DEVELOPMENT OF A GENERIC MODEL FOR MANUFACTURING MANAGEMENT SYSTEMS

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ABSTRACT

The work reported in this thesis is related to the development of a generic model for a 'make-to-stock' manufacturing organisation. This research is based upon the hypothesis that every type of manufacturing company should have a generic model. The objectives of the model are first, to help SMEs (Small and Medium sized Enterprises) who cannot afford external help and second, to fulfil the need for modelling that arose from a review of modelling literature. These were the basic driving forces in carrying out this research and from which the objectives are derived.

A survey of various system design and analysis methods was carried out. Initially SSADM, SADT, IDEF0, MERISE, STRIM and GRAI were selected for the study. The reason for the selection of these methods was that each contained graphical tools and fulfilled the requirements for modelling. Further investigation showed GRAI and IDEF0 to be the most suitable methods for modelling manufacturing systems and these were selected for further investigation.

A direct comparison of the GRAI and IDEF0 methods was carried out using a case study. The results of this indicated that the GRAI method was the most suitable for the analysis and design of manufacturing systems and demonstrated advantages over the IDEF0 method. For this reason the GRAI method was selected and applied to case study 'make-to-stock' manufacturing organisations. The case studies demonstrated that several similar characteristics existed in 'make-to-stock' manufacturing organisations, supporting the hypothesis of the research. The case studies also indicated that the application methodology had some significant drawbacks. On the basis of this investigation, a detailed methodology to apply the GRAI method was formulated and validated using a further detailed case study. After the methodology had been validated, it was used to develop a generic model for a 'make-to-stock' manufacturing organisation. The model developed presents the activities carried out at the strategic, tactical and operational levels of the management hierarchy. Details of typical decision horizon and review periods are also included in the model.

The thesis presents the first detailed methodology for applying the GRAI method and first application to develop a generic model. It also presents the first detailed comparison between the IDEF0 and GRAI methods. The findings of this research and recommendations for future work are presented in the final chapter.

RESEARCH PAPERS

The following refereed papers have been published as a direct result of this research.

"A model of the production management system in a make-to-stock company", *Advances in Manufacturing Technology VIII, Proceeding of the 10th National Conference on Manufacturing Research, 1994,* Loughborough, pp 208-212.

"The development of a generic model for manufacturing management system in a make to stock company", *Fourth International Conference on Factory 2000, 1994,* York, 398, pp 196-202.

"Re-engineering Manufacturing System at Presto Engineers Cutting Tools", *Journal of Corporate Transformation, Business Change and Re-engineering, 1995*, Vol. 2, No. 4, pp 21-32.

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CHAPTER-1

INTRODUCTION

1.1 BACKGROUND OF THE RESEARCH

Manufacturing management is an attempt to achieve organisational objectives through the integration of resources such as the workforce, machinery and material. The management process is usually considered to be the combination of several procedures such as the establishment of objectives, planning, organisation, integration, co-ordination, allocation of personnel and the measurement of performance of the manufacturing functions.

To be successful in today's competitive global environment, manufacturers must be able to respond quickly to change (Levary, 1996). Although many authors recognise the need, there is some confusion concerning the area to be changed. Wray (1991) suggests that manufacturing is being threatened by a lack of understanding of the key role of manufacturing system design. Owen (1989) recognises that manufacturing industry is suffering due to poor infrastructure and poor management. He adds

'As the decline in manufacturing and its damaging effects become increasingly hard to disguise in the coming years, something will have to be done which is not being done now.'

Harrison and Burns (1991) state that most manufacturing industries have an inefficient organisational structure and suggest that the organisational and management structure should change. Foster (1986) argues that industry should be constantly seeking opportunities for innovation to meet an incremental change in the market. Skinner (1974) identified four basic areas (productivity, efficiency, focusing, and structure of policies) which need to be changed in the management of manufacturing. Daniel and Millward (1984) identified three forms of technical change including:

- Advanced technical change: Introduction of new plant machinery or equipment which includes the microelectronics technology.
- Conventional technical change: New plant machinery or equipment not including microelectronics technology.
- Organisational change: Substantial change in work organisation or working practices not including new plant, machinery or equipment.

From the above it is clear that the introduction of change in the structure of manufacturing management system is a key issue.

1.2 WHY MODEL MANUFACTURING SYSTEMS ?

Most small companies do not have adequate information about their management system. Their management structures are inefficient to meet global competition and many have small management teams, where individuals undertake many responsibilities at the same time. Teams do not work systematically due to a lack of awareness of the system. One of the most frequent problems facing manufacturing companies is their ability to share information. To overcome these problems Carrie et al (1993) suggest that manufacturing companies should be re-engineered by developing appropriate modelling techniques.

The ability to model the manufacturing management system is key to achieving successful manufacturing change. A model can be used to identify any shortcomings that require a remedy. It can also be used to illustrate how a new system will appear once it is redesigned and can be used for detailed planning purposes.

The management team in manufacturing organisations make decisions at various time intervals. According to Hayes and Schmenner (1978) these fall into two broad categories 'Facilities decisions' and 'Infrastructure decisions'.

a) Facilities decisions:

- Determine the total amount of manufacturing and logistics capacity to provide for each product line over time.
- Determine how this capacity is broken up into operating units, their size and form, their location and the degree or manner of their specialisation, for example, according to product and process.
- Determine the kind of equipment and manufacturing technology which should be used.

b) Infrastructure decisions involve:

- Policies that control the loading of the factory or factories, such as raw material purchasing, inventory and logistics policies.
- Policies that control the movement of goods through the factory, such as process design, work force policies and practices, production scheduling and quality control.

The decision making process aims to seek the best solution to the problem. This may entail identifying a number of feasible solutions and alternatives. The alternatives which the organisation is seeking must have the potential to correct the problem at hand and promote the organisation's goals and objectives. Its goals and objectives help to guide the search for appropriate solutions, but it can be argued that all manufacturing organisations need to improve their decision making system. This need arises because in general, organisations face scarcity of resources and therefore they need to make the most effective use of those available. The problem, most common in small organisations, is that major decisions are taken by key individuals using knowledge of what has been done in the past. In this manner, decision making seems incomplete and the decision makers are usually reliant upon the skills and insight they have developed through years of experience. This reliance may work with non-programmed decisions, but often does not with programmed decisions. Here we define non-programmed decisions as those which have no structure such as an urgent requirements, or a machine breakdowns. Programmed decisions have a structure such as those executed by the Master Production Schedule. Hence the need has arisen to structure decisions. This can be achieved by better modelling of the structure of decisions.

To ensure competitiveness, manufacturing companies must improve their manufacturing management structure. Manufacturing management systems must have the following characteristics:

- Complete integration of all manufacturing functions
- Availability of faster and more intelligent information systems
- Ability to share information resources
- Multiple facilities
- On-line monitoring and control, and ability to take corrective action
- Democratic behaviour of the management team
- All programmed decisions should be structured
- All procedures should be defined and systematically applied.

1.3 AIMS AND OBJECTIVES OF THE RESEARCH

This research aims to develop and document a manufacturing management model based on the identification of decision centres. Consequently the information systems should be designed to support the decisions made in these decision centres.

Initially the research was based upon the hypothesis that every type of manufacturing system (for example 'make-to-stock', 'make-to-order') should have a reference model.

The aim of the research was to produce a generic model which could be used to assist a manufacturing company to improve its manufacturing management system with minimum external help. The model would be a helpful tool to analyse existing manufacturing management systems and design or modify the manufacturing management system as desired. The generic model would enable a manufacturing company to look critically at its management structure and information system. This is necessary because advances in manufacturing systems and technologies have a considerable effect on the position of decision centres and the information used in the manufacturing environment.

Further investigation restricted these aims, because although the existing methods could be used to develop generic models, they did not fulfil all the requirements of modelling. The review of existing modelling methods and their applications indicated that the methodology employed to develop the generic model needed to be reformulated. In view of this investigation, the research objectives were modified to:

- Review basic manufacturing systems and identify basic system classifications
- Identify the most suitable method to analyse and design the manufacturing management system and in particular to:

    a) analyse the existing manufacturing management system of different manufacturing organisations within one class of system
    b) identify the inconsistencies within the system analysed
    c) identify areas to be modified
    d) identify the problems associated with the using the method selected
    e) reformulate the method to eliminate the problems identified

- Develop a reference manual to guide and assist the analyst and designer to use the reformulated method
- Develop a generic model of one class of manufacturing system
- Contribute to the research literature on manufacturing system analysis and design.

1.4 THESIS STRUCTURE

This thesis contains nine chapters which have been organised as follows:

Chapter 1 provides an introduction to the thesis. This describes the background to the research undertaken and identifies the need for a system modelling methodology. The chapter also shows the organisation of the thesis.

Chapter 2 briefly reviews the basic concepts of manufacturing systems. Existing classifications of manufacturing systems are also reviewed and the relevance of plant layout, manufacturing planning and control techniques such as inventory planning and control, master production scheduling, capacity planning and control, MRP, MRPII, just in time (JIT), and quality planning and control are briefly discussed. Finally the chapter examines manufacturing management and suggests that it comprises a three level hierarchy (Strategic, Tactical and Operational), containing the functions of the manufacturing management system.

Chapter 3 presents a detailed survey of existing modelling methods. The objective of this survey is to identify the most suitable method for use in this research. A variety of modelling methods are reviewed including SSADM, SADT, IDEF0, MERISE, STRIM, and GRAI.

Chapter 4 describes a case study using two modelling methods, GRAI and IDEF0. Both methods were applied to the existing manufacturing management system of a 'make-to-stock' company. Both methods have a topdown approach. The topdown approach exposes one level of detail at a time, that is, it begins as a descriptive process by placing the modelling system as a whole at the highest level and then decomposes it, level by level, to describe each of the subsystems within the system hierarchy. The objectives of this chapter are to:

- analyse and identify inconsistencies in the existing management system of the company

- compare the GRAI and IDEF0 methods.

The chapter demonstrates that the GRAI method is the most appropriate modelling method for the analysis and design of manufacturing management systems. Although the method has some drawbacks. These include:

- The interview techniques of the method have not been fully developed
- The method is not supported by any computerised tools.

Chapter-5 describes three case studies involving 'make-to-stock' manufacturing organisations. The objectives of this chapter are to:

- further investigate the GRAI method
- carry out a comparison of the GRAI model developed for each company.

The comparison shows several similarities between 'make-to-stock' manufacturing organisations. On the basis of this comparison, a novel model of the activities in a 'make-to-stock' company has been developed. This chapter confirms that a generic model of a 'make-to-stock' manufacturing organisations can be developed.

Chapter 6 describes the methodology developed to apply the GRAI method. The method has been reformulated and interview techniques have been devised based upon a series of three questionnaires. Questionnaire 1 relates to the company background and management hierarchy. Questionnaire 2 relates to the construction of the GRAI grid which identifies the relationship between decision centres. Questionnaire 3 relates to the construction of the GRAI nets used to analyse the decision centres identified after the analysis of questionnaire 2. The formulation of the methodology comprises several steps. The chapter demonstrates that each step of the methodology guides and assists both the analyst and the designer, in the analysis of the existing system, its redesign and implementation.

Chapter 7 validates the methodology developed to apply the GRAI method using a detailed case study. The manufacturing organisation chosen for the case study is a 'make-to-stock' company. The methodology was applied to the existing management system of the company and several inconsistencies in the system were identified. Modifications of the system are also presented. The chapter demonstrates that the methodology is easy to use and can be applied to any manufacturing management system. The chapter also demonstrates the benefits of using the questionnaires to structure the interviews.

Chapter 8 describes the development of the model. The model is developed following the detailed analysis of the manufacturing management system of the case study company. The model improves the system by developing structured, programmed decision making. The chapter concludes that although the model was specifically developed for the case study company, it has a generic nature and can be used as a reference model for any 'make-to-stock' manufacturing organisation.

Finally, **Chapter 9** presents the overall conclusions and presents recommendations and proposals for future research work.

CHAPTER-2

BASIC CONCEPTS OF MANUFACTURING SYSTEMS

2.1 INTRODUCTION

Production is an input-output system converting factors of production into saleable goods. In a narrow technological sense production is understood as the transformation of material into products by a series of energy applications, each of which affects well defined changes in the physical or chemical characteristics of the material. Since this definition applies to tangible goods as the output of production, it may be termed manufacturing. So here we define the term manufacturing as only applicable to product industries and not service industries. The original meaning of the term manufacturing was to make things by hand but the present meaning is the 'conversion of a design into finished products' (Young and Mayer 1984). The international conference on production engineering defined manufacturing as " a series of interrelated activities and operations involving the design, material selection, planning, quality assurance, management and marketing of products of the manufacturing industries" (Hitomi, 1990).

Hitomi (1990) suggests that manufacturing systems can be defined with reference to three aspects termed: structural, transformational and procedural aspects. The structural aspects of a manufacturing system are defined as a combination of the work force, machine tools, material handling equipment and other supplementary devices. The transformational aspect of a manufacturing system is defined as the system that converts the raw material into finished items. The procedural aspect defines that a manufacturing system has several procedures which include planning, control and implementation.

On the basis of Hitomi's definitions, the basic structure of a manufacturing system can be developed as shown in Figure 2.1. The structure represents the overall activities of a manufacturing system. The upper part of the diagram represents the procedural aspect and lower part represents the transformational aspects of the system. The components of a manufacturing system will be discussed in this chapter.

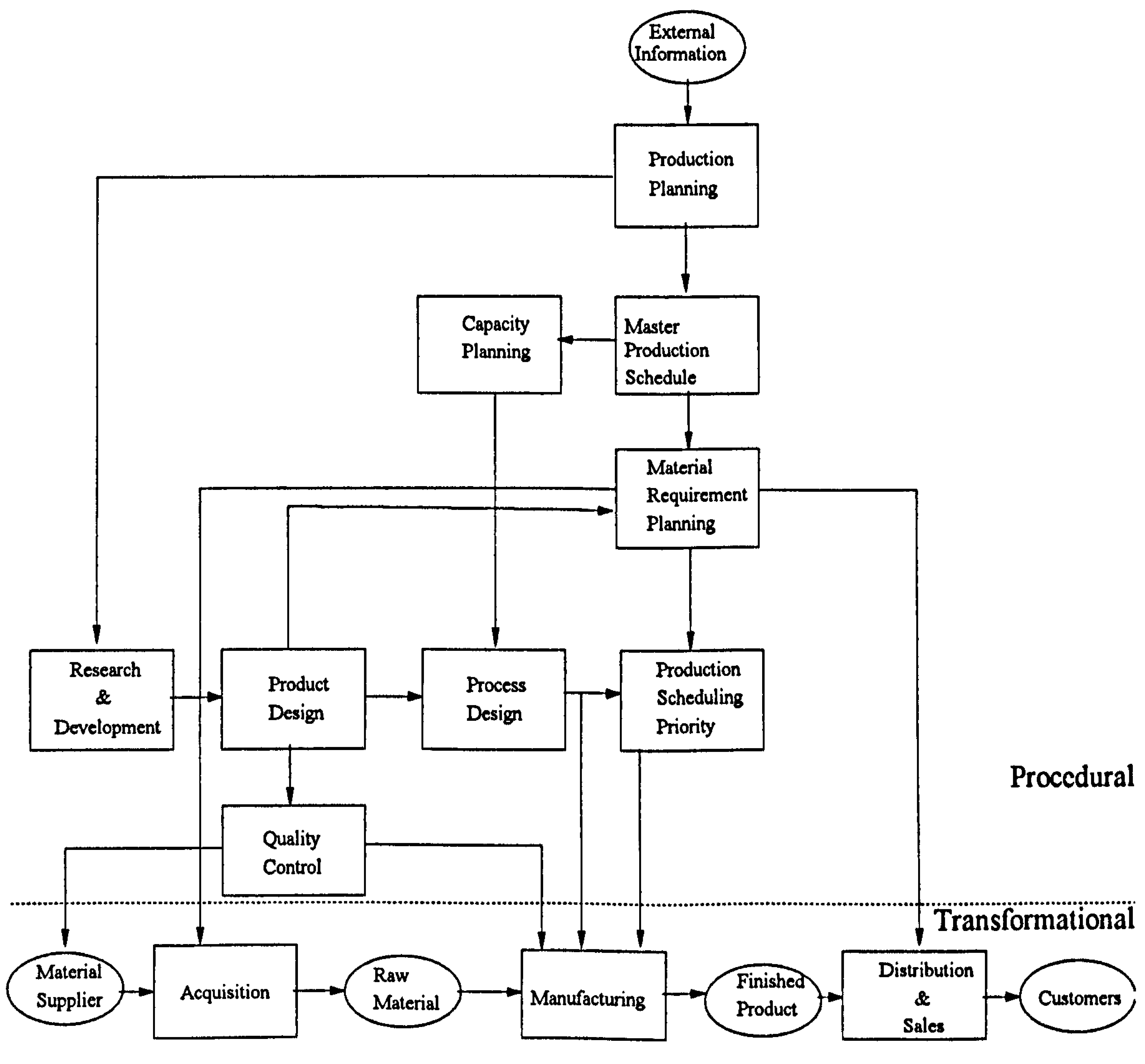

Figure 2.1 Basic structure of a Manufacturing System

2.2 MANUFACTURING OPERATIONS

During a manufacturing operation, activities are carried out at a specific station where all the facilities required are available. A product is then completed after a series of operations. The following manufacturing operations have been identified (Schey, 1977):

a) Basic Operations: Giving the raw material its basic shape and form.

b) Secondary Operations: Transform the item produced by basic processes into the final desired shape. This process is performed using machines tools.

c) Enhancing Operations: Modify and improve the physical properties of the product without disturbing the shape. These include operations such as heat treatment or film coating etc.

d) Finishing Operations: Improve the appearance of the product without disturbing the shape.

2.3 BASIC LAYOUTS

The layout is the arrangement of machinery, components and associated services which support the flow of material and provide the production rate required at economic cost. The layout indicates the physical disposition of manufacturing plant and location of the various departments or workshops. The layout affects the organisation of the manufacturing plant, the technology used and the flow of work through the plant. The following basic layouts have been identified by Slack et al, 1995:

2.3.1 Fixed position Layout

This is where the material and resources move, but the product remains stationary during the manufacturing operations. The reason for this is that the product is too large or too delicate to move. Aircraft and ship building are examples of fixed position layout.

2.3.2 Process Layout

In process layout, similar processes are located together which perform similar functions. It is convenient for the operations to be grouped together. When products flow through the operation they take a route from process to process according to the design. This type of layout requires material handing systems such as a conveyor belt or fork lift truck to transport the product between processes. An example of this type of layout is the manufacture of hand tools.

2.3.3 Product Layout

In product layout, machines are grouped in a sequential manner to produce a specific product or limited range of near identical products. Each product follows a prearranged route in which the sequence of activities required matches the sequence in which the processes have been located. The product flows along a line of processes and for this reason product layout is sometimes called flow line layout. A car assembly plant is a typical example of this type of layout.

2.3.4 Cell Layout

This type of layout is based on a work cell where different operations are performed. The cell itself may be arranged in either a process or product layout. After passing through the cell, the product may go to another cell for a further operation.

Table 2.1 shows the relationship between manufacturing process and basic layouts and Table 2.2 reviews the advantages and disadvantages of each.

Manufacturing Process	Basic Layout
Project	Fixed Position
Job	Fixed Position
Job	Process
Batch	Process
Batch	Cell/Product
Mass	Cell/Product

Table 2.1 Relationship between manufacturing process and basic layouts
(Source: Slack et al, 1995)

Layout	Advantages	Disadvantages
Fixed Position	Very high mix and product flexibility Product not moved or disturbed High variety of tasks for employees	Very high unit costs Scheduling of space and activities can be difficult Can flow much movement of plant and staff
Process	High mix and product flexibility Relatively robust in the case of disruptions Relatively easy supervision of machines and products	Low facilities utilisation Can have very high work in progress Complex flow can be difficult to control
Product	Low unit cost for high volume Gives opportunities for specialisation of machines Product movement is relatively convenient	Can have low mix flexibility Not very robust against disruption Work can be very repetitive
Cell	Can give good compromise between cost and flexibility for relatively high variety of operations Fast throughput Group work can result in high motivation.	Can be costly to rearrange existing layout Can require more plant and equipment Can give lower plant utilisation

Table 2.2 Advantages and disadvantages of basic layouts
(Source: Slack et al, 1995)

2.4 CLASSIFICATION OF MANUFACTURING SYSTEMS

Traditionally manufacturing systems have been classified into three types (Johnson and Montgomery 1974).

1- Project

2- Intermittent processes

3- Continuous processes

1- Project. Project refers to a system where the product remains stationary throughout the production process and workers, equipment and material arrive at the site to perform tasks. Civil construction work and shipbuilding are examples of project manufacturing.

2- Intermittent. In this type, the products are manufactured in batches and the products follow the same sequence through the shop (i.e. flow shop). Alternatively they may be processed in a sequence which differs substantially by product type (i.e. a job shop).

3- Continuous. Continuous refers to the production of a small range of products in high volume, or similar products manufactured at a uniform rate. Special types of machine are normally used. Typical examples of this system include circuit board assembly, car assembly and oil refineries.

This type of classification only focuses upon process characteristics. Manufacturing systems can also be classified according to their operational objectives. Examples of this classification are 'make-to-stock' and 'make-to-order'.

a) Make-To-Stock

In a 'make-to-stock' production system the end items are produced or assembled in anticipation of a customer order. Product specification and design are established in advance of the order. The production quantity and range is established by market research. Hence the production process, method of operation, volumes and other production conditions are known in advance, resulting in relative simple production planning (Vonderembse and White, 1991).

In a pure 'make-to-stock' environment, the management determine the competitiveness of the company, by determining both the location and size of finished product inventories and the use of appropriate distribution requirement planning (Marucheck and McClelland 1986).

b) Make-To-Order

In 'make-to-order' production, the end items are only produced or assembled on the receipt of confirmed orders. Product specification, design and manufacturing routes are designed on the receipt of orders. In a 'make-to-order' environment the competitive lead time would include the lead time in producing some parts and materials, as well as the time spent in some portion of the total manufacturing cycle, This may also include some fabrication, subassembly and shipping time.

Ingham (1971) classifies companies according to the observed sales and the range of products on offer. Four types of manufacturing company are suggested together with their sub categories:

Type I: This includes organisations who manufacture to stock, in anticipation of product demand. This usually comprises a defined product range of specific design, as chosen/identified by the manufacturer.

Type II: This category comprises specialist manufacturers, making a particular type of product according to customers' design and specifications.

Type III: This type of manufacturing company begins production only upon the receipt of an order. A wide range of products are usually made.

Type III A: Companies in this category offer a wide range of products and manufacture upon the receipt of an order as for type III. The difference here however, is that a minimum finished stock level is maintained in anticipation of orders.

Type III B: As for type III, this group of organisations manufacture upon order receipt, but the range of products made also includes standard, common components. These companies 'make-to-stock' in anticipation of assembly.

Type III C: This type of company is a combination of types III A and III B. Products are manufactured upon the receipt of an order, but some products are also held as finished goods. In addition some common components are kept from which assembled products can be made more quickly.

Type IV A: This category of company includes manufacturers who offer general production facilities. Customers can request their own product, to be made within the manufacturing capabilities of the equipment owned by the company. The product range is comparatively smaller than that available from Type III companies and tends to be 'capital goods[1]'.

Type IV B: This type of company comprises those as Type IV A, but is a jobbing manufacturer. Unlike Type II, which also manufacture products as required by their customers, companies of Type IV B will be prepared to accept orders for small quantities regardless of whether such orders are large enough to make long production runs possible. They usually manufacture to customers' design and specifications.

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[1] Capital goods are considered as having high unit value and are manufactured on a contract basis, for example ship building.

Wild (1989) has defined four basic types of manufacturing company according to their operating structure:

1) Make from stock, to stock, to customer: This type of manufacturing company keeps two types of stock, one for raw material and one for finished products. All raw materials are located in an initial stock then manufactured and placed in a finished goods stock, from where customers are served.

2) Make from source, to stock, to customer: This type of manufacturing company keeps only a stock of finished products. The raw material comes directly from the supplier(s) and customers are served from the finished product stocks.

3) Make from stock, direct to customer: Manufacturing companies of this type keep only raw material stock and manufacture once a customer's order has been received.

4) Make from source, direct to customer: In this case no material stock is held and all goods are manufactured upon receipt of a customer's order.

This classification demonstrates how a system will handle inputs and provide the outputs. The first two are referred to as 'make-to-stock' systems and the last two as 'make-to-order' manufacturing systems.

Schmitt and Klastorin (1985) classify production companies according to their operational characteristics. The classification is represented on the basis of a three dimensional cube, based upon the general production control system. This cube is called the PSC cube and based on three characteristics, namely Task Divisibility, Production Rate Uniformity and Routing Restrictions.

Barber and Hollier (1986) divided manufacturing systems into six groups according to product complexity:

Group 1: This type of Manufacturing system is characterised by technologically complex products including long lead times, where an indirect work force is required to support manufacturing operations. A small product range is manufactured to specific customer orders and the manufacturing cost involved are quite high. Ship building and aircraft industries are typical examples of this type.

Group 2: This is similar to Group 1 except that a greater number of products are manufactured. This type of company has a shorter product lead time and makes less complex products. Machine tool manufacturing companies are an example of this Group.

Group 3: Manufacturing systems in this Group are characterised by low product complexity and simple manufacturing operations. Several different products are manufactured, a relatively large proportion being held in stock. This type of company have a very short product lead time and low level of Work-in-Progress.

Group 4: This Group of manufacturing systems is characterised by low product complexity and a very low complexity of manufacturing operations. Companies in this group manufacture a wide range of products.

Group 5: Manufacturing systems in this Group are characterised by medium product and manufacturing operations complexity. A wide range of products is manufactured, for example cutting tool manufacturing companies.

Group 6: This type of Group of manufacturing system is characterised by a low product complexity but a high complexity of manufacturing operations. Companies in this group have a comparatively large work force and manufacture a wide range of products on a 'make-to-stock' basis. Examples of this group are industrial batteries and hand tools manufacturing companies.

McCarthy (1995) classifies manufacturing companies according to the principles used in biological taxonomy. The classification model is shown in Figure 2.2. McCarthy concludes that this classification is easy to understand and more detailed than the other classification systems evaluated.

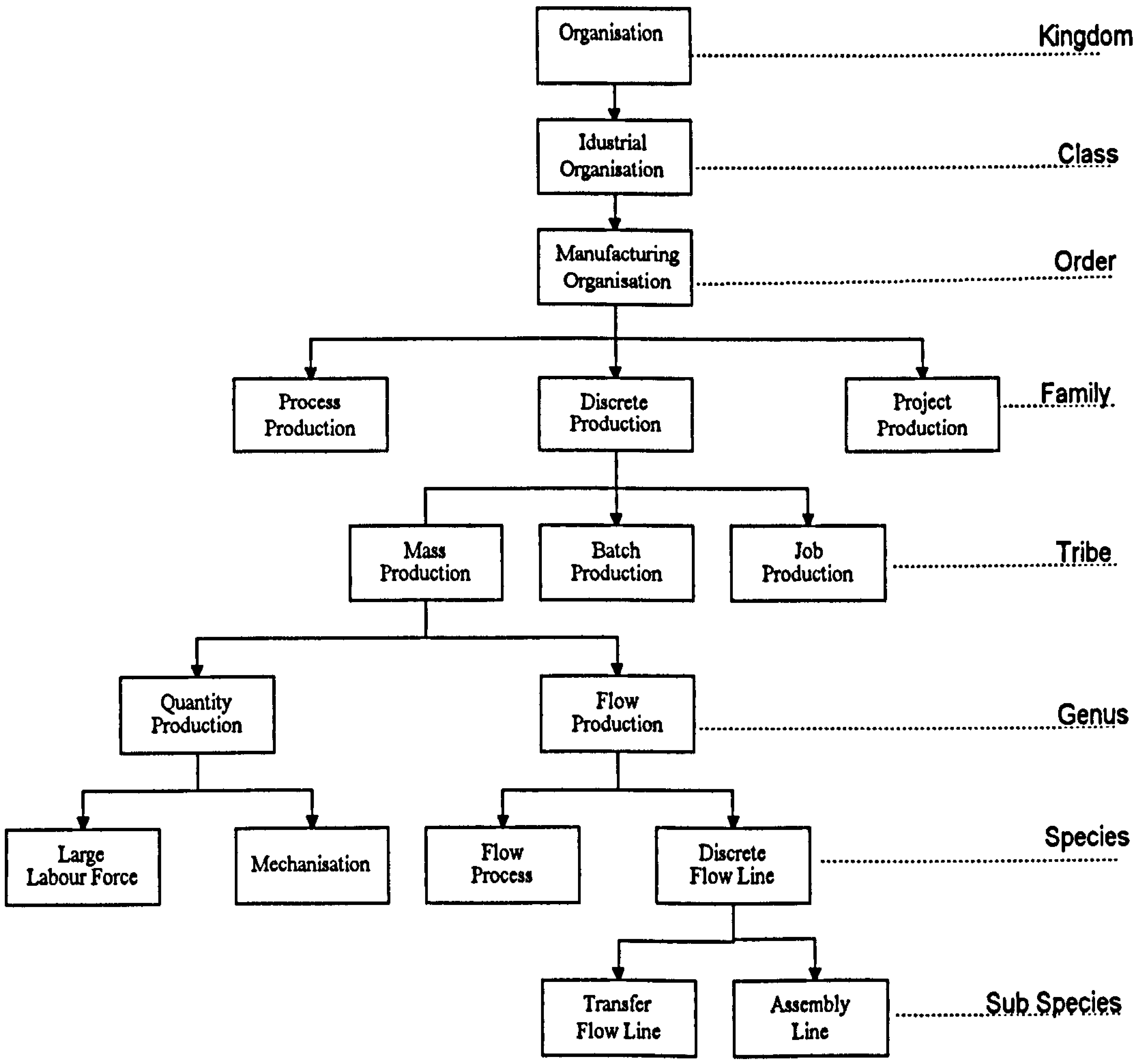


Figure 2.2 Manufacturing Classification based on Biological Taxonomy
(Source: McCarthy, 1995)

Having examined the different types of manufacturing organisation classification, 'make-to-stock' has been adopted for this research. This class of manufacturing company is apparent in all the major classification systems reviewed. 'Make-to-Stock' is a fundamental class of manufacturing system that includes all related activities and key issues faced by industry and is therefore ideal for modelling. These activities include production planning, sales, scheduling, material management, human resource management and production shop activities. These are required for proper decision making because inadequate decisions may lead to costly and ineffective use of resources.

2.5 MANUFACTURING PLANNING AND CONTROL

A plan is a statement of an intended action or event. It cannot in its own right, provide a guarantee that the action or event will occur (Walley, 1986).

Control is the process of coping with change in variables. It may require plans to be redrawn in the short term (Walley, 1986). It may also mean that intervention will be needed to bring an operation back on track. To summarise, a plan is the intention, whilst control is the driving force necessary to monitor the plan.

Planning and control focus on the utilisation of all the resources in a company required to produce a product. They ensure that the operation runs effectively. This ensures that resources and operations are available in the appropriate quantities and at the required time.

2.5.1 Types of Planning and Control

During the literature survey three types of planning and control were identified: long term, medium term and short term planning which includes the time required to execute the particular strategy. The time horizon of these different planning phases depends on the operating environment of the company.

2.5.1.1 Long Term Planning

Long term planning is concerned with the manufacturing resources required and strategic objectives to be achieved. The horizon of this planning function should exceed the time required to acquire new facilities and equipment. The planning activities include manufacturing strategies, forecasting, product planning, sales planning, resource requirement planning and financial planning. The activities may exist interdependently, but strategic planning dictates that each is feasible and that all are compatible. The time frame for long term planning varies from one year to ten years (Fogarty et al, 1991).

2.5.1.2 Medium Term Planning

Medium term planning covers the period from 1-2 months to 12-18 months (Fogarty et al, 1991). Its exact boundaries depend on the time constraints for changing from strategic to tactical levels of production in a particular situation. The planning horizon for medium term planning is usually at least as long as the longest product lead time. Medium term planning is concerned with the activities of distribution planning, material requirement planning, master production scheduling and capacity planning.

2.5.1.3 Short Term Planning

Short term planning covers periods from 1 day to a few weeks, depending on the nature of a company's operations (Fogarty et al, 1991). Short term planning involves setting job priorities according to the manufacturing requirements. The production schedule or stock control system provides details of gross manufacturing requirement, which drives the short term planning system. The master production schedule or material requirement planning provides priority planning. Priority control is achieved through production activities. The final assembly schedule and packing order of finished goods are typical examples of short term planning.

2.5.2 Techniques of Planning and Control of Manufacturing System

In order to understand manufacturing system planning and control, it is necessary to examine some of the techniques used in planning and control. The techniques include: Inventory planning and control, Master Production Schedule (MPS), Capacity planning, MRP, MRPII, JIT and Quality control.

2.5.2.1 Inventory Planning and Control

According to Riggs (1987) inventory is defined as 'the stored accumulation of material resources in a transformation system' which is a very important function of the manufacturing planning and control system. The objective of an inventory planning and control system is to execute decisions regarding inventory levels that result in an optimum balance between the purpose of holding inventories and cost associated with it. Typical decisions involve include:

- determining when an order should placed to replenish the inventory
- determine the size of the order to be placed.

The basic source of inventory planning is the Master Production Schedule.

Meredith (1992) identifies four types of inventory: raw material inventory, Work-in-Progress, intermediaries and finished items inventories. These are used to fulfil five basic functions of inventories. These functions are transit inventories, buffer or safety stock to protect against uncertainty, inventories to anticipate periods of high demand, de-coupling inventories to smooth flows between processes with different production rates, and cycle inventories to reduce the overall costs of ordering and holding stock.

Inventory is usually managed through computer based information systems which have a number of functions, including updating stock records, generating orders, generating inventory status reports and forecasting demand. Different methods of managing inventory systems used include: reorder point, periodic review and economic order quantity (EOQ).

2.5.2.2 Master Production Schedule (MPS)

The MPS is a predicted schedule for manufacturing end products based upon anticipated demand (Wall et al, 1992). The MPS is a statement of production and not a forecast. The sales forecast is an input to the MPS. The MPS takes account of capacity limitations as well as the desire to utilise capacity fully. The primary objectives of the MPS are firstly, to schedule finished goods to meet delivery needs and secondly, to maintain efficient utilisation of work centres by avoiding overloading or under-loading. Often firms produce their MPS on an annual basis. The MPS is prepared using actual customer orders, sales forecasts and historical ratios. The process also considers inventories of final goods and the desired safety stock. The schedule indicates exactly when each item should be produced to meet the predicted demand.

2.5.2.3 Capacity Planning and Control

Capacity planning and control considers the utilisation of available resources such as the workforce and machines over a specified time (Aherns, 1981). Production is often cyclical, such as seasonal, which can negatively affect capacity. By evaluating the cycle of product demand, firms can predict where smoothing is required and take steps to improve the use of capacity. Capacity planning and control is the task of optimising the use of plant capacity so that it can respond to the demands placed upon it. This usually means deciding upon how the operation should react to meet fluctuations in demand.

Capacity planning and control is sometimes referred to as aggregate planning and control. This is because at the highest level of the planning and control process, capacity planning is performed on an aggregate basis which does not discriminate between the different products an operation might produce.

The Master Production Schedule (MPS) is the primary source used to develop a capacity plan. There is a close relationship between capacity planning and scheduling, to the point that it improves the efficiency of scheduling, particularly if multiple outputs are involved.

Vollmann (1992) identifies four techniques to plan capacity:

1. *Capacity planning* is the complete predicted capacity loading based upon past data.
2. *The capacity bill*, contains detail about individual products.
3. *The resource profile* includes the specific timing within the capacity requirement.
4. *The capacity requirement* is derived from the time phase of MRP record and shop floor data and calculates the physical capacity required to produce each product.

2.5.2.4 MRP (Material Requirement Planning)

MRP is a computerised system which calculates how many components of a particular type are required and when. It also provides information about the inventory in hand. MRP combines inventory control with production planning (Orlicky, 1975).

The basic operation of MRP uses information from the bill of material and individual component lead time to derive a complete scheduling plan. This determines factors such as when individual components should be purchased and when the manufacture of subassemblies and assemblies should begin.

A simple model of MRP is shown in Figure 2.3. The inputs of the MRP system are the Master Production Schedule, the bill of materials and inventory data (Bolay et al, 1989). The MPS indicates exactly when each order item will be produced. The bill of material indicates all the raw material, components, subassemblies and assemblies required to produce an item. The inventory data contains detailed information regarding the number of each item on hand, on order and committed to use at each point in time. The MRP system accesses this information and produces an output. The output comprises an order action report, an open order report and a planned order release report. The order action report indicates which orders are to be released. The open orders report shows which order should be expedited. The planned order release report shows the plan for orders to be released in the future.

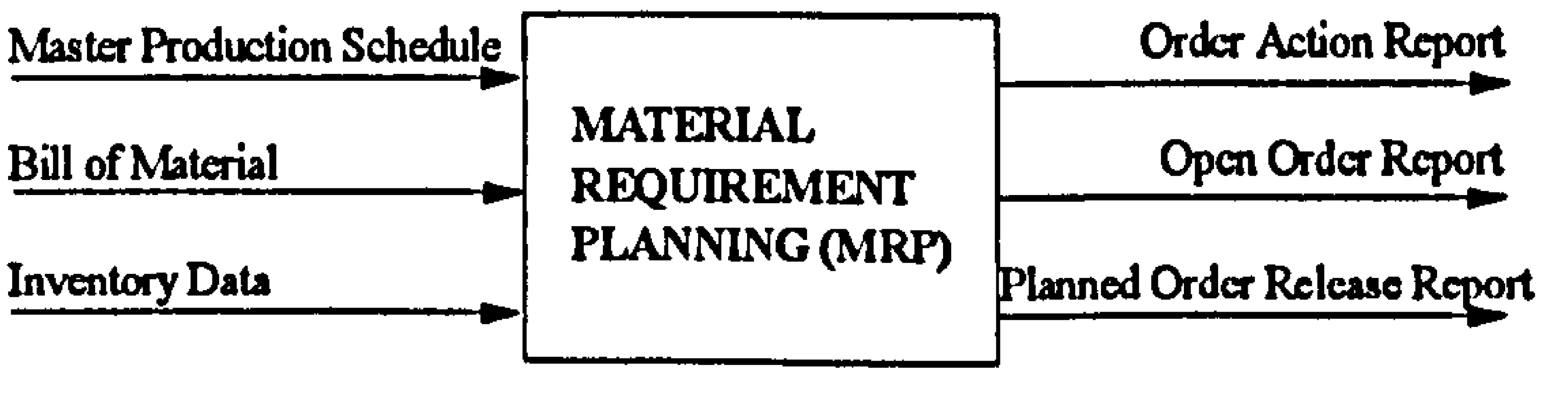


Figure 2.3 Inputs and Output in MRP System

An MRP system serves a central role in material planning and control. It translates the overall plans for production into the detailed individual steps necessary to accomplish those plans. It provides information for developing capacity plans and links it to the systems responsible for production.

2.5.2.5 MRPII (Manufacturing Resources Planning)

Material Requirement Planning (MRP) essentially aims at the planning and control of production and inventory in manufacturing firms. However, the concepts have been extended to include other functions, to form MRPII (Manufacturing Resources Planning). Wight (1982) defines MRP II as *"a game plan for planning and monitoring all the resources of a manufacturing company: manufacturing, marketing, finance and engineering"*

MRPII links the MRP to other functions in the rest of the firm, including engineering, purchasing, finance, sales accounting, maintenance and distribution.

MRPII is based on an integrated system containing a database which can be accessed by the whole company, according to individual functional requirements. The system analyses the complete product cycle, from corporate plans to the finished product. By knowing the current status of orders, inventories, output and other operating data, questions can be routinely answered which were previously compounded through lack of data.

2.5.2.6 Just In Time (JIT)

The idea of JIT (Just-In-Time) was developed by Toyota Motors in Japan in the mid 70s (Lubhen, 1988). JIT keeps work continuously moving all the time from receipt of the material to delivery of finished product to the customer. JIT is a revolutionary manufacturing philosophy. The basic approach of JIT is to reduce product costs by the elimination of waste. It means that no rejects, no delay, no stock piles, no queues and no idleness is allowed. JIT is also known as zero inventory or stockless production.

The technique used to implement a JIT system is called Kanban (Pervozvansky, 1994). Kanban uses two types of cards to control product movement and production. Kanban cards constitute a simple flexible planning and control system that promotes close co-ordination between work stations in repetitive manufacturing. The amount of material in the system is controlled by having a prescribed number of containers in circulation at any one time. A user workstation pulls containers from a supplier work station with a 'move' card. A supplier cannot push a container out to a user until the user is ready as indicated by the arrival of the 'move card'. Moreover the supplier cannot produce until it receives a 'production' card. This means that JIT is a 'Pull'[2] as opposed to 'Push'[3] system.

We can compare JIT manufacturing with traditional manufacturing (Figure 2.4). JIT manufacturing runs smooth material management with no buffer. In contrast traditional manufacturing employs buffers of material between workstations.

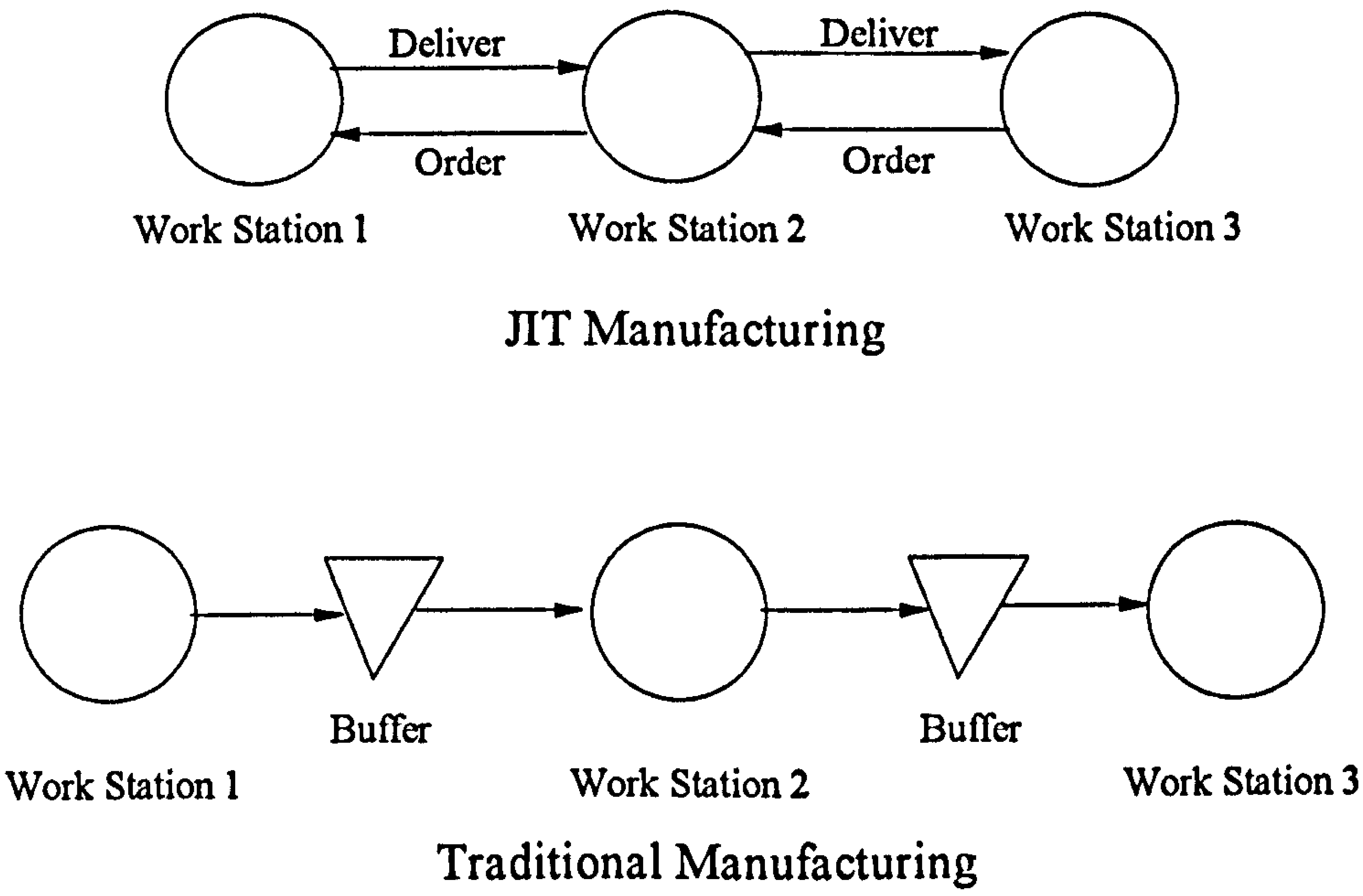


Figure 2.4 JIT Manufacturing vs. Traditional Manufacturing

2.5.2.7 Quality Planning and Control

Gummesson (1993) writes that 'Higher quality is beneficial on both revenues and cost'. Quality is defined as the best possible in term of the product's specification. Wild (1995) defines *"The quality of a product or service is the degree to which it satisfies customers' requirement"*.

