation of data transaction procedures, as well as in/out data communications. In relation to the multiple-database features in the embryo system, these attributes were examined in great detail before the databases were incorporated into the final embryo system. A highly efficient database control system was also developed to ensure the optimal results in an integrated environment.

9.10.2 SYSTEM DATA INTEGRITY AND COMPATIBILITY

As data communications in the embryo system can be divided into five different types, stringent procedures have to be designed and applied wherever appropriate to ensure compatibility during the data transfer.

On the other hand, because of the multiple database approach, it is quite possible to duplicate some data items within the embryo system, which probably leads to data redundancy. Such data redundancy is not easy to detect in normal operation and may cause data inaccuracies during the the process of data updating. Checking routines should therefore be developed and used to eliminate the possibility of data redundancy.

During the system development, a dBASE utility program was developed to help solve this problem. The program reads in the structure of each data file in the system, and sorts them into specified order. For example, the records can be sorted in the order of data field names , or in the order of functional cells to which they belong. By using this program, any redundant data or inconsistent data field names can be identified and rectified immediately.

9.10.3 LOCALISED DATABASE APPROACH

The use of a multiple database approach has complimented the the cellular approach used in the design of the embryo system. Each local database has an 'owner' and is designed to support activities within it.

In general, because the sizes of these databases are relatively small, they are more controllable within a cellular integrated system. It also permits the specific objective of defining each cell more clearly in relation to the overall cellular structure of the system.

9.10.4 RETRIEVAL AND UPDATING OF REQUIRED DETAILS

9.10.4.1 GENERAL DISCUSSION OF TYPES OF DATA

Data retrieval and updating in a centralised integrated system can be done relatively easily, as all data is stored in one single location, and all data transactions are done through the central database. However, in a multiple-database system, such as the one used in the embryo system, the retrieval and updating of data is more complicated.

In order to appreciate the problem, the structure of a local database is examined in detail. As mentioned in previous chapters, data in a local database can be divided into two main sections : data for sharing, and data for local functions. Because of this, the methods used to retrieve data from such a database also vary.

In addition to the internal divisions in a local database, data used in the embryo system can be generally classified into three main types, in accordance with the locations of the local databases. The first group consists of data which is entered during system installation and is therefore permanently stored in the local database. For example, before the system can be used, system configuration details, product structure details, part details and machine capacity details have to be defined, entered, and copied to the appropriate databases as permanent data. Figure 9.7 outlines the preparation procedures for this type of data.

The second type of data is generated within each cell. For examples, each work cell would have to generate its own specific requests for local parts, purchased parts and external parts, after the local MRP has been executed. In Figure 9.8, data is generated within work cell 1 and work cell 2, and is stored into D.B.1 and D.B.2 respectively.

The third type of data is created from distribution. For example, orders in the central MPS file are distributed into the local database within each work cell. Each work cell will not only receive the data distributed from central modules, but also data from other work cells, at specified intervals. Figure 9.9 illustrates that data is distributed from central module A into the two work cells, and some data is also transferred from work cell 1 to work cell 2.

It is important that the difference of these data groups must be recognised, as each type of data requires a specific method for efficient data retrieval and updating. Figure 9.10 outlines the different types of data within a local database. Note that only the permanent data group and the self-generated data group apply to a local database attached to a central cell. On the other hand, all three types of data apply to a local database attached to a work cell.

The effect of multiple databases, as well as distributed planning and control, on the overall system performance will be discussed in more detail when two test runs are conducted on the embryo system.

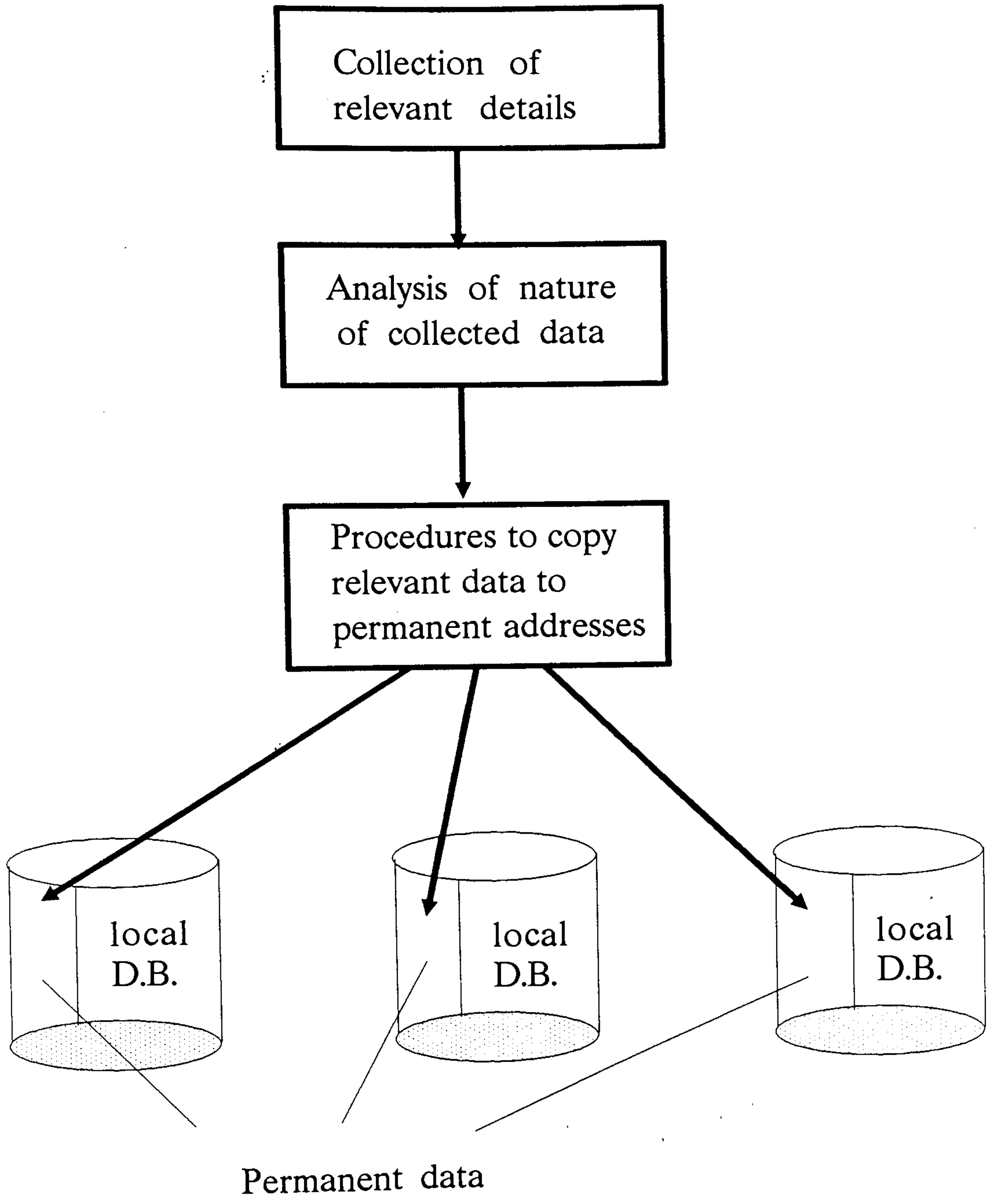


Figure 9.7 Initial preparation of data through direct data transfer

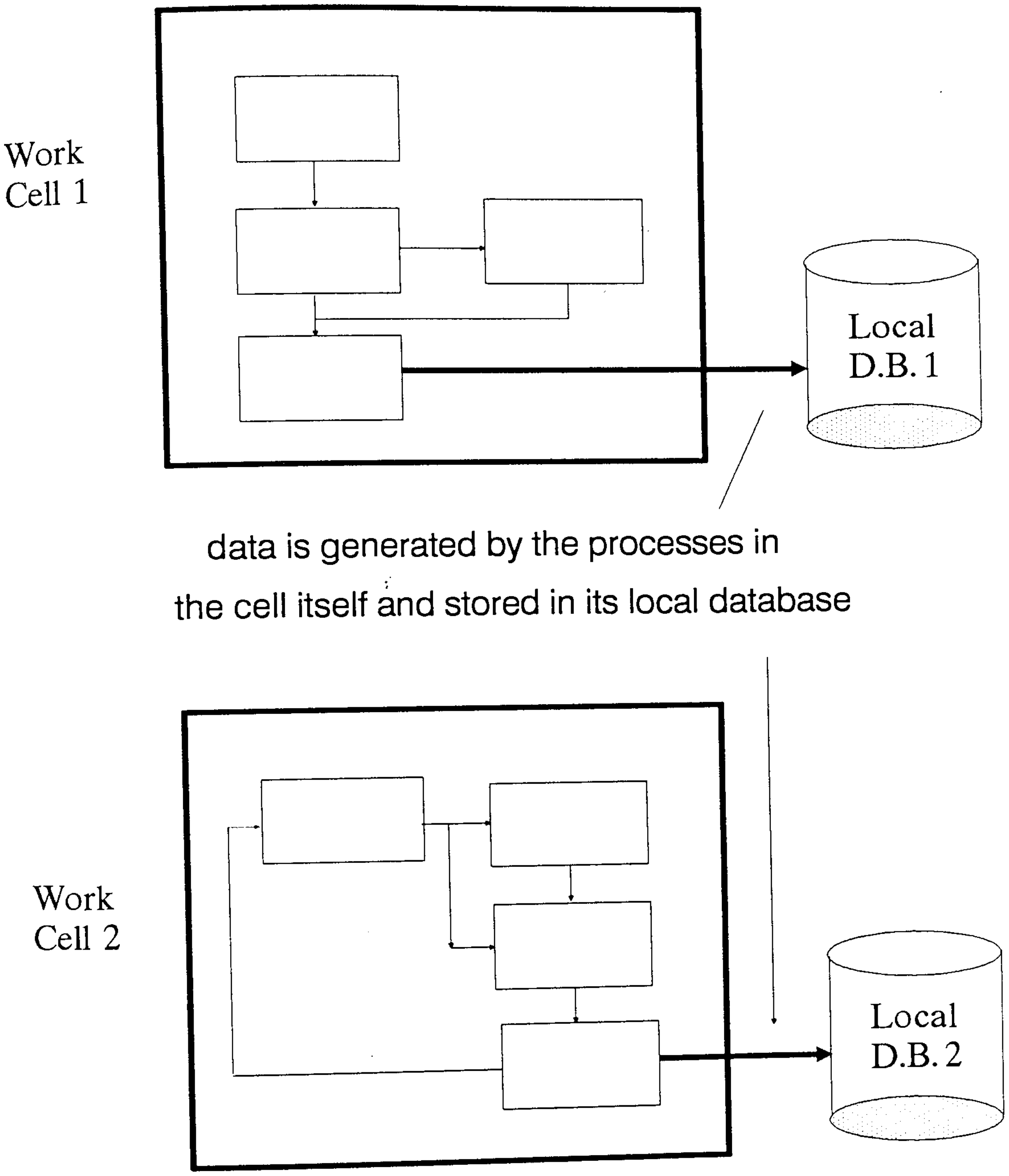


Figure 9.8 Generation of required data through local operations in a cell

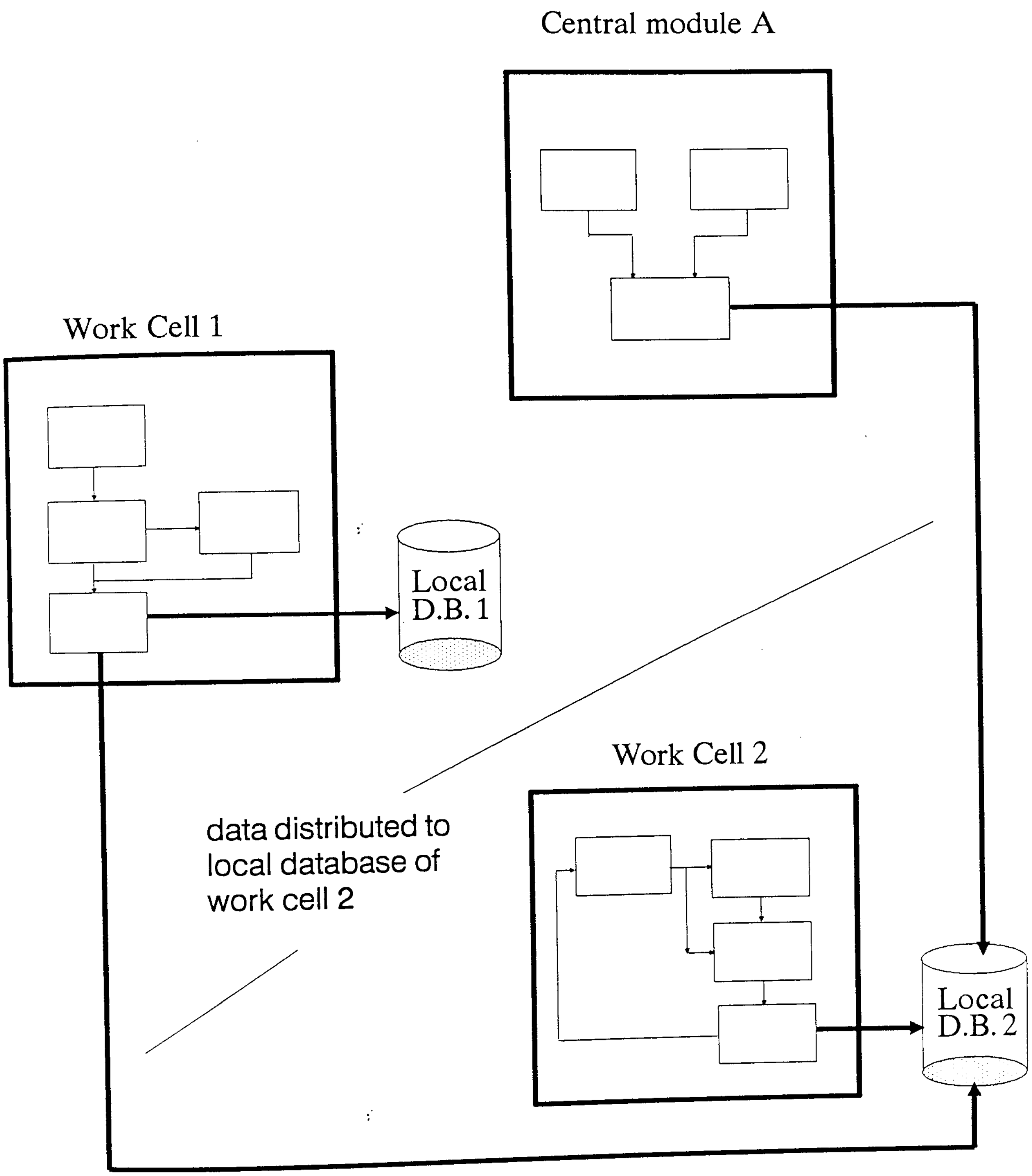


Figure 9.9 Generation of required data through data distribution from central modules to work cells

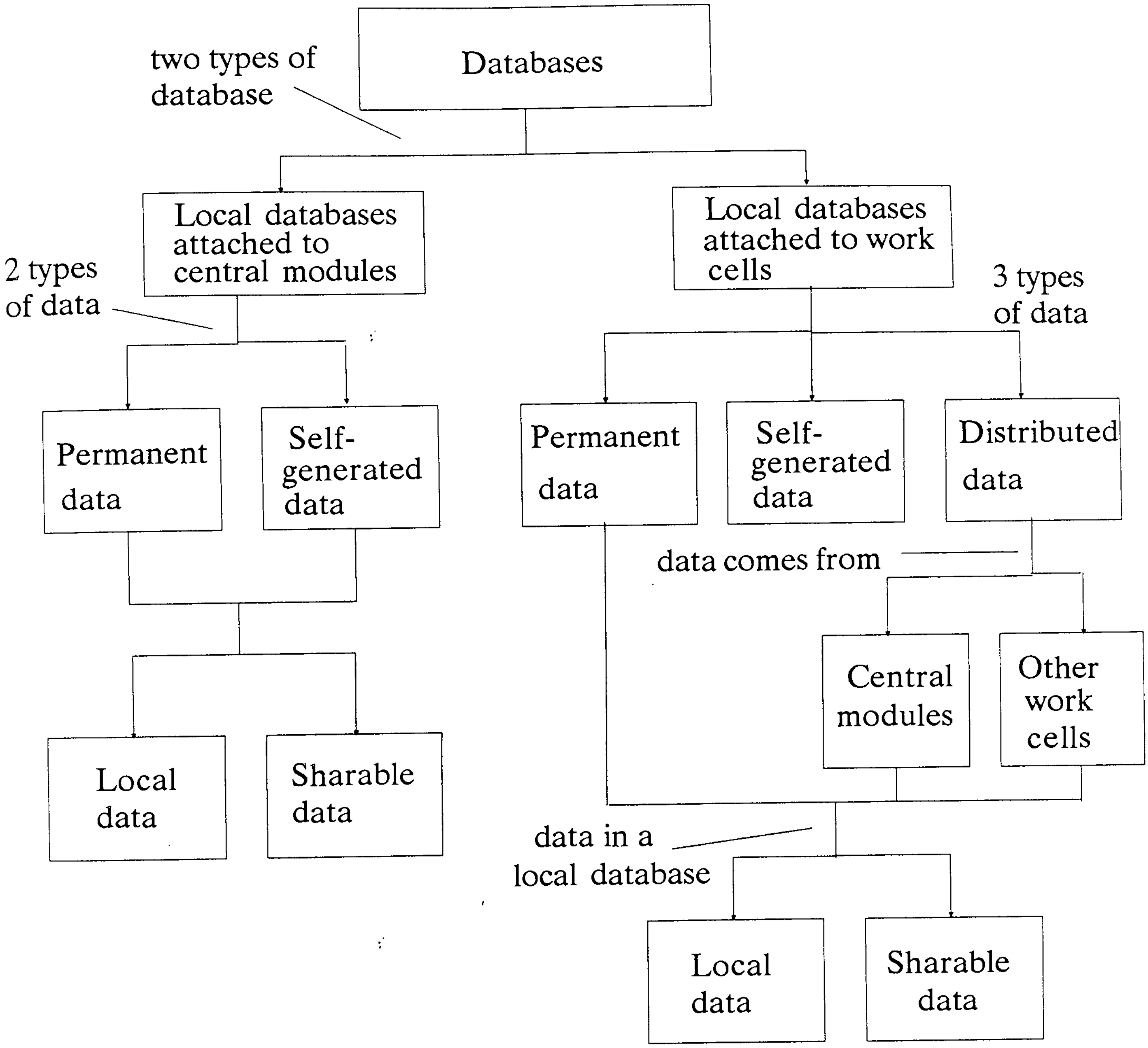


Figure 9.10 Divisions of local databases and their types of data within the system

9.10.4.2 UPDATING OF RELEVANT DATA IN THE SYSTEM

In general, although there are three different ways in which data can be prepared, subsequent modification of the data follows the same procedure as that used for creation.

Because data files of different functional cells may be stored in different hard disk locations in the system, some maps were designed to help identify the exact disk locations for each module. These maps, including the Configuration-Map, Module-Map, File-Map, and the Work-Cell Map, are generated during the initial system configuration. They are used when data records are updated via the LAN system.

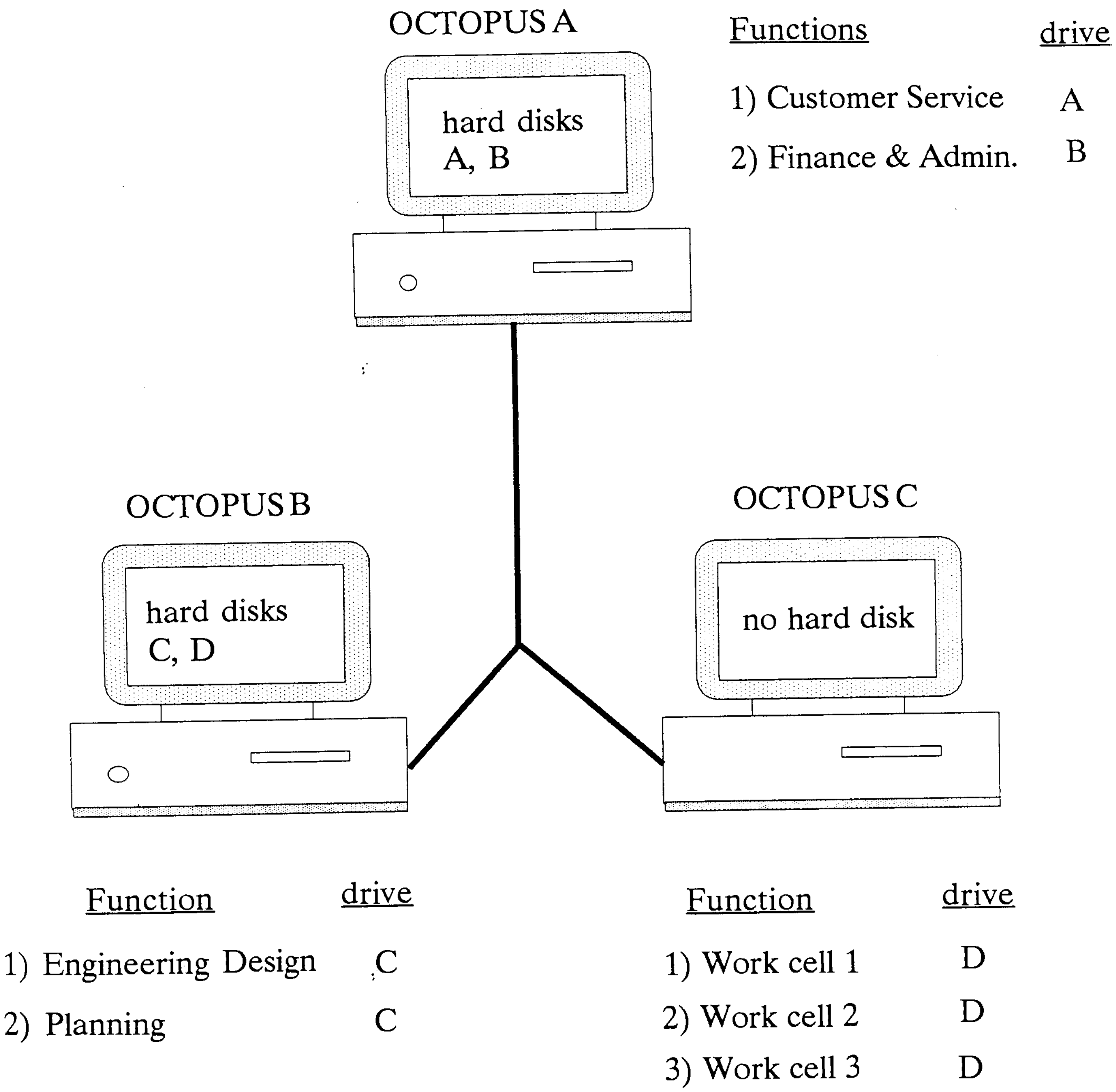
The System Configuration Map retains all information relevant to specific configurations when the embryo system is installed. This map is only needed when the entire system has to be re- configured or re-installed. There is normally only one Configuration Map which is stored in the computer with the master hard disk. Figure 9.11 shows the possible details stored in a System Configuration Map.

The Module-Map stores the locations of all software modules used in the embryo system. Table 9.1 shows the possible content of such a map. This is used along with the data links already built into each software module when communication is required between two modules. Normally, there is only one Module Map, and each computer will have to keep the same Module Map.

The File-Map has exactly the same function as the Module-Map, except it records the locations of various data files in the system. Table 9.2 shows the possible content of a File-Map.

When a data item is to be retrieved or updated, the host module will first check if the data is held locally in the database. If it is not, then the module will check the File-Map to locate the exact disk location for the file and send the data request across the LAN to the destination database.

This chapter has basically covered the fundamental concept regarding the system design methodology used in the embryo system development. The next chapter will concentrate on the actual program modules which were developed for the system. In addition to the description of each module, the chapter will also lay down some logical



Functions	drive
1) Customer Service	A
2) Finance & Admin.	B

Function	drive
1) Engineering Design	C
2) Planning	C

Function	drive
1) Work cell 1	D
2) Work cell 2	D
3) Work cell 3	D

Figure 9.11 Details stored in a System Configuration Map

Example of a Module-Map

Module Name	Node no.	Functional group	Disk drive
STRUGEN	A11	A	A
STRUMOD	A12	A	A
STRUDEL	A13	A	A
FILELIST	A21	A	A
FILELOG	A22	A	A
ORDERIN	B1	B	C
CUSTENQY	B2	B	C
BOMMOD	C12	C	B
BOMDEL	C13	C	B
BOMLP	C14	C	B
MPSPREP	E11	E	A
MPSEDIT	E12	E	A
MRPRUN	E13	E	A
TMPWOGEN	E14	E	A

Table 9.1

Example of a File-Map

File Name	Node no.	Functional group	Disk drive
FILE-1	A11	A	A
FILE-2	A21	A	A
BOM-FILE	C12	C	B
BOM-INDEX	C12	C	B
BOM-COST	C12	C	B
PROCESS1	C21	C	B
PROCESS2	C21	C	B
PRO-TEMPLATE	C31	C	B
PRO-MODIFY	C32	C	B

Table 9.2

procedures and particulars which must be taken into account when the system is operated. Two comprehensive test runs were also carried out to verify the capabilities of the system and will be discussed in chapter 11.

CHAPTER 10 DEVELOPED MODULES AND THEIR FUNCTIONS IN THE EMBRYO SYSTEM

In the last chapter, some specific design methodologies which were used in the development of an embryo cellular integrated system were explained. The main objective of this chapter is to give an in-depth view of the software modules which have been developed for this embryo system. The essence of their main functions and the system operation procedures will also be examined in this chapter.

In fact, Chapter 8, Chapter 9 and this chapter were designed to give the reader a general background understanding regarding the development of the embryo CIM system. Since Chapter 11 will be dedicated to system test runs whose main objective is to verify the various features of the system, it is essential that the fundamental concept of the system's operations is explained before moving onto the actual test run details.

10.1 MAJOR FUNCTIONS IN THE EMBRYO SYSTEM

10.1.1 DEFINITION OF THE FIVE FUNCTIONAL CELLS

As mentioned previously, the five major functional cells which have been defined in the embryo system are Customer Service, Design Engineering, Planning, Manufacture and Control, as well as Finance and Administration.

Each of these major cells consist of a number of different software modules. These software modules have been given a unique module code number which can be selected in the system main menu and sub-menus. Since the embryo system was designed using the menu driven approach, a specific module can be executed by entering the correct module code, irrespective of the emerging control of the system.

According to the cellular principle in this context, each functional cell in the embryo system should be an independent or a semi-independent entity which has its own control, systems and associated database.

10.1.2 FEATURES CONSIDERED FOR INCLUSION IN EACH OF THE FIVE FUNCTIONAL CELLS

The following sections list a number of features which could have been included in each of the five functional cells in a micro- based cellular CIM system.

10.1.2.1 SYSTEM CONFIGURATION CELL (GROUP A)

Functions which could be included in the System Configuration Cell are summarised as follows :

(1) system configuration
(2) preparation of system file structures, data files and their associated data;
(3) preparation of Configuration Map, System Module-Map and File-Map;
(4) quick report facilities for all data files;
(5) physical distributions of system modules and their associated files;
(6) preparation of a valid production calendar;
(7) maintenance of other general system details.

10.1.2.2 IN CUSTOMER SERVICE CELL (GROUP B)

The ideal functions which could be included in the Customer Service Cell are listed as follows :

(1) sales order entry;
(2) sales order processing (SOP);
(3) order in-take control;
(4) product information enquiry;
(5) product search for closest specifications;
(6) existing orders status enquiry;
(7) automatic order acknowledgement;
(8) automatic quotation;
(9) product shipment for due orders;
(10) maintenance of customer's details;
(11) new product design initialisation;
(12) internal order status enquiry;
(13) sales order history analysis.

10.1.2.3 DESIGN ENGINEERING CELL (GROUP C)

The major functions which could be included in the Design Engineering Cell are listed as follows :

(1) Computer-Aided Design and drafting (CAD);
(2) Computer-Aided Manufacturing (CAM);
(3) machining cycle time estimation;
(4) Computer-Aided Process Planning (CAPP);
(5) Bill-Of-Material (BOM) generator;
(6) product cost estimation.

10.1.2.4 CENTRAL PLANNING CELL (GROUP D)

The major functions which could be included in the Central Planning Cell are listed as follows :

(1) central Master Production Scheduling (MPS);
(2) central capacity requirements monitoring;
(3) Central purchasing;
(4) finished goods inventory control;
(5) vendors details maintenance;
(6) management simulation;
(7) work cell supervisor;
(8) distribution of data to work cells.

10.1.2.5 WORK CELLS (GROUP E)

The major activities which could be included in a work cell are listed as follows :

(1) CNC, NC;
(2) robotics;
(3) local Master Production Scheduling (MPS);
(4) local Material Requirements Planning (MRP);
(5) local Capacity Requirements Planning (CRP);
(6) local stock control;

(7) work orders management;
(8) Latest Start Date (LSD) calculation;
(9) work-to-list load analysis;
(10) Work-In-Progress (WIP) monitoring;
(11) quality control;
(12) shop scheduling;
(13) job costing and job recording.

10.1.2.6 FINANCE AND ADMINISTRATION CELL (GROUP F)

The major functions which could be included in the Finance and Administration Cell are listed as follows :

(1) long term forecasting;
(2) purchase ledger;
(3) payroll;
(4) budgeting;
(5) financial reports;
(6) nominal ledger;
(7) customer credit monitoring;
(8) sales ledger.

It must be noted that each of these functions are subsequently made up of a number of sub-cells and sub-sub-cells at different levels, depending on a function and the specific system configuration.

All the above functions represent a complete system, and were considered during the embryo system development. However, with the given amount of time, it was impossible to complete all relevant modules. In order to be able to demonstrate the intended characteristics of the embryo system, only those modules which are absolutely vital for illustrating the cellular and distribution principle would be developed and tested. The rest of the system functions, though not physically available, would be conceptually explained in the relevant context. In addition, necessary data links which are required for further expansion of the system would also be considered.

10.1.3 ACTUAL SOFTWARE MODULE DEVELOPED FOR THE EMBRYO SYSTEM

In comparison to the list of the ideal functions which could be included in the embryo system, this section introduces those modules which have been actually developed for the system. A brief description is given for each of the software modules which were all used in the system test runs. Procedures for conducting these tests will be explained in the next chapter. Each system module may be either represented by the file type 'MENU' (menu module), 'PRG' (program module) or 'SUB-PRG' (sub-program).

10.1.3.1 SYSTEM CONFIGURATION CELL (GROUP A)

The System Configuration Cell was assigned as functional group A in the system. All its software modules therefore have a module code which begins with the letter A for use in the menu path and for easy identification. Table 10.1 indicates the software modules which have been developed for the System Configuration Cell in the embryo system.

Although the information for each module given in Table 10.1 has been kept brief, it indicates the key functions which are included in the Configuration Cell. More details about each module's functions and its operations are found in Appendix A, B and C.

10.1.3.2 CUSTOMER SERVICE CELL (GROUP B)

The Customer Service Cell was assigned as functional group B in the embryo system. All its modules therefore have a module code beginning with a letter B. Modules which were developed for this cell and their functions are summarised in Table 10.2.

10.1.3.3 DESIGN ENGINEERING CELL (GROUP C)

Similarly, because the Design Cell was assigned as functional group C in the system, all its modules therefore have a letter C at the beginning of their module codes. Software modules which were developed for the Design Cell are summarised in Table 10.3.

SYSTEM MODULES

[INDEX :
M = PROGRAM MODULE
F = MENU MODULE
S = SUBSYSTEM MODULE
NA = NOT AVAILABLE]

FUNCTIONAL GROUP A - SYSTEM CONFIGURATION

MODULE CODE	FILENAME	TYPE	DESCRIPTION
A	CONFIG	F	CONFIGHURATOR MAIN MENU
A1	STRUFILE	F	PREPARE FILE STRUCTURE AND FILES
A11	STRUGEN	M	CREATE NEW FILE AND STRUCTURE
A12	STRUMOD	M	COPY AND MODIFY FILE STRUCTURE
A13	STRUDEL	M	DELETE STRUCTURE FILE
A14	STRFLP	M	LIST AND PRINT AVAILABLE STRUCTURE
A15	STRUVIEW	M	VIEW A PARTICULAR FILE STRUCTURE
A2	FILEMAN	F	QUICK ENTRY OF REQUIRED DATA
A21	FILELIST	M	LIST ALL FILES AND INDEX
A22	FILELOG	M	SELECT LOGGED FILE AND INDEX
A23	DATAADD	M	APPEND NEW RECORDS
A24	DATAMOD	M	MODIFY AND DELETE RECORDS
A25	DATALP	M	QUICK REPORT ON RECORDS IN FILES
A3	SYSCON	F	ACTUAL SYSTEM CONFIGURATION MENU
A31	SYSMAP	M	SYSTEM MAPS MAINTENANCE
A32	CHKMAP	M	CHECK FILES BY COMPARING FILE MAPS
A33	CONFSPEC	M	ENTER CONFIGURATION SPECIFICATIONS
A34	DISTSYS	M	DISTRIBUTE MODULES, FILES TO SYSTEM POINTS
A35	DISTCELL	M	DISTRIBUTE LOCAL MODULES, FILES TO WORK CELL POINTS
A36	CONFIGLP	M	LIST/PRINT CONFIGURATION TABLE
A4	CALENDAR	F	PREPARE PRODUCTON CALENDAR
A41	CALENGEN	M	CREATE NEW CALENDAR
A42	CALENMOD	M	MODIFY CALENDAR DETAILS
A43	CALENPRN	M	PRINT PRODUCTION CALENDAR
A44	HOLIMAN	M	NON-WORKING DAYS MAINTENANCE
A45	HOLIPRN	M	NON-WORKING DAYS PRINT
A5	COMPANY	M	COMPANY DETAILS MAINTENANCE

Table 10.1 Developed modules in Functional Droup A

FUNCTIONAL GROUP B - CUSTOMER SERVICE

MODULE CODE	FILENAME	TYPE	DESCRIPTION
B	CUSTOMER	F	CUSTOMER SERVICE MAIN MENU
B	ORDSTAT	S	DISPLAY CURRENT DETAILS FOR AN OPEN ORDER
B	INSTANT	S	PROVOKE FILE UPDATE PROCEDURES FOR INSTANT DELIVERY SALES
B	MPSDISP	S	DISPLAY MPS ORDER STATUS FOR A PRODUCT
B1	ORDERIN	M	SALES ORDER IN-TAKE
B2	CUSTENQY	M	CUSTOMER ENQUIRY
B3	ORDCHNGE	M	SALES ORDER CHANGES
B4	SEARCH	F	PRODUCT SEARCH MENU
B41	PRODSCH	M	SIMILAR PRODUCT SEARCH
B42	SCHPDIN	M	SEARCH GENERAL INFORMATION FOR A PRODUCT
B43	SCHMAIN	M	PRODUCT SEARCH DATABASE MAINTENANCE
B5	QUOTEMAN	F	QUOTATION FILE MAINTENANCE
B51	QUOTSEND	M	SEND OUT NEW QUOTES
B52	QUOTOLD	M	REGULAR CHECK FOR INVALID QUOTES (OLD)
B53	QUOTDEL	M	DELETE INDIVIDUAL QUOTES
B54	QUOTMOD	M	MODIFY INDIVIDUAL QUOTES
B55	QUOTELP	M	LIST ALL QUOTATIONS (VALID/INVALID)
B6	DESPATCH	M	WEEKLY DESPATCH MONITORING
B7	CUSTMAIN	F	CUSTOMER DETAILS MAINTENANCE
B71	CUSTINMN	M	CUSTOMER GENERAL DETAILS MAINTENANCE
B72	CUSTODMN	M	CUSTOMER INITIAL ORDER DETAILS MAINTENANCE
B73	CUSTENMN	M	CUSTOMER INITIAL ENQUIRY DETAILS MAINTENANCE
B8	ACKNOMAN	M	ACKNOWLEDGEMENT FILE MAINTENANCE
B9	INTNENQY	F	INTERNAL ENQUIRY MENU
B91	CUSTINFN	M	CUSTOMER INFORMATION ARCHIVE
B92	MPSDISPP	M	DISPLAY/PRINT MPS ORDER STATUS
B93	ORHISTMN	M	ORDER HISTORY MAINTENANCE
B94	ORDMONIT	M	OPEN ORDER DETAILS MONITORING

Table 10.2 Developed modules in Functional Group B

FUNCTIONAL GROUP C - ENGINEERING DESIGN

MODULE CODE	FILENAME	TYPE	DESCRIPTION
C	DESIGN	F	DESIGN ENGINEERING MAIN MENU
C1	BOM	F	BILL OF MATERIAL MENU
C11	BOMGEN	M	CREATE NEW BOM DETAILS
C12	BOMMOD	M	MODIFY BOM DETAILS
C13	BOMDEL	M	DELETE BOM
C14	BOMLP	M	LIST/PRINT A BOM
C2	PROCESS	F	PROCESS PLANNING MAIN MENU
C21	PROCTEPT	M	PROCESS TEMPLATES MAINTENANCE
C22	PROCGEN	M	CREATE NEW PROCESS ROUTES
C23	PROCMOD	M	MODIFY PROCESS ROUTES
C24	PROCDEL	M	DELETE PROCESS ROUTES
C25	PROCLP	M	LIST/PRINT PROCESS ROUTES
C3	PRODUCT	F	PRODUCT DETAIL MAINTENANCE MENU
C31	PRODGEN	M	CREATE NEW PRODUCT DETAILS
C32	PRODMOD	M	MODIFY PRODUCT DETAILS IN <PRODUCT> FILE
C33	PRODDEL	M	DELETE PRODUCT DETAILS
C34	PRODLP	M	LIST/PRINT PRODUCT DETAILS
C4	STDCCOST	F	STANDARD COST MAINTENANCE MENU
C41	STDCGEN	M	ESTIMATE STANDARD COST FOR A NEW PRODUCT
C42	STDCRGEN	M	UPDATING EXISTING STANDARD COST FOR A PRODUCT
C43	STDCRALL	M	REGENERATE STD COSTS FOR ALL OLD PRODUCTS FROM <SCTRACK>
C44	STDCMAN	M	STANDARD COST MAINTENANCE FOR INDIVIDUAL SUBASSEMBLY
C45	STDCLP	M	LIST/PRINT STANDARD COSTS
C5	ENG DRAWING	(NA)	MAIN MENU FOR ENGINEERING DRAWINGS
C6	COSTRATE	F	COST RATING ASSIGNMENTS
C61	LB-RATE	M	LABOUR RATE MAINTENANCE
C62	OH-RATE	M	OVERHEAD COSTING RATE FOR SUB-ASSEMBLY MAINTENANCE
C7	DESGNREQ	F	NEW DESIGN REQUEST MAINTENANCE

Table 10.3 Developed modules in Functional Group C

10.1.3.4 CENTRAL PLANNING CELL (GROUP D)

Note that because of the adoption of the distributed planning and control concept, most functions in the original Planning Cell have been distributed to various work cells at lower system hierarchies. Only some remaining central modules and co- ordination modules are retained in this cell. Table 10.4 lists the summary of modules included in this particular functional cell.

10.1.3.5 WORK CELLS (GROUP E)

The functional modules developed for use in multiple work cells play an important part in the distributed planning and control concept. However, it must be stressed that not all the developed modules of this kind are necessarily available in a work cell. It depends on the system configuration carried out at the beginning of implementation.

As the system was designed with flexibility as its main objective, various work cells may be specified to comprise different local functional modules - hence the individual requirements in each work cell can be satisfied. Table 10.5 indicates those possible modules which can be configured into a work cell.

10.1.3.6 FINANCE AND ADMINISTRATION CELL (GROUP F)

As explained in the previous section, it was not possible to develop all the functional modules within the time of the project - only a sufficient number of modules which are required to demonstrate the cellular and the distribution concept were developed. As a consequence, only a few modules have been available in this cell. The absence of the financial modules does not affect the demonstration of the cellular system approach or the distributed planning and control concept. Table 10.6 shows the limited modules developed for this functional cell.

10.1.3.7 SUPPLEMENTARY FUNCTIONAL MODULES

There are a considerable number of small but useful utilities developed over the project period, which act mainly as housekeeping modules. Some of the more important ones in relation to the system operation and support are the files back- up

FUNCTIONAL GROUP D - CENTRAL PLANNING

MODULE CODE	FILENAME	TYPE	DESCRIPTION
D	CENTRALP	F	CENTRAL PLANNING MAIN MENU
D1	MPSGEN	M	RE-GENERATE NEW MPS ORDERS AND HORIZON
D2	CAPAREQ	M(NA)	CAPACITY DETAILS REPORT
D3	MPSDISPP	M	DISPLAY/PRINT MSP ORDERS STATUS FOR A PRODUCT
D4	MPSLONGL	M(NA)	DISPLAY/PRINT SUMMARISED MPS LONG TERM PLAN
D5	WCSUPER	F	WORK CELL SUPERVISOR
D51	DISTMPS	M	DISTRIBUTE NEW MPS HORIZON AND ORDERS TO LOCAL WORK CELLS
D52	DISTBMRT	M	DISTRIBUTE ROUTING DETAILS OF EACH SUB-ASSEMBLY TO WORK CELL
D6	PURCHASE	F	CENTRAL PURCHASING MENU
D61	PURSCHGN	M	GENERATE NEW SCHEDULED PURCHASE ORDERS FROM MRP IN W.C.
D62	PURSCHMN	M	MAINTENANCE OF SCHEDULED PURCHASE ORDERS
D63	PURORDGN	M	GENERATE AND SEND NEW PURCHASE ORDERS FOR DUE SCHEDULE
D64	PURORDMN	M	LIST/PRINT AND SEND PURCHASE ORDERS
D65	PURARRVL	M	PARTS ARRIVAL UPDATE OPERATION
D66	ENDPRTMN	M	END PARTS / VENDOR DETAILS MAINTENANCE
D7	PRODINV	M	CENTRAL PRODUCT INVENTORY CONTROL

Table 10.4 Developed modules in Functional Group D

FUNCTIONAL GROUP E - WORK CELLS

MODULE CODE	FILENAME	TYPE	DESCRIPTION
E	WORKCELL	F	WORK CELL MODULES MAIN MENU
E1	LOCALMRP	F	LOCAL MPS & MRP RUN MENU
E11	MPSPREP	M	PREPARE LOCAL MPS DATA
E12	MPSEDIT	M	EDIT MPS DATA PRIOR TO MRP RUN
E13	MRPRUN	M	LOCAL MRP RUN
E14	TMPWOGEN	M	GENERATE TEMP W.O. FROM MRP RESULTS & GATHER WO <ISSUEWO?>
E15	TMPWOLSD	M	CALCULATE LSD FOR ORDERS IN <TEMPISS?> FILE
E16	ROUGHCRP	M	ROUGH CAPACITY REQUIREMENT PLANNING
E17	FIRMMRP	M	TO CONFIRM MRP RESULTS GENERATED FROM LOCAL MRP
E2	WKODGEN	F	GENERATE LOCAL WORK ORDERS MENU
E21	WOGENIND	M	GENERATE INDIVIDUAL SINGLE WORK ORDER
E22	MRPWOMOD	M	MODIFY MRP SUGGESTED WO BEFORE CONVERTED INTO REAL W.O.
E23	MRPTOWO	M	CONVERT MRP RESULTS INTO ACTUAL WORK ORDERS
E24	BATCHQTY	M	BATCH SIZE CALCULATION AND MAINTENANCE
E3	WKODMAIN	F	ISSUED BUT UN-RELEASED WORK ORDERS MAINTENANCE MENU
E31	WKODMOD	M	MODIFY UN-RELEASED WORK ORDERS
E32	WKODDEL	M	DELETE UN-RELEASED WORK ORDERS
E33	WKODDIS	M	DISPLAY ISSUED WORK ORDERS
E34	WKODPRN	M	PRINT ISSUED WORK ORDERS
E4	FLOORPLN	F	SHOP FLOOR PLANNING & ORDER RELEASE MENU
E41	WKODDIS	M	DISPLAY ISSUED WORK ORDERS IN MANY WAYS
E42	WKRELMOD	M	MODIFY RELEASED WORK ORDERS
E43	WKRELDEL	M	DELETE RELEASED COMPLETED WORK ORDERS
E44	WKODREL	M	RELEASE WORK ORDERS INTO SHOP FLOOR
E45	WCLOAD	M	INDIVIDUAL WORK CENTRE LOAD STATUS 10 DAYS/50 DAYS
E46	LOADCHRT	M	WORK-TO-LIST AND LOADING STATUS ON WORK CENTRES
E47	LSDGEN	M	GENERATE LSD FOR NEW ISSUED WORK ORDERS (M/C LOAD PRIORITY)
E48	CAPACITY	M	LOCAL CAPACITY DETAILS MAINTENANCE
E5	WIPMAIN	F	WIP DATA MAINTENANCE MENU
E51	WIPUPDT	M	UPDATE WIP DETAILS
E52	WIPDISP	M	DISPLAY/RINT WORK ORDER STATUS IN WIP FILE
E53	ENDWOMAIN	M	FINISHED WORK ORDER DETAILS MAINTENANCE IN <ENDWKOD?>
E6	STOCKCTL	F	STOCK CONTROL FOR LOCAL PARTS
E61	STOCKUPT	M	PARTS/COMPONENTS STOCK UPDATE
E62	STOCKREP	M	LOCAL STOCK STATUS REPORT
E63	PARTDEL	M	PART DETAILS MAINTENANCE
E64	WKONORDE	M	MADE-IN PARTS ON ORDER QTY DETAILS PREPARATION FOR MRP RUN
E65	BYONORDE	M	BUY-PART ON-ORDER QTY DETAILS PREPARATION PRIOR TO MRP RUN

Table 10.5 Developed modules in Functional Group E

FUNCTIONAL GROUP F - FORECASTING

MODULE CODE	FILENAME	TYPE	DESCRIPTION
F1	FORECAST	M	FORECAST MAIN MODULE, WITH ACCESS TO SMALLER MODULES
F1	FOREMOVE	S	MOVING AVERAGE FORECAST TECHNIQUE
F1	FOREEXPN	S	EXPONENTIAL SMOOTH FORECAST TECHNIQUE
F1	FOREREGN	S	LINEAR REGRESSION FORECASTING MODEL
F1	FOREMAIN	S	FORECAST DATA MAINTENANCE
F1	FOREC1	S	LOCATE NEW PRODUCTS BY COMPARING <PRODUCT> & <FORECAST>
F1	FOREC2	S	GENERATE FORECAST HORIZON FOR NEW PRODUCT IN <NEWPROD>
F1	FOREC3	S	DISPLAY AND MODIFY <FORECAST> FILE
F1	FOREC4	S	UPDATE FORECAST HORIZON FOR ALL PRODUCTS
F1	FOREC5	S	PRINT DATA IN <FORECAST> & <OLDFORE>

Table 10.6 Developed modules in Functional Group F

module, the universal report generator, and the file size management module. Their main functions are self-explanatory.

10.1.3.8 SUMMARY

Figure 10.1 shows the important functions which were developed for the embryo system. It also indicates the sequential information flows between these functional modules by the use of arrows. The relationships of the five major functional cells and their associated sub-cells are also illustrated.

Each of these developed modules conformed to a set of standardised data in/out formats and other specified features in design. They can be configured with reasonable flexibility for different work environments where needs vary. The systematic procedures to operate these system modules are described later in this chapter.

10.2 SPECIFICATIONS OF DATA FILE TYPES

As mentioned in the last chapter, each module program or data file has been assigned a name of up to eight characters plus the optional filename extension which may be up to 3 characters long. A typical complete filename therefore should look similar to 'x x x x x x x x . x x x'. In the system, some standard file extensions have been used throughout the development and are listed as follows :

.PRG -- dBASE executable program
.DBF -- dBASE data file
.NDX -- dBASE index file
.MEM -- dBASE memory variable file
.FRM -- dBASE report form file
.TXT -- dBASE data file with SDF format or ASC-II format
.FMT -- dBASE format file for screen display a print format

Apart from the above file extensions, other extensions were also used to represent different software modules and files in the system :

.STR -- structure file for a data file
.MNU -- menu program module
.HLP -- help programs used in embryo system

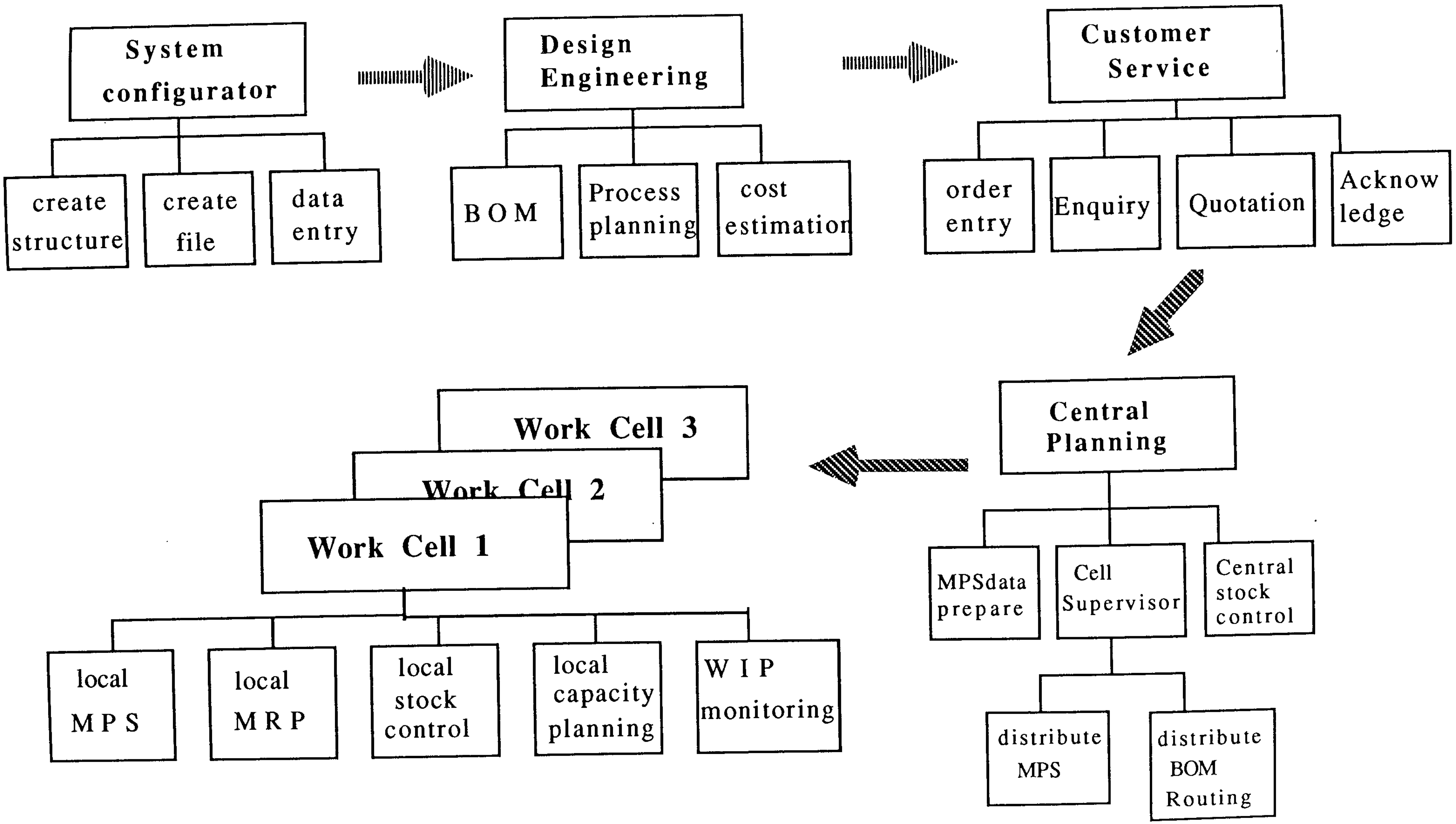


Figure 10.1 Essential modules and their operational sequence in the embryo system

.DOC -- documentation file
.MSG -- text message file

The dBASE defaulted file types are automatically defaulted throughout the system operation wherever appropriate. Other file types are assigned by individual system modules during operation.

10.3 OVERALL OPERATION SEQUENCE OF THE SYSTEM

The system operation begins with the receipt of new customer orders or customer enquiries. The requested quantity and delivery date will be analysed against the available capacity for a particular period. This order will be eventually accepted if it is feasible. Sometimes modifications to the original order are necessary before it can be accepted. If it is a customer enquiry, a quotation will be created automatically to include the quantity, confirmed price, and possible delivery date alongside the original request.

If the product which the customer has requested is not among the existing products, a general product search has to be carried out to look for a product whose specifications are closest to those given by the customer. The customer's requests for a new product design can also be accepted. This will be transferred to the Design Engineering Cell for subsequent design operations. Manufacturing lead times as well as total costs are then calculated when the preliminary design for a new product is completed.

A Central Master Production Schedule (MPS) is maintained at all times to monitor the total forecast demand and the total customer ordered quantity.

Before the central MPS data can be distributed, it is necessary to analyse the current orders and divide them into appropriate product groups. These product groups should have already been defined when the system was first configured and installed. Ideally, only one product group should be assigned to each single work cell. After the data analysis, appropriate data for each product group is then distributed from the central MPS file to the local databases in various work cells. Figure 10.2 illustrates the process in which central MPS data is classified and distributed into the destination work cells.

After this, the distributed MPS data is completely under the control of a work cell. According to the distributed planning and control principle, each work cell has been

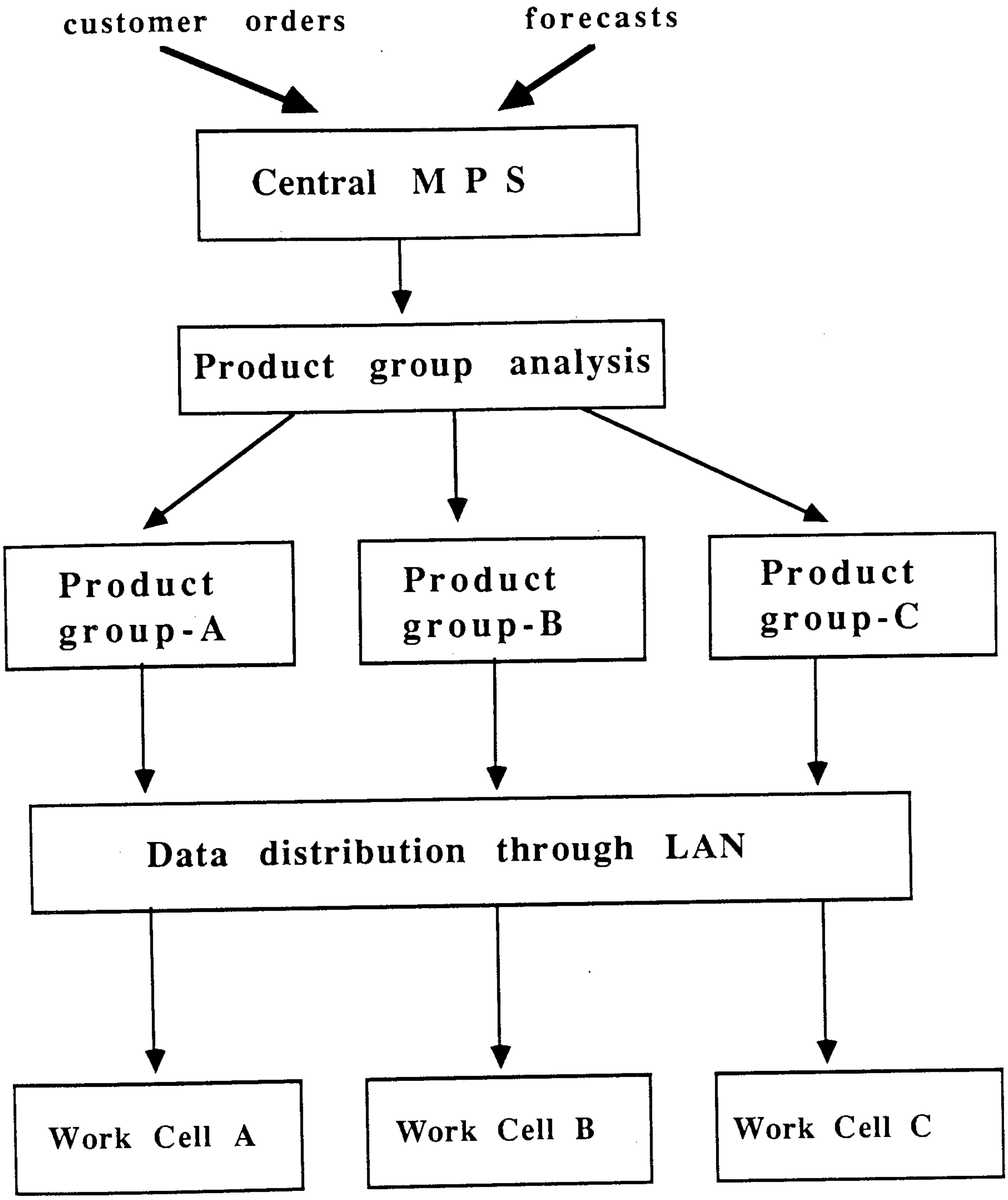


Figure 10.2 Procedures involved in MPS data distribution

assigned some management functions such as MPS, MRP, capacity planning and inventory control.

These work cells are fully responsible for altering schedule, calculating required materials and capacity, releasing appropriate work orders and generating purchase requests. They are also accountable for the inventory of local parts and the overall cell performance.

Finished goods will be transferred back to the central store and the corresponding inventory records will be also updated. Finally, the finished goods in the central store will be issued and shipped to customers in accordance with their orders.

The actual production time and other overhead cost details will be recorded in the work-in-progress file for further use.

10.4 OPERATION PRINCIPLES IN EACH OF THE FIVE FUNCTIONAL CELLS

In the last section, a brief overall description was given to illustrate how the various system modules interact in relation to the system operational sequence. The following sections are aimed to give in-depth descriptions about essential operations which take place in each major system module.

10.4.1 ESSENTIAL OPERATIONS WITHIN SYSTEM CONFIGURATION CELL [A]

The System Configuration Cell is mainly to support the following operations :

(1) to configure the hardware and software in the embryo system according to user's specifications;

(2) to prepare the initial data and information required by some system modules;

(3) to physically transfer the appropriate modules and data files to the specified hard disk locations;

(4) to maintain an up-to-date production calendar which will be referred to by other functions;

(5) to maintain the company details in a file for further reference by other functions.

Some important functions contained in the System Configuration Cell are described below in logical sequences of operation.

10.4.1.1 PREPARATION OF FILE STRUCTURES AND DATA FILES [A1]

This section is mainly to allow the user to define specific file structures in a flexible manner. A data file can be created only if its structure has been defined here. Each file structure is defined in terms of field name, field type and field length.

There are two ways to prepare data files. The user can either define the required file structures and create empty data files based on these structures, interactively, or, he can prepare these files directly in dBASE mode. User options provided by this section are shown in Appendix A under menu [A1].

10.4.1.2 QUICK PREPARATION OF DATA [A2]

After the required data files have been created, the user then needs to enter relevant data into these empty files. This section allows the user to prepare this data in a very quick manner. He can use one of the five user options to add, delete, modify, list or print the required data. Options available in this section are shown in Appendix A under menu [A2].

10.4.1.3 ACTUAL SYSTEM CONFIGURATION [A3]

This is a major function in the System Configuration Cell. It is responsible for the physical configuration of the system.

First, the user has to define two system maps, namely Module-map and File-Map. Functions for both maps were explained in previous sections. These maps are used when the actual configuration commences. If the embryo system is to be installed in a new environment, these two maps have to be entirely re- defined. This provides some flexibility to the system to suit differing needs.

After the two system maps have been defined, the user can then check to ensure that all modules and data files are available from the master storage disk.

The actual system configuration is based on details which are provided by the user. These details will be stored in a configuration table. The table consists of information on all the available hardware, computers and hard disks, and the allocation of this hardware to different functional cells. Figure 9.11 in the last chapter shows typical data contained in such a configuration table.

Finally, the actual system configuration can commence by transferring appropriate program modules and data files to specified destinations via the LAN system. Figure 10.3 illustrates the major procedures to complete a specific system configuration using modules mentioned in this section.

10.4.1.4 PREPARATION OF A PRODUCTION CALENDAR [A4]

The function of a production calendar which is maintained within the system has significant influence on the overall system accuracy. It records the number of hours available in all working days, and the non-working days in a two year period. Such information will be used in all subsequent production planning activities such as MRP and capacity planning.

Non-working days, for example, may indicate bank holidays, factory holidays, scheduled maintenance stoppage and any other specific details when there is no manufacturing capacity available.

Program modules in this section allow users to maintain an up-to- date production calendar and holiday-file. A typical production calendar print-out and a holiday-file are shown in Appendix F.

10.4.1.5 COMPANY DETAILS MAINTENANCE [A5]

This program allows the user to update the particulars of his company so that this information can be used wherever it is required. The name of the company will be displayed on the screen whenever the embryo system is loaded and it will also be printed on all reports.

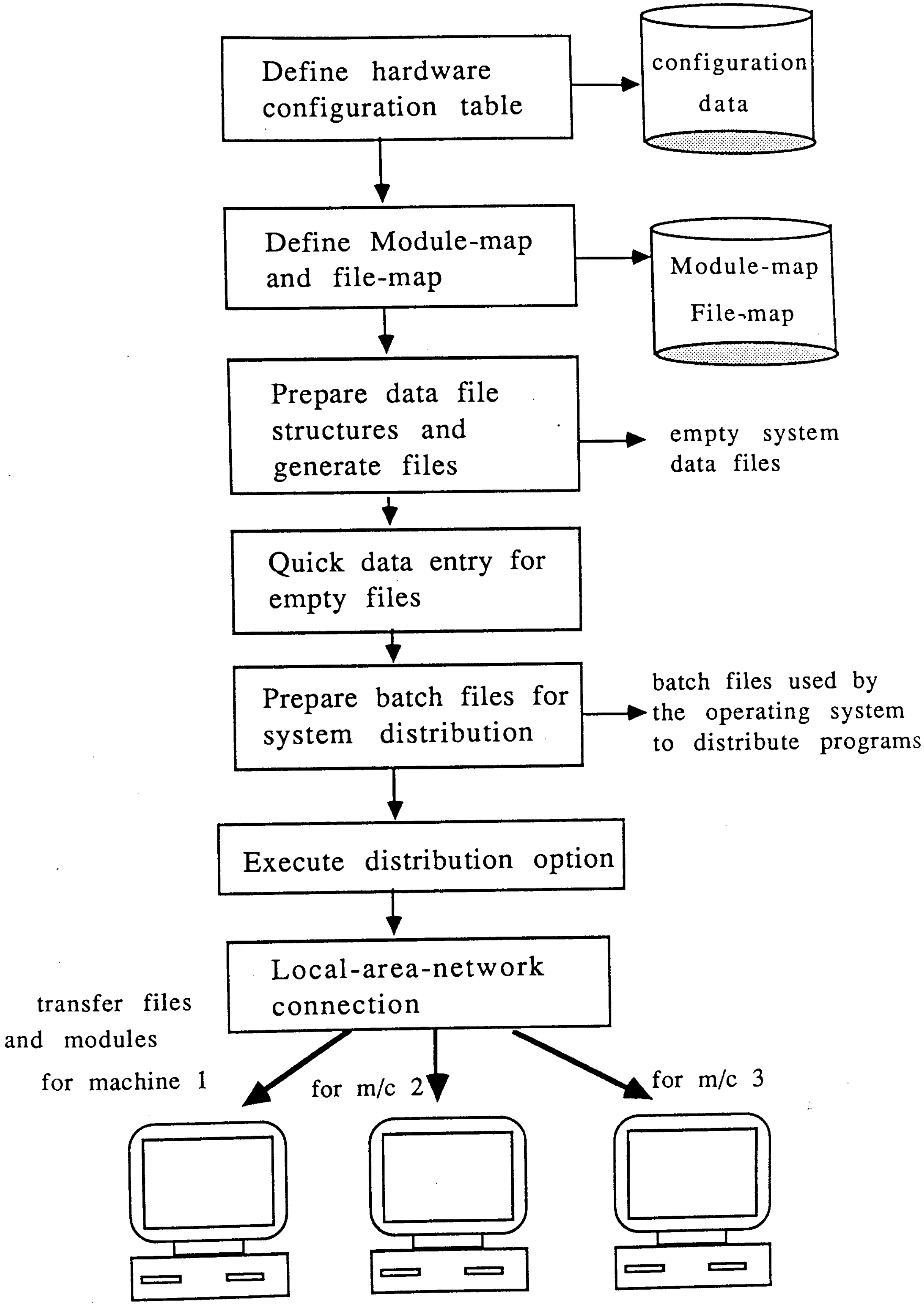


Figure 10.3 Procedures involved in completing system configuration

10.4.2 CUSTOMER SERVICE CELL [B]

The Customer Service Cell is mainly to provide different services in relation to customer demands. The following functions are supported by the Customer Service cell :

(1) to accept customer orders with the confidence of meeting their requested due dates;

(2) to advise any customer enquiry regarding the status of their accepted orders;

(3) to carry out a competent product search for similar products. The search details will be sent to the customer as part of the quotation;

(4) to determine whether any customer order change is acceptable in relation to the modified quantity and new delivery date;

(5) to send quotations to customers automatically when enquiries are received. Details from product search will also be included in the quotation;

(6) to maintain regular shipments of finished goods to customers with user-definable priority on each order. Automatic invoicing will also be activated and proper invoices will be printed and sent.

Major functions and operations in the Customer Service Cell are grouped and explained in the following paragraphs. These functions and operations are described according to their operational sequence and references are made from time to time to their module-codes which were referred to earlier in this chapter.

10.4.2.1 CUSTOMER ENQUIRY [B2] AND PRODUCT SEARCH [B4]

Customers often make enquiries about certain products before they committing themselves to place an order. These enquiries may be concerned with information such as the general and/or technical details of a product, free-stock availability, delivery conditions, product prices and possible bulk-purchase discount.