[2] Pull system: An approach to manufacturing in which materials are pulled through processing based on actual requirements for those materials (Vonderembse and White, 1991).
[3] Push system: An approach to manufacturing that force materials through processing based on a schedule (Vonderembse and White, 1991).

Quality planning and control is concerned with the systems and procedures which govern the quality of manufactured products by the operation. Slack et al (1995) suggests that there are six steps involved in quality planning and control. These are:

1. Define the quality characteristics of the product
2. Decide how to measure each quality characteristic
3. Set quality standards for each quality characteristic
4. Control quality against these standards
5. Find and correct causes of poor quality
6. Continue to make improvements.

The control of quality can be achieved by either inspecting 100 percent of products, or by using tools such as acceptance sampling and process control charts. Acceptance sampling involves the inspection of a sample number of products, a certain percentage of which will be permitted to fail. If a higher percentage of products fail, then the entire batch must be recalled. Process control charts are used to continuously monitor the product output from a process, to predict if the process requires any corrective action to and modify it, before products of poor quality are produced.

2.6 MANUFACTURING MANAGEMENT SYSTEMS

The task of the production management team is to achieve organisational objectives, utilising manufacturing and manufacturing resources. The management has a responsibility to manage all related activities that contribute to an effective production system. The manufacturing management system has two types of responsibilities, direct and indirect.

The activities related to direct responsibilities include:

- understanding the manufacturing strategic objectives
- developing a strategy for manufacturing

- designing the operation and processes of the production system
- improving operational performance

The indirect responsibilities include:

- informing other functions of factors such as the opportunities and constraints provided by the different process capabilities
- discussing with other functions how both operating plan and their own plans might be modified to the benefit of both functions
- encouraging other functions to suggest ways in which the manufacturing function can improve
- sharing information with other functions

Various methods have been used to describe the necessary components of a manufacturing management system. Some authors describe three or four categories, as indicated below.

Heubner (1991) suggests that a manufacturing management system can be defined in four categories: the goal, the task, the responsibilities and equipment. Pascale and Athos (1992) define three categories, namely strategy or plan of how to reach the goal; structure i.e. characteristics of the system; and the system itself, which includes the routines in place for communicating and processing. Forgarty (1991) describes three characteristics of manufacturing management systems: policies, techniques and procedures. To run smooth management policies, Gutenberg (1955) refers to, a) time adaptation, b) inventory adaptation, c) quantity adaptation, and d) subcontracts adaptation.

2.6.1 The Hierarchy of Manufacturing Management Systems

Many authors including Axaster (1981), Greenshwin et al (1984), Bonfiali et al (1986) and McPhersen et al (1994) suggest that manufacturing management systems are hierarchical in nature. Hammond and Oh (1973), and Alford (1973) state that a management system should have several layers of control, but Hynynen (1992) states that the usual hierarchy of a manufacturing management system consists of three levels. The hierarchy of management is shown in Figure 2.5.

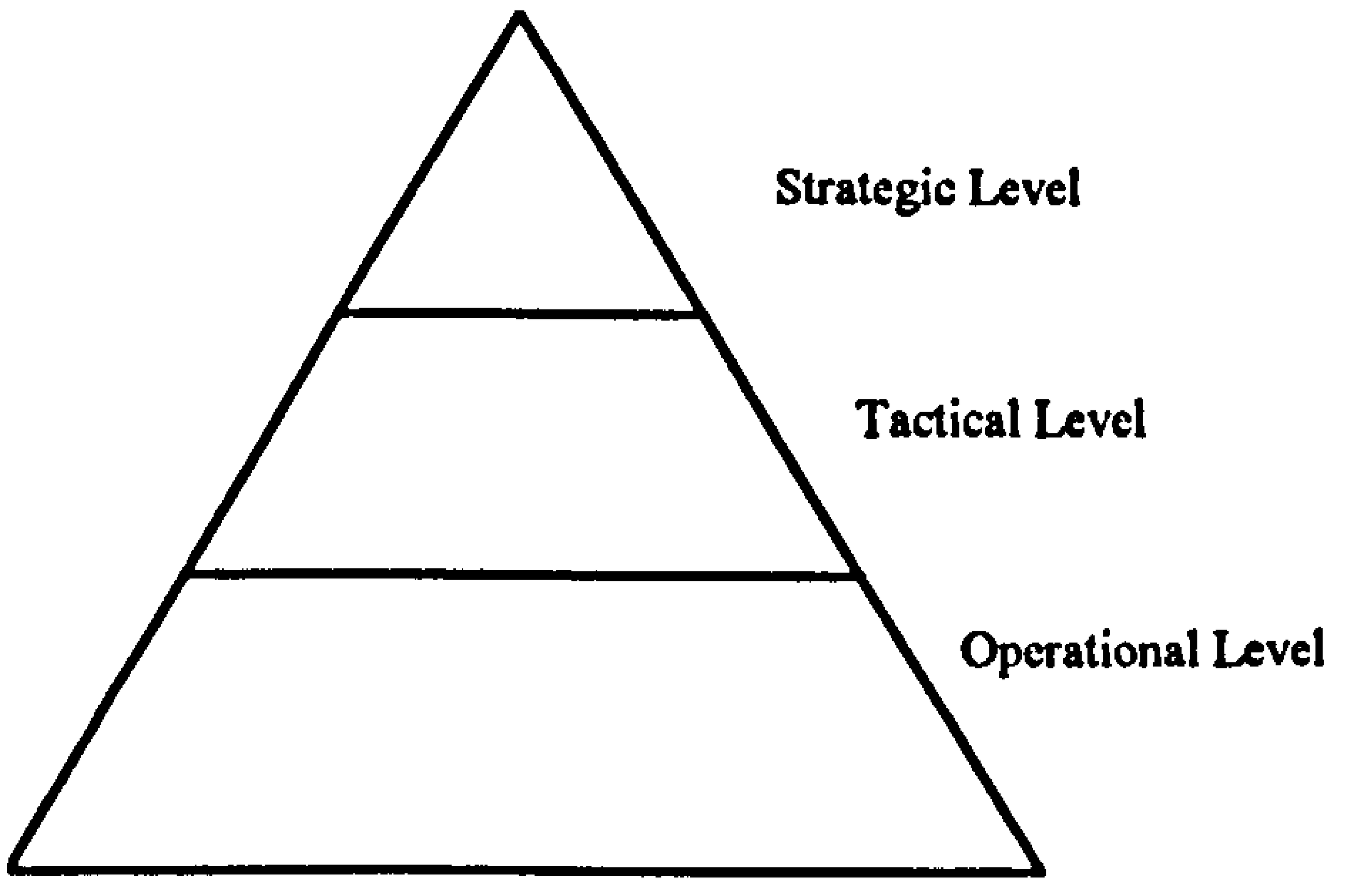


Figure 2.5 Hierarchy of Manufacturing Management

Using the hierarchy approach Banerjee et al (1994) identifies the three levels as: Strategic, Tactical and Operational. According to Mintzberg (1983) these equate to long term, medium term and short term planning levels. Both Hollway et al (1988) and Basnet and Mize (1994) confirm that decisions made at each level of the hierarchy have different time scales and different time intervals.

The strategic level deals with the strategies to be adopted and other issue such as the market available and competitiveness. Typical decisions made at this levels are:

- establishing manufacturing policy
- setting objectives
- selection of product technology (machines, software etc.)
- selection of process technology (scale, flexibility, dedication)
- determination of facilities (location, size, specification)
- identification of suppliers (number, relations, reputation)
- management of human resources (selection, training)
- allocation of overall resources

- determine the level of acceptable quality

The tactical level is based upon decisions made at the strategic level. This deals with the manufacturing system i.e. its components and the relationship between them. Typical decisions made at this level are:

- establishing functional control objectives for attaining the management goals
- planning and selecting courses of action to achieve the objectives
- preparing detailed functional work programs
- evaluating the performance of operative work and developing modification plans
- allocation of resources

The operational level is the routine execution of shop floor work, based upon the decisions made at the tactical level. Typical decisions made at this level are:

- implementation of operator work programmes
- distribution of work
- preparing courses of action to achieve the operational objectives
- modifying small errors of action

2.6.2 Functions of Manufacturing Management Systems

Clark (1994) suggests that manufacturing management systems contain certain functions for example preparing bills of material, issuing technical drawings and routing of products, product design, costing, purchasing and the planning of material required.

Rolstadas (1986) defines the following functions of a manufacturing management system:

- Production planning and control
- Material planning and control
- Product development and technological planning

- Quality assurance and quantity control
- Cost engineering

Doumeingts et al (1992) define some basic functions of a manufacturing management system. These basic functions exist in a manufacturing management system and comprise the following:

- Production planning and control
- Purchasing
- Quality control
- Managing human resources
- Managing technical resources
- Product designing

Whilst, the above are key to all manufacturing organisations, some companies will employ more refined and complex functions, depending upon the policies and nature of the individual organisation.

2.7 CONCLUSIONS

This Chapter has reviewed the classification and design of manufacturing management systems. A number of different classification systems have been reviewed. The class of manufacturing system termed 'make-to-stock' defined by Vonderembse and White (1991) has been selected for this research. The reasons for the selection are, firstly, that it appears in many classification systems reviewed. Secondly, it is a fundamental class of manufacturing that shows all related activities, ideal for modelling. Finally, it contains the following advantages:

- Production of standard items
- Low customisation

- Short delivery lead time
- Repetitive production
- Easy planning and control
- Low cost manufacturing.

The detailed analysis of the components found in a manufacturing management system has been carried out. The relative position of these components have been identified using a hierarchical model. The detailed analysis identifies the functions and decisions taken at the various levels of the management hierarchy.

The work described in this Chapter was necessary to identify the nature and relationship of the key components in the manufacturing management system associated with a 'make-to-stock' company.

CHAPTER-3

REVIEW OF MODELLING METHODS

3.1 INTRODUCTION

Given that different modelling methods have different individual characteristics, it is necessary to identify those which have already been developed and provide a structured approach specific to the analysis and design of manufacturing systems. This Chapter reviews current methods available for such analysis. The objective of this survey is to identify the most suitable method for this research.

Nicholls (1987) identifies the problems associated with system design as excessive project time and cost and the failure to meet the underlying needs of the system users. Modelling methods address these problems and represent a structured set of guidelines within which the analyst can progressively adapt, the concepts being used. Wu (1992) identifies the two primary functions of a system development method as:

1. Improving the efficiency of the systems development process
2. Providing a means of measuring the quality of a system design, such that informed decisions may be made and resources allocated accordingly.

Cutts (1987) identifies two further characteristics of any modelling method:

1. The degree to which the method assists the user
2. The ease of understanding, both of the method itself and of the documents produced by it.

Checkland (1981) suggests that a methodology is a set of principles of methods, which in any particular situation guides the designer or analyst towards a method uniquely suitable to a particular situation. A methodology must provide an overview which can be exploded piece by piece to provide more and more detailed local pictures. The view of the system must encompass three basic concepts: the data within the system, the flow of information around the constituent parts of the system and a representation of the effect of information flow or a function on the data over time. A good methodology should, wherever possible, provide graphical representations. Such representations must be capable of conveying large quantities of the information in a simple and concise form.

During the literature survey, several methods for modelling manufacturing management systems were identified, including, MISS (Modular Integrated System Strategy) (Mitchell, 1994), SASS (Structured Analysis and System Specification) (Demarco, 1979) and Organisational Activity Analysis (Leifer and Burk, 1994). Some methods are completely new and some are modifications or enhancements of other methods such as HPM (Hierarchical Process Modelling) (Mujtaba, 1994) and IDEF0-TD (IDEF0 Triple Diagonal) (Shunk et al, 1986). Those which have been selected for this study are: SSADM, SADT, IDEF0, MERISE, GRAI and STRIM. The reason for the selection of these is that they all have graphical tools. It is generally agreed upon that graphical representation of complex systems is much more comprehensive than text alone. Tse and Pong (1991) give the following reasons for favouring diagrams:

- Graphics are in two dimensions whilst text is in one dimension. The former gives an additional degree of freedom in presentation.
- Graphics are more useful in showing the hierarchical structure of complex systems and more natural in describing parallelism.
- A person reading graphics can do so selectively, depending on the level of detail required. If text alone, it is done so linearly.

These methods, where diagrams are employed to convey the information transfer within the system, are of great benefit and can be used for a variety of applications to aid structured analysis and design.

Baines et al (1994) carried out a review of different modelling methods on the basis of specific requirements of manufacturing strategy evaluation. The results of this study indicates that non of the methods support manufacturing strategy evaluation. A table is derived to see whether the modelling methods selected fulfil the requirements of the analysis and design of manufacturing management systems. This table shows the methods meeting the requirements of manufacturing management system.

3.2 SSADM (STRUCTURED SYSTEM ANALYSIS and DESIGN METHOD)

Downs et al (1988) and Eva (1992) report that SSADM originated in the UK government's Central Computer and Telecommunication Agency (CCTA) in 1981. SSADM is a procedural method of organising system analysis and design which guides the analyst through the process of software development in particular. The method consists of activities and products. The activities are described in two ways. Firstly, by *'when'* something should be done and secondly *'how'* it should be done. The products of SSADM are components, for example *'what'* is delivered by SSADM.

3.2.1 Modules of SSADM

The skeleton of SSADM is organised into five core modules as shown in Figure 3.1 (Eva, 1992) The modules are:

1- Feasibility Study

2- Requirement Analysis

3- Requirement Specification

4- Logical System Specification

5- Physical Design

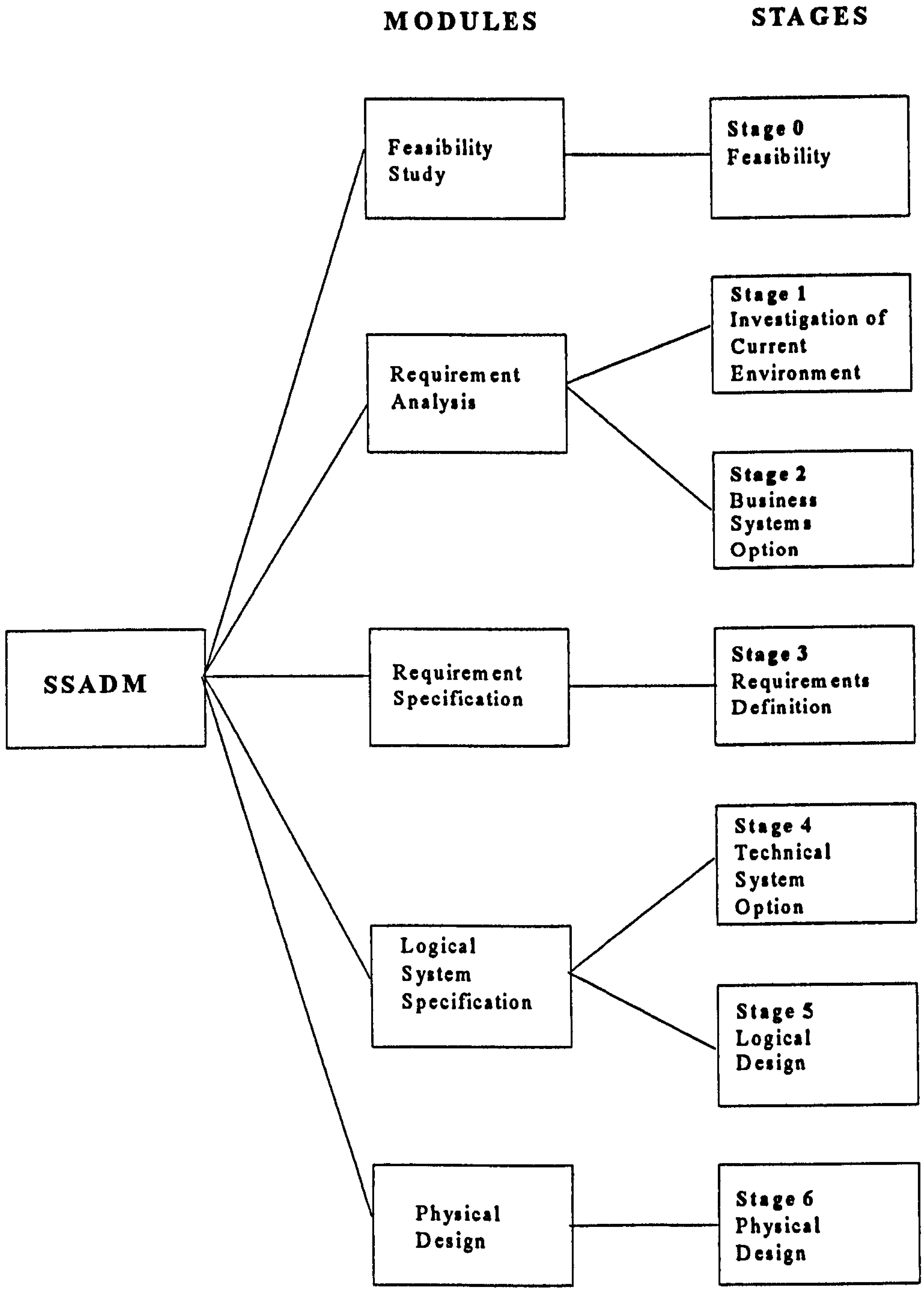


Figure 3.1 Module and Stages of SSADM

(Derived from Eva, 1992)

1- Feasibility Study

This activity, carried out in the first module of an SSADM project, using a Data Flow Diagram and Logical Data Modelling to examine both the current system, and the requirements of the new system. The feasibility study module consists of the stage 0 as shown in Figure 3.1. The objective of this stage is to prepare a feasibility report and comprises of the following steps:

- Prepare for the feasibility study
- Define problems
- Identify feasibility options
- Compile feasibility report.

2- Requirement Analysis

Requirement Analysis is carried out to identify problems with the current system. This module consists of two stages namely Investigation of Current Environment and Business System Options.

Stage 1, Investigation of Current Environment: The objectives of this stage are to prepare the initial tasks lists and resource estimates for the work and to model the procedures and data structures for those areas considered for modelling. The stage uses Data Flow Diagrams and Logical Data Modelling and comprises the following steps:

- Establish analysis framework
- Investigate and define requirements
- Investigate current processing
- Investigate current data.

Stage 2, Business System Options: The objective of this stage is to select a solution to the problems and requirements of the given system environment. The stage consists of the following steps:

- Define Business Systems Options
- Select Business System Options

3- Requirement Specification: In this module a specification of requirements is developed, based on the Business System Option selected in stage 2. The module uses the techniques of Relational Data Analysis and Entity Life History to define the requirements of the system. The objective of this stage are to produce user management approval of the Requirement Specification document and to specify measurable acceptance criteria for the design. Stage 3 consists of the following steps:

- Define required system processing
- Develop required data model
- Develop process functions
- Confirm system objectives.

4- Logical System Specification

This module define the technical environment in which the new system must operate and develops a Logical Specification for the system, based on stage 3. The techniques applied in this module are technical system options, Logical Database Process Design and Entity Analysis. The module consists of two stages namely Technical System Options and Logical Design.

Stage 4 Technical System Options: The objective of this stage are to identify and define ways of physically implementing the Requirements Specifications and to carry out a validation. The stage consists of the following steps:

- Define technical system options
- Select technical system options

Stage 5 Logical Design: The objectives of this stage are to create the logical specification of the system and to define the update dialogues of the new system. The stage consists of the following steps:

- Design user dialogues
- Compile logical design

5- Physical Design

In this module the logical specifications are translated into a physical data design and program specifications. This module consists of stage 6 as shown in Figure 3.1. The objectives of this stage are to specify the physical data, processes, inputs and outputs. Stage 6 comprises the following steps:

- Prepare for physical design
- Create physical data design
- Create function components implementation map
- Optimise physical data design
- Complete function specification
- Consolidate process data interface
- Compile physical design.

3.2.2 Modelling Tools of SSADM

SSADM uses four modelling tools (Wu, 1992):

1- Data Flow Diagrams (DFDs)

2- Entity Life History Diagrams (ELH)

3- Logical Data Structure (LDSs)

4- Relational Data Analysis (RDA)

3.2.2.1 Data Flow Diagrams (DFDs)

A Data Flow Diagram is a network representation of a system (Demarco, 1979) (Gane 1979). The system may be automated, manual or mechanised. The DFD portrays the system in terms of its components. These components and the symbols used in DFD are shown in Figure 3.2. These include:

- A shaded square for destination and source
- An open rectangle for data base
- A square with round corners for functions or activities
- Arrows indicating data flow.

Data flow can be broken down but Demarco (1979) suggests that the level of decomposition should not exceed three. DFD supports top down decomposition of the problem. The decomposition of DFDs into levels helps to control the size of the diagrams and makes them easier to understand.

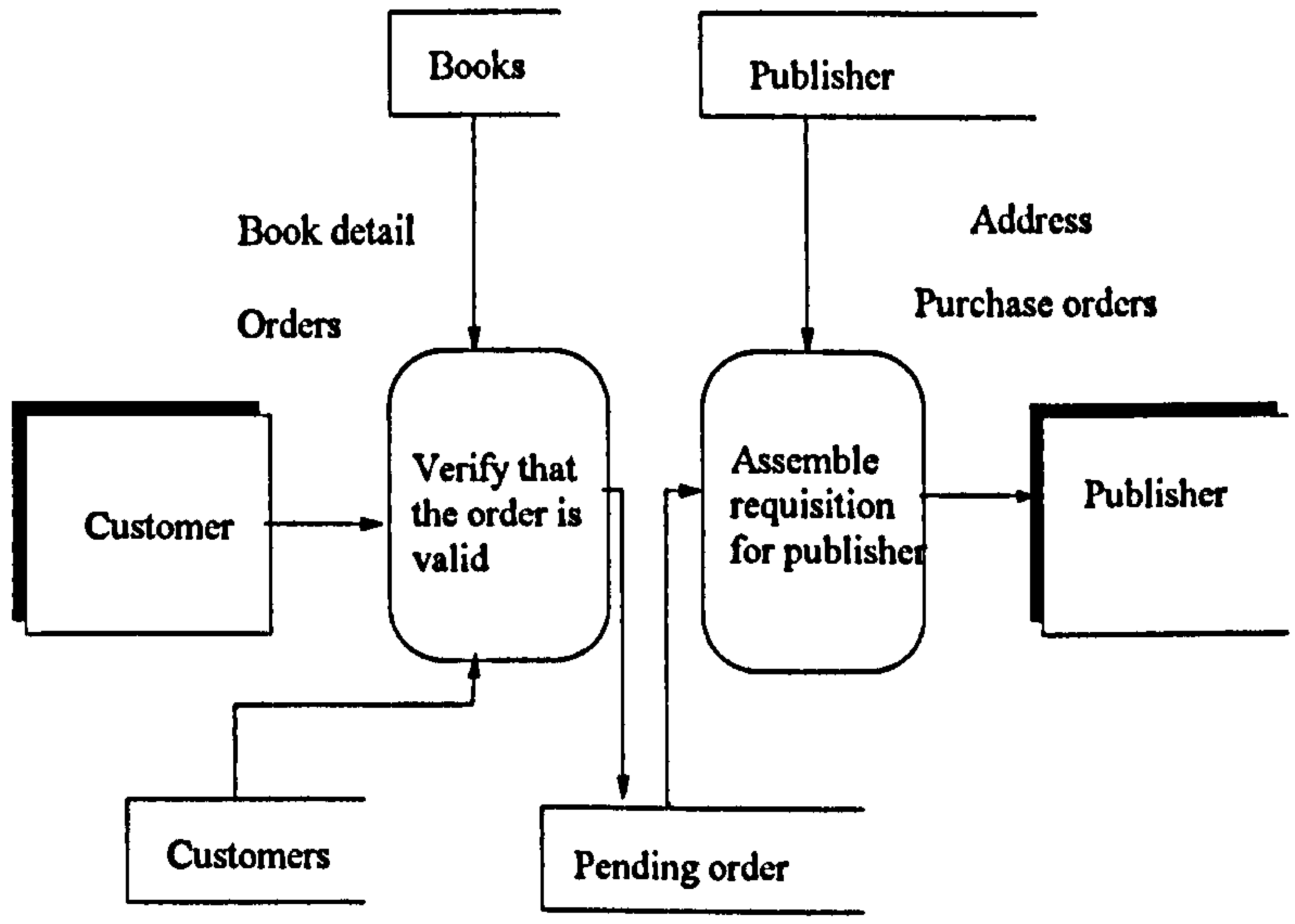


Figure 3.2 An example of a DFD
(Source: Gane, 1979)

3.2.2.2 Entity Life History (ELH)

The Entity Life History diagram, as shown in Figure 3.3 aids the validation of DFDs. by exploring the processing requirement of entities, describing an entity, identifying state transactions, recording the time sequences of change and clarifying event transactions. A two dimensional entity/event matrix can than be created and the events which change the state of entities marked with an asterisk.

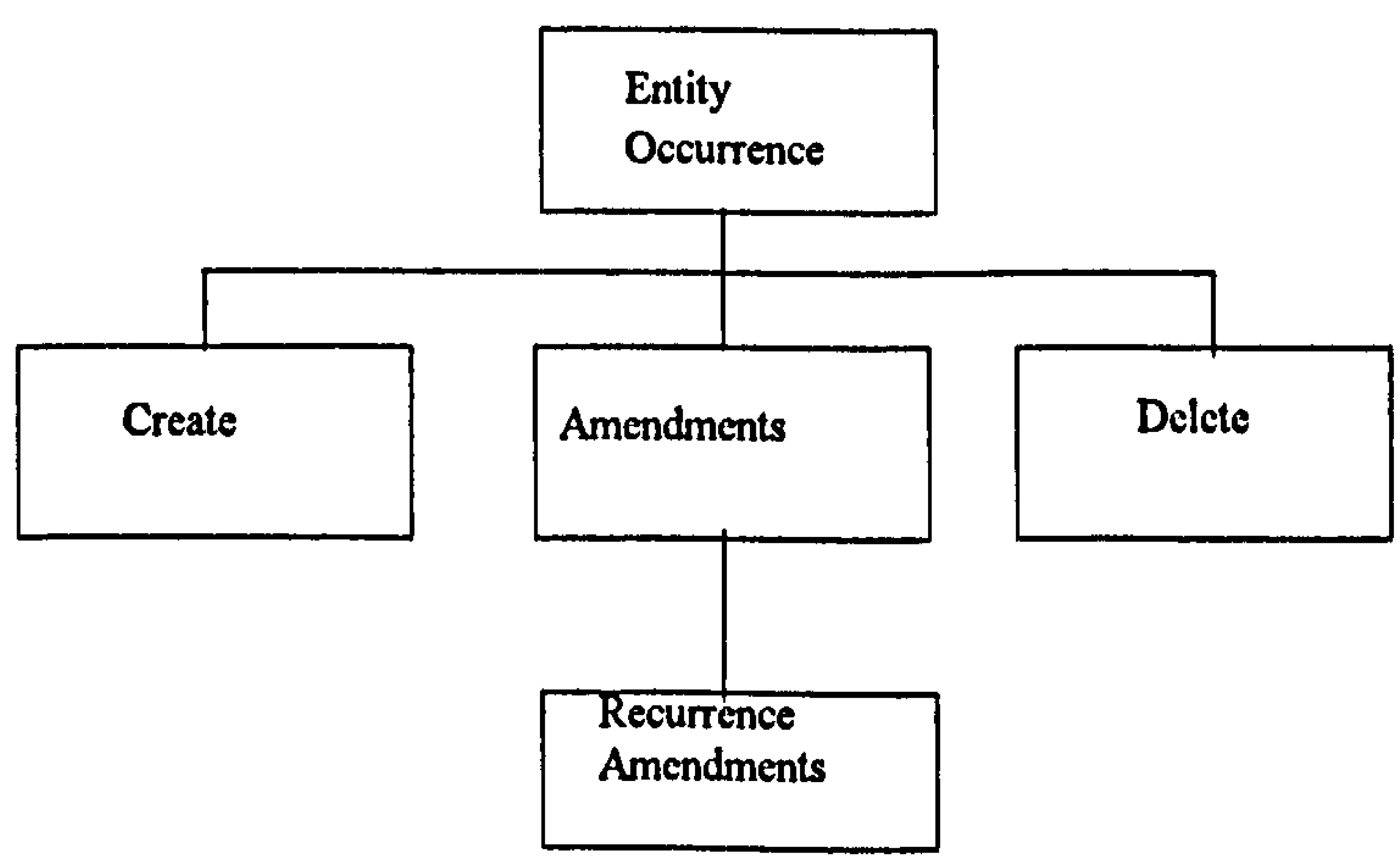


Figure 3.3 Entity Life History
(Source: Downs et al, 1988)

3.2.2.3 Logical Data Structuring (LDS)

Logical Data Structuring, is an entity modelling technique as shown in Figure 3.4, where an entity can be any element of the system, the company wishes to store information about. The first stage of LDS design is to identify the entities from the information flows shown in the DFDs. Following this, a two dimensional matrix can be created, listing all the identified entities on both axes. An asterisk is then used to indicate direct logical relationships between any two entities. From this information, an LDS diagram representing the logical data structure is created.

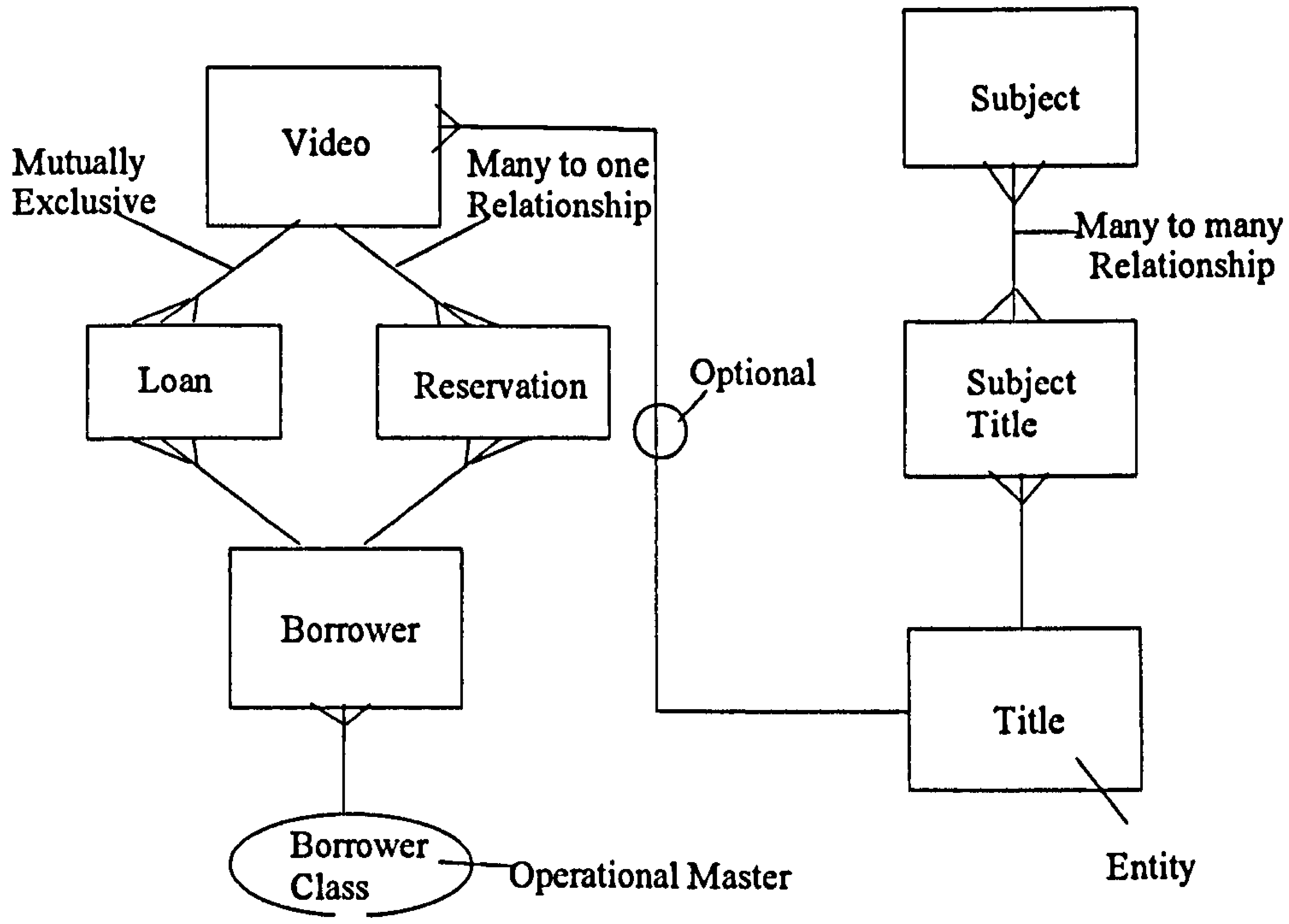


Figure 3.4 Logical Data Structuring
(Source: Gane, 1979)

3.2.2.4 Relational Data Analysis (RDA)

Relational Data Analysis is used in the structuring of data. Data is initially stored in data tables, in a similar manner to an address book. For a given table there exists a key, which is a piece of data that uniquely defines a set of data in the table. The first task in RDA is to sort out any repetitive data and select a key such that only one unique set of data is identified. Any field not fully dependent on the whole compound key is then removed.

3.2.3 Comments

SSADM is an effective method. It has a structural approach and graphical tools for modelling the system, but only supports the development of software. It does not support the manufacturing environment because it does not deal with time scale. DFDs are only appropriate for information systems and only present an overview of the information/material flow within a system. Martin and McClure (1988) suggest that DFDs are deceptively simple and that their use can produce models that appear visually correct, but further and more critical examination often identifies model inconsistencies. Pandya (1995) considers the construction of ELH (Entity Life History) diagrams cumbersome in practice because they do not present an unqualified view and are complex to use. Such a diagram does not support the decision making system. Overall SSADM does not comprehensively support manufacturing system.

3.3 SADT (STRUCTURED ANALYSIS & DESIGN TECHNIQUE)

SADT was developed in the early seventies and has been used extensively for system design (Ross, 1985). SADT consists of both techniques for performing system analysis and design and a process for applying these techniques in system development. The SADT system model employs both natural (text based) and graphical languages. The graphical language of the SADT provides the structure and semantics for the natural language contained in the model. SADT focuses on either system activities or system "things[1]". SADT model syntax allows an analyst to define the boundary of a model, connect the diagrams into one global picture and ensure compatibility between individual diagrams. The SADT model that focuses on system activities is called the activity model and the model which focuses on things is called the data model.

The method is divided into several phases such as analysis, design, implementation, integration, testing, installation and operation, but the technique was primarily developed for system analysis and design.

[1] The word "things" is used in the SADT method which represent variables of the system such as data, information, plans and machines (Marca and McGowan 1988).

3.3.1 Graphical Tools

SADT has two types of graphical tool: the activity diagram and the data diagram (Ross, 1985) as described below:

3.3.1.1 Activity Diagram

An activity diagram is made up of labelled boxes and arrows, as shown in Figure 3.5. The box represents an activity that can be decomposed into greater detail to lower levels. When the boxes in a diagram represent activities, they are described by a verb phrase, written inside the box. Each diagram is numbered at the lower right corner. The box is a component of the graphical language and structure of the system. The arrow entering the left hand side of the box is the input and the arrow entering the top of the box is the control. The arrow entering the bottom of the box is the mechanism and the arrow exiting the right side of the box is the output of the activity. The combination of the arrows is called ICOM (input, control, output and mechanism).

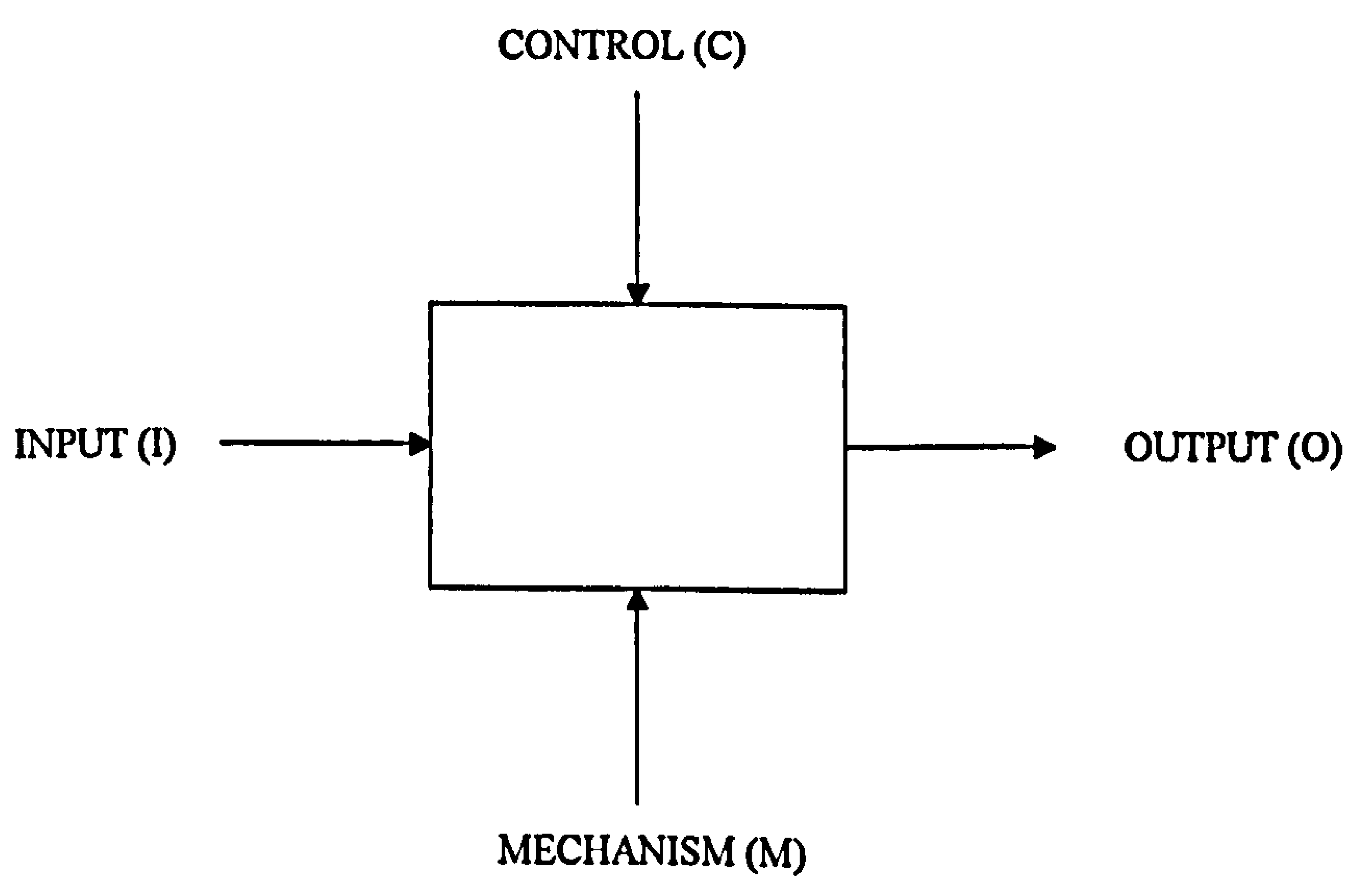


Figure 3.5 Activity Diagram
(Source: Ross, 1985)

3.3.1.2 Data Diagram

The data diagram uses the same graphical symbols as the activity diagram, but it has a dual opposite form of the activity diagram. In the data diagram the box representing the data has a noun phrase (Ross, 1985) (Chen et al, 1990) and describes types or states of things. The arrows of the diagram represent activities and are labelled with phrases. The arrows describe the activities that take place between the things.

3.3.2 SADT Hierarchy

SADT comprises hierarchically-organised diagrams. As demonstrated by Marca and McGowan (1988) diagrams are made up of between three and six boxes. Each box can then be detailed in another diagram. The box being detailed is called the 'parent diagram' and the diagram showing the details of the box is called the 'child diagram'.

The decomposition of the hierarchy is indicated by the node number. The node number organises the documentation of the system and illustrates the relationship between parent and child diagrams. The node number is the model name or an abbreviation, followed by slash, the capital letter A or D (A for activity model, D for data model), a hyphen and finally a number. For example ABC/A-0 is the number at the top level of the hierarchy that shows a single box. A separate single box describes the overall task performed by the system. 'C' numbers are used to identify the unique version of a diagram and are also used to link diagrams together between different detail levels.

3.3.3 Design Technique

The design technique of the SADT consists of the following steps:

Gathering Information: This is mainly derived from interviews. There are four types of interview used in SADT, namely:

1- *Fact finding interviews* are held to determine how an existing system operates.
2- *Problem identification interviews* highlight the problems with the existing system.

3- *Solution discussions* are held when the analyst wishes to examine how a future system will operate and determine whether it will solve the deficiencies and inconsistencies within the existing system.

4- *Author/Reader informal discussions* are held when there is disagreement between the author and reader. The interview review process is called the author/reader cycle. Ross and Schoman (1977) define the author a person who studies the system requirements and constraints, analyses the system functions and then represents them in a model based on the SADT format. The reader is a person who reads the SADT diagram for information, but is not expected to make written comments.

Other strategies for gathering information including reading documents, observing existing operations, carrying out questionnaire surveys and using ones own knowledge of situation.

Determine Purpose and View Point: The purpose is defined by stating the questions to be answered by the model. View point involves the selection of the perspective from which to describe the system.

Generating a Data List: The data list is the first step in developing each diagram in the SADT activity model. The second stage involves the derivation of the different functions. From the data list, all the major group and categories of information generated by the system are identified.

Generating an Activity List: Once the data list is generated, the second step is to create an activity list from the data list. The activities indicate the functions of the system to be designed. The activities are listed on the same page as the data list.

Drawing the A0 Diagram: The data and activity lists provide the initial content of the diagram. Marca and McGowan (1988) describe the following steps to draw the A0 diagram:

1- Lay out the boxes

2- Draw the primary constraint arrows

3- Draw the external arrows

4- Draw all the remaining arrows

Summarising the A0 Diagram: The next step of the model involves summarising the A0 diagram. This step is critical because every SADT diagram must have a parent diagram that contains its context. This context is represented by a single box with a set of input, control and output arrows. The A-0 parent diagram is created by using information already captured in the A0 child diagram.

3.3.4 Comments

SADT is a good method for system analysis and design. It is a combination of graphical and natural languages and provides comprehensive modelling techniques. However the method has some drawbacks, for example it has no decision-making ability, only the visual attribute of the diagram. It is not possible to interpret the entire system in one frame. Due to the excessive use of arrows and text, the diagram becomes cluttered and difficult to read.

The method does not illustrate the management hierarchy of the system. The activity diagram, although representing the activities or functions of the system, does not show how the activities are performed.

3.4 IDEF (Integrated Definition Method)

The US air force program for Integrated Computer Aided Manufacturing (ICAM) (ICAM, 1982) developed a system definition method called IDEF (Icam DEFinition) which consists of three modelling techniques:

IDEF0: is a functional model of the system which represents the activities and the exchange between them.

IDEF1: is an information model of the system describing the common, shared and discrete information necessary to support the activities of the system.

IDEF2: is a dynamic model of the system that shows the variation in behaviour with time of the system activities, information and resources.

In general IDEF is considered synonymous with IDEF0, whereas the complementary methods of IDEF1 and IDEF2 are used less frequently (Franks and Gorman 1989). The IDEF was further developed as shown in Table 3 A and the name of the method was changed from Icam DEFinition to Integrated Definition Method (Zgorzelski and Zgorzelsa, 1994).

Methods	Perspective
IDEF0	Function Modelling
IDEF1	Information Modelling
IDEF1X	Semantic Modelling
IDEF2	System Dynamics Modelling
IDEF3	Process Description Capture
IDEF4	Object-State Description Capture
IDEF5	Ontology Description Capture
IDEF6	Design Rationale Capture
IDEF7	Information System Audit Method
IDEF8	Human-System Interaction Modelling
IDEF9	Business-Constraint Driven Design
IDEF10	Implementation Architecture Modelling
IDEF11	Information Artefact Modelling
IDEF12	Organisation Modelling
IDEF13	3-Schema Mapping
IDEF14	Network Design

Table 3 A The IDEF family of methods

(Source: Zgorzelski and Zgorzelsa, 1994)

3.4.1 IDEF0

The power of SADT as a communications and analysis tool was recognised in 1978 by the United States Air Force, who selected it as the language to support the ICAM program. SADT activity modelling was formally adopted by the ICAM program. Ross (1985) explains that "SADT broke new ground in the area of problem analysis, requirement definition and functional specification because it allowed rigorous expression of high level ideas that had previously seemed too nebulous to treat technically". Subsequently SADT was revised by SofTech, Inc. to develop the IDEF0 (Bravoco and Yadav, 1985a).

IDEF0 describes manufacturing organisations in a structured graphical form and provides users with a powerful means of analysis and development. The IDEF0 model provides a method of examining the relationship between activities, in order to evaluate how a modification to an activity may impact upon other activities and influence the overall performance of the system.

IDEF0 was developed for modelling a wide variety of systems which use hardware, software and human resources to perform activities. An IDEF0 model consists of three components: diagrams, text and glossary (Colquhoun et al, 1993). In the diagram, a box represents a function or activity, a description of which is placed within the box. Arrows represent the interface and show the relationship between different activities in terms of the information or object used, produced or required by activities. The interface may be input, output, control or mechanism and it is assigned a descriptive title. Input (I) enters the box from the left, is transformed by the activity and exits the right side of the box as an output (O). A control (C) enters the top of the box and influences the activity performed. The mechanism (M) enters the box from the bottom side and is the tool or resource which performs the activity. This may be manpower or machines. The structure of the interface is usually referred to as the ICOM (Input, Output, Control and Mechanism) structure as shown in Figure 3.6.

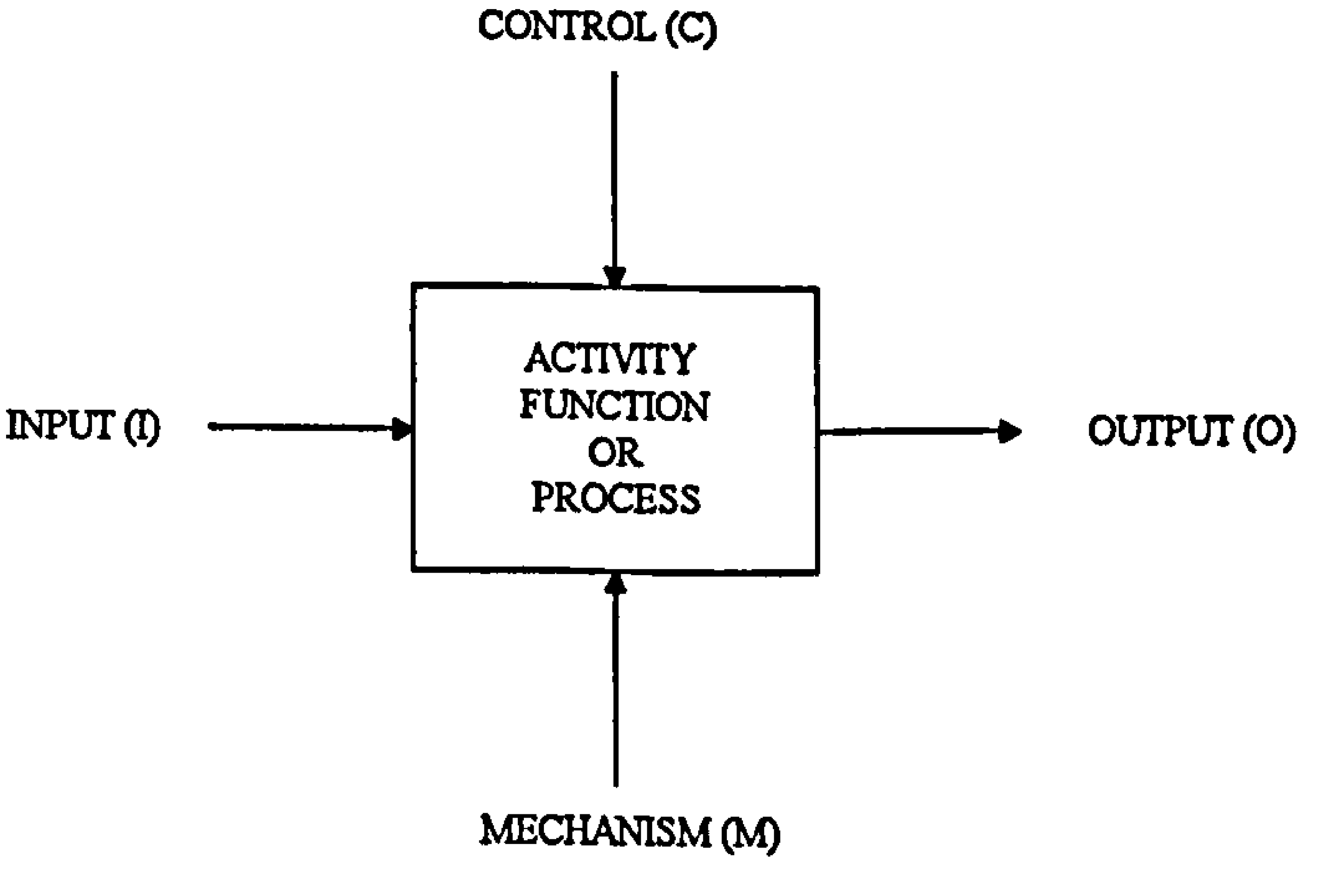


Figure 3.6 IDEF0 Function Block (ICOM)
(Source: Colquhoun et al, 1993)

3.4.1.1 IDEF0 Model Decomposition

IDEF0 provides a structured representation of the functions, information and objects which are interrelated in a manufacturing system. The model consists of a hierarchy of related diagrams which can be decomposed to any level of detail i.e. a function block in the system can be decomposed into more detailed function blocks further down the hierarchy. Each diagram has between three and six function boxes placed on a diagonal. Each function box in the diagram may be decomposed into a lower level of detail as shown in Figure 3.7. This feature restricts the amount of information that may be contained in the model on a single level. The resulting diagrams form a hierarchy of information, which are summarised in a node tree as shown in Figure 3.8 which shows the relationship between all the diagrams in the model. This is also called the 'parent- child' tree.

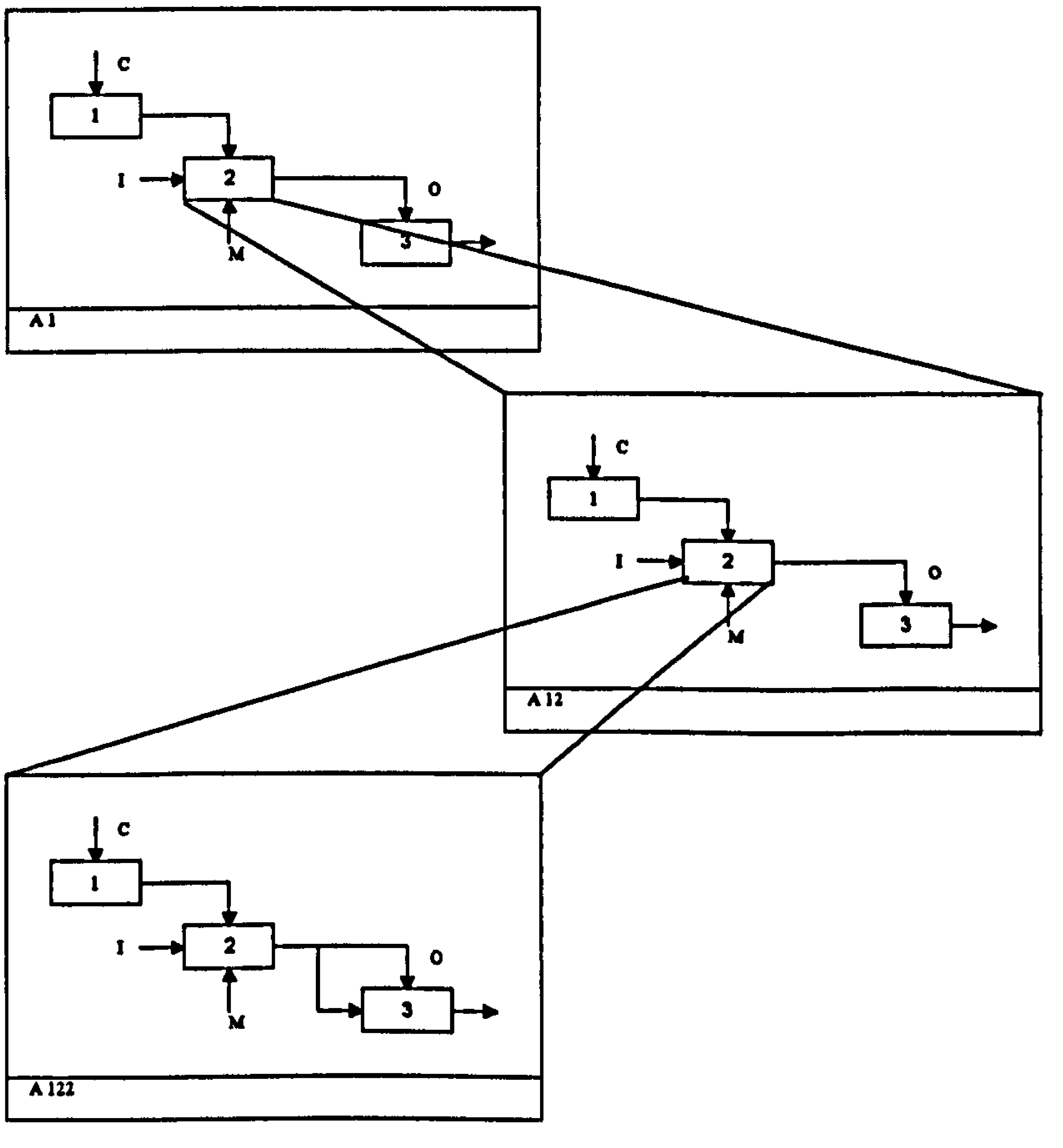


Figure 3.7 Decomposition of the level.

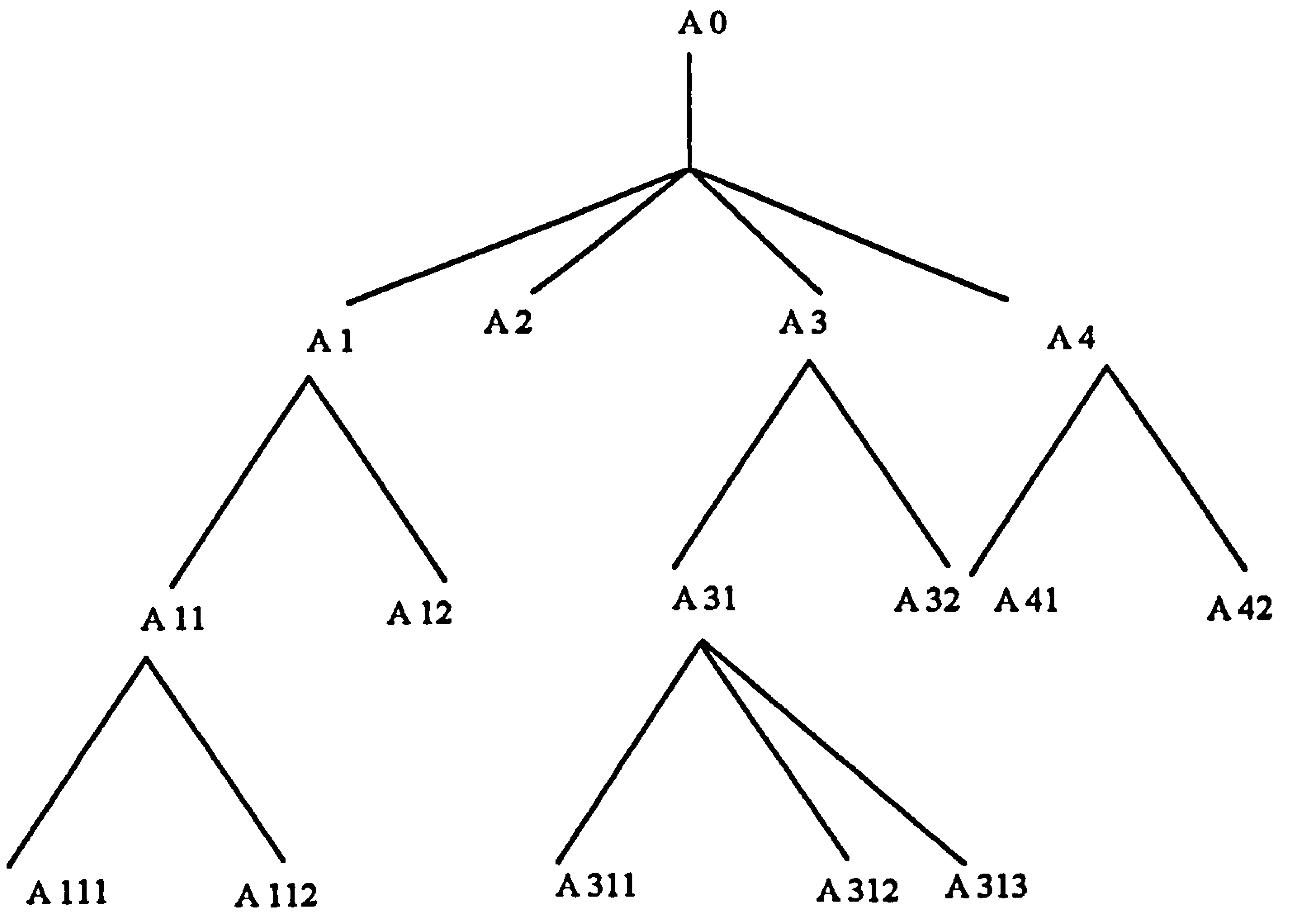


Figure 3.8 IDEF0 Parent-Child Tree.

3.4.2 Comments

IDEF0 is derived from SADT and was specifically developed for the manufacturing environment. It has a topdown decomposition approach and provides details of each activity performed at different levels. It enables the functions to be decomposed into lower levels using child-parent notations to represent the hierarchical relationships. The technique has some limitations, for example, the decomposition of blocks should only be between three to six, but there is no restriction applied to the numbers of possible levels. IDEF0 is unable to make decisions or show the decision structure and does not consider the time scale of the functions performed. It represents only information and material flow within the system.

3.5 MERISE

MERISE (Rochfeld and Tardieu, 1983) is a system design and development method developed in France specially for information system design. The framework of MERISE has three cycles:

1- Abstraction Cycle
2- Approval Cycle
3- Life Cycle

3.5.1 Abstraction Cycle

The abstraction cycle is commonly used in engineering to isolate relevant elements contributing to the description of a consistent system at one specific level. The MERISE abstraction cycle has three levels, namely: Conceptual level, Organisation level and Operational level.

3.5.1.1 Conceptual Level

It is the description of the classes of processes and the rules of behaviour which seem to the designer relevant, according to the objectives of the guidance system. This description is made using both a static and a dynamic approach.

3.5.1.2 Organisational Level

The organisational level describes the natures of resources which are used to support the static and dynamic descriptions. These resources can be human, machines or a combination of both.

3.5.1.3 Operational Level

The operational level is derived from the technical decisions made regarding technical targets and constraints.

The objectives of the abstraction cycle are to:

- verify the consistency of the information system at each level
- enable simulation of the behaviour of the system at each level
- take into account only one class of problem at each level.

3.5.2 Approval Cycle

According to Rochfeld (1983) the approval cycle consists of decisions at all hierarchies which must be made during the life cycle. These decisions include:

- Technical decisions
- Organisational decisions
- Management decisions
- Functional decisions.

3.5.3 Life Cycle

The life cycle of MERISE involves a series of steps to develop the model, these include:

- Long range planning
- Initial study
- Detailed study
- Implementation
- Supports, maintenance.

3.5.4 Data Processing Tool

The MERISE data processing tool is based on Event Operation Synchronisation concepts. This tool describes the major functions of the system using three concepts (Chen et al, 1990):

- The Event describes anything occurring
- The Process or operation describes anything resulting from an event
- The Synchronisation is the condition of starting up the process.

The data processing modelling tool is shown in Figure 3.9. The 'Event' comprises composed of three types of information which indicate state, an identity and any supplementary descriptive information. The process uses the information contained in the event to generate the results. The results are then considered as an Event created by the process and used again for the next process. The Synchronisation represents a condition which expresses the states of different Events using logic operators.

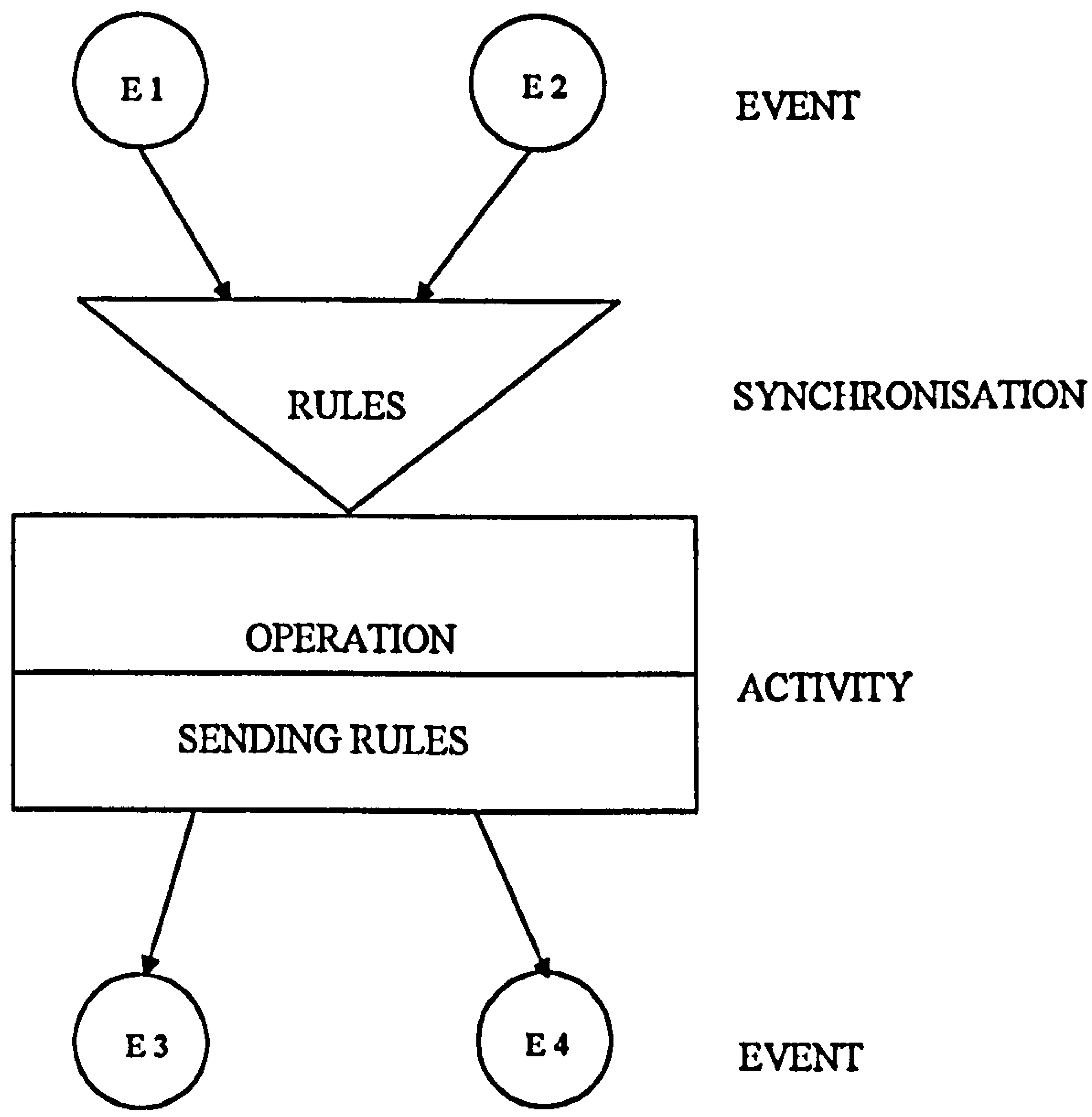


Figure 3.9 MERISE data processing tool
(Source: Chen et al, 1990)

3.5.5 Comments

MERISE is not a suitable technique for analysing and designing manufacturing systems. It was developed for modelling informational flow and cannot be used to represent a decision making system.

3.6 STRIM (SYSTEMATIC TECHNIQUE for ROLE and INTERACTION MODELLING)

As described by Huckvale and Ould (1994), STRIM was developed at Praxis Plc. Bath. It emphasises functional behaviour and organisational aspects of the system. The original work on which STRIM based was carried out as part of IPSE 2.5 with the UK Alvey program in 1986 (Ould, 1995). STRIM is the combination of a Role Activity Diagram (graphical language) and Requirement Modelling Language (RML) (Greenspan, 1985). Huckvale and Ould (1994) report that STRIM is modelled on five key concepts of a business process. These are:

1. What the organisation is aiming to achieve i.e. the business goals
2. What constraints the organisation places on behaviour through the business rules
3. How individuals attempt to achieve the goals by performing certain activities
4. How activities are divided between roles
5. How individuals within groups interact collaboratively to complete a task.

STRIM is a set of methods. It has been designed primarily for qualitative analysis (quantitative analysis requiring different and complementary methods). It can be used to identify and explore opportunities for both radical and incremental improvement of a system which means that it covers aspects of TQM (Total Quality Management) and BPR (Business Process Re-engineering).

3.6.1 Role Activity Diagram (RAD)

The Role Activity Diagram (RAD) is the modelling tool used in STRIM. The RAD is based on Petri net theory and it was first described by Holt et al (1993) in the context of modelling software engineering processes. In STRIM the process models are recorded in the form of RADs. The RAD is supported either in conjunction or integrated with Process Technology (PT) and Information Technology (IT). It effectively contains a state diagram for the design, showing which activities in the process change state. It uses three types of relationship which are:

1- Composition: The processes operate largely independently but mesh at various points.

2- Encapsulation: Detailed activities in a process are consider to be summarised in single activity.

3- Activation: One process triggers another to begin. The processes are independent but may mesh subsequently.

3.6.1.1 RAD Notations

A RAD represents the roles, component activities, interaction, together with external events and the logic that determines which activities are carried out and when. The symbols and notation used in the RAD are shown in Figure 3.10.

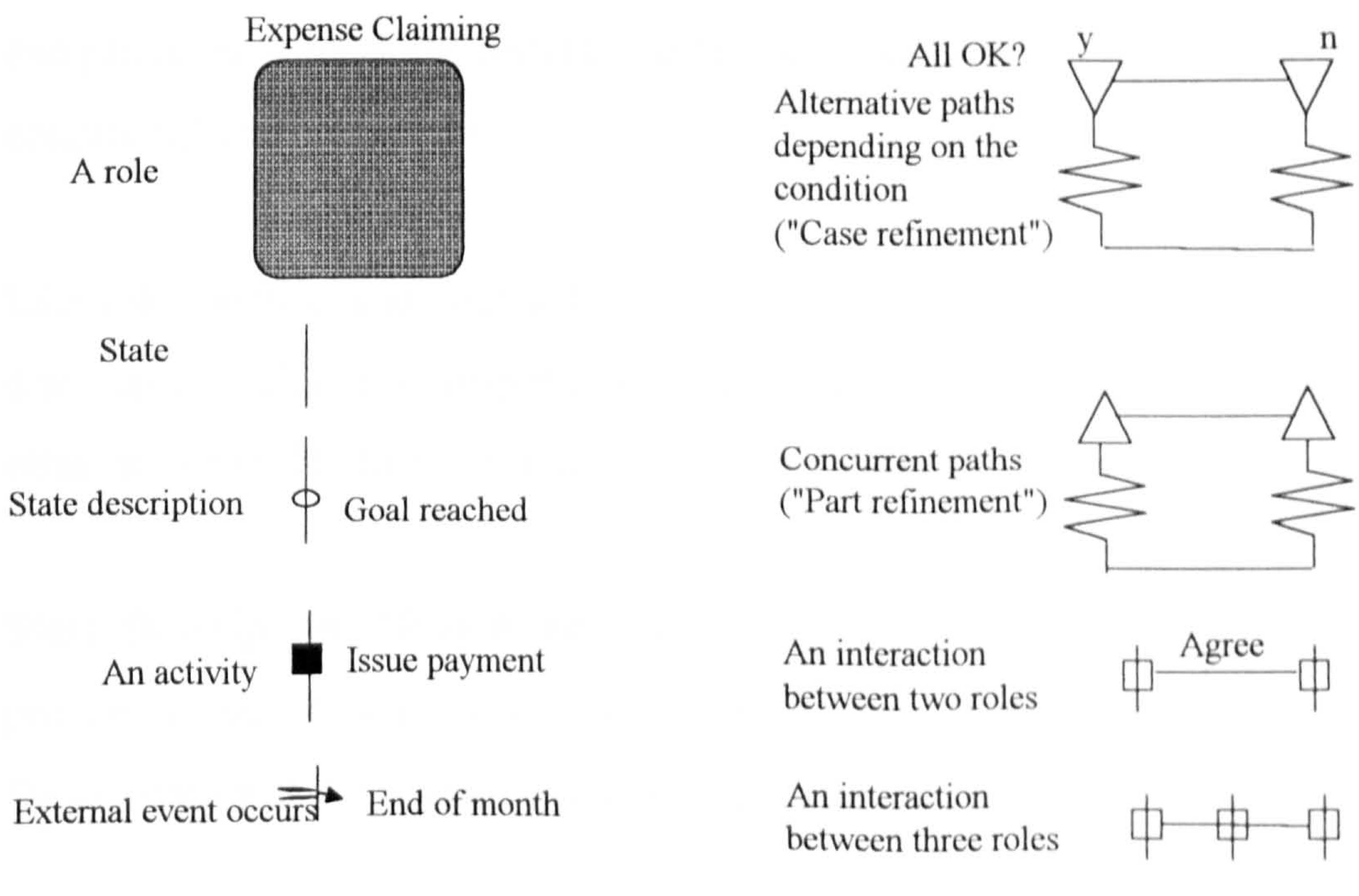


Figure 3.10 RAD notations
(Source: Huckvale and Ould, 1994)

Role: The role of a RAD is represented by the contents of a shaded block. The role comprises a set of activities which performed together, carry out particular responsibilities or sets of responsibilities. The activities produce and operate through entities and communicate, co-ordinate and collaborate through interactions. Roles can take many forms such as:

- a unique functional group, for example documentation or departments
- a unique functional position or post, for example Head of the Department or Managing Director
- a rank or job title, for example principal analyst
- a replicated functional group, for example section or branch of a company
- a class of person, for example trade union member or customer
- an abstraction, for example progress chasing

A role may wait, collect, check and monitor, a multiplicity of apparently non-productive activities which help further the process. They are part of management activities which are composed of roles required to organise or facilitate processes.

Activities: The black box in the RAD represents an activity. Activities are the function carried out by actors as individuals in their roles. An activity uses its inputs and produces outputs and relates to other activities in three different ways: sequential, conditional and concurrent.

Like roles, activities are defined in STRIM and can be given a name such as prepare, draw-up or verify. The property of the activity is that it can order or impose itself on other activities. It can be expanded for further detail.

State Description (Goal Reached): A goal may be thought of as a state that the process is trying to achieve within certain limitations. The RAD has two types of goal: Steady state and Point wise. These are described below.

a) Steady State Goal: This is a common type of goal in an organisation where the process is continuous or meets the desired demand. An example of this, maintaining a steady state in the factory is keeping a positive inventory.

b) Point Wise Goal: Perhaps more often a process works towards the achievement of a goal, rather than trying to maintain a certain state. The point wise goal indicates the particular target to be achieved within certain conditions.

External Events Occur: This indicates that something has occurred outside the process which has an impact on it and is purposely communicated to it. This shows the time when the next event will begin or indicate any uncertainty within the process. It can be shown with an activity or an interaction.

Interaction: An interaction between roles is shown as a white box in one role connected by a horizontal line to the white box in another role. It can be two process, involving two roles, or multi-processes. All processes are synchronous at the start and each finishes at the same moment. An interaction is neutral and has no implied dissection, but acts as a co-ordination between two roles.

Instance: An instance is the name of the role being performed. One instance can be carried out by more than one role simultaneously. One role instance can cause the creation of other role instances to perform new tasks. For example a production manager's role instance will create instances of other roles, such as that of a planner.

3.6.2 Design Technique

The following steps are used in the design of STRIM:

1-Deciding on the Objectives of the Model

a) Determine the objective of the model and obtain a clear idea of which type of process should be modelled

b) Predict the outcome of the process

c) Identify which perspective the model should take

d) Identify which processes need to be changed, either radically or incrementally.

2-Getting an Overall Picture

The aim of this step is to map out the area to be considered, in particular to identify the boundaries of the model.

3-Conducting Interviews

Three types of interview are used in STRIM. These are:

a) Interviews with senior managers. The analyst carries out the interviews with senior management regarding the nature of their work, any problems encountered and expectation about possible outcomes. Both radical or incremental change within the system should be discussed.

b) Group interviews: This is the second round of interviews. In this, the analyst arranges a group session with team leaders or middle management. The aim of the discussion session is to establish the roles played and determine the activities and role interactions that together make up the organisational processes. The analyst constructs the RADs in light of the discussion and rearranges the diagrams according to group desires.

c) Interviews with individuals: The group session can be pursued further if necessary, by a session with representatives of individual roles. This can provide a more detailed definition of processes where required.

4-Review, Revision and Validation of the Models

The aim of this step is to review or validate the RAD process model in the light of feedback provided by the management team. It is a continuous assessment of the model accuracy.

5-Analysing a Model

The analysis is based on interview techniques, where the analyst asks questions concerning the objectives and relationships presented in the RAD. The objectives of the analysis are to identify goals, roles, interactions, activities and improve the process in four ways. These include:

a) a point wise improvement to individual activities or interactions in a process
b) a flow wise improvement to a process
c) restructuring the roles within a process
d) realigning the organisational structure and the process structure.

3.6.3 Comments

STRIM provides a method for process modelling while its tool RAD, although useful for mapping processes, has some drawbacks. The major drawback of the method is that it is only an information system modelling method showing how the process exists rather than supporting decision making. It does not benefit the management structure and does not identify the process or function of the system, or represent its hierarchy. The technique lacks the ability to present the time scale of a process.

RADs consider each process case individually and so no generic rules are found. Every time an RAD is drawn, the roles, activities and interactions must be described. In addition, rather than providing complete process details, activities are combined into one activity presenting a process very briefly.

RADs can be decomposed from high to low levels and decomposed into a set of RADs. This set decomposes further, but has no notation to show decomposition i.e. no parent-child notation used, such as with IDEF0. Due to lack of directional flow a RAD is difficult to read, it has no symbol to end the process. It has also been observed that the value chain of RAD does not indicate a feed back loop and a corrective loop back. Difficulties in identifying interaction between activities have also been observed, especially when an existing system is being analysed. The interaction theory is complex and has an atomic nature. The addition of a role during the process is very complex particularly when external events are treated as interactions.

3.7 GRAI (GRAPHS with RESULTS and ACTIONS INTER-RELATED)

The GRAI method was developed in the late 1970's by the GRAI Laboratory at the University of Bordeaux I in France. The laboratory derives its name from its principal area of research Groupe de Recherché en Automatisation Integree. However, the method is named after a tool which produces a graphical model, Graphs with Results and Actions Inter-related (Grislain and Pun, 1979). The method was developed explicitly for analysing manufacturing management systems. The analysis does not simulate system activities, but examines the structure of the decision centres and the flow of information within this structure. The theory of the GRAI method is that decisions start and terminate events within a manufacturing management system. The events determine the performance and operating characteristics of the system. As a manufacturing management system is a dynamic system, serving both internal and external customers, decisions will only be appropriate for specific time periods (Horizons). Before the decision Horizon is reached, decisions can be adapted. This is reflected by a time interval known as the Period which represents the frequency with which decisions are reviewed.

The method is based on a structured approach and the use of graphical tools. The analysis and design phases of the method are based upon the GRAI conceptual models of hierarchical decomposition and graphical representation of the decision centres.

3.7.1 GRAI Conceptual Model

Doumeingts (1985) explains that the GRAI conceptual model consists of two parts: a macro structure and a micro structure. The first describes the organisation of a manufacturing management system and the second details the activities of the decision centres.

3.7.1.1 Macro structure

The macro structure of the GRAI conceptual model represents the global structure of the manufacturing management system and describes the links between its components (Doumeingts, 1985). It is oriented towards the decision structure. The model shown in Figure 3.11 consists of three subsystems. These are decisional subsystem, physical subsystem and informational subsystem.

a) Physical Subsystem

The physical subsystem is a set of components where raw material, component parts or sub-assemblies are converted into finished products according to manufacturing instructions. The physical subsystem is composed of men, machine tools and the manufacturing environment.

b) Decisional Subsystem

The decisional subsystem controls the activities of the physical subsystem. The aim is to control the physical subsystem to meet enable the economic and social targets set by the business, whilst taking various constraints into account. The decisional subsystem has a hierarchical nature that can be decomposed into different levels. These levels are strategic, tactical and operational.

c) Informational Subsystem

This subsystem helps the decisional subsystem to make decisions. It provides both internal and external information for the decisional subsystem. External information includes details of the market, competitors and future requirements, etc.. Internal information includes information concerning stock status, machine condition, workforce and Work-in-Progress.

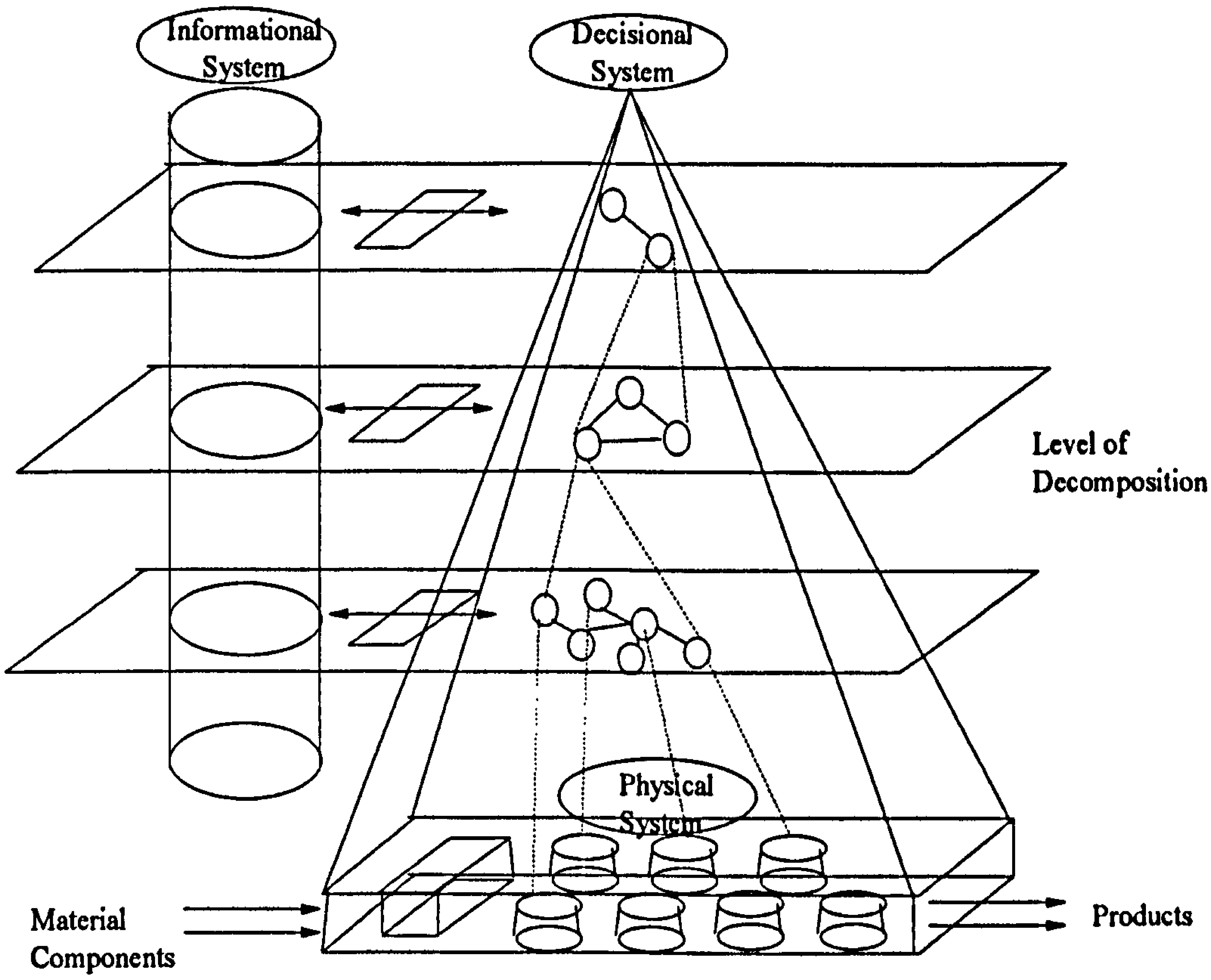


Figure 3.11 GRAI conceptual model (Structure of production control system)
(Source: Doumeingts, 1985)

3.7.1.2 Micro structure

After building the macro structure, i.e. the hierarchical structure of decision centres, Doumeingts (1985) developed the micro structure model. This model is based on the discrete activities and analyses the structure of the decision centres in detail as shown in Figure 3.12. The model defines the frame of the decision centre and indicates the basic elements and functions including action variables and their relationship, basic data requested, constraints, expected performance. The model shows how the decision maker allocates resources or defines frame of responsibilities for the immediate lower level. It also indicates the co-ordination between the decision centres at different levels. The structure of a decision centre therefore defines:

- the various activities of a decision centre
- the decision frame (variable and decision links)

- the decision made by the decision centre
- information used by the decision centre.

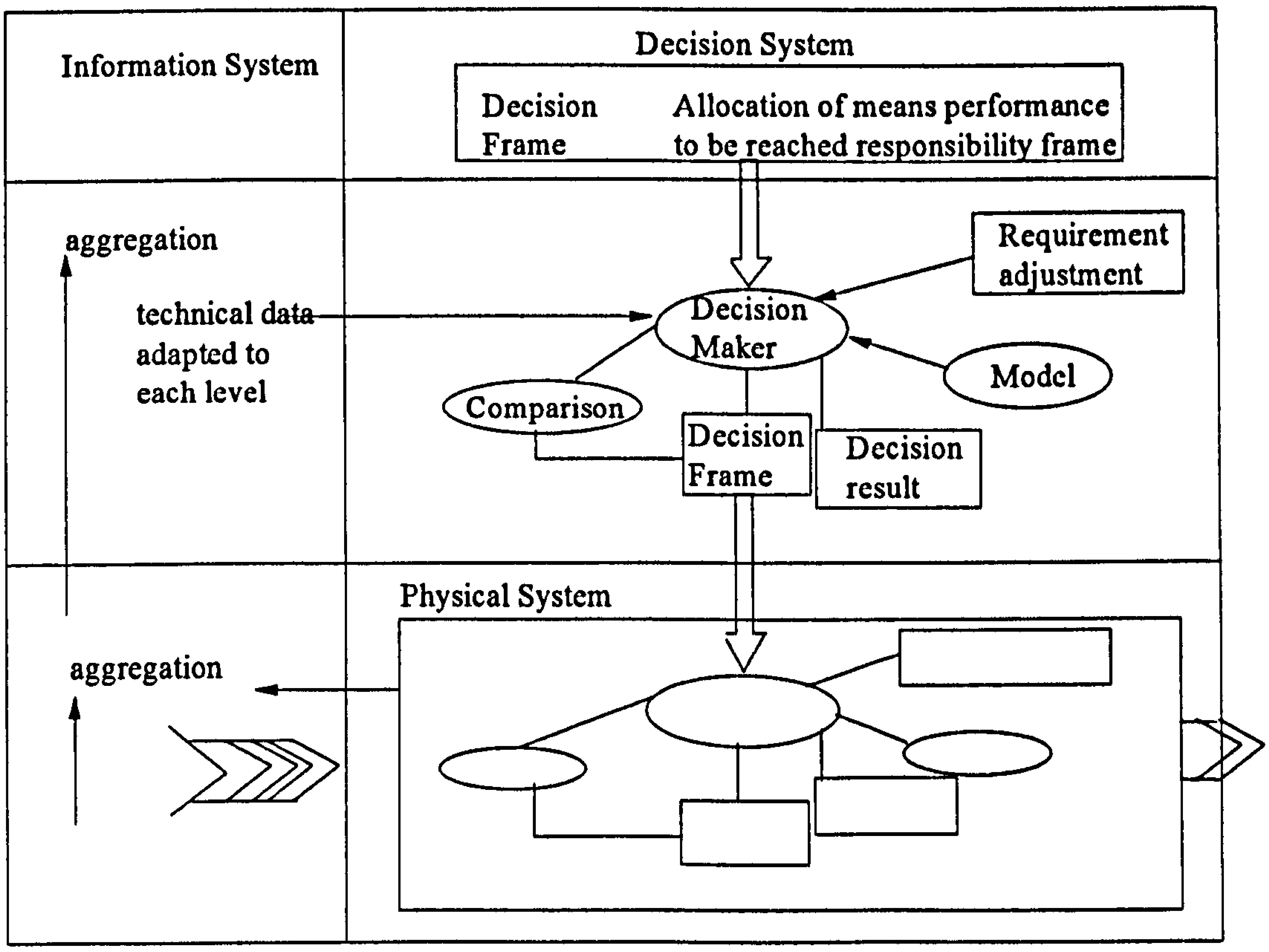


Figure 3.12 GRAI conceptual model (Structure of a decision system)
(Source: Doumeingts, 1985)

3.7.2 GRAI Tools

The GRAI method uses two tools: a GRAI grid and GRAI net (Doumeingts, 1985).

3.7.2.1 GRAI Grid

The GRAI grid as shown in Figure 3.13 represents the macro structure of the system and shows the links between main decision centres. The grid comprises the following components:

Columns: These represent the different functions of the manufacturing management system. The first column should be for external information and last column for internal information. The columns in between represent functions such as planning, designing, quality control, sales, etc..

Rows: These represents the different levels within the manufacturing management system. Normally these levels are strategic, tactical and operational. In the GRAI method, the number of rows depends on the number of horizons and review periods used by the organisation.

Square: Squares are used to identify decision centres (D C) at different levels in the hierarchy. Here, decision centres are defined as being capable of performing decisional activities.

Horizon(H): The Horizon is a time interval over which decisions are valid.

Review Period (R): The Review period is the time interval at the end of which decisions are revised.

Real Time (RT): This indicates the activities or decisions made in real time.

Double hollow arrows show the decisional transmission or links between decision centres at different levels. According to the rules of the GRAI method, arrows always flow from upper to lower level or similar level, but never from lower to upper level (GRAI, 1991).

Single arrows show the informational links between decision centres. Informational links can flow in any direction (GRAI, 1991).

Using the GRAI grid, functions, decision centre, horizons and review periods can be identified and analysed.

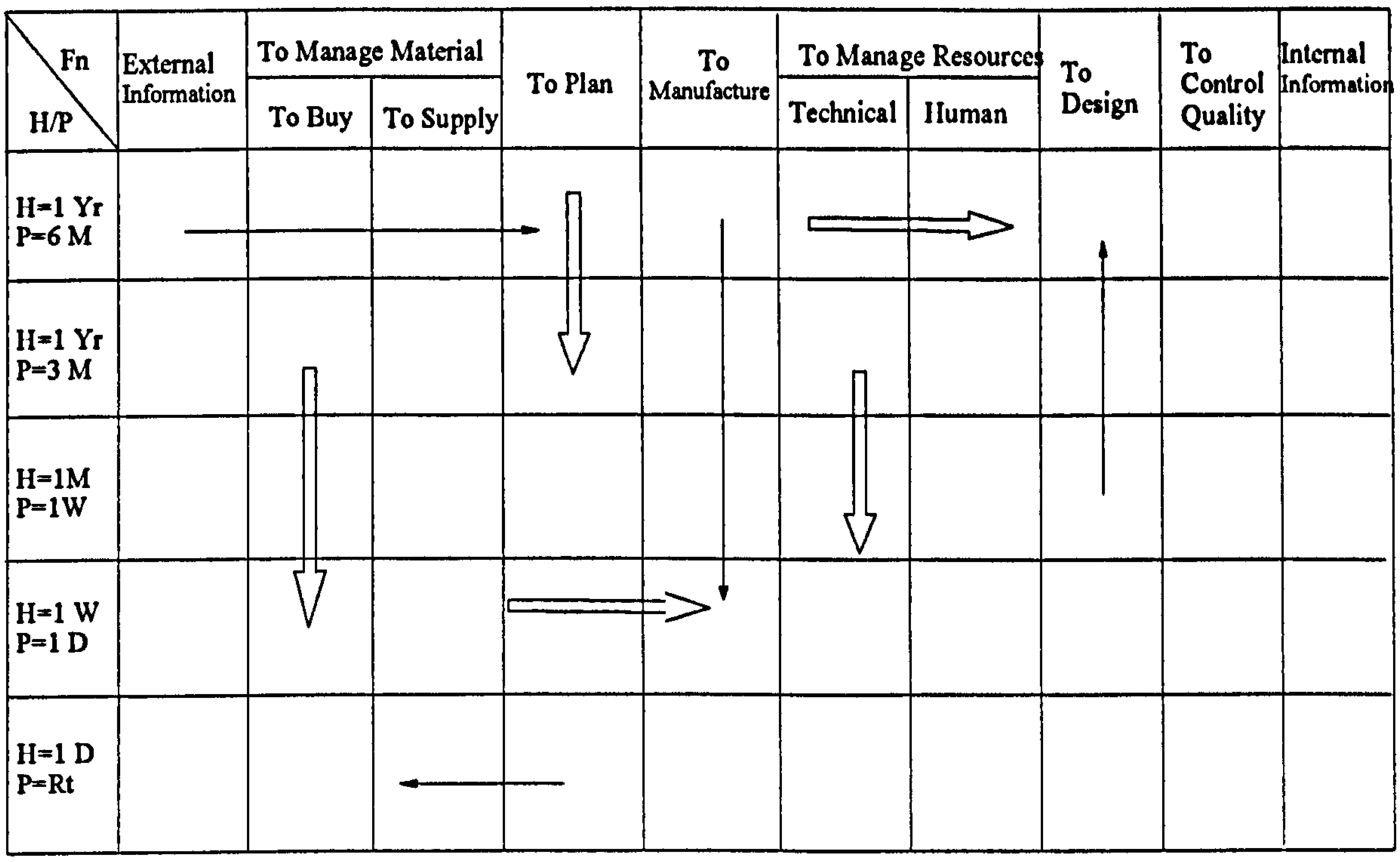


Figure 3.13 A typical GRAI grid

3.7.2.2 GRAI Net

The GRAI net is based on the micro structure of a system and examines the detailed activities of each decision centre. It is a symbolic representation of an activity chain within a decision centre and shows the relationship between the activities and the support they require. The basic net is shown diagrammatically in Figure 3.14. By using the GRAI net, the results of one discrete activity can be connected to support another discrete activity. Four fundamental elements can be identified in the GRAI net, namely:

- to do or decide (activity name)
- the initial state (main input of an activity)
- the supports (information, decision frame, method and material)
- the results (results of an activity)

These elements are represented by the different symbols, as shown in Figure 3.14. The vertical flow shows decisional activities and the horizontal flow denotes physical activities.