In this section, useful facilities are provided to deal with various customers' enquiries. Also included are facilities for those customers who have already placed their orders but require an up-to-date status report. When an enquiry is received, it is most likely to fall into one of the following categories :

10.4.2.2 ENQUIRY IN RELATION TO NEW CUSTOMERS ORDERS [B2]

This group of customer enquiries usually triggers the following questions :

(1) is the product available ?

(2) if it is available, what is the lead time, current ex- store quantity, selling price and the possible discount ?

(3) if the required product is not found, is there a similar product which could offer the closest specifications to the original request ?

(4) if the product is not found in the search, is it possible that the product can be designed, its total cost and delivery time estimation ?

The Customer Enquiry section in the Customer Service Cell provides appropriate information leading to possible answers to all these questions.

10.4.2.3 ENQUIRY IN RELATION TO EXISTING ORDERS [B2]

This group of enquiries is usually concerned with the latest situation of existing customer orders, leading to the following possible questions :

(1) what is the status of the order ? Is it going to be delivered on time? If not, what is the possible delay ?

(2) is it possible to change the order ?

(3) is cancellation of the order possible ?

Since these enquires are concerned with existing customer orders, and some orders may be already in production, data files from different areas of the system have to accessed in order to provide accurate information to the customers.

10.4.2.4 PRODUCT SEARCH [B4]

In the Product Search Cell [B4], a 'Master Product' details database is maintained to provide information on all existing products. These details may be expressed in terms of product dimensions, materials used, specifications and production details. The search database is used for searching similar products in comparison to specifications provided by the customer. The Product Search system can offer flexibility such as exact match or similar match, depending on the preference of the customer.

If a product is found in the existing production list, then the customer can makes further enquiries about the particular details of that product provided by another product details database. These details include full product description, price, on-hand quantity and available discount.

If the required product is found in the search, then the customer may want to place an order. In this case, the Customer Enquiry section will call in routines from the 'Order In-take' section to complete the sale order entry operation. However, the customer may want to enquire further about the product - such as the possible delivery date and the available on-hand quantity. In this case, he may request a quotation in which some agreed free stock can be reserved for a limited period of time.

10.4.2.5 CUSTOMER ORDER IN-TAKE [B1]

This module is responsible for taking customer orders and carrying out the necessary analysis to check if the required quantity and delivery dates can be met.

In order to use facilities within the Customer Service Cell in relation to customer orders in-take, a 'Master Forecast Horizon' which records expected sales for each saleable product must be established, during the implementation of the system.

When an order is received, the total demand for that period will be re-calculated and compared against the available capacity for that period. The order will be regarded as satisfactory if the difference between the total ordered quantity and the forecast quantity falls within a reasonable region. However, if the total demand exceed the forecast quantity for that period, then it is possible that the shop floor capacities will be overloaded in that period.

When a customer order has been analysed and firmly accepted, it will be appended to an 'Open Order Book'. The record will remain in that book until the order is completed and shipped to the customer. With the aid of a 'Master Forecast Plan' which usually covers 52 periods, a master MPS horizon of 10 periods is maintained within the system. The accepted order will be appended to the MPS file.

Data in the MPS file is divided into two sections, namely A and B. Section A is for forecast capacity balance, and Section B is for total quantities of customer orders and quotations with reserved stock. When a new customer order is accepted, its quantity will be added to Section A, whilst the reserved capacity in Section B will be adjusted accordingly to work out the new balance. Figure 10.4 highlights the operations which are automatically implemented to update relevant files when a customer order is received.

10.4.2.6 IMMEDIATE DELIVERY FROM THE FINISHED GOODS STORE [B1]

If a customer requests an immediate delivery, supposing there is enough on-hand stock, the following procedures will be automatically executed by the system :

(1) Update of the inventory status with the amount issued for this order;

(2) Preparation of the order acknowledgement;

(3) Activation of automatic invoicing process;

(4) Details are added to the sales history file.

10.4.2.7 QUOTATIONS FOR CUSTOMERS [B5]

When the customer has made an enquiry regarding an existing product, he may decide not to place any order, but may probably just request a quotation. A typical quotation may include the following details :

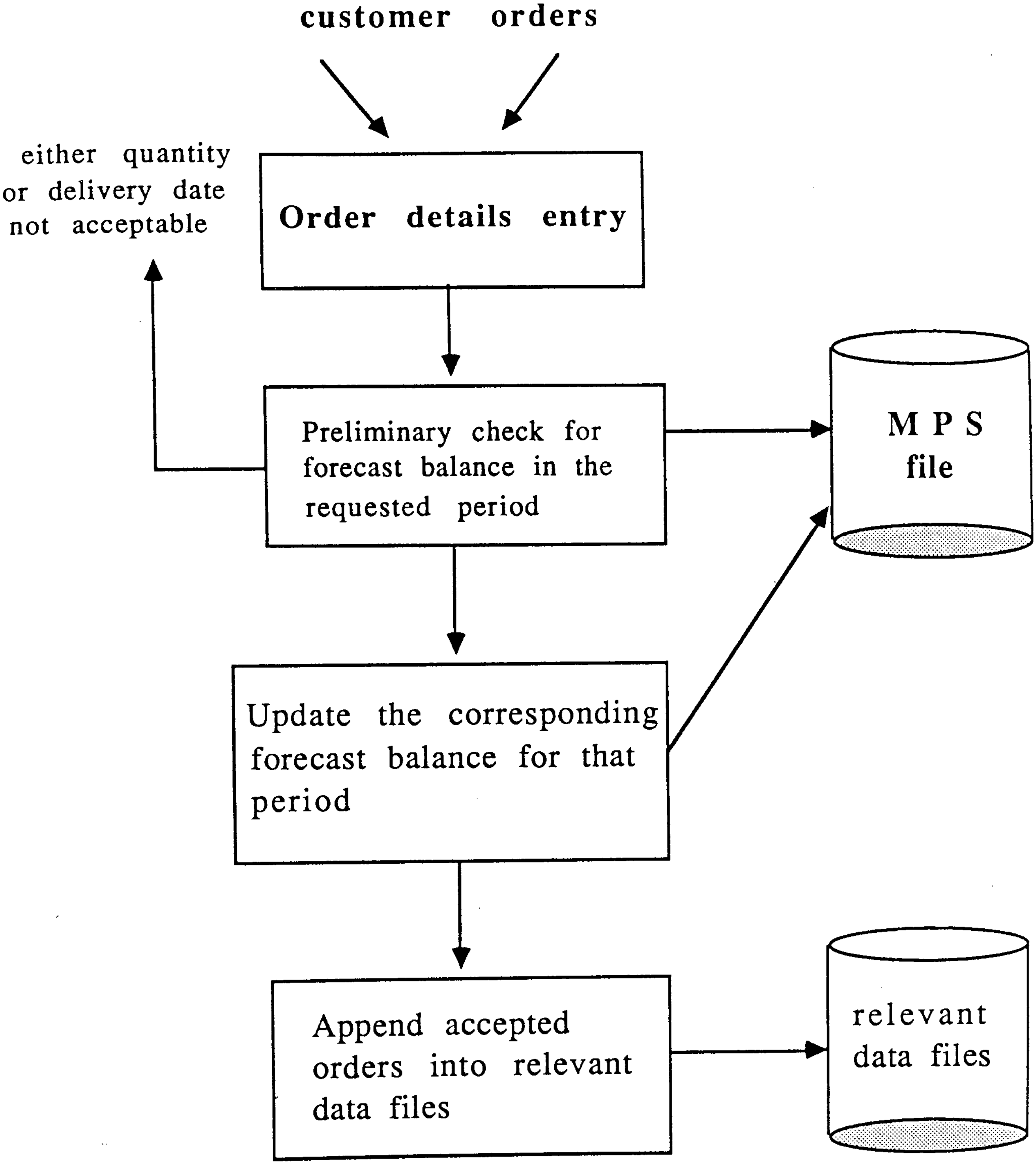


Figure 10.4 Procedures involved in entering a customer order

(1) product specifications and price;
(2) available quantity;
(3) estimated delivery date;
(4) valid duration of the effectiveness of the quotation.

Every newly generated quotation has been assigned a valid duration. The customer who receives the quotation has to respond within that period or else the record of that quotation will be deleted from the database automatically.

The features provided by the Automatic Quotation Module can be summarised as follows :

(1) to gather details obtained in the Product Search Module and the Order In-take Module;

(2) to allocate the reserved capacity to the current MPS file in a specific period;

(3) to send newly prepared quotations to prospective customers every time this module is executed;

(4) to locate and delete expired quotations from the master file. When they are deleted, their reserved quantity in the MPS file will also be released for other customers use;

(5) to modify existing quotation details if necessary.

10.4.2.8 CUSTOMER ORDER CHANGES [B3]

If a customer wants to change some details in an order he had previously placed, there are certain limits to these changes. In general, there are three zones in the MPS planning horizon : the frozen zone, the intermediate (those periods covered in the current MPS horizon), and the planning zone (covered by the forecast horizon). Figure 10.5 demonstrates the relationships of these three zones with respect to the MPS horizon. No changes are allowed in the frozen zone.

If the changes are in other zones besides the frozen zone, the original order will be first deleted from master files, and the altered order is then re-generated as a new order. Procedures to enter and check a new order will therefore be activated. The

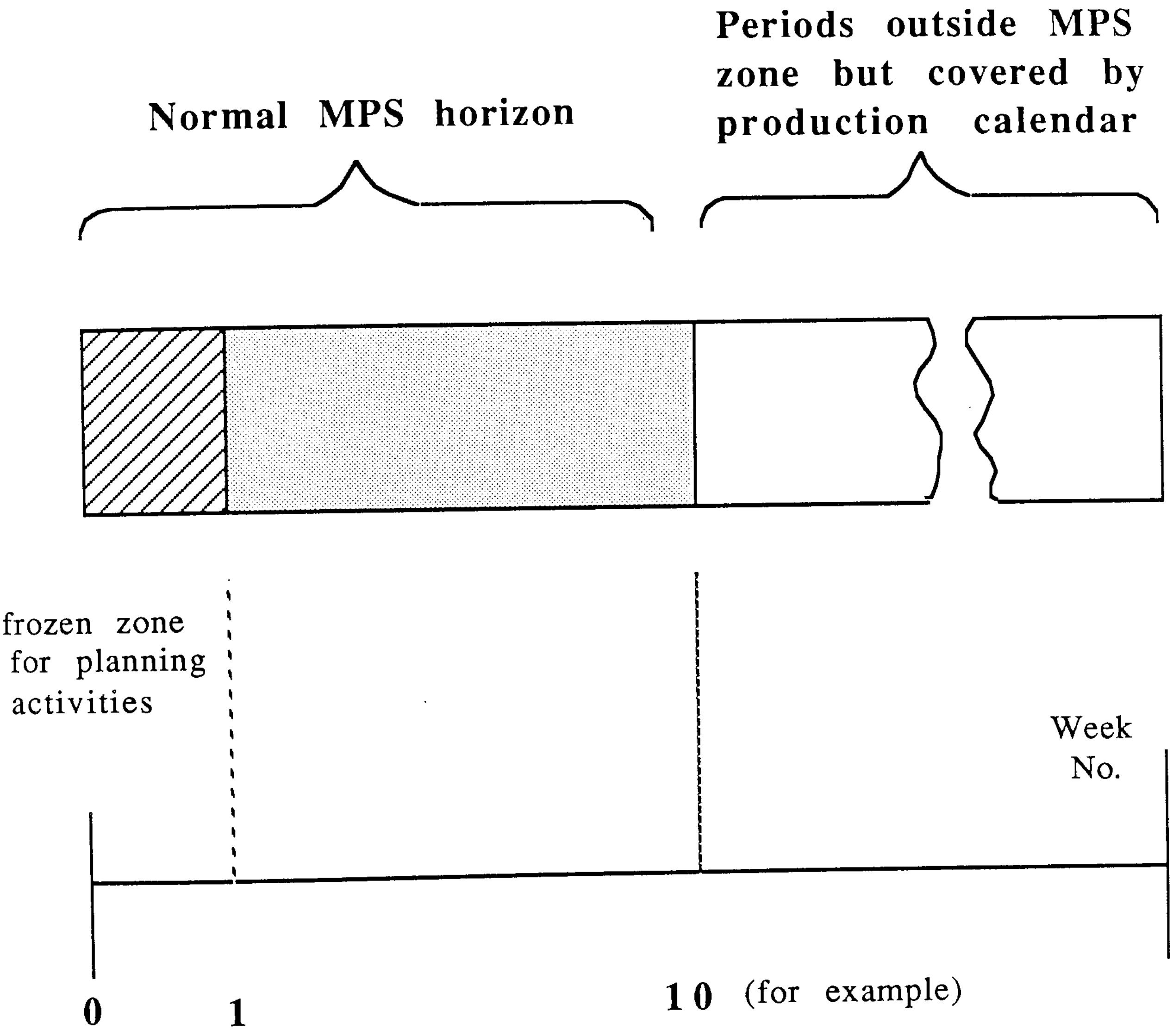


Figure 10.5 Relationships of the three zones on a planning horizon

embryo system has combined all these modules in a logical menu so that the system's complex logic are simplified from the user's point of view.

10.4.2.9 SHIPMENT FOR CUSTOMER ORDERS THAT ARE DUE [B6]

Order shipments will be made at the end of a period so that all inventory transactions will have been already updated.

The system will first locate customer orders that are due from the 'Open Order Book'. If there are sufficient stocks in the store, then each of these orders will go through the stock allocation procedures as follows :

(1) deletion of the order from the order book;

(2) addition of the order into the Order History data file;

(3) allocation of free stock;

(4) automatic invoicing will be automatically carried out and relevant files will be updated;

(5) the order is then added to a shipment schedule file and is ready for shipment.

However, if there is not enough free stock for all such orders, then manual intervention to assign priority to these orders will be necessary. Those overdue orders are always assigned an urgent priority code of delivery.

10.4.2.10 AUTOMATIC ORDER ACKNOWLEDGEMENT [B8]

When customer orders are received, provided the results obtained in the order in-take process are satisfactory, the Order Acknowledgement module will be activated.

The purpose of the order acknowledgement is to confirm the details which have been agreed during the order in-take process. These may include delivery date, quantity, price and other terms of conditions. All these details are automatically collected from various related files during the order in-taking procedures, and will be printed on the acknowledgement for that particular order.

10.4.2.11 MAINTENANCE OF A CENTRAL PRODUCT SEARCH DATABASE [B4]

The central product search database is one the most important features in the Customer Service Cell. The role of the database is to provide the most up-to-date information regarding existing products and saleable parts in the company, and it is frequently used during the order in-take and customer enquiry operations.

The design of the search database should provide good user flexibility so that it can be tailored to suit any particular product and is not restricted by its structure. Before the database can be used, a set of product characteristic labels must be defined for the product range which is to be located. The maximum number of labels that can be defined is five. The user has to analyse the best characteristics to describe a product and then has to specify the five product search labels to match these chosen characteristics.

For example, a product named PN-A can be best described by its :

(1) total length;
(2) length of cut;
(3) type of material;
(4) diameter of its cutting end;
(5) tolerance specification.

Figure 10.6 illustrates the external features of such a product.

On the other hand, another product PN-B may be best described by another set of features :

(1) grade of mild steel;
(2) length of thread;
(3) total length;
(4) number of cutting edges;
(5) type of cutting blades.

Figure 10.7 demonstrates the shape of this particular sample product.

In order to prepare the search database, these five search specifications must be first defined for a product family. More than one database can be used if other product

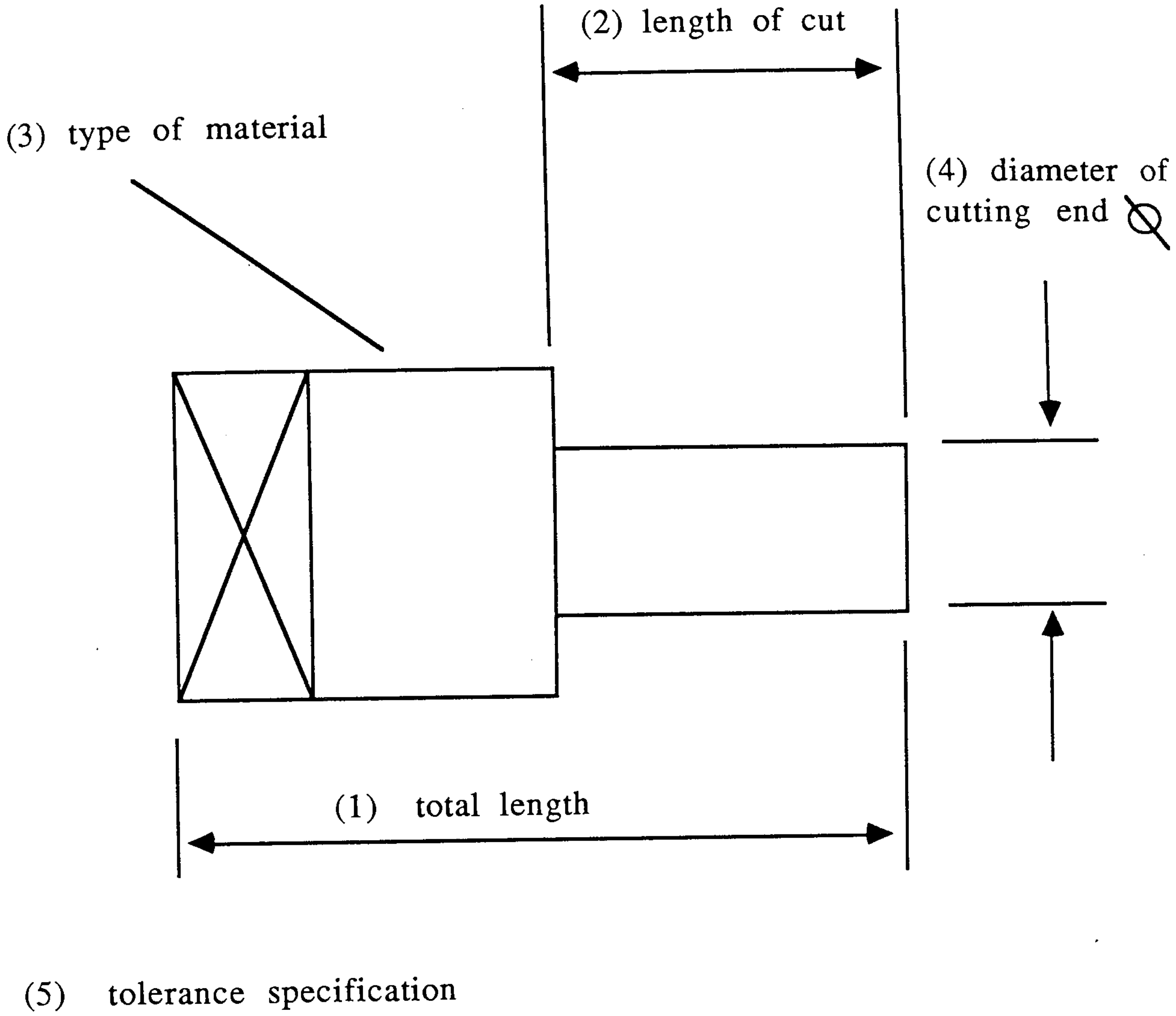


Figure 10.6 The five specific charateristics of a sample product PN-A

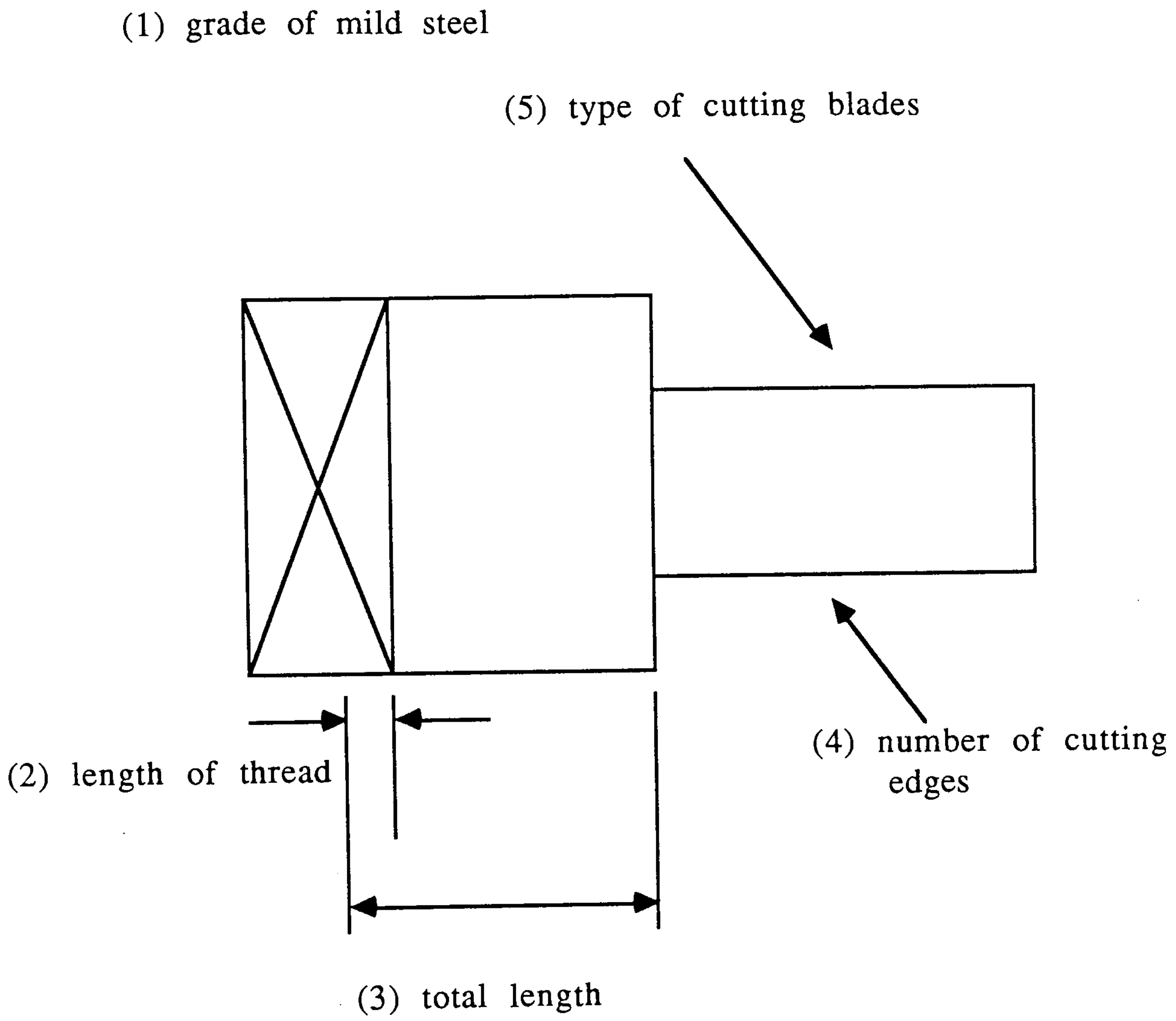


Figure 10.7 The five specific charateristics of a sample product PN-B

families also require locating. After defining the search labels, the user must enter details of all relevant products in order to fill the database.

10.4.3 ESSENTIAL FUNCTIONS IN THE ENGINEERING DESIGN CELL [C]

This section is responsible for all the design tasks are required to prepare technical data for a new product. Similarly if there are changes to be made to existing products, facilities provided within this section will also allow the user to update all the details for such products. The schematic diagram in Figure 10.8 shows the important features accommodated in this section. Note that only those design modules which are required to demonstrate the cellular principle and distribution theory have been developed and discussed here.

10.4.3.1 BILL OF MATERIAL GENERATOR [C1]

The function of a BOM generator is to provide various facilities to create a product-tree structure, known as Bill-Of-Materials (BOM), based on the required part lists for a product.

In order to use the MRP modules, a BOM record must be created for each existing product. These BOM records will later be distributed to relevant work cells, according to the distributed planning and control methodology, and used by the local MRP modules.

The BOM generator provides essential options to modify, to delete, to print existing BOM records, and even to create an entirely new BOM.

10.4.3.2 PROCESS PLANNING [C2]

After the initial design operations and the BOM generation have been completed, it is then necessary to decide what optimum manufacturing processes are required for each assembly and subassembly in that product.

A powerful feature included within this section is the universal Process Planning Template. This template can be used to provide swift preparation of process details for a product. A database is maintained to keep all the details for common process

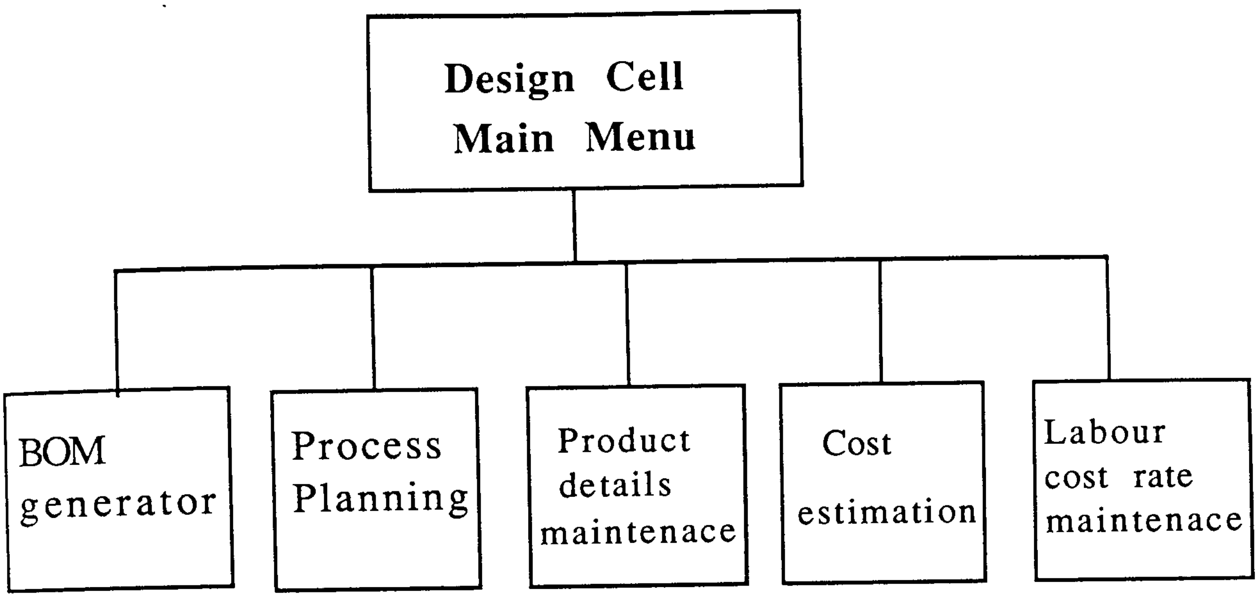


Figure 10.8 Major features in the Design Cell

operations such as facing, turning and milling within specified times. It allows references to be made to some frequently used machining operations so that the creation of a complete process route for a new product can be expedited. Table 10.7 shows a print-out on process template details. It can be indeed regarded as a library of standard operations which are copied onto a specific product's process route.

Other standard features relate to process planning, such as modifying and deleting routing details already in existence, are also provided in this module. Routing details can be generated either for a single subassembly, or for the entire product if the user prefers. Figure 10.9 summarises the available facilities provided in this section.

10.4.3.3 STANDARD COST DETAILS GENERATION [C4]

This section gathers information from the following design processes so that a standard cost can be generated for each existing or new product :

(1) BOM - the type and quantity of parts used in each product;

(2) Process Planning - the production time of each machining or assembly operation required for a product;

(3) Labour rate - the level of skill of labour (and hence the payment rate) required for each manufacturing operation;

(4) Overhead cost - the overhead cost specified for each subassembly or product.

All the above files provide information which is needed to work out the total production cost for each product. The final results will be stored in a central product cost file.

Because of the frequent changes in product structures and probably even technical specifications for existing products, this section also provides an option which enables the user to re-generate the standard cost for one or all existing products by considering their latest design information such as the BOM and routing details.

The labour-rates and overhead costs are prepared separately in two other program modules within the same section.

```
                PROCESS TEMPLATE  -   OPERATION 10  TO OPERATION 100
                                                                         WORK CELL NO.
                          DESCRIPTION                                    -------------
OPERATION  ---------------------------------------------------------
---------
                                                                              WC1
    10     TURN SHANK + GRIND ALLOWANCE (ON INVESTMENT CAST)                  WC1
    20     TURN SHANK,GRIND ALLOW.,CENTRE,TURN BODY,PART OFF                  WC1
    30     MILL FLATS (TAPER, CLARKSON, WHISTLE & WELDON)                     WC1
    40     MILL TIP SEATS/ MILL CLEARANCE                                     WC2
    50     TURN SHANK,GRIND ALLOW.,CENTRE,TURN BODY, PART OFF                 WC2
    60     MILL SHANK (CLARKSON, WHISTLE)                                     WC2
    70     MILL TEETH SHAPE, GRIND TEETH                                      WC2
    80     HEAT TREATMENT TO HARDEN THE CUTTING EDGE                          WC3
    90     INDUCTION BRAZE, INSERT, GRIND LOC                                 WC3
   100     FINISH GRIND CARBIDE / FINISH HEATREATED EDGE
```

Table 10.7 Print-out on process template details

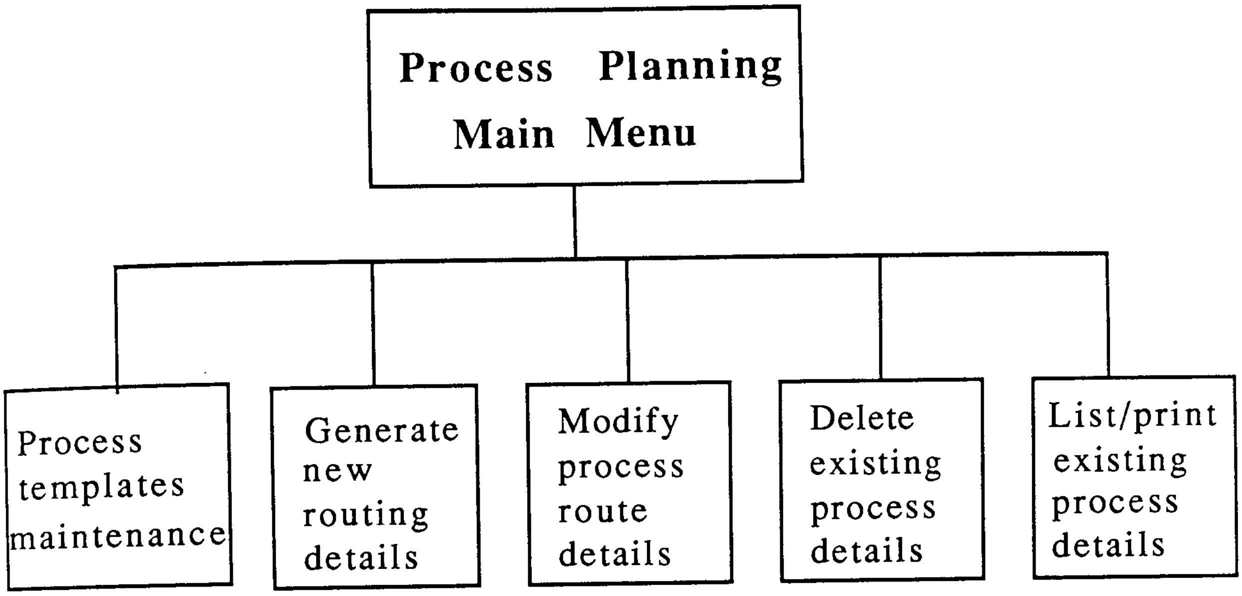


Figure 10.9 Major features in the Process Planning main menu

10.4.3.4 TOTAL PRODUCT DETAILS GENERATION AND CONTROL [C3]

The main purpose of carrying out all the above processes is to complete the preparation of design data for a product. Instead of carrying out these processes one by one separately, a total option is provided here to allow the user to do all the required data preparations in one single process. This is achieved by combining all the necessary design processes into a single module in which they are re-arranged in a logical operational sequence as explained in the following :

(1) general product details initialisation;
(2) BOM detail generation;
(3) routing details preparation;
(4) overhead cost allocation;
(5) total product costs estimation.

After these processes are completed, all the relevant data files will be automatically updated by the newly generated information.

This module is especially useful when the system is first implemented, as the database then is virtually empty. It provides the user with an integral set of modules in one single menu so that entry of design data for existing products can be carried out efficiently. On the other hand, the separate modules introduced earlier will be used to keep the system design database up-to-date as time goes on. Figure 10.10 summarises the procedures required to complete the entering of design data into the product database for a new product.

10.4.4 CENTRAL PLANNING CELL [D]

Because of the use of the distributed planning and control concept, most of the original module-cells, which could have been existed in this central planning cell, have been transferred to work cells throughout the system.

In this central cell, available facilities mainly act as co- ordinators between central modules in central cells and local modules in work cells. As most of the planning and control functions have been distributed to various work cells, only a few planning functions remain in here. Figure 10.11 shows an simplified layout of all major facilities provided in this section.

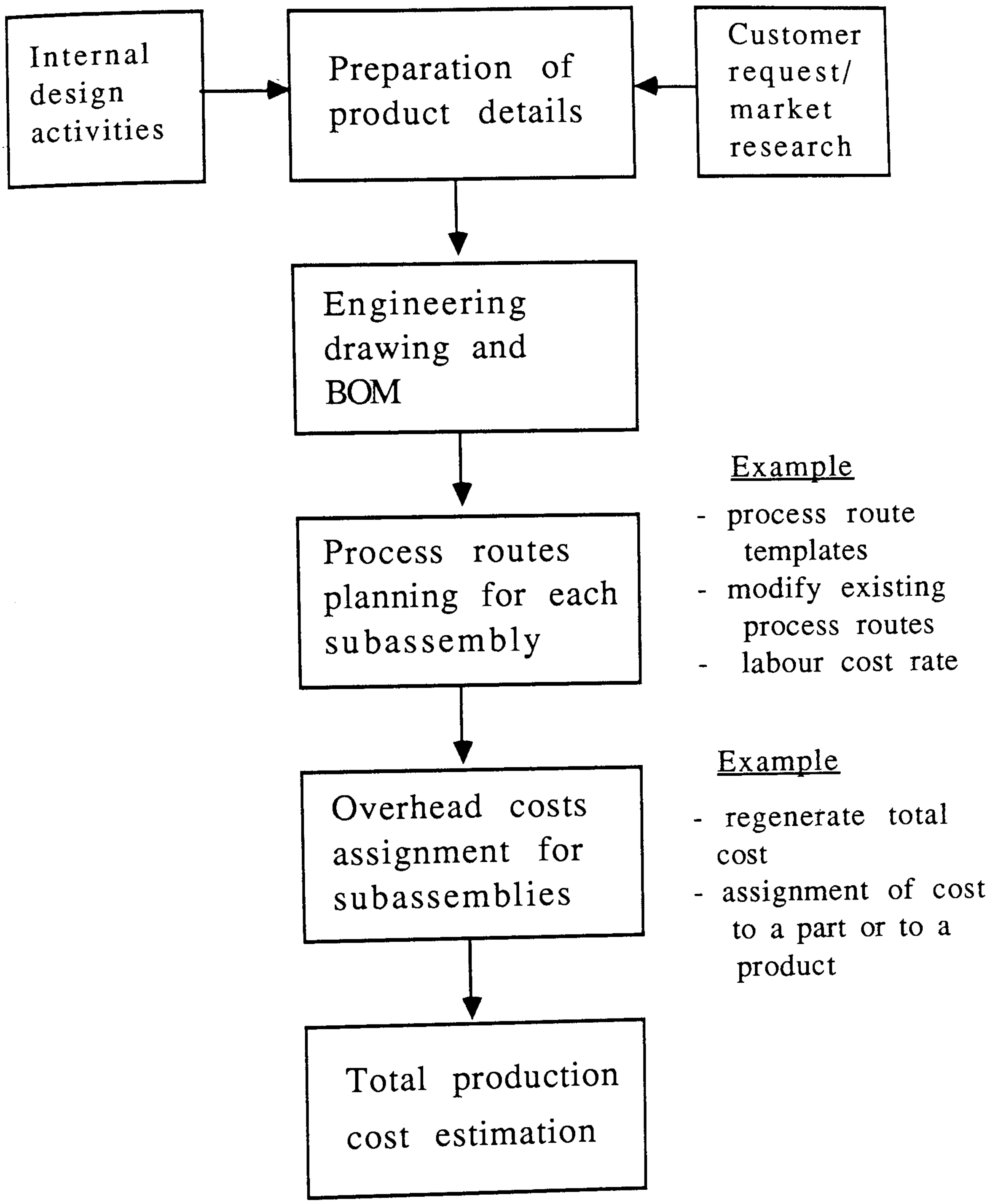


Figure 10.10 Procedures involved in entering design details of a product

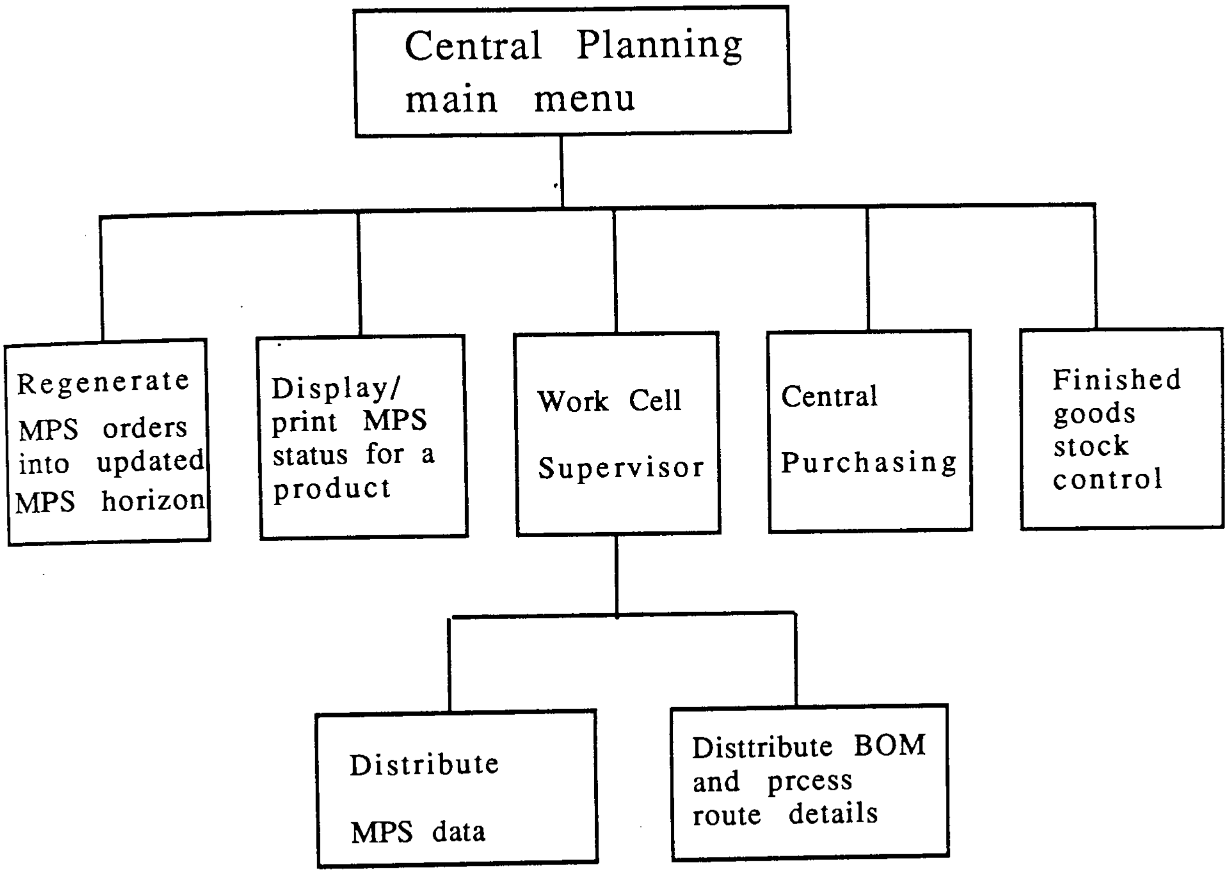


Figure 10.11 Major features in the Central Planning main menu

10.4.4.1 CENTRAL MASTER PRODUCTION SCHEDULE UPDATING [D1]

Although the actual MPS scheduling is done locally in each work cell, the remaining central MPS module in this section gathers all order details from the Customer Service Cell so that the MPS data can be distributed to the work cells.

The central MPS file comprises mainly of firm customer orders, quotation with reserved quantity and spare forecast capacity. Prior to this stage, demands of products were mixed together without any grouping. As time goes on, the MPS planning horizon must be refreshed at regular intervals so that new customer orders can be accommodated into the updated MPS planning zone.

In general, the main function of this central MPS module is to update the system MPS planning horizon and its associated orders, reserved quantity, and forecast balance in each period over the planning horizon. It is important to carry out this updating procedure at a specified frequency so that accurate information regarding product gross requirements and other changes can be available to all local MPS and MRP tasks in work cells.

10.4.4.2 DISTRIBUTION OF THE MPS ORDERS AND PLANNING HORIZON [D51]

After the preparation of the new central MPS horizon and orders, the next operation is to analyse and sub-divide the central MPS file into proper groups of data, in accordance with, the product group definition for each work cell.

Once the grouping of product details in the central MPS file has been completed, the next step is to physically distribute the classified product gross requirements into destination work cells who are concerned with the production of a specific product group. It may not necessarily be true that each work cell is only responsible for a single product group. The definitions of these product groups and their work cell allocations must be done during the initial stages of system configuration. A single work cell sometimes is responsible for the production of two or more groups of the product.

Note that the existence of a common work cell such as a general assembly cell is feasible. In this case, all the orders for products which require final assembly operations would be first distributed to the local MPS file of that common assembly cell. Subsequent requirements for other parts and subassemblies will then be transferred from the assembly cell after its local MRP has been completed to other destination work cells in accordance with the process routes. Both the local BOM and routing files will be required to identify the work cell locations in the processes routes. Figure 10.12 demonstrates the key procedures in which MPS data is distributed to the two assembly work cells, and subsequently to the other work cells.

10.4.4.3 DISTRIBUTION OF BOM DETAILS AND ROUTING DETAILS [D52]

Although a central BOM file and a central routing file are kept in the embryo system, based on the theory of distributed planning and control, their data will be distributed to work cells along with the MPS data distribution.

When a BOM is first created, details of parts and subassemblies for a product are entered. During the data distribution, the entire BOM is analysed in terms of its components and their designated work cells. BOM and routing details for parts and subassemblies which are made in a specific work cell will be copied into the local database of that work cell. In the end, each work cell will maintain the partial BOM and routing records, just for components made in there. These details are stored in the local BOM file and local routing file respectively.

During the distribution of MPS data, BOM data and routing data, into local databases held within work cells, the Work-Cell map is used for identifying the physical location of each work cell so that appropriate data can be transferred across through the LAN system.

Basically, the distribution process can be divided into the following steps :

(1) first, a complete product structure (BOM) is read into the system, and the final top assembly, which is usually the product itself, is located. Its associated process requirements are also read from the central routing file;

(2) this assembly will then form the top of a separate partial BOM record;

(3) the next component of the product is then read and its status is checked. The status of a component indicates whether it is a subassembly or an end

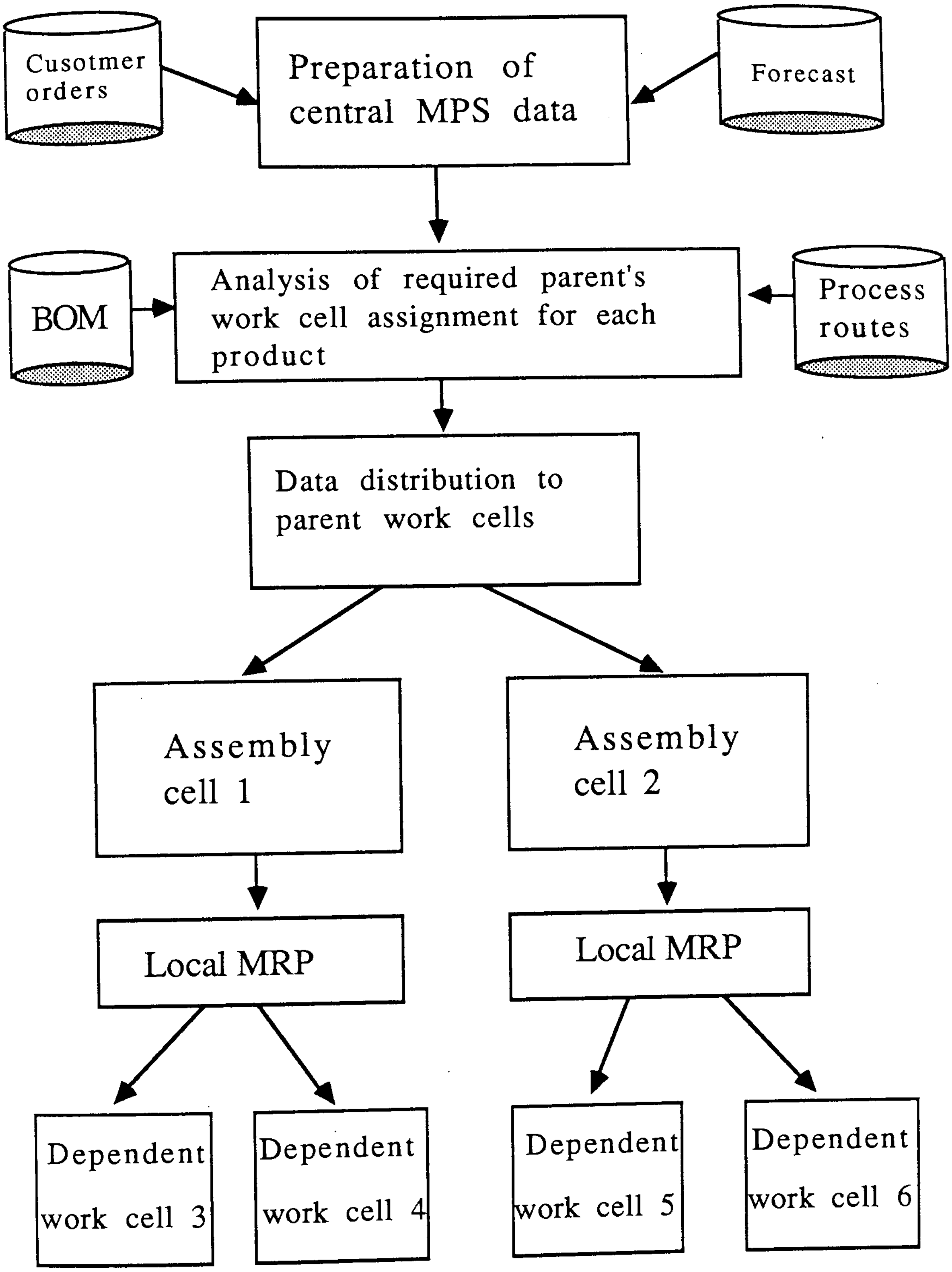


Figure 10.12 Data distribution prior to local MRP run

component. If it is a subassembly, then its work cell designation will be checked.

Several conditions may occur here. If the work cell is different from its parent, then this part will form the end of the current partial BOM record. At the same time, it also forms the top part of another new partial BOM record.

If either its work cell designation is identical to that of its parent, or if it is the bottom component of the current partial BOM, then the part searching loop will continue until no more parts are read from the original BOM, or until a different work cell designation is located;

(4) the next component will be continuously read in and its status checked as in step (3);

(5) as each subassembly is read in, its associated routing details are also located and copied from the master routing file into a local routing file.

Basically these five steps are repeated until all subassemblies and parts are exhausted from the original BOM and all local files are ready. Figure 10.13 illustrates, with the aid of schematic diagrams, how these steps are carried out. It is essential to understand the significance of this data distribution, as the data so distributed will greatly influence the subsequent operations in each work cell.

Note that the distribution of these BOM and routing details has only to be done once at the early stage of system configuration. After that, only technical modifications which lead to subsequent changes in the BOM or routing file will make the re-distribution necessary.

10.4.4.4 CENTRAL PURCHASING CELL [D6]

This central purchasing cell is no different to any traditional purchasing function, in which purchase orders for components are issued and monitored. However it differs from others in that its decisions on purchase requirements are based on the part-requests generated and gathered from various work cells.

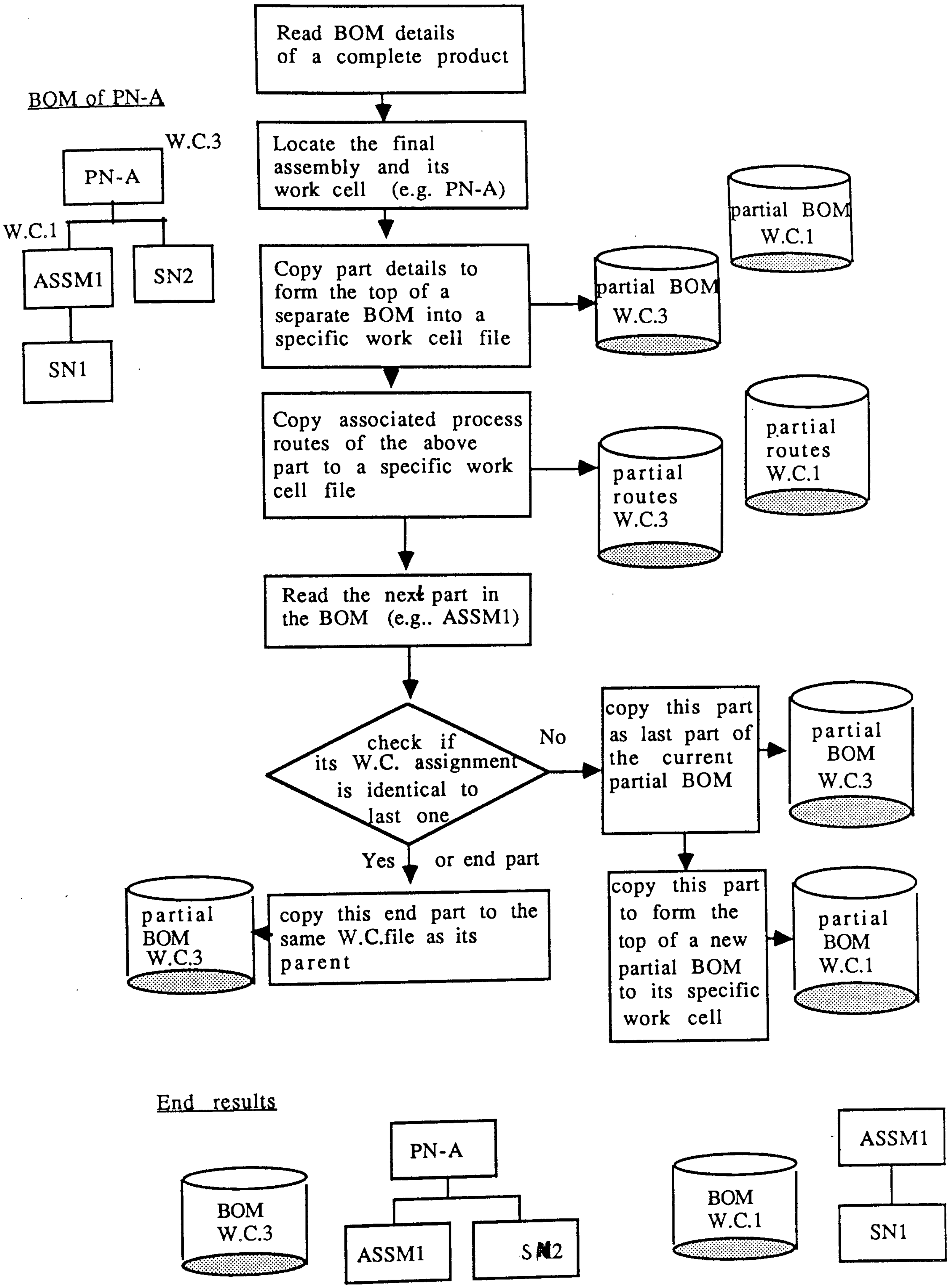


Figure 10.13 Distribution of BOM and routing details into work cells

Because both the MPS and MRP functions have been decentralised and become local modules within each work cell, suggested purchase orders generated in work cells are transferred to the Central Purchasing Cell for further appropriate action.

Since each work cell is flexible in carrying out its local MPS and MRP functions as frequently as required under the local management, there are some rules or guidelines for generating purchase orders so that duplication can be avoided. Figure 10.14 displays the interrelationship between the Central Purchasing Cell and local work cells.

The Central Purchasing Cell has a number of facilities to ensure efficient management of purchase orders and their corresponding updates. These facilities are shown as user options in Appendix A under menu [D6].

A central purchase schedule is maintained at all time to record all the purchased part requests which are received from work cells. Each prospective purchase order in the schedule has a due date for order placement and a scheduled arrival date. When these purchase orders are due, they will be picked up automatically by the system and sent to corresponding vendors for prompt delivery. Different options are provided here for the user to monitor and update the details of each order sent. Order details will remain in the central purchase file until goods are received from vendors.

As each part-purchase request can be traced back to the specific work cell which originated the request, the local part inventory file in that work cell is updated automatically as a consequence of the receipt of inwards goods.

10.4.5 MAJOR FUNCTIONS IN A WORK CELL [E]

As discussed in earlier chapters, because of the adoption of the distributed planning and control methodology, most responsibilities concerning manufacturing planning and control in the embryo system have actually been transferred to various work cells at a lower hierarchy. These work cells, apart from possessing normal production processes, carry out designated planning and control functions such as local master production scheduling, material requirements planning and capacity planning.

Figure 10.15 indicates the possible local modules which are available for a fully configured work cell. The approach so used to develop these work cell makes the tailoring of individual work cells possible. Every work cell, during the initial system configuration, are configured to contain different modules, in accordance with its

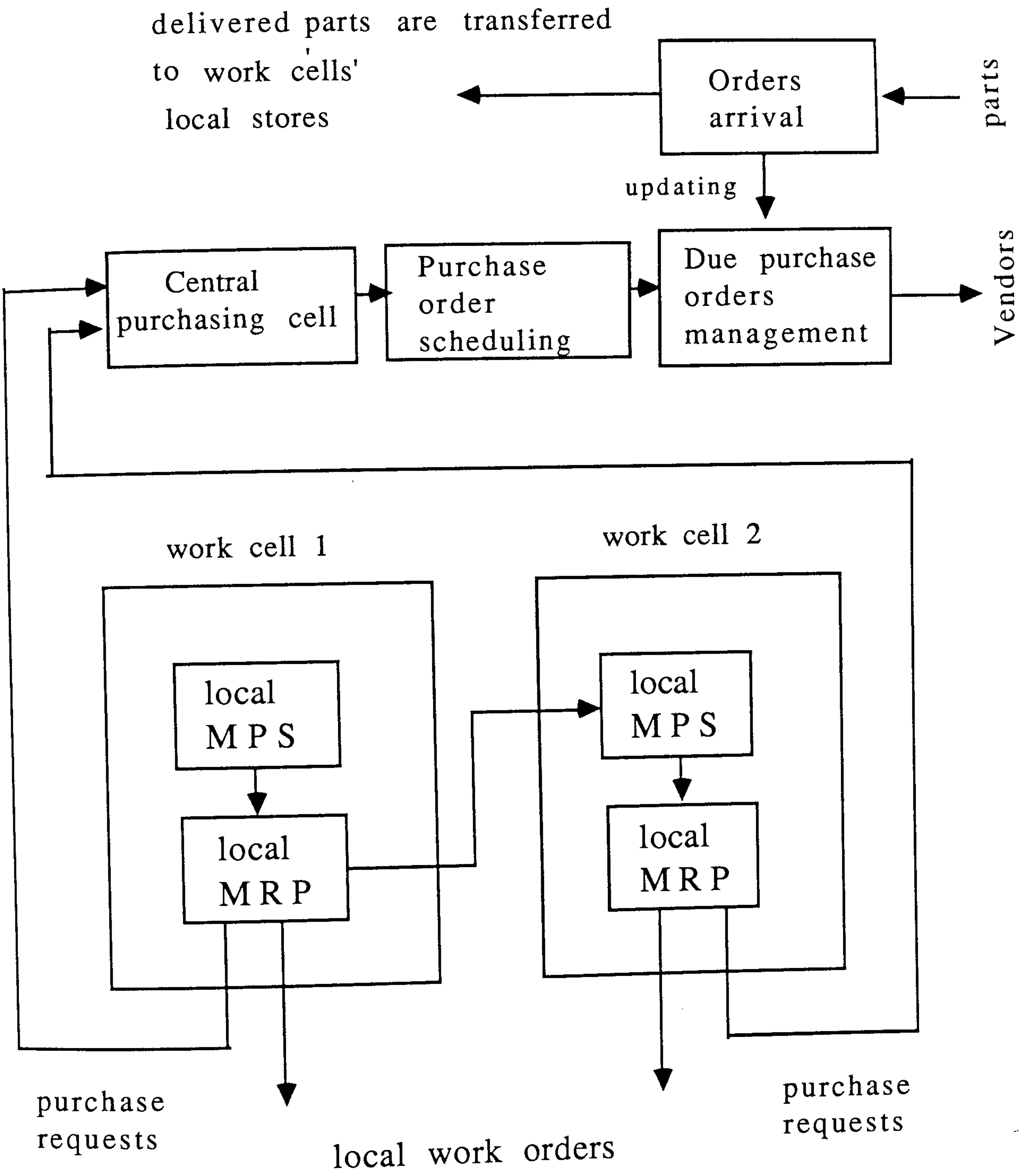


Figure 10.14 Interactions between local work cells and the central Purchase Cell

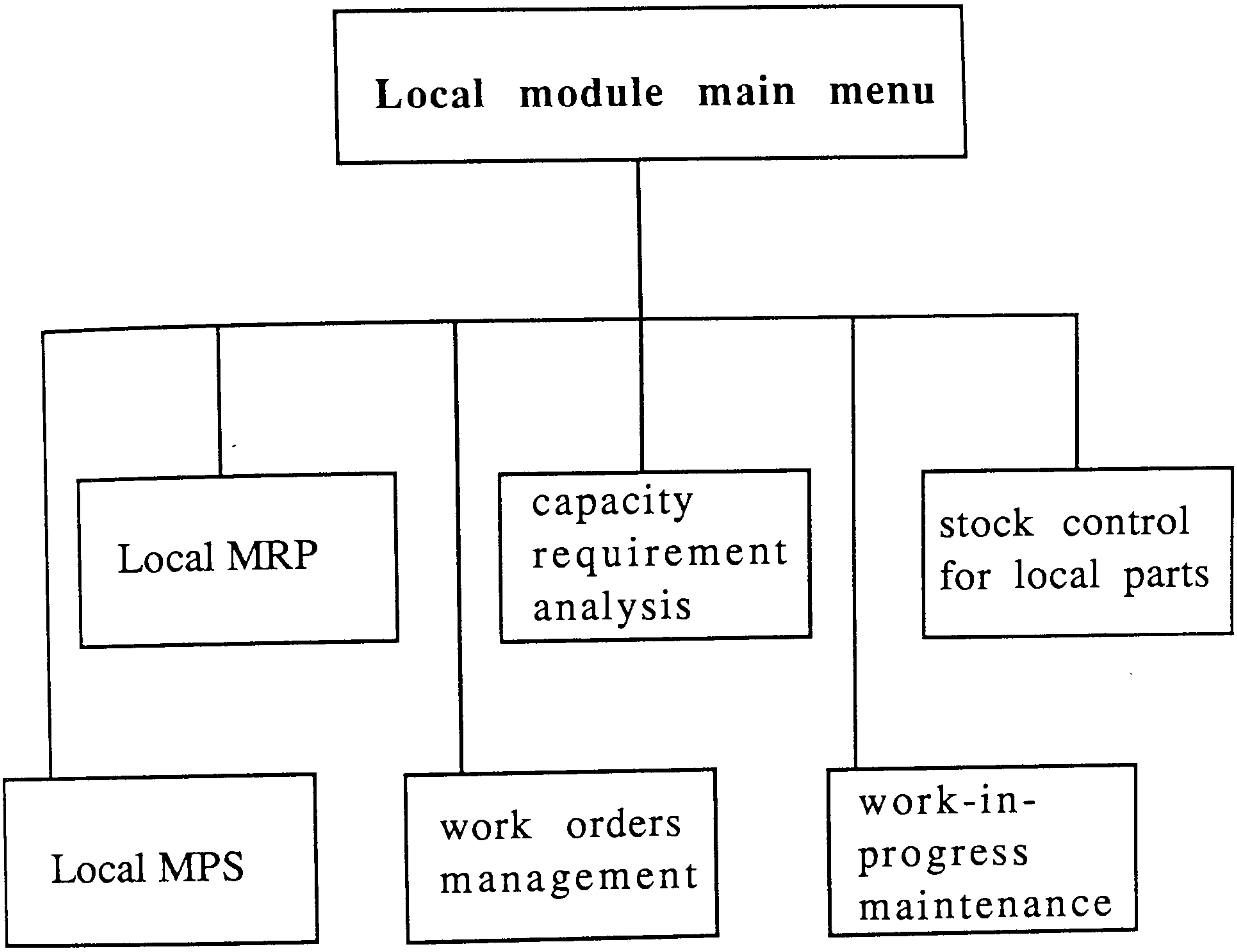


Figure 10.15 Possible local features in a work cell

specific needs. For examples, work cell A can be assigned all local modules, whilst work cell B may only contain a few essential modules, as its requirements probably are different from work cell A.

10.4.5.1 LOCAL MATERIAL REQUIREMENTS PLANNING [E1]

When the Work Cell Supervisor begins its distribution of MPS data, gross requirements of products (including customer orders and forecast) are first re-arranged into product groups and are then distributed into work cells through the LAN system. BOM and routing details are also distributed to these work cells to form partial BOM and process routes in their local databases.

After the initial data distribution is complete, these work cells are then functionally disconnected from central cells and begin to take full control in planning and control processes.

Before a local MRP function can commence, some important data preparation must be done. This preparation is explained in the following sections.

10.4.5.1.1 MPS DATA PREPARATION [E11]

This process is mainly to summarise the distributed MPS data and the other part requests, which have been generated by, and received from, other work cells. The totalled results are stored in a single output file which will subsequently be used in the next local MRP run. Figure 10.16 illustrates the amalgamation of MPS data and part requests received from other work cells prior to a local MRP run.

The necessity of considering part-requests generated by other work cells, and combining them with local gross requirements, is part of the distributed planning philosophy. While each work cell should provide all the required operations for one or more product groups, it may require some operations which are carried out in other work cells. For instance, the presence of a common assembly cell would be responsible for all the assembling processes.

If, for example, there are two product groups which require identical final assembling processes, these processes can be combined together in a single common assembly cell for the convenience of operation. In this configuration, the MPS orders for both

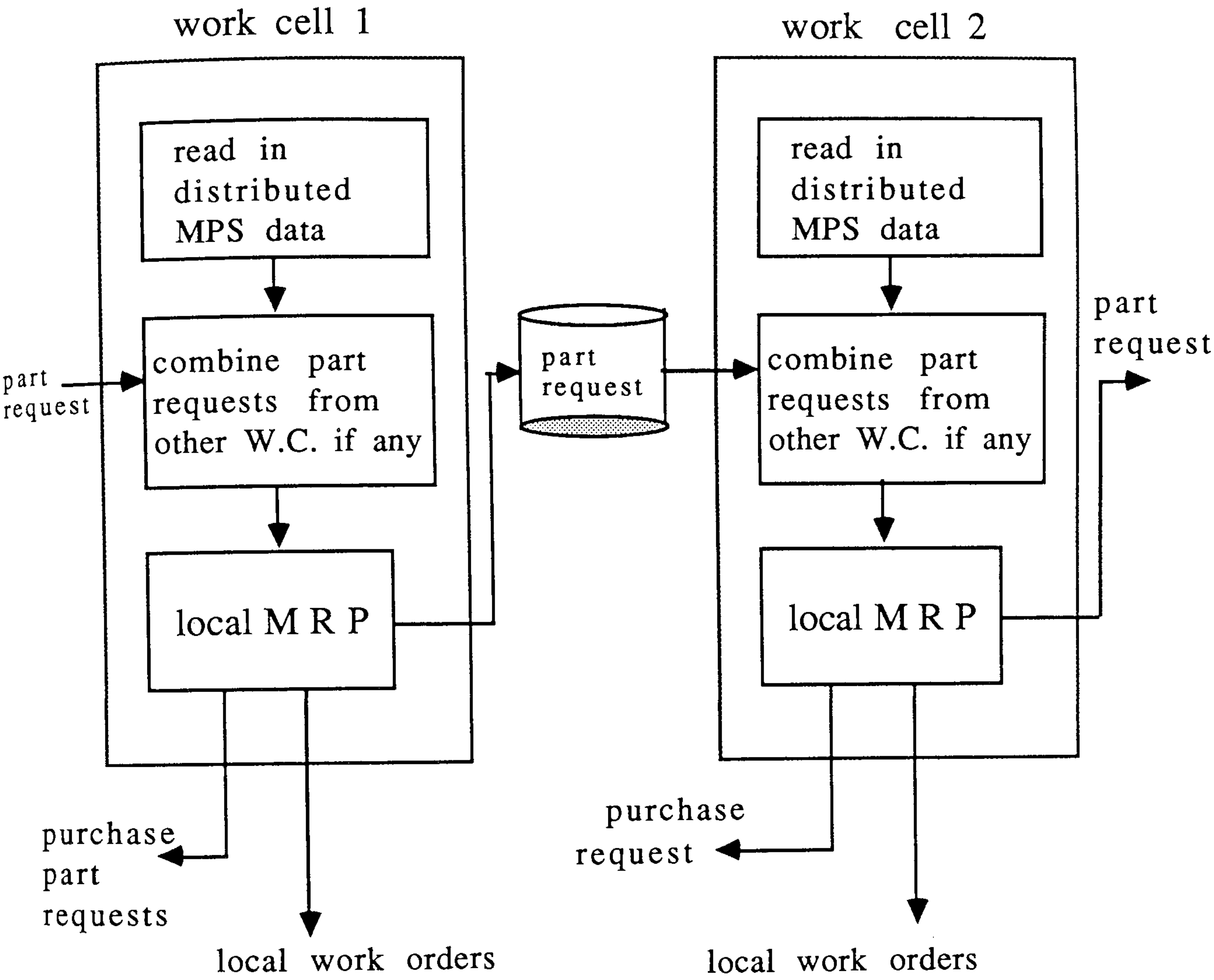


Figure 10.16 Amalgamation of distributed MPS data in part-request from other cell in a local work cell

product groups will be first distributed to the common assembly cell. After the local MRP process is finished, the requests for subassemblies are then transferred to two separate work cells which make these products. Figure 10.17 demonstrates the interrelationships of the two ordinary work cells and the common assembly cell.