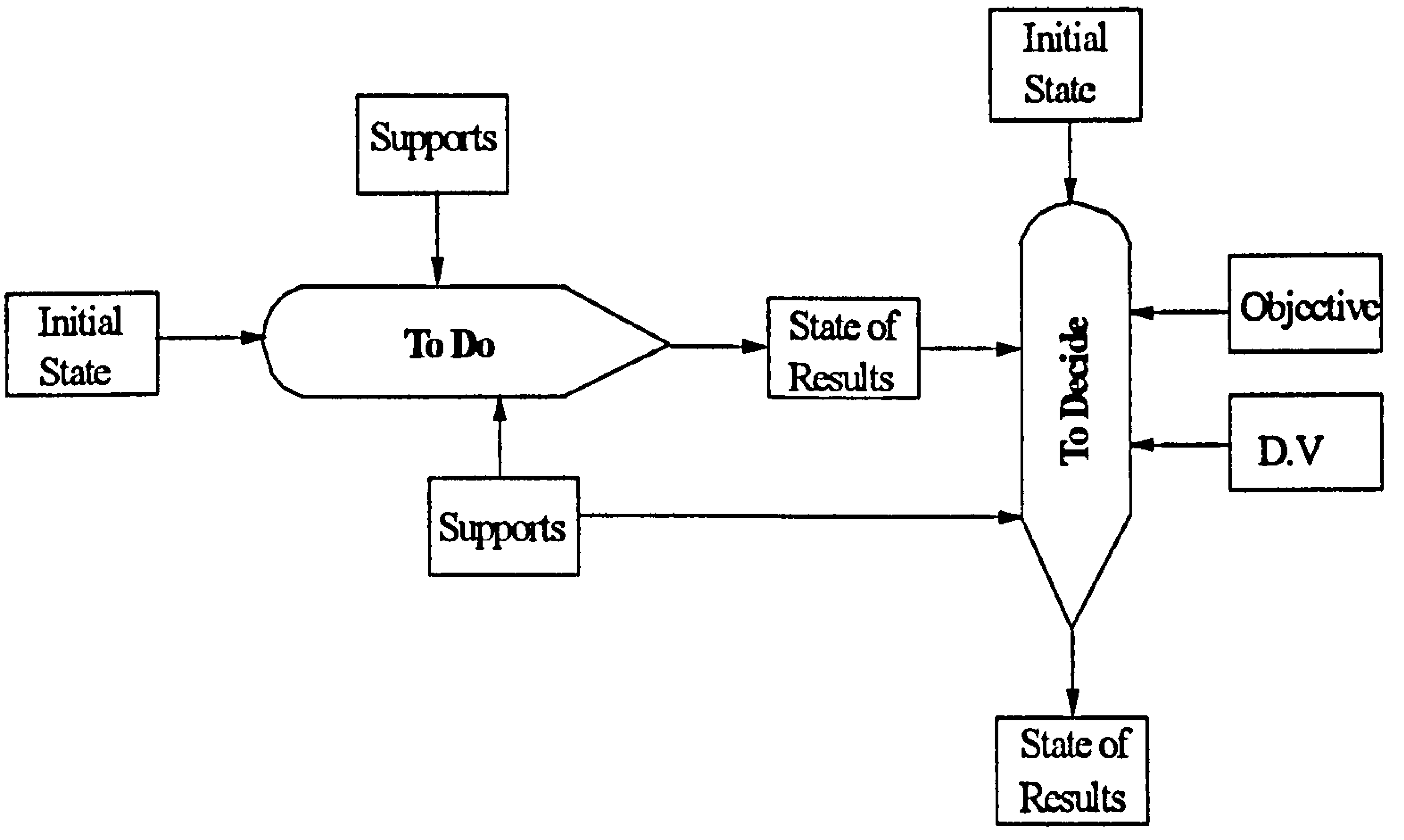


Figure 3.14 GRAI net

3.7.3 The Structured Approach of the GRAI Method

The application of the GRAI method must be structured (shown by Figure 3.15) and follow a strict procedure as described by Doumeingts et al (1992). The application of the method in manufacturing companies requires:

- **An analysis group:** This comprises one or more analysts, whose job is to collect the data required for analysis using interviews with the synthesis group.

- **A synthesis group:** This includes the management team involved in the decision making process. The synthesis group is interviewed by the analysis group. The responsibilities of the synthesis group are to provide the necessary information to the analyst, check and validate the results at various stages of the model and to guide the design of the new system.

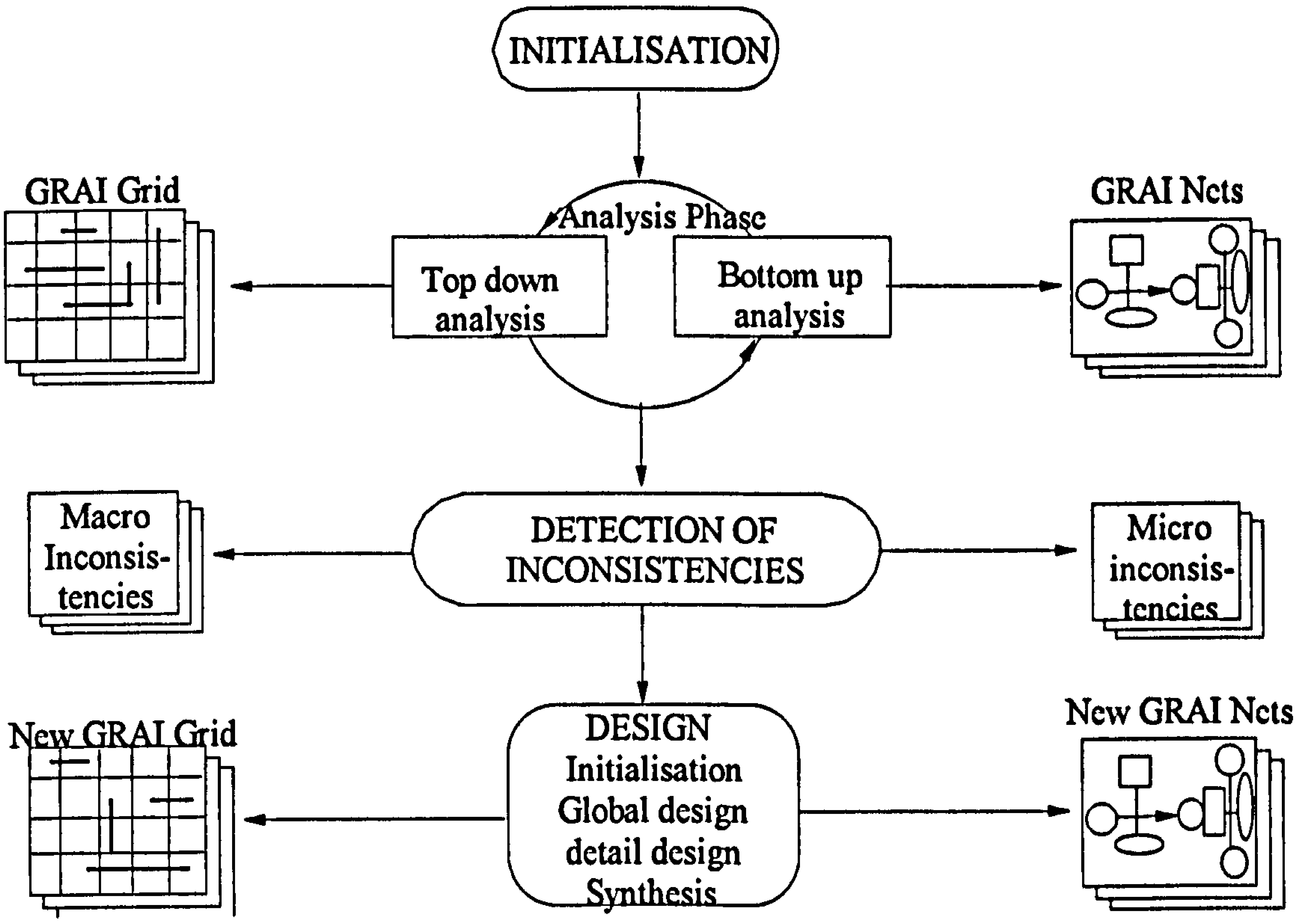


Figure 3.15 Structured approach of the GRAI

(Source: Doumeingts et al, 1992)

The GRAI method consists of two phases, namely the analysis phase and design phase.

3.7.3.1 Analysis Phase

The purpose of the analysis phase is to analyse the existing management system of the company using the interview techniques, identify inconsistencies in the system and collect all necessary data for a new or modified design. The analysis phase is split into two sub-phases, related to macro and the micro structure of the conceptual model. These are top down and bottom up analysis.

3.7.3.1.1 Top down Analysis

The first step of the GRAI method is a top down analysis, which involves drawing a frame using the GRAI grid tools, (Figure 3.13). This phase of the analysis is based on the macro structure of the GRAI conceptual model. The analysis group conducts a series of interviews with the synthesis group to obtain the necessary information. Questions are normally asked regarding the responsibilities, horizons and review periods. The analyst will construct the GRAI grid once all the information has been collected and the functions, decision centres horizons and review periods have been identified. The GRAI grid represents the overall structure and hierarchy of the existing management system of the organisation.

3.7.3.1.2 Bottom up Analysis

This phase is based on the micro structure of GRAI conceptual model. The bottom up analysis consists of drawing an individual decision frame using the GRAI net tool (Figure 3.14). The technique used to collect the data for this phase is a second round of more detailed interviews with the decision makers identified during the top down analysis. The analysis represents both decisions and the information required to perform activities. Information is obtained regarding:

- specific decisions made in each decision centre
- constraints or variables and criteria used to make the decision
- necessary information used to make the decision
- rules between input and output
- the decision frame
- the flow of information and decisions
- the level of the decision centre.

This information should initially be collected and verified by the synthesis group.

3.7.3.1.3 Analysing the Results

Examination of the results obtained from both the topdown and bottom up analysis, i.e. the GRAI grid and associated nets, allows inconsistencies in the management structure and system to be identified. There are commonly three types of inconsistency identified (Doumeingts, 1984):

1- Transmission of information:

no updating of lead times

no knowledge of big orders

very slow transmission of information

redundancy of data

inconsistencies between measurement parameters

2- Specific to a decision

no influence of delay on purchasing negotiations

no inventory level, not enough detailed information

no follow up of stock data

3- Co-ordination between decision centres

in the frequency of general planning and of orders

decisions in manufacturing induce perturbations in inventory control.

These inconsistencies are solved in the design phase.

3.7.3.2 Design Phase

The design phase aims to solve the inconsistencies identified during the analysis phase. It starts from two points:

- the economic and technical objectives given by the synthesis group
- the list of inconsistencies identified during the analysis phase.

The design phase has two steps:

- The construction of a frame using the GRAI grid tool to represent the proposed structure of the manufacturing management system.
- The construction of the decisional frame for each decision centre using the GRAI net tool. The nets show activities carried out at each decision centre in detail.

The design phase of the GRAI method is based upon the use of the two GRAI conceptual models the macro and micro structures. These models guide the designer to resolve inconsistencies and define the new or modified manufacturing management system.

3.7.4 Comments

The GRAI method provides techniques and tools for modelling manufacturing systems. The method is capable of analysing and designing the manufacturing management system, especially the management decisions. The advantages of the method are that it:

- analyses the whole manufacturing management system and related functions
- gives a hierarchical representation of the decision centres
- is easy to read and apply
- shows the links between decision centres and functions
- details the information flow between decision centres and functions at different levels
- covers the time aspect of the system
- represents both process and decisional activities
- models the time frame of decisions taken.

An important aspect of the application of the GRAI method is the combined evaluation and verification of the results obtained by the synthesis group. This on-going involvement allows the group to identify its own deficiencies and inadequacies. It is this process which is key to the acceptance of the results of the study and acceptance of any modifications recommended.

3.8 ASSESSMENT OF THE METHODS

Ideally any modelling method selected must meet the following requirements:

A. Model the activities involved in manufacturing management

B. Employ a structured approach to develop the model

C. Utilise graphical tools

D. Consider all the different manufacturing functions

E. Operate with hierarchical planning and control

F. Include the capability to model decision

G. Consider the time scale of activities

H. Indicate details of the information source and destination

The comparison of selected modelling methods has been carried out regarding the characteristics listed above, the results of which are shown in Table 3.1. The objective of this assessment was to select the most suitable method for this research.

METHODS	CHARACTERISTICS								TOTAL
	A	B	C	D	E	F	G	H	
SSADM	1	3	3	1	1	1	1	2	13
SADT	1	2	3	1	1	1	1	2	12
IDEF0	3	2	3	3	2	1	1	2	17
MERISE	1	1	1	1	1	1	1	3	10
STRIM	2	1	2	2	1	1	1	1	11
GRAI	3	2	3	3	3	3	3	2	22

Key: 3 = Highly Recommended

2 = Recommended

1 = Not Recommended

Table 3.1 Comparison of the methods

SSADM is not a suitable method for analysing a manufacturing system. It is a methodology specifically developed for software engineering and cannot present the decisional activities of the system. SSADM is also deficient in real time systems and the analysis and is expensive to run, making it inappropriate for small projects (Maji, 1988). For these reasons SSADM has been disregarded for this work.

SADT, although a thorough, more appropriate method, does not support the decisional and time activities of the system. Its successor IDEF0 is more appropriate for the manufacturing environment. For this reason SADT has been rejected.

IDEF0 was selected for further research, because it fulfils all the requirements of the desired model of the system except time and decision activities. In addition it supports decomposition of the system and gives detail at each level of the system. Harrington (1984) states that IDEF0 provides the understanding of the complexity of manufacturing processes and provides a two dimensional map that allows the human mind to picture specific elements whilst retaining overall relationships. Harrington (1984) also suggests two applications of IDEF0:

1. The development of a generic model of a manufacturing system as a base, from which to evaluate or establish deficiencies in an organisation.
2. The use of IDEF0 models as a means of planning the integration of manufacturing functions.

Crossly (1982), Parnaby (1988), Baines and Colquhoun (1990), and Sarkis (1994) support the suggestion that IDEF0 can be used as a tool to improve a manufacturing system.

MERISE was eliminated as a possible modelling tool because it was specifically developed for information systems only.

The organisation of STRIM is not well structured. Role Activity Diagrams (RADs) are based on complex theory and do not present the direction of flow of information. The interview techniques of STRIM are also complex. The method does not present the hierarchy of different functions and does not support time and decision activities. STRIM has therefore been rejected for this study.

The GRAI method has also been selected for further research and study. The reason for its selection is that it fulfils all the basic requirements of a good modelling method and is appropriate for modelling manufacturing management systems. In addition Buchel et al (1984) conclude that "the GRAI model is a model for structuring a specific application field and that it is in this class only that we may find decomposition criteria, conceptual solution models and integration of different view points".

Table 3.1 shows that the IDEF0 and GRAI are the suitable modelling methods for manufacturing management systems. This is supported by Pandya (1995).

3.9 CONCLUSIONS

The objective of this Chapter was to identify suitable methods for modelling manufacturing management systems.

SSADM, SADT, IDEF0, MERISE, STRIM and GRAI modelling methods were selected and reviewed. The reason for the selection of these methods was that they all use graphical tools for modelling the system. SSADM was specifically developed for software engineering and cannot represent decisional activities in the systems. SADT does not the organisational environment and structure of the system (Yadav, 1983). IDEF0 is an appropriate method for modelling manufacturing management systems because it supports decomposition of the system and allows the user to map the functions and activities of the system. MERISE does not support any decision making and it was specifically developed for information systems. The organisation of STRIM is not well structured. The method does not present the hierarchy of functions and does not support decision making. The GRAI method is also appropriate of modelling manufacturing management systems because it models both the information and decision making systems.

After an initial review, an assessment of these methods was carried out which was based on the requirements of modelling manufacturing management systems. On the basis of this assessment a table was derived (Ref. Table 3.1). This Table demonstrates that the GRAI and IDEF0 are most suitable methods for modelling manufacturing management systems. The GRAI method has more advantages compared to IDEF0, as it shows the time scale at different levels of the model hierarchy and supports the decision making process.

To evaluate the methods selected in more detail it was necessary to apply both in an industrial case study. This comparison will be presented in Chapter 4.

CHAPTER-4

INDUSTRIAL APPLICATION OF THE GRAI AND IDEF0 METHODS

4.1 INTRODUCTION

This chapter compares and contrasts the GRAI and IDEF0 modelling methods through their application to a case study company. In this case the company concerned, Footprint Tools Ltd. Sheffield, is classified as a 'make-to-stock' company of the type defined by Vonderembse and White (1991).

The GRAI method uses the identification and analysis of decision centres at different levels of the hierarchy. These levels are strategic, tactical and operational. The strategic level involves establishing the policies and objectives of the company and specifying what the manufacturing function has to achieve within a specific time frame. The horizon of this level is based on long term policies. The tactical level is the routine tactical planning and control level which is based upon strategic decisions made at the higher level. The horizon of this level is based on medium term planning. The operational level is the routine execution of work based on decisions made at the tactical level and includes the implementation of work according to desired programs. The horizon of this level is based on short term planning and the decisions made are reviewed to overcome real time problems.

GRAI and IDEF0 both use a topdown approach which exposes one level of detail at a time. Both begin the description process by modelling the system as a whole at the highest level and then decomposing this level by level to describe each of the subsystems within the system hierarchy.

Both GRAI and IDEF0 methods have been applied in numerous different applications. Peoples et al (1992) used the GRAI grid to analyse the material flow within a small batch manufacturing environment. The GRAI method was also used by Ridgway (1992) to analyse the project management of a multi-contract turnkey project. Ho and Ridgway (1994 a) employed the GRAI method to design a cellular manufacturing system also Ho and Ridgway (1994 b) demonstrated that GRAI could be used to schedule work in manufacturing cell. Doumeingts (1995) and Chodari et al (1994 and 1995) have demonstrated that the GRAI method can be used to model the management of a manufacturing company.

The use of IDEF0 has been demonstrated in a number of projects. Dennis et al (1994) demonstrates the use of the IDEF0 in business process re-engineering. Hargrove (1993) used IDEF0 to develop a model of fixture planning and design and Ang et al (1993) suggest that IDEF0 could be used to model a project plan. Ranky (1991) used IDEF0 to develop a generic model of a Flexible Manufacturing System and Colquhoun et al (1991) used IDEF0 to develop a model of the process planning function. Evers et al (1990) modelled the infrastructure of a company using the IDEF0 method.

This work represents the first direct case study comparison between the GRAI and IDEF0 methods for modelling a 'make-to-stock' manufacturing organisation.

4.2 INTRODUCTION TO THE CASE STUDY COMPANY

Footprint Tools Ltd., was established in 1875 when Thomas R. Ellin began a company to produce an innovative wrench and a range of high quality hand tools. It is the largest privately own hand tool manufacturing company in the United Kingdom. The Company has approximately 200 employees and exports 66% of its production to 80 countries throughout the world. The turnover of the Company is £4 M per year.

4.2.1 Operational Objectives

The Company manufactures products mainly on a 'make-to-stock' basis, but does produce a limited range of products for several large customers on a 'make-to-order' basis. Traditionally this type of company has predicted stock levels and manufactures according to stock status (Wild, 1989). Stocks are held for each type of product manufactured. Customers place orders through the sales department, who then initiate delivery from the warehouse. As deliveries are made, stock levels fall until they reach a predicted level, known as the reorder level. At this point a signal is passed to the production department, who schedule the production of a specific quantity of replacement products. The replacement quantity is usually calculated using the Economic Batch Quantity (EBQ) equation (see below). The replenishment stock is manufactured by the company, whilst products continue to be sold from stock.

In this system the critical decisions involve:

1. The positioning of the reorder level, which should enable the replenishment stock to arrive just before the warehouse runs out of product.
2. The manufacturing lead time.
3. The economy order quantity, which is based on the equation.

$$EBQ = \sqrt{\frac{2UCo}{Ch}}$$

Where U = Annual usage
Co = Order cost per order
Ch = Annual holding cost per unit

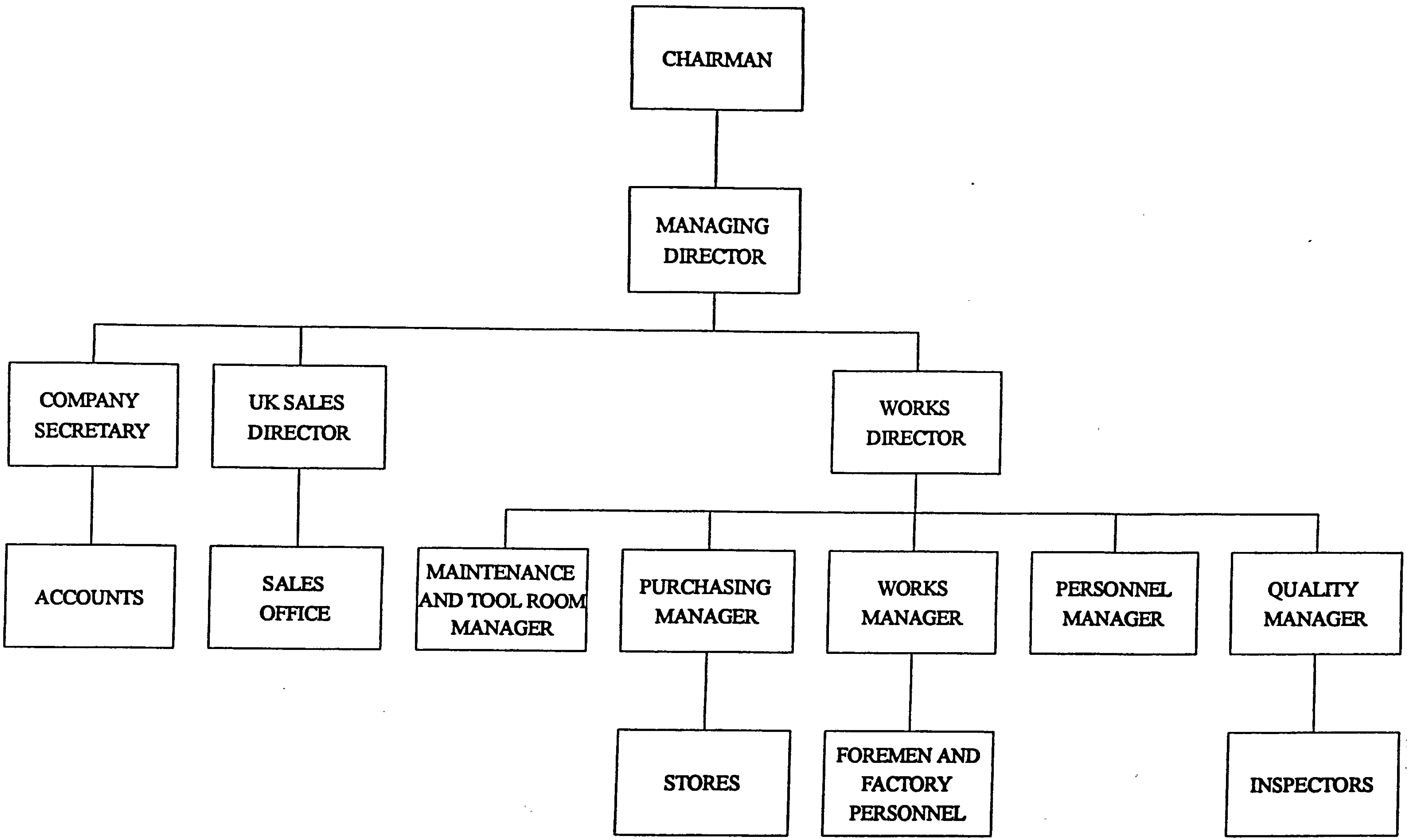


Figure 4.1 Organisation Structure of the Company

4.2.2 Product Range

Footprint Tools Ltd. manufactures a wide range of hand tools including:

Wrenches	Woodworker tools	Hammer
Tin snips	Saws	Knives
Carving Tools	Zip bits	Drills
Augers	Planes	Screw drivers

4.2.3 Organisation Structure

The organisation structure of the company is shown in Figure 4.1. This is a typical line structure organisation (Gray and Strake, 1984), in which all positions are in the line of authority from top, to bottom, with each level in the organisation subordinate to the one above.

4.2.4 Factory Layout

The layout of the factory is primarily functional, but a small number of product shops also exist. The main manufacturing sections of Footprint Tools Ltd. are shown in Table 4.1.

Process-Based Section	Product-Based Section	Material-Based Section	Support-Section
Forge	Tinsnip	Wood shop	Machine-shop
Grinding machines	Wrench		
Wet wheel	Plane		
Packing			
Heat treatment			

Table 4.1 Manufacturing sections of the Company

The layout within the product based sections are not arranged in a flow line (i.e. to minimise handling and transportation). The sections are organised in a functional layout, which loses the advantages of the product-based approach.

A SUMMARY OF RULES RELATED TO GRAI METHOD

Table 4A: Rules Related to GRAI Grid

- Horizon and time period must be unique for each level.
- The horizon of any level must be equal to at least two periods of the level below.
- The levels are classified by decreasing periods, and for equal periods, decreasing horizons.
- There must be at least three levels relating to strategic, tactical and operational decisions.
- A function must contain at least one decision centre.
- A level must contain at least one decision centre.
- At any given level, the horizon must be longer than review period.
- The horizon of a decision making activity must be greater than the longest cycle of the activities which decision centre controls.
- Each level of decision must generate an action at one decision frame at lower level.
- Each decision making activity centre must receive a decision frame from an activity centre on the same or higher level.
- A decision making activity centre must not be isolated on a grid, but must be linked to at least one other activity centre.
- Every decision making activity centre must transmit a decision frame to one or more decision making activity centres on the same or lower levels, except those on the bottom level, which generate work instructions.
- Every decision making activity centre should only receive one decision frame. If more than one is received their objectives must be checked for conflict. The resources of the decision frames must also be checked.
- A decision frame should not go from a lower level to higher level.
- Every activity centre which generates a decision frame must contain a decision making activity centre.
- An activity centre should not receive a decision frame from a function which concerns basic elements (resources, products, time) not considered by the function containing that activity centre.
- A structure is coherent if all elements seek to satisfy the objectives of the overall system. Each decision frame should be linked by information chains and have similar origins.

(Source GRAI Rules, 1991)

4.3 APPLICATION OF THE GRAI METHOD

4.3.1 Analysis Phase

As suggested by Doumeingts (1983 and 1985) the analysis phase of the study is based on two rounds of interviews. The first round, topdown analysis, is used to construct a GRAI grid and the second, bottom up analysis, is used to construct the GRAI nets.

Using the organisation structure as shown in Figure 4.1, employees are selected who are directly involved in the decision making process. This group, known as the synthesis group, provides the information which determines the hierarchical links between decision centres. These are then plotted on a GRAI grid. A bottom up analysis is then performed to construct GRAI nets and scrutinise the decision centres.

The synthesis group identified for interview comprised the following members:

- The Chairman
- The Managing Director
- The Works Director
- The Purchasing Manager
- The Maintenance Manager
- The Works Manager
- The Assistant Works Manager
- The Quality Manager
- A Forman from each workshop.

4.3.1.1 Top Down Analysis

The top down analysis consisted of interviews with the synthesis group and carries out in the view of rules related to GRAI grid as shown in Table 4A. It examined the overall production management system and produced an overall picture of the existing system. The initial round of interviews was used to determine the activities performed,

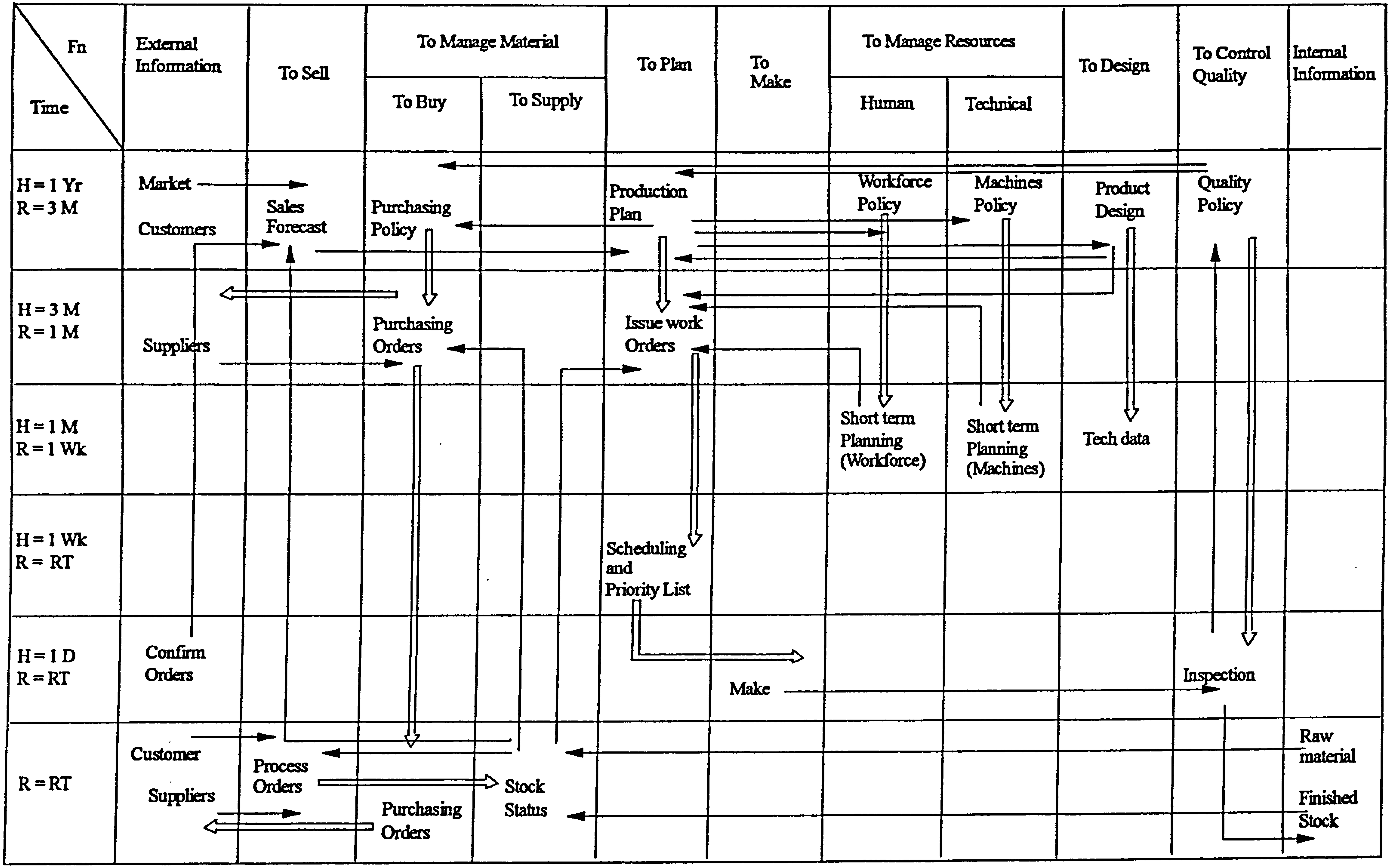


Figure 4.2 GRAI Grid for Existing Manufacturing Management System

decisions made and the perception of the role of each member of the synthesis group. The decisions were related to the horizons, review periods and functions of the Company. After collection, the information and the key management functions were identified and a GRAI grid was constructed as shown in Figure 4.2.

i) Identification of Functions

The following functions were identified:

- To Sell
- To Manage Material
    - To Buy
    - To Supply
- To Plan
- To Make
- To Manage Resources
    - Human
    - Technical
- To Design
- To Control Quality

To Sell

The sell function controls all sales activities. It manages customers' orders and inquiries. If orders are confirmed, the sales department first check the finished stock to ascertain whether the required items are available. If items are available in stock, they are delivered to customers, otherwise details of the order are sent to production planning. The sales function also assesses orders and determines whether they are standard or special products. Special products are sent to the design department for a feasibility study and cost estimation. The sales function then provides a quotation including the estimated delivery time, cost and any other relevant information to customers. It is also responsible for producing the forecast of future demand, checking the finished stock status and confirming orders.

To Manage Material

This function concerns material management, including the supply and purchase of products and components. It involves ensuring that the correct materials are available at the appropriate time, ready for manufacturing activities. It also involves an assessment of the value of purchased items and the selection of suitable suppliers, based on the criteria of cost and quality. The function is responsible for supplying the finished products to customers and checking the stock status of raw materials and finished products.

To Plan

This function, to which all other functions are related either through decisional activities or informational flows, is the core of the grid. The activities performed and decisions taken relate to planning and scheduling jobs throughout the manufacturing process.

To Make

This is related to the physical activities involved in the manufacture of products. It involves the translation of the production schedule into finished products, according to the required technical specification and quality standards.

To Manage Resources

This function is responsible for the management of workforce and technical resources necessary to accomplish the Company's plans.

To Design

This function involves the design of products, processes and procedures. The activities and decisions undertaken most commonly relate to the engineering design and modification of products according to customer requirements. The design function releases the information in the form of engineering drawings, technical specifications, process routes and other design documents.

To Control Quality

This function is related to the quality control of products. The company practises BS 5750 but the quality function is mainly concerned with product quality. The quality control function is responsible for the issue and inspection of the raw materials and products to specific quality standards. The function also evaluates rejections and customers complaints.

ii) Identification of Horizon and Review Periods

The horizon is defined as the time interval over which the decisions are valid and the review period is a time interval over which decisions are reviewed. The purpose of the review period is to verify that the decision taken is achieving the desired aims, if it is not, then the decision must be modified. The following horizons and review periods were identified:

H = 1 Year	R = 3 Months
H = 3 Months	R = 1 Month
H = 1 Month	R = 1 Week
H = 1 Week	R = Real Time
H = 1 Day	R = Real Time
Real Time	

H = 1 Year R = 3 Months

This horizon represents the strategic level of the Company. The manufacturing activities start from the sales forecast. The primary production plans are made according to the company policy and the information provided by the design and quality functions. The purchasing policy is made with reference to the production plans and sales forecasts. The GRAI grid (Figure 4.2) shows all the planning activities in terms of quality control, workforce planning and planning for machine utilisation.

The Company reviews such decisions every three months and if any problems exist, changes to the programme are implemented.

H = 3 Months R = 1 Month

This horizon is concerned with the issue of work and purchase orders. Purchasing includes the selection of suppliers and ordering raw material for manufacture. The works orders are issued according to the production plans and information provided by the Manage Resource function. Normally the information comprises the availability of workforce, machines and materials.

The review period for this horizon is one month. At this time the activities analysed include the identification of urgent orders, shortages of material or machine break-downs.

H = 1 Month R = 1 Week

This horizon is concerned with the short term planning of machines, workforce and the issue of technical data. This uses information such as the manufacturing process routes and technical drawings. The review period is one week.

H = 1 Week R = Real time

This horizon concerns the scheduling, priority and distribution of work to the shop floor. The work is allocated under instruction from a higher level together with information regarding the raw material, workforce, machines, technical data and manufacturing processes. The decisions made are reviewed and adjusted in real time. If problems occur, for example a machine break-down, or quality problems, the production plan changes accordingly.

H=1 day R = real time

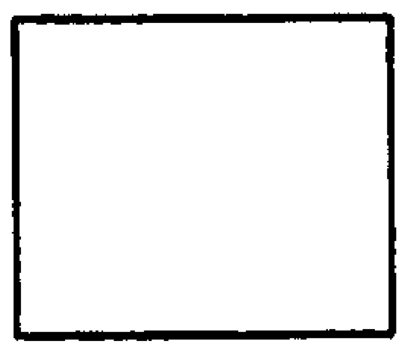
This horizon represents activities at the shop floor. The raw material is converted to saleable goods of specific quality at this level, according to the manufacturing instructions. The review period for the horizon is real time. The horizon also indicates the decision to supply customers directly if stock is available. This represent the most usual form of supply.

Table 4B: Rules Related to GRAI Net

- Every piece of information sent by a net, must appear somewhere in another net.
- The support of a decision making activity must include an objective, some constraints, and some decisional variables.
- The decision variables are the parameters on which the decision is based.
- Each activity must have a unique label in the same net.
- Each activity must produce results.
- The results of a decisional activity must be used by another activity.
- The results of an activity must not be used as a support of the same activity.
- All relationships existing in the grid must appear on the net.

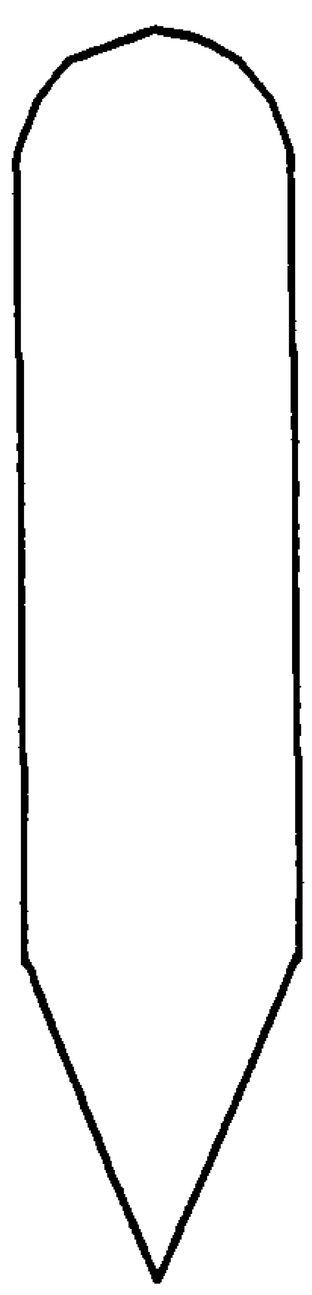
(Source GRAI Rules, 1991)

Table-4C Summary of Diagrammatic Representation Used on the GRAI Nets

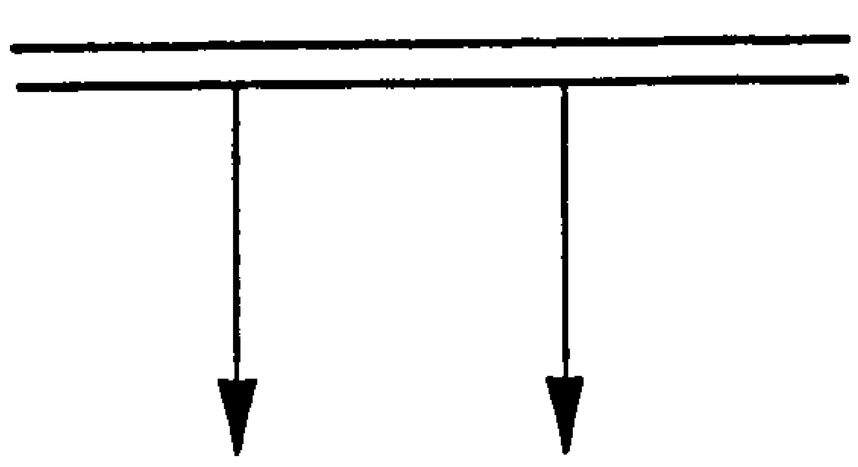


The square represents support, input and output

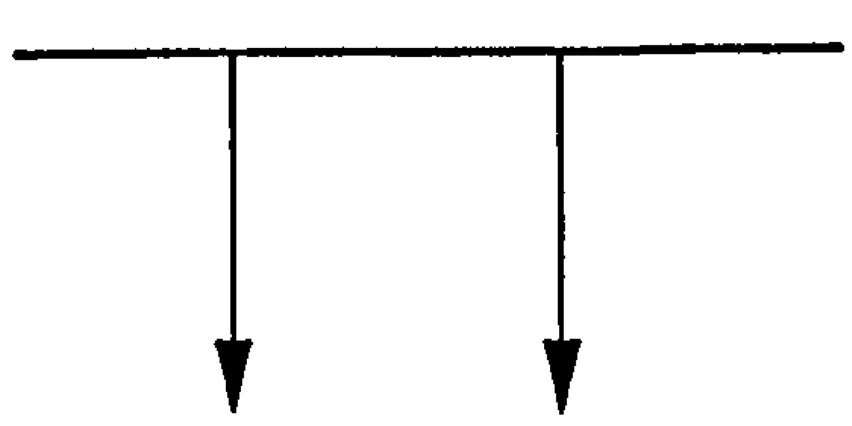
This symbol represents an executing activity



This symbol represents decisional activity

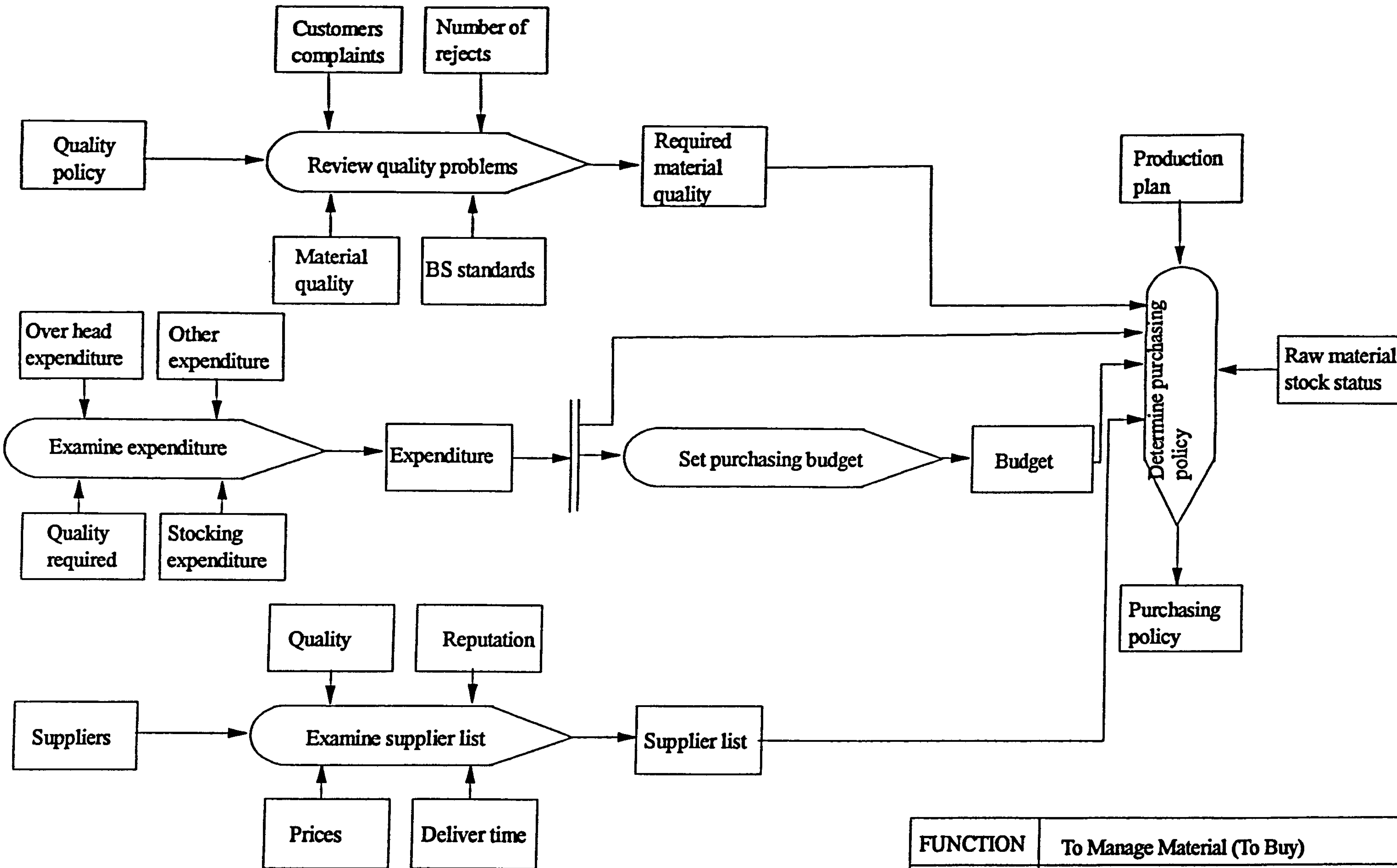


This symbol represents the logic AND operator



This symbol represents the logic OR operator

(Source GRAI Rules, 1991)



FUNCTION	To Manage Material (To Buy)
H/R	H = 1 Year R = 3 Months
TITLE	PURCHASING POLICY

Figure 4.3 GRAI Net for Purchasing Policy

4.3.1.2 Bottom up Analysis (Construction of GRAI nets)

This phase of the GRAI method involves the second round of interviews with the synthesis group and analyses the decision centres identified during the top down analysis in detail. This analysis carries out in the view of rules related to GRAI net as shown in Table 4B. The symbols that are used of drawing GRAI net shown in Table 4C. To analyse the decision centres identified and construct their associate GRAI nets it is necessary to identify:

- The various activities performed and the decisions taken at each decision centre
- The relationship between activities and the decision undertaken at a decision centre
- The information required to make a specific decision.

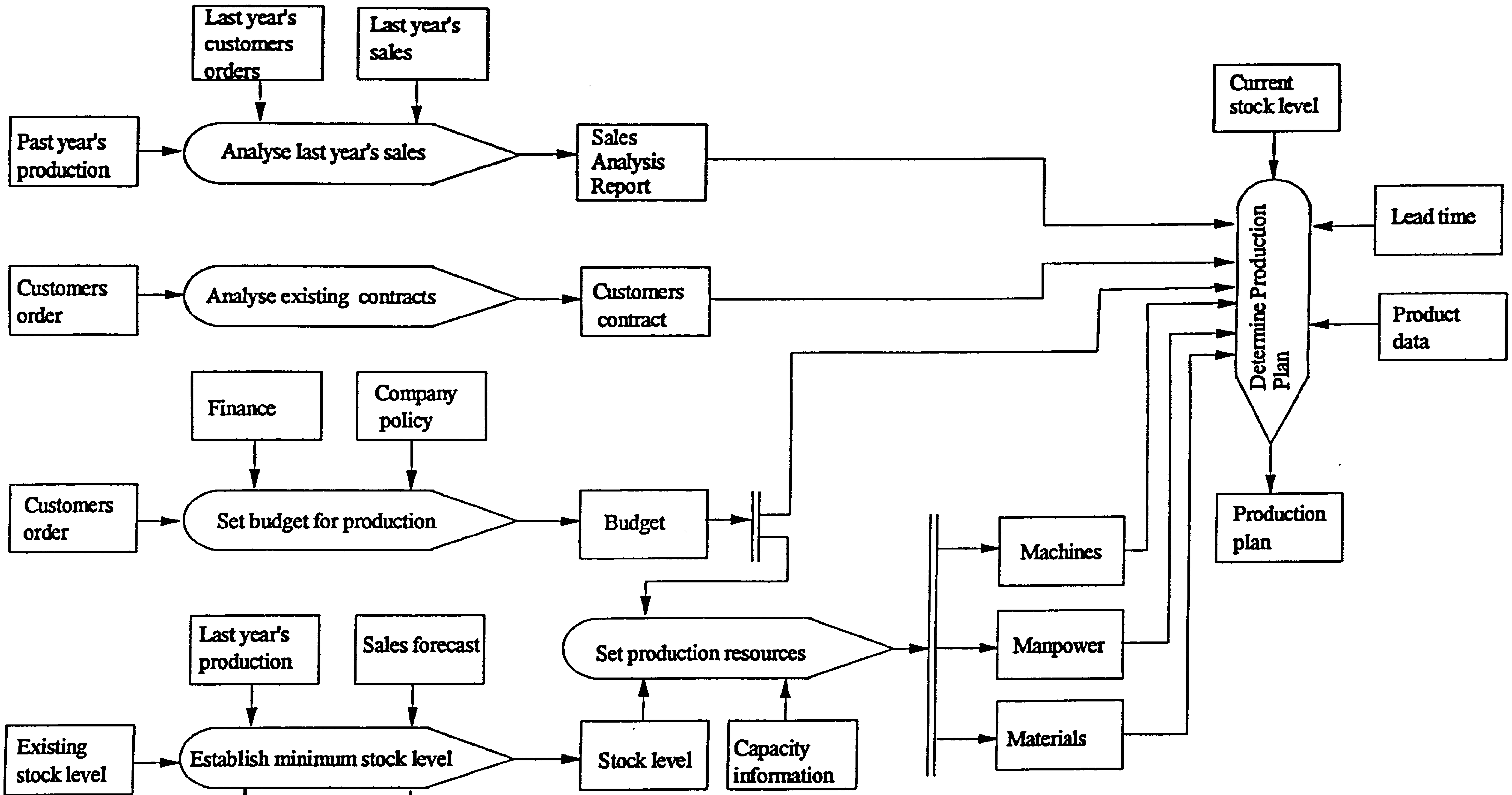
A total of ten GRAI nets were constructed to model the decision centres identified in the GRAI grid. They are described in relation to their horizons as shown in Figures 4.3 - 4.12.

H = 1 Year R = 3 Months

Function:- To Manage Material (To Buy)

Title:- Purchasing policy

This decision centre is related to the preparation of the purchasing policy for the Company as shown in Figure 4.3. Four major activities were identified. The first activity assesses any quality problems of the raw material previously supplied. This activity assesses customer complaints, the number of rejects, the quality policy, material quality and relevant British Standards. The output of this activity is a statement of the material to be purchased. The second activity assesses the purchasing expenditure. The third activity reviews the information provided by the suppliers including prices, delivery times, quality detail and reputation. The output of this activity is details of the selected suppliers. The fourth activity of this decision frame sets the purchasing budget.



FUNCTION	To Plan
H/R	H = 1 Year R = 3 Months
TITLE	PRODUCTION PLAN

Figure 4.4 GRAI Net for Production Plan

The purchasing decision is made with reference to the production plans and the results of the different activities performed. The output of the decision frame is a purchasing policy which consists of:

- A statement of the quality of materials to be purchased.
- The list of suppliers who fulfil the material quality requirement.
- The allocation of a budget for material to be purchased.
- The allocation of a contingency budget for occasions such as machine break-down, parts to be changed and material shortages.

The main purpose of the purchasing policy is to control all the purchasing activities to be performed during the year and set down a purchasing procedure.

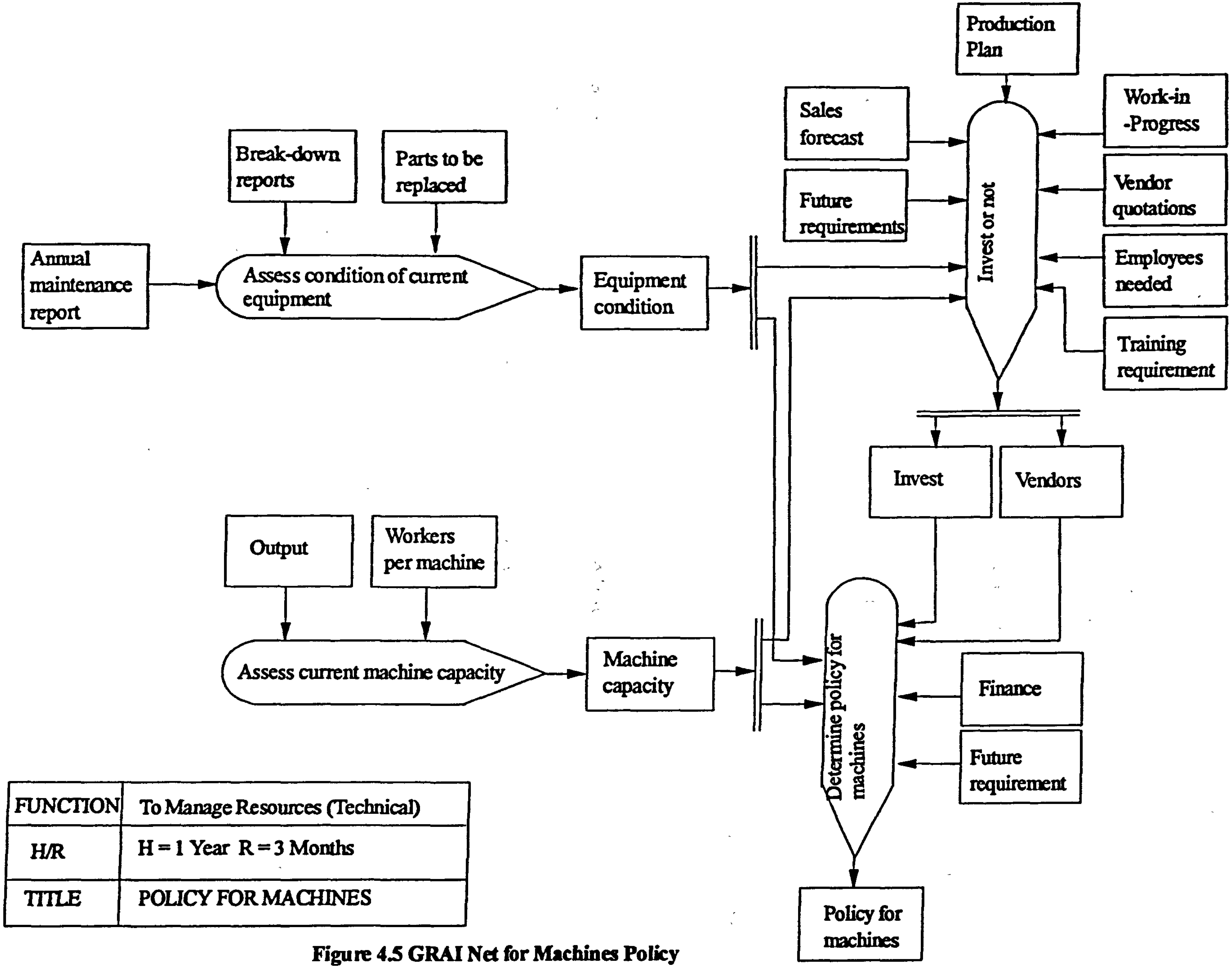
H=1 Year R = 3 Months

Function: To plan

Title: Production plan

This decision centre is related to the preparation of the production plan as shown in Figure 4.4. Five major activities were required to produce a feasible production plan within the system boundaries at Footprint Tools. The first activity produces a sales analysis report based on last year's sales. The second analyses the existing contracts. The third activity sets the budget for production after examination of customers' orders, the Company policy and finance available. The fourth activity reviews the safety stock levels, existing stock levels, last year's production and sales forecast. The output of this activity is the stock level. The fifth activity assesses the production resources, including the availability of workforce, machines and material.

Decisions regarding production are made with reference to the output of the different activities performed and the information provided by current stock levels, the product lead time, quality and product data. The output of the decision is an estimate of annual production. It expresses the overall plans in terms of specific end items which can be given priorities. The production plan sets a level of operations which aim to



FUNCTION	To Manage Resources (Technical)
H/R	H = 1 Year R = 3 Months
TITLE	POLICY FOR MACHINES

Figure 4.5 GRAI Net for Machines Policy

balance market demand with the material, labour and machine capabilities of the company. It consists of:

- Estimate of numbers and types of products to be manufactured
- Product quality
- Completion date

The objectives of the decision are to:

- estimate material requirements
- estimate the plant and resources capacity requirements
- facilitate information processing

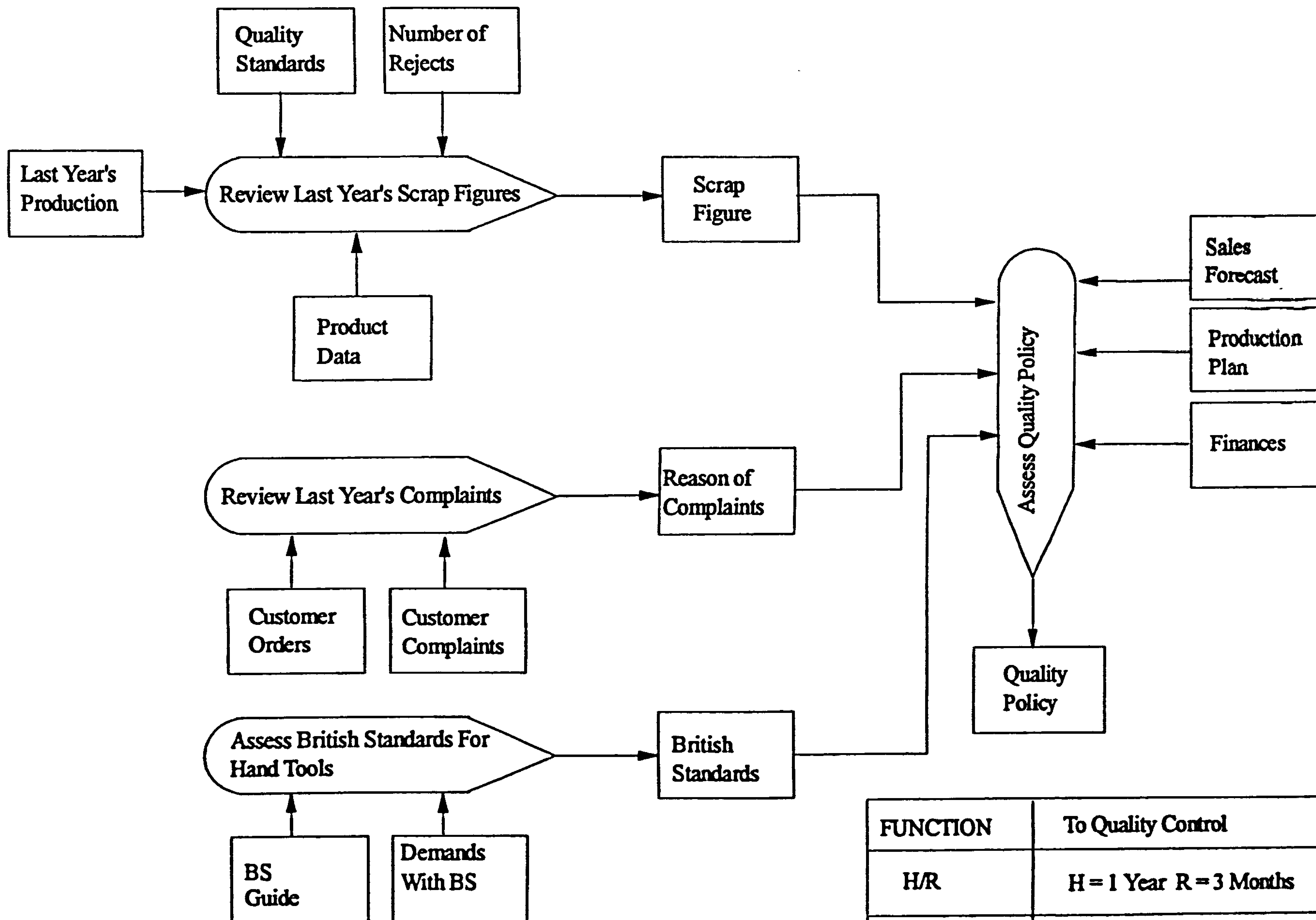
H = 1 Year   R = 3 Months

Function: To Manage Resources

Title: Machines Policy

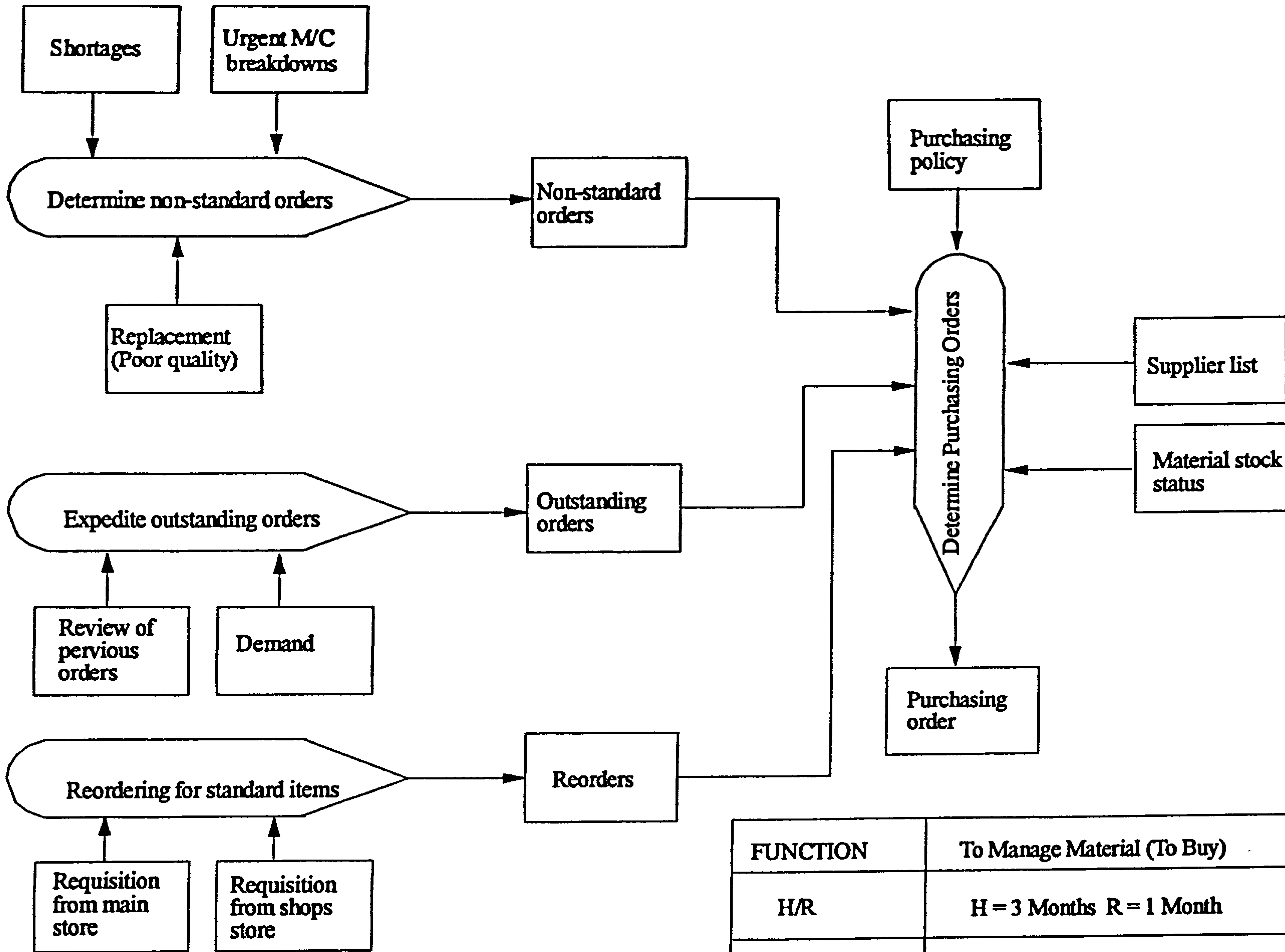
This decision relates to the preparation of the policy for machines as shown in Figure 4.5. Two major activities are required to produce the policy. The first activity assesses the current condition of machines. The activity is performed with reference to the information provided by the annual maintenance report, break-down report and the identification of parts to be replaced. The maintenance department has the responsibility to provide this information. The output of the activity is details of the current condition of the machines. The second activity analyses the machine capacity.

Two types of decision are made to determine the policy. One decision taken is whether to invest in new machines. The decision is made with reference to the information provided by the production plan, the sales forecast, future requirements, current work load, vendors' quotations and the number of employees required. The output of this decisional activity is whether to invest or make parts in-house. The second decision is made with reference to the previous decision and other relevant information. The output of this decision centre is the policy for machines which controls all activities including maintenance and new machine purchases.



FUNCTION	To Quality Control
H/R	H = 1 Year R = 3 Months
TITLE	QUALITY POLICY

Figure 4.6 GRAI Net for Quality Policy



FUNCTION	To Manage Material (To Buy)
H/R	H = 3 Months R = 1 Month
TITLE	PURCHASING ORDERS

Figure 4.7 GRAI Net for Purchasing Order

H = 1 Year R = 3 Months

Function: To Control Quality

Title: Quality Policy

The decision frame is related to the preparation of the quality policy, as shown in Figure 4.6. Three major activities were found. The first activity analyses the reasons for the occurrence of scrap. The second activity analyses customers complaints and the third activity assesses the relevant British standards.

The quality policy uses information provided by the sales forecast, the production plan and the activities performed. The output of the decision is the quality policy, which comprises quality standards for both the raw material and finished products, and inspection instructions procedures.

H = 3 Months R = 1 Month

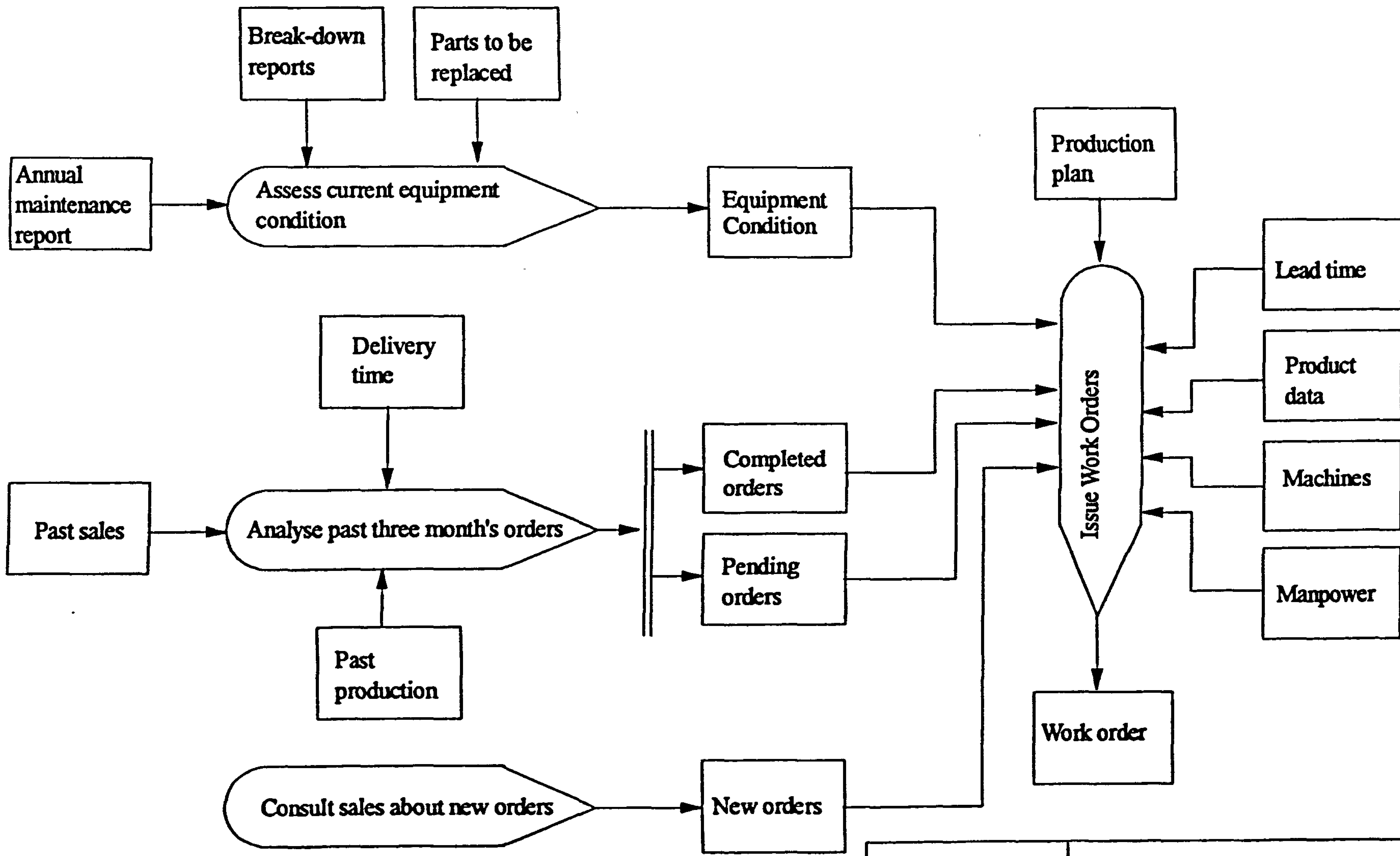
Function: To Manage Material (To Buy)

Title: Purchasing Orders

This decision centre relates to the decision to initiate a purchase order as shown in Figure 4.7. Three types of activity were found. The first activity analyses the reorder level of standard items. It also checks requisitions that arrive from different shops and the main store. The second activity is performed to expedite outstanding orders. It reviews the previous orders and the demand for outstanding orders. If an item is in high demand, notification is issued to buy it. The third activity determines any non-standard items such as machine parts required due to break-downs, unexpected shortages or replacements due to poor quality.

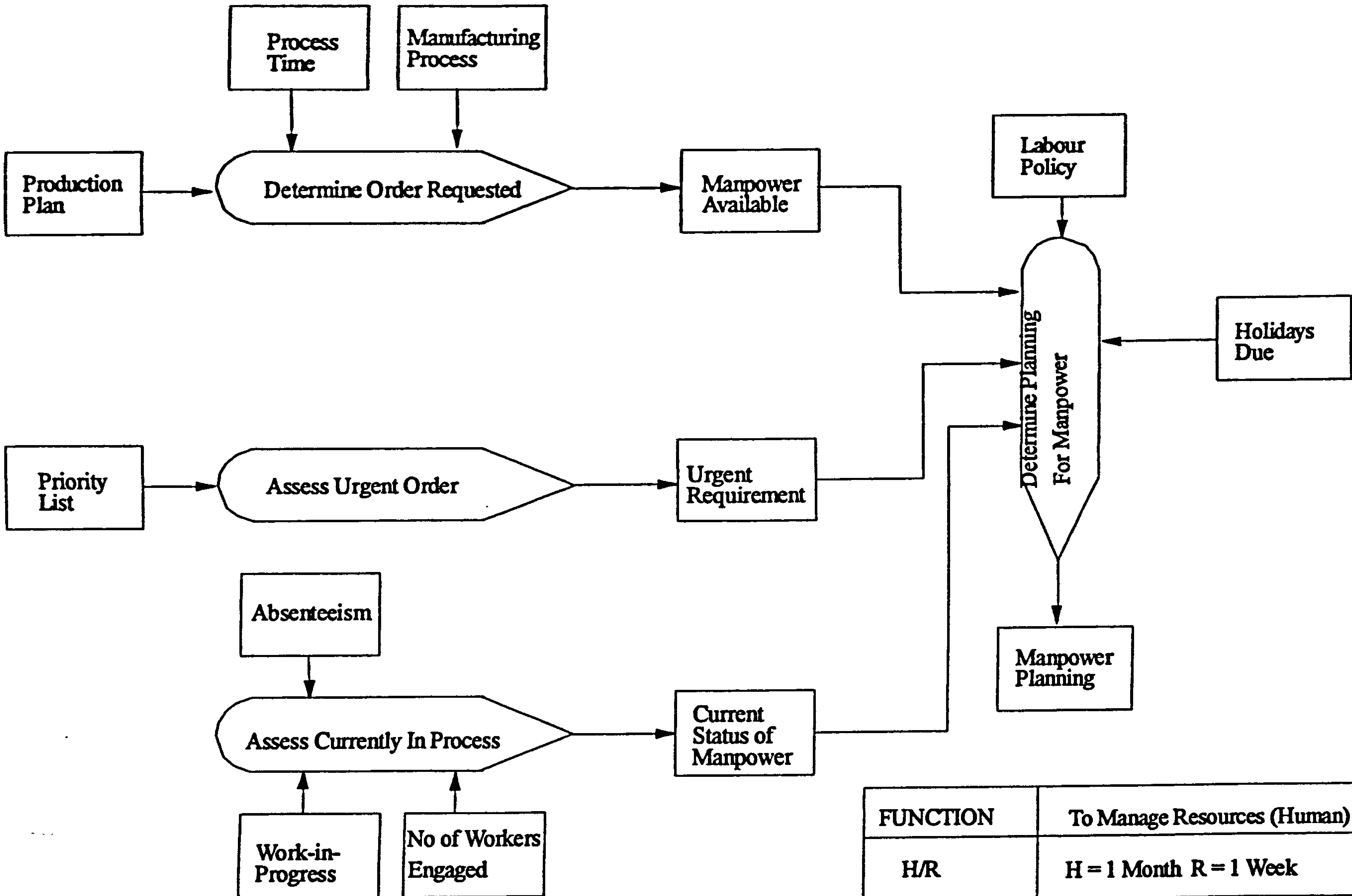
The output of the decision frame is the purchase order. The horizon of the frame is three months and the decision is reviewed every month. The main objective of the decision is to control and centralise all the purchasing activities of the Company. It consists of:

- Material to be purchased
- The quality and quantity of material required



FUNCTION	To Plan
H/R	H = 3 Months R = 1 Month
TITLE	ISSUE WORK ORDER

Figure 4.8 GRAI Net for Issue Work Order



FUNCTION	To Manage Resources (Human)
H/R	H = 1 Month R = 1 Week
TITLE	Short Term Planning For Workforce

Figure 4.9 GRAI Net for Short Term Planning of Workforce

H = 3 Months R = 1 Month

Function: To Plan

Title: Issue Work Orders

The decision frame relates to the issue of a work orders as shown in Figure 4.8. Three major activities were found. The first activity analyses the orders on hand. The second activity analyses orders issued during the last three months and the third activity examines new orders.

The decision is made regarding the production plan and other relevant information. The output of the decision frame is the work orders. The main purpose of this decision is to control the production activities with reference to production plans. The decision centre translates the production plan into specific numbers of end items to be produced within specific time periods. In this case, the horizon of the decision centre is three months and the review period is one month. The objectives of the decision are to:

- Translate the production plans into specific end items.
- Evaluate alternative schedules.
- Effectively utilise capacity.
- Generate the material requirement.
- Generate the capacity requirement.
- Facilitate information processing.

The decision consists of:

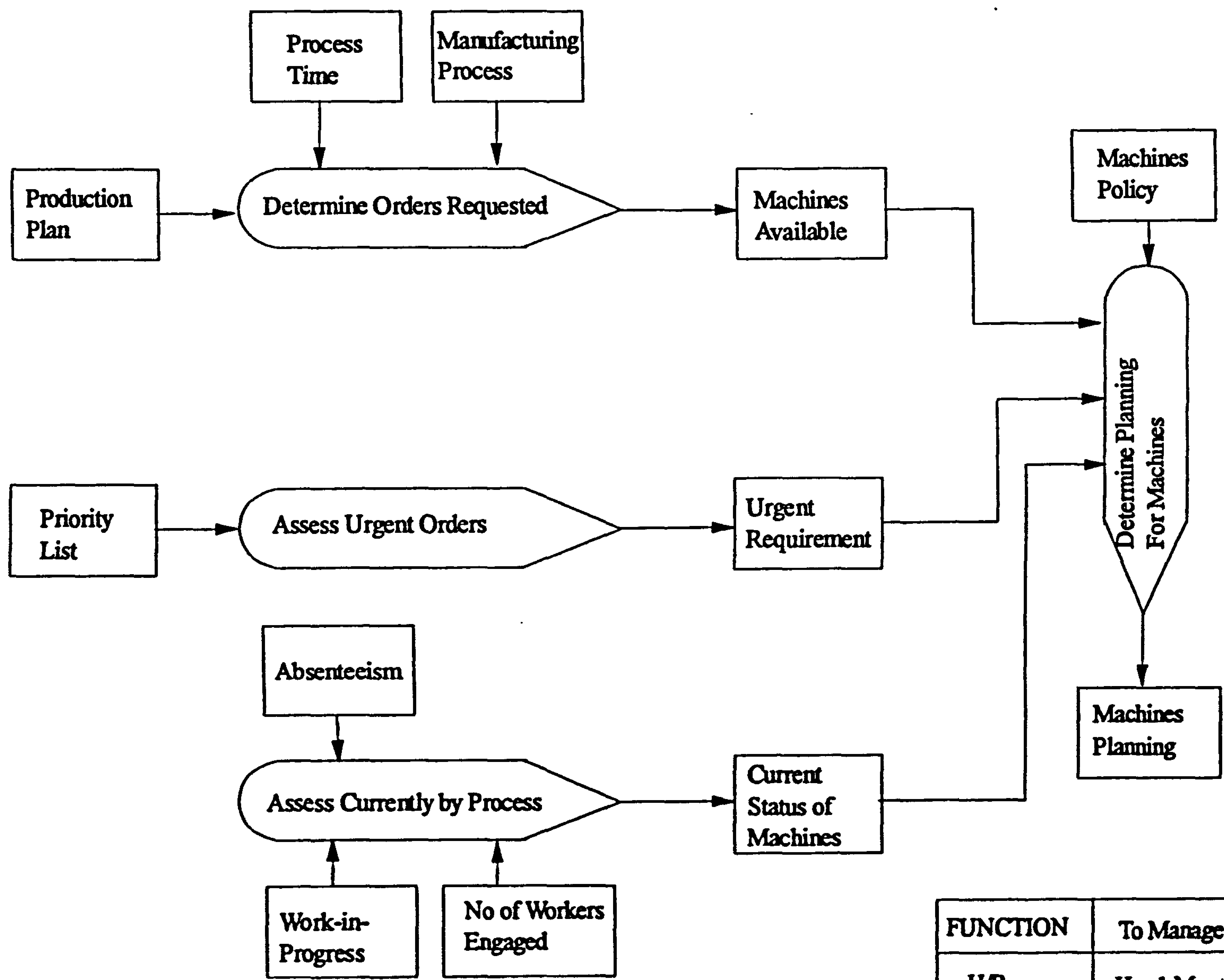
- The products types to be manufactured
- The quality and quantity of products
- The respective completion dates.

H = 1 Month R = 1 Week

Function: To Manage Resources (Human)

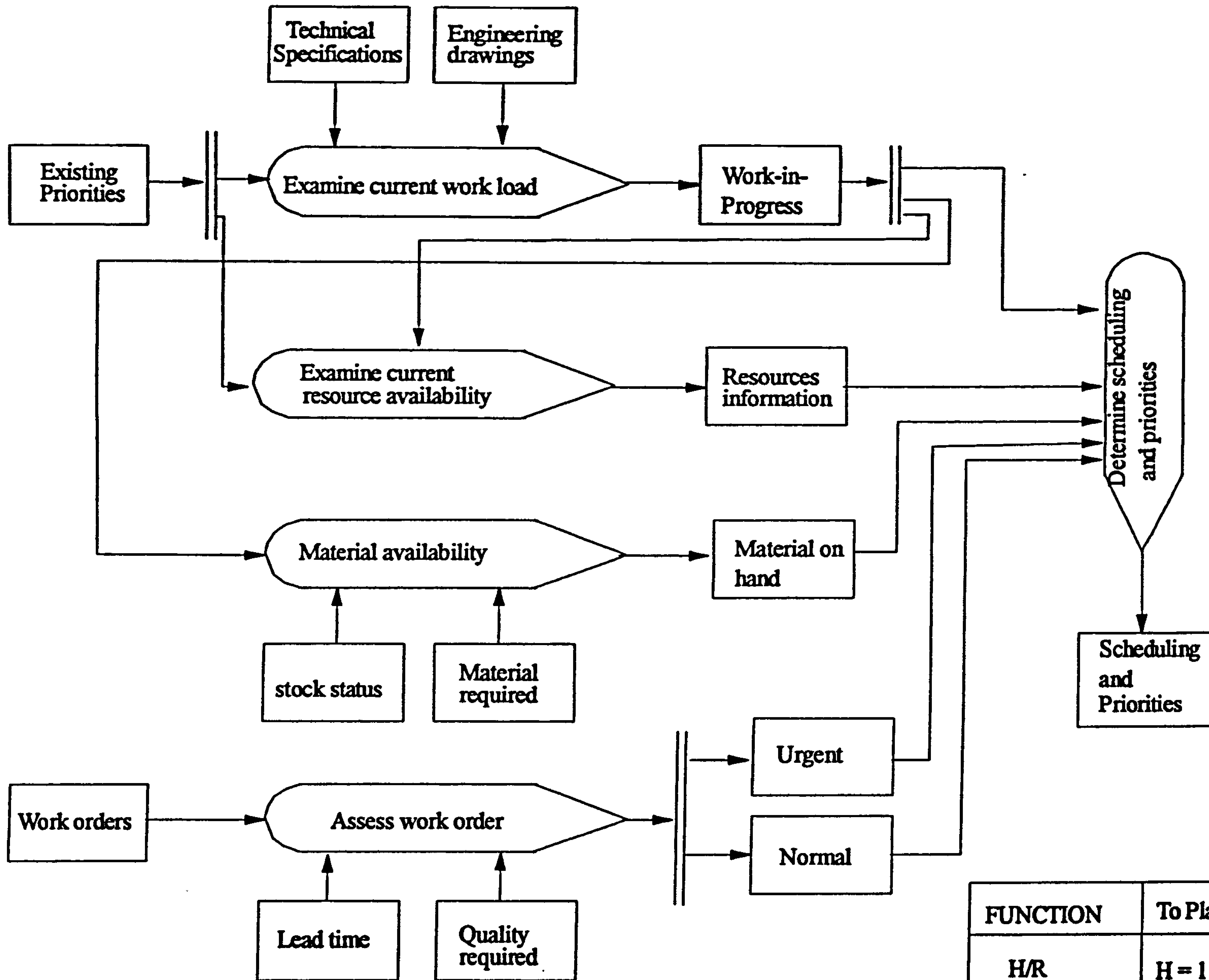
Title: Short Term Planning For Workforce

The decision frame is shown in Figure 4.9. Three types of activities are performed to identify workforce planning requirements. The output of the first activity shows the



FUNCTION	To Manage Resources (Technical)
H/R	H = 1 Month R = 1 Week
TITLE	Short Term Planning of Machines

Figure 4.10 GRAI Net for Short Term Planning of Machines



FUNCTION	To Plan
H/R	H = 1 Week R = 1 Day
TITLE	SCHEDULING AND PRIORITIES

Figure 4.11 GRAI Net for Scheduling and Priorities

availability of the workforce. The second activity identifies any urgent demand items and the third analyses the work currently being processed and how many people are being used. The output of this activity is the current status of the workforce.

The decision is made in the view of the labour policy, holidays due and outputs of the various activities performed. The result is a plan of the workforce usage for one month. The decision centre reviews and modifies the plan every week, as required.

H = 1 Month   R = 1 Week

Function: To Manage Resources (Technical)

Title: Short Term Planning For Machines

The decision frame is shown in Figure 4.10. Three types of activities are performed in this decision centre. The first activity determines the work orders and assesses the availability of machines. The second activity assesses any urgent production demand and the third analyses the amount of work currently being processed. The output of this activity identifies the current status of machine loading.

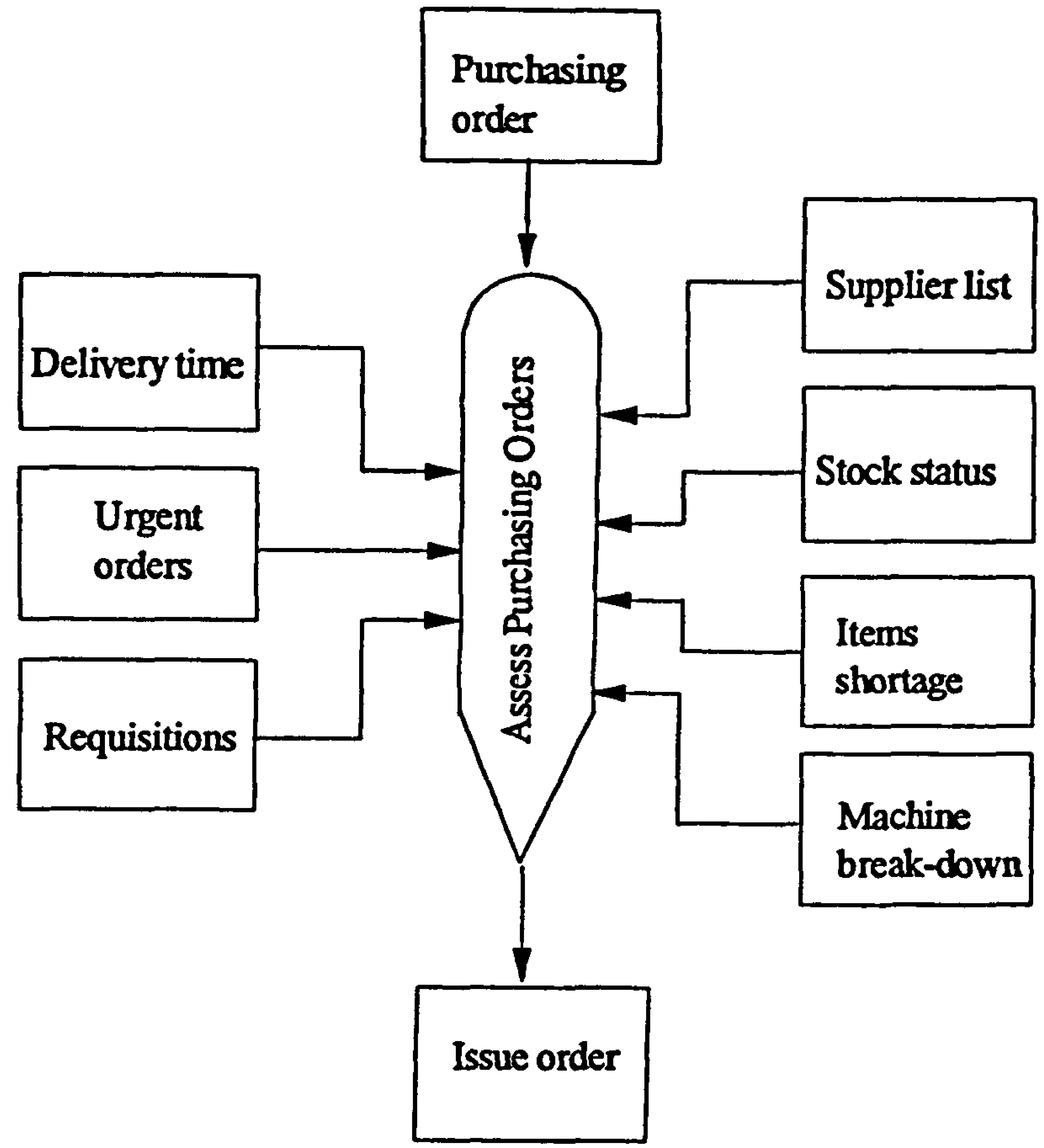
The decision is made in the view of the machine policy and outputs of the various activities performed. The result presents a plan of machine loading for one month. The decision centre reviews the plans every week and modifies it as required.

H = 1 Week   R = Real Time

Function: To Plan

Title: Scheduling and Priorities

The decision frame is related to the priorities and distribution of the work at the shop floor level as shown in Figure 4.11. Four major activities are needed to perform the decision. The first activity examines the current work load and assesses the work in progress. The second activity examines current resources and third assesses the availability of material required. The fourth activity identifies urgent or normal work orders.



FUNCTION	To manage Material (To Buy)
H/R	H = Real Time
TITLE	ISSUE PURCHASING ORDERS

Figure 4.12 GRAI Net for Issue Purchasing Order

After performing these activities the decision is taken to prioritise and distribute the work. The review period for the decision is real time and the decision frame controls the activities at shop floor level. It translates the work orders into priorities and distributes work to machines and operators accordingly. The objectives of the decision are to:

- Maintain valid priorities.
- Evaluate alternatives in the case of emergency or urgent requirements.
- Effectively utilise capacity.

Real Time
Function; To Manage Material (To Buy)
Title: Purchasing Order
The decision frame shown in Figure 4.12 represents the real time evaluation of material requirements. It determines urgent requirements for raw material, machine parts due to break down and any materials shortage.

4.3.2 Results

Five horizons and review periods were identified and examined in detail. The policies implemented indicate an emphasis on short term planning. The maximum horizon for any decision was only one year.

There appears to be a discrepancy between the decisions to issue work orders and the management of resources. Work orders are issued to meet a three month horizon, but the resources are only planned over a one month horizon (Figure 4.2).

No such re-order system for raw material was identified. The reason for this is that purchasing orders are based on requisitions. This means that the purchasing orders are issued at real time.

Production planning is not precise and changes are made at frequent intervals.