10.4.5.1.2 LOCAL PART INVENTORY CONTROL [E6]

As with any other MRP system, the local MRP module also requires accurate information about the on-hand inventory for those parts which the MRP system controls. Typical transactions of these parts such as issue of material, shop floor returns and stock check adjustments are monitored and controlled in a local inventory management module. This local module will be discussed in more detail later on in this chapter.

10.4.5.1.3 PARTS ON ORDER INFORMATION [E64, E65]

The local MRP run requires on-order information for local parts and subassemblies, and on-order information for components bought-out through the central purchase cell.

The on-order information for both made-in parts and bought-out parts is monitored in the local inventory management module. Users can either accept the system defaults which are maintained automatically for scheduled bought-out part arrivals, or they can modify this information manually through the inventory management module.

Figure 10.18 summarises the essential information which has to be prepared before a local MRP run can be carried out effectively. Test runs conducted in next chapter are mainly concerned with local MRP runs as they are the main core of a distributed system and would therefore affect the overall system performance.

10.4.5.2 LOAD ANALYSIS AND LATEST START DATE CALCULATION [E45, E46, E47]

After the first local MRP run is complete, users can select some optional modules to evaluate the implication of the current MRP results using 'Latest Start Date' (LSD) calculation and work-load analysis modules. These optional modules will read data obtained from the last MRP run and store the output results in temporary files. The user then has an opportunity to evaluate the impact of current MRP results on work

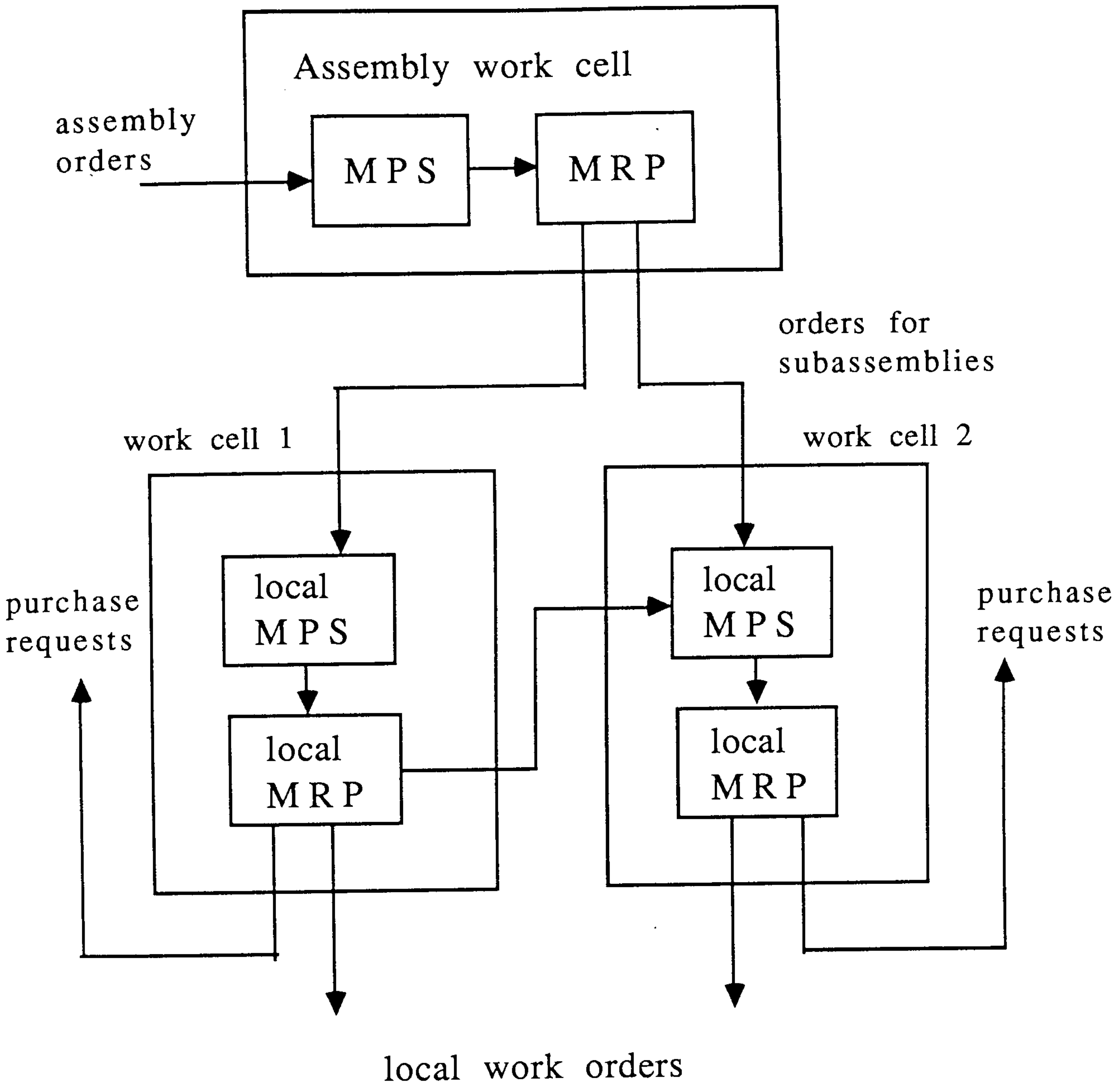


Figure 10.17 Interrelationships between two normal work cells and an assembly cell

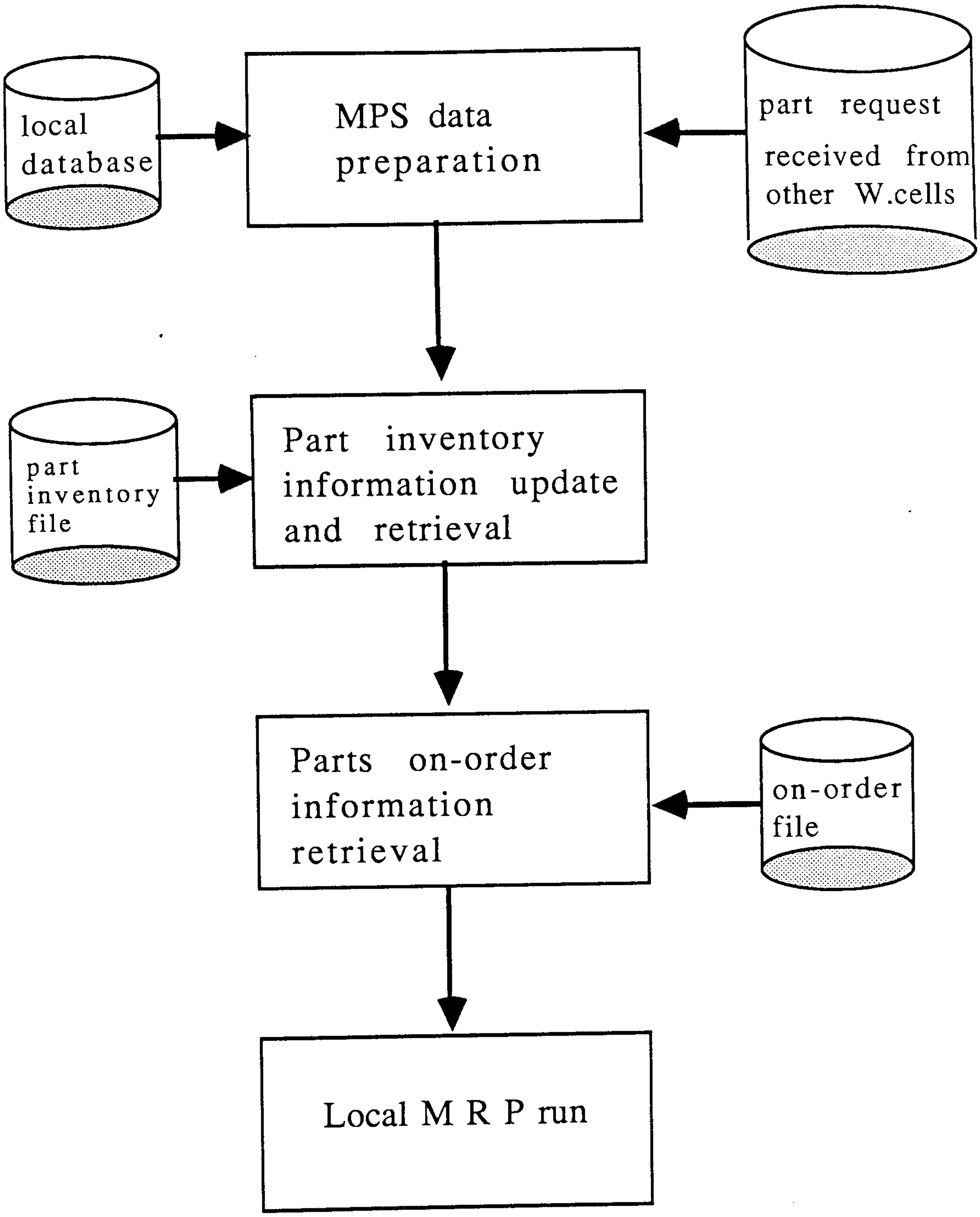


Figure 10.18 Essential information required prior to a local MRP run

centre loading and to estimate the capacity requirements, before he can firmly accept these results.

After running these modules, if the user is not satisfied with the loading situation, he can modify the corresponding local MPS data and run the MRP again in order to alter the corresponding loading situation. Figure 10.19 illustrates the iteration procedures for repeating a local MRP run until the results are satisfactory.

Note that at the end of the iteration, the user must confirm acceptance of the current MRP results so that he can move on to other local control modules. The final results obtained from a MRP run can be classified into the following groups :

(1) work orders for local parts;
(2) requests for subassemblies which are made in other cells;
(3) suggested purchase orders for bought-out components.

Local work orders, as its name implies, are generated for those products/parts which are made locally in that cell. Part requests requiring resources from other work cells are sent to destination work cells respectively through the LAN system, which will be amalgamated with local MPS data maintained in those work cells. Finally, purchase requests will be sent to the Central Purchasing Cell for further appropriate actions.

10.4.5.3 WORK ORDER GENERATION [E2]

This is a very powerful function within the work cells with MRP modules. As the MRP module only makes recommendations on make and buy orders, these recommendations have to be confirmed, and eventually converted into real orders. The function here provides an automatic means of converting user- confirmed MRP results into separate un-released work orders. If the user wishes, he can switch off this automatic function and enter required work orders one by one using a manual entry method, but it is strongly advised that this automatic conversion option should be used.

During the automatic conversion, the user is allowed to make modifications such as the batch size of the order. The final output is work orders which have been assigned with unique work order numbers and are stored in an open work order file. Once these work orders have been generated in this module, they must be treated as serious work orders and any intended changes have to be accompanied by sound reasons.

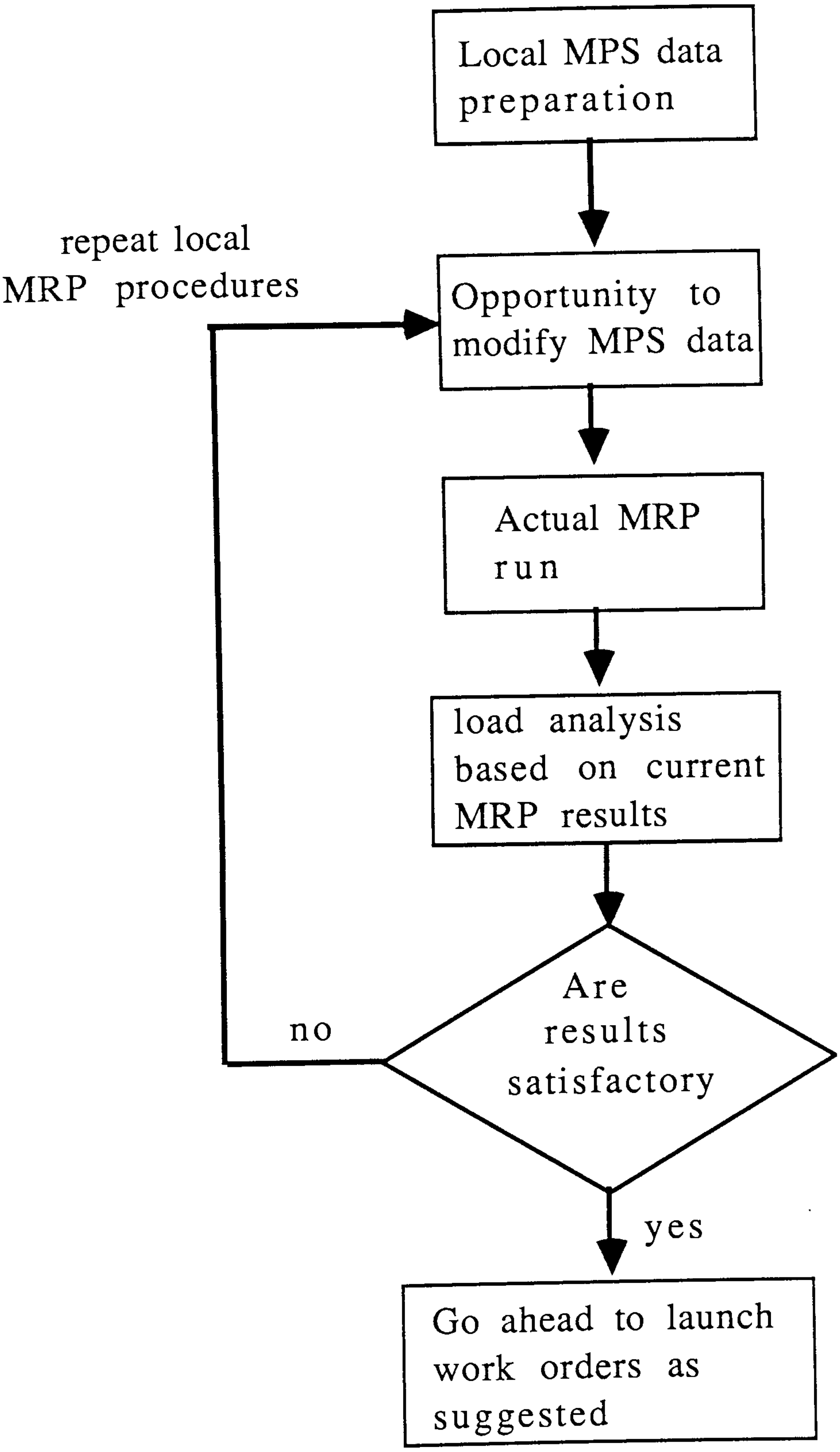


Figure 10.19 Iteration procedures involved in consecutive MRP processes

10.4.5.4 OPEN WORK ORDER MAINTENANCE [E3]

Once a work order is generated, it is then regarded as an open order and can only be deleted from the system when it is completed and returned to the local store. There are many options provided by a work cell to keep track of these open work orders.

When a new work order is generated, a corresponding latest start date must be calculated for each of the operations required to complete this order. Only when a work order has gone through the LSD procedure can it then be used in other load-analysis modules such as Work Centre Loading and Work-to-list evaluation.

Finally, a work order must be released to the shop floor when it is due. Only released orders will be executed in the shop floor.

To improve accurate results for work centre loading analysis, a local capacity database must be maintained to keep up-to-date information regarding the available capacity.

10.4.5.5 WORK-IN-PROGRESS (WIP) MONITORING [E5]

The WIP monitoring facility may or may not be present in a work cell, and this is dependent on the actual requirements of each particular work cell. This module mainly allows the user to update operation details for each separate work order until the order has been completed. Operation details of a work order, which requires updating, include the actual production quantity, scrap produced, total production time, and total down time.

When an order is released, its associated routing, latest-start- date and operation details, are also released to the shop floor in the form of a WIP format which is stored in a master WIP file. The user has to update the WIP file as soon as an operation has finished. When all the required operations of an order have been completed, the order will be regarded as a completed work order and will be deleted from the master WIP file. Other relevant files including the local inventory file, and the open work order file, will be subsequently updated. The central inventory file for finished goods will also be updated if the order is for a final product assembly.

10.4.5.6 LOCAL INVENTORY MANAGEMENT [E6]

The main objective of a local inventory management module is to replace the functions of a central stock control module. Instead of monitoring stock transactions for all available parts and components at a single location with a single database, these parts are divided into groups in accordance with the product group definitions. These groups are stored accordingly in various local databases of the work cells. Each work cell is only responsible for keeping the inventory status for its local parts and subassemblies. Typical features for stock transaction are available in the local inventory module.

10.4.6 FUNCTIONS IN FINANCE AND ADMINISTRATION [F]

As explained at the beginning of this chapter, since the main emphasis of the embryo system is demonstrate the effects of the cellular principle, and the distribution concept, on manufacturing planning and control, functions developed for this particular area are therefore limited due to the limit of time.

In fact, some functions located in the Customer Service Cell could have been transferred into here. For example, customer details maintenance, automatic invoicing and customer credit control could be grouped under the Finance and Administration Cell, if necessary. However, the absence of financial modules has not affected the demonstration of the cellular and distribution principle. Modules in this functional cell can be developed as part of the further work to enhance the existing system, and will be discussed in the final chapter.

10.4.6.1 FORECASTING MODULES [F1]

Figure 10.20 shows the available options enclosed in the forecasting modules. Brief descriptions are also given for each option.

One important concept which has to be explained is that an up-to- date forecast horizon must be maintained at regular intervals. As mentioned in previous sections, because the customer order in- take control module works on the basis of a sound forecast horizon, the current horizon should always cover the planning periods used in the MPS and MRP modules.

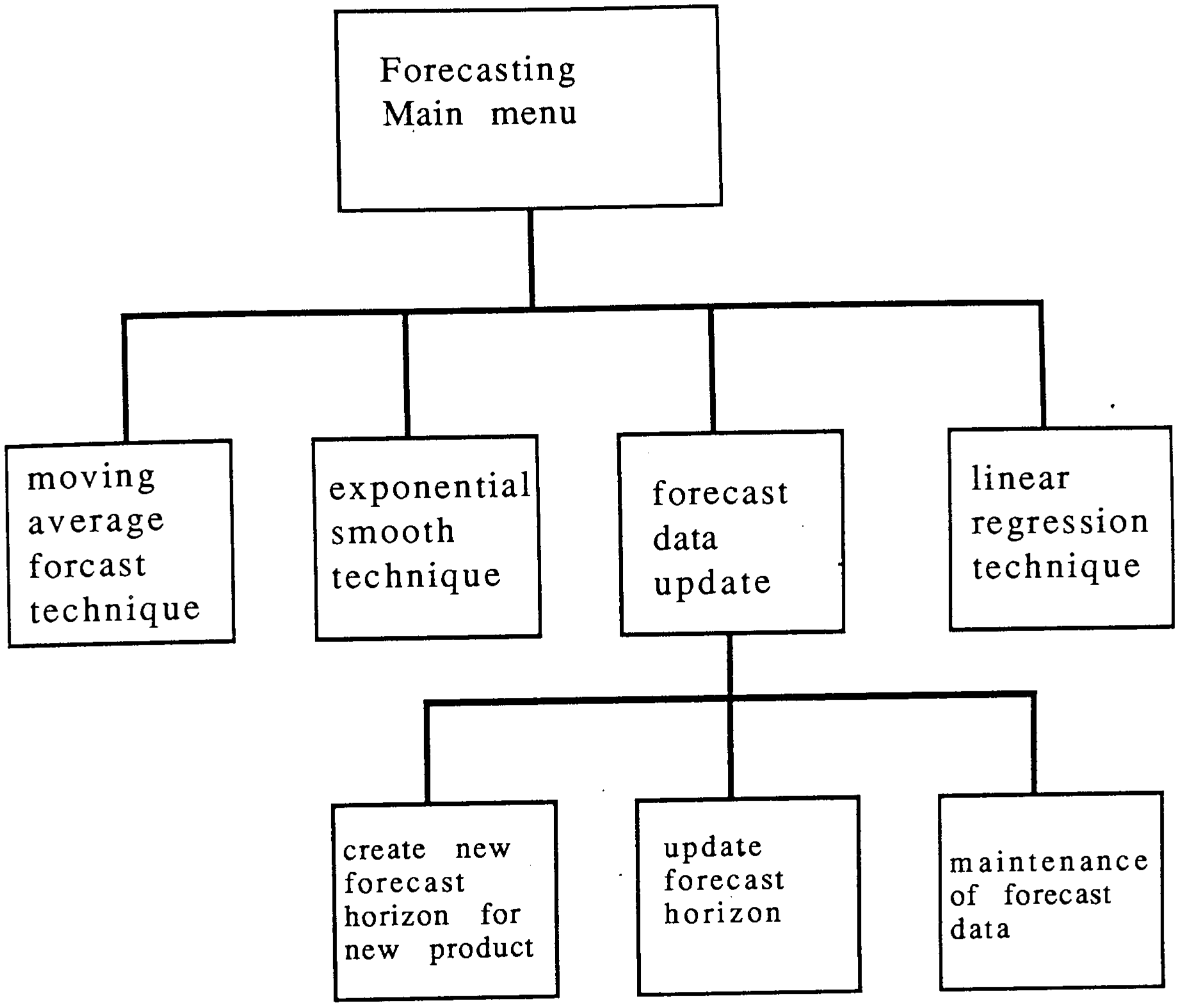


Figure 10.20 Major features in the Forecasting module

10.4.7 OTHER MISCELLANEOUS FUNCTIONS

This section contains other supporting modules and functions which were developed to improve the efficiency of the system.

10.4.7.1 QUICK REPORT GENERATOR

This is a generic module which can be either used along with a central module or a local module. It allows the user to define his own report forms and styles using a standard data-entry format. It can be used with any data file in any module.

10.4.7.2 FILE SIZES MONITORING

In order to maintain an efficient database and optimal disk-space utilisation, it is always advised to allocate only the required amount of disk space to each data file concerned. In the case of the embryo system, because the number of files involved is substantial, and the disk space is limited, file sizes must be under tight control.

This function allows the user to pre-define a maximum number of records for each data file, and the total disk space required is then calculated. When the system is in use, the actual number of records in each file should be monitored at regularly intervals. As soon as the file concerned reaches the pre-defined limit, a warning signal will be generated, so that the user can take appropriate actions.

10.4.7.3 HOUSE KEEPING

This section provides some data management facilities which can be used with any data file in the system. For example, a data- packing module is provided to release the disk space occupied by deleted records in a file; a file back-up module allows the user to make frequent back-ups of desired data areas, and other disk management utilities allows the user to make copying and transferring of files between computers, and between hard disks, easier.

Chapter 8, chapter 9 and chapter 10 together provide a fundamental concept of how the embryo system was designed; what modules were developed, and the logical sequence in which these modules should be operated. Most of the modules described in this chapter were verified during some comprehensive test runs of the system. The next chapter will examine two of these test runs which were conducted to verify the various functions claimed in the system, and more importantly, to demonstrate, the cellular principle and the distributed planning and control methodology, through the results obtained in these tests.

CHAPTER 11 TEST RUNS ON THE EMBRYO SYSTEM

The last three chapters highlighted the development procedures taken to develop an embryo cellular CIM system. The main objective of such system development is to demonstrate the cellular approach, as well as the concept of distributed planning and control, in an integrated system environment. Individual topics included software and hardware selection, structured and modular programming for software design, an overview of the system's features of the modules and their interactions, and also some brief descriptions of the system operation itself.

In addition, the fundamental concept of how the embryo system operates was also mentioned in the last three chapters. This concept includes the initial system configuration, essential data preparation, sequence of operations for data and module integration, as well as the procedures of data distribution from central cells into destination work cells. These sections together have formed an essential operation logic for the system, on which the test runs introduced in this chapter are based.

In this chapter, two major test runs on the embryo system will be discussed in detail. The main objective of these test runs is to verify the various functions of the developed system, and to demonstrate the two important theories postulated in this thesis. One theory is that the cellular approach is feasible in an integrated system, and the other is that the new concept of distributed planning and control has many advantages over the traditional centralised planning and management approach. Results obtained in these tests will be examined, compared and discussed at the end of the chapter.

11.1 MAIN OBJECTIVES OF THESE TEST RUNS

The main objective of the embryo system development is to demonstrate that both of the mentioned theories in the above paragraph can be achieved. Various test runs, therefore, had to be carried out to provide evidence which supports the two hypotheses.

Two major test runs were carried out using the embryo system. The first test was designed to examine the various system modules for their planned functions and data compatibility, whilst the second test was aimed to give an in-depth demonstration of the distributed planning and control concept in a cellular system environment. The interactions between different work cells, in such a data distribution environment, were also examined in the second test.

11.2 GENERAL INTRODUCTION OF THE TWO TEST RUNS

There could be many different combinations, in terms of hardware and software configuration, which could lead to a considerably large number of possible test runs. However, in this chapter, only two important test runs are discussed in detail. Results obtained from these contribute significantly to the final conclusion of this thesis. Other possible tests using the embryo system will be suggested in the next chapter.

The two most important elements in these test runs were the number of computers used, and the number of work cells configured, in the system.

In the first test run, the configuration only comprised one computer and one work cell. In general, this test was more comprehensive than the second, in terms of verifications of system functions and data. Its main objective was to provide an overall examination of all functional modules in the system, and, in addition, the effect of having only one work cell and one computer used in the system. Each module's functions and their associated data-links were checked as were the results and reports obtained. The single work cell environment resembles the conventional shop floor approach in which all planning and control activities are concentrated at a single location.

The second test run, however, was more specific. It basically concentrated on the issue of the distributed planning and control concept. In this test, two OCTOPUS computers were used, and three work cells were configured in the system. All the three work cells were assigned local MPS, MRP and capacity planning modules. Further details related to the two tests are presented later in this chapter.

11.3 GENERAL PROCEDURES FOR SYSTEM SET-UP AND FOR BASIC DATA PREPARATION PRIOR TO A TEST RUN

There are certain standard procedures which must be followed in order to complete a test run although the emphasis varies between the two tests. These procedures included the initial system configuration and data file preparation at the beginning, as well as the logical steps to activate each module in the order of their operational sequence. Detailed descriptions of most of these operations were already mentioned in Chapter 10, the following section therefore is aimed to only give a summary of these test run procedures:

(1) to specify details of system configuration :
    a. number of computers;
    b. number of printers;
    c. number of work cells intended;
    d. software modules available;

(2) to designate hard disk locations to each system module and work cell, so that the required system maps can be generated;

(3) to assign different production product groups to available work cells, and to decide the links of process routes between them;

(4) to run the System Configurator to activate configuration procedures;

(5) to prepare essential data files in each of the following cells :

    a. Customer Service Cell;
    b. Engineering Design Cell;
    c. Central Planning Cell;
    d. each individual work cell;
    e. forecast modules in the Administrative Cell.

(6) to run the Design Cell so that details of existing products and parts can be entered into appropriate data files;

(7) to run central purchase modules to register available vendors in data files. Opening stock on-hand balance has also to be specified for each stocked finished products;

(8) to run separate work cells to register the available capacity details within them;

(9) to run forecasting modules to generate a 52-period long of planning horizon for each existing product;

(10) to run product sales modules to create new customer orders and new quotations;

(11) to run the Central Planning Cell to prepare the central MPS file and forecast file for analysis before data distribution;

(12) to distribute central MPS, BOM and routing details into destination work cells;

(13) in each work cell, to run the local MPS module and to combine the distributed MPS data with part requests received from other work cells;

(14) to run the local stock control module and to prepare part on-order details prior to a MRP run;

(15) to run the local MRP and to generate three end results :
  a. local work orders;
  b. part requests to other work cells;
  c. purchased part requests to central purchase cell;

(16) to run preliminary load analysis modules to decide if the MRP results are satisfactory;

(17) to accept these MRP results by copying data from temporary files into master reference files. Part requests will be sent to other destination work cells and to the Central Purchase Cell respectively;

(18) to generate the Latest-Start-Date (LSD) details for each local work order so that priority can be assigned;

(19) to run the local capacity planning modules to decide the exact schedule for resources;

(20) to release work orders with preferential priority to the shop floor. While these orders are being released, a corresponding WIP record will be generated for each of these orders;

(21) to update corresponding WIP operation details as production continues;

(22) to update the local stock files when an order has been completed;

(23) if work orders associated with final assemblies have been completed, then the central stock file of finished product will also be updated;

(24) to run the central purchase modules to collect the latest purchase requests generated by various work cells in their local MRP runs;

(25) to update corresponding local stock files when parts are received from vendors;

(26) to check customer orders periodically so that any orders that are due can be picked up for shipment;

(27) to monitor customer quotation records periodically so that any expired quotes can be cancelled in time to release any reserved stocks or capacity.

Some of these procedures have to be repeated as production continues. It must be also stressed that the sequence of MRP operations in the work cells would follow a specified route defined during the system configuration. The significance of this on data transfer between work cells is already explained in early chapters.

11.4 TEST RUN ONE FOR THE EMBRYO SYSTEM

11.4.1 OBJECTIVES OF TEST RUN ONE

As mentioned before, the main objective of this test run was to examine the performance and functions of the embryo system. The single work-cell, single computer configuration used here, resembles many real situations in which only one main host computer is used, and there is no product group division on the shop floor.

All the basic operation procedures for a test run described in the previous section were followed, except local modules were only confined to one work cell.

In this test run, MPS and BOM details were still distributed from the Central Planning Cell to the single work cell, but this should be no different from a traditionally centralised planning environment in which all planning is done at a single location.

Detailed examination of each essential module was carried out to demonstrate that the module was capable of performing the intended functions. Results obtained from each module concerned will be either attached in the main text as supplementary evidence, or in Appendix F for reference.

11.4.2 SYSTEM CONFIGURATION IN TEST RUN ONE

The test run began with the system configuration. Since only one OCTOPUS computer was used in this test, there were two volumes of hard disks which could be used, namely drive A and drive B.
In this test run, the configuration details were specified as follows :

DRIVE LOCATION	MODULE ASSIGNMENTS
A	All modules in the System Configuration Cell (Function group A)
A	All modules in the single work cell (Function group E)
B	All modules in the Customer Service Cell (Function group B)
B	All modules in the Design Cell (Function group C)
B	All modules in the Central Planning Cell (Function group D)

In order to enter these configuration details, the System Configurator (Menu A) in the main menu must be selected at the current drive. The options available in this menu are shown in Appendix A.

Table F-1 in Appendix F shows a print-out obtained from the system after the initial configuration details had been entered. It summarises the main details for this particular configuration.

11.4.2.1 PRODUCTION CALENDAR

A production calendar must be generated at this stage. It records all working days and non-working days of the company. The number of working hours in a working day is also specified.

Before a production calendar can be created, a non-working day file must be maintained. This non-working day file may vary according to schedule for different companies. Table 11.1 displays the screen-print of typical non-working days in such a file.

```
ASTON UNIVERSITY C.I.M.S.                                         01/01/88
  Listing of Holidays/Non-Working Days
--------------------------------------------------------------------------
   DATE                    YEAR                  REASON

                                                 FACTORY
 3 - January ----          1988 -------          NEW YEAR
 4 - January ----          1988 -------          FACTORY
 5 - January ----          1988 -------          BANK HOLI
 1 - February ---          1988 -------          EASTER
 1 - April ------          1988 -------          EASTER
 4 - April ------          1988 -------          FACTORY
 5 - April ------          1988 -------          BANK HOLI
 2 - May --------          1988 -------          BANK HOLI
13 - June -------          1988 -------          FACTORY
11 - July -------          1988 -------          FACTORY
12 - July -------          1988 -------          FACTORY
13 - July -------          1988 -------          FACTORY
14 - July -------          1988 -------          FACTORY
15 - July -------          1988 -------          BANK HOLI
29 - August -----          1988 -------          CHRISTMAS
26 - December ---          1988 -------          CHRISTMAS
27 - December ---          1988 -------          NEW YEAR
30 - December ---          1988 -------
==========================================================================
 2 - January ----          1989 -------          NEW YEAR
--------------------------------------------------------------------------
```

Table 11.1   Typical content in a non-working day file

The embryo system is capable of producing a full 2 year-calendar based on the given information. A sample print-out of such a production calendar from 1988 to 1989 is shown as Table 11.2.

11.4.2.2 PREPARATION OF OTHER RELEVANT DATA FILES

Some data files should be prepared before the actual configuration takes place. The available options in this section are shown under the screen menu [A2] in Appendix A.

The user can use these options to prepare data for some essential files prior to configuration. For example, he can use option [A22] to set the default file name and index first, before using option [A23] to enter the required data.

Specific details about the user's company also have to be entered using option [A6], at this stage. These details will be mainly used for screen display and report heading. Table 11.3 shows the specific company details stored in the system.

11.4.2.3 ACTUAL SYSTEM CONFIGURATION

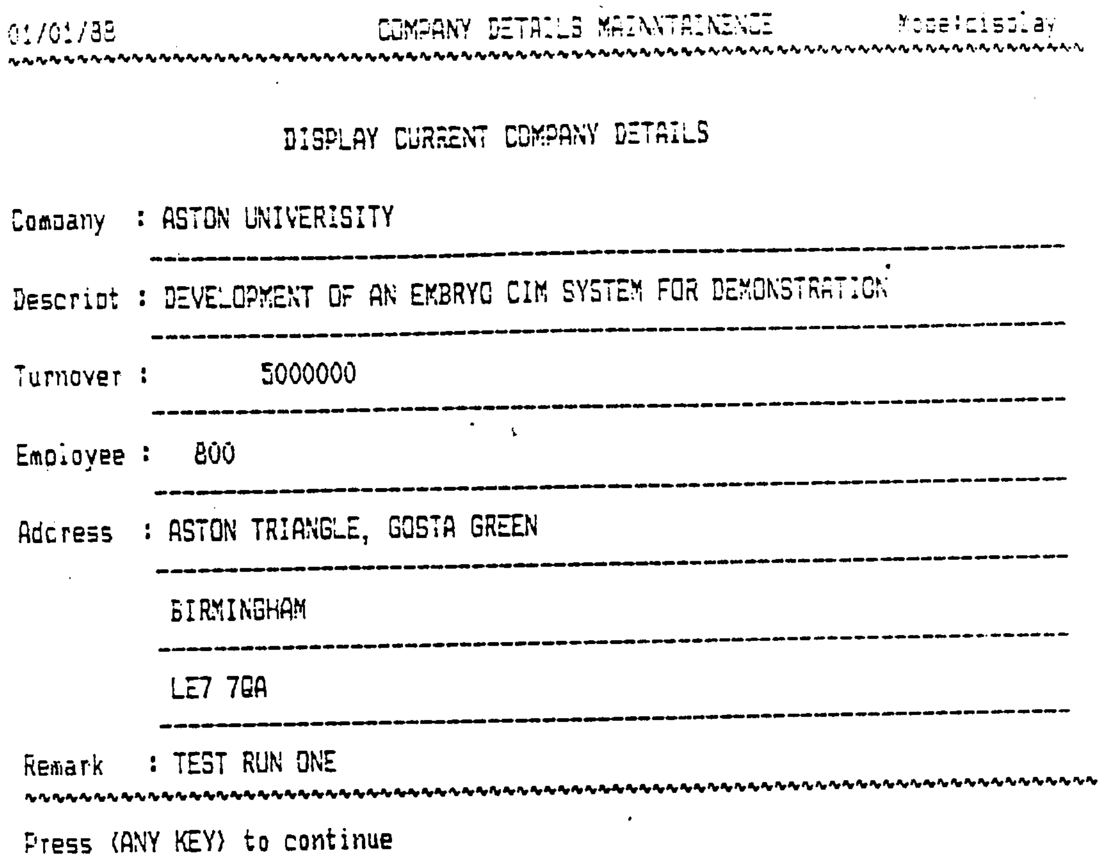
When all the required program modules, data files, and menu files were all present in the current disk drive, the user had to choose menu [A3] in order to choose one of the following options :

A31 - system-maps and module-map maintenance menu;
A32 - to check the physical presence of these modules and files;
A33 - to specify details for system configuration;
A34 - distribution process for central modules and files;
A35 - distribution process for local modules to work cells;
A36 - list or print system configuration details.

These options should be selected in operational order. No network system was involved in this test as there was only one computer used.

```
ASTON UNIVERISITY C.I.M.S.
        Production Calendar for the Year 1988                                01/01/88
----------------------------------------------------------------------------------------------------------------------------
I      MON        I      TUE        I      WED        I      THU        I      FRI        I      SAT        I      SUN        I
----------------------------------------------------------------------------------------------------------------------------
                                                                          001  1-JAN  7.0 I 002  2-JAN  0.0 I 003  3-JAN  0.0 I
I
I 004  4-JAN  0.0 I 005  5-JAN  0.0 I 006  6-JAN  8.0 I 007  7-JAN  8.0 I 008  8-JAN  7.0 I 009  9-JAN  0.0 I 010 10-JAN  0.0 I
I 011 11-JAN  7.5 I 012 12-JAN  7.5 I 013 13-JAN  8.0 I 014 14-JAN  8.0 I 015 15-JAN  7.0 I 016 16-JAN  0.0 I 017 17-JAN  0.0 I
I 018 18-JAN  7.5 I 019 19-JAN  7.5 I 020 20-JAN  8.0 I 021 21-JAN  8.0 I 022 22-JAN  7.0 I 023 23-JAN  0.0 I 024 24-JAN  0.0 I
I 025 25-JAN  7.5 I 026 26-JAN  7.5 I 027 27-JAN  8.0 I 028 28-JAN  8.0 I 029 29-JAN  7.0 I 030 30-JAN  0.0 I 031 31-JAN  0.0 I

----------------------------------------------------------------------------------------------------------------------------
I      MON        I      TUE        I      WED        I      THU        I      FRI        I      SAT        I      SUN        I
----------------------------------------------------------------------------------------------------------------------------
I 032  1-FEB  0.0 I 033  2-FEB  7.5 I 034  3-FEB  8.0 I 035  4-FEB  8.0 I 036  5-FEB  7.0 I 037  6-FEB  0.0 I 038  7-FEB  0.0 I
I 039  8-FEB  7.5 I 040  9-FEB  7.5 I 041 10-FEB  8.0 I 042 11-FEB  8.0 I 043 12-FEB  7.0 I 044 13-FEB  0.0 I 045 14-FEB  0.0 I
I 046 15-FEB  7.5 I 047 16-FEB  7.5 I 048 17-FEB  8.0 I 049 18-FEB  8.0 I 050 19-FEB  7.0 I 051 20-FEB  0.0 I 052 21-FEB  0.0 I
I 053 22-FEB  7.5 I 054 23-FEB  7.5 I 055 24-FEB  8.0 I 056 25-FEB  8.0 I 057 26-FEB  7.0 I 058 27-FEB  0.0 I 059 28-FEB  0.0 I
I 060 29-FEB  7.5 I

----------------------------------------------------------------------------------------------------------------------------
I      MON        I      TUE        I      WED        I      THU        I      FRI        I      SAT        I      SUN        I
----------------------------------------------------------------------------------------------------------------------------
I                   061  1-MAR  7.5 I 062  2-MAR  8.0 I 063  3-MAR  8.0 I 064  4-MAR  7.0 I 065  5-MAR  0.0 I 066  6-MAR  0.0 I
I 067  7-MAR  7.5 I 068  8-MAR  7.5 I 069  9-MAR  8.0 I 070 10-MAR  8.0 I 071 11-MAR  7.0 I 072 12-MAR  0.0 I 073 13-MAR  0.0 I
I 074 14-MAR  7.5 I 075 15-MAR  7.5 I 076 16-MAR  8.0 I 077 17-MAR  8.0 I 078 18-MAR  7.0 I 079 19-MAR  0.0 I 080 20-MAR  0.0 I
I 081 21-MAR  7.5 I 082 22-MAR  7.5 I 083 23-MAR  8.0 I 084 24-MAR  8.0 I 085 25-MAR  7.0 I 086 26-MAR  0.0 I 087 27-MAR  0.0 I
I 088 28-MAR  7.5 I 089 29-MAR  7.5 I 090 30-MAR  8.0 I 091 31-MAR  8.0 I

----------------------------------------------------------------------------------------------------------------------------
I      MON        I      TUE        I      WED        I      THU        I      FRI        I      SAT        I      SUN        I
----------------------------------------------------------------------------------------------------------------------------
                                                                          092  1-APR  0.0 I 093  2-APR  0.0 I 094  3-APR  0.0 I
I
I 095  4-APR  0.0 I 096  5-APR  0.0 I 097  6-APR  8.0 I 098  7-APR  8.0 I 099  8-APR  7.0 I 100  9-APR  0.0 I 101 10-APR  0.0 I
I 102 11-APR  7.5 I 103 12-APR  7.5 I 104 13-APR  8.0 I 105 14-APR  8.0 I 106 15-APR  7.0 I 107 16-APR  0.0 I 108 17-APR  0.0 I
I 109 18-APR  7.5 I 110 19-APR  7.5 I 111 20-APR  8.0 I 112 21-APR  8.0 I 113 22-APR  7.0 I 114 23-APR  0.0 I 115 24-APR  0.0 I
I 116 25-APR  7.5 I 117 26-APR  7.5 I 118 27-APR  8.0 I 119 28-APR  8.0 I 120 29-APR  7.0 I 121 30-APR  0.0 I

----------------------------------------------------------------------------------------------------------------------------
I      MON        I      TUE        I      WED        I      THU        I      FRI        I      SAT        I      SUN        I
----------------------------------------------------------------------------------------------------------------------------
                                                                                                              122  1-MAY  0.0 I
I
I 123  2-MAY  0.0 I 124  3-MAY  7.5 I 125  4-MAY  8.0 I 126  5-MAY  8.0 I 127  6-MAY  7.0 I 128  7-MAY  0.0 I 129  8-MAY  0.0 I
I 130  9-MAY  7.5 I 131 10-MAY  7.5 I 132 11-MAY  8.0 I 133 12-MAY  8.0 I 134 13-MAY  7.0 I 135 14-MAY  0.0 I 136 15-MAY  0.0 I
I 137 16-MAY  7.5 I 138 17-MAY  7.5 I 139 18-MAY  8.0 I 140 19-MAY  8.0 I 141 20-MAY  7.0 I 142 21-MAY  0.0 I 143 22-MAY  0.0 I
I 144 23-MAY  7.5 I 145 24-MAY  7.5 I 146 25-MAY  8.0 I 147 26-MAY  8.0 I 148 27-MAY  7.0 I 149 28-MAY  0.0 I 150 29-MAY  0.0 I
I 151 30-MAY  7.5 I 152 31-MAY  7.5 I

----------------------------------------------------------------------------------------------------------------------------
I      MON        I      TUE        I      WED        I      THU        I      FRI        I      SAT        I      SUN        I
----------------------------------------------------------------------------------------------------------------------------
                                      153  1-JUN  8.0 I 154  2-JUN  8.0 I 155  3-JUN  7.0 I 156  4-JUN  0.0 I 157  5-JUN  0.0 I
I
I 158  6-JUN  7.5 I 159  7-JUN  7.5 I 160  8-JUN  8.0 I 161  9-JUN  8.0 I 162 10-JUN  7.0 I 163 11-JUN  0.0 I 164 12-JUN  0.0 I
I 165 13-JUN  0.0 I 166 14-JUN  7.5 I 167 15-JUN  8.0 I 168 16-JUN  8.0 I 169 17-JUN  7.0 I 170 18-JUN  0.0 I 171 19-JUN  0.0 I
I 172 20-JUN  7.5 I 173 21-JUN  7.5 I 174 22-JUN  8.0 I 175 23-JUN  8.0 I 176 24-JUN  7.0 I 177 25-JUN  0.0 I 178 26-JUN  0.0 I
I 179 27-JUN  7.5 I 180 28-JUN  7.5 I 181 29-JUN  8.0 I 182 30-JUN  8.0 I
```

Table 11.2 Print-out on production calendar



```
01/01/88                COMPANY DETAILS MAINNTAINENCE          Mode:display
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

                    DISPLAY CURRENT COMPANY DETAILS

Company   : ASTON UNIVERISITY
            ---------------------------------------------------------

Descript  : DEVELOPMENT OF AN EMBRYO CIM SYSTEM FOR DEMONSTRATION
            ---------------------------------------------------------

Turnover  :       5000000
            ---------------------------------------------------------

Employee  :   800
            ---------------------------------------------------------

Address   : ASTON TRIANGLE, GOSTA GREEN
            ---------------------------------------------------------

            BIRMINGHAM
            ---------------------------------------------------------

            LE7 7GA
            ---------------------------------------------------------

Remark    : TEST RUN ONE
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Press (ANY KEY) to continue
```

Table 11.3   Print-out on company details

11.4.3 DESIGN MODULES IN OPERATION

Before other modules in the system can be used, it is important that the user must convert details of existing products into compatible formats which would then be stored in various data files. The main design options in the design main menu [C] includes the following options :

C1 - Bill-Of-Material (BOM) generator menu;
C2 - Process Planning menu;
C3 - product details maintenance menu;
C4 - standard cost details maintenance menu;
C5 - engineering drawing menu;
C6 - labour cost rating maintenance;
C7 - new product design details maintenance.

The major details required for each existing product were stored in four separate files, namely the product details file, BOM file, routing file and standard costs file.

In this test run, only three sample products were used for the sake of simplicity. The three products are named PNC, PND, and PNSR111. All the three products are cutters. Figure 11.1 illustrates the BOM details and operation requirements for each of these products. Note that all machining operations were done in Work Cell 3 in the system. Each product requires several machining operations selected from OP10, OP20, OP30, OP40, OP90 and OP100.

Note that the most important data here is the BOM, as the accuracy of MRP operation depends on it. Table 11.4, 11.5, and Table 11.6 are print-outs showing the actual BOM details stored in the main file for PNC, PND, and PNSR111 respectively. Table 11.7 lists the summary of the BOM of all the three products.

When process routes were entered, the user could either choose to enter details for each assembly and subassembly, or to enter process routes for the whole product using the BOM data previously prepared. Table 11.8 shows the exact process details stored in the main file for PNC and PND, whilst Table 11.9 displays the process routes summary for all the three products in part numbers sequence.

Finally, the design operations ended with standard cost estimation in which labour cost, overhead cost and material cost was calculated based on design details previously entered. Options for standard cost estimation are shown in Appendix A under menu

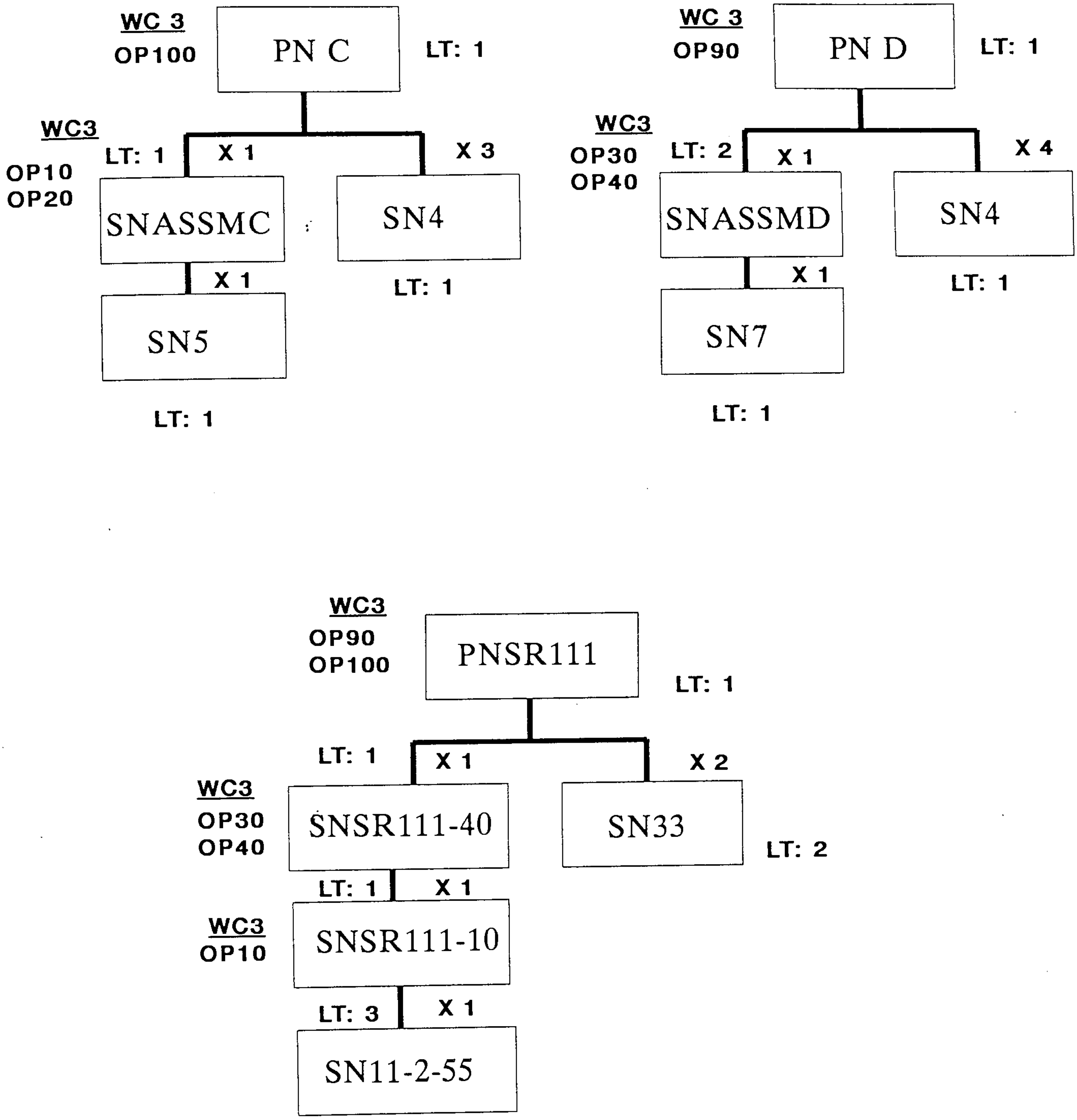


Figure 11.1 BOM and Routing details for product PNC, PND and PNSR111 in Test Run one

```
                   BILL OF MATERIAL FOR PRODUCT : PNC WITH INDEXED BILL LEVEL

PARENT             PART NO.          QTY  LD TIME LEVEL  END COMPONENT
----------         ------------      ---- ------- -----  -------------
SNPNC              SNPNC              1      1      0          N
SNPNC              SNASSMC            1      1      1          N
SNASSMC            SN5                1      1      2          Y
SNPNC              SN4                3      1      1          Y
```

Table 11.4. BOM details of PNC

```
                   BILL OF MATERIAL FOR PRODUCT : PND WITH INDEXED BILL LEVEL

PARENT             PART NO.          QTY  LD TIME LEVEL  END COMPONENT
----------         ------------      ---- ------- -----  -------------
SNPND              SNPND              1      1      0          N
SNPND              SNASSMD            1      2      1          N
SNASSMD            SN7                1      1      2          Y
SNPND              SN4                4      1      1          Y
```

Table 11.5 BOM details of PND

```
                     BILL OF MATERILA FOR PRODUCT : PNSR111 IN ENTRY SEQUENCE

PARENT          PART NO.          QTY  LD TIME LEVEL  END COMPONENT
----------      ------------      ---- ------- -----  -------------
PNSR111         SNPNSR111          1      1      0
SNPNSR111       SNSR111-40         1      1      1
SNPNSR111       SN33               2      2      1          E
SNSR111-40      SNSR111-10         1      1      2
SNSR111-10      SN11-2-55          1      3      3          E
```

Table 11.6   BOM details of PNSR111 stored in file

```
08/01/88    PRINT-OUT OF ALL CENTRAL BILL-OF-MATERIAL DATA

PRODUCT NO. PARENT      PART NO.     QTY   LEAD TIME  BILL LEVEL  END COMPONENT
----------- ------      --------     ----- ---------  ----------  -------------

PNC         PNC         SNPNC         1        1          0             N
PNC         SNPNC       SNASSMC       1        1          1             N
PNC         SNPNC       SN4           3        1          1             Y
PNC         SNASSMC     SN5           1        1          2             Y
PND         PND         SNPND         1        1          0             N
PND         SNPND       SNASSMD       1        2          1             N
PND         SNPND       SN4           4        1          1             Y
PND         SNASSMD     SN7           1        1          2             Y
PNSR111     PNSR111     SNPNSR111     1        1          0
PNSR111     SNPNSR111   SNSR111-40    1        1          1
PNSR111     SNPNSR111   SN33          2        2          1             E
PNSR111     SNSR111-40  SNSR111-10    1        1          2
PNSR111     SNSR111-10  SN11-2-55     1        3          3             E

(((((((((((((((((((((((((((((((((E N D  O F  B I L L - O F - M A T E R I A L  F I LE)))))))))))))))))))))))))))))))
```

Table 11.7 BOM summary for all three products

```
01/01/88               PROCESS ROUTE FOR PRODUCT : PNC

SUB-ASSEMBLY OP NO.                DESCRIPTION                      WORK CELL SET T  PROD T  LAB G.  SCRAP %  LAST UPDT
------------ -----  ----------------------------------------------  --------- -----  ------  -----  -------  ---------

SNPNC         100  FINAL ASSEMBLY PROCESS                               WC1     20      12     A       0.0    01-01-88
SNASSMC        10  TURN SHANK + GRIND ALLOWANCE (ON INVESTMENT CAST)    WC1     40      10     B       0.0    01-01-88
               20  TURN SHANK,GRIND ALLOW.,CENTRE,TURN BODY,PART OFF    WC1     50       5     B       0.0    01-01-88
SN5                THIS IS END COMPONENT !
SN4                THIS IS END COMPONENT !
```

```
01/01/88               PROCESS ROUTE FOR PRODUCT : PND

SUB-ASSEMBLY OP NO.                DESCRIPTION                      WORK CELL SET T  PROD T  LAB G.  SCRAP %  LAST UPDT
------------ -----  ----------------------------------------------  --------- -----  ------  -----  -------  ---------

SNPND          90  FINAL ASSM INDUCTION BRAZE, INSERT, GRIND LOC        WC1     20      15     A       0.0    01-01-88
SNASSMD        30  MILL FLATS (TAPER, CLARKSON, WHISTLE & WELDON)       WC1     22      10     B       0.0    01-01-88
               40  MILL TIP SEATS/ MILL CLEARANCE                       WC1     30      20     B       0.0    01-01-88
SN7                THIS IS END COMPONENT !
SN4                THIS IS END COMPONENT !
```

Table 11.8 Print-outs on process route details of PNC & PND

```
08/01/88     PRINT-OUT OF ALL CENTRAL ROUTING DETAILS

PART NO.     OPERATION  OPERATION DESCRIPTION                           WORK  SET   PROD.  LABOR  SCRAP  LAST
                NO.                                                     CELL  TIME  TIME   GRADE  (%)    UPDATE
--------     ---------  --------------------                            ----  ----  -----  -----  -----  --------

SN1          50         TURN SHANK,GRIND ALLOW.,CENTRE,TURN BODY, PART OFF WC3   0      0  B      0.0    08-04-86
SNASSMC      10         TURN SHANK + GRIND ALLOWANCE (ON INVESTMENT CAST)  WC3  40     10  B      0.0    01-01-88
SNASSMC      20         TURN SHANK,GRIND ALLOW.,CENTRE,TURN BODY,PART OFF  WC3  50      5  B      0.0    01-01-88
SNASSMD      30         MILL FLATS (TAPER, CLARKSON, WHISTLE & WELDON)     WC3  22     10  B      0.0    01-01-88
SNASSMD      40         MILL TIP SEATS/ MILL CLEARANCE                     WC3  30     20  B      0.0    01-01-88
SNEM777-50   50         TURN SHANK,GRIND ALLOW.,CENTRE,TURN BODY, PART OFF WC3   0     30  B      2.0    12-12-85
SNEM777-70   60         MILL SHANK (CLARKSON, WHISTLE)                     WC3   0     10  C      2.0    12-12-85
SNEM777-70   70         MILL TEETH SHAPE, GRIND TEETH                      WC3   0     15  B      2.0    12-12-85
SNEM777-80   80         HEAT TREATMENT TO HARDEN THE CUTTING EDGE          WC3   0     40  B      0.0    12-12-85
SNFB444-20   20         TURN SHANK,GRIND ALLOW.,CENTRE,TURN BODY,PART OFF  WC3   0     35  B      2.0    12-12-85
SNFB444-40   30         MILL FLATS (TAPER, CLARKSON, WHISTLE & WELDON)     WC3   0      8  C      2.0    12-12-85
SNFB444-40   40         MILL TIP SEATS/ MILL CLEARANCE                     WC3   0     20  B      2.0    12-12-85
SNPNC        100        FINAL ASSEMBLY PROCESS                             WC3  20     12  A      0.0    01-01-88
SNPND        90         FINAL ASSM INDUCTION BRAZE, INSERT, GRIND LOC      WC3  20     15  A      0.0    01-01-88
SNPNEM777    100        FINISH GRIND CARBIDE / FINISH HEATREATED EDGE      WC3   0     15  A      0.0    12-12-85
SNPNFB444    90         INDUCTION BRAZE, INSERT, GRIND LOC                 WC3   0     15  C      0.0    12-12-85
SNPNFB444    100        FINISH GRIND CARBIDE / FINISH HEATREATED EDGE      WC3   0     20  A      0.0    12-12-85
SNPNJHF      100        FINISH GRIND CARBIDE / FINISH HEATREATED EDGE      WC3  20    100  A     12.0    12-12-85
SNPNJHF      110        TEST ONLY                                          WC3  20    100  A     12.0    12-12-85
SNPNSR111    90         INDUCTION HRAZE, INSERT, GRIND LOC                 WC3   0     20  C      0.0    12-12-85
SNPNSR111    100        FINISH GRIND CARBIDE / FINISH HEATREATED EDGE      WC3   0     25  A      0.0    12-12-85
SNSR111-10   10         TURN SHANK + GRIND ALLOWANCE (ON INVESTMENT CAST)  WC3   0     15  C      2.0    12-12-85
SNSR111-40   30         MILL FLATS (TAPER, CLARKSON, WHISTLE & WELDON)     WC3   0     10  C      2.0    12-12-85
SNSR111-40   40         MILL TIP SEATS/ MILL CLEARANCE                     WC3   0     30  B      2.0    12-12-85

(((((((((((((((((((((((((((((E N D   O F   C E N T R A L   R O U T I N G   F I L E)))))))))))))))))))))))))))
```

Table 11.9   Summary of process route details for all three products

[C4]. Some system print-outs on cost details stored in the system are also shown as Table F-3 in Appendix F.

11.4.4 CREATION OF NEW PLANNING HORIZON FOR EACH PRODUCT

As explained in chapter 10, a planning horizon for up to 52 periods has to be created and maintained for each product so that functions such as forecasting, MPS, and MRP can be carried out in the current planning horizon. Through the forecast modules, a defaulted forecast quantity of demand is specified for each product in each period. Table F-4 shows a typical planning horizon of 52 periods for PNC, with a defaulted forecast value of 60 in each period.

11.4.5 MAINTENANCE OF THE PRODUCT SEARCH DATABASE

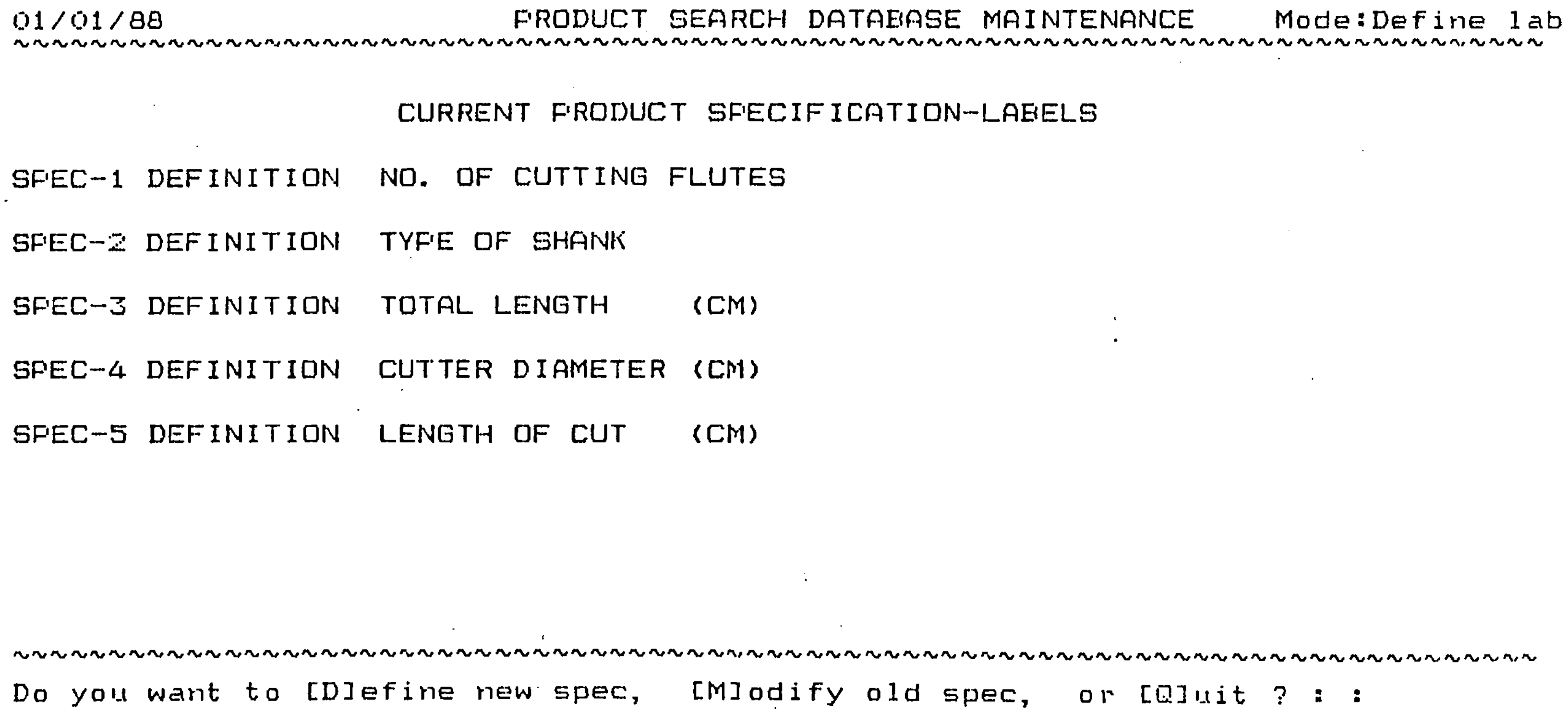
The embryo system has a product search database facility. This module is used to locate a similar product whose specifications are the closest to those given by a customer. The search process is necessary when a required product can not be found directly from the product file.

The search database can be tailored by users - up to five search labels can be defined. Table 11.10 shows the search labels defined for test one. After search labels had been defined, the user must enter details of the existing products into the search database, with respect to the defined search labels. Table F-5 shows the full contents stored in such a product search database.

11.4.6 GENERATION OF NEW CUSTOMER ORDERS AND QUOTATIONS WITH STOCK RESERVE

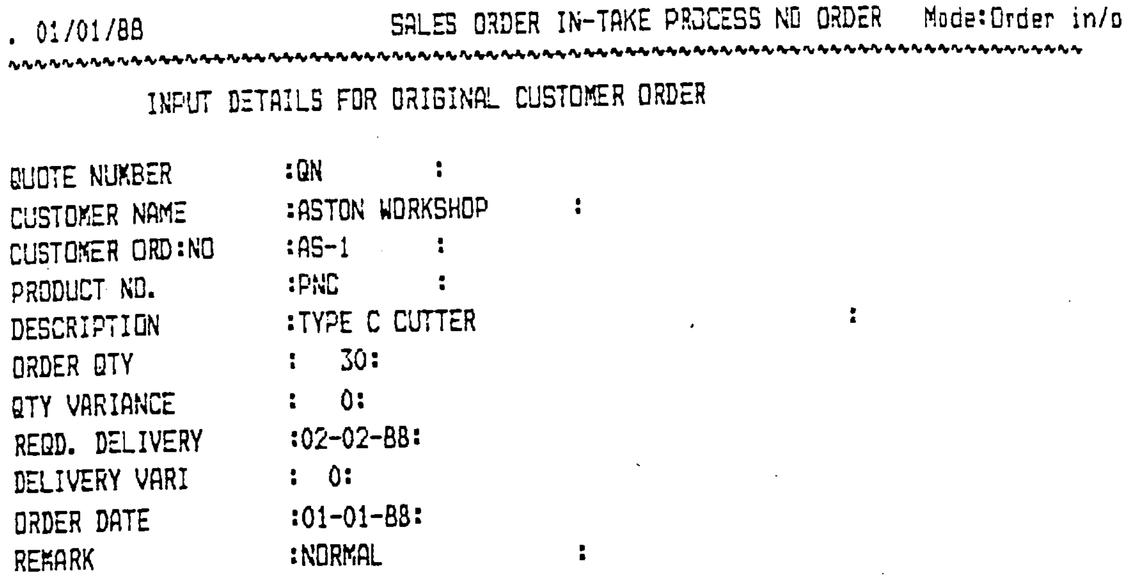
Through the options in the Customer Service menu [B], new customer orders and quotations can be generated. Table 11.11 shows the screen-prints of sales order entry for PNC and PND respectively.

As for the creation of customer quotations, each of them can either be assigned a code of 'ASAP' which stands for 'As Soon As Possible', or 'RESERVE' which means stocks have been reserved for this particular quotation. If it is the second type, then an expire

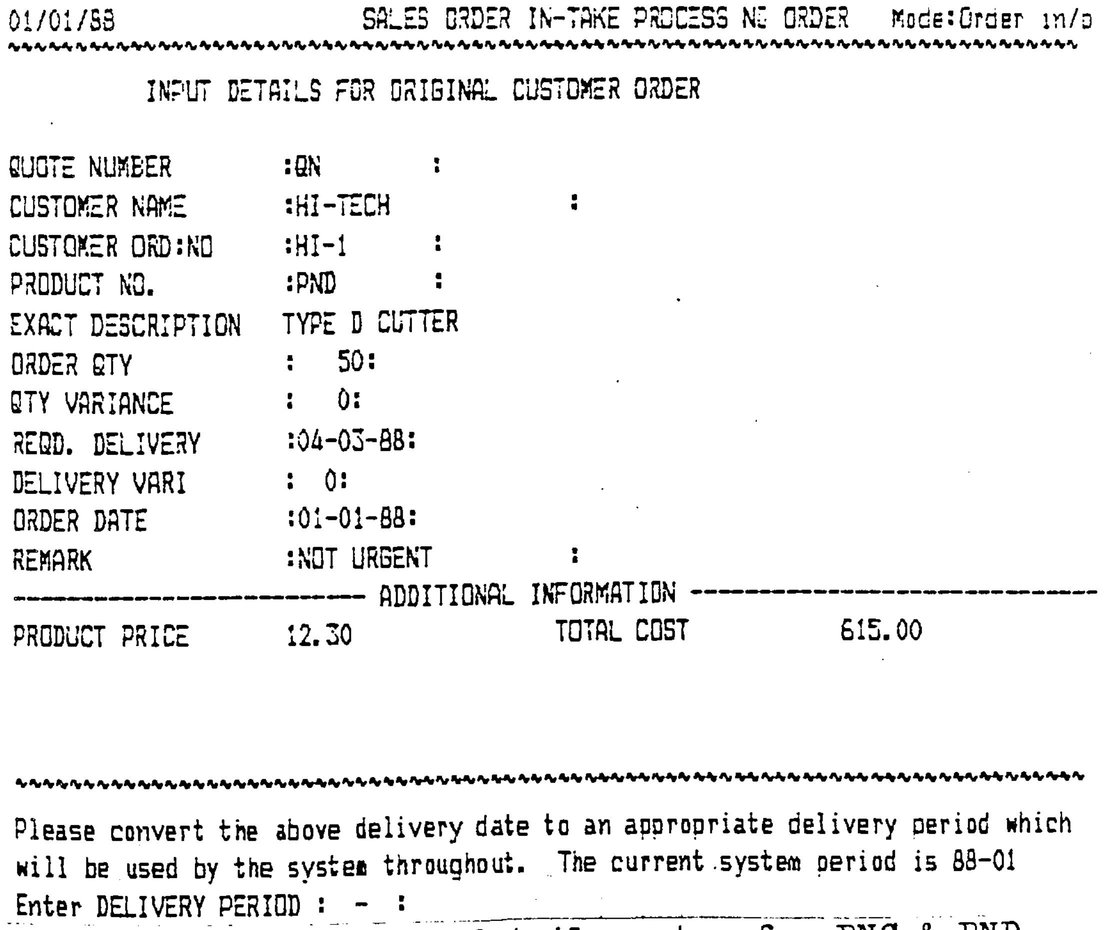


```
01/01/88                     PRODUCT SEARCH DATABASE MAINTENANCE    Mode:Define lab
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

                     CURRENT PRODUCT SPECIFICATION-LABELS

SPEC-1 DEFINITION  NO. OF CUTTING FLUTES

SPEC-2 DEFINITION  TYPE OF SHANK

SPEC-3 DEFINITION  TOTAL LENGTH    (CM)

SPEC-4 DEFINITION  CUTTER DIAMETER (CM)

SPEC-5 DEFINITION  LENGTH OF CUT   (CM)




~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Do you want to [D]efine new spec,  [M]odify old spec,  or [Q]uit ? : :
```

Table 11.10   Search field specifications for the Product Search database



```
. 01/01/88                SALES ORDER IN-TAKE PROCESS NO ORDER   Mode:Order in/o
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
        INPUT DETAILS FOR ORIGINAL CUSTOMER ORDER

QUOTE NUMBER        :QN        :
CUSTOMER NAME       :ASTON WORKSHOP       :
CUSTOMER ORD:NO     :AS-1      :
PRODUCT NO.         :PNC       :
DESCRIPTION         :TYPE C CUTTER                         :
ORDER QTY           :   30:
QTY VARIANCE        :    0:
REQD. DELIVERY      :02-02-88:
DELIVERY VARI       :  0:
ORDER DATE          :01-01-88:
REMARK              :NORMAL               :
```



```
01/01/88                  SALES ORDER IN-TAKE PROCESS NO ORDER   Mode:Order in/o
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
        INPUT DETAILS FOR ORIGINAL CUSTOMER ORDER

QUOTE NUMBER        :QN        :
CUSTOMER NAME       :HI-TECH              :
CUSTOMER ORD:NO     :HI-1      :
PRODUCT NO.         :PND       :
EXACT DESCRIPTION   TYPE D CUTTER
ORDER QTY           :   50:
QTY VARIANCE        :    0:
REQD. DELIVERY      :04-03-88:
DELIVERY VARI       :  0:
ORDER DATE          :01-01-88:
REMARK              :NOT URGENT           :
----------------------- ADDITIONAL INFORMATION ---------------------------
PRODUCT PRICE       12.30              TOTAL COST          615.00


~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Please convert the above delivery date to an appropriate delivery period which
will be used by the system throughout.  The current system period is 88-01
Enter DELIVERY PERIOD :  - :
```

Table 11.11 Order details entry for PNC & PND date will also be specified. Table 11.12 shows a typical quote for PNC, which was created for a customer company called Hi-Tech Ltd.

After several sales orders had been prepared, the system merged them with the remaining forecast capacity balance, to form the main structure of the central MPS file. Table 11.13 shows the print-out of a central MPS file. Note that in the table, all customer orders, quotations and forecast balance are stored in the order of product no.

11.4.7 CENTRAL MPS DISTRIBUTION TO WORK CELL

As explained at the beginning of this chapter, a single work cell production environment represents a traditional production situation in which planning functions like MPS, MRP as well as other shop planning activities are done at a single location. It must be stressed that the embryo system is quite capable of handling multiple work cells. The one work-celled configuration is simply to show that the system can be configured in accordance to requirements. The other reason to have only one work cell here is for comparisons to be made with the second test run, in which there are three work cells in the system.

Since there is only one work cell, all MPS data was transferred to the specified disk location of the work cell, drive A, in this case. The content of the local MPS file in the work cell, after the process of data distribution, was identical to those previously shown in Table 11.13. After the MPS data distribution, individual orders for each product were combined for each period in the planning horizon to form a local MPS summary file which was subsequently used in the MRP function. Table 11.14 shows the content of this MPS summary.

11.4.8 DISTRIBUTION OF BOM AND ROUTING DETAILS

This process is very sophisticated for a multiple work cell situation. However, in this particular test run, all details stored in the central BOM file and in the central routing file would be transferred to the single work cell in the system. However, because the system was designed to handle multiple work cells, all product details, including BOM and routing, would still have to be analysed and distributed to its new location. In a single work cell environment, this process is considered inefficient, but as the main intention is to demonstrate the flexibility in terms of system configuration, the procedure was implemented.

```
DATE : 01/01/88     C U S T O M E R   Q U O T A T I O N

                    QUOTATION NUMBER :  QN-HITECH1
                    ------------------------------

CUSTOMER NAME  :  HI-TECH LTD

PRODUCT NO.    :  PNC

DESCRIPTION    :  TYPE A CUTTER

REQUESTED QTY  :    200

REQUESTED DEL  :  88-05

QUOTED QTY     :    150

QUOTED DEL     :  88-05

PRICE          :      12.30

TOTAL COST     :      1845.00

STOCK RESERVED:         0

VALID TILL     :  88-02

ISSUE PERIOD   :  88-01

DATE OF QUOTE  :  01-01-88
```

Table 11.12   Entry format for a customer quotation

```
. USE
08/01/88      CURRENT MPS ORDERS BASED ON ALL RECORDS

ORDER NO.   CUSTOMER NAME      PRODUCT     QTY   PERIOD   VALID TO (IF RESERVED)   QUOTE NO. (IF ANY)
---------   -------------      -------     ---   ------   ----------------------   ------------------

FORECAST    FORECAST           PNC          40   88-02
FORECAST    FORECAST           PNC          50   88-03
ON23        HI-TECH            PNC          20   88-03
ON24        ASTON WORKSHOP     PNC          30   88-03
FORECAST    FORECAST           PNC          80   88-04
ON25        ASTON WORKSHOP     PNC          40   88-04
ON26        HI-TECH            PNC          25   88-04
FORECAST    FORECAST           PNC           0   88-05
ON61        ASTON WORKSHOP     PNC          30   88-05
RESERVE     HI-TECH LTD        PNC         130   88-05       88-02                    QN-HITECH1
ON27        HI-TECH            PNC          45   88-05
ON29        HI-TECH            PNC          20   88-05
ON30        BRITISH STEEL      PNC          35   88-05
FORECAST    FORECAST           PNC          50   88-06
ON28        HI-TECH            PNC          50   88-06
ON31        BRITISH STEEL      PNC          30   88-06
ON32        HI-TECH            PNC          22   88-06
FORECAST    FORECAST           PNC          40   88-07
ON62        ASTON WORKSHOP     PNC          40   88-07
ON33        HI-TECH            PNC          40   88-07
ON34        HI-TECH            PNC          25   88-07
ON35        ASTON WORKSHOP     PNC          45   88-07
FORECAST    FORECAST           PNC          85   88-08
FORECAST    FORECAST           PNC          85   88-09
FORECAST    FORECAST           PNC          20   88-10
ON40        HI-TECH            PNC          55   88-10
FORECAST    FORECAST           PNC          20   88-11
FORECAST    FORECAST           PND          45   88-02
FORECAST    FORECAST           PND         130   88-03
ON71        ASTON WORKSHOP     PND          20   88-03
ON72        HI-TECH            PND          22   88-03
FORECAST    FORECAST           PND          45   88-04
ON73        BRITISH STEEL      PND          30   88-04
ON74        ASTON WORKSHOP     PND          30   88-04
ON14        HI-TECH            PND          44   88-04
FORECAST    FORECAST           PND         100   88-05
ON75        ASTON WORKSHOP     PND          35   88-05
FORECAST    FORECAST           PND          20   88-06
ON76        ASTON WORKSHOP     PND          20   88-06
ON16        HI-TECH            PND          30   88-06
ON80        BRITISH STEEL      PND          40   88-06
FORECAST    FORECAST           PND          50   88-07
FORECAST    FORECAST           PND          30   88-08
ON77        HI-TECH            PND          44   88-08
FORECAST    FORECAST           PND          30   88-09
ON63        HI-TECH            PND          50   88-09
ON78        ASTON WORKSHOP     PND          50   88-09
ON82        BRITISH STEEL      PND          35   88-09
ON86        BRITISH STEEL      PND          45   88-09
FORECAST    FORECAST           PND          80   88-10
ON64        HI-TECH            PND          80   88-10
ON79        ASTON WORKSHOP     PND          25   88-10
FORECAST    HI-TECH            PND          60   88-11
ON22        HI-TECH            PNSR111      80   88-02
FORECAST    FORECAST           PNSR111      30   88-02
RESERVE     HI-TECH            PNSR111      44   88-03       88-04                    QN896
FORECAST    FORECAST           PNSR111      50   88-03
ON56        ASTON WORKSHOP     PNSR111      40   88-04
FORECAST    FORECAST           PNSR111      60   88-04
ON84        ASTON WORKSHOP     PNSR111      30   88-04
RESERVE     ASTON WORKSHOP     PNSR111      40   88-04       88-05                    QN654
ON54        BRITISH STEEL      PNSR111     120   88-05
FORECAST    FORECAST           PNSR111      80   88-05
RESERVE     ASTON WORKSHOP     PNSR111      20   88-05       88-06                    QN633
FORECAST    FORECAST           PNSR111      70   88-06
ON85        HI-TECH            PNSR111      40   88-06
RESERVE     HI-TECH            PNSR111      30   88-06       88-09                    QN644
ON55        BRITISH STEEL      PNSR111      55   88-07
FORECAST    FORECAST           PNSR111      50   88-07
FORECAST    FORECAST           PNSR111      70   88-08
ON88        HI-TECH            PNSR111      50   88-08
FORECAST    FORECAST           PNSR111      20   88-09
RESERVE     BRITISH STEEL      PNSR111      30   88-09       88-10                    QN414
FORECAST    FORECAST           PNSR111      10   88-10
FORECAST    FORECAST           PNSR111      20   88-11

((((((((((((((((((((((((((((((END OF MPS ORDERS LIST))))))))))))))))))))))))))))))
```

Table 11.13 Content of a MPS file

```
08/01/88     LOCAL MPS SUMMARY REPORT FOR WORK CELL 3

PRODUCT      HORIZON FROM  PERIOD 1  PERIOD 2  PERIOD 3  PERIOD 4  PERIOD 5  PERIOD 6  PERIOD 7  PERIOD 8  PERIOD 9  PERIOD 10
-------      ------------  --------  --------  --------  --------  --------  --------  --------  --------  --------  ---------

PNC             88-02           40       100       145       260       152       190        85        85        75        20
PND             88-02           45       172       149       135       110        50        74       210       185        60
PNSR111         88-02          110        94       170       220       140       105       120        50        10        20

((((((((((((((((((((((((((((((((E N D  O F  M P S L O N G))))))))))))))))))))))))))))))))))))))))
```

Table 11.14 Content of a MPS summary file

11.4.9 MATERIAL REQUIREMEN T PLANNING (MRP) PROCESS

After the MPS, BOM and routing details had been distributed, the MRP process in the work cell commenced.

During the MRP calculation process, the user has the option of monitoring the calculation progress by printing essential data on the paper automatically. Table 11.15a,b show a sample print-out of this process.

After the MRP process was complete, there were three types of output generated, namely the recommended work orders, purchase orders, and part requests to other work cells. Since there was only one work cell in this test, only work orders and purchased orders were produced. A print-out on the recommended work orders is shown in Table 11.16, and some recommended purchase orders for bought-out parts are also shown in Table 11.17. During the MRP process, the gross requirement for each assembly was also recorded automatically into a file for further reference, and the content of this file is shown as Table F-6.

At this stage, the system provided an option to the user to do some preliminary load analysis based on the Latest-Start-Date (LSD) information for each order. This process involves converting the current MRP results into temporary work orders so that, the potential load on shop floor capacities, can be analysed. Table 11.18 lists the temporary work orders derived from MRP results. Note that each order is preceded by 'WO000000', indicating that they are only temporary orders and, as such, are stored in a temporary file.

These temporary work orders were then combined with other work orders already issued, and the results would be stored in a single file. This file forms the basis for load analysis for each individual work centre.

In general, the system provides two options for load analysis. The on-screen option allows the work centre's load details to be displayed for up to 10 production days (see Table 11.19). The print option allows the load details to be printed for up to 50 production days (see Table 11.20).

This preliminary load analysis can be disregarded by the user if such an analysis is not required in a particular situation. The user must, however, confirm the current MRP results are satisfactory at the end of this process. When he has done that, the

```
PRODUCT NO. : PNC          PART NO. : SNPNC                 LEAD TIME :    1
00001  GROSS REQ        0    40   100   145   260   152   190    85    85    75    20
00002  ON ORDER         0     0     0     0     0     0     0     0     0     0     0
00003  ON HAND          0     0     0     0     0     0     0     0     0     0     0
00004  NET REQ          0    40   100   145   260   152   190    85    85    75    20
00005  RECOMM ORD       0   140   145   260   152   190    85    85    75    20     0


PRODUCT NO. : PNC          PART NO. : SNASSMC               LEAD TIME :    1
00001  GROSS REQ        0   140   145   260   152   190    85    85    75    20     0
00002  ON ORDER         0     0     0     0     0     0     0     0     0     0     0
00003  ON HAND         70     0     0     0     0     0     0     0     0     0     0
00004  NET REQ          0    70   145   260   152   190    85    85    75    20     0
00005  RECOMM ORD       0   215   260   152   190    85    85    75    20     0     0


PRODUCT NO. : PNC          PART NO. : SN4                   LEAD TIME :    1
00001  GROSS REQ        0   420   435   780   456   570   255   255   225    60     0
00002  ON ORDER         0     0     0     0     0     0     0     0     0     0     0
00003  ON HAND        140     0     0     0     0     0     0     0     0     0     0
00004  NET REQ          0   280   435   780   456   570   255   255   225    60     0
00005  RECOMM ORD       0   715   780   456   570   255   255   225    60     0     0


PRODUCT NO. : PNC          PART NO. : SN5                   LEAD TIME :    1
00001  GROSS REQ        0   215   260   152   190    85    85    75    20     0     0
00002  ON ORDER         0     0     0     0     0     0     0     0     0     0     0
00003  ON HAND         50     0     0     0     0     0     0     0     0     0     0
00004  NET REQ          0   165   260   152   190    85    85    75    20     0     0
00005  RECOMM ORD       0   425   152   190    85    85    75    20     0     0     0


PRODUCT NO. : PND          PART NO. : SNPND                 LEAD TIME :    1
00001  GROSS REQ        0    45   172   149   135   110    50    74   210   185    60
00002  ON ORDER         0     0     0     0     0     0     0     0     0     0     0
00003  ON HAND          0     0     0     0     0     0     0     0     0     0     0
00004  NET REQ          0    45   172   149   135   110    50    74   210   185    60
00005  RECOMM ORD       0   217   149   135   110    50    74   210   185    60     0


PRODUCT NO. : PND          PART NO. : SNASSMD               LEAD TIME :    2
00001  GROSS REQ        0   217   149   135   110    50    74   210   185    60     0
00002  ON ORDER         0     0     0     0     0     0     0     0     0     0     0
00003  ON HAND        130     0     0     0     0     0     0     0     0     0     0
00004  NET REQ          0    87   149   135   110    50    74   210   185    60     0
00005  RECOMM ORD       0   371   110    50    74   210   185    60     0     0     0


PRODUCT NO. : PND          PART NO. : SN4                   LEAD TIME :    1
00001  GROSS REQ        0  1288  1031  1320   896   770   551  1095   965   300     0
00002  ON ORDER         0     0     0     0     0     0     0     0     0     0     0
00003  ON HAND        140     0     0     0     0     0     0     0     0     0     0
00004  NET REQ          0  1148  1031  1320   896   770   551  1095   965   300     0
00005  RECOMM ORD       0  2179  1320   896   770   551  1095   965   300     0     0
```

Table 11.15a   Print-out on the MRP calculation process

```
PRODUCT NO. : PND          PART NO. : SN7                  LEAD TIME :    1
00001  GROSS REQ       0    371    110     50     74    210    185     60      0      0      0
00002  ON ORDER        0      0      0      0      0      0      0      0      0      0      0
00003  ON HAND       230      0      0      0      0      0      0      0      0      0      0
00004  NET REQ         0    141    110     50     74    210    185     60      0      0      0
00005  RECOMM ORD      0    251     50     74    210    185     60      0      0      0      0


PRODUCT NO. : PNSR111         PART NO. : SNPNSR111            LEAD TIME :    1
00001  GROSS REQ       0    110     94    170    220    140    105    120     50     10     20
00002  ON ORDER        0      0      0      0      0      0      0      0      0      0      0
00003  ON HAND        30      0      0      0      0      0      0      0      0      0      0
00004  NET REQ         0     80     94    170    220    140    105    120     50     10     20
00005  RECOMM ORD      0    174    170    220    140    105    120     50     10     20      0


PRODUCT NO. : PNSR111         PART NO. : SNSR111-40           LEAD TIME :    1
00001  GROSS REQ       0    174    170    220    140    105    120     50     10     20      0
00002  ON ORDER        0      0      0      0      0      0      0      0      0      0      0
00003  ON HAND        20      0      0      0      0      0      0      0      0      0      0
00004  NET REQ         0    154    170    220    140    105    120     50     10     20      0
00005  RECOMM ORD      0    324    220    140    105    120     50     10     20      0      0


PRODUCT NO. : PNSR111         PART NO. : SN33                 LEAD TIME :    2
00001  GROSS REQ       0    348    340    440    280    210    240    100     20     40      0
00002  ON ORDER        0      0      0      4     68     68     65     23      3    200      0
00003  ON HAND        30      0      0      0      0      0      0      0      0    160    160
00004  NET REQ         0    318    340    436    212    142    175     77     17      0      0
00005  RECOMM ORD      0   1094    212    142    175     77     17      0      0      0      0


PRODUCT NO. : PNSR111         PART NO. : SNSR111-10           LEAD TIME :    1
00001  GROSS REQ       0    324    220    140    105    120     50     10     20      0      0
00002  ON ORDER        0      0      0      0      0      0      0      0      0      0      0
00003  ON HAND        30      0      0      0      0      0      0      0      0      0      0
00004  NET REQ         0    294    220    140    105    120     50     10     20      0      0
00005  RECOMM ORD      0    514    140    105    120     50     10     20      0      0      0


PRODUCT NO. : PNSR111         PART NO. : SN11-2-55            LEAD TIME :    3
00001  GROSS REQ       0    514    140    105    120     50     10     20      0      0      0
00002  ON ORDER        0      0      0      0      0      0      0      0      0      0      0
00003  ON HAND        45      0      0      0      0      0      0      0      0      0      0
00004  NET REQ         0    469    140    105    120     50     10     20      0      0      0
00005  RECOMM ORD      0    834     50     10     20      0      0      0      0      0      0
```

Table 11.15b   Print-out on the MRP calculation process

```
08/01/88  CURRENT WORK ORDERS RECOMMENDATION FROM LAST MRP RUN FOR LOCAL PARTS

WORK CELL : 3       FOR PERIOD : 88-02     CURRENT SYSTEM PERIOD : 88-01
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

PART NO.     PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD
             88-02   88013   88011   68011   88011   88011   88011   88011   88011   88011
--------     ------  ------  ------  ------  ------  ------  ------  ------  ------  ------

SNASSMC        215     260     152     190      85      85      75      20       0       0
SNASSMD        371     110      50      74     210     185      60       0       0       0
SNPNC          140     145     260     152     190      85      85      75      20       0
SNPND          217     149     135     110      50      74     210     185      60       0
SNPNSR111      174     170     220     140     105     120      50      10      20       0
SNSR111-10     514     140     105     120      50      10      20       0       0       0
SNSR111-40     324     220     140     105     120      50      10      20       0       0

((((((((((((((((((((((((((((((E N D   O F   R E C O M M E N D E D   W O R K   O R D E R S))))))))))))))))))))))))))
```

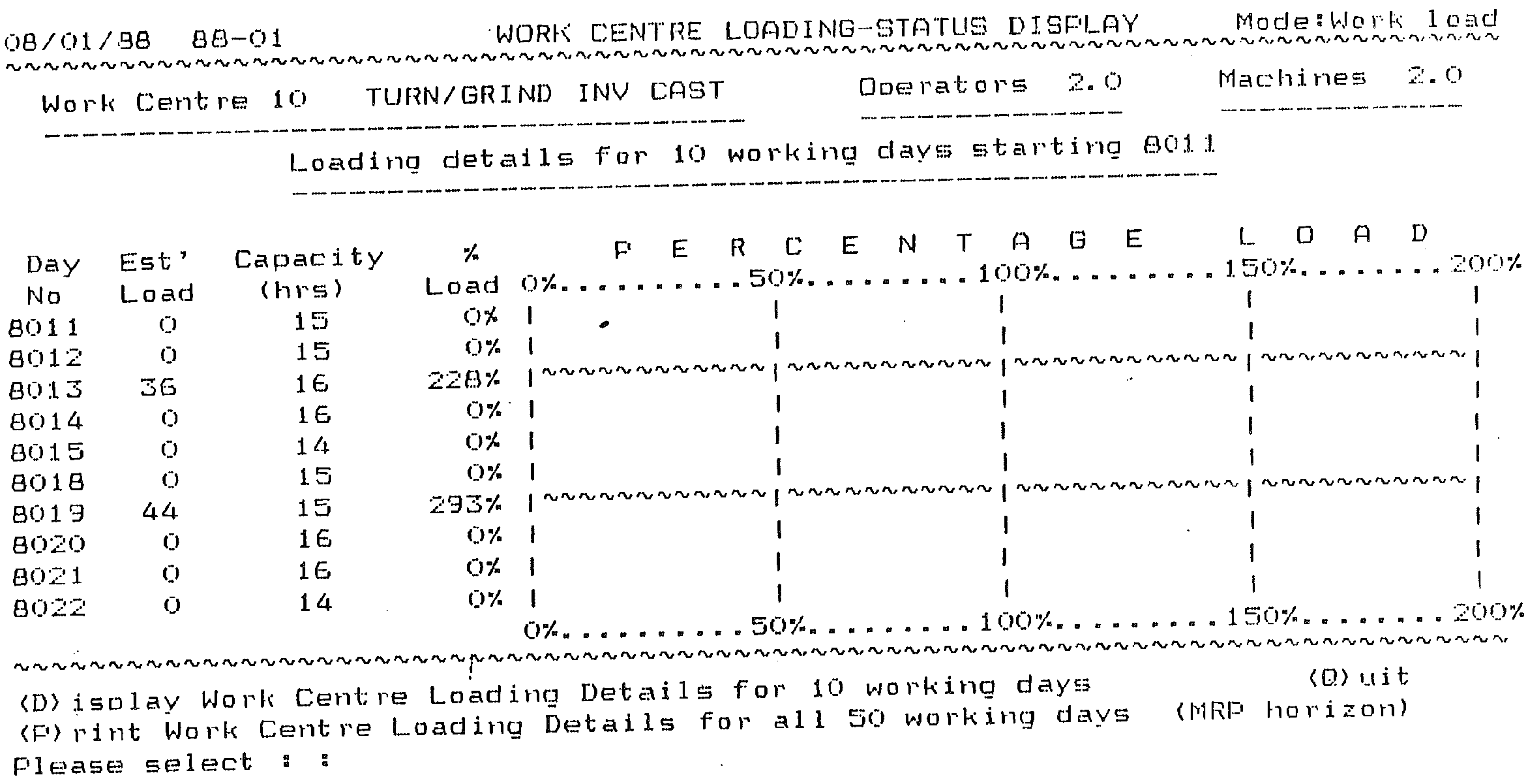
Table 11.16   Print-out on recommended work orders

```
08/01/88  CURRENT BUY-ORDER RECOMMENDATION FROM LAST MRP RUN FOR EXTERNAL PARTS

WORK CELL : 3        FOR PERIOD : 88-02     CURRENT SYSTEM PERIOD : 88-01
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

PART NO.     PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD
             88-02   880:3   880:1   880:1   880:1   880:1   880:1   880:1   880:1   880:1
--------     ------  ------  ------  ------  ------  ------  ------  ------  ------  ------

SN4            2179    1320     896     770     551    1095     965     300       0       0
SN5             425     152     190      85      85      75      20       0       0       0
SN7             251      50      74     210     185      60       0       0       0       0
SN33           1094     212     142     175      77      17       0       0       0       0
SN11-2-55       834      50      10      20       0       0       0       0       0       0

((((((((((((((((((((((((((((((((E N D  O F  R E C O M M E N D E D  B U Y  O R D E R S))))))))))))))))))))))))))
```

Table 11.17   Print-out on recommended purchase orders

```
08/01/88  DISCRETE WORK ORDERS CONVERTED FROM MRP TO BE CONFIRMED FOR ISSUE
          INTO WORK CELL : 3                 ON DATE : 08/01/88
          FOR PERIOD : 88-02         CURRENT PERIOD : 88-01

WORK ORDER NO.  PART NO.          ORDER QTY   BATCH SIZE   SCHEDULED LAUNCH PERIOD
--------------  --------          ---------   ----------   -----------------------

W0000000-001    SNASSMC              215           0              88-02
W0000000-002    SNASSMC              260           0              88-03
W0000000-003    SNASSMC              152           0              88-04
W0000000-004    SNASSMC              190           0              88-05
W0000000-005    SNASSMC               85           0              88-06
W0000000-006    SNASSMC               85           0              88-07
W0000000-007    SNASSMC               75           0              88-08
W0000000-008    SNASSMC               20           0              88-09
W0000000-009    SNASSMD              371           0              88-02
W0000000-010    SNASSMD              110           0              88-03
W0000000-011    SNASSMD               50           0              88-04
W0000000-012    SNASSMD               74           0              88-05
W0000000-013    SNASSMD              210           0              88-06
W0000000-014    SNASSMD              185           0              88-07
W0000000-015    SNASSMD               60           0              88-08
W0000000-016    SNPNC                140           0              88-02
W0000000-017    SNPNC                145           0              88-03
W0000000-018    SNPNC                260           0              88-04
W0000000-019    SNPNC                152           0              88-05
W0000000-020    SNPNC                190           0              88-06
W0000000-021    SNPNC                 85           0              88-07
W0000000-022    SNPNC                 85           0              88-08
W0000000-023    SNPNC                 75           0              88-09
W0000000-024    SNPNC                 20           0              88-10
W0000000-025    SNPND                217           0              88-02
W0000000-026    SNPND                149           0              88-03
W0000000-027    SNPND                1s5           0              88-04
W0000000-028    SNPND                110           0              88-05
W0000000-029    SNPND                 50           0              88-06
W0000000-030    SNPND                 74           0              88-07
W0000000-031    SNPND                210           0              88-08
W0000000-032    SNPND                185           0              88-09
W0000000-033    SNPND                 60           0              88-10
W0000000-034    SNPNSR111            174           0              88-02
W0000000-035    SNPNSR111            170           0              88-03
W0000000-036    SNPNSR111            220           0              88-04
W0000000-037    SNPNSR111            140           0              88-05
W0000000-038    SNPNSR111            105           0              88-06
W0000000-039    SNPNSR111            120           0              88-07
W0000000-040    SNPNSR111             50           0              88-08
W0000000-041    SNPNSR111             10           0              88-09
W0000000-042    SNPNSR111             20           0              88-10
W0000000-043    SNSR111-10           514           0              88-02
W0000000-044    SNSR111-10           140           0              88-03
W0000000-045    SNSR111-10           105           0              88-04
W0000000-046    SNSR111-10           120           0              88-05
W0000000-047    SNSR111-10            50           0              88-06
W0000000-048    SNSR111-10            10           0              88-07
W0000000-049    SNSR111-10            20           0              88-08
W0000000-050    SNSR111-40           324           0              88-02
W0000000-051    SNSR111-40           220           0              88-03
W0000000-052    SNSR111-40           140           0              88-04
W0000000-053    SNSR111-40           105           0              88-05
W0000000-054    SNSR111-40           120           0              88-06
W0000000-055    SNSR111-40            50           0              88-07
W0000000-056    SNSR111-40            10           0              88-08
W0000000-057    SNSR111-40            20           0              88-09

<<<<<<<<<<<<<<<<<<<<<<<<<<<<< E N D   O F   F I L E >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
```

Table 11.18   Temporary work orders created using MRP results



```
08/01/88  88-01              WORK CENTRE LOADING-STATUS DISPLAY        Mode:Work load
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 Work Centre 10   TURN/GRIND INV CAST        Operators  2.0     Machines  2.0
----------------------------------------------------------------------------------
               Loading details for 10 working days starting 8011
               -------------------------------------------------

 Day   Est'   Capacity     %       P   E   R   C   E   N   T   A   G   E     L   O   A   D
 No    Load    (hrs)     Load 0%..........50%.........100%.........150%.........200%
8011    0       15         0% |            |            |            |            |
8012    0       15         0% |            |            |            |            |
8013   36       16       228% |~~~~~~~~~~~~|~~~~~~~~~~~~|~~~~~~~~~~~~|~~~~~~~~~~~~|
8014    0       16         0% |            |            |            |            |
8015    0       14         0% |            |            |            |            |
8018    0       15         0% |            |            |            |            |
8019   44       15       293% |~~~~~~~~~~~~|~~~~~~~~~~~~|~~~~~~~~~~~~|~~~~~~~~~~~~|
8020    0       16         0% |            |            |            |            |
8021    0       16         0% |            |            |            |            |
8022    0       14         0% |            |            |            |            |
                              0%..........50%.........100%.........150%.........200%
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
(D)isplay Work Centre Loading Details for 10 working days              (Q)uit
(P)rint Work Centre Loading Details for all 50 working days  (MRP horizon)
Please select : :
```

Table 11.19   Screen-print on load status for work centre 10

```
08/01/88          LOADING DETAILS FOR 50 Working Days Beginning 8011
                              FOR WORK CELL . 3
------------------------------------------------------------------------------------------------------------------------------

Work Centre          Description              No of Operators                    No of Machines
    20          TURN/GRIND/CENTRE/PT                2.0                                2.0
------------------------------------------------------------------------------------------------------------------------------

Day  Estimated  Capacity    %                               P   E   R   C   E   N   T   A   G   E     L   O   A   D
No   Load(Hrs)   (Hrs)    Load 0%.......................50%......................100%......................150%......................200
---- ---------  --------  ---- |                        |                        |                        |                        |
8011      0        15       0% |                        |                        |                        |                        |
8012      0        15       0% |                        |                        |                        |                        |
8013      0        16       0% |                        |                        |                        |                        |
8014      0        16       0% |                        |                        |                        |                        |
8015      0        14       0% |                        |                        |                        |                        |
8018      0        15       0% |                        |                        |                        |                        |
8019      0        15       0% |                        |                        |                        |                        |
8020     18        16     117% |************************|************************|*******
8021      0        16       0% |                        |                        |                        |                        |
8022      0        14       0% |                        |                        |                        |                        |
8025      0        15       0% |                        |                        |                        |                        |
8026     22        15     150% |************************|************************|************************
8027      0        16       0% |                        |                        |                        |                        |
8028      0        16       0% |                        |                        |                        |                        |
8029      0        14       0% |                        |                        |                        |                        |
8033      0        15       0% |                        |                        |                        |                        |
8034     13        16      84% |************************|*****************
8035      0        16       0% |                        |                        |                        |                        |
8036      0        14       0% |                        |                        |                        |                        |
8039      0        15       0% |                        |                        |                        |                        |
8040      0        15       0% |                        |                        |                        |                        |
8041     16        16     104% |************************|************************|*
8042      0        16       0% |                        |                        |                        |                        |
8043      0        14       0% |                        |                        |                        |                        |
8046      0        15       0% |                        |                        |                        |                        |
8047      0        15       0% |                        |                        |                        |                        |
8048      0        16       0% |                        |                        |                        |                        |
8049      7        16      49% |************************
8050      0        14       0% |                        |                        |                        |                        |
8053      0        15       0% |                        |                        |                        |                        |
8054      0        15       0% |                        |                        |                        |                        |
8055      0        16       0% |                        |                        |                        |                        |
8056      7        16      49% |************************
8057      0        14       0% |                        |                        |                        |                        |
8060      0        15       0% |                        |                        |                        |                        |
8061      0        15       0% |                        |                        |                        |                        |
8062      0        16       0% |                        |                        |                        |                        |
8063      7        16      44% |**********************
8064      0        14       0% |                        |                        |                        |                        |
8067      0        15       0% |                        |                        |                        |                        |
8068      0        15       0% |                        |                        |                        |                        |
8069      0        16       0% |                        |                        |                        |                        |
8070      0        16       0% |                        |                        |                        |                        |
8071      2        14      17% |*******
8074      0        15       0% |                        |                        |                        |                        |
8075      0        15       0% |                        |                        |                        |                        |
8076      0        16       0% |                        |                        |                        |                        |
8077      0        16       0% |                        |                        |                        |                        |
8078      0        14       0% |                        |                        |                        |                        |
8081      0        15       0% |                        |                        |                        |                        |
---- ---------  --------  ---- 0%.......................50%......................100%......................150%......................200
```

Table 11.20 Print-out on load status for work centre 20 suggested orders generated from the MRP are then automatically converted into real orders. Table 11.21 shows the final work orders generated using the MRP results. Note that this time each order is preceded by a proper date as part of the order number.

These newly generated work orders were then combined with existing work orders and stored in a single file. Different options can be used to list the content of this file. Some of these listings are included in Appendix F for reference.

11.4.10 CAPACITY PLANNING

Each work cell (only one in this test) has to maintain a local capacity database. The typical content of such a database is shown as Table 11.22.

As with the process of preliminary work load analysis, each newly issued work order has to go through a process by which its Latest-Start-Date (LSD) is generated. This permits it to be considered in the capacity planning process. A listing of such a LSD file is shown as Table F-7, indicating that each individual operation has been assigned a LSD.

Each work centre, as before, can be analysed for its projected load generated by the work orders. The load report can be specified for a range of periods, either to be displayed on the screen, or to be printed on paper. In addition to this, an extra option here will allow the user to examine the work-to-list of all work centres - giving an overview of the potential load situation. Table 11.23 shows a typical work-to-list for all work centres based on current work orders. Note that the status (released or un-released) of each work order, as well as their load on corresponding work centre, are shown in this report for detailed analysis.

When a work order is released to the shop, corresponding WIP details are also generated for its required operations. These WIP details have to be updated to indicate the progress of that order. Table 11.24 shows a summary of WIP details generated for work orders which were released.

When an order has been completed, its WIP details are deleted from the master file and copied to another file in which all finished orders are stored.

```
08/01/88  DISCRETE WORK ORDERS CONVERTED FROM MRP TO BE CONFIRMED FOR ISSUE
          INTO WORK CELL : 3                ON DATE : 08/01/88
          FOR PERIOD : 88-02       CURRENT PERIOD : 88-01

WORK ORDER NO.  PART NO.         ORDER QTY   BATCH SIZE   SCHEDULED LAUNCH PERIOD
--------------  --------         ---------   ----------   -----------------------

WO080188-001    SNASSMC                300          100            88-02
WO080188-002    SNASSMC                200          100            88-03
WO080188-003    SNASSMC                200          100            88-04
WO080188-004    SNASSMC                200          100            88-05
WO080188-005    SNASSMC                100          100            88-06
WO080188-006    SNASSMC                100          100            88-08
WO080188-007    SNASSMD                371            1            88-02
WO080188-008    SNASSMD                110            1            88-03
WO080188-009    SNASSMD                 50            1            88-04
WO080188-010    SNASSMD                 74            1            88-05
WO080188-011    SNASSMD                210            1            88-06
WO080188-012    SNASSMD                185            1            88-07
WO080188-013    SNASSMD                 60            1            88-08
WO080188-014    SNPNC                  140            1            88-02
WO080188-015    SNPNC                  145            1            88-03
WO080188-016    SNPNC                  260            1            88-04
WO080188-017    SNPNC                  152            1            88-05
WO080188-018    SNPNC                  190            1            88-06
WO080188-019    SNPNC                   85            1            88-07
WO080188-020    SNPNC                   85            1            88-08
WO080188-021    SNPNC                   75            1            88-09
WO080188-022    SNPNC                   20            1            88-10
WO080188-023    SNPND                  217            1            88-02
WO080188-024    SNPND                  149            1            88-03
WO080188-025    SNPND                  135            1            88-04
WO080188-026    SNPND                  110            1            88-05
WO080188-027    SNPND                   50            1            88-06
WO080188-028    SNPND                   74            1            88-07
WO080188-029    SNPND                  210            1            88-08
WO080188-030    SNPND                  185            1            88-09
WO080188-031    SNPND                   60            1            88-10
WO080188-032    SNPNSR111              174            1            88-02
WO080188-033    SNPNSR111              170            1            88-03
WO080188-034    SNPNSR111              220            1            88-04
WO080188-035    SNPNSR111              140            1            88-05
WO080188-036    SNPNSR111              105            1            88-06
WO080188-037    SNPNSR111              120            1            88-07
WO080188-038    SNPNSR111               50            1            88-08
WO080188-039    SNPNSR111               10            1            88-09
WO080188-040    SNPNSR111               20            1            88-10
WO080188-041    SNSR111-10             600          200            88-02
WO080188-042    SNSR111-10             200          200            88-03
WO080188-043    SNSR111-10             200          200            88-05
WO080188-044    SNSR111-40             324            1            88-02
WO080188-045    SNSR111-40             220            1            88-03
WO080188-046    SNSR111-40             140            1            88-04
WO080188-047    SNSR111-40             105            1            88-05
WO080188-048    SNSR111-40             120            1            88-06
WO080188-049    SNSR111-40              50            1            88-07
WO080188-050    SNSR111-40              10            1            88-08
WO080188-051    SNSR111-40              20            1            88-09
```

Table 11.21   Final work orders created using MRP results

```
08/01/88     Listing of Work Centre Data in WORK CENTRE No order
                    FOR WORK CELL = 3
--------------------------------------------------------------------------------------------

Work Centre           Description           Number of        Number of          Performance
  Number                                    Operators        Machines               %

      10 ................. TURN/GRIND INV CAST............ 2.0 ................... 2.0 ......................... 100
      20 ................. TURN/GRIND/CENTRE/PT........... 2.0 ................... 2.0 ......................... 100
      30 ................. MILL FLATS..................... 2.0 ................... 2.0 ......................... 100
      40 ................. MILL TIP/CLEARANCE............. 2.0 ................... 2.0 ......................... 100
      50 ................. TURN SHANK/GRIND/PAR........... 1.0 ................... 1.0 ......................... 100
      60 ................. MILL SHANK (CLK WHI)........... 1.0 ................... 1.0 ......................... 100
      70 ................. MILL TEETH SHAPE/GRI........... 1.0 ................... 1.0 ......................... 100
      80 ................. HEAT TREATMENT................. 1.0 ................... 1.0 ......................... 100
      90 ................. INDUCTION BRAZE, INST.......... 1.0 ................... 2.0 ......................... 100
     100 ................. FINSIH GRIND/HEATREA........... 1.0 ................... 2.0 ......................... 100
     300 ................. SMALL CAPSTANS................. 0.0 ................... 0.0 ......................... 100
     320 ................. LARGE CAPSTANS................. 0.0 ................... 0.0 ......................... 100
     340 ................. CENTRE LATHES.................. 0.0 ................... 0.0 ......................... 100
     360 ................. VERTICAL MILLING............... 0.0 ................... 0.0 ......................... 100
     380 ................. HORIZONTAL MILLING............. 0.0 ................... 0.0 ......................... 100
     400 ................. SPIRAL MILLING................. 0.0 ................... 0.0 ......................... 100
     420 ................. DRILLING & TAPPING............. 0.0 ................... 0.0 ......................... 100
     440 ................. SUB-CON  KEYWAYS............... 0.0 ................... 0.0 ......................... 100
     444 ................. test...........................25.0 ..................25.0 .........................  25
     460 ................. BENCH (NO CARBIDE)............. 0.0 ................... 0.0 ......................... 100
     480 ................. INDUCTION BRAZING.............. 0.0 ................... 0.0 ......................... 100
     485 ................. TORCH BRAZING.................. 0.0 ................... 0.0 ......................... 100
     500 ................. CYLINDRICAL GRINDING........... 0.0 ................... 0.0 ......................... 100
     540 ................. SURFACE GRINDING............... 0.0 ................... 0.0 ......................... 100
     560 ................. INTERNAL GRINDING.............. 0.0 ................... 0.0 ......................... 100
     580 ................. LAPPING (FACE CARB')........... 0.0 ................... 0.0 ......................... 100
     620 ................. BACK OFF CARBIDE............... 0.0 ................... 0.0 ......................... 100
     640 ................. FORM GRINDING.................. 0.0 ................... 0.0 ......................... 100
     680 ................. GENERAL GRINDING............... 0.0 ................... 0.0 ......................... 100
     700 ................. SPIRAL FACING.................. 0.0 ................... 0.0 ......................... 100
     760 ................. BENCH (WITH CARBIDE)........... 0.0 ................... 0.0 ......................... 100
     780 ................. SPIRAL UNIT.................... 0.0 ................... 0.0 ......................... 100
     800 ................. R & D - GRAPHITE............... 0.0 ................... 0.0 ......................... 100
     806 ................. INSPECTION..................... 0.0 ................... 0.0 ......................... 100
     820 ................. WAXING UNIT.................... 0.0 ................... 0.0 ......................... 100
     840 ................. SUB-CON  HEAT TREAT............ 0.0 ................... 0.0 ......................... 100
     860 ................. SUB-CON........................ 0.0 ................... 0.0 ......................... 100
     880 ................. BENCH - FINAL DRESS............ 0.0 ................... 0.0 ......................... 100
     900 ................. RESEARCH & DEVELOPMT........... 0.0 ................... 0.0 ......................... 100
--------------------------------------------------------------------------------------------
```

Table 11.22   Listing of capacity resources in Work Cell 3

01/01/88

WORK-TO-LIST LOADING CHART until 8020

WORK CENTRES

		10			20			30			40			90			100											
Order No	Status	Op No	Hrs	LSD	Op No	Hrs	LSD	Op No	Hrs	LSD	Op No	Hrs	LSD	Op No	Hrs	LSD	Op No	Hrs	LSD	Op No	Hrs	LSD	Op No	Hrs	LSD	Op No	Hrs	LSD
WO010188-001	Rel	10	40	8001	20	67	8011																					
WO010188-002	Rel	10	32	8014	20	54	8020																					
WO010188-003	UnR	10	32	8020																								
WO010188-009	Rel							30	339	8001	40	684	8001															
WO010188-010	Rel							30	103	8001	40	176	8001															
WO010188-011	Rel							30	103	8001	40	175	8011															
WO010188-012	Rel							30	103	8001	40	176	8018															
WO010188-013	UnR							30	103	8006																		
WO010188-014	UnR							30	103	8013																		
WO010188-015	UnR							30	103	8020																		
WO010188-016	UnR																100	176	8001									
WO010188-017	UnR																100	88	8014									
WO010188-018	UnR																100	88	8020									
WO010188-025	Rel													90	440	8001												
WO010188-026	Rel													90	220	8001												
WO010188-027	Rel													90	220	8001												
WO010188-028	Rel													90	220	8001												
WO010188-029	UnR													90	220	8008												
WO010188-030	UnR													90	220	8015												
WO010188-031	UnR													90	220	8022												
WO010188-034	UnR													90	466	8001	100	583	8001									
WO010188-035	UnR													90	233	8001	100	291	8001									
WO010188-036	UnR													90	233	8001	100	291	8001									
WO010188-037	UnR													90	233	8001	100	291	8001									
WO010188-038	UnR													90	233	8001	100	291	8001									
WO010188-039	UnR													90	233	8001	100	291	8001									
WO010188-040	UnR													90	233	8001	100	231	8011									
WO010188-041	UnR													90	233	8001	100	291	8018									
WO010188-042	UnR													90	233	8001												
TOTAL LOAD		105 Hours			121 Hours			1017 Hours			1214 Hours			4096 Hours			2978 Hours			0 Hours			0 Hours			0 Hours		
TOTAL CAPACITY		168 Hours			168 Hours			168 Hours			168 Hours			84 Hours			84 Hours			0 Hours			0 Hours			0 Hours		
PERCENTAGE		63%			72%			605%			722%			4876%			3546%			100%			100%			100%		

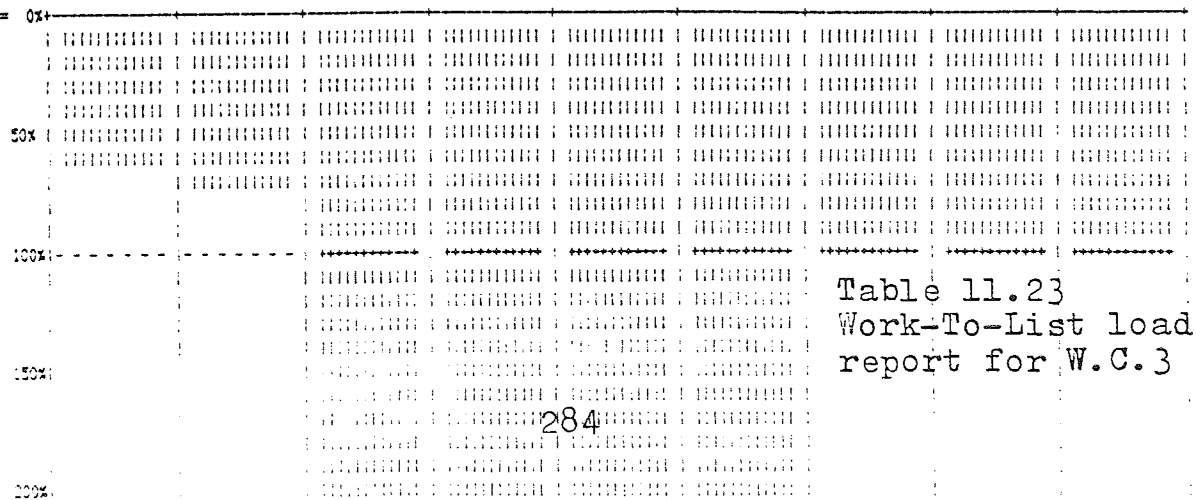


Table 11.23
Work-To-List load
report for W.C.3

```
08/01/88              LISTING OF ALL WORK-IN-PROGRESS DETAILS

           FOR WORK CELL : 3              SYSTEM PERIOD : 88-01
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

WORK NO.     PART NO.     OP:NO WC:NO L.B.D.  O. QTY  ACT QTY  EST.TOT.P.TM  ACT PROD T  ACT DOWN T  ACT OVER T  REL DATE  FIN DATE
--------     --------     ----- ----- ------  ------  -------  ------------  ----------  ----------  ----------  --------  --------

W0010188-002 SNASSMC      10    10    8014    640     0              1960        0           0           0       01/01/88
             SNASSMC      20    20    8020    640     0              3250        0           0           0       01/01/88
             SNASSMC      9999  END   8029    640     0               100        0           0           0       01/01/88
W0010188-010 SNASSMD      30    30    8001    880     0              6182        0           0           0       01/01/88
             SNASSMD      40    40    8001    880     0             10590        0           0           0       01/01/88
             SNASSMD      9999  END   8036    880     0               100        0           0           0       01/01/88
W0010188-011 SNASSMD      30    30    8001    880     0              6182        0           0           0       01/01/88
             SNASSMD      40    40    8011    880     0             10590        0           0           0       01/01/88
             SNASSMD      9999  END   8043    880     0               100        0           0           0       01/01/88
W0010188-012 SNASSMD      30    30    8001    880     0              6182        0           0           0       01/01/88
             SNASSMD      40    40    8018    880     0             10590        0           0           0       01/01/88
             SNASSMD      9999  END   8050    880     0               100        0           0           0       01/01/88
W0010188-026 SNPND        90    90    8001    880     0             13220        0           0           0       01/01/88
             SNPND        9999  END   8029    880     0               100        0           0           0       01/01/88
W0010188-027 SNPND        90    90    8001    880     0             13220        0           0           0       01/01/88
             SNPND        9999  END   8036    880     0               100        0           0           0       01/01/88
W0010188-028 SNPND        90    90    8001    880     0             13220        0           0           0       01/01/88
             SNPND        9999  END   8043    880     0               100        0           0           0       01/01/88

<<<<<<<<<<<<<<<<<<<<<<<<  E N D   O F   W. I. P.   F I L E  >>>>>>>>>>>>>>>>>>>>>>>>
```

Table 11.24 Print-out on Work-In-Progress details for Work Cell 3

11.4.11 CENTRAL PURCHASING

All recommended purchase orders generated in the local MRP process are retrieved by the central purchasing module, where these suggested orders will be converted into real purchase orders. Table F-8 indicates the original part requests generated by Work Cell 3, and Table 11.25 shows the purchase orders generated using these part requests.

When a purchase order is due, it will be picked up, printed and ready to be sent to the vendor. A sample print-out of such an order is shown as Table F-9.

When component parts are received from vendors, the stock status of the corresponding parts in the local stock file are updated automatically. Table 11.26 shows the content such a local stock file.

11.4.12 SHIPMENTS FOR CUSTOMER ORDERS

Like the purchase order, when a customer order is due, it will be picked up automatically by the system. On-hand stock is then allocated to this order before shipment can be made. However, if there is not enough stock available for all the orders due, the user has to assign some priorities for final shipment.

11.4.13 CONCLUSIONS

Test run one comprised a set of comprehensive operations through which various parts of the embryo system were examined and verified. Results obtained in this test run prove that all the developed system modules operate and interact as desired. The single work cell configuration, on the other hand, represents a common shop floor practice - all machining processes are grouped into one single location. Results obtained during the MPS data distribution and the local MRP process will be compared with those results obtained in the second test run.

The preliminary evidence shows that the distribution mechanism built in the system to distribute MPS orders, BOM and routing details actually work satisfactorily. This mechanism would be tested more fully when several work cells are used in the system, and this is one of the objectives when the second test run is described in following sections.

```
08/01/88     LISTING OF CURRENT SCHEDULED PURCHASE ORDERS IN (PURSCHED)
             CURRENT SYSTEM PERIOD 88-01

PURCHASE NO.  PART NO.      REQ QTY  WORK CELL  SCH. ORDER-PERIOD  LD:TIME  SCH. ARRIV-PERIOD  SENT  LAST:UPDT
------------  --------     -------   --------   -----------------  -------  -----------------  ----  ---------

PUR1          SN33             5596  WC3                    88-02        2              88-04     N   08/01/88
PUR2          SN33             1332  WC3                    88-03        2              88-05     N   08/01/88
PUR3          SN33             1332  WC3                    88-04        2              88-06     N   08/01/88
PUR4          SN33             1335  WC3                    88-05        2              88-07     N   08/01/88
PUR5          SN33             1377  WC3                    88-06        2              88-08     N   08/01/88
PUR6          SN33             1397  WC3                    88-07        2              88-09     N   08/01/88
PUR7          SN33             1200  WC3                    88-08        2              88-0*     N   08/01/88
PUR11         SN4             14320  WC3                    88-02        1              88-03     N   08/01/88
PUR12         SN4              4840  WC3                    88-03        1              88-04     N   08/01/88
PUR13         SN4              4840  WC3                    88-04        1              88-05     N   08/01/88
PUR14         SN4              4840  WC3                    88-05        1              88-06     N   08/01/88
PUR15         SN4              4840  WC3                    88-06        1              88-07     N   08/01/88
PUR16         SN4              4840  WC3                    88-07        1              88-08     N   08/01/88
PUR17         SN4              4840  WC3                    88-08        1              88-09     N   08/01/88
PUR18         SN4              4840  WC3                    88-09        1              88-0*     N   08/01/88
PUR21         SN7              4230  WC3                    88-02        1              88-03     N   08/01/88
PUR22         SN7               880  WC3                    88-03        1              88-04     N   08/01/88
PUR23         SN7               880  WC3                    88-04        1              88-05     N   08/01/88
PUR24         SN7               880  WC3                    88-05        1              88-06     N   08/01/88
PUR25         SN7               880  WC3                    88-06        1              88-07     N   08/01/88
PUR26         SN7               880  WC3                    88-07        1              88-08     N   08/01/88

((((((((((((((((((((((((((((((E N D   O F   S C H E D U L E D   P U R C H A S E   O R D E R S)))))))))))))))))))))))
```

Table 11.25   Purchase orders generated using MRP results

```
08/01/88        STOCK STATUS REPORT FOR WORK CELL : 3

                SYSTEM PERIOD : 88-01
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

PART NO.      DESCRIPTION                      ON-HAND QTY   BOUGHT-IN PART   LAST UPDATE
--------      -----------                      -----------   --------------   -----------

PNC           TYPE C CUTTER                        100            NO           01/01/88
PND           TYPE D CUTTER                        120            NO           01/01/88
PNEM777                                             60            NO           01/01/88
PNFB444                                            100            NO           01/01/88
PNSR111       SUPEROUTER CUTTER                     40            NO           01/01/88
PNTEST        TEST PRODUCT                          50            NO           01/01/88
SN24          THIS IS PART24                       633            YES          02-05-86
SN4           CUTTING BLADES                       200            YES          01/01/85
SN5           RAW STEEL BAR WITH DIA 100            50            YES          01/01/88
SN7           RAW STEEL BAR DIA 150                 70            YES          01/01/88
SNA           THIS IS ASSEMBLY  A                    0            NO           04-08-86
SNA1          PART SNA1                              0            YES          01-01-85
SNASSMC       SUBASSEMBLY FOR CUTTER C             870            NO           08-01-88
SNASSMD       SUBASSEMBLY FOR CUTTER D            3100            NO           08-01-88
SNC           ASSEMBLY SNC                          20            NO           01-02-85
SNC1          END PART SNC1                         20            YES          01-02-86
SND1          END PART SND1                         10            YES          01-01-86
SNE           ASSEMBLY SNE                          40            NO           01-01-86
SNPND         FINAL ASSEMBLY FOR CUTTER D         1000            NO           01-08-88
SNPNSR111     SUPEROUTER CUTTER                     30            NO           01/01/88
SNPNTEST1     TEST PRODUCT 1                         0            NO           01-06-85
SNPNTEST2     TEST PRODUCT 2                        10            NO           01-01-85
SNPNTEST3     TEST PRODUCT 3                         0            NO           02-04-84
SNTEST4       THIS IS TEST PART 4                 6000            YES          01-01-85
SNTEST6       THIS IS TEST PART 6                  100            NO           01-01-85
SNTEST7       THIS IS TEST PART 7                 2000            YES          01-01-85
SNTEST9       THIS IS TEST PART 9                 3600            NO           01-01-85

 <<<<<<<<<<<<<<<<<<<<<<<  E N D   O F   S T O C K   F I L E  >>>>>>>>>>>
```

Table 11.26   Stock status report for Work Cell 3

11.5 TEST RUN TWO FOR THE EMBRYO SYSTEM

Test run two differed from test run one, in that there were two computers and three work cells configured in this system. The local-area-network system was also used in this test for communications between computers.

11.5.1 OBJECTIVES OF TEST RUN TWO

In test run one, the single work cell configuration represented a common manufacturing environment, in which MPS, MRP and capacity planning are all done at a central location.

The main objective of the second test run is focused on the demonstration and verification of the distributed planning and control features developed in the embryo system.

As there were three work cells used in this test, the characteristics of data distribution from the central MPS module into a local database in each of the work cells therefore can be demonstrated. In addition, the links for data transfer between work cells were also examined with reference to the concept of distributed control.

Another characteristic of this test, when compared to the first, is that both BOM and routing details were distributed from their central files into different work cells. This concept is closely associated with the distribution of MPS data, as all these details shall be required during the local MRP process.

Most of the initial setting-up procedures required in this test are almost identical to those in the first test, and will not be repeated here unless they are different.

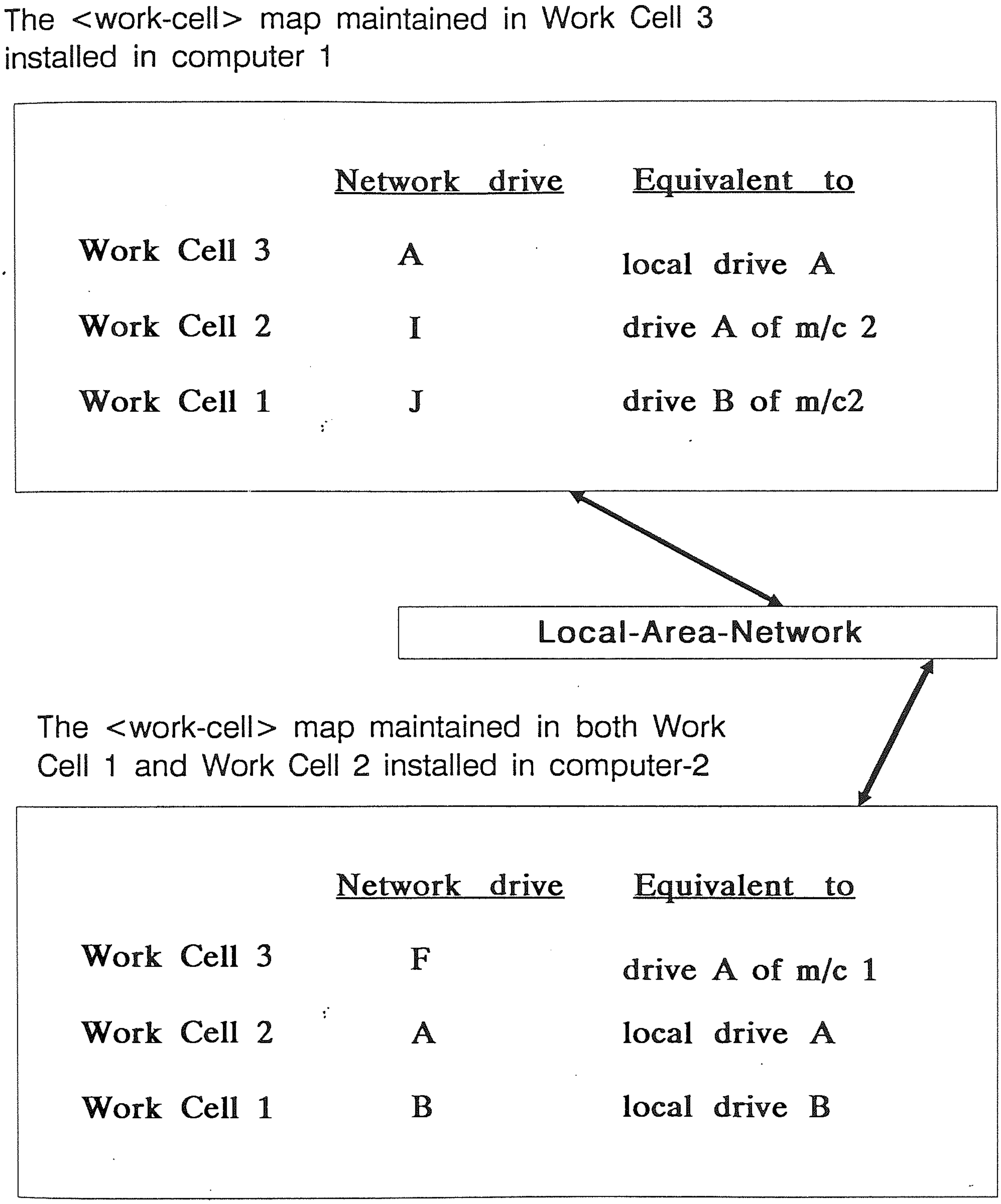
11.5.2 SYSTEM CONFIGURATION FOR TEST RUN TWO

Since there were 2 hard-disk computers in this test, the number of disk drives available, therefore, was four. Because both computers have drive A and B, different drive letters therefore had to be assigned when the two computers were used simultaneously. This was also essential for the local network system to operation accurately.

In this test, the configuration details were specified as follows :

COMPUTER	DRIVE LOCATION	MODULE ASSIGNMENTS
1	A	All modules in the System Configuration Cell (Function group A)
1	A	All local modules in work cell 3
1	B	All modules in the Customer Service Cell
1	B	All modules in the Design Cell (Function group C)
1	B	All modules in the Central Planning Cell (Function group D)
2	A	All local modules in work cell 2.
2	B	All local modules in work cell 1.

The third OCTOPUS computer which has only one disk drive could also have been used here, although it would mainly act as a display terminal. This extra computer, if used, would have to be assigned a hard disk from another computer. Because of the use of LAN, a unique work cell map was maintained separately in each configured work cell so that the mapping of disk drives could be accurately identified. Figure 11.2 illustrates the details for disk drive mapping for all three work cells in this particular system configuration.



The <work-cell> map maintained in Work Cell 3
installed in computer 1

	Network drive	Equivalent to
Work Cell 3	A	local drive A
Work Cell 2	I	drive A of m/c 2
Work Cell 1	J	drive B of m/c2

The <work-cell> map maintained in both Work
Cell 1 and Work Cell 2 installed in computer-2

	Network drive	Equivalent to
Work Cell 3	F	drive A of m/c 1
Work Cell 2	A	local drive A
Work Cell 1	B	local drive B

Figure 11.2 Work Cell maps associated with all three work cells

11.5.3 GENERAL PREPARATION PROCEDURES BEFORE DATA DISTRIBUTION

Although most of the initial setting-up procedures in here are identical to those in the first test, there are significant changes to the structure of the products used in the tests. For the reason of data consistency, the three previously used products, namely PNC, PND and PNSR111, were also used in this test run. Their BOM remain unchanged but certain changes to work cell allocation had been carried out so that the principle of data distribution can be illustrated much more clearly.

Figure 11.3 shows the product structures for all the three products with modified work cell assignments for their subassemblies. Each product, in this case, has to be processed in more than one work cell. For example, product PNSR111 has to be first processed in work cell 1, then 2, and finally assembled in work cell 3. This sequence is shown in its BOM details in the same figure.

Major system configuration procedures are no different to those mentioned in test one, except there were four drives and three work cells in here, instead of two drives and one work cell.

Procedures used to set up design databases were also similar to those in test one, except the new changes described above had to be re-entered into the system. Table 11.27 shows the listing of routing details for all three products after changes were made. Note that operations in Work Cell 1, 2 and 3 are shown in the listing.

Sales order entry, as before, were carried out through the customer service menu. For the sake of demonstration, sales orders which had been used in the first test were retained so that comparison can be made between the two tests based on similar conditions. Table 11.28, Table 11.29 and Table 11.30 show orders created for product PNC, PND and PNSR111 respectively. There are altogether 75 orders in these files - the number is identical to that in the first test, which was shown in Table 11.13. It is important to realise this as the following results would be based on the initial orders.

When all the above procedures are completed, the system was then ready to distribute its central data to various work cells.