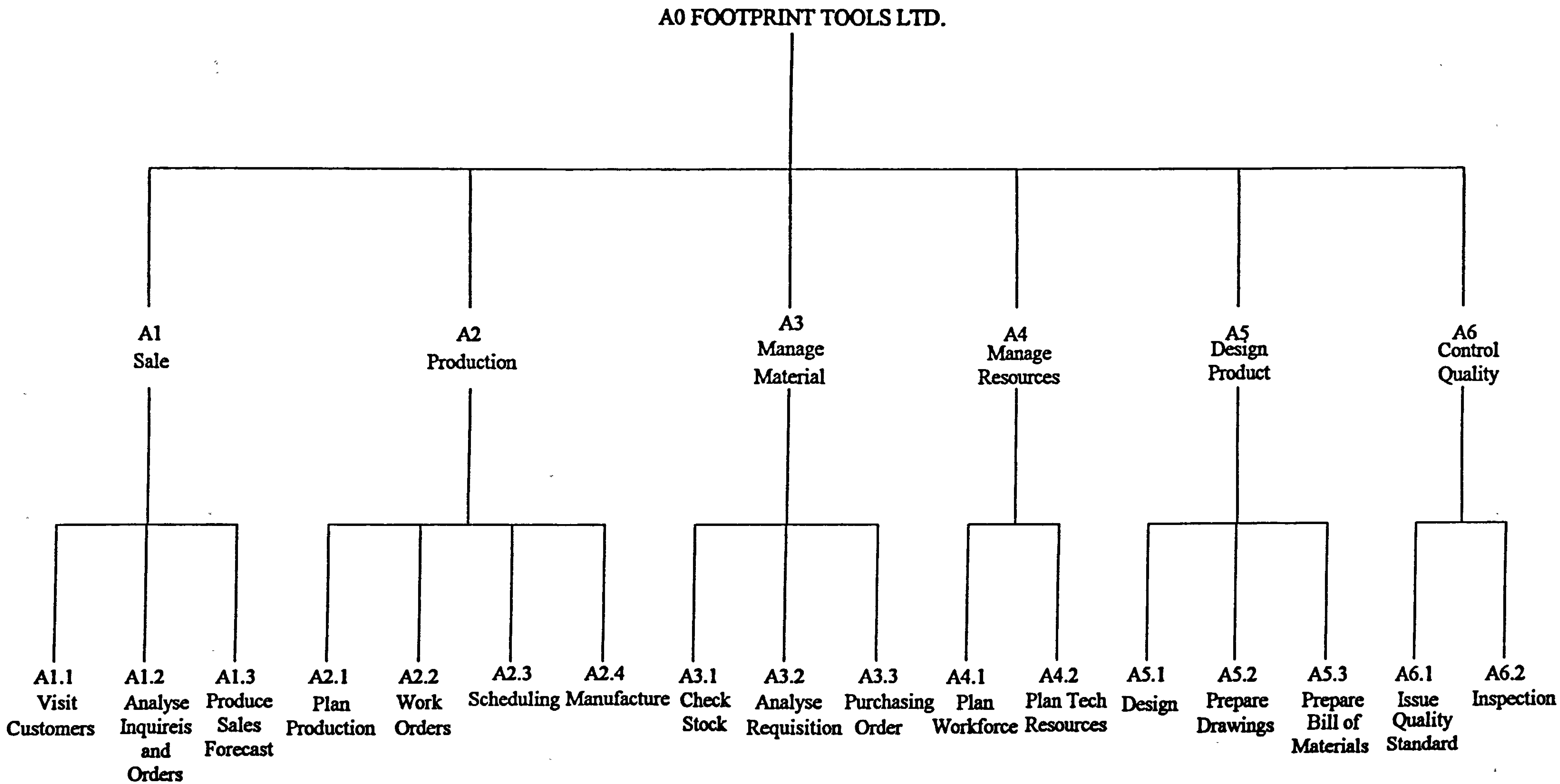


Figure 4.13 Node Tree of Footprint Tools Ltd.

4.4 APPLICATION OF THE IDEF0 METHOD

The IDEF0 modelling method starts from an IDEF0 node tree. The. node tree for Footprint Tools Ltd is shown in Figure 4.13.

The A0 diagram as shown in Figure 4.14 represents the simplified overview of the Company's operations. At this level the input arrows show customer orders, inquiries and the raw material. The control of the function is the stock status because the main operational objective of the Company is 'make-to-stock'. The mechanisms to perform the function are planning and the machine tools. The outputs of this function are quotations which include prices, delivery promises, quality and finished products.

The relationship between functions is shown in Figure 4.15. This is the decomposition of the model to its first level, which represents the overall informational structure of the Company. The subsequent levels comprise the following:

A0 Footprint Tools Ltd.

- A1 Sales
    - A1.1 Visit customers
    - A1.2 Analyse customers' inquiries and orders
    - A1.3 Produce sales forecast
- A2 Production
    - A2.1 Plan production
    - A2.2 Work orders
    - A2.3 Scheduling
    - A2.4 Manufacture
- A3 Manage Material
    - A3.1 Check stock
    - A3.2 Analyse requisition
    - A3.3 Purchasing order
- A4 Manage Resources
    - A4.1 Plan workforce

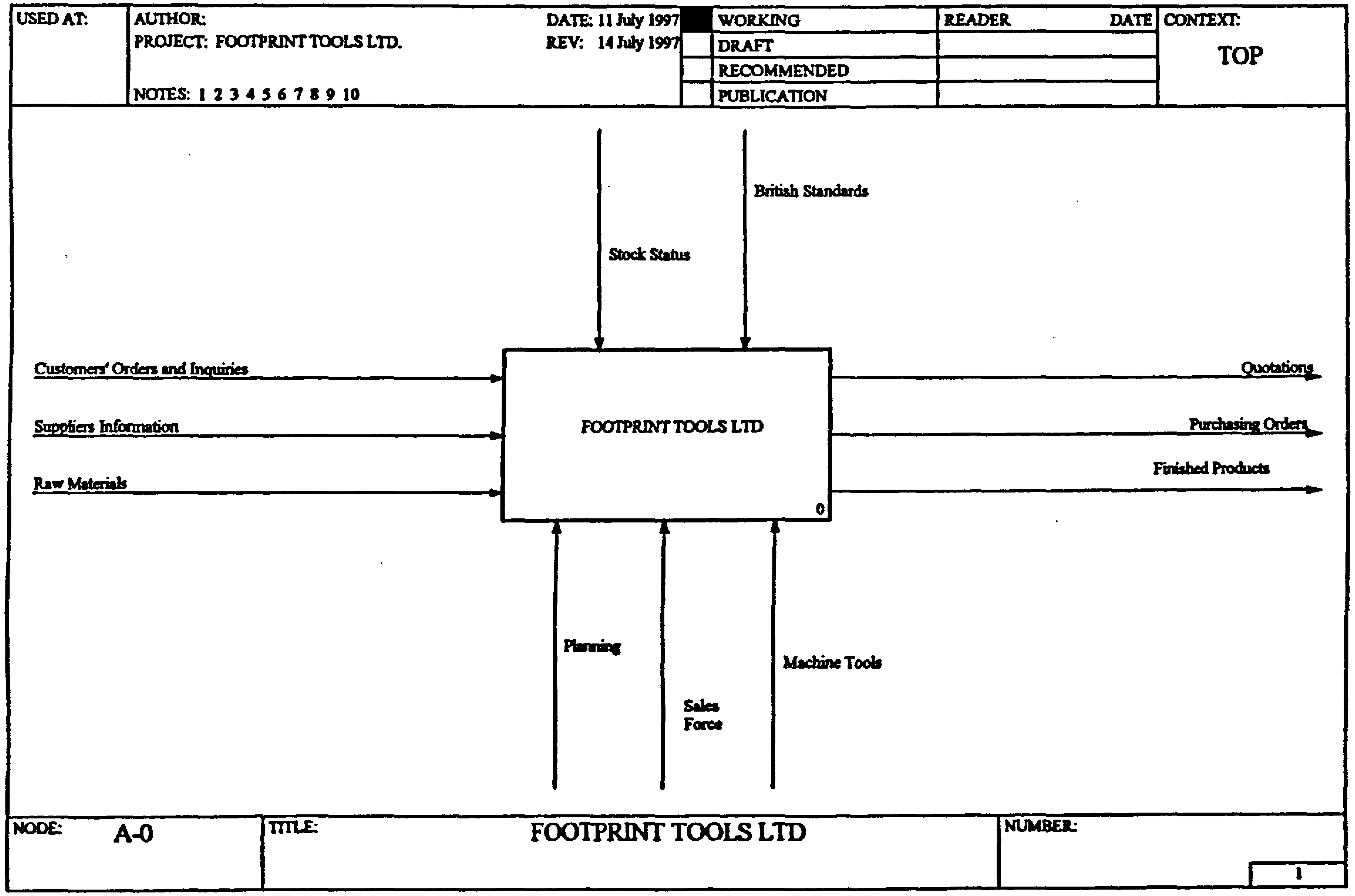


Figure 4.14 An overview of Footprint Tools Ltd.

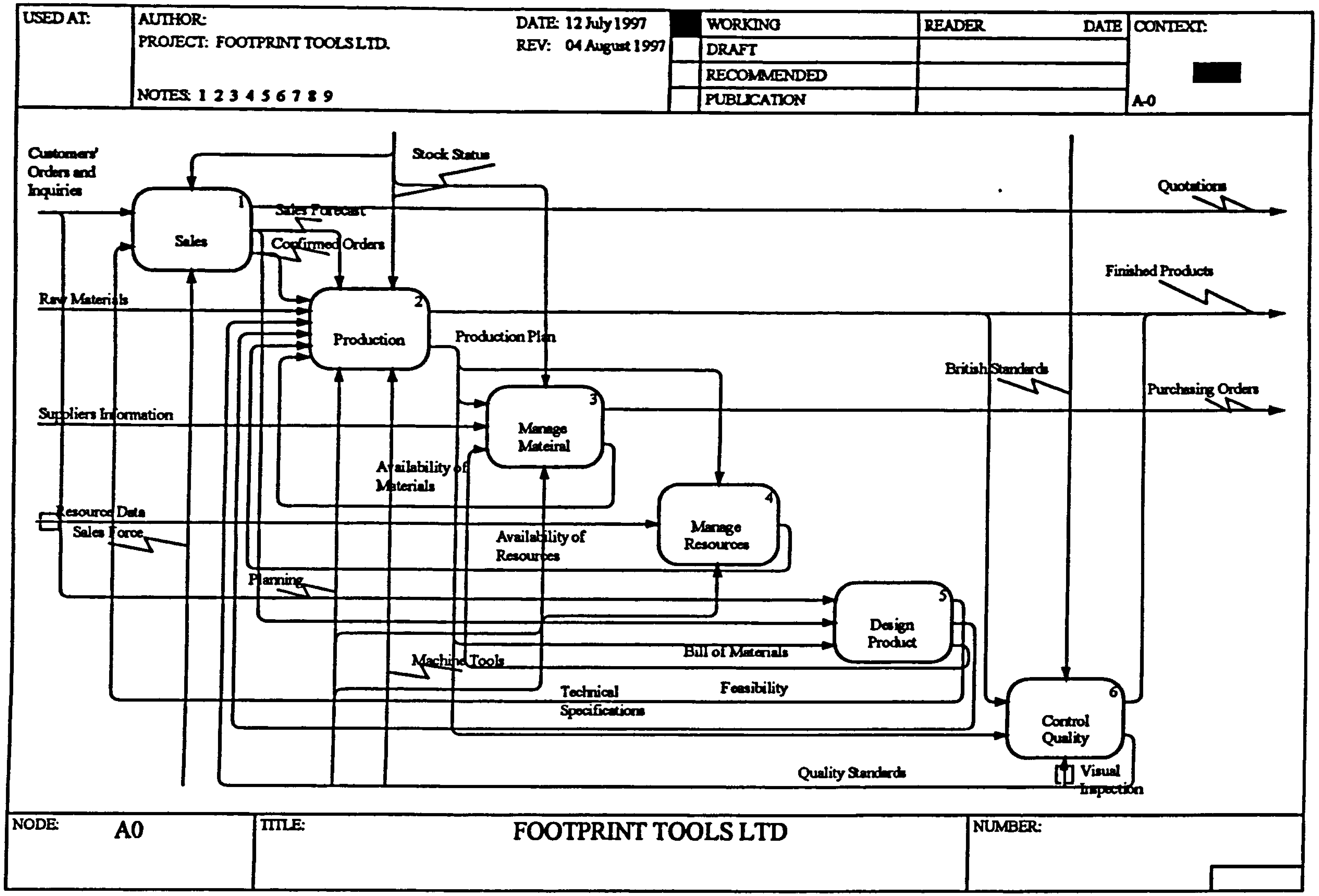


Figure 4.15 Relationships between functions of the Company

    - A4.2 Plan technical resources
- A5 Design Product
    - A5.1 Design
    - A5.2 Prepare drawings
    - A5.3 Prepare bill of materials
- A6 Control quality
    - A6.1 Issue quality standards
    - A6.2 Inspection

A1 SALES

The activities of the Company start from customer orders or inquiries, which the sales function manages. This function is controlled by the stock status, because the operational objective of the company is 'make-to-stock'. The sales function first checks finished product status. If the required product(s) are available in stock, they are delivered to the customer. A further activity of the function is to assess the status of orders and customer inquiries. If they are for special products, details are sent to the design function to assess feasibility and estimate costs. The major outputs of the function are the quotations and sales forecasts. The sales forecast is made after considering confirmed customer orders, the stock status and future requirements.

A2 PRODUCTION

The second function at this level is Production. The function is controlled by the sales forecast and stock status. The main purposes of the function are to establish the production plans and convert raw material into finished products. The production plan is made after considering the confirmed orders, sales forecast, the stock status of finished products and information regarding quality standards from the quality function. The production plan is sent to the Manage Material, Manage Resources and Design functions. The second output of the function is finished products, which are sent to the quality control function for final inspection.

A3 MANAGE MATERIAL

The third function at this level is to Manage Material. It is controlled by the stock status of raw materials. The inputs of the function are the production plan, the bill of materials. The function first checks the status of the material and the production department is informed accordingly, after which a purchase order is raised. Details of the material and prices are obtained from different suppliers. The major output of the function is the purchase orders.

A4 MANAGE RESOURCES

The fourth function is Manage Resources. This is controlled by the production plan. The inputs of the function are information of workforce and machines. The output of the function is an estimate of the resources available, details of which are sent to the production function.

A5 DESIGN PRODUCT

The main purposes of the function are to design products, to prepare drawings, prepare the bills of materials and establish the manufacturing processes. The control of the function is the production plan. The input of the function is the sales forecast. The output is confirmation of feasibility, which is sent to the sales department. Technical specifications and drawings are sent to the production department and the bill of materials is sent to the purchasing department.

A6 CONTROL QUALITY

The last function of the A0 level is quality control. This is controlled by relevant British standards. The major output of the function is the confirmation of quality standards which are sent to the production department.

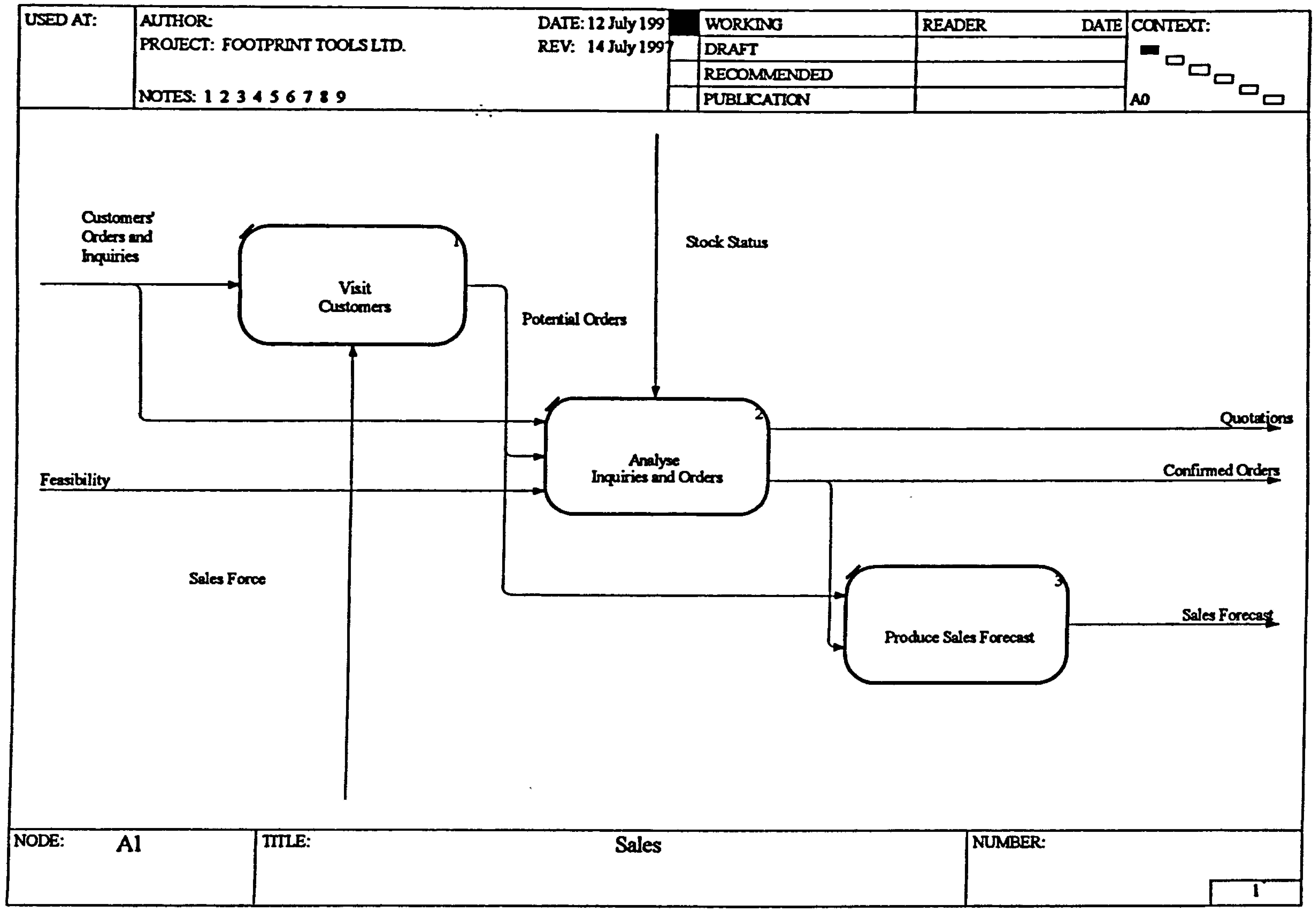


Figure 4.16 Decomposition of the sales function

Decomposition of A1 Sales Function

The level as shown in Figure 4.16 is further decomposed into three sub-functions:

- A1.1 Visit Customers
- A1.2 Analyse Inquiries and Orders
- A1.3 Produce Sales Forecast

A1.1 Visit Customers

The purpose of this function is to provide information to customers concerning the product qualities and prices. The mechanism to perform this activity is the sales force. The outputs of the function are potential orders. The orders are sent directly to the Order Analysis function for further consideration.

A1.2 Analyse Inquiries and Orders

This function analyses the customers' inquiries and orders. The inputs of the function are customers' inquiries, orders and potential orders. Outputs of this function are quotations which are sent to the customer and confirmed orders that are sent to the production department.

A1.3 Produce Sales Forecast

This function collects detail of potential orders, trends in the market and confirmed orders. A sales forecast is produced using this information.

Decomposition of A2 Production Function

The production function shown in Figure 4.17 is further decomposed into four sub-functions:

- A2.1 Production Plan
- A2.2 Work Order
- A2.3 Scheduling
- A2.4 Manufacture

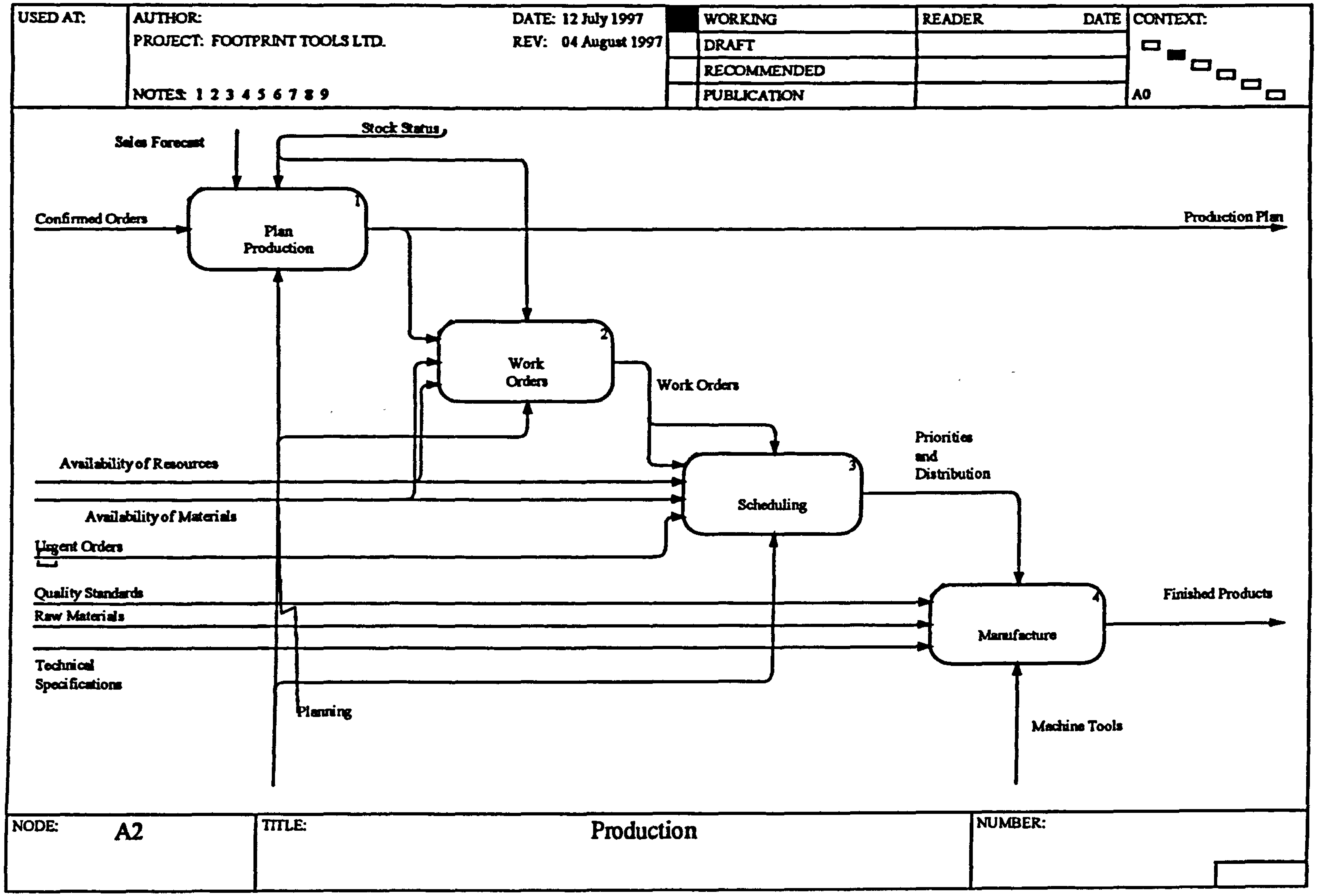


Figure 4.17 Decomposition of the production function

A2.1 Production Plan

The production plan is controlled by the sales forecast and the stock status of finished products. The input of the function is the confirmed orders. The production plan expresses the overall plan in terms of specific end products together with their technical specification and promised delivery date. In reality the production plan of the Company exist only at a very low level, mostly only on a weekly basis.

A2.2 Work Orders

The work orders represent the short term planning of production. The inputs to this function are the production plan and the availability of material, workforce and machines. The main objective of the function is to assess all the information then issue the work order accordingly. It is controlled by the stock status of finished products and the mechanism to perform the function is manual as no computer system is available.

A2.3 Scheduling

The main purpose of this sub-function is to distribute work according to the instructions. This shop floor activity checks all the information concerned with manufacturing such as the availability of workforce, machines, raw material, delivery dates and the production lead time. The work orders are converted into priorities and distributed to operators and machines accordingly.

A2.4 Manufacture

The function represents the physical activities of the Company, where the raw material is converted into finished products. It is controlled by production priorities. The input of the function is the raw material that supplied with technical drawings and manufacturing processes. The mechanism to perform the function is different types of machines such as turning and milling. The inputs are raw materials and the output is finished products, which are then sent to the quality control function for final inspection.

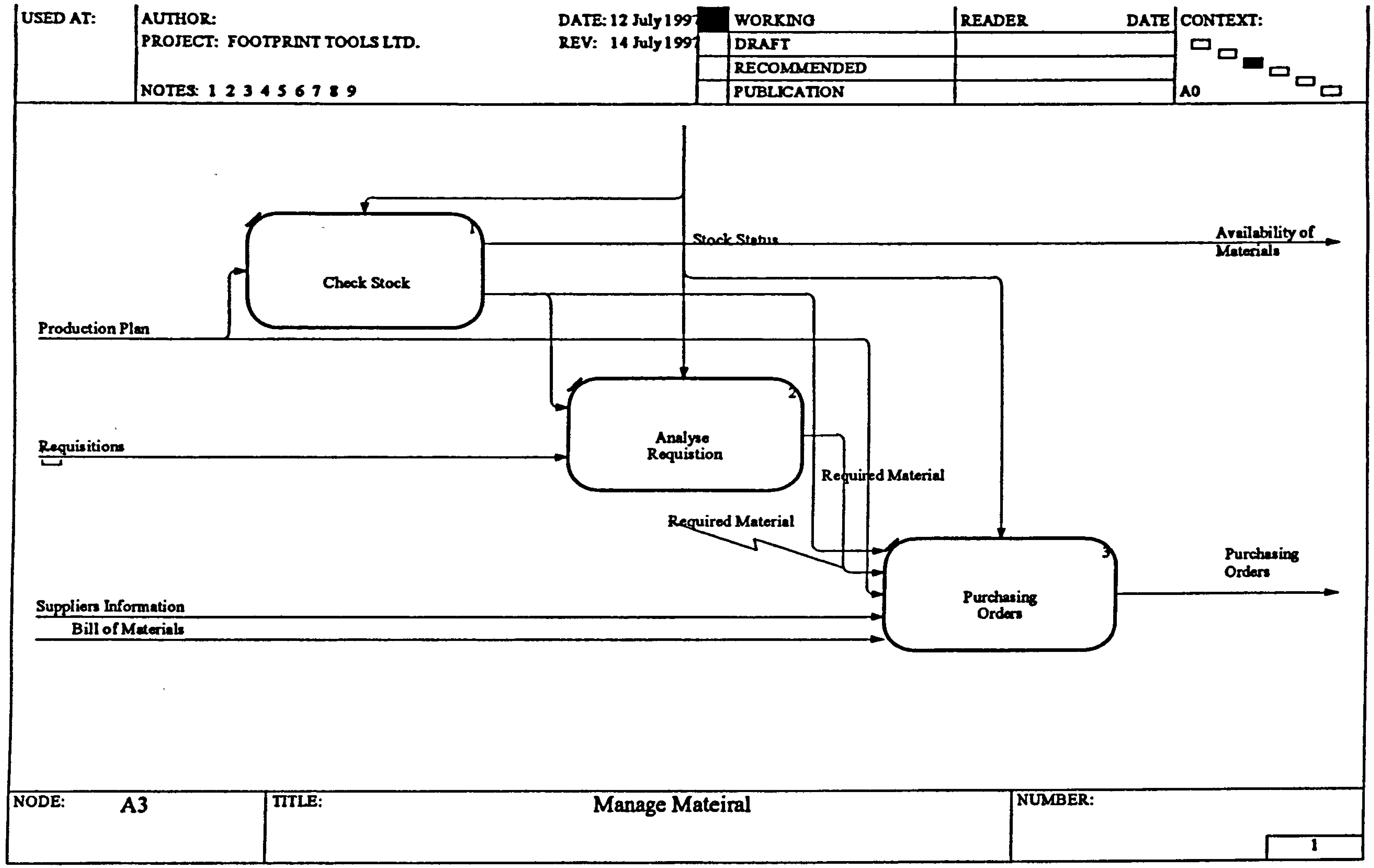


Figure 4.18 Decomposition of the manage material function

Decomposition of A3 Manage Material Function

The main objective of the function is to control all the purchasing activities within the Company. It is controlled by the stock status of the raw material. The function as shown in Figure 4.18 is further decomposed into three sub-functions:

- A3.1 Check Stock
- A3.2 Analyse Requisitions
- A3.3 Purchasing orders

A3.1 Check Stock

The input of the function is the production plan. The function first assesses the production plan and confirms the stock status. If the material is available the production department is informed, otherwise information is sent to the function that analyses requisitions. It is controlled by the stock status of the raw material.

A3.2 Analyse Requisitions

This function analyses the requisitions submitted from different sections of the Company. After analysis, the function issues orders for the required quantity of material to the purchase order function.

A3.3 Purchase orders

The main purpose of this function is to issue the purchase orders to the suppliers. The function first checks the requested quantity and other relevant information, then issues the purchasing orders to different suppliers.

Decomposition of A4 Manage Resources Function

The function as shown in Figure 4.19 is further decomposed into two sub-functions:

- A4.1 Plan Workforce
- A4.2 Plan Technical Resources

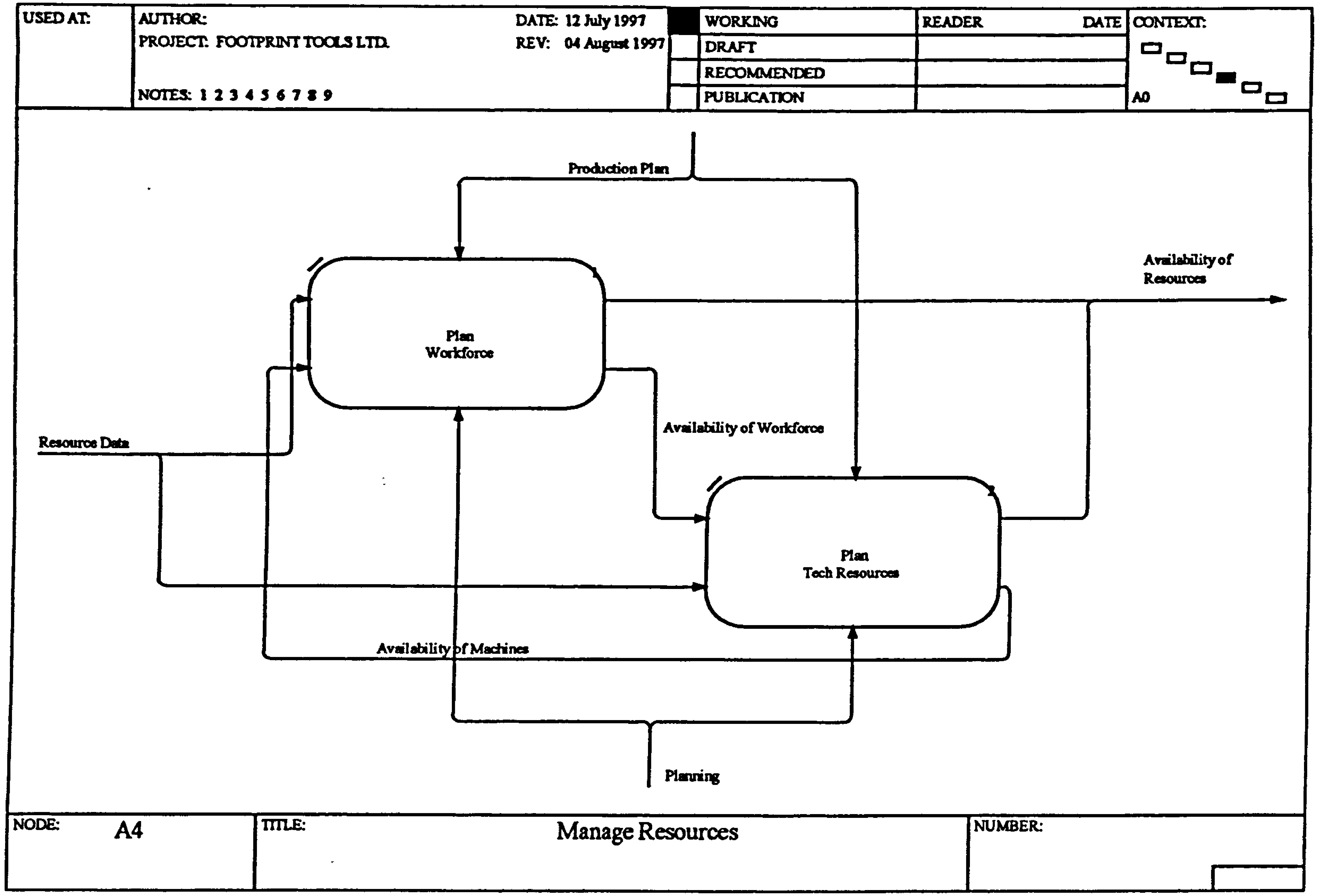


Figure 4.19 Decomposition of the manage resources function

Although it is recommended that an IDEF0 function block should be broken down into between three and six sub-function blocks, no further details were available at the Company to fulfil this rule.

A4.1 Plan Workforce

The objective of the function is to arrange the workforce according to the instructions provided by the production plan. The input of the function is workforce data and it is controlled by the production plan. The output of the function is the availability of the workforce. This information is fed-back to the production department, where the production plan can be revised if necessary.

A4.2 Technical Resources

The technical function provides information concerning the availability and condition of machines. The input of the function is machine data and it is controlled by the production plan. This information is sent to the production function.

Decomposition of A5 Design Function

The function as shown in Figure 4.20 can be further decomposed into three sub-functions:

- A5.1 Design
- A5.2 Prepare Drawings
- A5.3 Issue Bill of Material

A5.1 Design

This function is not very active because the Company manufactures traditional hand tools which do not vary greatly. The design function is only active when customer inquires relate to special products. The design activities originate from the inquiry where the manufacturing feasibility is assessed and a production cost evaluated.

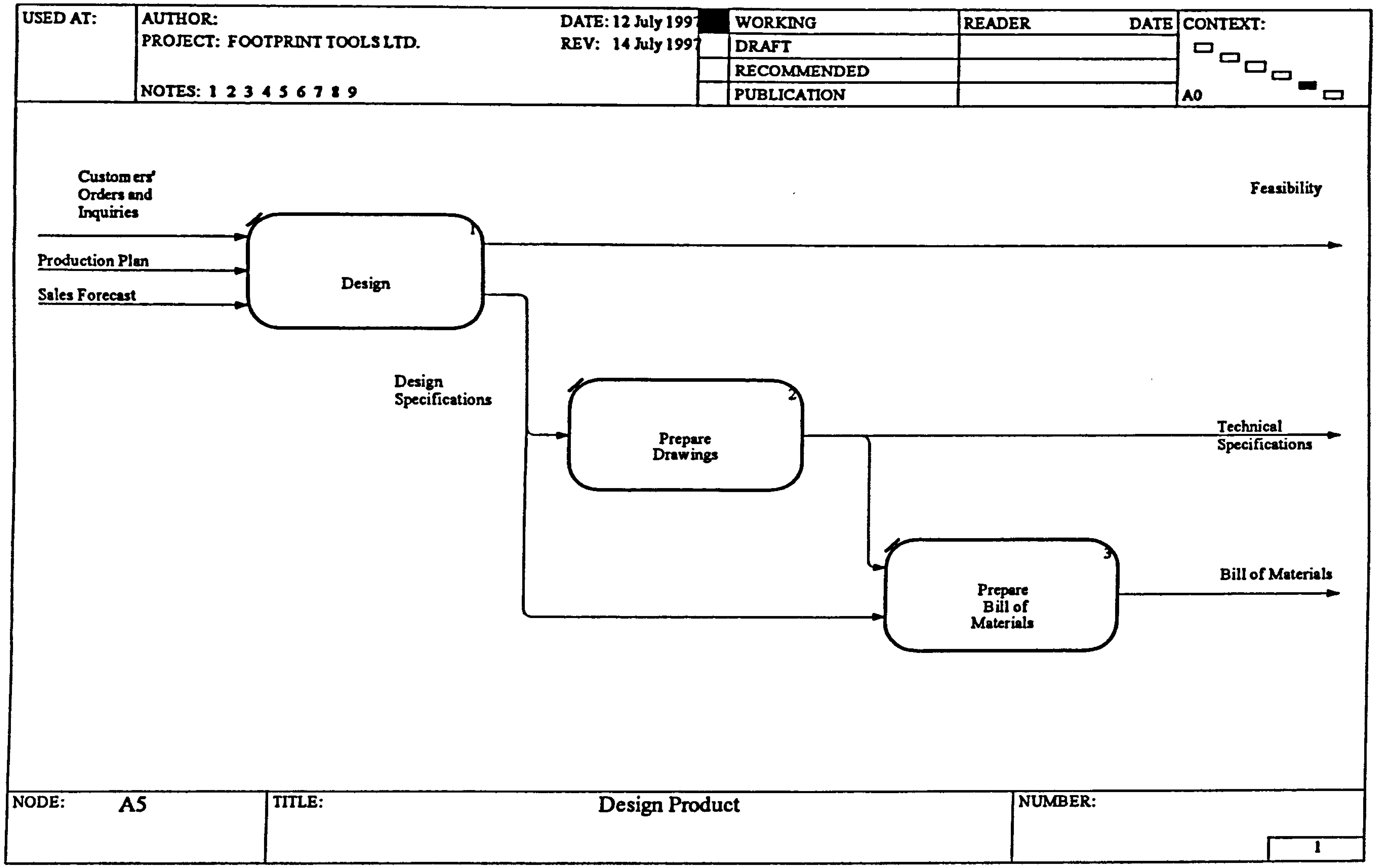


Figure 4.20 Decomposition of the product design function

A5.2 Prepare Drawings

The activity of preparing drawing starts after receiving the design specification from the design function. The mechanism of performing the activity is manual as no CAD system is available. The output of the function consists of technical drawings and the manufacturing route.

A5.3 Issue Bill of Materials

The main purpose of this activity is to issue the bill of materials to the purchasing and production departments. The inputs of the activity are the design and technical specifications.

Decomposition of A6 Control Quality Function

The function as shown in Figure 4.21 can be further decomposed into two sub-functions:

- A6.1 Issue Quality Standards
- A6.2 Inspection

Although it is recommended that an IDEF0 function block should be broken down into between three and six sub function blocks no further details were available to fulfil this rule. The company practises BS5750 but only product quality has been considered here.

A6.1 Issue Quality Standards

This function issues the quality standards for the products. The input of the function is the production plan and the control is the relevant British or international standards. The output is the operational quality standards which are sent to the material and production departments.

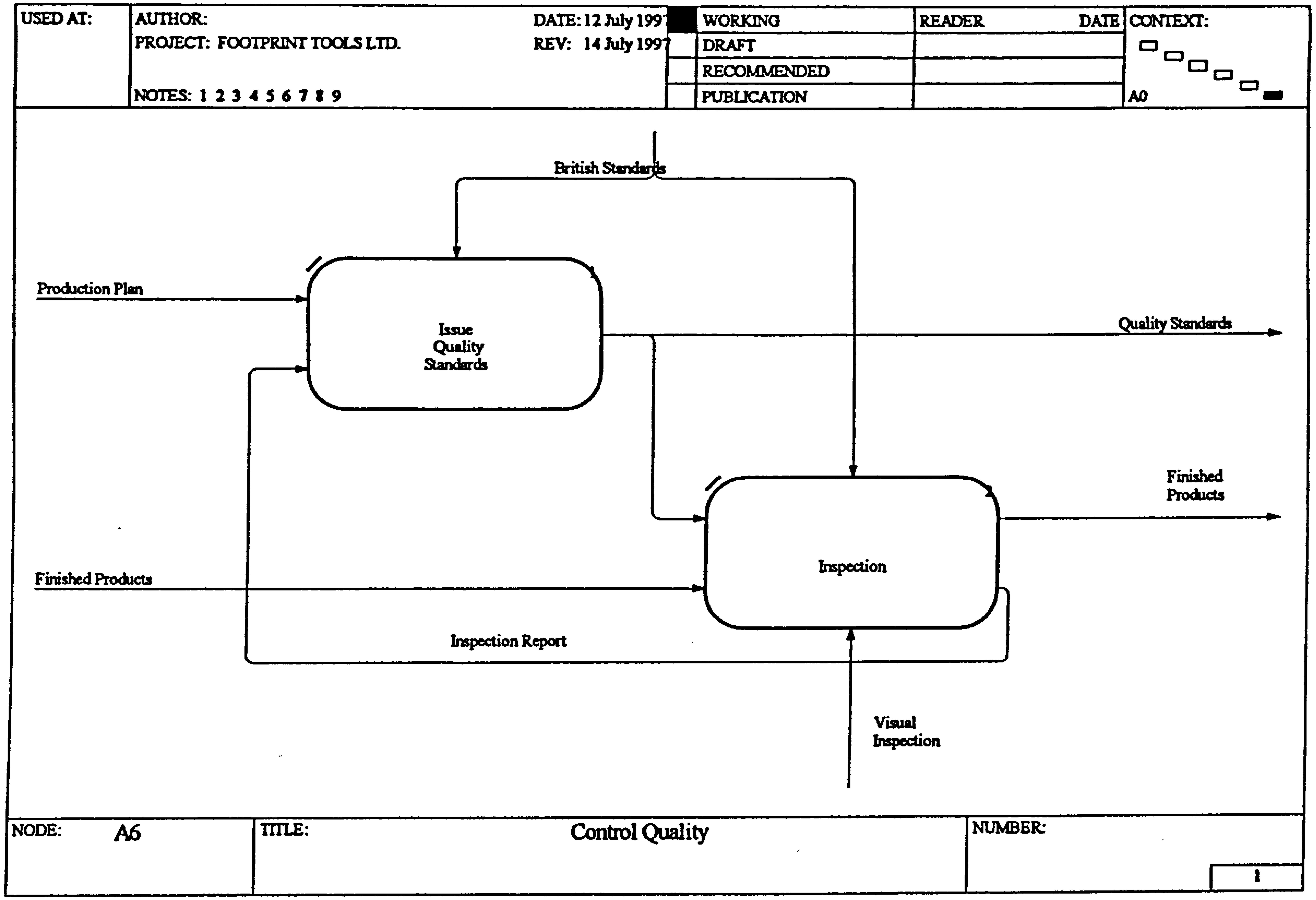


Figure 4.21 Decomposition of the quality function

A6.2 Inspection

The inspection function follows the quality instruction. The main purpose of this function is to confirm that the finished products meet the required quality standards. The method of inspection is visual and manual using inspection tools.

4.5 A COMPARISON OF THE GRAI AND IDEF0 MODELLING METHODS

Two fundamental differences can be seen between the GRAI and IDEF0 methods. Firstly the GRAI method focuses on the identification and analysis of decision centres and information. In contrast, IDEF0 focuses on activities and the relationship between activities in terms of information. Secondly a time scale of planning horizons and review periods is a fundamental dimension of the GRAI grid, but IDEF0 cannot represent a time scale at any level.

The GRAI net identifies decisions from the GRAI grid and plots the information and resources required to execute the decision. In contrast IDEF0 represents the activity, information and material flow involved in a process, but the method does not focus on the decisional structure of the system.

The main drawback of IDEF0 is that the user may not see a particular process as part of a large system. In IDEF0 models it is difficult to understand where information is coming from and going to. For this reason, the reader cannot see the whole model in one view. Conversely a GRAI grid presents the whole system in a single view (Figure 4.2), enabling the reader to see where information and decisions are coming from and going to.

In the IDEF0 model it can be seen that the similar symbols are used to show information and material flow (see Figure 4.14). The GRAI grid can distinguish between decisional and informational flow because different styles of arrow are employed.

Both the GRAI and IDEF0 methods have a validation phase. GRAI models are validated by the synthesis group. In contrast, the IDEF0 validation phase is known as the author/reader cycle. Several iterations take place before the final model can be approved.

The IDEF0 method lacks the ability to relate an interface item with its originating activity directly and lacks clarity in defining hierarchical and interface relationships. Such a hierarchy of functions does not accurately represent the conditions and sequence of processing. Consequently, great manual effort and interpretation may be required to identify the function which should process a specific input and verify its consistency. In contrast the GRAI diagrams contain different information which makes them easier to interpret. The decomposition of the GRAI models consists of two layers (GRAI grid and nets) which makes them easier to understand.

IDEF0 only concentrates on the informational and material flow but the GRAI method concentrates on most aspects of manufacturing systems, because it represents the manufacturing functions and control hierarchy with horizons and review periods, decisional and informational flow. The GRAI nets provide the detail of individual decision centres and shows how decisions are made at different time scales.