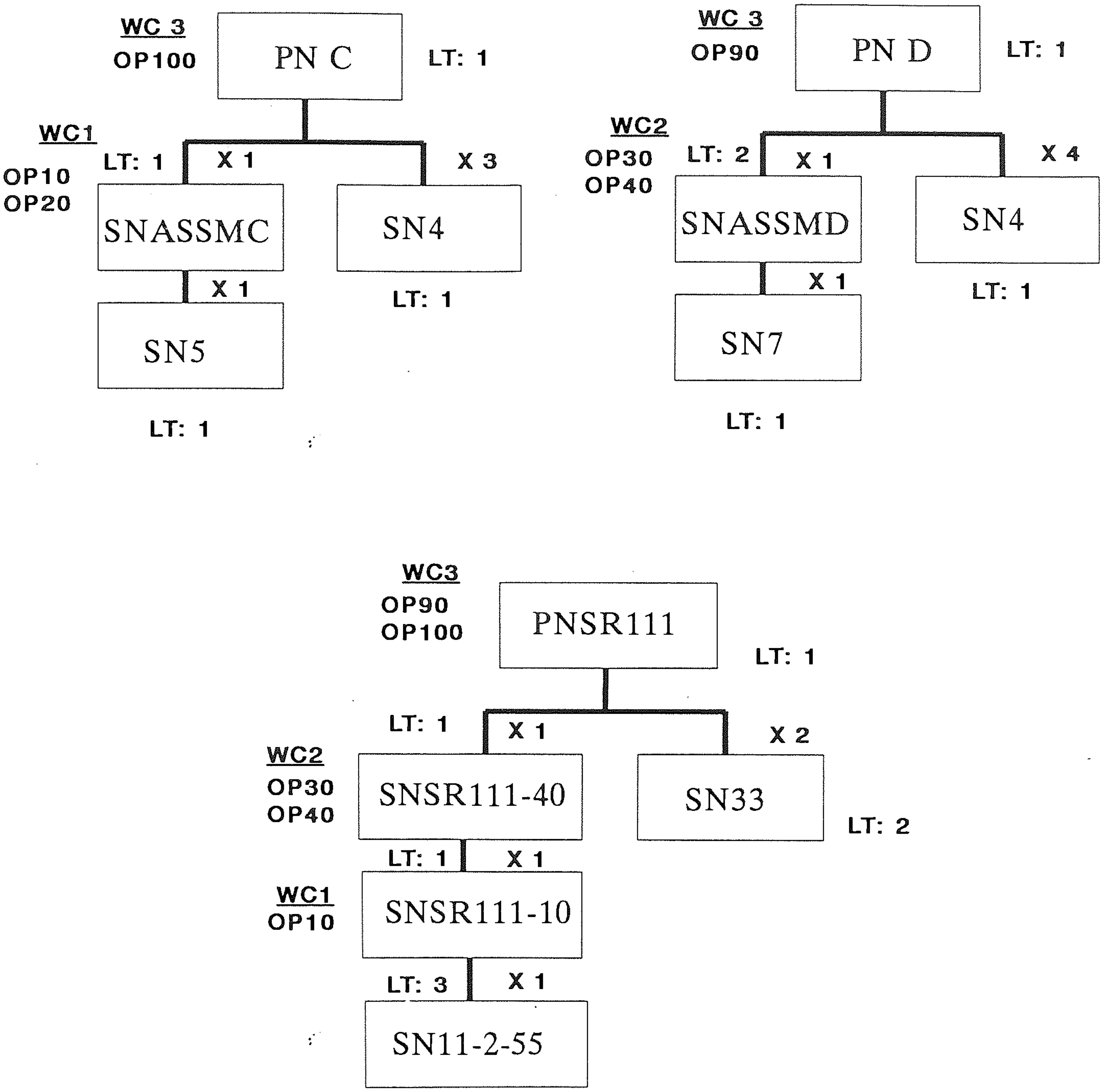


Figure 11.3 BOM and Routing details for products PNC, PND and PNSR111 in Test Run two

```
01/01/88       ALL AVAILABLE PROCESS ROUTES IN (PROCESS) FILE

SUB-ASSEMBLY OP NO.                 DESCRIPTION                      WORK CELL SET T  PROD T  LAB S.  SCRAP %  LAST UPDT
------------ -----  ------------------------------------------------  --------- -----  ------  -----  -------  ---------

SN1           50  TURN SHANK,GRIND ALLOW.,CENTRE,TURN BODY, PART OFF     WC3     0       0     B       0.0    08-04-86
SNASSMC       10  TURN SHANK + GRIND ALLOWANCE (ON INVESTMENT CAST)      WC1    40      10     B       0.0    01-01-88
SNASSMC       20  TURN SHANK,GRIND ALLOW.,CENTRE,TURN BODY,PART OFF      WC1    50       5     B       0.0    01-01-88
SNFSSMD       30  MILL FLATS (TAPER, CLARKSON, WHISTLE & WELDON)         WC2    22      10     B       0.0    01-01-88
SNASSMD       40  MILL TIP SEATS/ MILL CLEARANCE                         WC2    30      20     B       0.0    01-01-88
SNEM777-50    50  TURN SHANK,GRIND ALLOW.,CENTRE, TURN BODY, PART OFF    WC3     0      30     B       2.0    12-12-85
SNEM777-70    60  MILL SHANK (CLARKSON, WHISTLE)                         WC3     0      10     C       2.0    12-12-85
SNEM777-70    70  MILL TEETH SHAPE, GRIND TEETH                          WC3     0      15     B       2.0    12-12-85
SNEM777-80    80  HEAT TREATMENT TO HARDEN THE CUTTING EDGE              WC3     0      40     B       0.0    12-12-85
SNFB444-20    20  TURN SHANK,GRIND ALLOW.,CENTRE,TURN BODY,PART OFF      WC3     0      35     B       2.0    12-12-85
SNFB444-40    30  MILL FLATS (TAPER, CLARKSON, WHISTLE & WELDON)         WC3     0       8     C       2.0    12-12-85
SNFB444-40    40  MILL TIP SEATS/ MILL CLEARANCE                         WC3     0      20     B       2.0    12-12-85
SNPNC        100  FINAL ASSEMBLY PROCESS                                 WC3    20      12     A       0.0    01-01-88
SNPND         90  FINAL ASSM INDUCTION BRAZE, INSERT, GRIND LOC          WC3    20      15     A       0.0    01-01-88
SNPNEM777    100  FINISH GRIND CARBIDE / FINISH HEATREATED EDGE          WC3     0      15     A       0.0    12-12-85
SNPNFB444     90  INDUCTION BRAZE, INSERT, GRIND LOC                     WC3     0      15     C       0.0    12-12-85
SNPNFB444    100  FINISH GRIND CARBIDE / FINISH HEATREATED EDGE          WC3     0      20     A       0.0    12-12-85
SNPNJHF      100  FINISH GRIND CARBIDE / FINISH HEATREATED EDGE          WC3    20     100     A      12.0    12-12-85
SNPNJHF      110  TEST ONLY                                              WC3    20     100     A      12.0    12-12-85
SNPNSR111     90  INDUCTION HRAZE, INSERT, GRIND LOC                     WC3     5      20     C       0.0    12-12-85
SNPNSR111    100  FINISH GRIND CARBIDE / FINISH HEATREATED EDGE          WC3     5      25     A       0.0    12-12-85
SNSR111-10    10  TURN SHANK + GRIND ALLOWANCE (ON INVESTMENT CAST)      WC1     3      15     C       2.0    12-12-85
SNSR111-40    30  MILL FLATS (TAPER, CLARKSON, WHISTLE & WELDON)         WC2     3      10     C       2.0    12-12-85
SNSR111-40    40  MILL TIP SEATS/ MILL CLEARANCE                         WC2     5      30     B       2.0    12-12-85

((((((((((((((((((((((((((((((((((((((((((((E N D   O F   F I L E))))))))))))))))))))))))))))))))))))))))))))
```

Table 11.27 Process routes details generated for Test Run Two

```
01/01/88     CURRENT MPS ORDERS BASED ON PRODUCT PNC

ORDER NO.   CUSTOMER NAME      PRODUCT     QTY   PERIOD   VALID TO (IF RESERVED)   QUOTE NO. (IF ANY)
---------   -------------      -------     ---   ------   ----------------------   ------------------

FORECAST    FORECAST           PNC          40   88-02
FORECAST    FORECAST           PNC          50   88-03
ON23        HI-TECH            PNC          20   88-03
ON24        ASTON WORKSHOP     PNC          30   88-03
FORECAST    FORECAST           PNC          80   88-04
ON25        ASTON WORKSHOP     PNC          40   88-04
ON26        HI-TECH            PNC          25   88-04
FORECAST    FORECAST           PNC           0   88-05
ON61        ASTON WORKSHOP     PNC          30   88-05
RESERVE     HI-TECH LTD        PNC         130   88-05      88-02                  QN-HITECH1
ON27        HI-TECH            PNC          45   88-05
ON29        HI-TECH            PNC          20   88-05
ON30        BRITISH STEEL      PNC          35   88-05
FORECAST    FORECAST           PNC          50   88-06
ON28        HI-TECH            PNC          50   88-06
ON31        BRITISH STEEL      PNC          30   88-06
ON32        HI-TECH            PNC          22   88-06
FORECAST    FORECAST           PNC          40   88-07
ON62        ASTON WORKSHOP     PNC          40   88-07
ON33        HI-TECH            PNC          40   88-07
ON34        HI-TECH            PNC          25   88-07
ON35        ASTON WORKSHOP     PNC          45   88-07
FORECAST    FORECAST           PNC          85   88-08
FORECAST    FORECAST           PNC          85   88-09
FORECAST    FORECAST           PNC          20   88-10
ON40        HI-TECH            PNC          55   88-10
FORECAST    FORECAST           PNC          20   88-11

((((((((((((((((((((((((((((END  OF  MPS  ORDERS  LIST))))))))))))))))))))))))))))))
```

Table 11.28   MPS orders created for PNC

```
01/01/88     CURRENT MPS ORDERS BASED ON PRODUCT PND

ORDER NO.  CUSTOMER NAME     PRODUCT   QTY  PERIOD  VALID TO (IF RESERVED)  QUOTE NO. (IF ANY)
---------  -------------     -------   ---  ------  ----------------------  ------------------

FORECAST   FORECAST          PND        45  88-02
FORECAST   FORECAST          PND       130  88-03
ON71       ASTON WORKSHOP    PND        20  88-03
ON72       HI-TECH           PND        22  88-03
FORECAST   FORECAST          PND        45  88-04
ON73       BRITISH STEEL     PND        30  88-04
ON74       ASTON WORKSHOP    PND        30  88-04
ON14       HI-TECH           PND        44  88-04
FORECAST   FORECAST          PND       100  88-05
ON75       ASTON WORKSHOP    PND        35  88-05
FORECAST   FORECAST          PND        20  88-06
ON76       ASTON WORKSHOP    PND        20  88-06
ON16       HI-TECH           PND        30  88-06
ON80       BRITISH STEEL     PND        40  88-06
FORECAST   FORECAST          PND        50  88-07
FORECAST   FORECAST          PND        30  88-08
ON77       HI-TECH           PND        44  88-08
FORECAST   FORECAST          PND        30  88-09
ON63       HI-TECH           PND        50  88-09
ON78       ASTON WORKSHOP    PND        50  88-09
ON82       BRITISH STEEL     PND        35  88-09
ON86       BRITISH STEEL     PND        45  88-09
FORECAST   FORECAST          PND        80  88-10
ON64       HI-TECH           PND        80  88-10
ON79       ASTON WORKSHOP    PND        25  88-10
FORECAST   HI-TECH           PND        60  88-11

((((((((((((((((((((((((((((((E N D   O F   M P S   O R D E R S   L I S T))))))))))))))))))))))))))))))
```

Table 11.29   MPS orders created for PND

```
01/01/88     CURRENT MPS ORDERS BASED ON PRODUCT PNSR111

ORDER NO.   CUSTOMER NAME         PRODUCT    QTY   PERIOD   VALID TO (IF RESERVED)   QUOTE NO. (IF ANY)
---------   -------------         -------    ---   ------   ----------------------   ------------------

ON22        HI-TECH               PNSR111     80   88-02
FORECAST    FORECAST              PNSR111     30   88-02
RESERVE     HI-TECH               PNSR111     44   88-03    88-04                    QN896
FORECAST    FORECAST              PNSR111     50   88-03
ON56        ASTON WORKSHOP        PNSR111     40   88-04
FORECAST    FORECAST              PNSR111     60   88-04
ON84        ASTON WORKSHOP        PNSR111     30   88-04
RESERVE     ASTON WORKSHOP        PNSR111     40   88-04    88-05                    QN654
ON54        BRITISH STEEL         PNSR111    120   88-05
FORECAST    FORECAST              PNSR111     80   88-05
RESERVE     ASTON WORKSHOP        PNSR111     20   88-05    88-06                    QN633
FORECAST    FORECAST              PNSR111     70   88-06
ON85        HI-TECH               PNSR111     40   88-06
RESERVE     HI-TECH               PNSR111     30   88-06    88-09                    QN644
ON55        BRITISH STEEL         PNSR111     55   88-07
FORECAST    FORECAST              PNSR111     50   88-07
FORECAST    FORECAST              PNSR111     70   88-08
ON88        HI-TECH               PNSR111     50   88-08
FORECAST    FORECAST              PNSR111     20   88-09
RESERVE     BRITISH STEEL         PNSR111     30   88-09    88-10                    QN414
FORECAST    FORECAST              PNSR111     10   88-10
FORECAST    FORECAST              PNSR111     20   88-11

((((((((((((((((((((((((((((((E N D   O F   M P S   O R D E R S   L I S T))))))))))))))))))))))))))))))
```

Table 11.30 MPS orders created for PNSR111

11.5.4 DATA DISTRIBUTION TO THE THREE WORK CELLS

This is the most important section in the second test, as it is designed to indicate that the concept of distributed planning and control can be practically incorporated into an integrated system to improve its performance. This is actually achieved by transferring central responsibilities and associated data into various work cells at a lower hierarchy in the overall structure.

Here, two separate data distribution processes had to be carried out. The first phase involved the distribution of central BOM and routing details into appropriate work cells. The second phase was to distribute central MPS data to those cells which make the products. The accuracy, and probably efficiency, of both data distribution processes depend on the definitions of product group allocations, BOM and process routes.

In order to complete both phases of data distribution, the user had to select options in the system modules D51 and D52. D51 - [DISTMPS], distributed updated planning horizon and new orders into appropriate work cells. D52 - [DISTBMRT], distributed BOM and routing details for each subassembly and parts into the work cells. Note that the distribution process for BOM and routing details has only to be done once when the system is first installed. There is no need to update such information in the work cells unless there are drastic technical changes which may affect the data accuracy.

After both distribution processes were complete, each work cell should have sufficient data to operate separately. The local database in each work cell, by now, should contain partial BOM and relevant routing details, which would be required later in the local MRP process. Table 11.31, Table 11.32 and Table 11.33 show the BOM and routing details distributed to Work Cell 1, Work Cell 2 and Work Cell 3, respectively.

In addition to BOM and process route details, MPS data was also distributed to the various work cells based on the product group definitions for each final product assembly. For example, as the final assembly, PNC, was made in Work Cell 3, the MPS orders for this product would be released there first, despite the fact that its subassembly SNASSM-C was made in Work Cell 1.

According to the routing details previously defined, all the three products were to be assembled in Work Cell 3. Consequently, there should not be any data distributed to other work cells except Work Cell 3. Table 11.34 lists all the orders distributed to Work Cell 3. Note that these orders represent the summation of all sales orders for

```
01/01/88     UPDATED LOCALIZED BOM DETAILS FOR WORK CELL 1

PRODUCT         PARENT          PART NO.          QTY   LD:TIME   LEVEL  ENDMARK
-------         ------          --------          ----  -------   -----  -------

SNASSMC         SNPNC           SNASSMC            1       1        0       N
SNASSMC         SNASSMC         SN5                1       1        1       Y
SNSR111-10      SNSR111-40      SNSR111-10         1       1        0
SNSR111-10      SNSR111-10      SN11-2-55          1       3        1       E
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<< E N D   O F   F I L E >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
```

```
01/01/88     UPDATED LOCALIZED ROUTING DETAILS FOR WORK CELL 1

PART NO.     OP NO.  OPERATION DESCRIPTION                              WORK      SET   PROD  LABOR  SCRAP   LAST
                                                                        CELL NO.  TIME  TIME  GRADE   (%)    UPDATE
--------     -----   --------------------                               --------  ----  ----  -----  -----   ------

SNASSMC      10      TURN SHANK + GRIND ALLOWANCE (ON INVESTMENT CAST)   WC1       40    10     B     0.0    01-01-88
SNASSMC      20      TURN SHANK,GRIND ALLOW.,CENTRE,TURN BODY,PART OFF   WC1       50     5     B     0.0    01-01-88
SNSR111-10   10      TURN SHANK + GRIND ALLOWANCE (ON INVESTMENT CAST)   WC1        3    15     C     2.0    12-12-85
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<< E N D   O F   F I L E >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
```

Table 11.31 BOM and routing details distributed to Work Cell 1

```
01/01/88    UPDATED LOCALIZED BOM DETAILS FOR WORK CELL 2

PRODUCT         PARENT          PART NO.          QTY   LD:TIME   LEVEL   ENDMARK
-------         ------          --------          ---   -------   -----   -------

SNASSMD         SNPND           SNASSMD            1       2        0        N
SNASSMD         SNASSMD         SN7                1       1        1        Y
SNSR111-40      SNPNSR111       SNSR111-40         1       1        0
SNSR111-40      SNSR111-40      SNSR111-10         1       1        1
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<< E N D   O F   F I L E >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
```

```
01/01/88    UPDATED LOCALIZED ROUTING DETAILS FOR WORK CELL 2

PART NO.      OP NO.  OPERATION DESCRIPTION                          WORK      SET   PROD  LABOR  SCRAP  LAST
                                                                     CELL NO.  TIME  TIME  GRADE  (%)    UPDATE
--------      ------  --------------------                           --------  ----  ----  -----  -----  ------

SNASSMD        30     MILL FLATS (TAPER, CLARKSON, WHISTLE & WELDON)  WC2       22    10     B     0.0   01-01-88
SNASSMD        40     MILL TIP SEATS/ MILL CLEARANCE                  WC2       30    20     B     0.0   01-01-88
SNSR111-10     10     TURN SHANK + GRIND ALLOWANCE (ON INVESTMENT CAST) WC1      3    15     C     2.0   12-12-85
SNSR111-40     30     MILL FLATS (TAPER, CLARKSON, WHISTLE & WELDON)  WC2        3    10     C     2.0   12-12-85
SNSR111-40     40     MILL TIP SEATS/ MILL CLEARANCE                  WC2        5    30     B     2.0   12-12-85

(((((((((((((((((((((((((((((((E N D   O F   F I L E)))))))))))))))))))))))))))))))
```

Table 11.32   BOM and routing details distributed to Work Cell 2

```
01/01/88     UPDATED LOCALIZED BOM DETAILS FOR WORK CELL 3

PRODUCT        PARENT         PART NO.         QTY    LD TIME    LEVEL   ENDMARK
--------       ------         ---------        ----   -------    -----   -------

PNC            PNC            SNPNC             1        1         0        N
PNC            SNPNC          SNASSMC           1        1         1        N
PNC            SNPNC          SN4               3        1         1        Y
PND            PND            SNPND             1        1         0        N
PND            SNPND          SNASSMD           1        2         1        N
PND            SNPND          SN4               4        1         1        Y
PNSR111        PNSR111        SNPNSR111         1        1         0
PNSR111        SNPNSR111      SNSR111-40        1        1         1
PNSR111        SNPNSR111      SN33              2        2         1        E

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<< E N D   O F   F I L E >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
```

```
01/01/88     UPDATED LOCALIZED ROUTING DETAILS FOR WORK CELL 3

PART NO.     OP NO.  OPERATION DESCRIPTION                                WORK     SET   PROD   LABOR  SCRAP   LAST
                                                                          CELL NO. TIME  TIME   GRADE  (%)     UPDATE
---------    ------  -------------------                                  -------- ----  ----   -----  -----   ------

SNASSMC      10      TURN SHANK + GRIND ALLOWANCE (ON INVESTMENT CAST)    WC1       40    10     B     0.0    01-01-88
SNASSMC      20      TURN SHANK,GRIND ALLOW.,CENTRE,TURN BODY,PART OFF    WC1       50     5     B     0.0    01-01-88
SNASSMD      30      MILL FLATS (TAPER, CLARKSON, WHISTLE & WELDON)       WC2       22    10     B     0.0    01-01-88
SNASSMD      40      MILL TIP SEATS/ MILL CLEARANCE                       WC2       30    20     B     0.0    01-01-88
SNPNC        100     FINAL ASSEMBLY PROCESS                               WC3       20    12     A     0.0    01-01-88
SNPND        90      FINAL ASSM INDUCTION BRAZE, INSERT, GRIND LOC        WC3       20    15     A     0.0    01-01-88
SNPNER111    90      INDUCTION HRAZE, INSERT, GRIND LOC                   WC3        5    20     C     0.0    12-12-85
SNPNSR111    100     FINISH GRIND CARBIDE / FINISH HEATREATED EDGE        WC3        5    25     A     0.0    12-12-85
SNSR111-40   30      MILL FLATS (TAPER, CLARKSON, WHISTLE & WELDON)       WC2        3    10     C     2.0    12-12-85
SNSR111-40   40      MILL TIP SEATS/ MILL CLEARANCE                       WC2        5    30     B     2.0    12-12-85

((((((((((((((((((((((((((((((E N D   O F  F I L E)))))))))))))))))))))))))))))))
```

Table 11.33 BOM and routing details distributed to Wrok Cell 3

```
01/01/88     MPS ORDERS TO BE DISTRIBUTED TO WORK CELL 3
             CURRENT MPS HORIZON FROM 88-02

ORDER NO.   CUSTOMER          PRODUCT/PART NO.   QTY   PERIOD   VALID TO (IF ANY)        QUOTE NO.
---------   --------          ----------------   ---   ------   -----------------        ---------

FORECAST    FORECAST             PNC              40   88-02
FORECAST    FORECAST             PNC              50   88-03
ON23        HI-TECH              PNC              20   88-03
ON24        ASTON WORKSHOP       PNC              30   88-03
FORECAST    FORECAST             PNC              80   88-04
ON25        ASTON WORKSHOP       PNC              40   88-04
ON26        HI-TECH              PNC              25   88-04
FORECAST    FORECAST             PNC               0   88-05
ON61        ASTON WORKSHOP       PNC              30   88-05
RESERVE     HI-TECH LTD          PNC             130   88-05        88-02                QN-HITECH1
ON27        HI-TECH              PNC              45   88-05
ON29        HI-TECH              PNC              20   88-05
ON30        BRITISH STEEL        PNC              35   88-05
FORECAST    FORECAST             PNC              50   88-06
ON28        HI-TECH              PNC              50   88-06
ON31        BRITISH STEEL        PNC              30   88-06
ON32        HI-TECH              PNC              22   88-06
FORECAST    FORECAST             PNC              40   88-07
ON62        ASTON WORKSHOP       PNC              40   88-07
ON33        HI-TECH              PNC              40   88-07
ON34        HI-TECH              PNC              25   88-07
ON35        ASTON WORKSHOP       PNC              45   88-07
FORECAST    FORECAST             PNC              85   88-08
FORECAST    FORECAST             PNC              85   88-09
FORECAST    FORECAST             PNC              20   88-10
ON40        HI-TECH              PNC              55   88-10
FORECAST    FORECAST             PNC              20   88-11
FORECAST    FORECAST             PND              45   88-02
FORECAST    FORECAST             PND             130   88-03
ON71        ASTON WORKSHOP       PND              20   88-03
ON72        HI-TECH              PND              22   88-03
FORECAST    FORECAST             PND              45   88-04
ON73        BRITISH STEEL        PND              30   88-04
ON74        ASTON WORKSHOP       PND              30   88-04
ON14        HI-TECH              PND              44   88-04
FORECAST    FORECAST             PND             100   88-05
ON75        ASTON WORKSHOP       PND              35   88-05
FORECAST    FORECAST             PND              20   88-06
ON76        ASTON WORKSHOP       PND              20   88-06
ON16        HI-TECH              PND              30   88-06
ON80        BRITISH STEEL        PND              40   88-06
FORECAST    FORECAST             PND              50   88-07
FORECAST    FORECAST             PND              30   88-08
ON77        HI-TECH              PND              44   88-08
FORECAST    FORECAST             PND              30   88-09
ON63        HI-TECH              PND              50   88-09
ON78        ASTON WORKSHOP       PND              50   88-09
ON82        BRITISH STEEL        PND              35   88-09
ON86        BRITISH STEEL        PND              45   88-09
FORECAST    FORECAST             PND              80   88-10
ON64        HI-TECH              PND              80   88-10
ON79        ASTON WORKSHOP       PND              25   88-10
FORECAST    HI-TECH              PND              60   88-11
ON22        HI-TECH              PNSR111          80   88-02
FORECAST    FORECAST             PNSR111          30   88-02
RESERVE     HI-TECH              PNSR111          44   88-03        88-04                QN896
FORECAST    FORECAST             PNSR111          50   88-03
ON56        ASTON WORKSHOP       PNSR111          40   88-04
FORECAST    FORECAST             PNSR111          60   88-04
ON84        ASTON WORKSHOP       PNSR111          30   88-04
RESERVE     ASTON WORKSHOP       PNSR111          40   88-04        88-05                QN654
ON54        BRITISH STEEL        PNSR111         120   88-05
FORECAST    FORECAST             PNSR111          80   88-05
RESERVE     ASTON WORKSHOP       PNSR111          20   88-05        88-06                QN633
FORECAST    FORECAST             PNSR111          70   88-06
ON85        HI-TECH              PNSR111          40   88-06
RESERVE     HI-TECH              PNSR111          30   88-06        88-09                QN644
ON55        BRITISH STEEL        PNSR111          55   88-07
FORECAST    FORECAST             PNSR111          50   88-07
FORECAST    FORECAST             PNSR111          70   88-08
ON88        HI-TECH              PNSR111          50   88-08
FORECAST    FORECAST             PNSR111          20   88-09
RESERVE     BRITISH STEEL        PNSR111          30   88-09        88-10                QN414
FORECAST    FORECAST             PNSR111          10   88-10
FORECAST    FORECAST             PNSR111          20   88-11

((((((((((((((((((((((((((((((((( E N D   O F   F I L E )))))))))))))))))))))))))))))))))
```

Table 11.34   MPS orders distributed to the assembly cell (W.C.3)

PNC, PND and PNSR111 shown in Table 11.28, Table 11.29 and Table 11.30, respectively. The number of orders, after distribution, is also 75.

11.5.5 LOCAL MRP PROCESS IN WORK CELL 3

After data distribution, the three work cells began to operate separately. However, there was a suggested MRP sequence for this particular test, based on the process requirements for each product.

As the final assemblies for all three products were made in Work Cell 3, it is essential that the local MRP in that cell should be performed first. Referring to Figure 11.3, among the three products, only PNSR111 requires operations in more than 2 work cells. It is therefore suggested the MRP in Work Cell 2 should be the next one to be performed, so that its subsequent orders would be passed to the last work cell, 1. Finally, the local MRP module in Work Cell 1 should be carried out, so that the data transfer interaction would stop here.

Before the local MRP commenced, the MPS orders distributed to Work Cell 3 were combined to form a MPS summary file, which is shown as Table 11.35.

During the MRP process, the progress of data calculation was monitored and printed. A sample print-out of such a monitoring process is shown in Table G-1 in Appendix G.

As before, there were three types of output generated in a local MRP process. Table 11.36 indicates the local work orders recommended for work cell 3 itself. Table 11.37 shows the suggested purchase orders generated. Finally, because of the process requirements, there were also recommended part-requests generated for work cell 2 and work cell 1, and they are shown in Table 11.38 and Table 11.39 respectively.

After all the above processes were complete, the user then confirmed these results to convert them into real orders. Table 11.40 shows the actual work orders generated for Work Cell 3, using the MRP results as previously shown in Table 11.36. The part orders generated for Work Cell 1 and Work Cell 2 were also physically transferred to their destination databases via the LAN system.

All the subsequent operations after this stage were identical to those described in the first test. These included generating the LSD details for each work order, analysing the possible load on each work centre, releasing them to the shop floor, and monitoring

```
01/01/88      LOCAL MPS SUMMARY REPORT FOR WORK CELL 3

PRODUCT     HORIZON FROM  PERIOD 1  PERIOD 2  PERIOD 3  PERIOD 4  PERIOD 5  PERIOD 6  PERIOD 7  PERIOD 8  PERIOD 9  PERIOD 10
-------     ------------  --------  --------  --------  --------  --------  --------  --------  --------  --------  ---------

PNC            88-02          40       100       145       260       152       190        85        85        75        20
PND            88-02          45       172       149       135       110        50        74       210       185        60
PNSR111        88-02         110        94       170       220       140       105       120        50        10        20

((((((((((((((((((((((((((((((((((( E N D   O F   M P S L O N G )))))))))))))))))))))))))))))))))))))))))
```

Table 11.35   MPS summary after order distribution to the assembly cell

```
01/01/88  CURRENT WORK ORDERS RECOMMENDATION FROM LAST MRP RUN FOR LOCAL PARTS

WORK CELL : 3        FOR PERIOD : 88-02     CURRENT SYSTEM PERIOD : 88-01
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

PART NO.      PERIOD   PERIOD   PERIOD   PERIOD   PERIOD   PERIOD   PERIOD   PERIOD   PERIOD   PERIOD
              88-02    880:3    880:1    880:1    880:1    880:1    880:1    880:1    880:1    880:1
--------      ------   ------   ------   ------   ------   ------   ------   ------   ------   ------

SNPNC           140      145      260      152      130       85       85       75       20        0
SNPND           217      149      135      110       50       74      210      185       60        0
SNPNSR111       174      170      220      140      105      120       50       10       20        0

((((((((((((((((((((((((((((E N D   O F   R E C O M M E N D E D   W O R K   O R D E R S))))))))))))))))))))))))
```

Table 11.36 Work order recommendations created for Work Cell 3

```
01/01/88  CURRENT BUY-ORDER RECOMMENDATION FROM LAST MRP RUN FOR EXTERNAL PARTS

WORK CELL : 3        FOR PERIOD : 88-02     CURRENT SYSTEM PERIOD : 88-01
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

PART NO.      PERIOD   PERIOD   PERIOD   PERIOD   PERIOD   PERIOD   PERIOD   PERIOD   PERIOD   PERIOD
              88-02    880:3    880:1    880:1    880:1    880:1    880:1    880:1    880:1    880:1
--------      ------   ------   ------   ------   ------   ------   ------   ------   ------   ------

SN4            2179     1320      896      770      551     1095      965      300        0        0
SN33           1094      212      142      175       77       17        0        0        0        0

((((((((((((((((((((((((((((E N D   O F   R E C O M M E N D E D   B U Y   O R D E R S))))))))))))))))))))))))
```

Table 11.37 Purchase order recommendations created for Work Cell 3

```
01/01/88  MRP RESULTS - PART REQUESTS TO BE SENT TO OTHER WORK CELLS
          ------------------------------------------------------------

          FOR PERIOD : 88-02             CURRENT SYSTEM PERIOD : 88-01

FROM WORK CELL : 3             TO WORK CELL : 2
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

ORDER NO.     REQUESTED BY WORK CELL     PART NO.        REQ QTY    DELI. PERIOD
---------     ----------------------     --------        -------    ------------

CELL REQ      WORK CELL 3                SNASSMD             217       88-02
CELL REQ      WORK CELL 3                SNASSMD             149       88-03
CELL REQ      WORK CELL 3                SNASSMD             135       88-04
CELL REQ      WORK CELL 3                SNASSMD             110       88-05
CELL REQ      WORK CELL 3                SNASSMD              50       88-06
CELL REQ      WORK CELL 3                SNASSMD              74       88-07
CELL REQ      WORK CELL 3                SNASSMD             210       88-08
CELL REQ      WORK CELL 3                SNASSMD             185       88-09
CELL REQ      WORK CELL 3                SNASSMD              60       88-10
CELL REQ      WORK CELL 3                SNSR111-40          174       88-02
CELL REQ      WORK CELL 3                SNSR111-40          170       88-03
CELL REQ      WORK CELL 3                SNSR111-40          220       88-04
CELL REQ      WORK CELL 3                SNSR111-40          140       88-05
CELL REQ      WORK CELL 3                SNSR111-40          105       88-06
CELL REQ      WORK CELL 3                SNSR111-40          120       88-07
CELL REQ      WORK CELL 3                SNSR111-40           50       88-08
CELL REQ      WORK CELL 3                SNSR111-40           10       88-09
CELL REQ      WORK CELL 3                SNSR111-40           20       88-10

<<<<<<<<<<<<< PART REQUEST FROM WORK CELL-3  TO  WORK CELL-2 >>>>>>>>>>>>>>>>
```

Table 11.38 Part-requests generated by Work Cell 3 to Work Cell 2

```
01/01/88  MRP RESULTS - PART REQUESTS TO BE SENT TO OTHER WORK CELLS
          ----------------------------------------------------------

          FOR PERIOD : 88-02               CURRENT SYSTEM PERIOD : 88-01

FROM WORK CELL : 3            TO WORK CELL : 1
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

ORDER NO.     REQUESTED BY WORK CELL    PART NO.       REQ QTY    DELI. PERIOD
---------     ----------------------    --------       -------    ------------

CELL  REQ     WORK  CELL  3             SNASSMC          140        88-02
CELL  REQ     WORK  CELL  3             SNASSMC          145        88-03
CELL  REQ     WORK  CELL  3             SNASSMC          260        88-04
CELL  REQ     WORK  CELL  3             SNASSMC          152        88-05
CELL  REQ     WORK  CELL  3             SNASSMC          190        88-06
CELL  REQ     WORK  CELL  3             SNASSMC           85        88-07
CELL  REQ     WORK  CELL  3             SNASSMC           85        88-08
CELL  REQ     WORK  CELL  3             SNASSMC           75        88-09
CELL  REQ     WORK  CELL  3             SNASSMC           20        88-10
 <<<<<<<<<<<<< PART REQUEST FROM WORK CELL-3  TO  WORK CELL-1 >>>>>>>>>>>>>>>>>
```

Table 11.39   Part requests generated by Work Cell 3 to Work Cell 1

```
01/01/88   DISCRETE WORK ORDERS CONVERTED FROM MRP TO BE CONFIRMED FOR ISSUE
           INTO WORK CELL : 3                ON DATE : 01/01/88
           FOR PERIOD : 88-02        CURRENT PERIOD : 88-01

WORK ORDER NO.  PART NO.         ORDER QTY  BATCH SIZE  SCHEDULED LAUNCH PERIOD
--------------  --------         ---------  ----------  -----------------------

WO010188-001    SNPNC                140         1              88-02
WO010188-002    SNPNC                145         1              88-03
WO010188-003    SNPNC                260         1              88-04
WO010188-004    SNPNC                152         1              88-05
WO010188-005    SNPNC                190         1              88-06
WO010188-006    SNPNC                 85         1              88-07
WO010188-007    SNPNC                 85         1              88-08
WO010188-008    SNPNC                 75         1              88-09
WO010188-009    SNPNC                 20         1              88-10
WO010188-010    SNPND                217         1              88-02
WO010188-011    SNPND                149         1              88-03
WO010188-012    SNPND                135         1              88-04
WO010188-013    SNPND                110         1              88-05
WO010188-014    SNPND                 50         1              88-06
WO010188-015    SNPND                 74         1              88-07
WO010188-016    SNPND                210         1              88-08
WO010188-017    SNPND                185         1              88-09
WO010188-018    SNPND                 60         1              88-10
WO010188-019    SNPNSR111            174         1              88-02
WO010188-020    SNPNSR111            170         1              88-03
WO010188-021    SNPNSR111            220         1              88-04
WO010188-022    SNPNSR111            140         1              88-05
WO010188-023    SNPNSR111            105         1              88-06
WO010188-024    SNPNSR111            120         1              88-07
WO010188-025    SNPNSR111             50         1              88-08
WO010188-026    SNPNSR111             10         1              88-09
WO010188-027    SNPNSR111             20         1              88-10
```

Table 11.40   Local work orders generated for Work Cell 3

WIP details. Table 11.41 illustrates a sample print- out on work-to-list for work centre 90 and 100 in work cell 3. Local capacity details and other relevant print-outs obtained in this section are enclosed in Appendix G.

11.5.6 LOCAL MRP PROCESS IN WORK CELL 2

After the MRP process was completed in Work Cell 3, relevant part requests were transferred, via the LAN, to Work Cell 2 and Work Cell 1, according to the required operations of subassemblies. The MPS data in Work Cell 2, therefore, was made up of part requests generated by Work Cell 3. Table 11.42 shows the MPS orders maintained in Work Cell 2. These orders were then summarised to form a MPS summary file which would be required in the local MRP process. This MPS summary file is shown as Table 11.43.

After the MRP process was completed, results were then stored in various different files. Table 11.44 shows the recommended work orders generated for work cell 2 itself; Table 11.45 shows the suggested purchase orders, and Table 11.46 indicates the part requests generated by Work Cell 2 for parts made in Work Cell 1.

After confirmation, the system converted all MRP recommended work orders into real work orders, as is shown in Table G-2.

Finally, standard operations were carried out until all work orders were completed, and relevant files were updated. Some relevant print-outs obtained regarding the LSD generation, capacity details file maintenance, and load analysis are included in Appendix G which contains useful information on this section.

11.5.7 LOCAL MRP PROCESS IN WORK CELL 1

This was the final local MRP process which, after which, would complete the whole test run. The significance of data distribution and part request transfer between work cells were already demonstrated earlier.

However, the MPS orders used here are different to those in Work Cell 2. It not only comprised orders transferred by the assembly cell (W.C.3), but also part-requests generated by Work Cell 2 when it performed its local MRP process. Table 11.47 shows the MPS orders maintained in Work Cell 1. Before the MRP process

```
08/01/88        WORK-TO-LIST LOADING CHART  until  8081      WORK CELL : 3
-----------------------------------------------------------------------------

                       W  O  R  K     C  E  N  T  R  E  S

                 90     100
Order No  Status |Op No Hrs LSD |Op No  Hrs LSD|Op No Hrs LSD |Op No  Hrs LSD|Op No Hrs LSD |Op No  Hrs LSD|Op No Hrs LSD |Op No  Hrs LSD|Op No  Hrs LSD|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-001 UnR |              |100    28 8019|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-002 UnR |              |100    29 8025|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-003 UnR |              |100    52 8026|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-004 UnR |              |100    30 8039|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-005 UnR |              |100    38 8043|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-006 UnR |              |100    17 8055|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-007 UnR |              |100    17 8062|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-008 UnR |              |100    15 8069|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-009 UnR |              |100     4 8078|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-010 UnR |90     54 8013|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-011 UnR |90     37 8022|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-012 UnR |90     34 8029|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-013 UnR |90     27 8040|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-014 UnR |90     12 8049|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-015 UnR |90     18 8055|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-016 UnR |90     52 8055|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-017 UnR |90     46 8063|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-018 UnR |90     15 8076|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-019 UnR |90     58 8001|100    72 8011|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-020 UnR |90     56 8006|100    70 8018|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-021 UnR |90     73 8006|100    91 8019|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-022 UnR |90     46 8022|100    58 8034|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-023 UnR |90     35 8036|100    43 8042|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-024 UnR |90     40 8041|100    50 8049|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-025 UnR |90     16 8057|100    20 8062|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-026 UnR |90      3 8070|100     4 8071|
-----------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
W0010188-027 UnR |90      6 8076|100     8 8077|
=================+==============+==============+==============+==============+==============+==============+==============+==============+==============+
 TOTAL  LOAD     |  637 Hours   |  654 Hours   |   0 Hours    |   0 Hours    |   0 Hours    |   0 Hours    |   0 Hours    |   0 Hours    |   0 Hours    |

=================+==============+==============+==============+==============+==============+==============+==============+==============+==============+
 PERCENTAGE      |     167%     |     172%     |     100%     |     100%     |     100%     |     100%     |     100%     |     100%     |     100%     |
=============  0%+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
                 | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  |
                 | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  |
                 | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  |
                 | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  |
              50%| |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  |
                 | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  |
                 | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  |
                 | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  |
                 | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  | |||||||||||  |
             100%| +++++++++++  | +++++++++++  | +++++++++++  | +++++++++++  | +++++++++++  | +++++++++++  | +++++++++++  | +++++++++++  | +++++++++++  |
                 | |||||||||||  | |||||||||||  |              |              |              |              |              |              |              |
                 | |||||||||||  | |||||||||||  |              |              |              |              |              |              |              |
                 | |||||||||||  | |||||||||||  |              |              |              |              |              |              |              |
                 | |||||||||||  | |||||||||||  |              |              |              |              |              |              |              |
             150%| |||||||||||  | |||||||||||  |              |              |              |              |              |              |              |
                 | |||||||||||  | |||||||||||  |              |              |              |              |              |              |              |
                 |              | |||||||||||  |              |              |              |              |              |              |              |
                 |              |              |              |              |              |              |              |              |              |
                 |              |              |              |              |              |              |              |              |              |
             200%|              |              |              |              |              |              |              |              |              |
                 +--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
```

Table 11.41   Print-out on work-to-list for Work Cell 3

```
08/01/88  LISTING OF ALL MPS ORDERS (INCLUDE PART REQUESTS FROM OTHER CELLS)
          ------------------------------------------------------------------

          AT WORK CELL : 2                    SYSTEM PERIOD : 88-01
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

ORDER NO.  CUSTOMER         PRODUCT/PART   QTY   DELI. PERIOD  VALID TILL  QUOTE NO.
---------  --------         ------------   ---   ------------  ----------  ---------

CELL REQ   WORK CELL 3      SNASSMD        217   88-02
CELL REQ   WORK CELL 3      SNASSMD        149   88-03
CELL REQ   WORK CELL 3      SNASSMD        135   88-04
CELL REQ   WORK CELL 3      SNASSMD        110   88-05
CELL REQ   WORK CELL 3      SNASSMD         50   88-06
CELL REQ   WORK CELL 3      SNASSMD         74   88-07
CELL REQ   WORK CELL 3      SNASSMD        210   88-08
CELL REQ   WORK CELL 3      SNASSMD        185   88-09
CELL REQ   WORK CELL 3      SNASSMD         60   88-10
CELL REQ   WORK CELL 3      SNSR111-40     174   88-02
CELL REQ   WORK CELL 3      SNSR111-40     170   88-03
CELL REQ   WORK CELL 3      SNSR111-40     220   88-04
CELL REQ   WORK CELL 3      SNSR111-40     140   88-05
CELL REQ   WORK CELL 3      SNSR111-40     105   88-06
CELL REQ   WORK CELL 3      SNSR111-40     120   88-07
CELL REQ   WORK CELL 3      SNSR111-40      50   88-08
CELL REQ   WORK CELL 3      SNSR111-40      10   88-09
CELL REQ   WORK CELL 3      SNSR111-40      20   88-10

((((((((((((((((((((((((((((((E N D  O F  L O C A L  M P S  O R D E R S))))))))))))))))))))))))))))
```

Table 11.42   MPS orders in Work Cell 2

```
08/01/88     LOCAL MPS SUMMARY REPORT FOR WORK CELL 2

PRODUCT     HORIZON FROM  PERIOD 1  PERIOD 2  PERIOD 3  PERIOD 4  PERIOD 5  PERIOD 6  PERIOD 7  PERIOD 8  PERIOD 9  PERIOD 10
-------     ------------  --------  --------  --------  --------  --------  --------  --------  --------  --------  ---------

SNASSMD        88-02         217       149       135       110        50        74       210       185        60          0
SNSR111-40     88-02         174       170       220       140       105       120        50        10        20          0

(((((((((((((((((((((((((((((((((E N D   O F   M P S L O N G)))))))))))))))))))))))))))))))))))))))))
```

Table 11.43 MPS order summary in Work Cell 2

```
08/01/88  CURRENT WORK ORDERS RECOMMENDATION FROM LAST MRP RUN FOR LOCAL PARTS

WORK CELL : 2        FOR PERIOD : 88-02     CURRENT SYSTEM PERIOD : 88-01
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

PART NO.     PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD
             88-02   88013   88011   88011   88011   88011   88011   88011   88011   88011
--------     ------  ------  ------  ------  ------  ------  ------  ------  ------  ------

SNASSMD        872     220     100     148     420     370     120       0       0       0
SN3R111-40     668     440     280     210     240     100      20      40       0       0

((((((((((((((((((((((((((((E N D  O F  R E C O M M E N D E D  W O R K  O R D E R S))))))))))))))))))))))))))
```

Table 11.44   Recommended work orders for Work Cell 2

```
08/01/88  CURRENT BUY-ORDER RECOMMENDATION FROM LAST MRP RUN FOR EXTERNAL PARTS

WORK CELL : 2        FOR PERIOD : 88-02     CURRENT SYSTEM PERIOD : 88-01
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

PART NO.     PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD
             88-02   88013   88011   88011   88011   88011   88011   88011   88011   88011
--------.    ------  ------  ------  ------  ------  ------  ------  ------  ------  ------

SN7            862     100     148     420     370     120       0       0       0       0

((((((((((((((((((((((((((((E N D  O F  R E C O M M E N D E D  B U Y  O R D E R S))))))))))))))))))))))))))
```

Table 11.45   Recommended purchased orders for Work Cell 2

```
08/01/88  MRP RESULTS - PART REQUESTS TO BE SENT TO OTHER WORK CELLS
          ----------------------------------------------------------

          FOR PERIOD : 88-02               CURRENT SYSTEM PERIOD : 88-01

FROM WORK CELL : 2             TO WORK CELL : 1
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

ORDER NO.    REQUESTED BY WORK CELL    PART NO.        REQ QTY   DELI. PERIOD
---------    ----------------------    --------        -------   ------------

CELL REQ     WORK CELL 2               SNSR111-10        668        88-02
CELL REQ     WORK CELL 2               SNSR111-10        440        88-03
CELL REQ     WORK CELL 2               SNSR111-10        280        88-04
CELL REQ     WORK CELL 2               SNSR111-10        210        88-05
CELL REQ     WORK CELL 2               SNSR111-10        240        88-06
CELL REQ     WORK CELL 2               SNSR111-10        100        88-07
CELL REQ     WORK CELL 2               SNSR111-10         20        88-08
CELL REQ     WORK CELL 2               SNSR111-10         40        88-09

<<<<<<<<<<<<< PART REQUEST FROM WORK CELL-2  TO  WORK CELL-1 >>>>>>>>>>>>>>>>
```

Table 11.46   Suggested part-requests generated by Work Cell 2 to Work Cell 1

```
08/01/88  LISTING OF ALL MPS ORDERS (INCLUDE PART REQUESTS FROM OTHER CELLS)
          ------------------------------------------------------------------

          AT WORK CELL : 1                    SYSTEM PERIOD : 88-01
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

ORDER NO.    CUSTOMER              PRODUCT/PART   QTY      DELI. PERIOD   VALID TILL   QUOTE NO.
---------    --------              ------------   ---      ------------   ----------   ---------

CELL REQ     WORK CELL 3           SNASSMC         140        88-02
CELL REQ     WORK CELL 3           SNASSMC         145        88-03
CELL REQ     WORK CELL 3           SNASSMC         260        88-04
CELL REQ     WORK CELL 3           SNASSMC         152        88-05
CELL REQ     WORK CELL 3           SNASSMC         190        88-06
CELL REQ     WORK CELL 3           SNASSMC          85        88-07
CELL REQ     WORK CELL 3           SNASSMC          85        88-08
CELL REQ     WORK CELL 3           SNASSMC          75        88-09
CELL REQ     WORK CELL 3           SNASSMC          20        88-10
CELL REQ     WORK CELL 2           SNSR111-10      668        88-02
CELL REQ     WORK CELL 2           SNSR111-10      440        88-03
CELL REQ     WORK CELL 2           SNSR111-10      280        88-04
CELL REQ     WORK CELL 2           SNSR111-10      210        88-05
CELL REQ     WORK CELL 2           SNSR111-10      240        88-06
CELL REQ     WORK CELL 2           SNSR111-10      100        88-07
CELL REQ     WORK CELL 2           SNSR111-10       20        88-08
CELL REQ     WORK CELL 2           SNSR111-10       40        88-09

((((((((((((((((((((((((((((((E N D   O F   L O C A L   M P S   O R D E R S))))))))))))))))))))))))))))))
```

Table 11.47   MPS orders maintained in Work Cell 1 commenced, these orders were summarised and is shown as Table 11.48. After the MRP process had been completed, the recommended local work orders generated in the process are shown in Table 11.49, and the purchase orders generated are shown in Table 11.50, respectively.

Other relevant results including work orders, capacity, LSD, work-to-list and load analysis are also enclosed in Appendix G.

11.5.8 CENTRAL PURCHASING FOR TEST RUN TWO

Following the completion of all local MRP processes, the central purchase module then picked up all purchase requests generated in each work cell, and converted them into proper purchase orders. Table 11.51 shows the summary of purchase requests received from all three work cells, and Table 11.52 indicates the actual purchase orders which were generated based on these requests.

11.5.9 CONCLUSIONS

Throughout the test, evidence was gathered from the results and print-outs obtained at different stages and in different processes, that the algorithm of distributed planning and control built into the embryo system proved to function as desired. This is important in relation to the whole thesis, which focused on the cellular principle and the distribution concept.

The use of the LAN system here to aid communications between computers - between cells, also proved feasible. Data transfer was done, with the aid of dedicated system maps, across the LAN, to destination cells.

As for the performance of the system itself with respect to the multiple work cells set-up, time duration consumed by several essential processes have been recorded during the two test runs. These are compared, and discussed, in the following section.

11.6 DISCUSSION OF TEST RUNS ON THE EMBRYO SYSTEM

The single work cell configuration in test one, as emphasised before, represents a traditional shop floor set-up, in which all processes, such as MPS, MRP, capacity planning and inventory control, are carried out at a single location. The multiple work

```
08/01/88     LOCAL MPS SUMMARY REPORT FOR WORK CELL 1

PRODUCT      HORIZON FROM PERIOD 1 PERIOD.2 PERIOD 3 PERIOD 4 PERIOD 5 PERIOD 6 PERIOD 7 PERIOD 8 PERIOD 9 PERIOD 10
-------      ------------ -------- -------- -------- -------- -------- -------- -------- -------- -------- ---------

SNASSMC         88-02         140      145      260      152      190       85       85       75       20         0
SNSR111-10      88-02         668      440      280      210      240      100       20       40        0         0

((((((((((((((((((((((((((((((((((E N D   O F   M P S L O N G))))))))))))))))))))))))))))))))))))))))
```

Table 11.48 MPS order summary in Work Cell 1

```
08/01/88  CURRENT WORK ORDERS RECOMMENDATION FROM LAST MRP RUN FOR LOCAL PARTS

WORK CELL : 1        FOR PERIOD : 88-02     CURRENT SYSTEM PERIOD : 88-01
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

PART NO.        PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD
                88-02   880:3   880:1   880:1   880:1   880:1   880:1   880:1   880:1   880:1
---------       ------  ------  ------  ------  ------  ------  ------  ------  ------  ------

SNASSMC           500     520     304     380     170     170     150      40       0       0
SNSR111-10       2186     560     420     480     200      40      80       0       0       0

((((((((((((((((((((((((((((E N D   O F   R E C O M M E N D E D   W O R K   O R D E R S))))))))))))))))))))))))))
```

Table 11.49   Recommended work orders for Work Cell 1

```
08/01/88  CURRENT BUY-ORDER RECOMMENDATION FROM LAST MRP RUN FOR EXTERNAL PARTS

WORK CELL : 1        FOR PERIOD : 88-02     CURRENT SYSTEM PERIOD : 88-01
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

PART NO.        PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD  PERIOD
                88-02   880:3   880:1   880:1   880:1   880:1   880:1   880:1   880:1   880:1
---------       ------  ------  ------  ------  ------  ------  ------  ------  ------  ------

SN5               970     304     380     170     170     150      40       0       0       0
SN11-2-55        3601     200      40      80       0       0       0       0       0       0

((((((((((((((((((((((((((((E N D   O F   R E C O M M E N D E D   B U Y   O R D E R S))))))))))))))))))))))))))
```

Table 11.50   Recommended purchase orders for Work Cell 1

```
08/01/88    CURRENT PURCHASED-PART REQUESTS FROM WORK CELL
            MPS HORIZON FROM : 88-02

RECD NO. PART NO.     WORK CELL PERIOD PERIOD PERIOD PERIOD PERIOD PERIOD PERIOD PERIOD PERIOD PERIOD
                         NO.    88-02  88-03  88-04  88-05  88-06  88-07  88-08  88-09  88-0*  88-01
-------- --------     --------- ------ ------ ------ ------ ------ ------ ------ ------ ------ ------

   4     SN33            WC3     1094    212    142    175     77     17      0      0      0      0
   3     SN4             WC3     2179   1320    896    770    551   1095    965    300      0      0
   1     SN5             WC1      970    304    380    170    170    150     40      0      0      0
   2     SN7             WC2      862    100    148    420    370    120      0      0      0      0

((((((((((((((((((((((((((((((((((E N D  O F  F I L E))))))))))))))))))))))))))))))))))))))))))
```

Table 11.51 Summary of purchased-part requested

```
08/01/88      LISTING OF CURRENT SCHEDULED PURCHASE ORDERS IN <PURSCHED>
              CURRENT SYSTEM PERIOD 88-01

PURCHASE NO.  PART NO.       REQ QTY  WORK CELL  SCH. ORDER-PERIOD  LD:TIME  SCH. ARRIV-PERIOD  SENT  LAST:UPDT
------------  --------       -------  ---------  -----------------  -------  -----------------  ----  ---------

PUR4          SN33              1094  WC3              88-02           2           88-04         N    08/01/88
PUR5          SN33               212  WC3              88-03           2           88-05         N    08/01/88
PUR6          SN33               142  WC3              88-04           2           88-06         N    08/01/88
PUR7          SN33               175  WC3              88-05           2           88-07         N    08/01/88
PUR8          SN33                77  WC3              88-06           2           88-08         N    08/01/88
PUR9          SN33                17  WC3              88-07           2           88-09         N    08/01/88
PUR14         SN4               2179  WC3              88-02           1           88-03         N    08/01/88
PUR15         SN4               1320  WC3              88-03           1           88-04         N    08/01/88
PUR16         SN4                896  WC3              88-04           1           88-05         N    08/01/88
PUR17         SN4                770  WC3              88-05           1           88-06         N    08/01/88
PUR18         SN4                551  WC3              88-06           1           88-07         N    08/01/88
PUR19         SN4               1095  WC3              88-07           1           88-08         N    08/01/88
PUR20         SN4                965  WC3              88-08           1           88-09         N    08/01/88
PUR21         SN4                300  WC3              88-09           1           88-0*         N    08/01/88
PUR24         SN5                970  WC1              88-02           1           88-03         N    08/01/88
PUR25         SN5                304  WC1              88-03           1           88-04         N    08/01/88
PUR26         SN5                380  WC1              88-04           1           88-05         N    08/01/88
PUR27         SN5                170  WC1              88-05           1           88-06         N    08/01/88
PUR28         SN5                170  WC1              88-06           1           88-07         N    08/01/88
PUR29         SN5                150  WC1              88-07           1           88-08         N    08/01/88
PUR30         SN5                 40  WC1              88-08           1           88-09         N    08/01/88
PUR34         SN7                862  WC2              88-02           1           88-03         N    08/01/88
PUR35         SN7                100  WC2              88-03           1           88-04         N    08/01/88
PUR36         SN7                148  WC2              88-04           1           88-05         N    08/01/88
PUR37         SN7                420  WC2              88-05           1           88-06         N    08/01/88
PUR38         SN7                370  WC2              88-06           1           88-07         N    08/01/88
PUR39         SN7                120  WC2              88-07           1           88-08         N    08/01/88
((((((((((((((((((((((((((((((((E N D   O F   S C H E D U L E D   P U R C H A S E   O R D E R S)))))))))))))))))))))))
```

Table 11.52 Newly generated purchase orders for Test Run two cells configuration, however, represents a suitable simulated work environment for verifying the advantages of the distributed planning and control methodology.

11.6.1 DISCUSSION ON THE RESULTS

Since the main difference between the two tests is the concept of data distribution, comparisons can be highlighted with reference to the efficiency of local MRP processes. Referring to Table 11.53, the times recorded for various related activities in both tests are shown. Since the initial conditions for both tests are almost the same , including the number of customer orders (there were 45), number of products (there were 3) and their structures, and open stock balance, it is reasonable to compare these recorded times, and to draw conclusions based on these results.

It is worth knowing that because there was only one computer used in test one, no operation was done via the LAN system. On the other hand, data distribution and transfer in test two was mostly done via the LAN system. This, to certain extent, explains the slightly prolonged times recorded for some via-LAN operations.

11.6.1.1 DISTRIBUTION OF BOM / ROUTING DETAILS

Referring to Table 11-53, 'distribute BOM/routing details' is the process in which data in the central BOM and routing files was sub-divided and distributed to the destination work cells. Although three identical products were used in both tests, it took 1 minute and 4 seconds to distribute the BOM and routes details during test one, whilst, in the second test, 1 minute and 21 seconds was consumed to complete the same operation. Although same number of parts were involved in both tests, the difference can be accounted for by the fact that the data transmission to Work Cell 1 and Work Cell 2, from Work Cell 3 which is the assembly cell, was done via the LAN.

11.6.1.2 DISTRIBUTION OF MPS DETAILS

'Distribute MPS' represents the process in which order details in the central MPS file were distributed to the work cell(s). There were altogether 75 orders to be distributed, including customer orders, quotation, and forecast balance. In test run one, 37 seconds were taken to distribute these orders to Work Cell 3 (the only work cell), whilst 39 seconds were taken to distribute the same number of orders into Work Cell 3 in test

ACTIVITIES	TEST 1	TEST 2		
	W.Cell 3	W.Cell 3	W.Cell 2	W.Cell 1
1) distribute BOM/routes	1m 4s	1m 21s (total)		
2) distribute MPS	37s	39s		
3) local MRP	6m 30s	3m 21s	2m 12s	2m 38s
4) convert MRP to local work orders	11m 5s	7m 22s	5m 2s	6m 15s
5) LSD calculations				
a) copy routing details	4m 10s	2m 11s	1m 15s	1m 25s
b) calculate LSD	8m	4m 30s	2m 39s	2m 31s

(m = minute, s = second)

Table 11.53 Times recorded in the two test runs two. Because Work Cell 3 was the assembly cell in test run two, all orders were sent to just this work cell. The 2 second difference was probably due to the fact that in test run two, the system had to go through the search procedure for all three work cells, although this may not have been necessary.

11.6.1.3 LOCAL MRP PROCESSES

Times recorded in various MRP processes carried out by different cells show a major difference between the two tests.

In the first test, the complete MRP process took 6 minutes and 30 seconds, whilst the longest time recorded in any MRP process during test two was only 3 minutes 21 seconds. This was due to the fact that calculations for required parts were made in each work cell, during the second test. Referring to Figure 11.3 (BOM and routing details of the three products) for test two, each work cells were only accountable for a limited number of parts. For example, Work Cell 3 only made the final assemblies - PNC, PND and PNSR111; Work Cell 2 was responsible for SNASSMD and SNSR111, and Work Cell 1 made SNASSMC and SNSR111-40. On the other hand, since there was only one work cell in test one, calculations for every part (total of seven) were carried out as a single process (referring to Figure 11.1).

11.6.1.4 CONVERSION OF MRP RESULTS INTO WORK ORDERS

This is a process which would be done automatically by the system when the user confirmed the current MRP results were satisfactory. In test 1, 11 minutes and 5 seconds were taken to convert MRP results into 51 work orders. In test two, 7 minutes and 22 seconds were taken to complete this process in Work Cell 3, 5 minutes and 2 seconds in Work Cell 2, and 6 minutes and 15 seconds in Work Cell 1. The time records were variable in accordance with the number of potential orders that were to be generated.

It is worth knowing that there were a total of 57 work orders generated in test two, instead of the 51 in test one. It is because during MRP results were converted into real work orders in test one, a slightly different batch size were used for parts SNASSMC (batch size = 100) and SNSR111 (batch size = 200), whilst lot-for-lot technique was used for all the others. This evidence can be provided by comparing Table 11.21 (51 orders generated and batch size 100, 200 used) to Table F-11 which shows the 57 temporary orders generated, all using lot-for-lot technique (indicated by batch size 0). Because no special batch rule was used in test two, the total number of work orders produced was therefore 57.

11.6.1.5 CALCULATION OF LATEST START DATE

Basically, this process can be split into two sections. First, relevant routing details were copied into the LSD file for each order, before the calculations of the LSD could begin.

In test one, there were a total of 12 minutes and 10 seconds to complete the entire process in Work Cell 3. On the other hand, the longest time recorded for the same process in test two was 6 minutes and 41 seconds in Work Cell 3. Other times recorded were 3 minute and 54 seconds by Work Cell 2, and 3 minutes and 56 seconds by Work Cell 1, both showing significant difference when compared to that in test one. The difference between times recorded in the two tests was accounted by the number of orders needed to be handled in each situation.

11.7 OVERALL CONCLUSIONS ON RESULTS

Since the main objective of these test runs was to demonstrate the improved system efficiency and flexibility using the distribution algorithm in an integrated system, the recorded times, therefore, have fully supported the hypothesis.

As predicted, times recorded in the second test show much improved system efficiency compared to the first. This is mainly because of the amount of data needed to be processed was very different - a result of the application of the distribution concept. The MRP process in the first test had to take all subassemblies and parts into its calculations, whilst in the second test, the complete MRP process sequence was divided into three phases, which were then subsequently performed in a different work cell.

The improved efficiency shown in the multiple work cells set-up provides strong evidence that the much discussed distributed planning and control methodology can improve the overall performance of an integrated system. The cellular approach as a whole, also improved the system flexibility in terms of control and operations. The use of LAN in an integrated system also provided good facilities with respect to linking smaller computer systems and cellular software modules. In general, the use of system maps created for the embryo system enabled the resulting system, with the aid of LAN, to be tailored more effectively for the end user's needs.

With the system configurator, specifications of the system, including the number of computers used, number of work cells, disk locations of each functional cell, modules contained in each work cell, and operational requirements for each product, can be defined by the user prior to system implementation. This facility, with respect to a small integrated system, provides the user with more control, possibly leading to greater cost effectiveness, over the whole system within a specific application environment.

Finally, improved data accountability was another obvious advantage observed during the two tests. In a multiple work cell environment, each work cell is granted its own right of planning and control on local resources. With the aid of data distribution, these work cells are extremely flexible in relation to the overall system layout.

In conclusion, the evidence gathered from the test runs carried out on the embryo system have demonstrated improved system flexibility, more user control, faster overall data processing efficiency, and enhanced modular and cellular modules programming all of which are important features in a small CIM system. These benefits, will also be resulted, if the distribution technique is applied to other areas such as CAD, CAM, purchasing and financial operations.

CHAPTER 12 CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK

12.1 CONCLUSIONS

12.1.1 CENTRALISED SYSTEM APPROACHES IN CIM

As it is generally recognised that numerous problems are associated with 'islands of automation', Computer-Integrated Manufacturing (CIM) has been introduced in order to improve this situation. Earlier chapters highlighted examples of CIM system development carried out by different companies in different countries. Because of the differing needs in these companies, the emphases in their CIM development has been very diverse.

Basically, there are two main global approaches used for CIM development. While the first approach suggests that a CIM system can be built using existing system elements, the second approach insists a CIM system is best built from first principles. Although both global approaches are used, and, in fact the second one is in preference, there is a common characteristic to all these projects - the adoption of a centralised system methodology. According to this methodology, a central common database should be used as an information centre for all activities in the application environment.

From the literature search on CIM and its control algorithm, the centralised system approach has imposed vast technical difficulties, such as an over-complicated design of the central database, and the general lack of system flexibility. This, unfortunately, has not only hindered the progress of CIM development, but has also deterred smaller manufacturing companies from participation.

12.1.2 CELLULAR SYSTEM APPROACH IN CIM

Based on general criticism received with respect to these major problems associated with the centralised system approach, a more flexible system definition for CIM should be designated. Such a system definition has to be derived from the fundamental principles and objectives of integration in manufacturing. In addition, the new definition should enable a more open and flexible system specification to be used. This is particularly important for the development of smaller integrated systems.

An alternative approach, known as the cellular system approach, was introduced to replace the centralised approach. Although the new approach is mainly aimed to improve system flexibility for the development of smaller integrated systems, it can also be incorporated into the design of any CIM system, because of its capability to simplify the overall complexity of any integrated system.

According to its definition, a cellular approach regards a CIM system as a combination of smaller semi-independent functional units, which are collectively known as cells. Each cell not only has its own database and maintains control over its activities, it should also be capable of transferring required data to other cells in the system. Such an approach allows the complexity of an integrated system to be divided into smaller controllable units. In addition, the use of more than one database means that the sophistication of the original central database can be eliminated. A local database, which is attached to a cell, or a group of them, should generally support functions in that group.

The use of a local-area-network system allows these cells to be linked so that information transfer is possible. Data in a local database, therefore, can be used by another cell, if the link has already been built into the system during configuration.

The use of the cellular system approach in designing a CIM system has a number of major benefits over the traditionally adopted centralised approach. These benefits may include improved overall system interrelationships, simpler individual database structures, faster localised data processing, better data accountability, and most importantly a more flexible system structure.

Further application of the cellular system approach led to the concept of distributed planning and control. This concept can be incorporated into a cellular CIM system to complement its cell characteristics. The distribution concept can indeed be applied to many central functions. However, only the most obvious areas such as MPS, MRP, BOM and capacity planning were selected for experimentation with respect to the distribution principle.

In general, the concept of distributed planning and control should be used as a tool to enhance cellular features in the integrated system. For example, a work cell can now have more control over decisions to modify the main production schedule, plan the required resources, and suggest potential work orders and purchase orders for its parts. Another important characteristics of the distribution concept is the downloading of central data into a number of work cells, so that data can be processed locally in a more efficient manner. The processed data from the local MRP in the first work cell can be transferred, if necessary, to the next work cell for subsequent operations. The direction and sequence of this data transfer will depend on the assignment of different resources in relation to the definition of product groups.

The essence of distributed MPS and MRP makes the frequent updating of the local master schedule and work order plans much simpler, as each work cell is responsible for a much smaller amount of data which is considerably more manageable than a massive central database.

12.1.3 DEVELOPMENT OF AN EMBRYO CELLULAR CIM SYSTEM

In order to prove the feasibility of the cellular principle, and more importantly the significance of the distributed planning and control concept, an embryo integrated system was developed for demonstration purposes.

Throughout the process of the development of the embryo system, guidelines have been produced so that further development and enhancement of the system is possible.

The developed embryo system is able to demonstrate most of the typical manufacturing and planning functions. However, areas such as CAD, CAM and finance were relatively unattended, purely because of the lack of development time. Already in some chapters, suggestions were made to use existing software to compensate for this deficiency. Other suggestions will also be included in the recommendation section later in this chapter.

All the software modules developed in the embryo system were based on modular programming techniques so that their compatibility with the final integrated system is assured.