IDEF0 is a rigid method and has certain rules which every user should follow. For example the decomposition of functions should be broken down to between three and six sub-functions. Another rule is that when a box is expanded into a lower level diagram, that diagram must have the same inputs, controls and mechanism as the parent diagram (Harrington, 1984). Due to this rule it is difficult to add new inputs to lower levels. For example the input of analysis requisition function is the requisition. This is the new input which cannot be shown in the parent diagram (see Figure 4.18). There is no such restriction for adding support activities to model decisions using a GRAI net.

4.6 CONCLUSIONS

The GRAI and IDEF0 modelling methods were applied to analyse the existing manufacturing management system at Footprint Tools Ltd. Several modelling techniques exist, but the GRAI and IDEF0 methods have been chosen as both methods support the manufacturing environment, better than the other methods evaluated in Chapter 3.

As a result of this application, several inconsistencies within the system have been identified. It is evident that elements of production management exist, but not in a structure that promotes co-ordination and coherence.

The main reason for this application was to provide a comparison of the GRAI and IDEF0 modelling methods in a real life situation. The IDEF0 method only concentrates on the flow of information and material and lacks a clear visual distinction between the two when looking at the charts. Goldman and Cullinane (1987) suggest that limited application of the method relates to the lack of decision rules for model decomposition and a lack of explicit links between information flow. IDEF0 does not support the decision making system. Roboam et al (1989) carried out a survey of manufacturing design techniques. They conclude that it is not possible to use IDEF0 for the analysis and design of both physical and decisional systems. Similarly, Baines and Colquhoun (1991) confirm that the IDEF0 technique is not suitable to develop decision making models of manufacturing systems. Godwin et al (1989) evaluated IDEF0 and concluded that the method was inaccurate as a system description. IDEF0 provides a structure of controlling and documenting the model and could be used to model any information system. The method does not demonstrate how to conduct the interviews to analyse the existing system and is not flexible in its application. Similarly, the quality of the model depends to a large extent on the skill of the designer. These shortcomings make IDEF0 inadequate for the consistent analysis and design of manufacturing systems.

The GRAI method is more capable of analysing and designing manufacturing management systems and is easy to use. It provides a flexible methodology that covers all aspects of manufacturing environment, such as information and material flow, decision making and most importantly, the time scale.

BPwin a software package was used to draw the IDEF0 model. This package has been developed specifically to draw IDEF0 model.

At the time of this study software is not wildly available to support the drawing and analysis of GRAI models. A software package CAGS (Computer Aided GRAI System) was developed by Wainwright et al (1995) to produce GRAI grids. References to the work state that it is in an embryonic state and undergoing testing in several companies. More detailed information is not available in the public domain. Therefore two other graphics packages, Freelance (1993) and Visio (1992) were used. This was not an ideal solution, as the GRAI grid and GRAI nets were time consuming to construct.

The application and comparison of the GRAI and IDEF0 modelling methods demonstrated that the GRAI method is the most suitable method to analyse and design manufacturing systems. The GRAI method has been selected to develop a generic model for the 'make-to-stock' manufacturing environment. Although deficiencies exit in the method, particularly relating to conducting the interviews necessary to obtain and interpret the data and produce consistent models. The methodology therefore needs to be developed further. One of the objectives of this research is to resolves inconsistencies in the GRAI method and guide the user, step by step to produce consistent models.

CHAPTER-5
COMPARISONS OF THE GRAI MODELS

5.1 INTRODUCTION

Having accepted the benefits of the GRAI method as described in the Chapter 4, it has been applied in case studies for further research. This chapter presents these case studies. In addition to Footprint Tools Ltd. two further manufacturing organisations have been selected for the study. All the companies selected are situated in Sheffield and are classified as 'make-to-stock' companies. The GRAI method is applied to their existing manufacturing management system. The objectives of this study are:

- To apply the GRAI method
- To develop a GRAI grid of each company
- To develop GRAI nets of each company
- To analyse the GRAI grids and GRAI nets constructed
- To identify inconsistencies within the manufacturing management system of each company
- To carry out a comparison of the GRAI models constructed for each company

The purpose of the comparison of the GRAI models developed, is to find the similarities between the different 'make-to-stock' manufacturing organisations with reference to their organisation, functions, activities and decision making. This comparison is necessary because this research is based on the hypothesis that each type of manufacturing company should have a generic model.

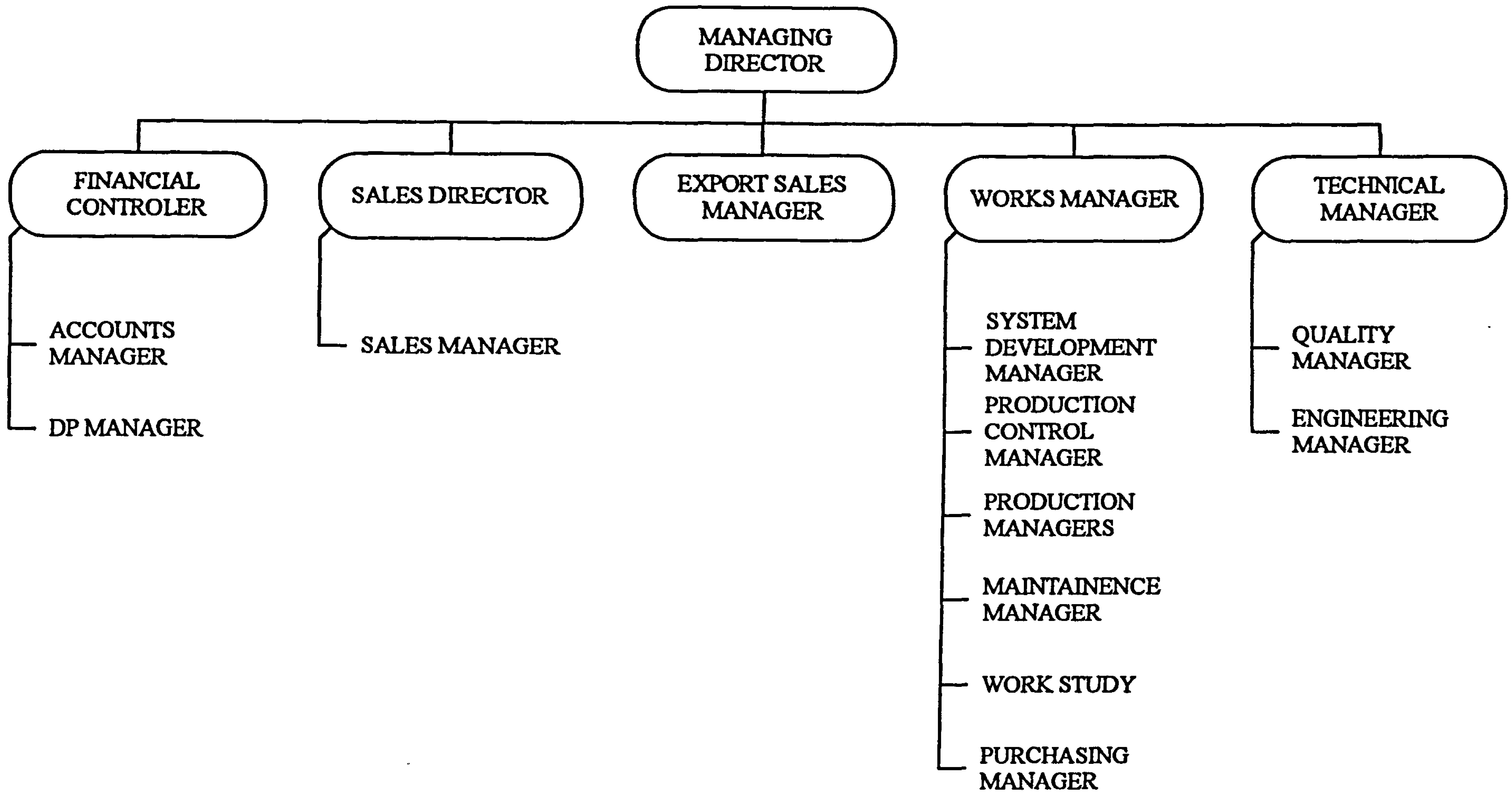


FIGURE 5.1 ORGANISATION STRUCTURE OF THE COMPANY

5.2 APPLICATIONS OF THE GRAI METHOD

The GRAI method was applied to different 'make-to-stock' manufacturing organisations. These applications are presented in the form of case studies as detailed below:

- Case Study-1: Footprint Tools Ltd.
- Case Study-2: Presto Engineers Cutting Tools
- Case Study-3: Paramo Hand Tools

5.2.1 Case Study-1: Footprint Tools Ltd.

For details please see Chapter 4.

5.2.2 Case Study-2: Presto Engineers Cutting Tools

5.2.2.1 Introduction to the Company

Presto Engineers Cutting Tools is a production to order and to stock replenishment company that manufactures high quality cutting tools. It has more than 400 employees. Export sales form 30% of the total production and are distributed to over 90 countries.

i) Products

The Company manufactures 24000 stock lines which comprise, high speed steel twist drills, reamers, tool bits, milling cutters, solid carbide twist drills and milling cutters, carbon steel taps and dies and a range of pipe threading tools and associated threading equipment.

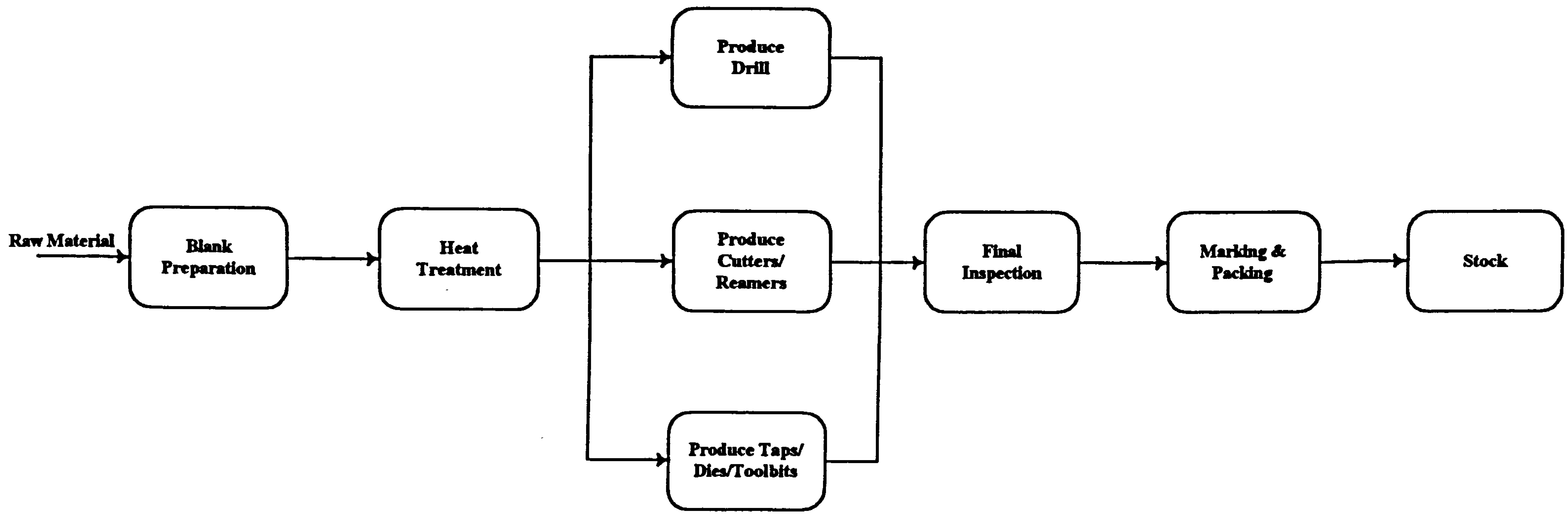


FIGURE 5.2 PRODUCTION PROCESSES

ii) Management Structure

The company being considered is structured in four distinct departments which are co-ordinated by the Managing Director of the company. The departments of the company are:

- Finance and administration
- Sales (marketing and export)
- Production
- Technical control

Each department is split into several sub departments or sections that are co-ordinated by departmental heads. The organisation structure of the company is shown in Figure 5.1.

iii) Production Process

Figure 5.2 shows the general production process used in the Company. Nine different sections are directly involved in overall production.

5.2.2.2 Analysis Phase

The analysis phase of the study comprises two phases, construction of a GRAI grid and construction of GRAI nets, and involves interviews with a synthesis group.

a) Identification of the synthesis group

Following members of a synthesis group were selected for the interviews:

- Sales Director
- Works Manager
- System Development
- Production Control Manager
- Production Manager (Blank Preparation)
- Production Manager (Heat Treatment)
- Production Manager (Drill)
- Production Manager (Cutter/Reamers)

FIGURE 5.3 GRAI GRID OF THE COMPANY

- Production Manager (Taps/Dies)
- Purchasing Manager
- Technical Director
- Quality Manager

b) Construction of the GRAI Grid

In the first round of interviews with the synthesis group the overall manufacturing management system was examined. This involved determining the activities performed and decisions made and gathering information concerning to the functions, horizons and review periods. The GRAI grid of the existing manufacturing management system of the company was constructed as shown in Figure 5.3.

c) Identification of management functions

Following management functions were identified:

- To Sell
- To Manage Material
    - To Buy
    - To Deliver
- To Design
- To Plan Production
- To Manufacture
- To Manage Resources
    - Technical
    - Human
- To Control Quality

d) Identification of decision horizons and review periods

Following horizons and review periods of the decision centres were identified:

- Horizon = 1 Year, Review Period = 6 Months
- Horizon = 1 Year, Review Period = 1 Month
- Horizon =? Review Period = 1 Week
- Horizon = 1 Month, Review Period = 1 Day

- Horizon = 1 Week, Review Period = 1 Day
- Horizon = 1 Day, Review Period = Real Time

Horizon = 1 Year, Review Period = 6 Months

This horizon represents the strategic level of the company. Only one decision centre was identified. This decision centre produces the sales forecast. The sales forecast is made after reviewing the average sales figures over the last three years. The sales forecast is reviewed every month.

Horizon = 1 Year, Review Period = 1 Month

This horizon is also represented in the strategic level of the company. Only one decision centre was identified. This decision centre produces a production forecast which is made after reviewing the market requirement. This forecast is reviewed every month.

Horizon =?, Review Period = 1 Week

The MRP system is reviewed weekly, no horizon was identified.

Horizon = 1 Month, Review Period = 1 Day

This represents the tactical level of the company. Three decision centres were identified. These decision centres relate to the decisions concerning the issue of purchasing orders, the production plan and establishing quality standards.

Horizon = 1 Week, Review Period = 1 Day

This horizon represents the operational level of the company. It is involved with producing the production plans including the workforce and machine loading plan. These decisions are made after reviewing the production plan. The CAD/CAM system provides the manufacturing process routes for the products. The review period of the decisions is one day.

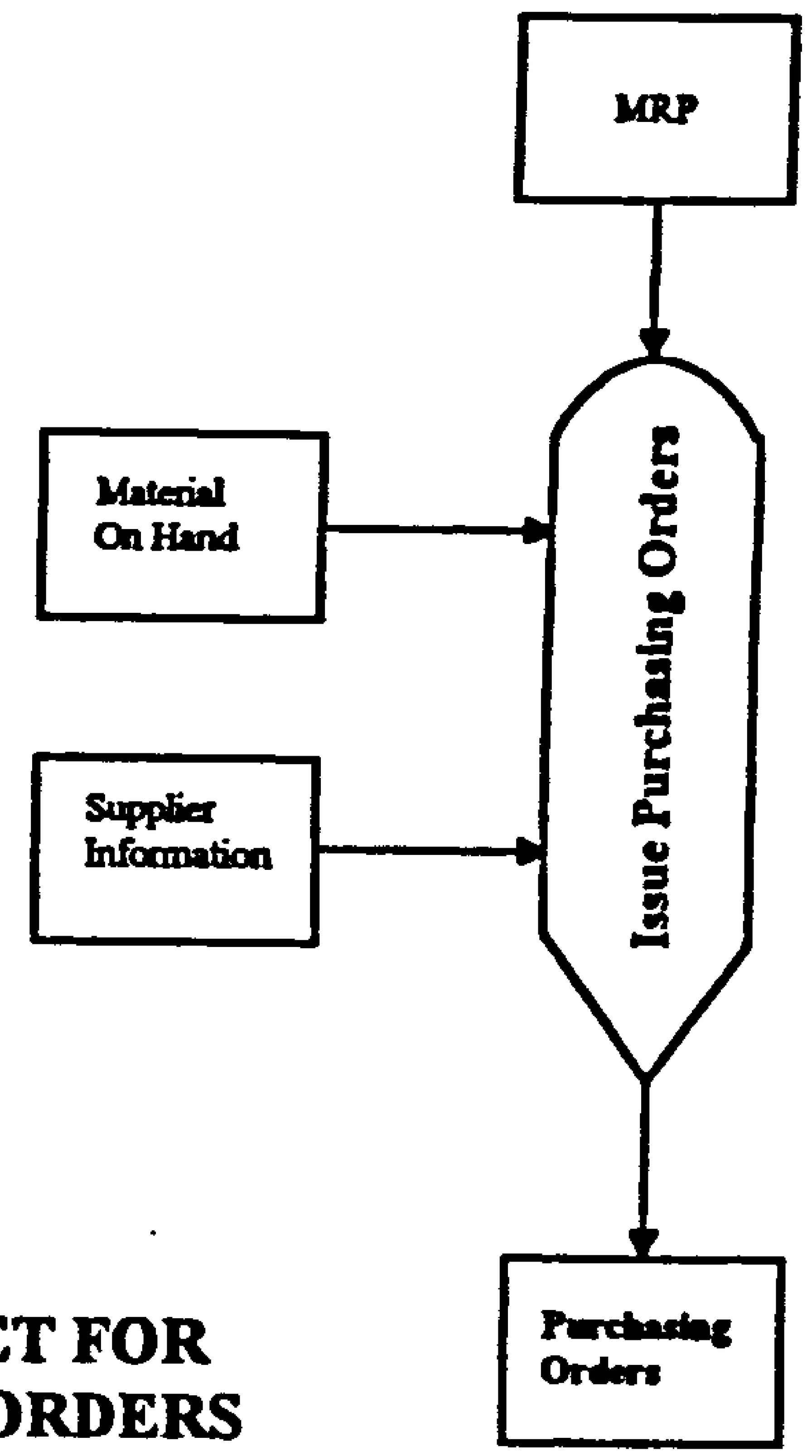


FIGURE 5.4 GRAI NET FOR THE PURCHASING ORDERS

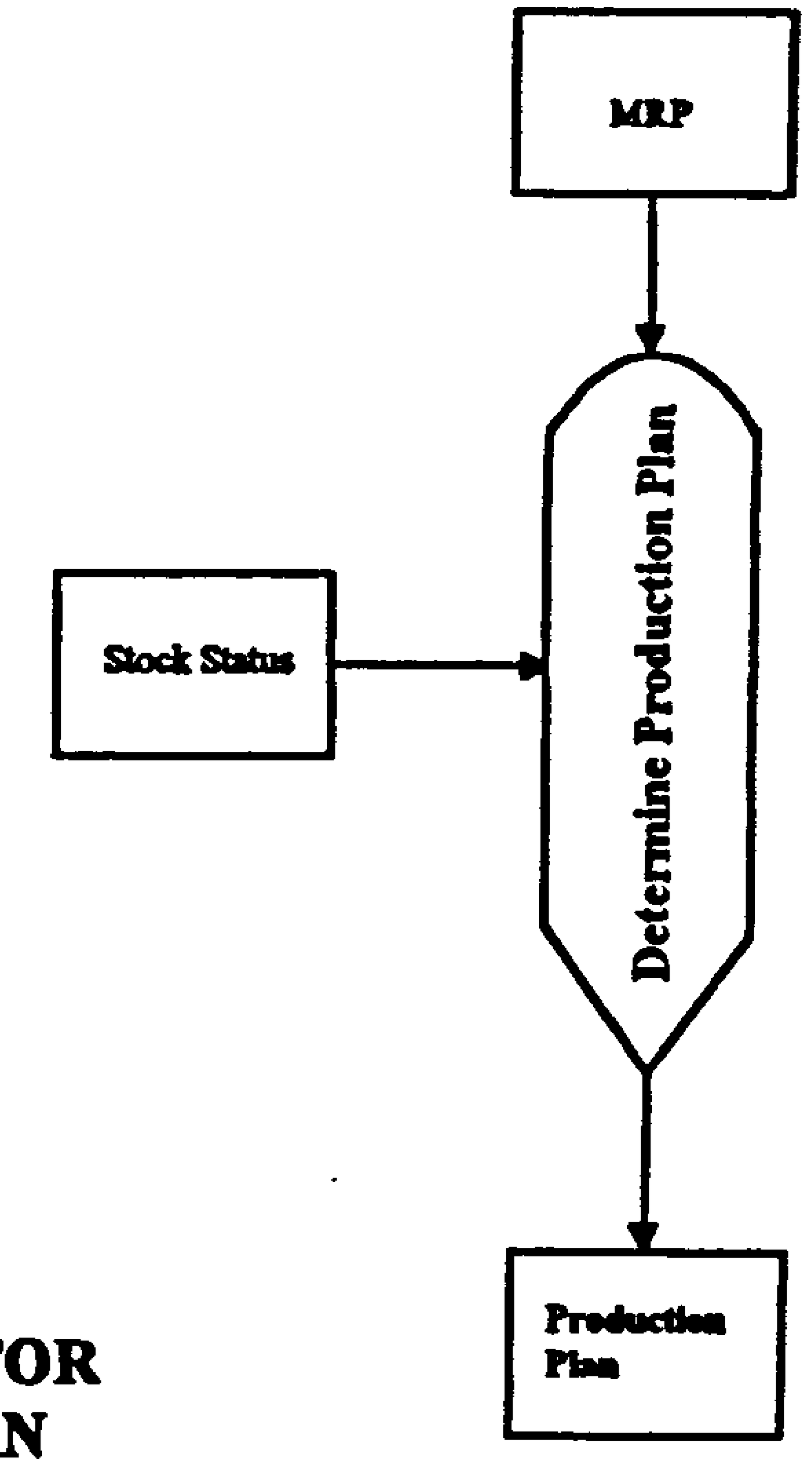


FIGURE 5.5 GRAI NET FOR THE PRODUCTION PLAN

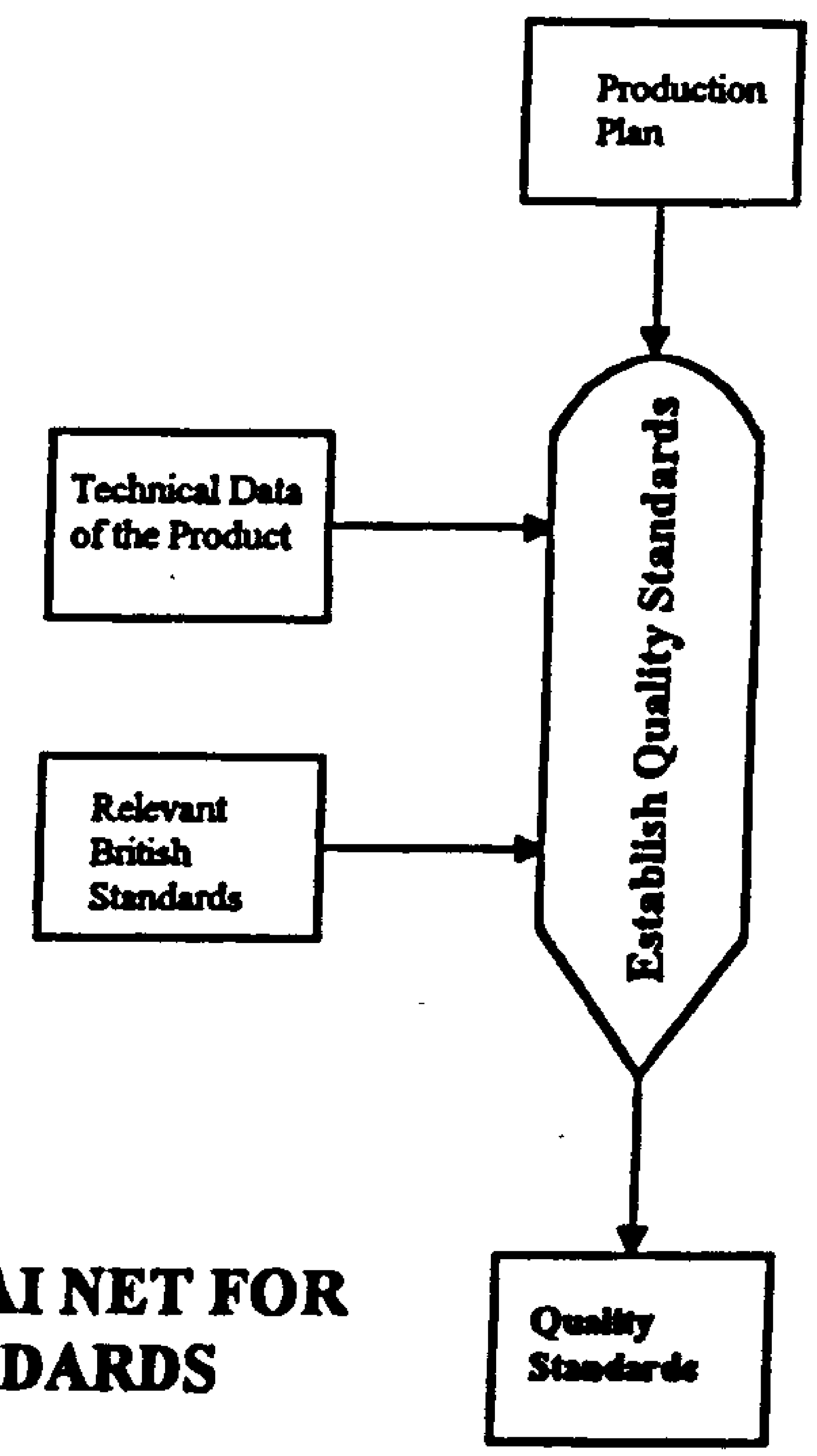


FIGURE 5.6 GRAI NET FOR QUALITY STANDARDS

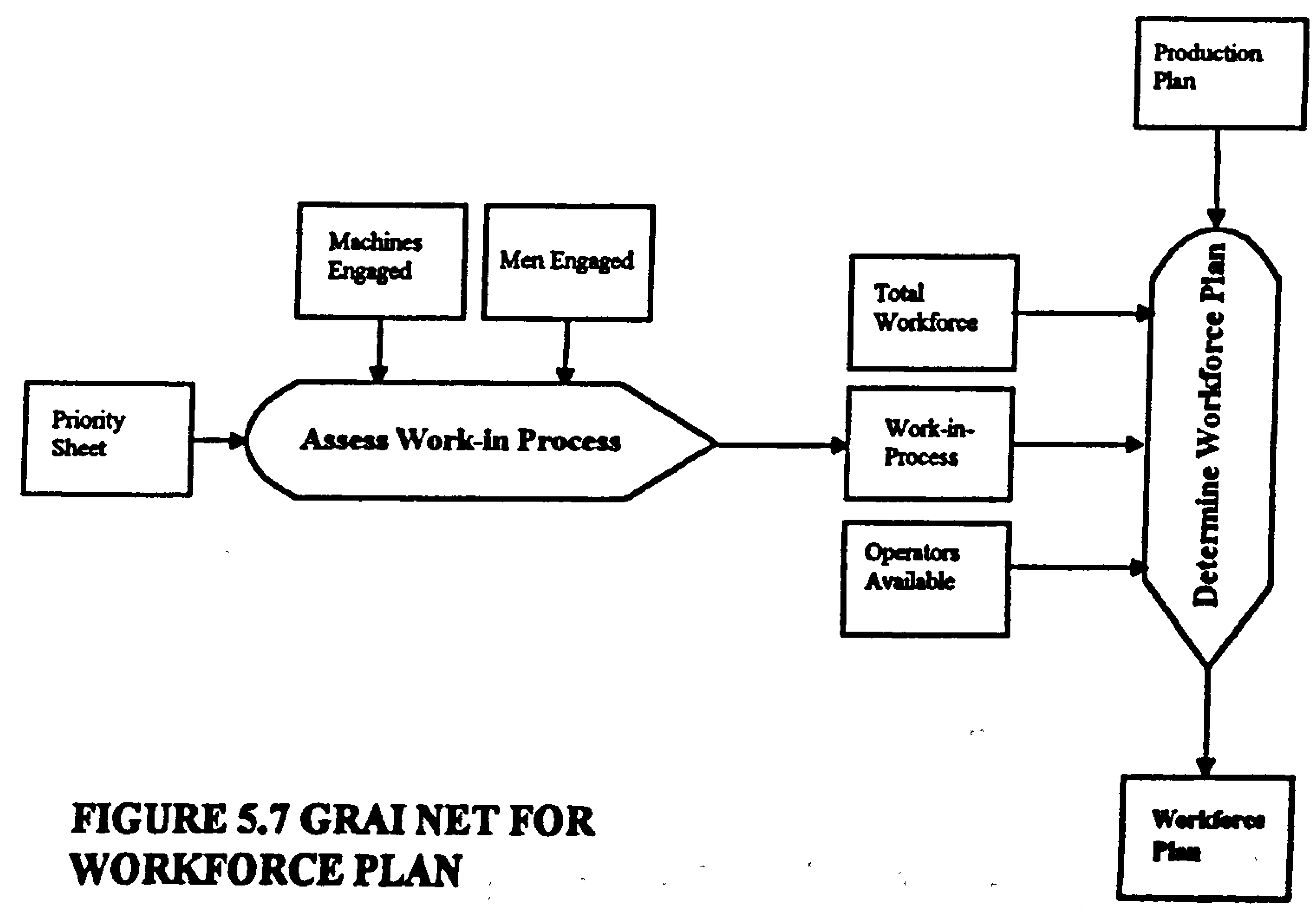


FIGURE 5.7 GRAI NET FOR WORKFORCE PLAN

Horizon = 1 Day, Review Period = Real Time

This horizon shows the operational and manufacturing activities at shop floor level. A daily priority sheet for production is issued. The work is distributed to the machine and operators according to the instructions provided by the daily priority sheet.

e) Construction of GRAI Nets

This phase involved a more detailed programme of interviews with the synthesis group to evaluate, in greater detail, the decision centres identified in the GRAI grid. Using the information from the interviews the following GRAI nets were constructed:

Horizon = 1 Month, Review Period = 1 Day

Function: To Manage Material (To Buy)

Title: Purchasing Orders

This decision centre is related to the issue of purchasing orders as shown in Figure 5.4. Due to the MRP system the decision centre only concentrates on the suppliers' information including prices, quality and delivery date.

Horizon = 1 Month, Review Period = 1 Day

Function: To Plan Production

Title: Production Plan

This decision centre is shown in Figure 5.5. The decision centre follows the instructions provided by the MRP system. No real production plan was identified. The decision centre checks the requirements and decides which products to launch for manufacturing. This information is sent to the relevant sections.

Horizon = 1 Month, Review Period = 1 Day

Function: To Control Quality

Title: Quality Standards

The activities of this decision centre are shown in Figure 5.6. The decision centre receives technical information from the design section. The decision is performed with reference to the relevant British Standards.

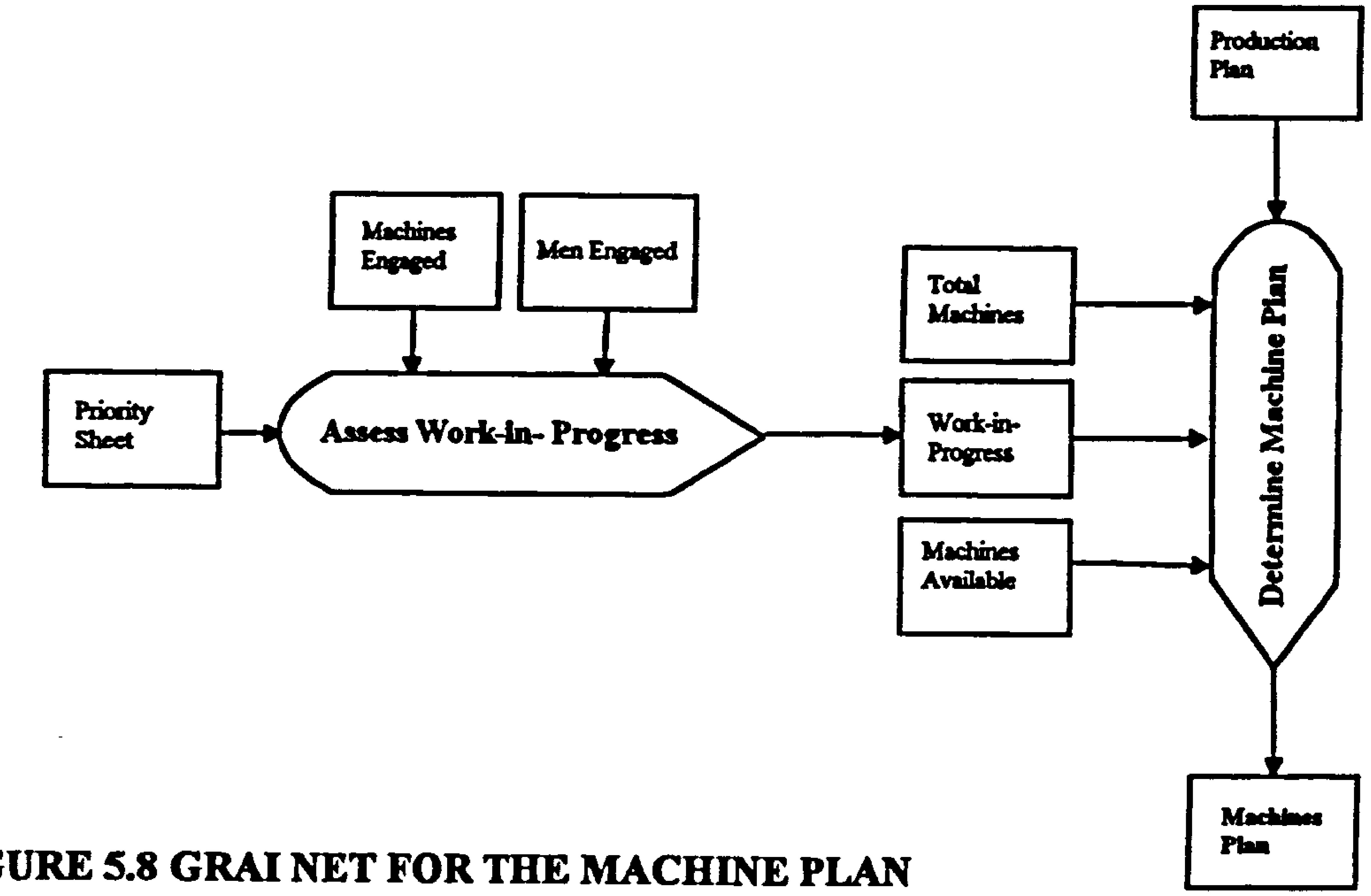


FIGURE 5.8 GRAI NET FOR THE MACHINE PLAN

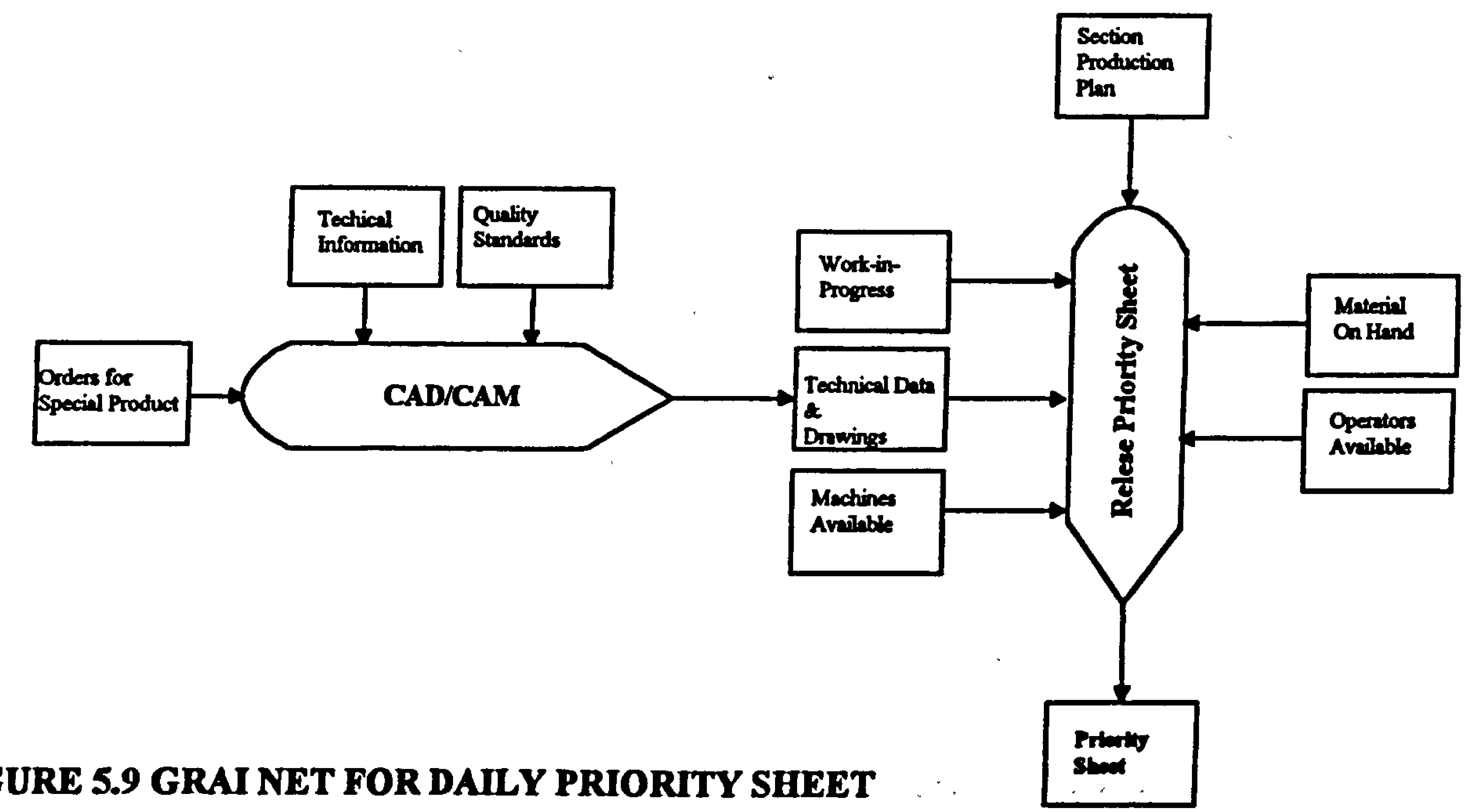


FIGURE 5.9 GRAI NET FOR DAILY PRIORITY SHEET

Horizon = 1 Week, Review Period = 1 Day

Function: To Manage Resources (Technical & Human)

Title: Machine and Workforce Plan

The activities of the decision centre are shown in Figures 5.7 and 5.8. One associated activity required to support the decision was identified. This activity assesses the work-in-progress with respect to the engagement of men and machines. This information is sent to the decision centre. The decision made shows the availability of men and machines with respect to the production plan.

Horizon = 1 Day, Review Period = Real Time

Function: To Plan Production

Title: Production Plan

The activities of the decision centre are shown in Figure 5.9. Only one activity required to support the decision was identified. This activity provides the technical data on the product including drawings, manufacturing process, bill of materials and quality standards. The decision centre assesses the availability of men, machines and materials then issues the work priority sheet.

5.2.2.3 Results of the Analysis

- It has been observed that the company does not utilise the sales forecast and production forecast.
- Due to the MRP system and the priority of work, no advance planning for production was identified.
- The MRP system runs once each week and is provided with information about the requirements for raw material and finished products, but the horizon of the production plan and purchasing order is one month. This horizon is not matched by the horizon and review period of the MRP system.
- Most of the decisions are made at the operational level of the company, with no involvement of the middle management in the decision making process.

- Because the work priority sheet is issued daily in the morning, no advance plan for the manufacturing, machines and workforce were identified. Similarly no fixed targets for production were observed.
- The design section of the company is not very active. Design activities are only carried out when orders for a special product come through the sales department. Similarly no research and development activities were identified.
- No Master Production Schedule was identified. All planning activities are carried out during real time and plans are made very late.
- It was observed that some sections purchased their material directly without concerning the purchasing department. This seems expensive and creates problems of inventory management.
- The GRAI nets constructed show that the decision making is not performed in an efficient manner. The decision makers use very little information to make the decisions.
- The company need to make a Master Production Schedule (MPS) at least one year in advance. The MPS would act to provide the basic information for other related plans including planning of material, inventory, workforce and machines.
- The MRP system should run at least one month in advance and the tactical levels should make their decisions accordingly.
- The work orders at shop floor level, should be issued at least one week in advance to enable the operational levels to make their plans accordingly. Priorities should be issued one day in advance.
- All the purchasing activities need to be centralised.

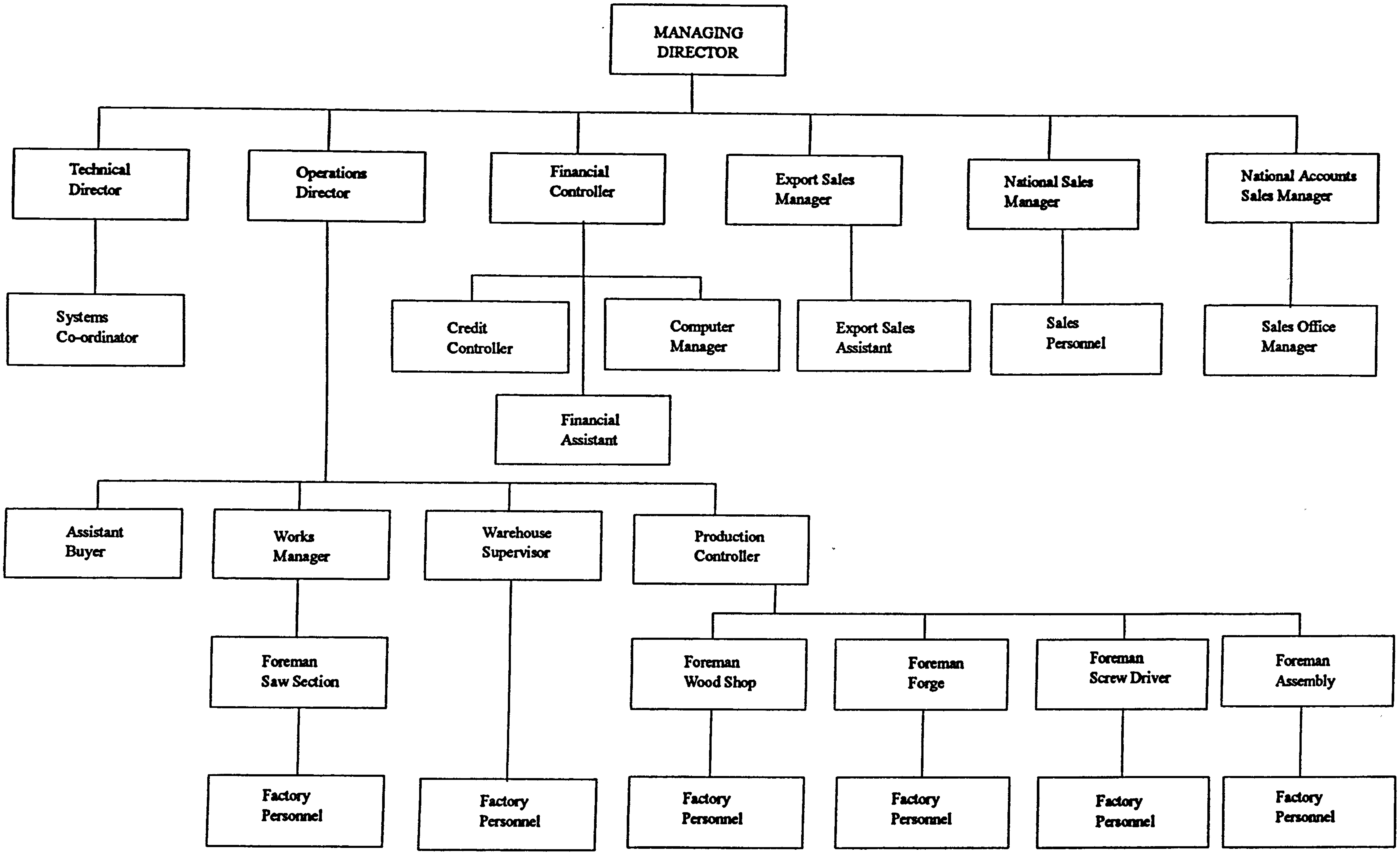


FIGURE 5.10 ORGANISATION STRUCTURE OF THE COMPANY

5.2.3 Case Study-3: Paramo Hand Tools

5.2.3.1 Introduction to the Company

The Paramo Hand Tools Group has three different manufacturing sites and a warehouse. The group headquarters is situated in Sheffield and the Company has additional sites in the Midlands and Rotherham and a warehouse and distribution site in Ecclesfield.