Another special feature of the embryo system is that it can demonstrate the important features of the distributed planning and control principle. In order to demonstrate this, two comprehensive test runs were carried out.

The first test, basically, was aimed at examining the global features of the embryo system. These features include the updating of local database located in different computers, the extensive use of networking features and the general functions of a fully configured work cell. Results were obtained in the form of reports and screen-dumps so that these could be used as reference material later.

On the other hand, the main objective of the second test run was to verify the data distribution capability provided by the embryo system. Three work cells were used in the system instead of one. To demonstrate the distribution principle, data was passed down from central cells into various work cells. The processed data was then transferred from one work cell to another, in accordance with the previously defined route. From the evidence observed during the test, the logic of such data distribution characteristics is fully demonstrated and supported by the results obtained.

Based on the results obtained in the two major test runs, it can be observed that the embryo system is capable of demonstrating the characteristics of a cellular integrated system. This included the use of the multiple databases at different computer locations, the data transactions between central modules and work cell modules, the distribution of central data into local modules in various work cells, and the data transfer between local modules in different work cells. The results indicate that both the cellular system approach and the distributed planning and control can greatly simplified the development of an integrated system. In addition, the proposal that microcomputers can form the basic backbone of hardware in an integrated system is also supported.

Although the proof for the two main concepts was derived from a basic integrated system with some limitations, it is believed that such concepts can also be incorporated into the design of a more sophisticated system. The use of microcomputers and LAN should not be restricted only to small systems, and the fact that many LAN systems can be integrated together strongly supports this idea.

As for the distributed planning and control concept itself, although it was mainly used in MPS, MRP and capacity analysis functions in this project, it can be applied to other areas within a company. These areas include CAD, CAM, and other major cost accounting activities, in which they can be shared and transferred into the more independent and controllable work cells through data distribution. For example, engineering design details, in relation to product group specifications, can be distributed to, and stored in, local databases of production work cells. Any technical changes or machining requirements can be made locally without the consent from other cells. The end results, if most of the major functions have been distributed, will be the presence of more self-contained and yet integrated work cells in the company.

The distribution concept, when it is fully developed, will have significant implications on traditional management strategies presently used in manufacturing companies.

12.2 RECOMMENDATIONS FOR FURTHER WORK

The suggestions provided in this section regarding further work can be grouped into two categories. The first group is mainly concerned with the actual enhancement of the present embryo system, whilst the second category is associated with the further research into the application of the cellular theory and the concept of distributed control illustrated in this thesis.

12.2.1 FURTHER WORK ON THE EMBRYO SYSTEM

Although the original intention of the embryo system development was to demonstrate the discussed cellular system principle and the distributed planning and control concept, the developed system itself represents a sophisticated end product which may be used in small companies. Some areas can be improved and these include using the latest version of dBASE, integrating other dBASE systems such as CAMAC, increasing the number of computers and the capacity of hard disks, and finally incorporating existing CAD system such as MLD2 or AUTOCAD.

12.2.1.1 DBASE LANGUAGE UPDATE

The decision of using dBASE II as the major development language, at the time of the project, was justified by the powerful features it provided. There were, however, some constraints in the language (as seen in Appendix E), which imposed some restrictions with respect to the embryo system. Serious constraints include the number of memory variables being limited to 64, number of data files opened at one time being limited to 2, the number of fields per record being limited to 32, the length of each record being limited to 1000 characters, and more importantly, the relatively slow execution speed.

To eliminate all these constraints, dBASE III Plus, which is the latest version available, can be used. The user-interface of the system language has more improved user-friendliness facilities. Appendix E includes a simple comparison of the technical features in dBASE II and in dBASE III Plus. At the moment, Ashton Tate has already made an announcement about the launch of dBASE IV, which is the latest version of dBASE. The new package will feature a built-in compiler to improve program speed.

12.2.1.2 MICROCOMPUTERS AND HARD DISK CAPACITY

As the 32-bit 80386-processor-based microcomputers become more popular and cheaper, they can be used to replace the old 16-bit OCTOPUS computers used in the embryo system. Such a 80386 computer is many times faster than the OCTOPUS. The performance of the embryo system will be dramatically improved using these new powerful machines.

The emergence of PS/2 by IBM, which is a machine based on both 80286 and 80386 microprocessors, will definitely accelerate the acceptance of 80386-based machines as the industrial standard.

On the other hand, because prices for Winchester hard disks have come down dramatically in recent years, it will be possible to have local hard disks for all computers used in the embryo system. This will not only increase the data storage capacity, but also eliminate the overload situation on hard disks. This is particularly important when new modules are to be integrated into the system.

12.2.1.3 OPERATING SYSTEM

If 80386-based computers are to be used, then some state-of-the- art multi-tasking operation systems could be used to explore the full power of these computers. One such product which has been specifically designed for 386-machines is called Concurrent DOS 386 from Digital Research, which allows up to four gigabytes of address space. Other alternative products such as PCMOS and MS- WINDOW 386 could also be considered.

The announcement of Microsoft's OS/2 will have the biggest impact of all with respect to operating system (OS) for microcomputers. It was not available at the time this thesis was written. It supports a wide range of networking and multi-tasking functions, and is able to access a much larger memory than MSDOS.

12.2.1.4 CAMAC CODING AND CLASSIFICATION SYSTEM

As introduced in chapter 8, a coding and classification system called CAMAC, which was also written in dBASE and developed at Aston University, could be incorporated into the present embryo system in order to enhance the product search and process planning facilities.

The inclusion of the CAMAC system into the embryo system will logically substitute the product search module in the Customer Service Cell. Some design facilities of CAMAC can also be incorporated into the Design cell of the system. At the moment, CAMAC is already in dBASE III Plus version.

12.2.1.5 INCLUSION OF A CAD SYSTEM TO ENHANCE THE DESIGN CELL

As introduced in chapter 8, a two dimensional CAD system, such as MLD2, can be incorporated into the embryo system. This will definitely improve the value of the embryo system, as the present version does not have any drawing functions.

By using the MLL - the provided CAD language, the various functions of MLD2 can be integrated with the Design Cell in the embryo system.

On the other hand, it is quite possible to develop a distributed CAD system from first principles, so that it can further enhance the distribution capabilities of the system.

12.2.1.6 SCREEN INPUT AND OUTPUT MESSAGES

The present embryo system, as it was designed for demonstration purposes, displays full information on screen. This was very useful during the development, as data could be checked promptly through the screen input and output. However, the system's fluency and performance could be overloaded if it were expanded to a fully functional system within a company. It is therefore suggested that when the system is actually installed in small companies, the extra screen messages should be removed or simplified. This can be done relatively easily by removing or changing the display statements from the actual computer programs.

12.2.1.7 FINANCIAL MODULES ENHANCEMENT

Expansion of the financial modules was also omitted in the present version of the embryo system including basic budgeting, cost accounting, pay-roll and ledgering. It is suggested that some commercial systems can be incorporated into the embryo system. A lot of these systems support dBASE file formats, and should therefore impose no great difficulty with respect to compatibility with the embryo system. In addition, the modular design approach used in the embryo system supports such integration without much modification.

As mentioned in previous chapters, some program modules from the Manufacturing Control System (MCS), developed for the Marwin Cutting Tool Ltd, were incorporated into the system. This proves it is equally feasible to incorporate some financial packages, also written in dBASE, into the system using the same technique.

On the other hand, distributed financial modules can be developed from first principles. This will definitely enhance the distribution features of the system so that the benefits of cellular approach can be highlighted.

12.2.1.8 SIMULATION MODULE

There are already some simple load-analysis modules in the embryo system, which were designed to evaluate potential load on work centres. The incorporation of a more powerful simulation module can be used to examine 'what-if' situations more efficiently. It will also consider more data in each simulation. A number of micro-based simulation systems are available in the market, and most of these support dBASE's ASCII data formats as standard.

12.2.1.9 RECOMMENDATIONS FOR FURTHER TESTS OF THE EMBRYO SYSTEM

Although the two tests described in Chapter 11 represented a comprehensive evaluation of the features of the embryo system, different tests will further explore its potential capability.

The number of computers used, first, can be modified. Ideally, each major functional cell and work cell should be operated from a separate computer. This allows all cells to be operated at the same time without any possible delay. Also, data accountability will be much improved because of the use of a separate hard disk for each cell. This proposal will not complicate the system as the only changes will be in the system maps themselves so that new disk locations can be readily recognised.

The number of work cells can also be increased and their interrelationships altered. More products, and hence product groups, should be used in order to evaluate the distributed capabilities of the system to the fullest extent. The new work cells can be assigned different objectives for example there will be different modules in each work cell, yet the integration links between them can still be maintained.

12.2.2 FURTHER RESEARCH ON THE DISTRIBUTED PLANNING AND CONTROL CONCEPT

In this research, the biggest contribution is the introduction of the distribution concept into an cellular integration environment. As demonstrated by the embryo system, the distributed MPS and distributed MRP have had much impact on the improvement of cell performance.

Further research, with respect to an in-depth investigation of the significance of the distributed planning and control concept, has already commenced. Based on findings made in this thesis, Barekat [Love and Barekat,1988] focuses on the influence of a capacity -sensitive distributed MRP system in a cellular factory, in comparison with other possible techniques such as KANBAN and Optimum Production Technique (OPT).

While the embryo system is capable of demonstrating the fundamental principle of the distributed MPS and distributed MRP, Barekat will examine the reaction of permitting closed loop feedback between work cells, in relation to their local MRP processes. To illustrate this, for example, MRP is first run in the assembly work cell, and the part requests are transferred to Work Cell 1. During the local MRP process, Work Cell 1 has made some changes in its MPS. These changes will then be transferred back to the assembly cell so that it can re-run its MRP system. This process will continue until both cells are satisfied with the MRP status results. Barekat's commitment to this research topic, has further indicated the impact and potential benefits which can be obtained using the distributed planning and control concept in an integrated cellular environment.

Further research regarding the application of the distributed planning and control methodology, to other areas such as CAD, CAM, purchasing, and financial functions, is also recommended. In principle, it is possible to transfer most central functions into work cells through distribution. If this concept proves to be feasible, then the methodology of distributed planning and control will definitely produce significant improvements in the areas of manufacturing within several companies where the centralised management strategy is commonplace.

APPENDIX A

SCREEN MENUS AND OPTIONS IN THE EMBRYO SYSTEM

APPENDIX A SUMMARY OF SYSTEM MENU, SUB-MENUS AND OPTIONS

SYSTEM MAIN MENU

A -- CIM SYSTEM CONFIGURATION
B -- CUSTOMER SERVICE
C -- ENGINEERING DESIGN
D -- PLANNING
E -- MANUFACTURING & CONTROL
F -- FINANCE & ADMINISTRAION
G -- HOUSE KEEPING
I -- MISCELLENOUS FUNCTIONS
H -- HELP MENUS
Q -- QUIT

SYSTEM CONFIGURATION MAIN MENU [A]

A1 -- STRUCTURE FILES AND FILES PREPARATION MENU
A2 -- QUICK DATA PREPARATION MENU
A3 -- SYSTEM CONFIGURATION MODULES MENU
A4 -- PRODUCTION CALENDAR MAINTENANCE MENU
A5 -- COMPANY DETAILS MAINTENANCE
H -- HELP
M -- RETURN TO CIM MAIN MENU

SUB-MENU [A1] FOR PREPARATION OF FILE STRUCTURES & FILES

A11 -- CREATE NEW STRUCTURES AND FILES
A12 -- COPY & MODIFY FILE STRUCTURES
A13 -- DELETE STRUCTURE FILES
A14 -- LIST/PRINT AVAILABLE STRUCTURES
A15 -- VIEW A PARTICULAR FILE STRUCTURE
H -- HELP
M -- RETURN TO CIM MAIN MENU

SUB-MENU [A2] FOR QUICK PREPARATION OF DATA

A21 -- LIST ALL FILES, INDEXES
A22 -- SET DEFAULT FILE NAME & INDEX
A23 -- APPEND NEW DATA INTO FILE
A24 -- EDIT RECORDS IN DEFAULT FILE
A25 -- LIST/PRINT A SPECIFIC FILE
H -- HELP
M -- RETURN TO CIM MAIN MENU

SUB-MENU [A3] FOR ACTUAL SYSTEM CONFIGURATION MENU

A31 -- SYSTEM FILES/MODULES MAPS MAINTENANCE
A32 -- CHECK FILES/MODULES EXISTENCE AGAINST MAPS
A33 -- ENTER CONFIGURATION SPECIFICATIONS
A34 -- DISTRIBUTE FILES/MODULES TO SYSTEM POINTS
A35 -- DISTRIBUTE LOCAL FILES/MODULES TO WORK CELLS
A36 -- LIST/PRINT CONFIGURATION TABLE
H -- HELP
M -- RETURN TO CIM MAIN MENU

SUBMENU [A4] FOR PRODUCTION CALENDAR MAINTENANCE

A41 -- GENERATE NEW CALENDAR
A42 -- MODIFY EXISTING PRODUCTION CALENDAR
A43 -- PRINT PRODUCTION CALENDAR
A44 -- HOLIDAY DETAILS MAINTENANCE
A45 -- PRINT NON-WORKING DAYS
H -- HELP
M -- RETURN TO CIM MAIN MENU

CUSTOMER SERVICE MAIN MENU [B]

B1 -- SALES ORDER ENTRY AND CONTROL
B2 -- CUSTOMER ENQUIRY
B3 -- SALES ORDER CHANGES
B4 -- PRODUCT SEARCH MENU
B5 -- QUOTATION FILE MAINTENANCE MENU
B6 -- CUSTOMER ORDERS SHIPMENT
B7 -- CUSTOMER DETAILS MAINTENANCE MENU
B8 -- ACKNOWLEDGEMENT FILE MAINTENANCE
B9 -- INTERNAL ENQUIRY MENU
H -- HELP
M -- RETURN TO CIM MAIN MENU

SUB-MENU [B4] FOR PRODUCT SEARCH

B41 -- SIMILAR PRODUCT SEARCH
B42 -- SEARCH FOR PRODUCT GENERAL INFORMATION
B43 -- PRODUCT SEARCH DATABASE MAINTENANCE
H -- HELP
M -- RETURN TO CIM MAIN MENU

SUB-MENU [B5] FOR QUOTATION FILE MAINTENANCE

B51 -- PICK AND SEND NEW QUOTES TO CUSTOMERS
B52 -- CHECK OUT INVALID QUOTES
B53 -- DELETE INDIVIDUAL QUOTES
B54 -- MODIFY DETAILS OF QUOTES
B55 -- LIST/PRINT AVAILABLE QUOTES
H -- HELP
M -- RETURN TO CIM MAIN MENU

SUB-MENU [B7] FOR CUSTOMER DETAILS MAINTENANCE

B71 -- CUSTOMER DETAILS MAINTENANCE
B72 -- CUSTOMER ORDER DETAILS MAINTENANCE
B73 -- CUSTOMER ENQUIRY DETAILS MAINTENANCE
H -- HELP
M -- RETURN TO CIM MAIN MENU

SUB-MENU [B9] FOR INTERNAL ENQUIRY

B91 -- CUSTOMER INFORMATION ARCHIVAL
B92 -- DISPLAY/PRINT CURRENT MPS DETAILS
B93 -- ORDER HISTORY DETAILS MAINTENANCE
B94 -- OPEN CUSTOMER ORDERS MAINTENANCE
H -- HELP
M -- RETURN TO CIM MAIN MENU

ENGINEERING DESIGN MAIN MENU [C]

C1 -- BILL-OF-MATERIAL (BOM) GENERATOR MENU
C2 -- PROCESS PLANNING MENU
C3 -- PRODUCT DETAILS MAINTENANCE MENU
C4 -- STANDARD COST DETAILS MAINTENANCE MENU
C5 -- ENGINEERING DRAWING MENU (NOT EXIST YET)
C6 -- COST RATING MAINTENANCE MENU
C7 -- NEW DESIGN REQUEST MAINTENANCE MENU (NOT EXIST YET)
H -- HELP
M -- RETURN TO CIM MAIN MENU

SUB-MENU [C1] FOR BILL OF MATERIAL

C11 -- CREATE NEW BOM DETAILS
C12 -- MODIFY BOM DETAILS
C13 -- DELETE BOM DETAILS
C14 -- LIST/PRINT OF BOM DATA
H -- HELP
M -- RETURN TO CIM MAIN MENU

SUB-MENU [C2] FOR PROCESS PLANNING

C21 -- PROCESS TEMPLATE MAINTENANCE
C22 -- GENERATE NEW PROCESS ROUTES FOR A PART OR PRODUCT
C23 -- PROCESS ROUTE DETAILS MODIFICATION
C24 -- DELETE SUB-ASSEMBLY PROCESS ROUTES
C25 -- LIST/PRINT ROUTING DETAILS
H -- HELP
Q -- RETURN TO CIM MAIN MENU

SUB-MENU [C3] FOR PRODUCT DETAILS MAINTENANCE

C31 -- GENERATE REQUIRED DETAILS FOR A NEW PRODUCT
C32 -- MODIFY DETAILS FOR EXISTING PRODUCTS
C33 -- DELETE PRODUCT DETAILS
C34 -- LIST/PRINT PRODUCT DETAILS
H -- HELP
M -- RETURN TO CIM MAIN MENU

CW12

SUB-MENU [C4] FOR STANDARD COST DETAILS MAINTENANCE

C41 -- GENERATE STANDARD COST DETAILS FOR NEW PRODUCTS
C42 -- UPDATE STANDARD COST DETAILS FOR A PRODUCT
C43 -- REGENERATE STANDARD COSTS FOR ALL CHANGED PRODUCTS
C44 -- INDIVIDUAL SUB-ASSEMBLY STANDARD COSTS MAINTENANCE
C45 -- LIST/PRINT STANDARD COSTS IN DIFFERENT COMBINATIONS
H -- HELP
M -- RETURN TO CIM MAIN MENU

SUB-MENU [C5] FOR ENGINEERING DRAWING

OPTION 1 -- CREATE NEW ENGINEERING DRAWING
OPTION 2 -- MODIFY EXISTING DRAWING DETAILS
OPTION 3 -- DELETE DRAWING DETAILS
OPTION 4 -- ARCHIVE DRAWING AND OUTPUT
OPTION 5 -- LIST AVAILABLE DRAWINGS
H -- HELP
M -- RETURN TO CIM MAIN MENU

SUB-MENU [C6] FOR COST RATING MAINTENANCE

C61 -- LABOUR GRADE COST DETAILS MAINTENANCE
C62 -- SUB-ASSEMBLY OVERHEAD COST DETAILS MAINTENANCE
H -- HELP
M -- RETURN TO CIM MAIN MENU

SUB-MENU [C7] FOR NEW DESIGN REQUESTS MAINTENANCE

OPTION 1 -- LIST CURRENT DESIGN REQUESTS
OPTION 2 -- PRINT CURRENT DESIGN REQUESTS
OPTION 3 -- CANCEL DESIGN REQUEST DETAILS
H -- HELP
M -- RETURN TO CIM MAIN MENU

CENTRAL PLANNING MAIN MENU [D]

D1 -- REGENERATE NEW MPS ORDERS AND UPDATE HORIZON
D2 -- CAPACITY DETAILS REPORTED FROM WORK CELLS
D3 -- DISPLAY/PRINT MPS ORDER STATUS FOR A PRODUCT
D4 -- DISPLAY/PRINT SUMMARISED MPS PLANNED QTY
D5 -- WORK CELL SUPERVISOR AND DISTRIBUTION MENU
D6 -- CENTRAL PURCHASING MENU
D7 -- CENTRAL INVENTORY CONTROL FOR FINAL PRODUCTS
H -- HELP
M -- RETURN TO CIM MAIN MENU

WORK CELL SUPERVISOR MAIN MENU [D5]

D51 -- DISTRIBUTE MPS ORDERS AND HORIZON INTO WORK CELLS
D52 -- DISTRIBUTE PARTIAL BOM AND ROUTING DETAILS TO CELLS
H -- HELP
M -- RETURN TO CIM MAIN MENU

CENTRAL PURCHASING MAIN MENU [D6]

D61 -- GENERATE NEW SCHEDULED PURCHASE ORDERS FROM W. CELLS
D62 -- MAINTENANCE OF SCHEDULED PURCHASE ORDERS
D63 -- GENERATE AND SEND NEW PURCHASE ORDERS FOR DUE SCHD'E
D64 -- LIST/PRINT, MODIFY OF SENT OUT PURCHASE ORDERS DET'L
D65 -- PURCHASE ORDERS ARRIVAL UPDATE OPERATIONS
D66 -- END PARTS AND VENDOR DETAILS MAINTENANCE
H -- HELP
M -- RETURN TO CIM MAIN MENU

WORK CELL LOCAL MODULES MAIN MENU [E]

E1 -- LOCAL MRP EXECISE SUB-MENU
E2 -- GENERATE LOCAL WORK ORDERS SUB-MENU
E3 -- UN-RELEASED ISSUED WORK ORDERS MAINTENANCE SUB-MENU
E4 -- SHOP FLOOR PLANNING AND ORDER RELEASE SUB-MENU
E5 -- WORK-IN-PROGRESS DATA MAINTENANCE & UPDATE SUB-MENU
E6 -- LOCAL PARTS STOCK CONTROL SUB-MENU
H -- HELP
M -- RETURN TO CIM MAIN MENU

SUB-MENU [E1] FOR LOCAL MRP & MPS OPERATION

E11 -- PREPARE MPS DATA FROM CENTRAL MPS & WC'S PART-REQUEST
E12 -- EDIT MPS DATA PRIOR TO MRP RUN
E13 -- RUN LOCAL MRP
E14 -- GENERATE TEMP W.O. FROM MRP RUN & GATHER ISSUED W.O.
E15 -- GENERATE LATEST-START-DATE (LSD) FOR TEMP ORDERS
E16 -- ROUGH CAPACITY PLANNING (WORK LOAD ANANLYSIS)
E17 -- CONFIRM TO ACCEPT LAST MRP RESULTS
H -- HELP
M -- RETURN TO CIM MAIN MENU

SUB-MENU [E2] FOR GENERATION OF LOCAL WORK ORDERS

E21 -- GENERATE INDIVIDUAL SINGLE WORK ORDERS
E22 -- MODIFY MRP RECOMMENDED WORK ORDERS BEFORE RUN [E23]
E23 -- AUTOMATIC ISSUE OF WORK ORDERS FROM MRP RESULTS
E24 -- BATCH SIZE CALCULATION AND MAINTENANCE
H -- HELP
M -- RETURN TO CIM MAIN MENU

SUB-MENU [E3] FOR UN-RELEASED ISSUED WORK ORDERS MAINTENANCE

E31 -- MODIFY WORK ORDERS
E32 -- DELETE WORK ORDERS
E33 -- DISPLAY WORK ORDERS IN DIFFERENT COMBINATIONS
E34 -- PRINT WORK ORDERS IN DIFFERENT COMBINATIONS
H -- HELP
M -- RETURN TO CIM MAIN MENU

SUB-MENU [E4] FOR SHOP FLOOR PLANNING & ORDER RELEASE

E41 -- DISPLAY ISSUED WORK ORDERS IN DIFFERENT COMBINATIONS
E42 -- MODIFY RELEASED WORK ORDERS
E43 -- DELETE RELEASED WORK ORDERS
E44 -- RELEASED WORK ORDERS TO THE FLOOR
E45 -- INDIVIDUAL WORK CENTRE LOAD STATUS DISPLAY
E46 -- WORK-TO-LIST & LOADING STATUS ON WORK CENTRES
E47 -- GENERATE LSD (ORDER PRIORITY) FOR NEW ISSUED WK ORD
E48 -- WORK CENTRE CAPACITY DETAILS MAINTENANCE
H -- HELP
M -- RETURN TO CIM MAIN MENU

SUB-MENU [E5] FOR WORK IN PROGRESS DATA MAINTENANCE

E51 -- UPDATE W.I.P. DETAILS
E52 -- DISPLAY OR PRINT W.I.P. STATUS FOR WORK ORDERS
E53 -- MAINTENANCE OF COMPLETED WORK ORDERS DETAILS
H -- HELP
M -- RETURN TO CIM MAIN MENU

SUB-MENU [E6] FOR STOCK CONTROL

E61 -- PARTS / COMPONENTS STOCK UPDATE
E62 -- LOCAL STOCK STATUS REPORT
E63 -- PART DETAILS MAINTENANCE
E64 -- MADE-IN PARTS ON-ORDER INFORMATION PREPARATION
E65 -- BOUGHT-IN PARTS ON-ORDER INFORMATION PREPARATION
H -- HELP
M -- RETURN TO CIM MAIN MENU

FINANCE AND ADMINISTRATION MAIN MENU [F]

F1 -- FORECASTING MODULES
F2 -- SALES LEDGER MODULES SUB-MENU
F3 -- PURCHASE LEDGER MODULES SUB-MENU
F4 -- NOMINAL LEDGER MODULES SUB-MENU
F5 -- PAYROLL MODULES SUB-MENU
F6 -- INVOICING MODULES SUB-MENU
F7 -- JOB COSTING MODULES SUB-MENU
H -- HELP
M -- RETURN TO CIM MAIN MENU

HOUSE KEEPING MAIN MENU [G]

G1 -- FILE SIZE CHECK AND REPORTING
G2 -- SET SYSTEM ATTRIBUTES
G3 -- MASTER BACK-UP PROCEDURES
H -- HELP
M -- RETURN TO CIM MAIN MENU

MISCELLANEOUS FUNCTIONS MAIN MENU [I]

I1 -- LABELLING
I2 -- REPORT GENERATOR
H -- HELP
M -- RETURN TO CIM MAIN MENU

APPENDIX B

SELECTED HELP AND OPERATIONAL INSTRUCTIONS FOR EMBRYO SYSTEM'S MODULE

SECTION B1

FUNCTIONAL GROUP A - SYSTEM CONFIGURATION

[A11] STRUGEN - CREATE NEW DATA STRUCTURE FOR DATA FILE

```
*A11** [STRUGEN.HLP] *** CREATE NEW FILE STRUCTURES *************
*                                                               *
*                 EMBRYO CIM SYSTEM                By Andy Lung *
*   This is a HELP function to be called only by STRUGEN.CMD.   *
*   It is a program though named .HLP                           *
*                                                               *
*CIM TEST MODEL**************************************************

* DATAFILES : XXXXXXX.STR, DATAFILE.DBF, FILERECD

* VARI. IN  : Global var.
* VARI. OUT :
* TEMP. VAR : Mmode,Minputfile,Mfinished,Moption,Mcounter,Mline,
*             Mcol,Mend1,Mdate, Mfieldname,Mfieldtype,Mfieldlen,
*             Mfielddec,Myesno,Mfield1,Mfield2,Mfield3,Mindex1,
*             Mindex2,Mindex3,Mend3,Mend2,Mdescript,Mmaxrecdno

* TOTAL VAR : 34

* LINK FROM : (N)CIMMENU.CMD -> (A)CONFIG.FMT -> (A1)STRUFILE.FMT
              -> here
* LINK TO   : Back to STRUFILE.FMT

HELP FOR CREATING NEW STRUCTURE AND DATA FILE
=============================================

This  module  (STRUGEN.CMD)  allows  generation  of  new   system
databases and their corresponding structure files.


These structure files are separated from the respective databases
when  they are created.  The system will check if input  filename
already exists.  If the filename exists, it will prompt the  user
to  delete the existing one prior to generating a  database  with
the same file name.


In  this program, other relevant details of the created  database
will be asked too, like :

       1) Index file(s) you want to open.

       2) Description of the database.

       3) Max. no. of expected records.

       4) The date of creation.

* ~~~~~End of ~~~~~~~~~~~~~~~ [STRUGEN.HLP] ~~~~~~~~~~
```

[A31] SYSMAP - CREATE MAP DETAILS FOR SYSTEM CONFIGURATION

```
*A31** SYSMAP.HLP **** CREATE SYSTEM MAPS FOR CONFIGURATION *****
*                                                               *
*              EMBRYO CIM SYSTEM                By Andy Lung    *
*                                                               *
*   This is the Help function called by <SYSMAP.CMD>.  It is    *
*   itself a .CMD file just called .HLP for identification.     *
*                                                               *
*****************************************************************

* DATAFILES : IN   FILE: <FILE-MP>, <MODEL-MP>
*             OUT  FILE:
*             TEMP FILE: <MAP-TEMP>

* VARI. IN  : Global var.
* VARI. OUT :
* LOCAL VAR : Mfinished, Mcorrect, Moption, Moption1, Moption2,
*             Mmode, Mmapname, Mendadd, Mline, Mfunction, Mnodeno,
*             Mname, Mfield, Myesno, Mcolumn, Mrecordno, Mfull

* TOTAL VAR : 30

* LINK FROM : CIMMENU.CMD -> CONFIG.FMT -> SYSCON.FMT -> here
* LINK TO   : SYSCON.FMT


HELP FOR SYSTEM MAP MAINTAINENCE
================================

Since  the SYSTEM CONFIGURATION process will base on some  master
System  Modules and System Files, so that these modules  &  files
can  be  replicated and distributed to  the  different  networked
machines according to Configuration Specifications.


In order to keep track of all these modules & files, there are  2
System  maps which contain all System module details  and  System
file details respectively.


This  program provides all operations needed to maintain these  2
System maps Activities like ADD, MODIFY, DELETE, LIST & PRINT are
available for manipulating details in the 2 System maps.   Module
details  & file details can be added to, or deleted from,  the  2
Maps.


* ~~~~~End of ~~~~~~~~~~ SYSMAP.HLP ~~~~~~~~~~
```

[A32] CHKMAP - CHECK FILES AGAINS LIST SUGGESTED IN THE MAP

```
*A32** CHKMAP.HLP ***** CHECK FILE AVAILABILITY IN THE SYSTEM **
*                                                              *
*              EMBRYO CIM SYSTEM               By Andy Lung    *
*                                                              *
* This module is the HELP function for [CHKMAP.CMD] and is     *
* called by the latter uniquely.  It is actually a .CMD file   *
* but named .HLP just for identification.                      *
****************************************************************

* DATAFILES : IN   FILE: <FILE-MP>  <MODEL-MP>
*             OUT  FILE: <NOTEXIST>
*             TEMP FILE:

* VARI. IN  : Global var.
* VARI. OUT :
* LOCAL VAR : Mfinished, Moption, Mmode, Mmapname, Mfield, Mtype,
*             Mline, Mfunction, Mnodeno, Mname, Myesno

* TOTAL VAR : 24

* LINK FROM : CIMMENU.FMT -> CONFIG.FMT -> SYSCON.FMT -> here
* LINK TO   : Back to caller

HELP  FOR  CHECKING OF MASTER MODULES/FILES REQUIRED  FOR  SYSTEM
CONFIGURATION
=================================================================

This module is for checking the existence of all essential master
Modules and Files that are required for the System Configuration.


Some  of these are unique in the system, but some will be  needed
for  replication  and distributed into  the  differenet  machines
through  Configuration.  The program will first read in  the  map
details entered in [A31] - SYSMAP, then check if the Modules  and
Files  in the maps are existing in the current user area.   Names
for  any  missing  module  or file will be  stored  in  the  file
<NOTEXIST>,   which  can  be  listed  or  printed,  for   further
reference.


The  logical  options to run this program is first [F]  to  check
Files, then [M] to check Modules, finally [L] to list all missing
things  or  print them out on paper.  The content  of  <NOTEXIST>
will be updated automatically on each check.  So, there won't  be
any duplication with frequent checking.


* ~~~~~End of ~~~~~~~~~~ CHKMAP.HLP ~~~~~~~~~~
```

[A33] CONFSPEC - SPECIFICATION FOR SYSTEM CONFIGURATION

```
*A33** CONFSPEC.HLP ** SPECIFY DETAILS FOR SYSTEM CONFIGURATION *
*                                                                *
*             EMBRYO CIM SYSTEM        By Andy Lung              *
*                                                                *
*   This is the Help function for [CONFSPEC.CMD].  It is itself *
*   a  .CMD  file but called .HLP for identification with its   *
*   caller.                                                      *
*                                                                *
******************************************************************

* DATAFILES : IN    FILE: <STDSPEC>,   <CURRSPEC>
*             OUT   FILE: <HARDSPEC>, <CURRSPEC>, <WCELLMAP>
*             TEMP  FILE:

* VARI. IN   : Global var.
* VARI. OUT  :
* LOCAL VAR  :
* TOTAL VAR  :

* LINK FROM : CIMMENU.CMD -> CONFIG.FMT ->CONFIG.FMT ->SYSCON.FMT
              -> here
* LINK TO   : Back to SYSCON.FMT
```

HELP FOR SYSTEM CONFIGURATION SPECIFICATIONS

This program allows you to generate a Current System Specification Table, on which the System Configuration will be based.

The specifications include Hardware & Configuration details, which are stored in <HARDSPEC> & <CURRSPEC> respectively. The Hardware specification includes

1. No. of machine
2. Type of machines
3. Operating system

The Configuration details include :

1. Machine name
2. Memory available
3. Winchester disk
4. Floppy disk
5. Function code
6. Drive no.
7. Description

You are allowed to copy details from a Standard speci. file into the current one, and then modify it to form a specific configuration. When quit, the system will form a specific configuration file <WCELLMAP> to be used only by work cells.

~~~~ End of ~~~~~~~~~~ [A33 CONFSPEC] ~~~~~~~~~~~~~~
~~~~

[A34] DISTSYS - DISTRIBUTE FILES AND PROGRAMS TO COMPUTERS

```
*A34** DISTSYS.HLP** DISTRIBUTE FILES AND MODULES IN SYSTEM *****
*                                                              *
*              EMBRYO CIM SYSTEM                By Andy Lung   *
*                                                              *
*   This is the Help function for DISTSYS.CMD and is called by *
*   it exclusively.  It is named .HLP but in fact is a .CMD file*
*   because of easy identification.                            *
*                                                              *
****************************************************************

* DATAFILES : IN  FILE: <HARDSPEC>,<CURRSPEC>,<MODEL-MP>,<FILE-MP>
*             OUT  FILE: SUBMIT file for each machine for      .
              configuration
*             TEMP FILE: TEMPDIST, TEMPSUB

* VARI. IN   : Global var.
* VARI. OUT  :
* LOCAL VAR  : Mfinished,Moption,Mmode,Msubname,Mmc:total,Mcount,
*    Moutname,Mdiskno,Mfunctcode,Mmodelname,Mfilename,Mdrive:no

* TOTAL VAR  : 25

* LINK FROM  : CIMMENU.CMD -> CONFIG.FMT -> SYSCON.FMT -> here
* LINK TO    : Back to caller
```

HELP FOR DISTRIBUTION OF SYSTEM MODULES AND FILES ACROSS NETWORK

This is a very important module, which does the actual distribution of System programs and data files to the appropriate networked machines. There are 2 parts of System Configuration, one is the distribution of unique programs and data files to Functional Cell networked machines, the other is the distribution of replicated programs and data files to Work Cell networked m/cs.

The program first reads in no. of machine from Hardware spec. file <HARDSPEC>, then the System Configuration details from Current spec. file <CURRSPEC>. It is then found out which Functional Cells are located at which machines and hence drives. Finally, from map files <MODEL-MP> and <FILE-MP>, details are extracted to identify what actual programs and data files have to be distributed to the exact machines.

The output from this program are Executable Submit files, one for each machine, which are executed at CP/M level to carry out the allocation of files.

```
* ~~~~~~~~~~~~~~~ DISTSYS.HLP ~~~~~~~~~~
```

APPENDIX B

SELECTED HELP AND OPERATIONAL INSTRUCTIONS FOR EMBRYO SYSTEM'S MODULE

SECTION B2

FUNCTIONAL GROUP B - CUSTOMER SERVICE

[B1] ORDERIN - SALES ORDER IN-TAKE PROCEDURES

```
** [B1 - ORDERIN.HLP] *** SALES ORDER IN-TAKE MODULE ***********
*                                                             *
*              EMBRYO CIM SYSTEM              By Andy Lung    *
*                                                             *
*  This is the Help Function for [B1-ORDERIN.CMD] which is for *
*  sales order in-take and control.  This progam is named .HLP *
*  for easy identification.                                   *
*                                                             *
*CIM TEST MODEL************************************************

* DATAFILES : IN   FILE: All files needed in [CUSTOMER SERVICE]
*      OUT  FILE: <MPSORDER>, <PRODINV>, <ORDER-NO>, <ORDER-BK>,
                  <SHIPMENT>, <INVOICE>, <ORDHIST>, <QUOTE>
*      TEMP FILE:

* VARI. IN  : Global var.
* VARI. OUT :
* LOCAL VAR :
* TOTAL VAR :

* CALL SUB-PROGRAMS :[MPSORDER] - display MPS order for a product
*                    [INSTANT]  - update related files when an
                     order for instant-delivery is accepted

* LINK FROM : CIMMENU.CMD -> CUSTOMER.FMT -> here
* LINK TO   : CUSTOMER.FMT
```

HELP FOR CUSTOMER ORDER INTAKE PROCEDURES

This is the 1st module in |CUSTOMER| menu and is the most important. It allows new orders to be taken, with the requested quantity and delivery date verified based on a forecast-balance allocation technique.

It is a very long program, though already some of its standard functions are done by calling a series of sub-programs or sub-modules. Examples of this are :

[MPSDISP] - subprogram to display information of MPS firm/reserve orders for a particular product so that new orders which delivery period are within MPS horizon can be inserted to fill the forecast- balance at that period.

[B41 PRODSCH] - submodule under |B4 PRODUCT SEARCH| menu. It searches for similar products based on some given selection criteria, and is executed when an exact product is not found at the initial order-entry.

Fore each sales order, the following will be analysised :

(1) Do they have quotation before?

(2) Is the customer new?

(3) Is it necessary to check the customer credit if it is not new?

(4) Is the product existing?

(5) Is a similar-product search necessary?

(6) What type of order it belongs to?

(7) If the order belongs to instant-delivery, is there enough free-stock?

(8) If the order is [INSIDE] MPS horizon, is there any space for the order to be inserted without affecting the MPS final total schedule?

(9) Is the acknowledgement needed to be sent?

(10) What files need to be updated in different situations?

The module begins with entering details for an initial order from the customer, this file is normally only used for reference. The system then checks if a quote is included in the details, which is then checked for its existence and validity. If a quote is checked all right, then it is simly a straight conversion from a quote into a firm order, whatever the delivery period belongs to.

If a quote is checked no longer valid, then it will be deleted automatically and all associated reserve will be released. These reserve could be MPS orders derived from forecast-balance, or could be free-stock reserved from available inventory.

Apart in here, invalid quotes are normally picked up by a separate module which should be executed reguraly, preferably at the end of each period.

If a quote is not included in the initial details, then the order will be analysized through a series of steps until it is confirmed, accepted, and all relevant files updated. These steps include most of the order-analysis shown in the previous help screen. Note that the system throughout is using a SYSTEM PERIOD rather than date for its judgement for delivery and planning. Requested delivery date has therefore to be converted into delivery period. It is up to the company to define its own standard. An example for this is the 52 weeks could be used as 52 periods.

There are a few assumptions that must be followed :

1) Only one product and one qty is for each order (i.e. one order no. ONxxx). An initial order, however, can be split to smaller orders accordingly.

2) In each fresh day, a start-up option must be run once in order to update the MPS orders.

3) If the order is instant delivery, it by-passs normal planning function and acknowledged, invoiced, scheduled to ship, inventory order history updated.

4) All orders in shipment schedule must have been already invoiced, stock-updated, order-history updated. orders in here are assumed complete.

5) A module to send out acknowledgement for newly accepted orders must be run reasonably regular and frequent.

6) Shipment assignment is run at the end of each period to allocate available stock for due orders. Delivery is assumed immediate after the run.

7) When MPS forecast-balance shows negative, it means the demand at that period already outstands the forecast-demand for that period. No new order is allowed to be taken for that period if the order qty is greater than the updated forecast balance for that period.

For each sale, if it is outside the MPS zone, order will be taken into the open order book directly and awaits to be processed. If inside MPS, then it has to be inserted into forecast-balance gap, be it in 'Frozen zone' or not. If it is instant-delivery, then physical stock and forecast-balance for current system period are both checked if they are favourable for the order.

* ~~~~~End of ~~~~~~~~~~ [B1 ORDERIN.HLP] ~~~~~~~~~~

[B41] PRODSCH - SIMILAR PRODUCT SEARCH PROCESS

```
*B41 [PRODSCH.HLP] **** SIMILAR PRODUCT SEARCH *****************
*                                                              *
*               EMBRYO CIM SYSTEM                By Andy Lung  *
*                                                              *
*  This is the Help Function for [B41 PRODSCH], which is to    *
*  locate similar products from an existing 'product-search'   *
*  database by giving some selection criteria.  This program   *
*  is named .HLP for easy identification.                      *
*                                                              *
*CIM TEST MODEL*************************************************

* DATAFILES : IN  FILE: S:<SCHLABLE>, P:<PRODSCH> INDEX (PRODSCH)
*             OUT  FILE:
*             TEMP FILE: <TEMPSCH>

* VARI. IN  : Global var.
* VARI. OUT :
* LOCAL VAR : Mfinished,Mmode, Moption, Myesno, Mprod:no, Mspec1,
*             Mspec2,Mspec3,Mspec4, Mspec5,Mdescript, Msearchsum,
*             Mcomplete, Mline, Meof, Mrecdno, Mentry

* TOTAL VAR : 37 (include G var)

* LINK FROM : CIMMENU.CMD -> CUSTOMER.FMT -> SEARCH.FMT -> here
* LINK TO   : SEARCH.FMT
```

HELP FOR SIMILAR PRODUCT SEARCH

This is a module under |PRODUCT SEARCH| menu. It locates products which satify all the selection criteria entered prior to searching process. Although this module is grouped under the |PRODUCT SEARCH| menu, it could be called in by any other modules which need a 'similar product' search.

The search facility here is very powerful and flexible. User can define a total of 5 specifications that best describe each of his products. The lables (definitions) for these 5 specifications are stored in a file <SPCLABEL>. He must also store all his existing products (or as much as he wants) into a search database called <PRODSCH>, by inputing the 5 specifications for each product.

These specifications will then be used during the search so that matched records will be selected. The setting up of the Specification-Labels in <SPCLABEL> file and the converting of existing products into useful search data held in <PRODSCH> database is a once and for all job. After this done, user can select whatever products by providing 'searching criteria' in part or in full.

These search criteria include :

1. Product no. 2. Description 3. Spec - 1 to 5. These can be entered in part or in full, according to the accurarcy of search desired. Then the search will locate all products which have these features (or satisfied these specifications).

Search results are stored in a temporary file <TEMPSCH>, which can then be listed or printed. The flexibility as such will allow user to re-define the product features that best suit his products. This is done by deleting all the 5 labels in file <SPCLABEL> and input another 5 new labels. The existing details in the search database <PRODSCH> must be modified (or totally re-created) to reflect the new product specifcations.

Thus, the use of this module can be very flexible and user-tailorable. It is particularly useful when an exact product doesn't exist, and the customer wants to search through the existing products based on different combinations of criteria to see if there is one that fits and place an order.

* ~~~~~End of ~~~~~~~~~~ [PRODSCH.HLP] ~~~~~~~~~

APPENDIX B

SELECTED HELP AND OPERATIONAL INSTRUCTIONS FOR EMBRYO SYSTEM'S MODULE

SECTION B3

FUNCTIONAL GROUP C - DESIGN ENGINEERING

[C11] BOMGEN - CREATE NEW BILL OF MATERIAL DETAILS

```
*[C11] BOMGEN.HLP **** CREATE NEW BOM ***************************
*                                                               *
*              EMBRYO CIM SYSTEM               By Andy Lung     *
*                                                               *
*  This is the Help function for [BOMGEN] which is for the      *
*  generation of new BOM detail.  The Help function is named    *
*  .HLP because of easy identification.                         *
*                                                               *
*****************************************************************

* DATAFILES : IN   FILE: <BOM>
*             OUT  FILE: <BOM>
*             TEMP FILE: <TEMPBOM>

* VARI. IN  : Global var.
* VARI. OUT :
* LOCAL VAR : Mfinished,Mcolor, Moption,Mmode, Mprod:no, Mguide,
*             Mtotalno, Mline, Mcol, Mcount, Mpart:no, Mparent,
*             Mqty, Mld:time, Mlevel, Mendmark, Myesno

* TOTAL VAR : 34 (include G. var)

* LINK FROM : CIMMENU.CMD -> DESIGN.FMT -> BOM.FMT -> here
* LINK TO   : BOM.FMT
```

HELP FOR GENERATION OF NEW BOM DETAIL

This module is to generate new 'BILL OF MATERIAL' details for a new product. Each new product in term of 'DESIGN' will require additional detail in <PRODUCT>, <BOM>, <PROCESS PLAN> & <STANDARD COST> files. All these can be prepared in one go, in the option [C31] - create new product details. Or, these can be prepared separately by calling appropriate modules in correct sequence.

For a special reason, the BILL must be entered in a specific pattern; this module offers a 'Entry Guide' option for the user to create a new BILL much easier. The user first inputs Part no. only for all 'Elements' in the product-tree, these 'Elements' are stored in a TEMP file, and will then prompt for more detail for each of them later on. This has split the tedious procedures of entering the entire BILL in one goal, frequently causing confusion and forgetting where the entry was last up to. This 'Entry Guide' can be skipped if the user want to input full details of the entire BILL in one go.

```
* ~~~~~~~~~~~ End of ~~~~~ BOMGEN.HLP ~~~~~~~~~~
```

[C21] PROCTEPT - PROCESS ROUTES DETAILS TEMPLATE MAINTENANCE

```
*C21 PROCTEPT.HLP *** HELP FOR PROCESS TEMPLATE MAINTENANE ******
*                                                              *
*             EMBRYO CIM SYSTEM                 By Andy Lung   *
*                                                              *
*  This is the Help function for [PROCTEPT] which is for       *
*  maintenace of data in <PROCTEPT> file, storing all standard *
*  operations available on the shop floor.  This is named .HLP *
*  for easy identification of the call.                        *
*                                                              *
****************************************************************

* DATAFILES : IN   FILE: <PROCTEPT> INDEX <PROCTEMP>
*             OUT  FILE: <PROCTEPT>
*             TEMP FILE: <TEMPPCTP) INDEX <TEMPPCTP>

* VARI. IN  : Global var.
* VARI. OUT :
* LOCAL VAR : Mfinished, Moption, Mmode, Mcomplete,Mline, Mentry,
*             Mlast:page, Mlast:rec, Mrecd:no, Mpage, Mop:no,
*             Mwcell:no,Mop:desc,Mendedit,Msprint,Meprint, Myesno

* TOTAL VAR : 35 (include G var)

* LINK FROM : CIMMENU.CMD -> DESIGN.FMT -> PROCESS.FMT -> here
* LINK TO   : PROCESS.FMT
```

HELP FOR OPERATIONS TEMPLATE MAINTENANCE

This is a rather new feature to aids process planning. The module allows the user to store all standard available operations (machining or assembling) in a library (template) so that he could select combination of operations from there to create new process routes.

During the process of creating new process routes, the user can switch on or off this Template for reference, and he can at any time include new operations not found in the Template. All master data is stored in file <PROCTEPT>, and is copied to a <TEMP> file for manipulation. At the end, he can select to quit all changes done without updating the master <PROCTEPT> file. During the process, all stored operations will remain on the screen for direct reference and updating.

```
* ~~~~~~~End of ~~~~~~~~ PROCTEPT.HLP ~~~~~~~~~~
```

[C22] PROCGEN - CREATE NEW PROCESS ROUTE DETAILS

```
*C22 PROCGEN.HLP *** GENERATE PROCESS ROUTES ********************
*                                                              *
*               EMBRYO CIM SYSTEM                By Andy Lung  *
*                                                              *
*  This is the Help function for [PROCGEN.CMD] which is for the *
*  creation of new process route for either a single           *
*  sub-assembly or an entire product.   This program is named  *
*  .HLP for easy identification.                               *
*                                                              *
****************************************************************

* DATAFILES : IN FILE: P:<PROCESS> INDEX <PROCESS>, S:<BOM> INDEX
*                        <BOMLEVEL>, S:<PROCTEPT> INDEX <PROCTEPT>
*           OUT  FILE: P:<PROCESS>
*           TEMP FILE: S:<TEMPBOM>

* CALL PROGRAM : PROCGEN1

* VARI. IN   : Global var.
* VARI. OUT  :
* LOCAL VAR  : Mfinished, Moption, Mmode, Mstartline, Mproctept,
*              Mprod:no, Mbomrecd, Mpart:no, Moverwrite, Mop:no,
*              Mop:desc, Mwcell:no,Mset:tme, Mprod:time,Mlb:grade,
*              Mscraprate, Mlast:updt, Mok, Mcol, Mendadd, Mline

* TOTAL VAR  : 39 (include G var)

* LINK FROM  : CIMEMNU.CMD -> DESIGN.FMT -> PROCESS.FMT -> here
* LINK TO    : Back to caller
```

HELP FOR GENERATION OF NEW PROCESS ROUTES

This is one of the modules under PROCESS PLANNING menu, and is for the generation of new process routes for either a single sub-assembly or an entire product.

If the process route for the whole product is to be created, the program will read the entire product-bill from <BOM> file along which each sub-assembly will be explored (not end-component). The option for single sub-assembly requires user to input an sub-assembly part number each time. Both options will check each sub-assembly if they already exist in the master <PROCESS> file; the user could overwrite the old process route for that sub-assembly if so wished. The user can also optionally switch on or off the <PROCESS TEMPLATE> which will give the defaulted information for any chosen available operations.

```
* ~~~~~~~End of ~~~~~~~ PROCGEN.HLP ~~~~~~~~~~
```

[C41] STDCGEN - STANDARD COST DETAILS GENERATION

```
*C41 - [STDCGEN.HLP] ** INSTRUCTIONS FOR STANDARD COST GENERATION
*                                                                 *
*              EMBRYO CIM SYSTEM                 By Andy Lung     *
*                                                                 *
*  This is the Help function for [STDCGEN] which is to generate   *
*  standard cost (std labour, materail & o/h) for each            *
*  sub-assembly of a new product, and also to sum these cost to   *
*  update the cost details in <PRODUCT> file.  This program is    *
*  named .HLP for easy identification.                            *
*                                                                 *
*CIM TEST MODEL****************************************************

* DATAFILES : IN FILE: P:<PRODUCT> (PRODUCT),P:<SCTRACK> (SCTRACK),
                       P:<BOM> (BOMLEVEL), P:<PROCESS> (PROCESS)
* S:<ENDPART> (ENDPART),S:<LB-RATE> (LB-RATE),S:<OH-RATE> (OH-RATE)
*             OUT  FILE: S:<STDCOST>, P:<SCTRACK>, P:<PRODUCT>
*             TEMP FILE:

* VARI. IN  : Global var.
* VARI. OUT :
* LOCAL VAR : Mfinished, Mmode, Moption, Mover:cost, Mmat:cost,
*             Mlab:cost,Mtotalcost, Mprod:no,Mbompoint, Mbomskipno
*             Msumlabour, Msummat, Msumoh, Mpart:no, Mprocessok,
*             Mprocessin, Mlb:grade, Mendpartno, Mline, Mchoice

* TOTAL VAR : 39 (include G var)

* LINK FROM : CIMMENU.CMD -> DESIGN.FMT -> STDCOST.FMT -> here
* LINK TO   : Back to caller
```

HELP FOR STANDARD COST ESTIMATION OF A NEW PRODUCT

This is a very important module under |STANDARD COST| menu. It allows you to generate standard costs for a 'new product' - a product which hasn't yet gone through this cost-estimation process.

The program actually estimates std costs of labour, material & overhead for each sub-assembly of that product, and updates the std costs for that part in <STANDARD COST> file. These std costs in turns will be summed up to give the total std cost detail for that product, and will be used to update the product cost details in <PRODUCT> file.

Prior to run this module, some important data about this 'new product' must be first prepared in the files :

1) <PRODUCT> - general product details

2) <BOM> - product structure

3) <PROCESS> - operation details for each sub-assembly in the bill

4) <LB-RATE> - pay rates for the labour-grades associated with the operations

5) <ENDPART> - unit costs for end components used by the product

6) <OH-RATE> - fixed overhead cost attached to sub-assemblies wherever applied.

This module, however, provides certain degree of flexibilty for handling missing information. The working principle of this program is as follow :

1) Checks if the product has already gone through this cost estimation before

2) Checks if product detail available for this product in <PRODUCT> file

3) Checks if product structure available in <BOM> file.

When the above information is checked available, the program will then allow the user to make up any missing data required by the following processes :

4) If operation(s) for a part is missing, the user can either quit altogether and prepare the missing data separately, or he can input the data now through dBASE. The new operations will be added into <PROCESS> file.

5) If pay-rate for a particular labour-grade is missing, the user must input that rate right away. The new rate will be added into <LB-RATE> file.

6) If the unit cost for an used end-component is missing, the user must input the unit cost right away. This will update the <ENDPART> file.

The program estimates std costs (labour, material, o/h) for each sub-assembly based on the following principle :

It reads each sub-assembly from the <BOM>, and reads all operations for this part from <PROCESS>. Std labour cost = SUM (production time x labour rate) Then it locates all end-components used by this part from the <BOM>, and checks their unit costs from <ENDPART>. Std material cost = SUM (qty x unit cost) Finally, it checks if there is any overhead cost attached to this part from <OH-RATE> file. If not, zero std overhead cost will be assigned.

The std labour, material and o/h costs will be appended to <STDCOST> file, and the program will continue to read the rest sub-assemblies and repeat same calculation for each. When all parts are finished, their std costs will be totaled to give total std labour, material and o/h costs for the product. The relevant cost details in <PRODUCT> file will be updated. The product no. will be stored into file <SCTRACK> - standard cost tracking, so that next time it will not repeat cost estimation for the same product."

* ~~~~~~End of ~~~~~~~~~ STDCGEN.HLP ~~~~~~~~~~

APPENDIX B

SELECTED HELP AND OPERATIONAL INSTRUCTIONS FOR EMBRYO SYSTEM'S MODULE

SECTION B4

FUNCTIONAL GROUP D - CENTRAL PLANNING

[D51] DISTMPS - DISTRIBUTE CENTRAL MPS DATA INTO WORK CELLS

```
*[D51 DISTMPS.HLP ***** TO DISTRIBUTE CENTRAL MPS DATA **********
************** INTO WORK CELLS ACROSS LAN ***********************
*                                                                *
*               EMBRYO CIM SYSTEM               By Andy Lung     *
*                                                                *
*   This  is  the Help Function for [D51  DISTMPS]  which  is to*
*   classify the central MPS details into the local W.C. they   *
*   should belong to, and physically distribute these classified*
*   details across the LAN into their destinated Work Cells.    *
*   This Help program is named .HLP because of easy             *
*   identification.                                             *
*                                                                *
*CIM TEST MODEL**************************************************

* DATAFILES : IN   FILE: <MPSFROM>, <CMPSSTRU>, <MPSORDER>,
              <BOM> (BOMLEVEL), <PROCESS>, <WCELLMAP>, <PRODINV>
*             OUT  FILE: ONE <CMPS-?> FOR EACH W.C., <MPSORD-?>,
              <WCELLMAP>, <MPSFROM> SENT ACROSS NETWOKR
*             TEMP FILE: <TEMPCMPS> FILE IMMD DELETED AFTER USE :
              <TEMPD511>, <TEMPD512>, <TEMPD513>
* UPDATE :    UPDATE <PARTINV?> IN LOCAL W.C. BY EACH PRODUCT IN
              CENTRAL <PRODINV>

* VARI. IN  : Global var.
* VARI. OUT :
* LOCAL VAR : Mfinished, Moption, Mmode, Myesno, Mperiod:fr,
*             Mperiod:ed, Mwcid, Mmpseof, Mmpsrecdno, Mprod:no,
*             Mpart:no, Mline, Mdrive:no, Mtowcid, Mwcell:no,
*             Mfree:qty, Mdescript
* TOTAL VAR : 36 (include G var)

* LINK FROM : D |CENTRALP| -> D5 |WCSUPER| -> D51 [DISTMPS]
* LINK TO   : D5 |WCSUPER|
```

HELP FOR DISTRIBUTION OF CENTRAL MPS DATA INTO THEIR DESTINATED WORK CELLS

This is the Distribution module-1 under the sub-menu |WORK CELL SUPERVISOR| which is in turn under big menu |CENTRAL PLANNING|. The main function of this module is to distribute the Central MPS orders information of different products into the local database of various work cells which make them there.

When a new MPS horizon is re-generated (or updated) with appropriate orders, the data is stored in the central file <MPSORDER> which should then be distributed down onto the various Work Cells for later local MRP operation. The working principle of this module is : it will read each type of products from <MPSORDER>, then from <BOM> and <PROCESS>, its final assembly work cell is identified. All orders for this product are then copied onto a temporary MPS file which is named and dedicated to a particular work cell.

Each available W.C. would therefore have such a temporary MPS file at the end of the run which were already emptied at the ~~beginning so that they are now holding latest MPS order~~ information.

The above process repeats for all types of product in <MPSORDER>, and there be at the end a dedicated temporary MPS file for each work cell.

When all these temporary MPS files are ready, the user will be given a chance to print the content of these files for further reference. Then the system will display the current Work Cell Map <WCELLMAP> for the locations (drive no.) of the available work cells in the network configuration.

The system will distribute information in each of these temporary MPS files, even some of them may be empty becasue of no demand for that product, to their destinated drives assigned for each work cell through the use of network. Once the newer information is distributed to the work cells, all previous local MPS data will be overwritten.

After the distribution has finished, individual work cells can then carry out their local MRP operation. The sequence of carrying out the local MRP operation must be carefully designed, so that the chain-reaction from one W.C.'s MRP can be linked to the next affected W.C.'s MPS, and the chain-reaction goes on.

It is important to note that BOM and ROUTING details have also to be distributed from Central Planning database onto the various Work Cells local database for the use in local MRP calculation. However, they do not need be distributed everytime along with the new MPS information, unless there are changes in these details.

Both distributed BOM and ROUTING details will be held permanently in the local database in each Work Cell until the next similar distribution takes place. This module is recommended to be executed after new MPS horizon with orders has been reformed. However, the repititon of this module alone won't change the content of those resulted files as long as the initial input files haven't changed.

It is highly recommended that hard copies, whenever available, should be chosen for reference purpose.

It is worth noticing that apart from MPS data being distributed to their destinated W.C., there are also other information distributed along with MPS data across the network. Two files, namely <WCELLMAP> and <MPSFROM>, will be copied to each W.C. to overwrite their previous version there.

Note that the file <MPSFROM> has recorded the latest MPS horizon which is required in W.C. local MRP operation. The file <WCELLMSP> records the latest information about the system configuration details of various work cells; this information is rarely to be changed.

Also sent along with MPS data into the destinated work cells is the updated inventory status for each product (or sellable part) in central MPS. This will update the local part inventory with the product's latest available free qty which is needed during the local MRP operation.

* ~~~~~End of ~~~~~~~~~~ [D51 DISTMPS.HLP] ~~~~~~~~~~

[D52] DISTBMRT - DISTRIBUTE BOM DETAILS AND PROCESS ROUTE DETAILS

```
*[D52 DISTBMRT.HLP] ** DISTRIBUTION OF CENTRAL BOM /ROUTING *****
************************  DETAILS INTO LOCAL WORK CELLS *********
*                                                              *
*           EMBRYO CIM SYSTEM                   By Andy Lung   *
*                                                              *
*  This is the Help Function for [D52 DISTBMRT.CMD] which is to *
*  analysize the centrally held BOM & ROUTING details based on  *
*  available W.C. and distribute to them the result of analysis.*
*  This program is named .HLP in here because of easy           *
*  identification.                                              *
*                                                              *
*CIM TEST MODEL*************************************************

* DATAFILES : IN   FILE: <WCELLMAP>, <BOM>, <PROCESS>, <CBOMSTRU>
*             OUT  FILE: <CBOM-?> & <CROUTE-?> for each W.C, and
              become <BOM-?> & <ROUTE-?> after distribution
*             TEMP FILE: <TEMPCBOM>, <TEMPCROT>, <BOMBK>

* VARI. IN  : Global var.
* VARI. OUT :
* LOCAL VAR : Mfinished, Moption, Mmode, Myesno, Mwcid, Mbomrecdno,
*         Mbomeof, Mprod:no, Mbombkno, Mpart:no, Mlevel, Mwcell:no,
*         Mparent, Mrecdno, Mwcell:no2, Mendentry, Mentry, Mline,
*         Mdrive:no, Mtowcid
* TOTAL VAR : 40 (include G var)

* LINK FROM : CIMMENU.CMD -> D |CENTRALP| -> D5 |WCSUPER|
              -> D52 here
* LINK TO   : D5 |WCSUPER|
```

HELP FOR DISTRIBUTION OF CENTRAL BOM/ROUTING DATA INTO LOCAL WORK CELLS

This is the module-2 for data distribution from the central database into the work cells local databases. The main function of this module is to break the central BOM details of each product into work- cell-process orientated partial BILL, based on the work cell configuration in which the part is made, i.e., those parts of a product which are made in the same work cell are grouped together, and distributed into their destinated W.C. local databases.

Routing detail of each part will also be sent along with partial BOM to the W.C. The working principle is : The system will read the complete BOM of each product from the central <BOM> database, then with the aid of information from centroal <PROCESS> file, each part in the Bill is located with its manufacturing work cell. The first part that has been read in is regarded as a final sub-assembly and all the subsequent parts are then read in in the order of bill-level.

Those that they themselves are made, or their parents are made, in the same work cell as the final sub-assembly will be collected under a temporary BOM file, and their routing details will also be stored in a separate temporary ROUTE file. When all parts are finished, the end results are the two temporary files which will then be added onto another two centrally held temporary files named <CBOM-?> and <CROUTE-?> respectively.

These <CBOM-?> & <CROUTE-?> file are the preparation files which are finally to be distributed to their destinated work cell later when ready. The system will then read back hose parts that have been grouped into the same work cell, and check either if they are actually made there or if they are end-components, if so the part number will be used to delete the same part from the original but temporary product structure, leaving the rest of the structure which will have to go through the same process again in order to generate another two <CBOM-?> and <CROUTE-?> for another work cell.

When the whole product is completed, another product will be read from the central BOM database and the above procedures are repeated again. At all products are finished, there should be a <CBOM-?> and a <CROUTE-?> for each work cell. These files will be distributed to their destinated work cells' local databases and overwrite the relevant previous contents there.

Note that it is important to keep the work cells' local databases up-to-date so that accurate result can be obtained from local MRP operation. As mentioned earlier, this module only have to be executed once. It is only needed to be done again should there are changes in either BOM or PROCESS details for product(s).

The entire part-analysis and distribution process will take long time, as each product is broken into their individual parts and re-gathered according to their operation work cell. It is, however, not disastrous if this module is executed again and again without any actual changes in the central BOM & ROUTING details.

The end result files, the various <CBOM-?> and <CROUTE-?>, will be exactly the same and therefore cause no harm at all even distributed to their work cells. It is just a bit waste of time, and that is.

The system will check automatically if any part details already exist in any of <CBOM-?> or <CROUTE-?> from the previous cumulated data. If so, the system will not add the part details in to avoid repetition.

When the system has finished the part-classification and generated the necessary <CBOM-?> and <CROUTE-?> files, there is a chance given to print all the content of these files for reference purpose, or even as a judgement whether to go ahead the actual distribution or not.

The actual distribution of Work-Cell localized BOM & ROUTING details does not take long. However, it is important that the network system should be operating when the distribution takes place.

Because of the nature of data, both localized BOM and ROUTING details will have been indexed through this module, and these index files will also be distributed along their parent files to the destinated work cells. The order that they are indexed is identical to that their central data were indexed, i.e., partial BOM will be indexed on Product no. and bill level, and localized ROUTING will be indexed on Part no. and operation no.

* ~~~~End of ~~~~~~~~~~~ [D52 DISTBMRT.HLP] ~~~~~~~~~~

APPENDIX B

SELECTED HELP AND OPERATIONAL INSTRUCTIONS FOR EMBRYO SYSTEM'S MODULE

SECTION B5

FUNCTIONAL GROUP E - CONTROL IN WORK CELLS

[E11] MPSPREP - LOCAL MPS FILE PREPARATION

```
*[E11 MPSPREP.HLP] ** INSTRUCTIONS FOR MPS PREPARATION BEFORE ***
*****  MPR RUN **************************************************
*                                                               *
*               EMBRYO CIM SYSTEM                By Andy Lung   *
*                                                               *
*  This is the Help function for [E11 MPSPREP.CMD] which allows *
*  user to prepare the MPS details in the form for the next MRP *
*  run.  This module is named .HLP for easy identification.    *
*                                                               *
*CIM TEST MODEL**************************************************

*  DATAFILES   : IN FILE: <MPSORD-?> distributed from central MPS,
                 <MPSMIX-?>
*                OUT  FILE: <MPSLONG?>
*                TEMP FILE: <TEMPMPS?>

* VARI. IN   : Global var.
* VARI. OUT  :
* LOCAL VAR  : Mfinished, Mmode, Moption, Mwcid, Myesno, Mline,
*              Mperiod:fr, Mperiod:ed, Mperiod, Mprod:no, Meof,
*              Mnewprodno, Mcount, Myy, Mww, Mperiodqty, Msum

* TOTAL VAR  : 36 (include G var)

* LINK FROM  : |MAIN MENU| -> |E WORK CELL| -> |E1 LOCALMRP| ->
               [E11 MPSPREP]
* LINK TO    : Back to caller
```

HELP FOR MPS SUMMARISATION PROCESS PRIOR TO NEXT MRP RUN

This is a very important module under menu |LOCALMRP| which is for local MPS and MRP looping procedures. This module here will prepare necessary MPS information which will be used in the next local MRP run. Note that in normaly circumstance this has only to be done once.

When central MPS is executed, new MPS horizon with appropriate orders and forecasts would be reformed, and the result is then distributed to the work cells based on the product routing details. All MPS orders and forecasts will be transfered to the work cells which perform their first process, in accordance with their BOM and ROUTING details. This module is to summarise the MPS data which has been distributed from the central MPS, and also takes into account those part requests which has been sent by other work cells during their local MRP run. The result of summarisation is stored in file <MPSLONG&Mwcid>. This file will be used in the next MRP run which can be executed in another module.

It is perfectly alright if the MPS preparation process has been repeated by accident, as this won't affect the result in <MPSLONG&Mwcid>. However, it should only be executed once for each MRP exercise, no matter how many time the MRP operation has been executed, until a satisfactory result is archived. This module will read off all the part-requests of other cells from the file <MPSMIX-&Mwcid> and empty it. Then it scans for each product in the <MPSORD-&Mwcid> file and summarise the order qty for each MPS period-0.

Other options in this module includes [R] - print current MPS result, it prints the current content in file <MPSLONG&Mwcid>, and will be outdated if this option is chosen before running the MPS preparation process. Option [O] - print current orders in the file <MPSORD-&Mwcid>. Again, if the MPS preparation process has been run, it will include part-request from other cells, otherwise it only includes orders distributed from the central MPS file.

* ~~~~~End of ~~~~~~~~~~ [E11 MPSPREP.HLP] ~~~~~~~~~~

[E13] MRPRUN - LOCAL MRP RUN

```
*[E13 MRPRUN.HLP] ************ LOCAL MRP RUN ********************
*                                                               *
*              EMBRYO CIM SYSTEM                 By Andy Lung   *
*                                                               *
*  This is the Help Function for [E13 MRPRUN.CMD] which allows  *
*  user to carry out the MRP execution.  This module is named   *
*  .HLP for easy identification.                                *
*                                                               *
*CIM TEST MODEL**************************************************

* DATAFILES : IN    FILE: <MPSLONG?>, <PARTINV?>, <ONORDER?>,
*                   <ONBUY-?>, <BOM-?>, <ROUTE-?>, <WCELLMAP>
*  OUT  FILE: <WKORDER?>, <TEMPWC-?>, <TEMPBUY?>, <MRPWKOD?>
*  TEMP FILE: <GROSS-?>, <TEMPBOM?>, <MRP-?>, <TEMP?>, <TEMPMRP?>,
*             <TEMPAML?>

* VARI. IN   : Global var.
* VARI. OUT  :
* LOCAL VAR  : Mfinished, Moption, Mmode, Mwcid, Mperiod:fr,
*              Mperiod:ed,Mpart:no,Mparent, Mqty,Mlevel, Mld:time
*              Mendmark, Mrecdno, Mtimeno, Moh,Mq1 -> Mq10,Mp1:qty,
*          Mendno, Mmonitor, Mcol, Mline,Mwcell:no,Mtowcid, Myy,Mpp
* TOTAL VAR  : 55 (include G var)

* LINK FROM  : |MAIN MENU| -> |E WORKCELL| -> |E1 LOCALMRP|
               -> [E13 MRPRUN]
* LINK TO    : Back to caller
```

HELP FOR LOCAL M.R.P. EXECUTION

This is a very important Local module in Work Cell planning and control. It is mainly to carry out the Material Requirement Planning for that work cell, based on the local data and details about Master Production Schedule which have been distributed from the Central Planning, and the part requests from other work cells.

The overall MRP operational concept is simple, though the module structure and data links between Central Planning and various work cells is very complicated. The no. of files involved is large, and the transactions between them is very complex.

Anyway, the overall MRP explosion has been simplified because of the distribution, and can therefore be executed in each local work cell. This is the author's philosophy. The entire MRP process will be restricted within the cell, and will only access data from, or transfer data to, other work cells (foreign cells) when the parts are made outside there.

In each work cell, the MRP run will use local data within that cell. These data would be distributed from the central modules when central MPS function is executed from time to time. When the central MPS module is executed, new MPS horizon together with appropriate orders and forecasts would be reformed, and then ~~distributed to the work cells, based on the product routing~~ details.

All MPS orders and forecasts will be transfered to the work cells which perform their first process, in accordance with their BOM and ROUTING details. BOM details and ROUTING details are distributed to these cells separately, according to its process details. When all initial data has been distributed to the work cells concerned, MRP process is then executed locally in each cell. In each work cell, <MPSLONG?> should be first formed by using module [E11 MPSPREP] and edited by the module [E12 MPSEDIT]. Each product is then read from that file, and all its sub-assemblies and parts will go through the MRP process.

Results are recorded in some temporary local files, namely the <TEMPBUY&Mwcid> for bought-in end components, the <WKORDER&Mwcid> for parts manufactured locally, and the part-requests to other work cells are stored in <TEMPWC-?> for each work cell involved. Before the MRP begins, the system will ask if you want to monitor the MRP process by printing the MRP result for each part. It will of course slow down the system a little bit. But the advantage is that you can trace the MRP calculation for each part.

The important concept in distributed planning and control is : during the MRP running, if there is a part read from the product's BOM that it has to be manufactured in an exteranl cell other than locally, the module will automatically store these details into a separate TEMP file which is unique for each external work cell. These TEMP files will be taken into account by those cells as part of there local MPS, when this MRP run is satisfactory.

During the MRP process for each part, three other local files are accessed. They are <ONORDER&Mwcid> for the due in local parts, <PARTINV&Mwcid> for the latest inventory on-hand details, and <TEMPBUY&Mwcid> is for the due in bought-in parts. These files are all maintained under the |STOCK CONTROL| menu. They can either be prepared manually, or automatically from the existing data, depending on the sophistication of the work cell control system. Anyway, the links are already designed and are there. It should be just the matter of enough development time to automate all these data preparations. Modifications of this module now allows same part appears more than once in a single product bill. Also, the same part can exist in more than one product in the same work cell. All the results in which are stored in file <WKORDER&Mwcid> & <TEMPBUY&Mwcid> have already been totalled based on the part no.

When the MRP is finished executed each time, the user has to decide whether the results are satisfactory. He can use these data to do some short term Capacity Planning in order to make the decision. If he is not happy with the results, whether he has done the short term Capacity Planning or not, he can always go back to module [E12 MPSEDIT] and edit the current MPS details. Then he can run the MRP again, and therefore can repeat the optional Capacity Planning, until he is satisfied with all the results. When he has decided this is the final MRP run, then he should run module [E17 - FIRMMRP] in order to confirm all the temporary files so created during the MRP process, so that the system will use these files to update the master local data files.

Note this program may take quite a while to finish all the products demand details in the MPS file. It is however, drastically faster than a centralized MRP run which has to consider all the products in the central file.

* ~~~~~End of ~~~~~~~~~~ [E13 MRPRUN.HLP] ~~~~~~~~~~

[E51] WIPUPDT - WORK-IN-PROGRESS DETAILS UPDATE

```
*[E51 WIPUPDT.HLP] ******* WORK-IN-PROGRESS DETAILS UPDATE ******
*                                                              *
*              EMBRYO CIM SYSTEM                 By Andy Lung   *
*                                                              *
*  This is a Help File for module [E51 WIPUPDT.CMD] which allows*
*  user to update the operation details in the local WIP file.  *
*  This is named as .HLP for easy identification.              *
*                                                              *
*CIM TEST MODEL*************************************************

* DATAFILES : IN    FILE: <WIP-?>
*             OUT   FILE: <WIP-?>,<LSD-?>, <ISSUEWO?>, <PARTINV?>,
*                         <ENDWKOD?>
*             TEMP FILE: <TEMPWIP?>

* VARI. IN   : Global var.
* VARI. OUT  :
* LOCAL VAR : Mfinished, Moption,Mmode, Mwcid, Mwork:no, Mpart:no,
*    Mord:qty, Mline, Mendupdt, Mallfinish, Mop:no, Mact:qty,
*    Mact:prod, Mact:over,Mfindate,Myesno, Mfinishqty, Mfinishdat

* TOTAL VAR : 38 (include G var)

* LINK FROM : |MAIN MENU| -> |E WORK CELL| -> |E5 WIPMAIN| ->here
* LINK TO    : Back to caller
```

HELP FOR WORK-IN-PROGRESS DETAILS UPDATE

This is an important module under the Work-In-Progress maintenance sub-menu |E5 WIPMAIN|. It actually allows user to update all the operation details for those launched works orders which should have their routing records in the local WIP file <WIP-?>. These WIP records are generated when work orders were released into the shop floor.

User has to update the WIP records at regular intervals, or ideally is as soon as each operation is finished. When each work order is released, the system has always assigned a final allowance opertion which number is '9999' to each of them. The module here here will detect this operation no. '9999' as a completion symbol for a works order. That is, when the user updates the operation '9999' and finish it, the system will interpret the whole work order is finished, and will ask the ser if he wants to delete all the relevant details associated with this order n other files.

The user first has to enter a work no. for update, then he updates those operations which have been finished for that order. The system will repeat the process until there is no more operation he wants to update. All entered data has been put into a TEMP file. Finally the system will ask to confirm if he wants to update the master <WIP-?> file with those TEMP data. The system at this stage will detect the operation no. '9999' if it has been finished. If '9999' is detected finished, the system will remind the user about this before it deletes and updates all the relevant files for that order.

The system will also copy the operations details of the completed work order into a file called <ENDWKOD&Mwcid> for further reference. Other options include <A> to list all unfinished work orders in the <WIP-&Mwcid> file, <D> to display the operation details for a work order, and <P> to print the operation details for a work order.

* ~~~~~~~End of ~~~~~~~~ [E51 WIPUPDT.HLP] ~~~~~~~~~~~

APPENDIX C

SUMMARY OF SYSTEM FILES AND DATA FILES USED IN THE EMBRYO SYSTEM

APPENDIX C: SUMMARY OF SYSTEM FILES AND DATA FILES USED IN THE EMBRYO SYSTEM

SECTION 1: SUMMARY OF ESSENTIAL SYSTEM MODULES

```
C: CONFIG   FMT : STRUFILE FMT : STRUGEN  CMD : STRUMOD  CMD : STRUMOD  HLP
C: STRUGEN  HLP : STRUDEL  HLP : STRUDEL  CMD : STRFLP   HLP : STRFLP   CMD
C: STRUVIEW CMD : STRUVIEW HLP : FILEMAN  FMT : FILELIST CMD : FILELOG  CMD
C: DATAMOD  CMD : FILELIST HLP : FILELOG  HLP : DATAADD  CMD : DATAMOD  HLP
C: DATALP   CMD : DATALP   HLP : SYSCON   FMT : SYSMAP   HLP : SYSMAP   CMD
C: CHKMAP   CMD : CHKMAP   HLP : CONFSPEC CMD : CONFSPEC HLP : DISTSYS  CMD
C: DISTSYS  HLP : DISTCELL CMD : CALENDAR FMT : CALENGEN HLP : CALENMOD HLP
C: CALENMOD CMD : CIMMENU  FMT : CALENPRN HLP : HOLIMAN  CMD : HOLIMAN  HLP
C: HOLIPRN  CMD : HOLIPRN  HLP : COMPANY  DBF : COMPANY  CMD : COMPANY  HLP
C: CALENGEN CMD : CURRSPEC CMD : CIMINIT  CMD : CIMSIGN  CMD : INITNAME CMD
C: CIMDATE  CMD : CIMDELAY CMD : CIMERASE CMD : CIMNOTE  CMD : CALENPRN CMD
C: CIMMENU  CMD
      56 File(s)   157696 bytes free
```

Major modules in System Configurator Cell (A)

```
C: ORDERIN  CMD : ORDERIN  HLP : CUSTENQY CMD : CUSTENQY HLP : CUSTENQY DBF
C: CUSTENQY NDX : ORDCHNGE HLP : ORDCHNGE CMD : PRODSCH  DBF : PRODSCH  NDX
C: PRODSCH  CMD : PRODSCH  HLP : SCHPDIN  HLP : SCHPDIN  CMD : SCHMAIN  HLP
C: SCHMAIN  CMD : CUSTOMER FMT : SEARCH   FMT : MPSDISPP CMD : CUSTINMN CMD
C: CUSTODMN CMD : CUSTODMN HLP : CUSTENMN HLP : CUSTENMN CMD : ACKNOMAN HLP
C: ACKNOMAN CMD : QUOTSEND CMD : QUOTSEND HLP : QUOTOLD  HLP : QUOTOLD  CMD
C: QUOTDEL  CMD : QUOTMOD  CMD : DESPATCH HLP : ORHISTMN CMD : DESPATDU HLP
C: DESPATDU CMD : DESPATAL HLP : DESPATAL CMD : DESPATLP CMD : DESPATLP HLP
C: CUSTMAIN FMT : CUSTINMN HLP : INTNENQY FMT : CUSTINFN CMD : CUSTINFN HLP
C: MPSDISP  CMD : MPSDISPP HLP : QUOTEMAN FMT : SALENOTE CMD : ORHISTMN HLP
C: ORDMONIT HLP : ORDMONIT CMD : ORDSTAT  CMD : INSTANT  CMD : ORDCHNG1 HLP
C: QUOTELP  CMD : QUOTELP  HLP : DESPATCH CMD : CUSTENQ1 CMD
      59 File(s)    32768 bytes free
```

Major modules in Customer Service Cell (B)

```
C: DESIGN    FMT : BOM       FMT : BOMGEN    HLP : PROCGEN   CMD : BOMMOD    HLP
C: STDCOST   FMT : PROCESS   FMT : PROCTEPT  DBF : PROCTEPT  HLP : PROCTEPT  NDX
C: BOMDEL    HLP : BOMDEL    CMD : PROCLP    HLP : BOMLP     HLP : PROCTEPT  CMD
C: PROCGEN1  CMD : PROCGEN   HLP : STDCGEN   HLP : PRODGEN   HLP : PRODGEN   CMD
C: BOMGEN    CMD : STDCGEN   CMD : STDCRGEN  HLP : STDCRALL  CMD : OH-RATE   DBF
C: PROCMOD1  CMD : PROCDEL   HLP : PROCDEL   CMD : PROCLP    CMD : STDCLP    CMD
C: STDCLP        : STDCRGEN  CMD : STDCRALL  HLP : PRODMOD   HLP : PRODMOD   CMD
C: BOMLP     CMD : BOMMOD    CMD : STDCMAN   CMD : STDCMAN   HLP : STDCLP    HLP
C: PRODDEL   HLP : PRODLP    CMD : PRODLP    HLP : PRODLP1   CMD : DRAWING   FMT
C: PROCMOD   HLP : OH-RATE   NDX : OH-RATE   HLP : OH-RATE   CMD : PROCMOD   CMD
C: DESGNREQ  FMT : COSTRATE  FMT : LB-RATE   DBF : LB-RATE   NDX : LB-RATE   HLP
C: LB-RATE   CMD : PRODUCT   FMT : PRODDEL   CMD
       58 File(s)    169984 bytes free
```

Major modules in Design Cell (C)

```
C: MPSGEN    HLP : MPSGEN    CMD : MPSDISPP CMD : MPSDISPP HLP : WCSUPER  FMT
C: DISTMPS   HLP : DISTMPS   CMD : DISTBMRT CMD : DISTBMRT HLP : PURCHASE FMT
C: PURSCHGN  HLP : PURSCHGN  CMD : PURSCHMN CMD : PURSCHMN HLP : PURORDGN HLP
C: PURORDGN  CMD : PURORDMN  HLP : PURORDMN CMD : PURARRVL NDX : PURARRVL DBF
C: PURARRVL  HLP : ENDPRTMN  HLP : ENDPRTMN CMD : PRODINV  DBF : PRODINV  NDX
C: PRODINV   HLP : PRODINV   CMD : PURARRVL CMD : CENTRALP FMT
       29 File(s)    186368 bytes free
```

Major modules in Central Planning Cell (D)

```
C: WORKCELL FMT : MPSPREP  CMD : LOCALMRP CMD : LOCALMRP FMT : MPSPREP  HLP
C: WKODGEN  FMT : WOGENIND HLP : WOGENIND CMD : MPSEDIT  CMD : MPSEDIT  HLP
C: MRPRUN   HLP : TMPWOLSD CMD : LSDGEN   CMD : MRPWOMOD CMD : TMPWOGEN CMD
C: TMPWOGEN HLP : TMPWOLSD HLP : ROUGHCRP CMD : ROUGHCRP HLP : MRPWOMOD HLP
C: FIRMMRP  CMD : FIRMMRP  HLP : MRPTOWO  HLP : MRPTOWO  CMD : FLOORPLN FMT
C: LOADCHRT CMD : WKRELMOD CMD : WKODMAIN FMT : WKODMOD  HLP : WKRELMOD HLP
C: WKODMOD  CMD : WKRELDEL HLP : WKODDEL  CMD : WKODDEL  HLP : WKODDIS  CMD
C: WKRELDEL CMD : WKODDIS  HLP : WKODPRN  HLP : WKODPRN  CMD : BATCHQTY CMD
C: BATCHQTY HLP : MRPRUN   CMD : WKODREL  HLP : WKODREL  CMD : WCLOAD   HLP
C: WCLOAD   CMD : LOADCHRT HLP : LSDGEN   HLP : CAPACITY HLP : CAPACITY CMD
        50 File(s)    75776 bytes free
```

```
C: WIPMAIN  FMT : WIPUPDT  CMD : WIPUPDT  HLP : WIPDISP  CMD : WIPDISP  HLP
C: ENDWOMAN HLP : ENDWOMAN CMD : STOCKCTL FMT : STOCKUPT HLP : STOCKUPT CMD
C: STOCKREP HLP : STOCKREP CMD : PARTDET  CMD : PARTDET  HLP : WKONORDE HLP
C: WKONORDE CMD : BYONORDE HLP : BYONORDE CMD
        18 File(s)    598016 bytes free
```

Major modules in Work Cells (E)

```
C: TEMPFORE DBF : FOREMAIN HLP : FOREREGN HLP : FORECAST DBF : FOREMOVE CMD
C: FOREC5   CMD : FORECAST HLP : FOREMOVE HLP : FOREC5   HLP : FOREREGN CMD
C: FOREEXPN HLP : FOREC3   CMD : FORECAST CMD : FOREC4   HLP : FOREC2   CMD
C: FOREC1   HLP : FOREC1   CMD : FOREC2   HLP : FOREEXPN CMD : FOREC3   HLP
C: FOREMAIN CMD : FORECAST NDX : OLDFORE  DBF : OLDFORE  NDX : FOREC4   CMD
        25 File(s)    186368 bytes free
```

Major modules in Forecasting (F)

SECTION 2:

SUMMARY OF ESSENTIAL SYSTEM DATA FILES (.DBF FILES)

DATA FILE NAME

ACKNOWGE
BATQTY1
BATQTY2
BATQTY3
BOM
BOM-1
BOM-2
BOM-3
BUYPART1
BUYPART2
BUYPART3
CALENDAR
CALTEMP
CAPACIT3
CBOM-1
CBOM-2
CBOM-3
CBOMSTRU
CMPS-1
CMPS-2
CMPS-3
CMPSSTRU
COMPANY
CROUTE-1
CROUTE-2
CROUTE-3
CURRSPEC
CUSTENQY
CUSTOMER
CUSTORD
DESIGNRQ
DUE1ST
DUEORDER
DUEPROD
ENDPART
ENDWKOD3
FILE-MP
FILERECD
FORECAST
GROSS-3
HARDSPEC
HOLIDAYS
INVOICE
ISSUEWO3

DATA FILE NAME

LB-RATE
LOADCHT3
LSD-3
MAP-TEMP
MODEL-MP
MPSFROM
MPSLONG3
MPSMIX-1
MPSMIX-2
MPSMIX-3
MPSORD-1
MPSORD-3
MPSORDER
MRP-3
MRPWKOD3
NEWPROD
NOTEXIST
OH-RATE
OLDFORE
ONBUY-3
ONORDER3
ORDER-NO
ORDERBK
ORDHIST
PARTDET3
PARTINV1
PARTINV2
PARTINV3
PROCESS
PROCTEPT
PRODINV
PRODSCH
PRODUCT
PROFIT
PUR-NO
PURARRVL
PURORDER
PURORDSN
PURPLAN
PURREQ
PURSCHED
QUOTE
REVCAL
ROUTE-1

DATA FILE NAME

ROUTE-2
ROUTE-3
SCTRACK
SHIPMENT
SPCLABEL
STDCOST
STDSPEC
STRUTEMP
TEMPAML3
TEMPARRV
TEMPBOM
TEMPBOM3
TEMPBUY3
TEMPCBOM
TEMPCMPS
TEMPCROT
TEMPCRP3
TEMPCRT3
TEMPDIST
TEMPFORE
TEMPLSD3
TEMPMAST
TEMPPCTP
TEMPQUOT
TEMPREL3
TEMPSCH
TEMPWC-1
TEMPWC-2
TEMPWC-3
TEMPWIP3
TEMPWOMD
UNIVERSE
VENDOR
WCELLMAP
WCLOAD-3
WIP-3
WKODMOD3
WKODNO3
WKORDER3

APPENDIX D FUNCTIONS IN THE MANUFACTURING CONTROL SYSTEM (MCS)

Function 1) Process Planning - allows new cutting tools to be created in terms of part, material and operation details.

Function 2) Work order generation - generates new work orders and maintains existing orders.

Function 3) Production Planning and Order Releasing - calculates the priority for each newly created work orders, then releases them, according to their latest start dates, to the shop floor. It also maintains a work-to-list for each available work centre for capacity planning purposes.

Function 4) Work-In-Progress - allows current work orders' status to be displayed, printed and updated.

Function 5) Material Control - the module was not completed. It provides standard inventory control features such as material issues, material receipts and returns, current inventory status display, Re- order level monitoring, out-of-stock warning and supplier details storage. It, however, does not have a MRP type module.

Function 6) Job Costing - records the job details for each order so that its cost could be worked out. This module was not even started.

Function 7) Production Calendar - provides a powerful calendar generator which would take all working hours and factory non-working days (such as bank- holidays) into account.

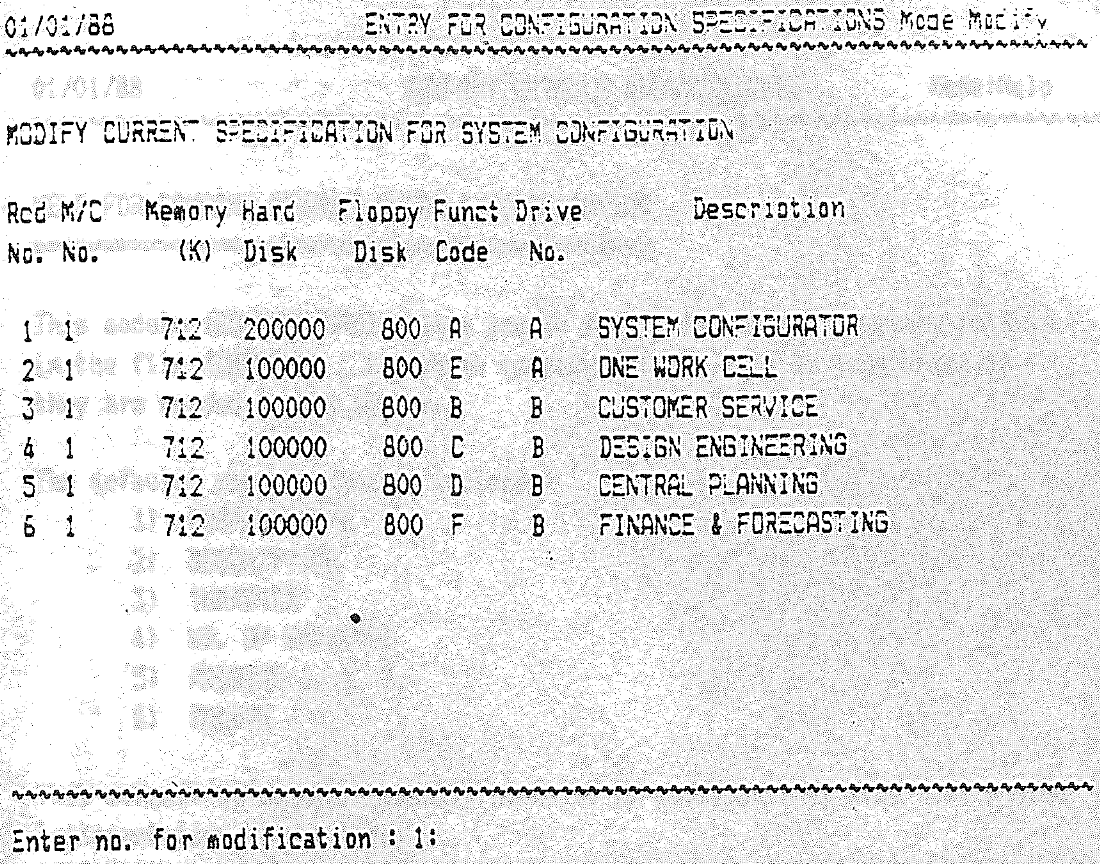
Function 8) House keeping - a collection of file utilities to keep the data files tidy and to maintain some system parameters.

APPENDIX E COMPARISON OF TECHNICAL CONSTRAINTS FOR dBASE II AND dBASE III PLUS

Max. data fields per record	32	128
Max. characters per record	1000	4000
Max records per database	65535	1 billion
Max. memory variables	64	256
Max. open data files allowed	2	10
Digits allowed	10	15.9

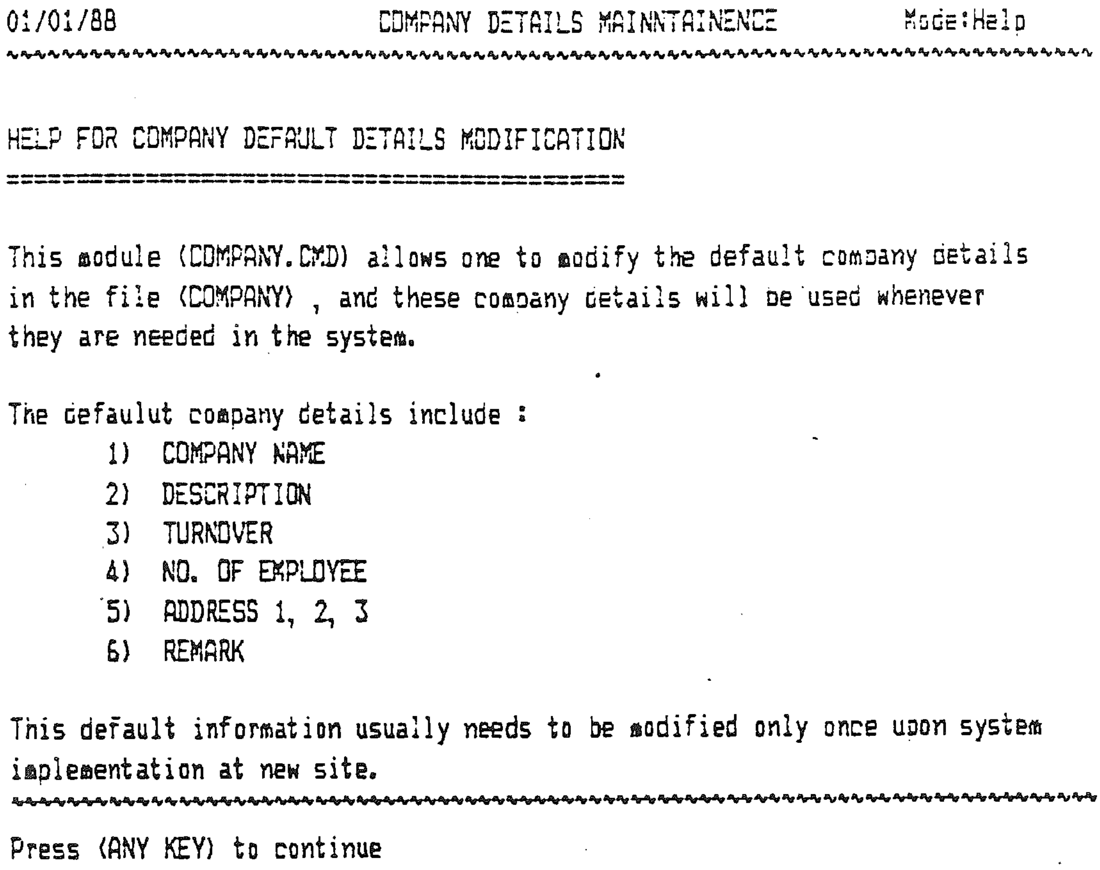
APPENDIX F

SUPPLEMENTARY RESULTS OBTAINED IN TEST RUN ONE



```
01/01/88                   ENTRY FOR CONFIGURATION SPECIFICATIONS Mode Modify
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

MODIFY CURRENT SPECIFICATION FOR SYSTEM CONFIGURATION

Rcd M/C  Memory Hard   Floppy Funct Drive        Description
No. No.    (K)  Disk    Disk  Code   No.

 1  1     712   200000    800  A      A    SYSTEM CONFIGURATOR
 2  1     712   100000    800  E      A    ONE WORK CELL
 3  1     712   100000    800  B      B    CUSTOMER SERVICE
 4  1     712   100000    800  C      B    DESIGN ENGINEERING
 5  1     712   100000    800  D      B    CENTRAL PLANNING
 6  1     712   100000    800  F      B    FINANCE & FORECASTING



~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Enter no. for modification : 1:
```

Table F-1   Print-out of system configuration details



```
01/01/88                    COMPANY DETAILS MAINNTAINENCE          Mode:Help
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

HELP FOR COMPANY DEFAULT DETAILS MODIFICATION
=============================================

This module (COMPANY.CMD) allows one to modify the default company details
in the file (COMPANY) , and these company details will be used whenever
they are needed in the system.

The defaulut company details include :
        1)  COMPANY NAME
        2)  DESCRIPTION
        3)  TURNOVER
        4)  NO. OF EMPLOYEE
        5)  ADDRESS 1, 2, 3
        6)  REMARK

This default information usually needs to be modified only once upon system
implementation at new site.
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Press (ANY KEY) to continue
```

Table F-2   Screen input-format for company details

```
01/01/88             COST DETAILS OF PRODUCT : PNC

PART NO.             STD LAB      STD MAT      STD O/H      TOTAL COST     LAST UPDT E
--------             -------      -------      -------      ----------     --------- -


SNPNC                   1.60         1.50         2.40          5.50       01/01/88  N
SNASSMC                 1.74         1.20         0.00          2.94       01/01/88  N
SN5                  NO COST DETAILS AVAILABLE FOR THIS PART                         Y
SN4                  NO COST DETAILS AVAILABLE FOR THIS PART                         Y

<<<<<<<<<<<<<<<<<<<<<<<< E N D   O F   B I L L >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>




01/01/88             COST DETAILS OF PRODUCT : PND

PART NO.             STD LAB      STD MAT      STD O/H      TOTAL COST     LAST UPDT E
--------             -------      -------      -------      ----------     --------- -


SNPND                   2.00         2.00         3.60          7.60       01/01/88  N
SNASSMD                 3.49         2.20         0.00          5.69       01/01/88  N
SN7                  NO COST DETAILS AVAILABLE FOR THIS PART                         Y
SN4                  NO COST DETAILS AVAILABLE FOR THIS PART                         Y

<<<<<<<<<<<<<<<<<<<<<<<< E N D   O F   B I L L >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
```

Table F-3   Cost details in the system for product PNC & PND

```
               FORECAST VALUE FOR PRODUCT NO.  PNC
                FROM 88-01    TO 88-52
FORECAST PERIOD                    QUANTITY
===============                    ========
    88-01                              60
    88-02                              60
    88-03                              60
    88-04                              60
    88-05                              60
    88-06                              60
    88-07                              60
    88-08                              60
    88-09                              60
    88-10                              60
    88-11                              60
    88-12                              60
    88-13                              60
    88-14                              60
    88-15                              60
    88-16                              60
    88-17                              60
    88-18                              60
    88-19                              60
    88-20                              60
    88-21                              60
    88-22                              60
    88-23                              60
    88-24                              60
    88-25                              60
    88-26                              60
    88-27                              60
    88-28                              60
    88-29                              60
    88-30                              60
    88-31                              60
    88-32                              60
    88-33                              60
    88-34                              60
    88-35                              60
    88-36                              60
    88-37                              60
    88-38                              60
    88-39                              60
    88-40                              60
    88-41                              60
    88-42                              60
    88-43                              60
    88-44                              60
    88-45                              60
    88-46                              60
    88-47                              60
    88-48                              60
    88-49                              60
    88-50                              60
    88-51                              60
    88-52                              60
```

Table F-4 Defaulted forecast demand for PNC from period 88-01 to 88-52

```
01/01/88                 LISTING OF PRODUCT SEARCH DATABASE
                         ==================================

SPEC-1              SPEC-2              SPEC-3              SPEC-4              SPEC-5
------              ------              ------              ------              ------

PRODUCT : PNA          DESCRIPTION : TYPE A CUTTER
3                                       180                 100                 80

PRODUCT : PNB          DESCRIPTION : TYPE B CUTTER
4                                       200                 150                 100

PRODUCT : PNC          DESCRIPTION : TYPE C CUTTER
3                                       180                 100                 80

PRODUCT : PND          DESCRIPTION : TYPE D CUTTER
4                                       200                 150                 100

PRODUCT : PNEM777      DESCRIPTION : END MILL (CLARKSON 110X25X40LOC)
3                   CLARKSON            110                 25                  40

PRODUCT : PNEM888      DESCRIPTION : END MILL (WHISTLE & WELDON 130X35X60LOC)
3                   WHISTLE & WELDON    130                 35                  60

PRODUCT : PNFB444      DESCRIPTION : FLAT BLADE CUTTER (CLARK. 120X28X40LOC)
4                   CLARKSON            120                 28                  40

PRODUCT : PNFB555      DESCRIPTION : FLAT BLADE CUTTER (CLARK. 180X35X60LOC)
4                   CLARKSON            180                 35                  60

PRODUCT : PNSR111      DESCRIPTION : SUPEROUTER CUTTER (150X50X50LOC)
2                   TAPER               150                 50                  50

PRODUCT : PNSR222      DESCRIPTION : SUPEROUTER CUTTER (170X52X60LOC)
2                   TAPER               170                 52                  60

PRODUCT : PNTEST1      DESCRIPTION : UIFDSUHFUIDSHFUIHSDUIF
8968648             896484              8936489             84484               89644896

PRODUCT : PNTEST2      DESCRIPTION : SFUISDFUISADHUIF
894489489489        4789484894          874894848           894894894           8944894

PRODUCT : PNTEST22     DESCRIPTION : TEST22
564                 49648               9648                896                 896

PRODUCT : PNTEST3      DESCRIPTION : SUIFDSUFHUSDHFUIADS
896848648894848     896484848           8948484894          894848484           894489484

PRODUCT : PNTEST4      DESCRIPTION : TEST 4
3                   4                   5                   6                   7

(((((((((((((((((((((((((((((((((((((((((((((( E N D   O F   F I L E ))))))))))))))))))))))))))))))))))))))))))))))
```

Table F-5 Listing of details stored in a Product Search Database

```
ROUGH PRINT FOR GROSS REQUIREMENT RECORDS FOR THE LATEST MRP RUN
-----------------------------------------------------------------

00001  PNC          88-02   40   100   145   260   152   190    85    85    75    20
00006  PND          88-02   45   172   149   135   110    50    74   210   185    60
00011  PNSR111      88-02  110    94   170   220   140   105   120    50    10    20
00016  SN11-2-55    88-02  514   140   105   120    50    10    20     0     0     0
00014  SN33         88-02  348   340   440   280   210   240   100    20    40     0
00004  SN4          88-02  420   435   780   456   570   255   255   225    60     0
00009  SN4          88-02  868   596   540   440   200   296   840   740   240     0
00005  SN5          88-02  215   260   152   190    85    85    75    20     0     0
00010  SN7          88-02  371   110    50    74   210   185    60     0     0     0
00003  SNASSMC      88-02  140   145   260   152   190    85    85    75    20     0
00008  SNASSMD      88-02  217   149   135   110    50    74   210   185    60     0
00002  SNPNC        88-02   40   100   145   260   152   190    85    85    75    20
00007  SNPND        88-02   45   172   149   135   110    50    74   210   185    60
00012  SNPNSR111    88-02  110    94   170   220   140   105   120    50    10    20
00015  SNSR111-10   88-02  324   220   140   105   120    50    10    20     0     0
00013  SNSR111-40   88-02  174   170   220   140   105   120    50    10    20     0
```

Table F-6 Print-out of a Gross requirement table generated by MRP

```
00003   W0080188-001  SNASSMC          20    20     1550   8019  N
00001   W0080188-001  SNASSMC          9999  END     100   8022  N
00005   W0080188-002  SNASSMC          10    10     2040   8020  N
00006   W0080188-002  SNASSMC          20    20     1050   8027  N
00004   W0080188-002  SNASSMC          9999  END     100   8029  N
00008   W0080188-003  SNASSMC          10    10     2040   8027  N
00009   W0080188-003  SNASSMC          20    20     1050   8034  N
00007   W0080188-003  SNASSMC          9999  END     100   8036  N
00011   W0080188-004  SNASSMC          10    10     2040   8034  N
00012   W0080188-004  SNASSMC          20    20     1050   8041  N
00010   W0080188-004  SNASSMC          9999  END     100   8043  N
00014   W0080188-005  SNASSMC          10    10     1040   8047  N
00015   W0080188-005  SNASSMC          20    20      550   8049  N
00013   W0080188-005  SNASSMC          9999  END     100   8050  N
00017   W0080188-006  SNASSMC          10    10     1040   8061  N
00018   W0080188-006  SNASSMC          20    20      550   8063  N
00016   W0080188-006  SNASSMC          9999  END     100   8064  N
00020   W0080188-007  SNASSMD          30    30     3732   8001  N
00021   W0080188-007  SNASSMD          40    40     7450   8007  N
00019   W0080188-007  SNASSMD          9999  END     100   8029  N
00023   W0080188-008  SNASSMD          30    30     1122   8026  N
00024   W0080188-008  SNASSMD          40    40     2230   8028  N
00022   W0080188-008  SNASSMD          9999  END     100   8036  N
00026   W0080188-009  SNASSMD          30    30      522   8040  N
00027   W0080188-009  SNASSMD          40    40     1030   8041  N
00025   W0080188-009  SNASSMD          9999  END     100   8043  N
00029   W0080188-010  SNASSMD          30    30      762   8043  N
00030   W0080188-010  SNASSMD          40    40     1510   8047  N
00028   W0080188-010  SNASSMD          9999  END     100   8050  N
00032   W0080188-011  SNASSMD          30    30     2122   8039  N
00033   W0080188-011  SNASSMD          40    40     4230   8046  N
00031   W0080188-011  SNASSMD          9999  END     100   8057  N
00035   W0080188-012  SNASSMD          30    30     1872   8048  N
00036   W0080188-012  SNASSMD          40    40     3730   8054  N
00034   W0080188-012  SNASSMD          9999  END     100   8064  N
00038   W0080188-013  SNASSMD          30    30      622   8067  N
00039   W0080188-013  SNASSMD          40    40     1230   8069  N
00037   W0080188-013  SNASSMD          9999  END     100   8071  N
00041   W0080188-014  SNPNC            100   100    1700   8019  N
00040   W0080188-014  SNPNC            9999  END     100   8022  N
00043   W0080188-015  SNPNC            100   100    1760   8025  N
00042   W0080188-015  SNPNC            9999  END     100   8029  N
00045   W0080188-016  SNPNC            100   100    3140   8026  N
00044   W0080188-016  SNPNC            9999  END     100   8036  N
00047   W0080188-017  SNPNC            100   100    1844   8039  N
00046   W0080188-017  SNPNC            9999  END     100   8043  N
00049   W0080188-018  SNPNC            100   100    2300   8043  N
00048   W0080188-018  SNPNC            9999  END     100   8050  N
00051   W0080188-019  SNPNC            100   100    1040   8055  N
00050   W0080188-019  SNPNC            9999  END     100   8057  N
00053   W0080188-020  SNPNC            100   100    1040   8062  N
00052   W0080188-020  SNPNC            9999  END     100   8064  N
00055   W0080188-021  SNPNC            100   100     920   8069  N
00054   W0080188-021  SNPNC            9999  END     100   8071  N
00057   W0080188-022  SNPNC            100   100     260   8078  N
00056   W0080188-022  SNPNC            9999  END     100   8078  N
00059   W0080188-023  SNPND            90    90     3275   8013  N
00058   W0080188-023  SNPND            9999  END     100   8022  N
00061   W0080188-024  SNPND            90    90     2255   8022  N
00060   W0080188-024  SNPND            9999  END     100   8029  N
00063   W0080188-025  SNPND            90    90     2045   8029  N
00062   W0080188-025  SNPND            9999  END     100   8036  N
00065   W0080188-026  SNPND            90    90     1670   8040  N
00064   W0080188-026  SNPND            9999  END     100   8043  N
00067   W0080188-027  SNPND            90    90      770   8049  N
```

Table F-7   A sample listing for part of the LSD file's records

00001	SN4	WC3	88-02	14320	4840	4840	4840	4840	4840	4840	4840	0	0
00002	SN7	WC3	88-02	4230	880	880	880	880	880	0	0	0	0
00003	SN33	WC3	88-02	5596	1332	1332	1335	1377	1397	1200	0	0	0

Table F-8 Purchase orders recommendations based on MRP results

```
        PURCHASE  ORDER        NO.  PUR1
        ===============

DATE:  08/01/88        SYSTEM  PERIOD:  88-02
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

VENDOR : MARWIN CARBIDE LTD          ADDRESS : LEICEST INDUSTRIAL CENTRE
                                               LEICEST LCC 512

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

PART NO. :  SN33                     QTY :      5596

UNIT COST :     2.30                 TOTAL COST :    12870.80
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

WORK CELL :  WC3
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

PURCHASE PERIOD :  88-02             LEAD TIME :      2

SCHEDULED PUR--PERIOD :  88-02       SCHEDULED ARRIVAL :  88-04
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

Table F-9 The actual print of a purchase order to be sent to a customer

```
08/01/88   TEMPORARY WORK ORDERS CREATED FROM MRP RECOMMENDATION. WITH ISSUEED
           WORK ORDERS WITHIN THE PLANNNG HORIZON

PLANNING HORIZON FROM : 88-02        TO : 88-11

WORK CELL : 3                  CURRENT SYSTEM PERIOD : 88-01
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

WORK ORDER NO. PART NO.      ORDER QTY  BATCH SIZE  SCHEDULED LAUNCH  SCHEDULED FINISH  RELEASED  L.S.D. OP-1
______________ ________      _________  __________  ________________  ________________  ________  ___________


WO000000-001   SNASSKC         215          0            88-02             88-03           N
WO000000-002   SNASSKC         260          0            88-03             88-04           N
WO000000-003   SNASSKC         152          0            88-04             88-05           N
WO000000-004   SNASSKC         190          0            88-05             88-06           N
WO000000-005   SNASSKC          85          0            88-06             88-07           N
WO000000-006   SNASSKC          85          0            88-07             88-08           N
WO000000-007   SNASSKC          75          0            88-08             88-09           N
WO000000-008   SNASSKC          20          0            88-09             88-10           N
WO000000-009   SNASSKD         371          0            88-02             88-04           N
WO000000-010   SNASSKD         110          0            88-03             88-05           N
WO000000-011   SNASSKD          50          0            88-04             88-06           N
WO000000-012   SNASSKD          74          0            88-05             88-07           N
WO000000-013   SNASSKD         210          0            88-06             88-08           N
WO000000-014   SNASSKD         185          0            88-07             88-09           N
WO000000-015   SNASSKD          60          0            88-08             88-10           N
WO000000-016   SNPNC           140          0            88-02             88-03           N
WO000000-017   SNPNC           145          0            88-03             88-04           N
WO000000-018   SNPNC           260          0            88-04             88-05           N
WO000000-019   SNPNC           152          0            88-05             88-06           N
WO000000-020   SNPNC           190          0            88-06             88-07           N
WO000000-021   SNPNC            85          0            88-07             88-08           N
WO000000-022   SNPNC            85          0            88-08             88-09           N
WO000000-023   SNPNC            75          0            88-09             88-10           N
WO000000-024   SNPNC            20          0            88-10             88-11           N
WO000000-025   SNPND           217          0            88-02             88-03           N
WO000000-026   SNPND           149          0            88-03             88-04           N
WO000000-027   SNPND           135          0            88-04             88-05           N
WO000000-028   SNPND           110          0            88-05             88-06           N
WO000000-029   SNPND            50          0            88-06             88-07           N
WO000000-030   SNPND            74          0            88-07             88-08           N
WO000000-031   SNPND           210          0            88-08             88-09           N
WO000000-032   SNPND           185          0            88-09             88-10           N
WO000000-033   SNPND            60          0            88-10             88-11           N
WO000000-034   SNPNSR111       174          0            88-02             88-03           N
WO000000-035   SNPNSR111       170          0            88-03             88-04           N
WO000000-036   SNPNSR111       220          0            88-04             88-05           N
WO000000-037   SNPNSR111       140          0            88-05             88-06           N
WO000000-038   SNPNSR111       105          0            88-06             88-07           N
WO000000-039   SNPNSR111       120          0            88-07             88-08           N
WO000000-040   SNPNSR111        50          0            88-08             88-09           N
WO000000-041   SNPNSR111        10          0            88-09             88-10           N
WO000000-042   SNPNSR111        20          0            88-10             88-11           N
WO000000-043   SNSR111-10      514          0            88-02             88-03           N
WO000000-044   SNSR111-10      140          0            88-03             88-04           N
WO000000-045   SNSR111-10      105          0            88-04             88-05           N
WO000000-046   SNSR111-10      120          0            88-05             88-06           N
WO000000-047   SNSR111-10       50          0            88-06             88-07           N
WO000000-048   SNSR111-10       10          0            88-07             88-08           N
WO000000-049   SNSR111-10       20          0            88-08             88-09           N
WO000000-050   SNSR111-40      324          0            88-02             88-03           N
WO000000-051   SNSR111-40      220          0            88-03             88-04           N
WO000000-052   SNSR111-40      140          0            88-04             88-05           N
WO000000-053   SNSR111-40      105          0            88-05             88-06           N
WO000000-054   SNSR111-40      120          0            88-06             88-07           N
WO000000-055   SNSR111-40       50          0            88-07             88-08           N
WO000000-056   SNSR111-40       10          0            88-08             88-09           N
WO000000-057   SNSR111-40       20          0            88-09             88-10           N

((((((((((((((((((((((((((E N D   O F   F I L E))))))))))))))))))))))))))))))
```

Table F-10   57 temporary work orders created for preliminary load analysis in Work Cell 3

```
08/01/88               LISTING OF ISSUED WORK ORDERS

SYSTEM PERIOD : 88-01          WORK CELL : 3

SELECTION CRITERIA :   RANGE OF SCHEDULED LAUNCH PERIOD FROM : 88-02
                                                          TO : 88-13

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

WORK NO.         PART NO.             BATCH O.QTY LAUNCH FINISH RELEASED ISS.DATE LSD/OP1
---------        ---------            ----- ----- ------ ------ -------- -------- -------

WO080188-001     SNASSMC                100   300 88-02  88-03  N        08/01/88
WO080188-007     SNASSMD                  1   371 88-02  88-04  N        08/01/88
WO080188-014     SNPNC                    1   140 88-02  88-03  N        08/01/88
WO080188-023     SNPND                    1   217 88-02  88-03  N        08/01/88
WO080188-032     SNPNSR111                1   174 88-02  88-03  N        08/01/88
WO080188-041     SNSR111-10             200   600 88-02  88-03  N        08/01/88
WO080188-044     SNSR111-40               1   324 88-02  88-03  N        08/01/88
WO080188-002     SNASSMC                100   200 88-03  88-04  N        08/01/88
WO080188-008     SNASSMD                  1   110 88-03  88-05  N        08/01/88
WO080188-015     SNPNC                    1   145 88-03  88-04  N        08/01/88
WO080188-024     SNPND                    1   149 88-03  88-04  N        08/01/88
WO080188-033     SNPNSR111                1   170 88-03  88-04  N        08/01/88
WO080188-042     SNSR111-10             200   200 88-03  88-04  N        08/01/88
WO080188-045     SNSR111-40               1   220 88-03  88-04  N        08/01/88
WO080188-003     SNASSMC                100   200 88-04  88-05  N        08/01/88
WO080188-009     SNASSMD                  1    50 88-04  88-06  N        08/01/88
WO080188-016     SNPNC                    1   260 88-04  88-05  N        08/01/88
WO080188-025     SNPND                    1   135 88-04  88-05  N        08/01/88
WO080188-034     SNPNSR111                1   220 88-04  88-05  N        08/01/88
WO080188-046     SNSR111-40               1   140 88-04  88-05  N        08/01/88
WO080188-004     SNASSMC                100   200 88-05  88-06  N        08/01/88
WO080188-010     SNASSMD                  1    74 88-05  88-07  N        08/01/88
WO080188-017     SNPNC                    1   152 88-05  88-06  N        08/01/88
WO080188-026     SNPND                    1   110 88-05  88-06  N        08/01/88
WO080188-035     SNPNSR111                1   140 88-05  88-06  N        08/01/88
WO080188-043     SNSR111-10             200   200 88-05  88-06  N        08/01/88
WO080188-047     SNSR111-40               1   105 88-05  88-06  N        08/01/88
WO080188-005     SNASSMC                100   100 88-06  88-07  N        08/01/88
WO080188-011     SNASSMD                  1   210 88-06  88-08  N        08/01/88
WO080188-018     SNPNC                    1   190 88-06  88-07  N        08/01/88
WO080188-027     SNPND                    1    50 88-06  88-07  N        08/01/88
WO080188-036     SNPNSR111                1   105 88-06  88-07  N        08/01/88
WO080188-048     SNSR111-40               1   120 88-06  88-07  N        08/01/88
WO080188-012     SNASSMD                  1   185 88-07  88-09  N        08/01/88
WO080188-019     SNPNC                    1    85 88-07  88-08  N        08/01/88
WO080188-028     SNPND                    1    74 88-07  88-08  N        08/01/88
WO080188-037     SNPNSR111                1   120 88-07  88-08  N        08/01/88
WO080188-049     SNSR111-40               1    50 88-07  88-08  N        08/01/88
WO080188-006     SNASSMC                100   100 88-08  88-09  N        08/01/88
WO080188-013     SNASSMD                  1    60 88-08  88-10  N        08/01/88
WO080188-020     SNPNC                    1   185 88-08  88-09  N        08/01/88
WO080188-029     SNPND                    1   210 88-08  88-09  N        08/01/88
WO080188-038     SNPNSR111                1    50 88-08  88-09  N        08/01/88
WO080188-050     SNSR111-40               1    10 88-08  88-09  N        08/01/88
WO080188-021     SNPNC                    1    75 88-09  88-10  N        08/01/88
WO080188-030     SNPND                    1   185 88-09  88-10  N        08/01/88
WO080188-039     SNPNSR111                1    10 88-09  88-10  N        08/01/88
WO080188-051     SNSR111-40               1    20 88-09  88-10  N        08/01/88
WO080188-022     SNPNC                    1    20 88-10  88-11  N        08/01/88
WO080188-031     SNPND                    1    60 88-10  88-11  N        08/01/88
WO080188-040     SNPNSR111                1    20 88-10  88-11  N        08/01/88

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<  E N D   O F   F I L E  >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
```

Table F-11   Listing of 51 final work orders in scheduled release period sequence

APPENDIX G

SUPPLEMENTARY RESULTS OBTAINED IN TEST RUN TWO

```
PRODUCT NO. : PNC          PART NO. : SNPNC                LEAD TIME :   1
00001  GROSS REQ      0    40   100   145   260   152   190    85    85    75    20
00002  ON ORDER       0     0     0     0     0     0     0     0     0     0     0
00003  ON HAND        0     0     0     0     0     0     0     0     0     0     0
00004  NET REQ        0    40   100   145   260   152   190    85    85    75    20
00005  RECOMM ORD     0   140   145   260   152   190    85    85    75    20     0


PRODUCT NO. : PNC          PART NO. : SN4                  LEAD TIME :   1
00001  GROSS REQ      0   420   435   780   456   570   255   255   225    60     0
00002  ON ORDER       0     0     0     0     0     0     0     0     0     0     0
00003  ON HAND      140     0     0     0     0     0     0     0     0     0     0
00004  NET REQ        0   280   435   780   456   570   255   255   225    60     0
00005  RECOMM ORD     0   715   780   456   570   255   255   225    60     0     0


PRODUCT NO. : PND          PART NO. : SNPND                LEAD TIME :   1
00001  GROSS REQ      0    45   172   149   135   110    50    74   210   185    60
00002  ON ORDER       0     0     0     0     0     0     0     0     0     0     0
00003  ON HAND        0     0     0     0     0     0     0     0     0     0     0
00004  NET REQ        0    45   172   149   135   110    50    74   210   185    60
00005  RECOMM ORD     0   217   149   135   110    50    74   210   185    60     0


PRODUCT NO. : PND          PART NO. : SN4                  LEAD TIME :   1
00001  GROSS REQ      0  1288  1031  1320   896   770   551  1095   965   300     0
00002  ON ORDER       0     0     0     0     0     0     0     0     0     0     0
00003  ON HAND      140     0     0     0     0     0     0     0     0     0     0
00004  NET REQ        0  1148  1031  1320   896   770   551  1095   965   300     0
00005  RECOMM ORD     0  2179  1320   896   770   551  1095   965   300     0     0


PRODUCT NO. : PNSR111          PART NO. : SNPNSR111            LEAD TIME :   1
00001  GROSS REQ      0   110    94   170   220   140   105   120    50    10    20
00002  ON ORDER       0     0     0     0     0     0     0     0     0     0     0
00003  ON HAND       30     0     0     0     0     0     0     0     0     0     0
00004  NET REQ        0    80    94   170   220   140   105   120    50    10    20
00005  RECOMM ORD     0   174   170   220   140   105   120    50    10    20     0


PRODUCT NO. : PNSR111          PART NO. : SN33                 LEAD TIME :   2
00001  GROSS REQ      0   348   340   440   280   210   240   100    20    40     0
00002  ON ORDER       0     0     0     4    68    68    65    23     3   200     0
00003  ON HAND       30     0     0     0     0     0     0     0     0   160   160
00004  NET REQ        0   318   340   436   212   142   175    77    17     0     0
00005  RECOMM ORD     0  1094   212   142   175    77    17     0     0     0     0
```

Table G-1   MRP minitoring process in Work Cell 3

```
08/01/88  DISCRETE WORK ORDERS CONVERTED FROM MRP TO BE CONFIRMED FOR ISSUE
          INTO WORK CELL : 2               ON DATE : 08/01/88
          FOR PERIOD : 88-02         CURRENT PERIOD : 88-01

WORK ORDER NO. PART NO.          ORDER QTY  BATCH SIZE  SCHEDULED LAUNCH PERIOD
-------------- --------          ---------  ----------  -----------------------

WO080188-001   SNASSMD              872         1               88-02
WO080188-002   SNASSMD              220         1               88-03
WO080188-003   SNASSMD              100         1               88-04
WO080188-004   SNASSMD              148         1               88-05
WO080188-005   SNASSMD              420         1               88-06
WO080188-006   SNASSMD              370         1               88-07
WO080188-007   SNASSMD              120         1               88-08
WO080188-008   SNSR111-40           668         1               88-02
WO080188-009   SNSR111-40           440         1               88-03
WO080188-010   SNSR111-40           280         1               88-04
WO080188-011   SNSR111-40           210         1               88-05
WO080188-012   SNSR111-40           240         1               88-06
WO080188-013   SNSR111-40           100         1               88-07
WO080188-014   SNSR111-40            20         1               88-08
WO080188-015   SNSR111-40            40         1               88-09
```

Table G-2   Actual work orders generated in Work Cell 2 based on MRP recommedations

```
01/01/88                   PROCESS ROUTE FOR PRODUCT : PND

SUB-ASSEMBLY  OP NO.                 DESCRIPTION                          WORK CELL SET T  PROD T  LAB S.  SCRAP %  LAST UPDT
============  =====  =============================================        ========= =====  ======  =====   =======  =========

SNPND          90    FINAL ASSM INDUCTION BRAZE, INSERT, GRIND LOC          WC3      20      15      A       0.0    01-01-88
SNASSMD        30    MILL FLATS (TAPER, CLARKSON, WHISTLE & WELDON)         WC2      22      10      B       0.0    01-01-88
               40    MILL TIP SEATS/ MILL CLEARANCE                         WC2      30      20      B       0.0    01-01-88
SN7                  THIS IS END COMPONENT !
SN4                  THIS IS END COMPONENT !
```

```
01/01/88                   PROCESS ROUTE FOR PRODUCT : PNSR111

SUB-ASSEMBLY  OP NO.                 DESCRIPTION                          WORK CELL SET T  PROD T  LAB S.  SCRAP %  LAST UPDT
------------  -----  ---------------------------------------------        --------- -----  ------  -----   -------  ---------

SNPNSR111      90    INDUCTION HRAZE, INSERT, GRIND LOC                     WC3       5      20      C       0.0    12-12-85
              100    FINISH GRIND CARBIDE / FINISH HEATREATED EDGE          WC3       5      25      A       0.0    12-12-85
SNSR111-40     30    MILL FLATS (TAPER, CLARKSON, WHISTLE & WELDON)         WC2       3      10      C       2.0    12-12-85
               40    MILL TIP SEATS/ MILL CLEARANCE                         WC2       5      30      B       2.0    12-12-85
SNSR111-10     10    TURN SHANK + GRIND ALLOWANCE (ON INVESTMENT CAST)      WC1       3      15      C       2.0    12-12-85
SN11-2-55            THIS IS END COMPONENT !
SN33                 THIS IS END COMPONENT !
```

Table G-3   Process routes for product PND and PNSR111

```
                                FOR WORK CELL = 3
--------------------------------------------------------------------------------------------------------------
Work Centre          Description          No of Operators          No of Machines
   90          INDUCTION BRAZE, INST            1.0                      2.0
--------------------------------------------------------------------------------------------------------------

Day  Estimated  Capacity   %                         P  E  R  C  E  N  T  A  G  E     L  O  A  D
No   Load(Hrs)   (Hrs)   Load 0%.......................50%.......................100%......................150%......................20
---- ---------  --------  ---- |                        |                        |                        |                        |
8011     0         7       0%  |                        |                        |                        |                        |
8012     0         7       0%  |                        |                        |                        |                        |
8013    54         8     682%  |************************|************************|************************|************************|
8014     0         8       0%  |                        |                        |                        |                        |
8015     0         7       0%  |                        |                        |                        |                        |
8018     0         7       0%  |                        |                        |                        |                        |
8019     0         7       0%  |                        |                        |                        |                        |
8020     0         8       0%  |                        |                        |                        |                        |
8021     0         8       0%  |                        |                        |                        |                        |
8022    84         7    1204%  |************************|************************|************************|************************|
8025     0         7       0%  |                        |                        |                        |                        |
8026     0         7       0%  |                        |                        |                        |                        |
8027     0         8       0%  |                        |                        |                        |                        |
8028     0         8       0%  |                        |                        |                        |                        |
8029    34         7     486%  |************************|************************|************************|************************|
8033     0         7       0%  |                        |                        |                        |                        |
8034     0         8       0%  |                        |                        |                        |                        |
8035     0         8       0%  |                        |                        |                        |                        |
8036    35         7     501%  |************************|************************|************************|************************|
8039     0         7       0%  |                        |                        |                        |                        |
8040    27         7     371%  |************************|************************|************************|************************|
8041    40         8     501%  |************************|************************|************************|************************|
8042     0         8       0%  |                        |                        |                        |                        |
8043     0         7       0%  |                        |                        |                        |                        |
8046     0         7       0%  |                        |                        |                        |                        |
8047     0         7       0%  |                        |                        |                        |                        |
8048     0         8       0%  |                        |                        |                        |                        |
8049    12         8     160%  |************************|************************|************************|****                    |
8050     0         7       0%  |                        |                        |                        |                        |
8053     0         7       0%  |                        |                        |                        |                        |
8054     0         7       0%  |                        |                        |                        |                        |
8055    71         8     895%  |************************|************************|************************|************************|
8056     0         8       0%  |                        |                        |                        |                        |
8057    16         7     239%  |************************|************************|************************|************************|
8060     0         7       0%  |                        |                        |                        |                        |
8061     0         7       0%  |                        |                        |                        |                        |
8062     0         8       0%  |                        |                        |                        |                        |
8063    46         8     582%  |************************|************************|************************|************************|
8064     0         7       0%  |                        |                        |                        |                        |
8067     0         7       0%  |                        |                        |                        |                        |
8068     0         7       0%  |                        |                        |                        |                        |
8069     0         8       0%  |                        |                        |                        |                        |
8070     3         8      42%  |********************    |                        |                        |                        |
8071     0         7       0%  |                        |                        |                        |                        |
8074     0         7       0%  |                        |                        |                        |                        |
8075     0         7       0%  |                        |                        |                        |                        |
8076    22         8     276%  |************************|************************|************************|************************|
8077     0         8       0%  |                        |                        |                        |                        |
8078     0         7       0%  |                        |                        |                        |                        |
8081     0         7       0%  |                        |                        |                        |                        |
---- ---------  --------  ---- 0%.......................50%.......................100%......................150%......................20
```

Table G-4 Load analysis for work centre 90 in Work Cell 3

```
08/01/88     Listing of Work Centre Data in WORK CENTRE No order
                        FOR WORK CELL : 3
===========================================================================================
Work Centre          Description          Number of        Number of         Performanc
  Number                                  Operators        Machines               %

    10  .................  TURN/GRIND INV CAST............  0.0  ..................  0.0  ........................  100
    20  .................  TURN/GRIND/CENTRE/PT...........  0.0  ..................  0.0  ........................  100
    30  .................  MILL FLATS.....................  0.0  ..................  0.0  ........................  100
    40  .................  MILL TIP/CLEARANCE.............  0.0  ..................  0.0  ........................  100
    50  .................  TURN SHANK/GRIND/PAR...........  0.0  ..................  0.0  ........................  100
    60  .................  MILL SHANK (CLK WHI)...........  0.0  ..................  0.0  ........................  100
    70  .................  MILL TEETH SHAPE/GRI...........  0.0  ..................  0.0  ........................  100
    80  .................  HEAT TREATMENT.................  0.0  ..................  0.0  ........................  100
    90  .................  INDUCTION BRAZE,INST...........  1.0  ..................  2.0  ........................  100
   100  .................  FINSIH GRIND/HEATREA...........  1.0  ..................  2.0  ........................  100
   300  .................  SMALL CAPSTANS.................  0.0  ..................  0.0  ........................  100
   320  .................  LARGE CAPSTANS.................  0.0  ..................  0.0  ........................  100
   340  .................  CENTRE LATHES..................  0.0  ..................  0.0  ........................  100
   360  .................  VERTICAL MILLING...............  0.0  ..................  0.0  ........................  100
   380  .................  HORIZONTAL MILLING.............  0.0  ..................  0.0  ........................  100
   400  .................  SPIRAL MILLING.................  0.0  ..................  0.0  ........................  100
   420  .................  DRILLING & TAPPING.............  0.0  ..................  0.0  ........................  100
   440  .................  SUB-CON  KEYWAYS...............  0.0  ..................  0.0  ........................  100
   460  .................  BENCH (NO CARBIDE).............  0.0  ..................  0.0  ........................  100
   480  .................  INDUCTION BRAZING..............  0.0  ..................  0.0  ........................  100
   485  .................  TORCH BRAZING..................  0.0  ..................  0.0  ........................  100
   500  .................  CYLINDRICAL GRINDING...........  0.0  ..................  0.0  ........................  100
   540  .................  SURFACE GRINDING...............  0.0  ..................  0.0  ........................  100
   560  .................  INTERNAL GRINDING..............  0.0  ..................  0.0  ........................  100
   580  .................  LAPPING (FACE CARB')...........  0.0  ..................  0.0  ........................  100
   620  .................  BACK OFF CARBIDE...............  0.0  ..................  0.0  ........................  100
   640  .................  FORM GRINDING..................  0.0  ..................  0.0  ........................  100
   680  .................  GENERAL GRINDING...............  0.0  ..................  0.0  ........................  100
   700  .................  SPIRAL FACING..................  0.0  ..................  0.0  ........................  100
   760  .................  BENCH (WITH CARBIDE)...........  0.0  ..................  0.0  ........................  100
   780  .................  SPIRAL UNIT....................  0.0  ..................  0.0  ........................  100
   800  .................  R & D - GRAPHITE...............  0.0  ..................  0.0  ........................  100
   806  .................  INSPECTION.....................  0.0  ..................  0.0  ........................  100
   820  .................  WAXING UNIT....................  0.0  ..................  0.0  ........................  100
   840  .................  SUB-CON  HEAT TREAT............  0.0  ..................  0.0  ........................  100
   860  .................  SUB-CON........................  0.0  ..................  0.0  ........................  100
   880  .................  BENCH - FINAL DRESS............  0.0  ..................  0.0  ........................  100
   900  .................  RESEARCH & DEVELOPMT...........  0.0  ..................  0.0  ........................  100
-------------------------------------------------------------------------------------------
 a
. quit
*** END RUN      dBASE II      ***
```

Table G-5   Capacity details for Work Cell 3

```
FOR WORK CELL
------------------------------------------------------------------------------------------------------
Work Centre        Description               No of Operators           No of Machines
  30             MILL FLATS                        2.0                        2.0
------------------------------------------------------------------------------------------------------

Day Estimated  Capacity      %                P   E   R   C   E   N   T   A   G   E       L   O   A   D
No  Load(Hrs)      (Hrs)    Load 0%......................50%......................100%.....................150%.....................2
---- ---------  --------    ----
8011      0        15        0% |                        |                        |                        |
8012      0        15        0% |                        |                        |                        |
8013      0        16        0% |                        |                        |                        |
8014      0        16        0% |                        |                        |                        |
8015     37        14      264% |************************|************************|************************|************************|
8018     35        15      233% |************************|************************|************************|************************|
8019     70        15      469% |************************|************************|************************|************************|
8020     40        16      250% |************************|************************|************************|************************|
8021      0        16        0% |                        |                        |                        |
8022      0        14        0% |                        |                        |                        |
8025      0        15        0% |                        |                        |                        |
8026      0        15        0% |                        |                        |                        |
8027      0        16        0% |                        |                        |                        |
8028      0        16        0% |                        |                        |                        |
8029     62        14      443% |************************|************************|************************|************************|
8033      0        15        0% |                        |                        |                        |
8034      0        16        0% |                        |                        |                        |
8035     17        16      106% |************************|************************|**
8036     25        14      178% |************************|************************|************************|*************
8039      0        15        0% |                        |                        |                        |
8040      0        15        0% |                        |                        |                        |
8041      0        16        0% |                        |                        |                        |
8042      0        16        0% |                        |                        |                        |
8043      0        14        0% |                        |                        |                        |
8046      0        15        0% |                        |                        |                        |
8047     16        15      111% |************************|************************|****
8048      0        16        0% |                        |                        |                        |
8049      0        16        0% |                        |                        |                        |
8050      0        14        0% |                        |                        |                        |
8053      0        15        0% |                        |                        |                        |
8054      0        15        0% |                        |                        |                        |
8055      0        16        0% |                        |                        |                        |
8056      0        16        0% |                        |                        |                        |
8057      0        14        0% |                        |                        |                        |
8060      0        15        0% |                        |                        |                        |
8061     20        15      135% |************************|************************|****************
8062      3        16       21% |*********
8063      0        16        0% |                        |                        |                        |
8064      0        14        0% |                        |                        |                        |
8067      0        15        0% |                        |                        |                        |
8068      6        15       44% |*********************
8069      0        16        0% |                        |                        |                        |
8070      0        16        0% |                        |                        |                        |
8071      0        14        0% |                        |                        |                        |
8074      0        15        0% |                        |                        |                        |
8075      0        15        0% |                        |                        |                        |
8076      0        16        0% |                        |                        |                        |
8077      0        16        0% |                        |                        |                        |
8078      0        14        0% |                        |                        |                        |
8081      0        15        0% |                        |                        |                        |
---- ---------  --------    ---- 0%......................50%......................100%.....................150%.....................20
```

Table G-6   Load analysis report on Work Cell 2

```
08/01/88          WORK-TO-LIST LOADING CHART     [illegible]     [illegible]
------------------------------------------------------------------------------------------------------------------------
                                      W     O     R     K         C     E     N     T     R     E     S

                  30      40
Order No  Status |Oo No Hrs LSD |Oo No  Hrs LSD|Oo No Hrs LSD |Oo No  Hrs LSD|Oo No Hrs LSD |Oo No  Hrs LSD|Oo No Hrs LSD |Oo No  Hrs LSD|Oo No  Hrs LSD|
----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+
WO080188-001 UnR |30    145 8001|40    291 8001|
----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+
WO080188-002 UnR |30     37 8015|40     73 8021|
----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+
WO080188-003 UnR |30     17 8035|40     33 8039|
----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+
WO080188-004 UnR |30     25 8036|40     49 8042|
----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+
WO080188-005 UnR |30     70 8019|40    140 8033|
----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+
WO080188-006 UnR |30     62 8029|40    123 8042|
----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+
WO080188-007 UnR |30     20 8061|40     40 8064|
----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+
WO080188-008 UnR |30    111 8001|40    334 8001|
----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+
WO080188-009 UnR |30     73 8001|40    220 8001|
----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+
WO080188-010 UnR |30     46 8001|40    140 8011|
----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+
WO080188-011 UnR |30     35 8018|40    105 8022|
----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+
WO080188-012 UnR.|30     40 8020|40    120 8027|
----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+
WO080188-013 UnR |30     16 8047|40     50 8049|
----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+
WO080188-014 UnR |30      3 8062|40     10 8063|
----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+
WO080188-015 UnR |30      6 8068|40     20 8069|
================+=================+=================+=================+=================+=================+=================+=================+=================+
 TOTAL  LOAD    |   710 Hours   |  1753 Hours   |    0 Hours    |    0 Hours    |    0 Hours    |    0 Hours    |    0 Hours    |    0 Hours    |    0 Hours    |
----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+-----------------+
 TOTAL  CAPACITY|   760 Hours   |   760 Hours   |    0 Hours    |    0 Hours    |    0 Hours    |    0 Hours    |    0 Hours    |    0 Hours    |    0 Hours    |
================+=================+=================+=================+=================+=================+=================+=================+=================+
 PERCENTAGE     |      93%      |     230%      |     100%      |     100%      |     100%      |     100%      |     100%      |     100%      |     100%      |
============  0%+---------------+---------------+---------------+---------------+---------------+---------------+---------------+---------------+---------------+
                | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| |
                | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| |
                | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| |
                | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| |
             50%| ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| |
                | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| |
                | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| |
                | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| |
                | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| | ||||||||||||| |
            100%| - - - - - -   | +++++++++++++ | +++++++++++++ | +++++++++++++ | +++++++++++++ | +++++++++++++ | +++++++++++++ | +++++++++++++ | +++++++++++++ |
                |               | ||||||||||||| |               |               |               |               |               |               |               |
                |               | ||||||||||||| |               |               |               |               |               |               |               |
                |               | ||||||||||||| |               |               |               |               |               |               |               |
                |               | ||||||||||||| |               |               |               |               |               |               |               |
            150%|               | ||||||||||||| |               |               |               |               |               |               |               |
                |               | ||||||||||||| |               |               |               |               |               |               |               |
                |               | ||||||||||||| |               |               |               |               |               |               |               |
                |               | ||||||||||||| |               |               |               |               |               |               |               |
                |               | ||||||||||||| |               |               |               |               |               |               |               |
            200%|               | ||||||||||||| |               |               |               |               |               |               |               |
                +---------------+---------------+---------------+---------------+---------------+---------------+---------------+---------------+---------------+
```

Table G-7 Work-To-List for work centre 30 and 40 in Work Cell 2

```
                              FOR WORK CELL : 1
--------------------------------------------------------------------------------------------------------------------
Work Centre         Description          No of Operators        No of Machines
    20           TURN/GRIND/CENTRE/PT          2.0                    2.0
--------------------------------------------------------------------------------------------------------------------
                                                 P   E   R   C   E   N   T   A   G   E      L   O   A   D
Day   Estimated  Capacity    x
No    Load(Hrs)   (Hrs)    Load 0%........................50%........................100%........................150%........................200
----  ---------  --------  ----  |                         |                         |                         |                         |
8011      0         15       0%  |                         |                         |                         |                         |
8012      0         15       0%  |                         |                         |                         |                         |
8013      0         16       0%  |                         |                         |                         |                         |
8014      0         16       0%  |     h                   |                         |                         |                         |
8015     42         14     303%  |************************|************************|************************|************************|
8018      0         15       0%  |                         |                         |                         |                         |
8019      0         15       0%  |                         |                         |                         |                         |
8020      0         16       0%  |                         |                         |                         |                         |
8021     44         16     276%  |************************|************************|************************|************************|
8022      0         14       0%  |                         |                         |                         |                         |
8025      0         15       0%  |                         |                         |                         |                         |
8026      0         15       0%  |                         |                         |                         |                         |
8027      0         16       0%  |                         |                         |                         |                         |
8028      0         16       0%  |                         |                         |                         |                         |
8029      0         14       0%  |                         |                         |                         |                         |
8033     26         15     174%  |************************|************************|************************|***********              |
8034      0         16       0%  |                         |                         |                         |                         |
8035      0         16       0%  |                         |                         |                         |                         |
8036      0         14       0%  |                         |                         |                         |                         |
8039     32         15     216%  |************************|************************|************************|************************|
8040      0         15       0%  |                         |                         |                         |                         |
8041      0         16       0%  |                         |                         |                         |                         |
8042      0         16       0%  |                         |                         |                         |                         |
8043      0         14       0%  |                         |                         |                         |                         |
8046      0         15       0%  |                         |                         |                         |                         |
8047      0         15       0%  |                         |                         |                         |                         |
8048     15         16      93%  |************************|********************      |                         |                         |
8049      0         16       0%  |                         |                         |                         |                         |
8050      0         14       0%  |                         |                         |                         |                         |
8053      0         15       0%  |                         |                         |                         |                         |
8054      0         15       0%  |                         |                         |                         |                         |
8055     15         16      93%  |************************|********************      |                         |                         |
8056      0         16       0%  |                         |                         |                         |                         |
8057      0         14       0%  |                         |                         |                         |                         |
8060      0         15       0%  |                         |                         |                         |                         |
8061      0         15       0%  |                         |                         |                         |                         |
8062     13         16      83%  |************************|***************           |                         |                         |
8063      0         16       0%  |                         |                         |                         |                         |
8064      0         14       0%  |                         |                         |                         |                         |
8067      0         15       0%  |                         |                         |                         |                         |
8068      0         15       0%  |                         |                         |                         |                         |
8069      0         16       0%  |                         |                         |                         |                         |
8070      0         16       0%  |                         |                         |                         |                         |
8071      4         14      29%  |*************            |                         |                         |                         |
8074      0         15       0%  |                         |                         |                         |                         |
8075      0         15       0%  |                         |                         |                         |                         |
8076      0         16       0%  |                         |                         |                         |                         |
8077      0         16       0%  |                         |                         |                         |                         |
8078      0         14       0%  |                         |                         |                         |                         |
8081      0         15       0%  |                         |                         |                         |                         |
----  ---------  --------  ----  0%........................50%........................100%........................150%........................200
```

Table G-8 Load analysis report for work centre' 20 in Work Cell 1

```
08/01/88        WORK-TO-LIST LOADING CHART   until   8081
------------------------------------------------------------------------------------------------------

                               W     O     R     K        C     E     N     T     R     E     S

                10      20
Order No  Status |Op No Hrs LSD |Op No  Hrs LSD|Op No Hrs LSD |Op No  Hrs LSD|Op No Hrs LSD |Op No  Hrs LSD|Op No Hrs LSD |Op No  Hrs LSD|Op No  Hrs LSD|
----------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+
WO080188-001 UnR |10    84 8001|20    42 8015|
----------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+
WO080188-002 UnR |10    87 8006|20    44 8021|
----------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+
WO080188-003 UnR |10    51 8021|20    26 8033|
----------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+
WO080188-004 UnR |10    64 8026|20    32 8039|
----------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+
WO080188-005 UnR |10    29 8042|20    15 8048|
----------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+
WO080188-006 UnR |10    29 8049|20    15 8055|
----------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+
WO080188-007 UnR |10    25 8057|20    13 8062|
----------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+
WO080188-008 UnR |10     7 8070|20     4 8071|
----------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+
WO080188-009 UnR |10   546 8001|
----------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+
WO080188-010 UnR |10   140 8001|
----------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+
WO080188-011 UnR |10   105 8015|
----------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+
WO080188-012 UnR |10   120 8020|
----------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+
WO080188-013 UnR |10    50 8042|
----------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+
WO080188-014 UnR |10    10-8056|
----------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+
WO080188-015 UnR |10    20 8062|
================+=============+=============+=============+=============+=============+=============+=============+=============+=============+
  TOTAL  LOAD   | 1369 Hours  |  192 Hours  |   0 Hours   |   0 Hours   |   0 Hours   |   0 Hours   |   0 Hours   |   0 Hours   |   0 Hours   |
----------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+
  TOTAL  CAPACITY|  760 Hours |  760 Hours  |   0 Hours   |   0 Hours   |   0 Hours   |   0 Hours   |   0 Hours   |   0 Hours   |   0 Hours   |
================+=============+=============+=============+=============+=============+=============+=============+=============+=============+
  PERCENTAGE    |    180%     |     25%     |    100%     |    100%     |    100%     |    100%     |    100%     |    100%     |    100%     |
```

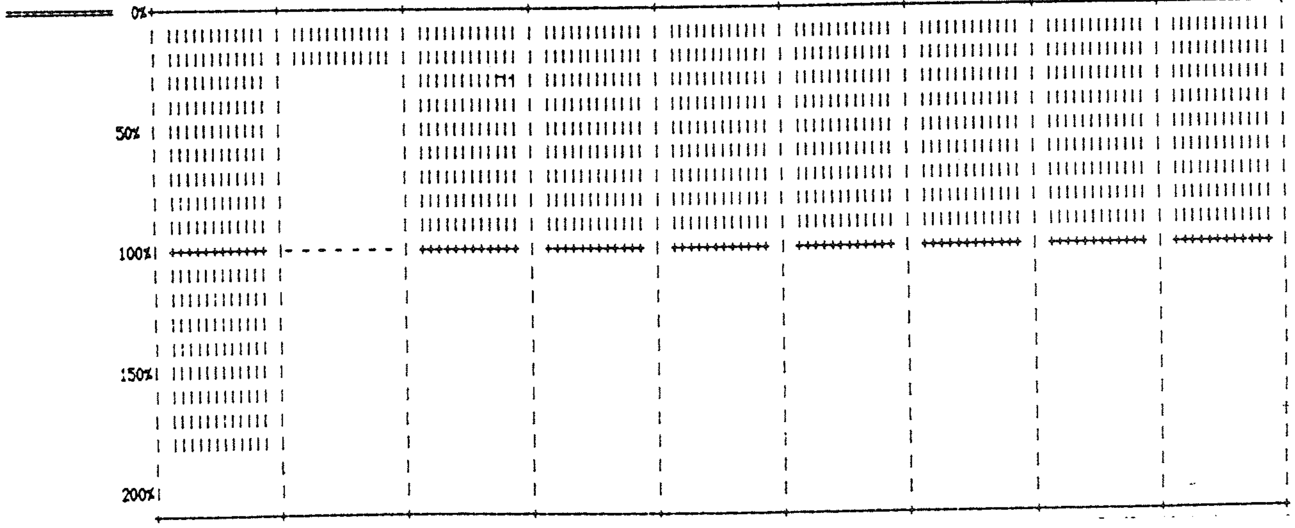


Table G-9 Work-To-List for work centre 10 and 20 in Work Cell 1

APPENDIX H

SELECTED DBASE PROGRAM LISTING

```
* [LOCALMRP.CMD] *************** LOCAL MRP EXPLOSION IN WORK CELL ************
*                                                                          *
*              CIM SYSTEM                 By Andy Lung                     *
*                                                                          *
*  This is a very important Local module in Work Cell planning and control.  *
*  It mainly is to carry out the Material Requirement Planning for that work *
*  cell based on local data and details about Master Production Schedule    *
*  distributed from the Central Planning.                                   *
*                                                                          *
*  The overall work concept is simple, although the module structure and    *
*  data links between Central Planning and various work cells is very       *
*  complicated.  The no. of files involved is large, and the transactions   *
*  between them is complex.  However, the MRP explosion has been simplified *
*  to each local work cell according to the author's philosophy, and only   *
*  access from, or be transfered to, other work cells (foreign cells) if    *
*  necessary.                                                               *
*                                                                          *
*  In each work cell, MPS and MRP activities will apply to local data of    *
*  that cell.  These data would be distributed from central modules when    *
*  central MPS function is executed.                                        *
*                                                                          *
*  When central MPS is executed, new MPS horizon with appropriate orders &  *
*  forecasts would be reformed, and then distributed to the work cells      *
*  based on the product manufacturing details.  All MPS orders and forecasts *
*  will be transfered to the work cells which do their first process, in    *
*  accordance with their BOM and ROUTING details.  BOM details will also be *
*  transfered along with MPS orders,  only ROUTING details are distributed  *
*  separately according to its own process details done in a particular    *
*  work cell.                                                               *
*                                                                          *
*  When all initial data has been distributed to variouts work cells, MRP   *
*  is then to be executed locally in each Cell.  In each work cell, MPSLONG *
*  is first formed by summing the like-product orders in the local          *
*  (MPSORDER) distributed from central planning.  Each product is then read *
*  from there, and all its parts will go through the MRP process.  Results  *
*  are recorded in two local files, the (BUYPART) for bought-in end         *
*  components, and the (WKORDER) for parts manufactured locally.            *
*                                                                          *
*  The important concept in distributed planning and control is : when a   *
*  part read from the product's BOM has to be manufactured in an exteranl   *
*  cell other than locally, the module will automatically pause the MRP     *
*  process for this part and transfer all relevant details about this part  *
*  across the LAN to the work cell concerned, and continue to read another  *
*  part from the same product's BOM until the end.                          *
*                                                                          *
*  During the MRP process for each part, two extra local files are needed.  *
*  They are (ONORDER) for the WIP of local parts, and (PARTINV) for latest  *
*  part inventory details.  (BUYPART) will also be refered if the part is a *
*  a bought-in component, the file initially is updated from MRP process    *
*  directly, but may be modified later by the Central Purchasing if         *
*  necessary.  These files can either be prepared manually, or automatically *
*  from the existing data, depending on the sophistication of the work cell *
*  control program, and of course, the time allowed for the development at  *
*  this stage.  Anyway, the links are all already designed and it should be *
*  just the matter of time to automate all these data preparations.         *
```

```
CIM TEST MODEL**************************************************************

* FIRST ON  : 14-05-86
* LAST REVD : 16/5,19/5,20/5

* ? - STANDS FOR WORK CELL I.D. NO.

* DATAFILES : IN   FILE: (MPSORD-?), (MPSMIX-?), (PARTINV?), (ONORDER?), (BUYPART?), (BOM-?), (ROUTE-?), (MPSLONG?), (WCELLMA
*             OUT  FILE: (MPSLONG?), (GROSS-?), (MRP-?), (WKORDER?), (BUYPART?)
*             TEMP FILE: (TEMPBOM?), (GROSS-?), (MRP-?)

* VARI. IN  : Global var.
* VARI. OUT :
* LOCAL VAR : Mfinished, Mmode, Moption, Mwcid, Myesno, Mperiod:fr, Mprod:no, Mmoseof, Mbomeof, Mskipbom, Mskipmps
*             Mpart:no, Mparent, Mqty, Mlevel, Mld:time, Mendmark, Mtimeno, Mno, Mpreoh, Monorder, Mgross, Moh
*             Mq1, Mq2, Mq3, Mq4, Mq5, Mq6, Mq7, Mq8, Mq9, Mq10, Mpl:qty, Mendno, Mwcell:no, Mtowcid, Mdrive:no

* TOTAL VAR : 60 (include G var)

* LINK FROM :
* LINK TO   :

* ~~~~~~~~~~~~~~~~~~~~~ PROGRAM BEGINS ~~~~~~~~~~~~~~~~~~~~~
ERASE
CLEAR GET
RELEASE ALL EXCEPT G*

* 1~~~~~~~~~~~~~~~~ SET LOCAL VARIABLES ~~~~~~~~~~
STORE F TO Mfinished
STORE "3" TO Mwcid

* 2~~~~~~~~~~~~~~~~ SET UP SCREEN ~~~~~~~~~~~~~~~~
@  0, 0  SAY DATE()
@  0,10  SAY CHR(27)+"aCE"+Gperiod
@  0,26  SAY Gcoloron
@  0,26  SAY "LOCAL MPS & MRP PROCESS"
@  0,64  SAY Gcoloroff
@  0,65  SAY "Mode:"
@  1, 0  SAY "~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~"

* 3~~~~~~~~~~~~~~~~ DO LOOP FOR OVERALL MODULE ~~~~~~~~~~
* DO WHILE========================111111111111111111111111111111111111111
DO WHILE .NOT. Mfinished
     STORE " " TO Moption
     STORE "Select    " TO Mmode
     @  0,70  SAY Mmode
     @  2, 0  SAY Gerasedown
     @ 20, 0  SAY "~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~"
     @ 21, 0  SAY "[S] - start local MPS & MRP          [P] - print current local MPS orders details"
     @ 22, 0  SAY "[R] - result of MRP calculation print-out"
     @ 23, 0  SAY "[H] - help                           [Q] - quit"

* 4~~~~~~~~~~ CHECK IF ENTRY CORRECT ~~~~~~~~~~
     DO WHILE .NOT. Moption$"SPRHQ"
```

```
      @ 23,52  SAY "Please select ootion " GET Mootion PICTURE "!"
      SET CONFIRM OFF
      READ
      SET CONFIRM ON
   ENDDO

5~~~~~~~~~~~~~~~~~ DO CASE FOR DIFFERENT Mootions ~~~~~~~~~~~~~~~~~~~~

   *DO CASE)))))))))))))))))))))))))))11111111111111111111111111111111111
   DO CASE

      * 6~~~~~~~~~~ CASE Mootion = H (HELP) ~~~~~~~~~~
      CASE Mootion = "H"
           DO Localmrp.hlp
           LOOP *to beginning

      * 7~~~~~~~~~~ CASE Moption = Q (QUIT) ~~~~~~~~~~
      CASE Moption = "Q"
           STORE T TO Mfinished
           LOOP *to beginning

      * 8~~~~~~~~~~ CASE Moption = S (START MRP) ~~~~~~~~~~
      CASE Mootion = "S"
           STORE "MPS & MRP " TO Mmode
           @  0,70  SAY Mmode
           @  2, 0  SAY Gerasedown

           * 9~~~~~~~~~~ SHORT NOTE AS REMINDER ~~~~~~~~~~
           @  2, 0  SAY Gcolor1+"IMPORTANT NOTES"+Gcoloroff
           @  3, 0  SAY "---------------"
           @  4, 0  SAY "Local MPS and MRP process will re-generate the reouirement details for this"
           @  5, 0  SAY "local work cell operaton.  The process is based on the latest MPS horizon and"
           @  6, 0  SAY "its orders information which should just be last updated in the CENTRAL PLANNING"
           @  7, 0  SAY "and distributed to here."
           @  9, 0  SAY "Note that if the current MPS order details are not consistent with the central"
           @ 10, 0  SAY "master MPS details, or the MPS horizon is not in pace with that in master MPS,"
           @ 11, 0  SAY "then all calculated results will be incorrect and misleading."
           @ 13, 0  SAY "However, if process were indeed carried out inappropriately, it should not"
           @ 14, 0  SAY "affect the local 'work order details' or 'buy part reouest' if there are back-"
           @ 15 ,0  SAY "up local files.  In this case, transfer the original details from these back up"
           @ 16, 0  SAY "files into concerned files, then the whole process is re-carried out but this"
           @ 17, 0  SAY "time with updated information."
           @ 19, 0  SAY "If decided to go ahead, initial local data files (BOM-?), (MPSORD-?) and"
           @ 20, 0  SAY "(ROUTE-?) should by now be available.  Files like (ONORDER?), (BUYPART?) and"
           @ 21, 0  SAY "(PARTINV?) should also have been updated."

           * 10~~~~~~~~~~ CHANCE TO QUIT ~~~~~~~~~~
           STORE " " TO Myesno
           DO WHILE .NOT. Myesno$"YN"
                @ 23, 0  SAY Gcoloron
                @ 23, 0  SAY "Go ahead to carry out the MPS and MRP funciton, [Y/N] ? " GET Myesno PICTURE "!"
                SET CONFIRM OFF
                READ
                SET CONFIRM ON
                @ 23,58  SAY Gcoloroff
```

```
         ENDDO

         IF Myesno = "N"
              LOOP *to beginning
         ENDIF

 11~~~~~~~~~~~~~~~~~~~~~ MPS AND MRP STARTS ~~~~~~~~~~~~~~~~~~~~~

         * 12~~~~~~~~~~ ARCHIVE PRSENT MPS HORIZON ~~~~~~~~~~
         @  2, 0  SAY Gerasedown
         @ 20, 0  SAY "~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~"
         @ 21, 0  SAY "Archiving new MPS horizon from (MPSFROM) ..."
         SELECT SECOND
         USE Mpsfrom
         STORE Period:fr TO Mperiod:fr
         STORE Period:fr TO Mperiod

         USE Mpslong&Mwcid INDEX Mpslong&Mwcid
         DELETE ALL
         PACK

         * 13~~~~~~~~~~ ADD (MPSMIX-?) TO (MPSORD-?) ~~~~~~~~~~
         @ 22, 0  SAY "Adding orders passed from foreign cells into local MPS orders ..."
         SELECT PRIM
         USE Mpsord-&Mwcid
         INDEX ON Prod:no+Period TO Mpsord-&Mwcid
         APPEND FROM Mpsmix-&Mwcid

         * 14~~~~~~~~~~ CLEAR (MPSMIX-?) CONTENT ~~~~~~~~~~
         DELE FILE Mpsmix-&Mwcid
         COPY STRU TO Mpsmix-&Mwcid

         GO TOP
         STORE Prod:no TO Mprod:no

         * 14a~~~~~~~~~~ FORM LATEST LOCAL (MPSLONG?) ~~~~~~~~~~
         @ 21, 0  SAY Gerasedown

         *DO======(MPSORD-?)===========11111111111111111111111111111111111111111111111111
         DO WHILE .NOT. EOF
              @ 21, 0  SAY $("Forming MPS order summary for "+Gcolor1+Mprod:no+Gcoloroff+" ...",1,79)
              SELECT SECOND
              APPEND BLANK

              * 15~~~~~~~~~~ SUM FOR 1ST PERIOD ~~~~~~~~~~
              @ 21,50  SAY Gcoloron+"PERIOD  1"+Gcoloroff
              SELECT PRIM
              SUM Qty TO Msum WHILE (Prod:no = Mprod:no) .AND. (Period <= Mperiod)
              STORE Period TO Mperiod

              * 15a~~~~~~~~~~ REPLACE P1:QTY WITH MSUM ~~~~~~~~~~
              SELECT SECOND
              REPLACE Prod:no WITH Mprod:no, Period:fr WITH Mperiod:fr, P1:qty WITH Msum

              * 16~~~~~~~~~~ LOOP TO SUM FOR THE REST 9 PERIODS ~~~~~~~~~~
```

```
     STORE 2 TO Mcount
     DO WHILE Mcount ( 11
          @ 21,50  SAY Gcoloron+"PERIOD "+STR(Mcount,2)+Gcoloroff
          IF Mcount = 10
               STORE "P"+STR(Mcount,2)+":QTY" TO Mperiodqty
          ELSE
               STORE "P"+STR(Mcount,1)+":QTY" TO Mperiodqty
          ENDIF

          * 17~~~~~~~~~~ SUM QTY FOR A PERIOD ~~~~~~~~~~
          SELECT PRIM
          SUM Qty TO Msum WHILE (Prod:no = Mprod:no) .AND. (Period = Mperiod)
          STORE Period  TO Mperiod
          STORE Prod:no TO Mprod:no

          * 18~~~~~~~~~~ REPLACE CURRENT PERIOD:QTY WITH MSUM ~~~~~~~~~~
          SELECT SECOND
          REPLACE &Mperiodqty WITH Msum

          STORE Mcount+1 TO Mcount
     ENDDO *while Mcount(11

     * 19~~~~~~~~~~ NEXT PRODUCT UNLESS EOF ~~~~~~~~~~
     SELECT PRIM
ENDDO *while not eof===(MPSORD-?)==========22222222222222222222222222222222222

* 20~~~~~~~~~~ CHANCE TO PRINT MPSLONG ~~~~~~~~~~
STORE " " TO Myesno
@ 21, 0  SAY Gerasedown
@ 21, 0  SAY "Do you want to print the MPS summary report on 80-col paper, [Y/N] ? "
DO WHILE .NOT. Myesno$"YN"
     @ 21,69  GET Myesno PICTURE "!"
     SET CONFIRM OFF
     READ
     SET CONFIRM ON
ENDDO

* 21~~~~~~~~~~ PRINT NEW MPS SUMMARY ~~~~~~~~~~
IF Myesno = "Y"
     @ 21, 0  SAY $("Printing is on the way, please wait ...",1,79)
     SET FORMAT TO PRINT

     * 22~~~~~~~~~~ PRINT HEADING ~~~~~~~~~~
     STORE 6 TO Mline
     @  0, 0  SAY Gprintn
     @  0, 1  SAY Gemphaon
     @  1, 0  SAY Gdate
     @  1,12  SAY "LOCAL MPS SUMMARY REPORT FOR WORK CELL "+Mwcid
     @  2, 0  SAY Gprints
     @  3, 0  SAY "PRODUCT"
     @  3,13  SAY "HORIZON FROM"
     @  3,27  SAY "PERIOD 1"
     @  3,37  SAY "PERIOD 2"
     @  3,47  SAY "PERIOD 3"
     @  3,57  SAY "PERIOD 4"
```

```
    @  3,67  SAY "PERIOD 5"
    @  3.77  SAY "PERIOD 6"
    @  3,87  SAY "PERIOD 7"
    @  3.97  SAY "PERIOD 8"
    @  3,107 SAY "PERIOD 9"
    @  3,117 SAY "PERIOD 10"
    @  4, 0  SAY "-------"
    @  4,13  SAY "-------------"
    @  4,27  SAY "--------"
    @  4,37  SAY "--------"
    @  4,47  SAY "--------"
    @  4,57  SAY "--------"
    @  4,67  SAY "--------"
    @  4,77  SAY "--------"
    @  4,87  SAY "--------"
    @  4,97  SAY "--------"
    @  4,107 SAY "--------"
    @  4,117 SAY "---------"

    @  5, 0  SAY Gemphaoff

    * 23~~~~~~~~~~ LOOP TO PRINT ALL (MPSLONG?) ~~~~~~~~~~
    SELECT SECOND
    GO TOP
    DO WHILE .NOT. EOF
         @  Mline, 0  SAY Prod:no
         @  Mline,16  SAY Period:fr
         @  Mline,29  SAY P1:qty
         @  Mline,39  SAY P2:qty
         @  Mline,49  SAY P3:qty
         @  Mline,59  SAY P4:qty
         @  Mline,69  SAY P5:qty
         @  Mline,79  SAY P6:qty
         @  Mline,89  SAY P7:qty
         @  Mline,99  SAY P8:qty
         @  Mline,109 SAY P9:qty
         @  Mline,119 SAY P10:qty

         STORE Mline+1 TO Mline
         SKIP 1
    ENDDO *while not eof

    @ Mline+1, 0  SAY "(((((((((((((((((((((((((((((((( E N D   O F   M P S L O N G ))))))))))))))))))))))
    @ Mline+2, 0  SAY CHR(12)
    SET FORMAT TO SCREEN
ENDIF *if myesno = y (PRINT)

* 23a~~~~~~~~~~ DELETE CONTENT OF RESULT FILES ~~~~~~~~~~
@ 21, 0  SAY Gerasedown+"Clearing the contents of relevant files ..."
SELECT SECOND

* 23b~~~~~~ CLEAR WKORDER ~~~~~~
USE Wkorder&Mwcid INDEX Wkorder&Mwcid
DELETE ALL
PACK
```

```
             * 23c~~~~~~~ CLEAR BUYPART ~~~~~~~
             USE Buypart&Mwcid INDEX Buypart&Mwcid
             DELETE ALL
             PACK


24~~~~~~~~~~~~~~~~~~~~ CARRY OUT ACTUAL MRP CALCULATION, READ EACH PRODUCT FROM (MPSLONG?) ~~~~~~~~~~~~~~~~~~~~

             SELECT SECOND
             USE
             STORE F TO Mmpseof
             STORE 0 TO Mskipmps

             *DO====(MPSLONG?)============33333333333333333333333333333333333333333333333
             DO WHILE .NOT. Mmpseof
                  @  2, 0  SAY Gerasedown
                  @ 20, 0  SAY "~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~"

                  * 25~~~~~~~~~~ READ A PRODUCT FROM (MPSLONG?) ~~~~~~~~~~
                  SELECT PRIM
                  USE Mpslong&Mwcid INDEX Mpslong&Mwcid
                  SKIP Mskipmps
                  STORE Mskipmps+1 TO Mskipmps

                  * 26~~~~~~~~~~ CHECK IF EOF ~~~~~~~~~~
                  IF EOF
                       STORE T TO Mmpseof
                       LOOP
                  ELSE
                       STORE TRIM(Prod:no) TO Mprod:no
                  ENDIF

                  @  2,10  SAY CHR(27)+"aEC"+"MRP EXPLOSION FOR PRODUCT : "+CHR(27)+"aE@"+Mprod:no+Gcoloroff

                  * 26a~~~~~~~~~~ CLEAR RELEVANT FILES ~~~~~~~~~~
                  @  3, 0  SAY "Clearing the contents of relevant files ..."
                  SELECT SECOND

                  * 26b~~~~~~~~ CLEAR GROSS ~~~~~~~~
                  USE Gross-&Mwcid INDEX Gross-&Mwcid
                  DELETE ALL
                  PACK

                  * 27~~~~~~~~~~ COPY PRODUCT GROSS FROM (MPSLONG?) INTO (GROSS?) ~~~~~~~~~~
                  @  4, 0  SAY "Copying the product gross requirement into (GROSS) ..."
                  SELECT PRIM
                  COPY TO Temp&Mwcid SDF WHILE Prod:no = Mprod:no
                  SELECT SECOND
                  APPEND FROM Temp&Mwcid SDF

                  * 28~~~~~~~~~~ COPY PRODUCT STRUCTURE TO (TEMPBOM?) ~~~~~~~~~~
                  @  5, 0  SAY "Copying product structure from local (BOM) into (Tempbom) ..."
                  SELECT PRIM
                  USE Bom-&Mwcid INDEX Bom-&Mwcid
```

```
FIND &Mprod:no

IF # ) 0
     SET INDEX TO
     COPY TO Tempbom&Mwcid WHILE Prod:no = Mprod:no
     USE Tempbom&Mwcid
ELSE
     @ 21, 0  SAY CHR(27)+"aBD"+"Something has gone wrong!  No Bill Of Material details found"
     @ 22, 0  SAY "for this product "+Gcolor1+Mprod:no+Gcoloroff
     @ 23, 0  SAY "Please check."
     SET CONSOLE OFF
     WAIT
     SET CONSOLE ON
ENDIF

* 29~~~~~~~~~~ READ EACH ELEMENT FROM PRODUCT STRUCTURE ~~~~~~~~~~
@  6, 0  SAY "Calculating each element in Temporary Bill if made locally ..."
STORE F TO Mbomeof
STORE 0 TO Mskipbom

*DO============================444444444444444444444444444444444444444444444444
DO WHILE .NOT. Mbomeof
     @  8, 0  SAY Gerasedown
     @ 20, 0  SAY "~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~"
     SELECT PRIM
     USE Tempbom&Mwcid
     SKIP Mskipbom
     STORE Mskipbom+1 TO Mskipbom

     IF EOF
          STORE T TO Mbomeof
          LOOP
     ELSE
          @ 8, 0  SAY Gcolor1+"Current logged in Part : "+Part:no+Gcoloroff
          @ 9, 0  SAY "Generating Gross-Requirement for the part ..."
          STORE Part:no TO Mpart:no
          STORE Parent  TO Mparent
          STORE Qty     TO Mqty
          STORE Level   TO Mlevel
          STORE Ld:time TO Mld:time
          STORE Endmark TO Mendmark
      ENDIF *if eof


      *IF-----------------------111111111111111111111111111111111111111111111111
      IF Mlevel = 0
      * 30~~~~~~~~ ARCHIVE PARENT GROSS FROM (GROSS-?) ~~~~~~~~
           SELECT SECOND
           USE Gross-&Mwcid INDEX Gross-&Mwcid
           FIND &Mparent

           IF # ) 0
                COPY TO Temp&Mwcid WHILE Parent = Mparent
                APPEND FROM Temp&Mwcid
                REPLACE Parent WITH Mpart:no, Period:fr WITH Mperiod:fr,  P1:qty WITH P1:qty*Mqty
```

```
                                REPLACE P2:aty WITH P2:aty*Maty, P3:aty WITH P3:aty*Maty, P4:aty WITH P4:aty*Maty
                                REPLACE P5:aty WITH P5:aty*Maty; P6:aty WITH P6:aty*Maty, P7:aty WITH P7:aty*Maty
                                REPLACE P8:aty WITH P8:aty*Maty, P9:aty WITH P9:aty*Maty, P10:aty WITH P10:aty*Maty
                           ELSE
                                @ 21, 0  SAY CHR(27)+"aBD"+"There is something gone wrong!  No initial data set is"
                                @ 22, 0  SAY "available.  Please check"+Gcoloroff
                                SET CONSOLE OFF
                                WAIT
                                SET CONSOLE ON
                           ENDIF

                      ELSE *~~~~~~ IF LEVEL ) 0 -----------11111111111111111
                      * 31~~~~~~~~ ARCHIVE PARENT GROSS FROM MRP RESULT TABLE FOR LOCAL MADE PART (WKORDER) ~~~~~~~
                           SELECT SECOND
                           USE Wkorder&Mwcid INDEX Wkorder&Mwcid
                           FIND &Mparent

                           IF # ) 0
                                COPY TO Temp&Mwcid WHILE Part:no = Mparent
                                USE Gross-&Mwcid INDEX Gross-&Mwcid
                                APPEND FROM Temp&Mwcid
                                REPLACE Parent WITH Mpart:no, Period:fr WITH Mperiod:fr,  P1:qty WITH P1:qty*Mqty
                                REPLACE P2:qty WITH P2:qty*Mqty, P3:qty WITH P3:qty*Mqty, P4:qty WITH P4:qty*Mqty
                                REPLACE P5:qty WITH P5:qty*Mqty, P6:qty WITH P6:qty*Mqty, P7:qty WITH P7:qty*Mqty
                                REPLACE P8:qty WITH P8:qty*Mqty, P9:qty WITH P9:qty*Mqty, P10:qty WITH P10:qty*Mqty
                           ELSE
                                @ 21, 0  SAY CHR(27)+"aBD"+"Something has gone wrong.  In theory, the current part "+Mpart
                                @ 22, 0  SAY "should be present in the so far (MRP) result, and used in GROSS REQUIREMTN"
                                @ 23, 0  SAY "calculation for "+Mpart:no
                                @ 23,30  SAY Gcoloron+"Please stop and check"+Gcoloroff
                                SET CONSOLE OFF
                                WAIT
                                SET CONSOLE ON
                           ENDIF
                       ENDIF *if Mlevel ) 0-------------------1111111111111111111111111111111111

~~~~~~~~~~ UP TO THIS POINT, PRIM IS (Tempbom?), SECOND IS (Gross-?) ~~~~~~~~~~

                       * 32~~~~~~~~~~ CHECK IF PART IS END PART, THEN CHECK IF IT IS MADE HERE ~~~~~~~~~~
                       IF .NOT. Mendmark$"YE"
                            SELECT PRIM
                            USE Route-&Mwcid INDEX Route-&Mwcid
                            FIND &Mpart:no

                            IF # ) 0
                            * 33~~~~~~~PART NOT MADE HERE ~~~~~~~
                                 IF .NOT. $(Wcell:no,3,2) = Mwcid
                                      STORE Wcell:no TO Mwcell:no

                                      IF VAL($(Wcell:no,3,2)) ) 9
                                           STORE $(Wcell:no,3,2) TO Mtowcid
                                      ELSE
                                           STORE $(Wcell:no,3,1) TO Mtowcid
                                      ENDIF
```

```
          @ 21, 0  SAY Gerasedown
          @ 21, 0  SAY "The part "+Gcolor1+Mpart:no+Gcoloroff+" is not made in this work cell."
          @ 22, 0  SAY "Its GROSS REQUIREMENT is being sent to "+Gcolor1+"W.C."+Mtowcid+Gcoloro
~~~~~~~~~~~~~~~~~~~~  CALL PROCEDURES TO TRANSFER DETAILS (PART'S GROSS) TO  W.C. CONCERNED ~~~~~~~~~~

          * 33a~~~~~~~~~~ CHECK FOREIGN CELL DRIVE LOCATION ~~~~~~~~~~
          SELECT PRIM
          USE Wcellmap INDEX Wcellmap
          FIND &Mwcell:no

          * 33b~~~~~~~~~~ COPY PART'S GROSS ACROSS TO FOREIGN CELL ~~~~~~~~~~  .
          IF # ) 0
               STORE Drive:no TO Mdrive:no
               SELECT PRIM
               USE &Mdrive:no.:Mosmix-&Mtowcid

               * 33c~~~~~~~~~~ LOOP TO COPY EACH NON-ZERO PERIOD ~~~~~~~~~~
               STORE 1 TO Mtimeno

               *DO===========================6666666666666666666666666666666666666
               DO WHILE Mtimeno ( 11
                    IF Mtimeno ( 10
                         STORE STR(Mtimeno,1) TO Mno
                    ELSE
                         STORE STR(Mtimeno,2) TO Mno
                    ENDIF

                    STORE VAL($(Mperiod:fr,1,2)) TO Myy
                    STORE VAL($(Mperiod:fr,4,2)) TO Mpp
                    STORE Mpp + (Mtimeno-1) TO Mpp
                    IF Mpp ) 52
                         STORE Mpp-52 TO Mpp
                         STORE Myy+1  TO Myy
                    ENDIF

                    IF Mpp ( 10
                         STORE STR(Myy,2) + ":0" + STR(Mpp,1) TO Mperiod
                    ELSE
                         STORE STR(Myy,2) + ":"  + STR(Mpp,2) TO Mperiod
                    ENDIF

                    SELECT SECOND
                    IF P&Mno.:qty () 0
                         SELECT PRIM
                         APPEND BLANK
                         REPLACE Order:no WITH "CELL REQ", Cust:name WITH Mwcell:no
                         REPLACE Prod:no WITH Mpart:no, Qty WITH P&Mno.:qty, Period WITH Mperi
                    ENDIF
                    STORE Mtimeno+1 TO Mtimeno
               ENDDO *while Mtimeno(11 ==============66666666666666666666666666

               SELECT PRIM
               USE
               RELEASE Mperiod,Myy,Mpp
```

```
                                ELSE
                                    @ 21, 0  SAY Gerasedown+CHR(27)+"aBD"
                                    @ 21, 0  SAY "Something has gone wrong!  Can not find the drive location for"
                                    @ 22, 0  SAY Gcolor1+Mwcell:no+Gcoloroff+" and therefore information can't be se
                                    @ 23, 0  SAY "across the network.  "+Gcoloron+"Please stop and check"+Gcoloroff
                                    SET CONSOLE OFF
                                    WAIT
                                    SET CONSOLE ON
                                ENDIF *if #)0

                                * 33d~~~~~~~~~~~ AVANCE TO NEXT PART IN (TEMPBOM?) ~~~~~~~~~~
                                LOOP *to Mbomeof

                            ENDIF
                        ELSE *~~~~~~~~ PART NOT FOUND IN (ROUTE-?) ~~~~~~~~~~
                            @ 21, 0  SAY Gerasedown+CHR(27)+"aBD"
                            @ 21, 0  SAY "Something has gone wrong!  The routing details for the part "+Gcolor1+Mpart:
                            @ 22, 0  SAY CHR(27)+"aBD"+"is not found in local database."
                            @ 22,33  SAY Gcoloron+"Please stop and check"+Gcoloroff
                            SET CONSOLE OFF
                            WAIT
                            SET CONSOLE ON
                        ENDIF *if # ) 0 (PART FOUND IN (ROUTE-?)

                    ENDIF *if not Mendmark$"YE"


* 34~~~~~~~~~~~ START ACTUAL MRP ~~~~~~~~~~


                    * 35~~~~~~~~ DELETE CURRENT CONTENT OF (MRP-?) ~~~~~~~~~~
                    @ 10, 0  SAY "Deleting current content of temp (MRP) file ..."
                    SELECT PRIM
                    USE MRP-&Mwcid
                    DELETE ALL
                    PACK

                    * 36~~~~~~~~~~ COPY GROSS TO MRP 1ST LINE ~~~~~~~~~~
                    @ 11, 0  SAY "Copying part "+Gcolor1+Mpart:no+Gcoloroff+"'s GROSS REQUIREMENT into MRP ..."
                    APPEND BLANK
                    REPLACE Item WITH "GROSS REQ", P1:qty WITH S.P1:qty, P2:qty WITH S.P2:qty, P3:qty WITH S.P3:qty
                    REPLACE P4:qty WITH S.P4:qty,  P5:qty WITH S.P5:qty, P6:qty WITH S.P6:qty, P7:qty WITH S.P7:qty
                    REPLACE P8:qty WITH S.P8:qty,  P9:qty WITH S.P9:qty, P10:qty WITH S.P10:qty

                    * 37~~~~~~~~~~~ COPY PART'S ON ORDER EITHER FROM (ONORDER?) OR (ONBUY-?) ~~~~~~~~~~
                    SELECT SECOND
                    @ 12, 0  SAY "Copying part's on-order arrival to 2nd line of MRP ..."

                    * ~~~~~~~ IF END COMPONENT ~~~~~~~~~~
                    IF Mendmark$"YE"
                        USE Onbuy-&Mwcid INDEX Onbuy-&Mwcid
                    ELSE *~~~~~~~~ IS SUBASSEMBLY ~~~~~~~~
                        USE Onorder&Mwcid INDEX Onorder&Mwcid
                    ENDIF

                    FIND &Mpart:no
```

```
IF # ) 0
     SELECT PRIM
     APPEND BLANK
     REPLACE Item WITH "ON ORDER", P1:qty WITH S.P1:qty, P2:qty WITH S.P2:qty, P3:qty WITH S.P3:qty
     REPLACE P4:qty WITH S.P4:qty, P5:qty WITH S.P5:qty, P6:qty WITH S.P6:qty, P7:qty WITH S.P7:qty
     REPLACE P8:qty WITH S.P8:qty, P9:qty WITH S.P9:qty, P10:qty WITH S.P10:qty
ELSE
     @ 21, 0  SAY Gerasedown+CHR(27)+"aBD"
     @ 21, 0  SAY "Something may have gone wrong, since no on-order record can be found for"
     @ 22, 0  SAY "this part "+Gcolor1+Mpart:no+CHR(27)+"aBD"+" from either (ONORDER) or (ONBUY)"
     @ 23, 0  SAY Gcoloron+"Copying blank to this line and assume nothing is on order"+Gcoloroff
     SELECT PRIM
     APPEND BLANK
     REPLACE Item WITH "ON ORDER"
ENDIF

* 39~~~~~~~~~~ COPY PART'S O/H QTY TO 3RD LINE MRP ~~~~~~~~~~
@ 13, 0  SAY "Copying the latest information of on-hand qty to MRP ..."

* 38a~~~~~~~~~~ EVEN IT IS PRODUCT ASSEMBLY, O/H QTY SHOULD BE THERE FROM CENTRAL (PRODINV) ~~~~~~~
SELECT SECOND
USE Partinv&Mwcid INDEX Partinv&Mwcid
FIND &Mpart:no

IF # ) 0
     SELECT PRIM
     APPEND BLANK
     REPLACE Item WITH "ON HAND", P0:qty WITH S.Oh:qty
ELSE
     @ 21, 0  SAY Gerasedown+CHR(27)+"aBD"
     @ 21, 0  SAY "Something may have gone wrong, since no on-hand inventory record can be"
     @ 22, 0  SAY "found for this part in local (PARTINV)."
     @ 23, 0  SAY Gcoloron+"The system will assume ZERO on-hand inventory for this part ..."+Gcolor
     SELECT PRIM
     APPEND BLANK
     REPLACE Item WITH "ON HAND"
ENDIF

* 39~~~~~~~~~~~~~~~~~~~~ LOOP TO CALCULATE NET REQUIREMENTS ~~~~~~~~~~~~~~~~~~~~

@ 14, 0  SAY "Calculating the net requirement at each period ..."
STORE 1 TO Mtimeno
SELECT PRIM
APPEND BLANK
REPLACE Item WITH "NET REQ"
APPEND BLANK
REPLACE Item WITH "RECOMM ORD"

*DO==========================555555555555555555555555555555555555555555555555
DO WHILE Mtimeno ( 11

     STORE STR(Mtimeno-1,1) TO Mno
     GOTO 3
     STORE P&Mno.:qty TO Moreoh
```

```
                        IF Mtimeno ( 10
                            STORE STR(Mtimeno,1) TO Mno
                        ELSE
                            STORE STR(Mtimeno,2) TO Mno
                        ENDIF

                        GOTO 2
                        STORE P&Mno.:qty TO Monorder

                        GOTO 1
                        STORE P&Mno.:qty TO Mgross

                        STORE Mpreoh + Monorder - Mgross TO Moh

                        * 40~~~~~~~~~ TEST IF Moh ( 0 ~~~~~~~~
                        IF Moh ( 0
                            GOTO 3
                            REPLACE P&Mno.:qty WITH 0
                            GOTO 4
                            REPLACE P&Mno.:qty WITH -Moh
                        ELSE
                            GOTO 3
                            REPLACE P&Mno.:qty WITH Moh
                        ENDIF

                        STORE Mtimeno+1 TO Mtimeno
                    ENDDO *while Mtimeno(11 ==================555555555555555555555555555555555

41~~~~~~~~~~~~~~ CALCULATE RECOMMENDED ORDERS ~~~~~~~~~~~~~~
                    @ 15, 0  SAY "Resulting the final recommended orders for the part ..."

                    * 42~~~~~~~~~~ STORE QTY AT RECD 4 INTO Q1 -) Q10 ~~~~~~~
                    GOTO 4
                    STORE 1 TO Mtimeno
                    DO WHILE Mtimeno ( 11
                        IF Mtimeno ( 10
                            STORE STR(Mtimeno,1) TO Mno
                        ELSE
                            STORE STR(Mtimeno,2) TO Mno
                        ENDIF

                        STORE P&Mno.:qty TO Mq&Mno
                        STORE Mtimeno+1 TO Mtimeno
                    ENDDO

                    * 43~~~~~~~~~~~ SUM RECOMM ORDERS FOR PERIOD 1 ~~~~~~~~~~
                    STORE 0 TO Mp1:qty
                    STORE 1 TO Mtimeno

                    DO WHILE Mtimeno ( Mld:time+2
                        STORE STR(Mtimeno,1) TO Mno
                        STORE Mp1:qty + Mq&Mno TO Mp1:qty
                        STORE Mtimeno+1 TO Mtimeno
                    ENDDO
```

```
        GOTO 5
        REPLACE P1:qty WITH Mq1:qty

        * 44~~~~~~~~~~~ LOOP TO GENERATE OTHER RECOMM ORDERS ~~~~~~~~~~~
        STORE 2 TO Mtimeno
        DO WHILE Mtimeno ( (11-Mld:time)
             IF Mtimeno ( 10
                  STORE STR(Mtimeno,1) TO Mno
             ELSE
                  STORE STR(Mtimeno,2) TO Mno
             ENDIF

             IF Mtimeno+Mld:time ( 10
                  STORE STR(Mtimeno+Mld:time,1) TO Mendno
             ELSE
                  STORE STR(Mtimeno+Mld:time,2) TO Mendno
             ENDIF

             REPLACE P&Mno.:qty WITH Mq&Mendno
             STORE Mtimeno+1 TO Mtimeno
        ENDDO

        * 45~~~~~~~~~~~ CHECK IF THIS IS END COMPONENT ~~~~~~~~~~~
        IF Mendmark$"YE"
             @ 16, 0  SAY "Adding part request orders to local (BUY PARTS) file ..."
             SELECT SECOND
             USE Buypart&Mwcid INDEX Buypart&Mwcid
             APPEND BLANK
             REPLACE Part:no WITH Mpart:no, Period:fr WITH Mperiod:fr, P1:qty WITH P.P1:qty
             REPLACE P2:qty WITH P.P2:qty, P3:qty WITH P.P3:qty, P4:qty WITH P.P4:qty
             REPLACE P5:qty WITH P.P5:qty, P6:qty WITH P.P6:qty, P7:qty WITH P.P7:qty
             REPLACE P8:qty WITH P.P8:qty, P9:qty WITH P.P9:qty, P10:qty WITH P.P10:qty

        ELSE *~~~~~~~~~~~ LOCAL MADE PART ~~~~~~~~~~~
             @ 16, 0  SAY "Adding part work orders to local (MAKE PART) request file ..."
             SELECT SECOND
             USE Wkorder&Mwcid INDEX Wkorder&Mwcid
             APPEND BLANK
             REPLACE Part:no WITH Mpart:no, Period:fr WITH Mperiod:fr, P1:qty WITH P.P1:qty
             REPLACE P2:qty WITH P.P2:qty, P3:qty WITH P.P3:qty, P4:qty WITH P.P4:qty
             REPLACE P5:qty WITH P.P5:qty, P6:qty WITH P.P6:qty, P7:qty WITH P.P7:qty
             REPLACE P8:qty WITH P.P8:qty, P9:qty WITH P.P9:qty, P10:qty WITH P.P10:qty
        ENDIF

   ENDDO *while not Mbomeof ===(TEMPBOM?)=====444444444444444444444444444444444

ENDDO *while not Mmpseof ===(MPSLONG?)=====333333333333333333333333333333333333

* 46~~~~~~~~~~~ NOTE AFTER ALL MRP EXPLOSION ~~~~~~~~~~~
@  2, 0  SAY Gerasedown
@  2, 0  SAY Gcolor1+"NOTE AFTER LOCAL MRP EXPLOSION FINISH"+Gcoloroff
@  3, 0  SAY "------------------------------------"
@  4, 0  SAY "You have just finished the local MRP calculation for the requirements of"
@  5, 0  SAY "local-made parts and bought-in parts directly related to this local Work Cell."
@  7, 0  SAY "Basically, the results are stored in 2 local files: (WKORDER?) - holds the"
```

```
    @  8, 0  SAY "recommended work orders needed for local-made parts, and (BUYPART?) - holds the"
    @  9, 0  SAY "recommended purchase request for bought-in parts."
    @ 11, 0  SAY "You can print all the results on paper with option [R] chosen at the beginning."
    @ 12, 0  SAY "Also, you may print the current MPS orders which have been distributed to this"
    @ 13, 0  SAY "cell from the [CENTRAL PLANNING].  These orders are inputs for MRP calculation"
    @ 14, 0  SAY "and should remain unchanged until the MRP explosion next time."
    @ 16, 0  SAY "Note that this work cell may have passed some parts' GROSS DEMAND information"
    @ 17, 0  SAY "to the external work cells concerned, as these parts are not made locally."
    @ 19, 0  SAY "It is extremely important to take action against the make/buy recommendations"
    @ 20, 0  SAY "resulted from this module so that these parts would be available on time in"
    @ 21, 0  SAY "accordance with the estimation of demand"
    @ 23, 0  SAY Gcoloron+"Press (ANY KEY) to return"+Gcoloroff
    SET CONSOLE OFF
    WAIT
    SET CONSOLE ON
    @ 23, 0  SAY $("Returning to beginning ...",1,79)

    RELEASE Myesno, Mprod:no, Mmpseof, Mbomeof, Mcount, Mskipmos, Mskipbom, Mno, Mpreoh, Monorder, Mgross
    SELECT SECOND
    USE
    SELECT PRIM
    USE
    LOOP *to beginning

* 47~~~~~~~~~~~ CASE Moption = P (PRINT LOCAL MPS ORDERS) ~~~~~~~~~~~
CASE Moption = "P"
     STORE " " TO Myesno
     STORE "Print MPS " TO Mmode
     @  0,70  SAY Mmode
     @ 21, 0  SAY Gerasedown
     @ 21, 0  SAY "If the MRP option has already been chosen, the orders information will include"
     @ 22, 0  SAY "make requests from other Work Cell.  Otherwise it will only contain MPS orders"
     @ 23, 0  SAY "distributed from CENTRAL PLANNING."+Gcoloron
     DO WHILE .NOT. Myesno$"YN"
          @ 23,35  SAY "Want to print on 80-col paper, [Y/N] ? " GET Myesno PICTURE "!"
          SET CONFIRM OFF
          READ
          SET CONFIRM ON
     ENDDO
     @ 21, 0  SAY Gcoloroff+Gerasedown

     IF Myesno = "Y"
          @ 21, 0  SAY "Printing is on the way, please wait ..."
          SELECT PRIM
          USE Mosord-&Mwcid INDEX Mosord-&Mwcid
     ELSE
          LOOP *to beginning
     ENDIF

     * 48~~~~~~~~~~~ PRINT HEADING ~~~~~~~~~~~
     STORE 8 TO Mline
     SET FORMAT TO PRINT
     @  0, 0  SAY Gprintn
     @  0, 1  SAY Gemphaon
     @  1, 0  SAY Gdate
```

```
    @  1,12  SAY "CURRENT LOCAL MPS-ORDER INFORMATION FOR WORK CELL "+Mwcid
    @  2,12  SAY "AT PERIOD "+Gperiod
    @  3, 0  SAY Gprints
    @  5, 0  SAY "ORDER NO."
    @  5,14  SAY "CUSTOMER"
    @  5,38  SAY "PRODUCT/PART"
    @  5,54  SAY "QTY"
    @  5,63  SAY "DELI. PERIOD"
    @  5,79  SAY "VALID TILL"
    @  5,93  SAY "QUOTE NO."
    @  6, 0  SAY "---------"
    @  6,14  SAY "--------"
    @  6,38  SAY "------------"
    @  6,54  SAY "---"
    @  6,63  SAY "------------"
    @  6,79  SAY "----------"
    @  6,93  SAY "---------"

    @  7, 0  SAY Gemphaoff

    DO WHILE .NOT. EOF
         @  Mline, 0  SAY Order:no
         @  Mline,14  SAY Cust:name
         @  Mline,38  SAY Prod:no
         @  Mline,54  SAY Qty
         @  Mline,66  SAY Period
         @  Mline,81  SAY Valid:to
         @  Mline,93  SAY Quote:no

         STORE Mline+1 TO Mline
         SKIP 1
    ENDDO

    @ Mline+1, 0 SAY "(((((((((((((((((((((((((((((E N D   O F   L O C A L   M P S   O R D E R S))))))))))))))
    @ Mline+2, 0 SAY CHR(12)
    SET FORMAT TO SCREEN
    USE
    RELEASE Mline, Myesno

* 49~~~~~~~~~~ CASE Moption = R (RESULT OF MRP PRINT) ~~~~~~~~~~
CASE Moption = "R"
     STORE " " TO Myesno
     STORE "MRP result" TO Mmode
     @  0,70  SAY Mmode
     @  2, 0  SAY Gerasedown
     @ 20, 0  SAY "~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~"
     @  2, 0  SAY Gcolor1+"IMPORTANT NOTE BEFORE PRINT"+Gcoloroff
     @  3, 0  SAY "---------------------------"
     @  4, 0  SAY "This print option will print the current content of 2 local action files, namely"
     @  5, 0  SAY "(WKORDER?) - holds recommended orders for local-made parts resulted from latest"
     @  6, 0  SAY "MRP operation, and (BUYPART?) - holds recommended orders for bought-in parts"
     @  7, 0  SAY "resulted from latest MRP operation."
     @  9, 0  SAY "If you have already run the local MRP option, then the details in these two"
     @ 10, 0  SAY "files will be the most updated, otherwise they only contain the results from"
     @ 11, 0  SAY "last MRP run and are only useful for reference purpose."
```

```
@ 13, 0  SAY "It is advisable to raise actual works orders and purchase orders in accordance"
@ 14, 0  SAY "with these recommendations in order to meet the demands of parts concerned."

DO WHILE .NOT. Myesno$"YN"
     @ 21, 0  SAY "Do you want to print these details on 80-col paper, [Y/N] ? " GET Myesno PICTURE "!"
     SET CONFIRM OFF
     READ
     SET CONFIRM ON
ENDDO

IF Myesno = "Y"
     @ 21, 0  SAY Gerasedown+"Printing local (WKORDER) file details ..."
     SELECT PRIM
     USE Wkorder&Mwcid INDEX Wkorder&Mwcid
     STORE Period:fr TO Mperiod:fr
ELSE
     LOOP *to beginning
ENDIF

* 50~~~~~~~~~~ PRINT HEADING ~~~~~~~~~~
STORE 9 TO Mline
SET FORMAT TO PRINT
@  0, 0  SAY Gprintn
@  0, 1  SAY Gemphaon
@  1, 0  SAY Gdate
@  1,10  SAY "CURRENT WORK ORDERS RECOMMENDATION FROM LAST MRP RUN FOR LOCAL PARTS"
@  2,10  SAY "FOR PERIOD : "+Mperiod:fr+"    CURRENT PERIOD : "+Gperiod
@  3, 0  SAY Gprints
@  5, 0  SAY "PART NO."
@  5,16  SAY "PERIOD"
@  5,26  SAY "PERIOD"
@  5,36  SAY "PERIOD"
@  5,46  SAY "PERIOD"
@  5,56  SAY "PERIOD"
@  5,66  SAY "PERIOD"
@  5,76  SAY "PERIOD"
@  5,86  SAY "PERIOD"
@  5,96  SAY "PERIOD"
@  5,106 SAY "PERIOD"

* 51~~~~~~~~~~ LOOP TO PRINT PERIOD ~~~~~~~~~~
STORE 1 TO Mtimeno
STORE 16 TO Mcol
STORE Mperiod:fr TO Mperiod

DO WHILE Mtimeno ( 11
     @  6,Mcol  SAY Mperiod
     STORE Mtimeno+1 TO Mtimeno
     STORE Mcol+10 TO Mcol
     STORE VAL($(Mperiod,1,2)) TO Myy
     STORE VAL($(Mperiod,4,2)) TO Mpp
     STORE Mpp+1 TO Mpp

     IF Mpp ) 52
          STORE Mpp-52 TO Mpp
```

```
            STORE Myy+1 TO Myy
            STORE STR(Myy,2)+":0"+STR(Mpp,1) TO Mperiod
         ELSE
            IF Mpp ( 10
                STORE STR(Myy,2)+"0:"+STR(Mpp,1) TO Mperiod
            ELSE
                STORE STR(Myy,2)+":"+STR(Mpp,2)  TO Mperiod
            ENDIF
         ENDIF
      ENDDO *while Mtimeno(11

      @  7, 0  SAY "--------"
      @  7,16  SAY "------"
      @  7,26  SAY "------"
      @  7,36  SAY "------"
      @  7,46  SAY "------"
      @  7,56  SAY "------"
      @  7,66  SAY "------"
      @  7,76  SAY "------"
      @  7,86  SAY "------"
      @  7,96  SAY "------"
      @  7,106 SAY "------"

      @  8, 0  SAY Seaphaoff

2~~~~~~~~~~ PRINT (WORK ORDER) FIRST ~~~~~~~~~~
      DO WHILE .NOT. EOF
          @ Mline, 0  SAY Part:no
          @ Mline,16  SAY P1:qty
          @ Mline,26  SAY P2:qty
          @ Mline,36  SAY P3:qty
          @ Mline,46  SAY P4:qty
          @ Mline,56  SAY P5:qty
          @ Mline,66  SAY P6:qty
          @ Mline,76  SAY P7:qty
          @ Mline,86  SAY P8:qty
          @ Mline,96  SAY P9:qtY
          @ Mline,106 SAY P10:qty

          STORE Mline+1 TO Mline
          SKIP 1
       ENDDO

       @ Mline+1, 0 SAY "((((((((((((((((((((((((((((((END OF RECOMMENDED WORK ORDERS)
       @ Mline+2, 0 SAY CHR(12)
       SET FORMAT TO SCREEN

53~~~~~~~~~~ PRINT (BUY PART) FILE ~~~~~~~~~~
       @ 22, 0  SAY "Printing local (BUYPART) file details ..."
       USE Buypart&Mwcid INDEX Buypart&Mwcid
       STORE Period:fr TO Mperiod:fr

       * 54~~~~~~~~~~ PRINT HEADING ~~~~~~~~~~
       STORE 9 TO Mline
       SET FORMAT TO PRINT
```

```
@  0, 0  SAY Gprintn
@  0, 1  SAY Gemonhaon
@  1, 0  SAY Gdate
@  1,10  SAY "CURRENT BUY-ORDER RECOMMENDATION FROM LAST MRP RUN FOR EXTERNAL PARTS"
@  2,10  SAY "FOR PERIOD : "+Mperiod:fr+"    CURRENT PERIOD : "+Gperiod
@  3, 0  SAY Gprints
@  5, 0  SAY "PART NO."
@  5,16  SAY "PERIOD"
@  5,26  SAY "PERIOD"
@  5,36  SAY "PERIOD"
@  5,46  SAY "PERIOD"
@  5,56  SAY "PERIOD"
@  5,66  SAY "PERIOD"
@  5,76  SAY "PERIOD"
@  5,86  SAY "PERIOD"
@  5,96  SAY "PERIOD"
@  5,106 SAY "PERIOD"

* 55~~~~~~~~~~ LOOP TO PRINT PERIOD ~~~~~~~~~~
STORE 1 TO Mtimeno
STORE 16 TO Mcol
STORE Mperiod:fr TO Mperiod

DO WHILE Mtimeno ( 11
     @  6,Mcol  SAY Mperiod
     STORE Mtimeno+1 TO Mtimeno
     STORE Mcol+10 TO Mcol
     STORE VAL($(Mperiod,1,2)) TO Myy
     STORE VAL($(Mperiod,4,2)) TO Mpp
     STORE Mpp+1 TO Mpp

     IF Mpp ) 52
          STORE Mpp-52 TO Mpp
          STORE Myy+1 TO Myy
          STORE STR(Myy,2)+":0"+STR(Mpp,1) TO Mperiod
     ELSE
          IF Mpp ( 10
               STORE STR(Myy,2)+"0:"+STR(Mpp,1) TO Mperiod
          ELSE
               STORE STR(Myy,2)+":"+STR(Mpp,2)  TO Mperiod
          ENDIF
     ENDIF
ENDDO *while Mtimeno(11

@  7, 0  SAY "--------"
@  7,16  SAY "------"
@  7,26  SAY "------"
@  7,36  SAY "------"
@  7,46  SAY "------"
@  7,56  SAY "------"
@  7,66  SAY "------"
@  7,76  SAY "------"
@  7,86  SAY "------"
@  7,96  SAY "------"
@  7,106 SAY "------"
```

```
          @  8, 0  SAY Gempnaoff

~~~~~~~~~ PRINT (BUYPART?) ~~~~~~~~~~
          DO WHILE .NOT. EOF
               @ Mline, 0  SAY Part:no
               @ Mline,16  SAY P1:qty
               @ Mline,26  SAY P2:qty
               @ Mline,36  SAY P3:qty
               @ Mline,46  SAY P4:qty
               @ Mline,56  SAY P5:qty
               @ Mline,66  SAY P6:qty
               @ Mline,76  SAY P7:qty
               @ Mline,86  SAY P8:qty
               @ Mline,96  SAY P9:qtY
               @ Mline,106 SAY P10:qty

               STORE Mline+1 TO Mline
               SKIP 1
          ENDDO

          @ Mline+1, 0 SAY "(((((((((((((((((((((((((((((( E N D   O F   R E C O M M E N D E D   B U Y   O R D E R S ))))
          @ Mline+2, 0 SAY CHR(12)

          RELEASE Mline, Mperiod, Myy, Mpp, Myesno, Mtimeno, Mperiod:fr
          SET FORMAT TO SCREEN

 ENDCASE *docase))))))))))))))))))111111111111111111111111111111111111

D *dowhile .not. mfinished================11111111111111111111111

ECT SECOND

ECT PRIM

EASE ALL EXCEPT G*
, 0  SAY $("Returning to menu ...",1,79)

URN
~~~~~~~~~ END OF PROGRAM ~~~~~~~~~~
```

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