All the sites manufacture hand tools for the home and international market. The company manufactures products with different brand names including Paramo, Clay, Ibbotson and Excalibur. The main products of the company are: saws, wood working tools, joiners tools, cold chisels, wrecking bars, marking gauges, screw drivers and wood chisels.

The Paramo Hand Tools, manufacturing site in Sheffield was considered for the study. The Paramo Hand Tools is a small company with 60 employees and manufactures hand tools. It is mainly a 'make-to-stock' company (90% of production) but it also manufactures to customer orders (10% of production). The company manufactures under its own brands and it also manufactures for other companies under the name of their products, for example marking gauges for the Stanley.

i) Organisational Structure

The organisational structure of the company is shown in Figure 5.10. The workforce of the company is multi-skilled.

ii) Departments

The company comprises four departments which are co-ordinated by the Managing Director. The departments are:

- Engineering and Quality
- Production

- Finance
- Sales

a) Engineering and Quality

The engineering and quality department consists of only two employees, a technical director and a system co-ordinator. The main responsibilities of the department are:

- To recommend and decide on group policy, with particular reference to technical matters.
- To maintain the system and develop quality standards throughout the company.
- To maintain and manage the company's quality management system in line with BS 5750 requirements.
- To design and develop new manufacturing processes, procedures and products.
- To advise and carry out any professional engineering function required, within the company, for example buying new machines, introducing new products and recruitment.

b) Production

Production is the main department of the company. The production department is not only responsible for production control as it is also involved in the purchasing of material, the handling of finished goods and raw material stocks, distribution and the delivery of goods. The responsibilities of the department are:

- To recommend and decide on company policy applicable specifically to operational matters.
- To maximise manufacturing efficiency through a factory management team.
- To control company stock, to specific financial levels commensurate with satisfying customer demand.
- To control all purchasing activities.
- To control a direct work force.
- To carry out general duties associated with factory management,
- To maintain the company's quality management system.

c) Sales

The responsibilities of the sales department are:

- To generate, quote and organise the administration of contacts and sales to all non-British Isles countries.
- To control certain designated national accounts.
- To examine export opportunities in all relevant areas.
- To examine the market appearance of the Company, to suggest and make changes where required.
- To motivate and monitor an external sales force and ensure their profitability.
- To control sales force orientation.
- To set and implement Company sales promotions.

d) Finance

The responsibilities of the finance department are:

- To monitor and control the financial resources of the Company.
- To organise and control office staff involved in providing financial services and information.
- To maintain the Company quality management system.

5.2.3.2 Layout

The layout of the Company is predominantly by product type, but areas of process layout have also been identified. The sections of the Company are shown in Table 5.1.

Sections	*Layout*
Wood Shop	Process
Screw Driver	Product
Assembly	Process
Saw	Product
Forge	Process

Table 5.1 Layout of the sections

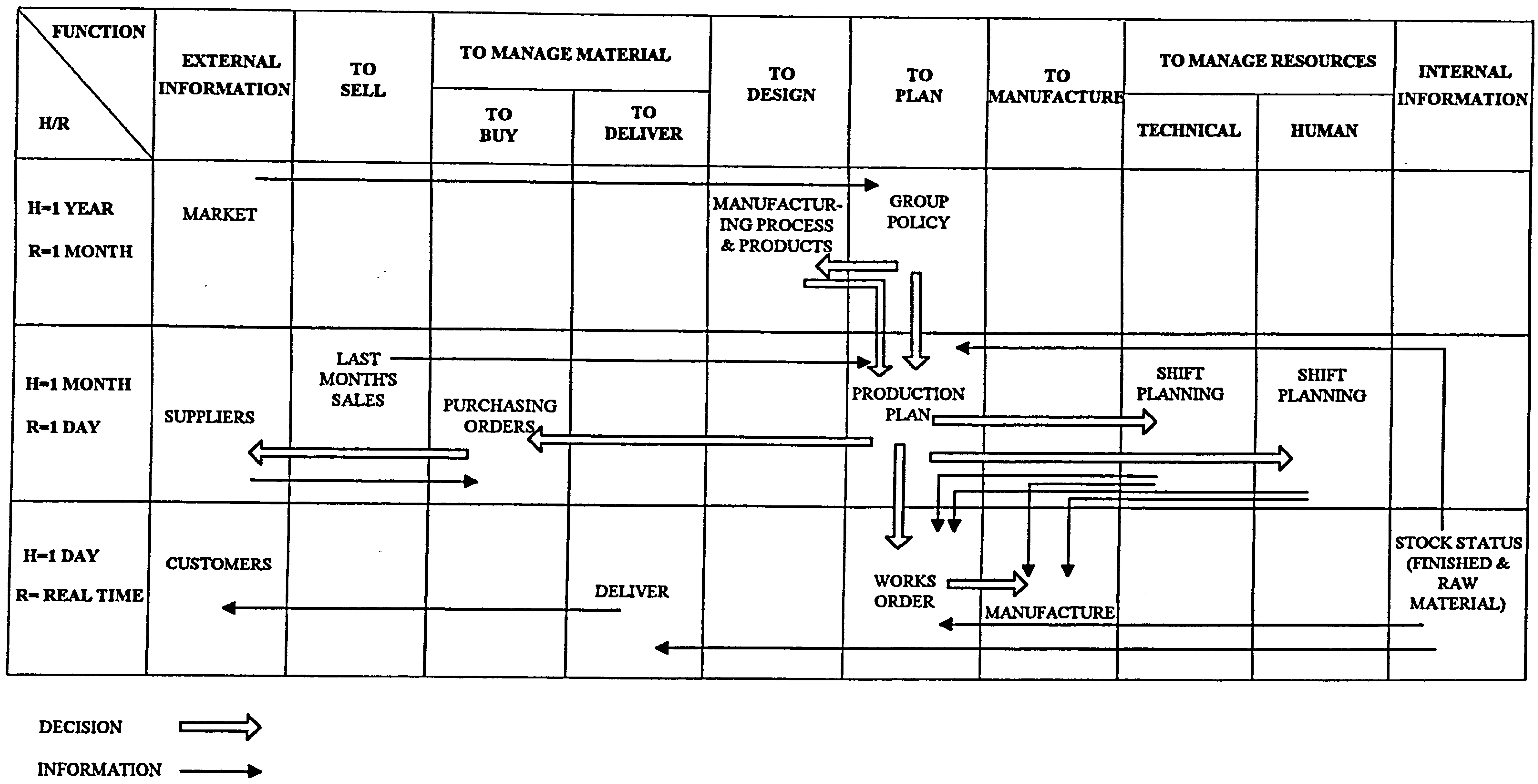


FIGURE 5.11 GRAI GRID FOR MANUFACTURING MANAGEMENT SYSTEM OF THE COMPANY

5.2.3.3 Analysis Phase

From the management structure (Figure 5.10), the people directly involved in the decision-making process were chosen. This group of people is known as the synthesis group. The synthesis group provided information for the determination of the hierarchy and the links between decisions. A bottom up analysis was then performed to scrutinise individual decision centres and to construct the GRAI nets.

The employees identified for the interviews were:

- Technical Director (Quality and Engineering)
- Operations Director (Production, Control and Purchasing)
- Production Controller (Production)
- System Co-ordinator (Quality)
- Purchasing Officer (Purchasing)
- Foreman (Wood Shop)
- Foreman (Forging)
- Foreman (Assembly)
- Foreman (Saw)
- Foreman (Screw Driver Shop)

A) Construction of the GRAI grid

The top down analysis was carried out in the first round of interviews. This examined the overall production management systems and produced a picture of the existing manufacturing management system. This initial round of interviews involved determining the activities performed, the decisions made and the role perception, the horizon and review periods and the functions of the company. The resulting GRAI grid is shown in Figure 5.11.

i) Identification of functions

The following functions of the Company were identified:

- To Sell

- To Manage Material
    - To Buy
    - To Deliver
- To Design
- To Plan
- To Manufacture
- To Manage Resources
    - Technical
    - Human

To Sell

This function provides information regarding product sales to the production planning function.

To Manage Material

This function is related to material management including the supply of raw materials and the delivery of products to customers. The function is divided into two sub-functions: to buy and to deliver.

To Buy: This function is involved in ensuring that the correct materials are available at the appropriate time for manufacture. It involves to an assessment of the cost of the purchased items and their quality, and the selection of suitable suppliers.

To Deliver: The delivery function refers to the delivery of finished products to a specified location. This location may be direct to a customer or the Company's own finished goods store. The activities under this function include test procedures to ensure that the finished products conform to the appropriate technical specifications and acceptable quality levels.

To Design

This function concerns the design aspects of products, processes and procedures. Activities and decisions normally undertaken relate to the products, engineering design and any product modifications necessary to satisfy products according to the customer requirements. The design function releases this information in the form of engineering drawings, technical specifications, process routes and the provision of other design documents.

To Plan

This function, to which all other functions are related either through decisional activities or information flows, is the core of the grid. The activities performed and decisions taken relate to the planning and scheduling of jobs throughout the entire manufacturing process.

To Manufacture

This is related to the physical activities involved in the manufacture of products in the governing production schedule, according to the required technical specification.

To Manage Resources

This function is related to management of available resources within the Company. It is divided into two sub-functions: technical and human.

Technical: Machines planning aims to produce plan for utilisation of the machines regarding the production plan.

Human: Workforce planning aims to produce feasible plan for utilisation of the workforce to complete the production plan. This is based upon the factors such as workforce availability.

ii) Identification of horizon and review periods

The following horizons and review periods were identified:

H = One year, R = One month

H = One month, R = One day

H = One day, R= Real time

H = One year, R = One month

This horizon relates to the planning and design functions. The Company reviews planning policies every month and if any problems exists, changes to the programme are implemented.

H = One month, R = One day

This horizon represents a typical horizon which enables raw materials suppliers to be selected, materials to be ordered and a firm production plan to be issued. The production plans are made according the Company policy, using the information provided by the design function and other internal information such as stock levels and last month's sales. The review period for this horizon is only one day. Day-to-day activities are analysed and if any problem exists, changes to the plans are implemented.

H = One day, R = Real time

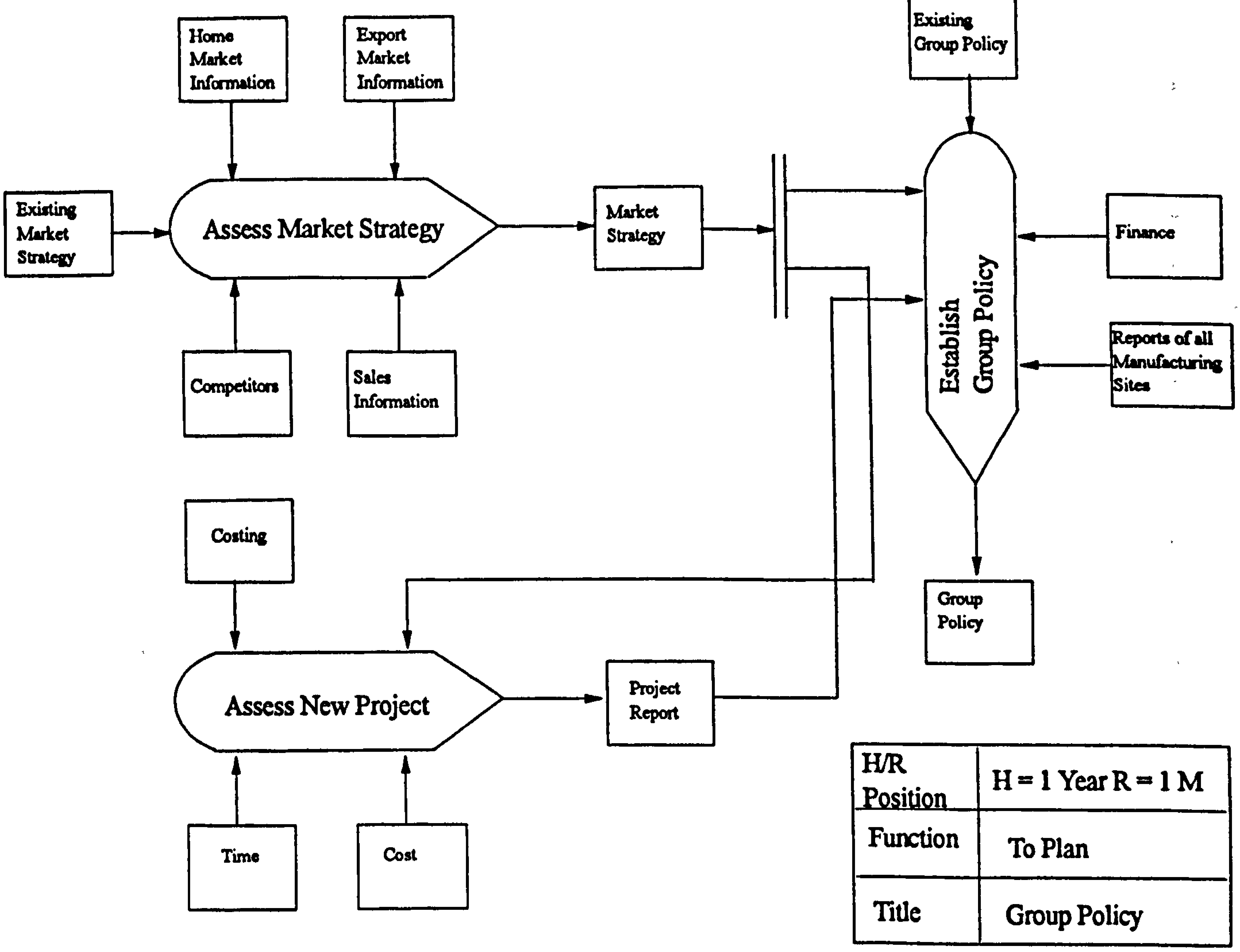
This horizon represents daily activities at the shop floor level. These activities include the issue of work orders, the distribution of work, personnel management, ensuring the quality of finished products and stock control. The review of this horizon is in real time and concerns real time problems.

B) Construction of GRAI nets

This phase of the GRAI method involves the second round of interviews with the synthesis group. To analyse the identified decision centres and construct their associated GRAI nets, it was necessary to identify the following:

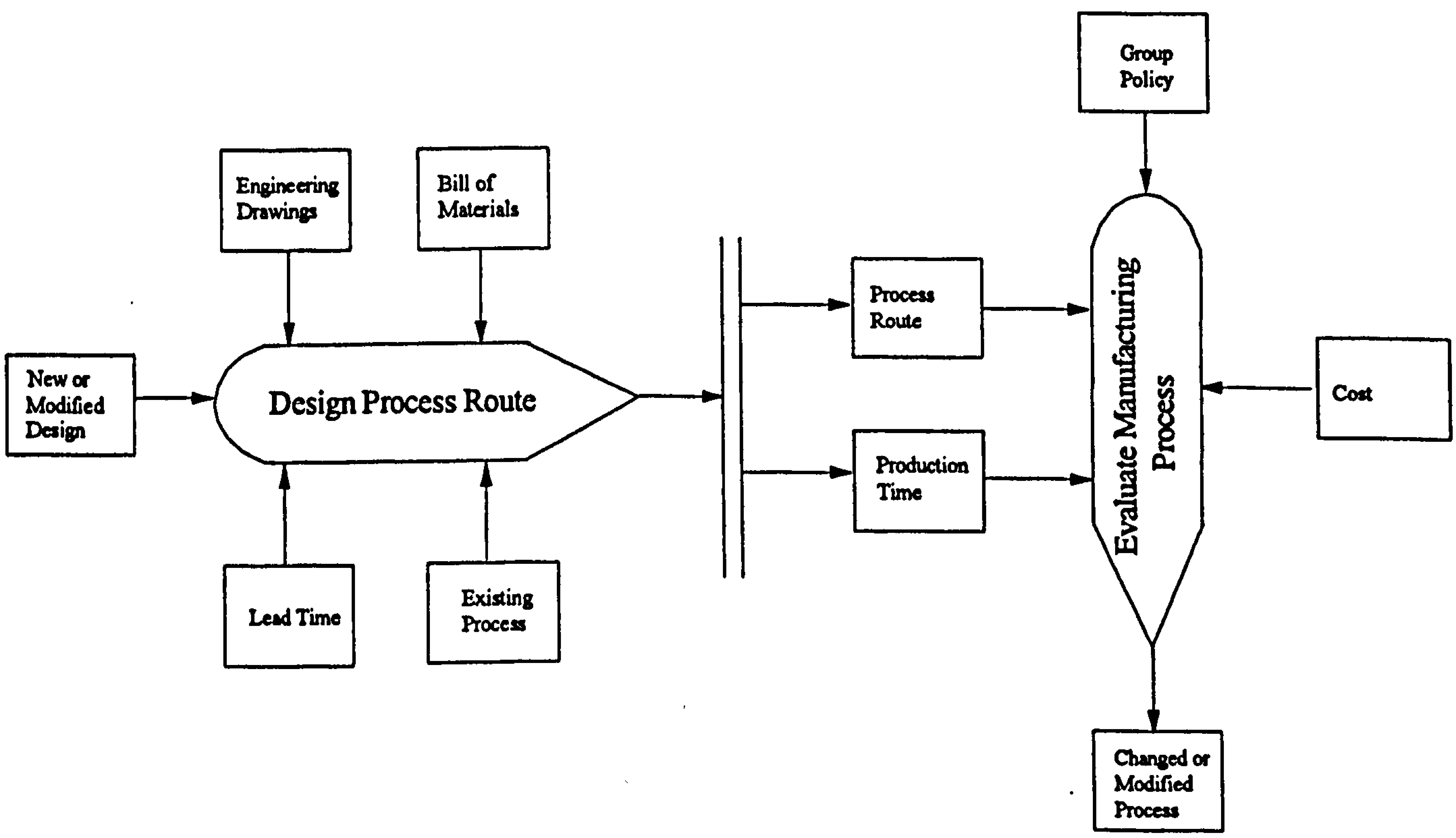
- The various activities performed and decisions taken at a given decision centre.
- The relationship between activities and the decision undertaken.
- The information required to make a specific decision.

Nine GRAI nets were constructed in total in accordance with the decision centres identified on the GRAI grid. They are discussed below in order of decreasing horizon.



H/R Position	H = 1 Year R = 1 M
Function	To Plan
Title	Group Policy

FIGURE 5.12 GRAI NET FOR DECISION CENTRE GROUP POLICY



H/R Position	H = 1 Year R = 1 M
Function	To Design
Title	Manufacturing Process

FIGURE 5.13 GRAI NET FOR MANUFACTURING PROCESS

H/P: H = One year R = One month

Function: To Plan

Title: Group Policy

This decision relates to the issue of the group policy, as shown in Figure 5.12. Two major activities were found to produce a feasible group policy. The first activity produces the market strategy in light of support information on the home market, export markets, sales and competitors. The second activity is related to the assessment of any new project. The group policy is then made with reference to the results of the activities performed, the existing group policy, the budget available and reports from all the manufacturing sites.

H/P: H = One year R = One month

Function: To Design

Title: Manufacturing Processes

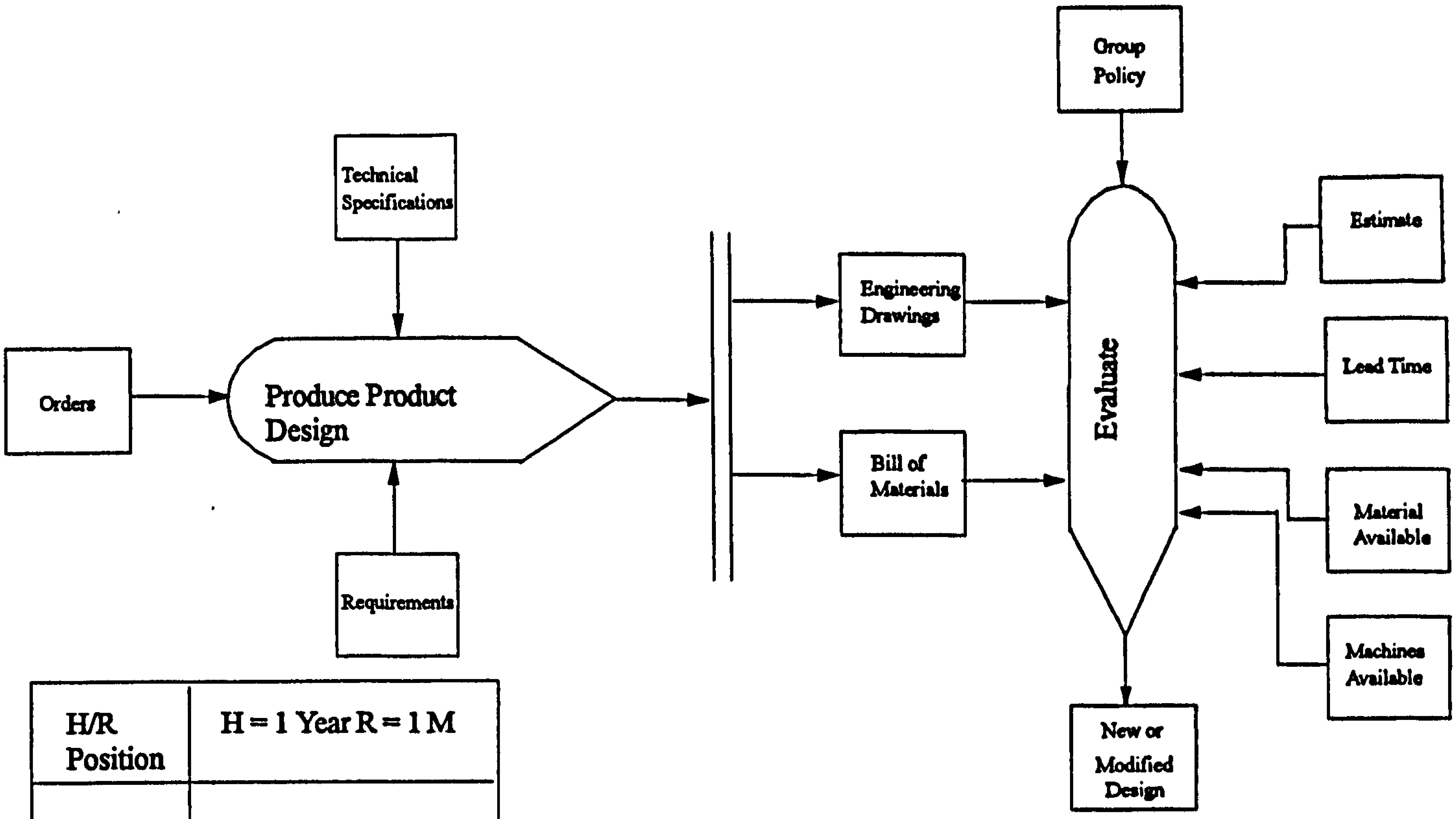
This decision relates to the issue of the manufacturing processes and process route as shown in Figure 5.13. Only one activity has been identified to support this decision. The activity is to design the product route with respect to the facilities available. The outputs of the activity are sent to the decision centre. The decision centre evaluates the activity with reference to the information provided by the group policy and the availability of finance. The order for a new or modified product route is then issued.

H/P: H = One year R = One month

Function: To Design

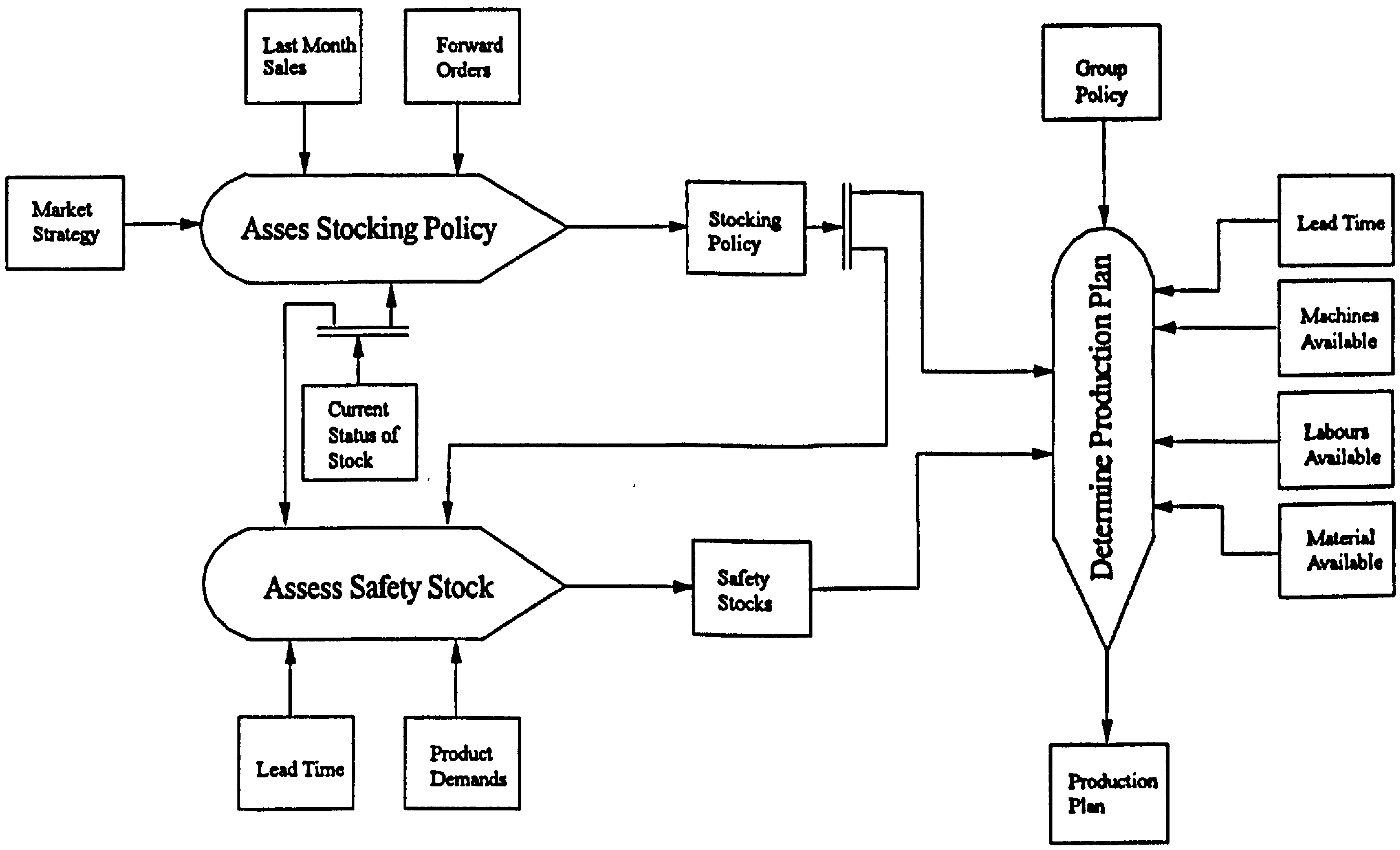
Title: Product Design

This decision frame relates to the preparation of product designs as shown in Figure 5.14. The one activity found to be related to this decision is the production of engineering drawings and bills of material. The outputs of the activity are sent to the decision centre which evaluates the cost and availability of material, machines and operators. The output of this decision is a recommendation for a new or modified design. This decision centre is not always active and only utilised when orders for a special product are received.



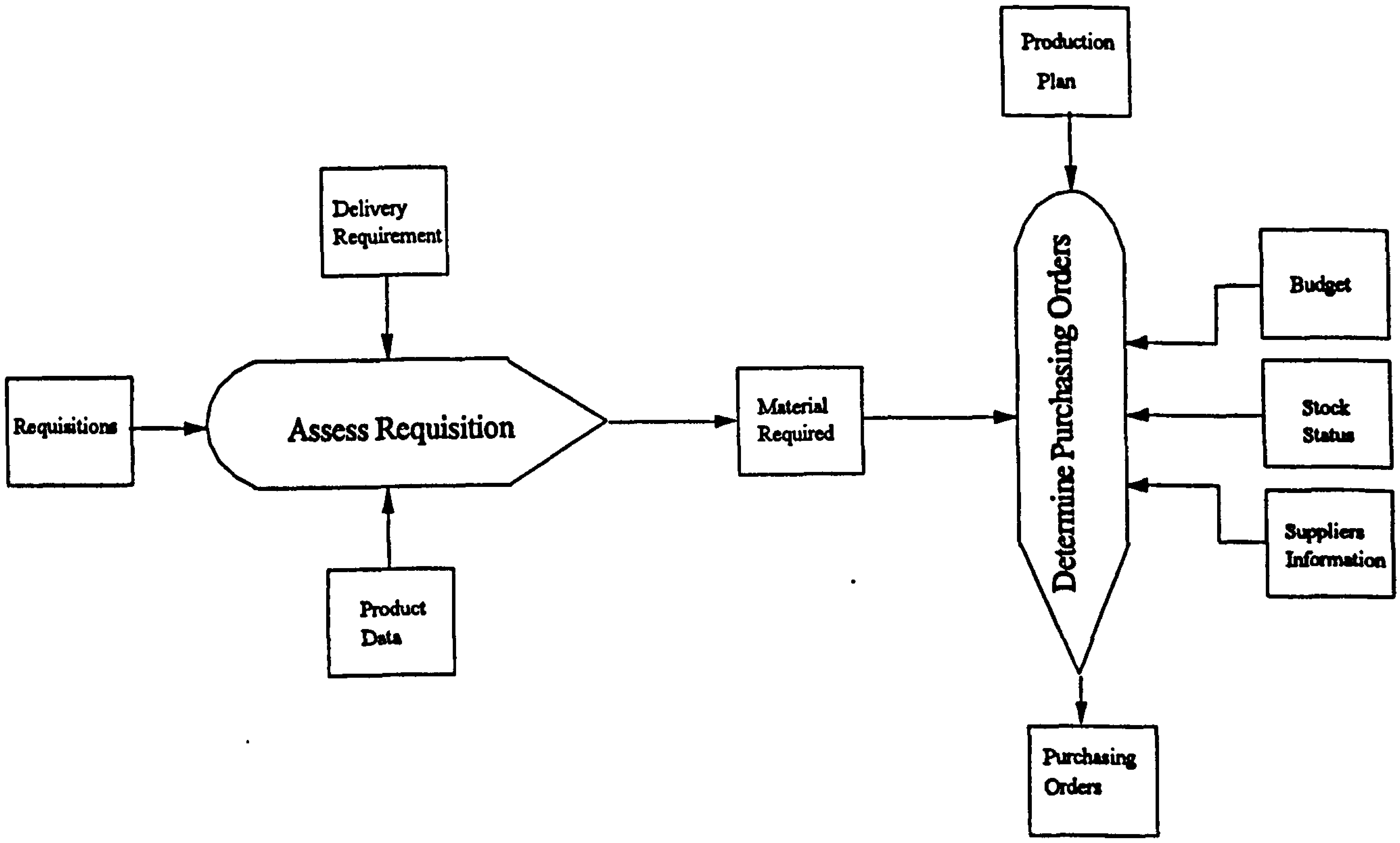
H/R Position	H = 1 Year R = 1 M
Function	To Design
Title	Product Design

FIGURE 5.14 GRAI NET FOR PRODUCT DESIGN



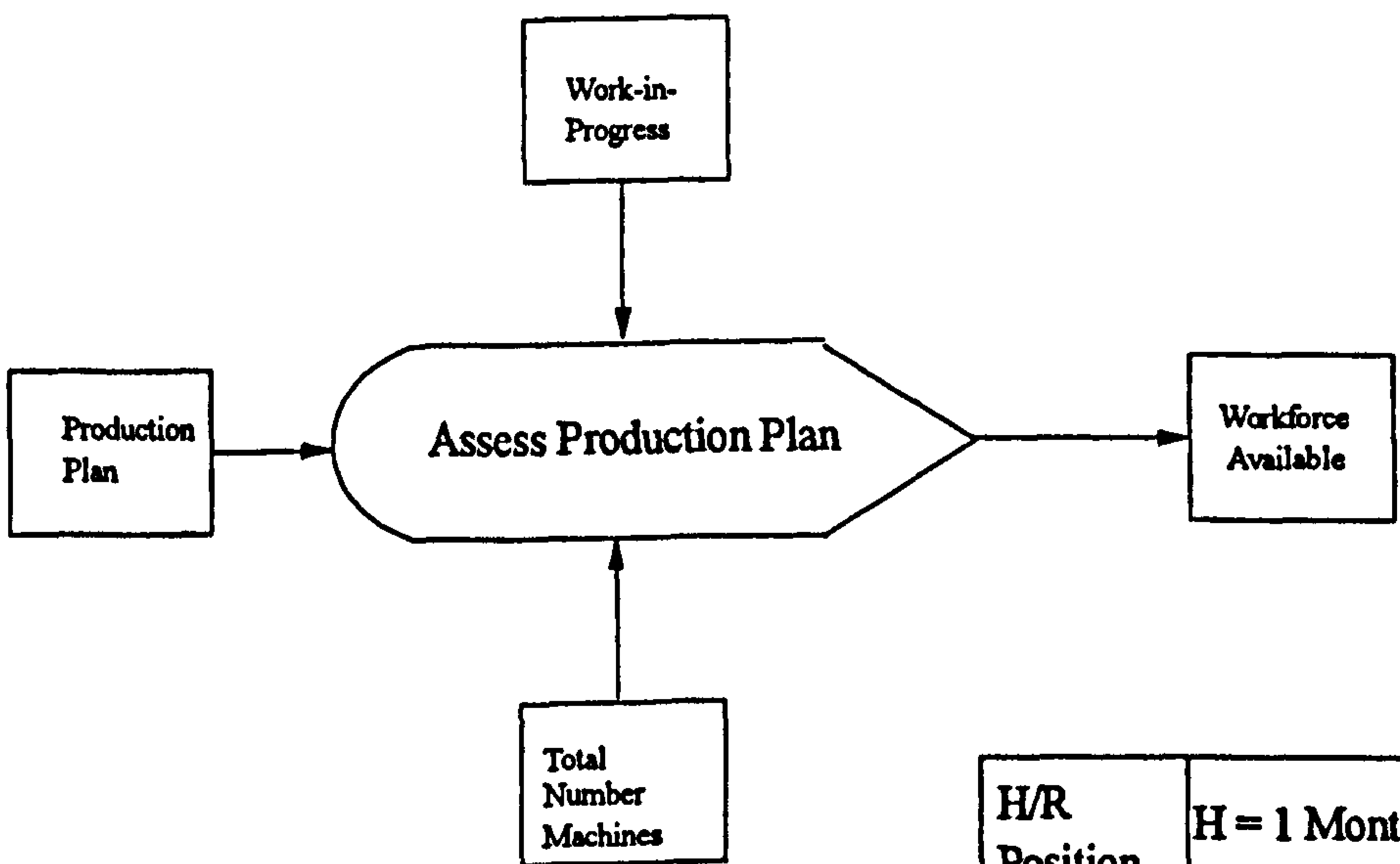
H/R Position	H = 1 M R = 1 D
Function	To Plan
Title	Production Plan

FIGURE 5.15 GRAI NET FOR PRODUCTION PLAN



H/R Position	H = 1 M R = 1 D
Function	To Manage Materials
Title	Purchasing Orders

FIGURE 5.16 GRAI NET FOR PURCHASING ORDERS



H/R Position	H = 1 Month R = 1 Day
Function	To Manage Resources (Human)
Title	Shift Planning

FIGURE 5.17 GRAI NET FOR THE ACTIVITY OF SHIFT PLANNING

H/P: H = One year R = One month

Function: To Plan

Title: Production Plan

This decision is related to the preparation of the production plan, as shown in Figure 5.15. Two major activities are associated with producing a feasible production plan. The first activity is the assessment of the stocking policy based upon the customer's orders, past sales and the current status of stock. The stocking policy is derived from the market strategy, provided by the sales department. The second activity is performed to set the level of safety stocks. It assesses the product lead time, product demand and stocking policy. Production plans are established as a result of the activities performed, group policy, product lead time, availability of machines, availability workforce, material required and the previous month's sales.

H/P: H = One month R = One day

Function: To Manage Material (To Purchase)

Title: Purchasing order

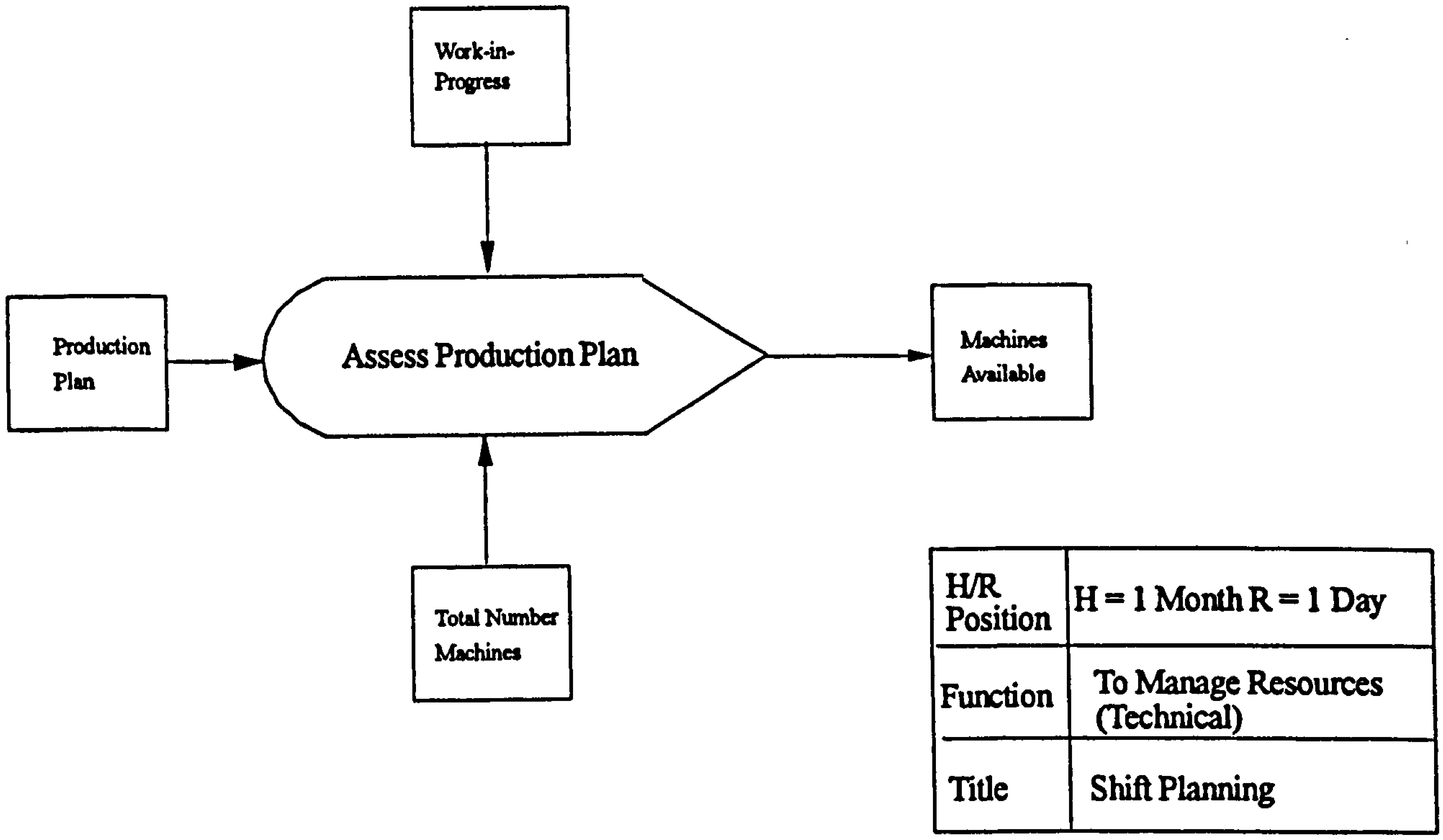
This decision frame is related to the issue of purchasing orders, as shown in Figure 5.16. Only one activity was identified. This activity assesses the requisition, material data and delivery demand. The resulting information is sent to the decision centre, which can then evaluate the material requirement in light of prices, stock status and production plan. Purchasing orders are then issued to the recommended suppliers.

H/P: H = One month R = One day

Function: To Manage Resources (Human)

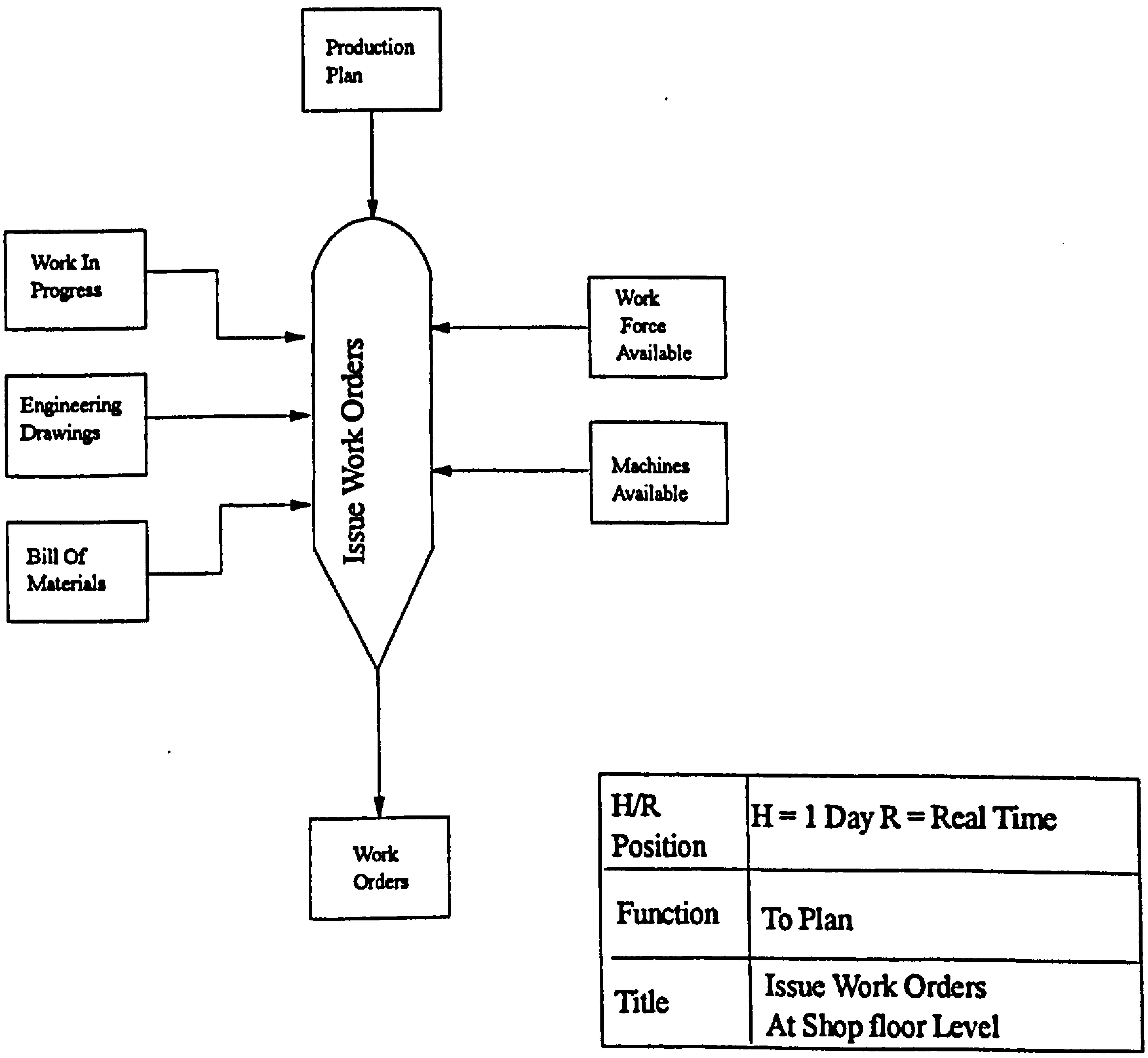
Title: Shift Plan

The activity to produce a shift plan is shown in Figure 5.17. It assesses the production plan according to the levels of Work-in-Progress and the total number of operators. The result of the activity indicates the availability of the operators.



H/R Position	H = 1 Month R = 1 Day
Function	To Manage Resources (Technical)
Title	Shift Planning

FIGURE 5.18 GRAI NET FOR THE ACTIVITY OF SHIFT PLANNING



H/R Position	H = 1 Day R = Real Time
Function	To Plan
Title	Issue Work Orders At Shop floor Level

FIGURE 5.19 GRAI NET FOR ISSUE WORK ORDERS AT SHOP LEVEL

H/P: H = One month R = One day

Function: To Manage Resources(Technical)

Title: Shift Plan

The activity to produce a shift plan is shown in Figure 5.18. It assesses the production plan in view of the Work-in-Progress and the total number of machines. The result of the activity is details of the availability of the machines.

H/P: H = One day R = Real time

Function: To Plan

Title: Issue work orders at shop level

This decision relates to the issue of work orders at the shop floor level as shown in Figure 5.19. The decision centre reviews the production plan together with the available resources (both machinery and human operators) and Work-in-Progress levels. Each shop is analysed to determine its ability to meet the work orders. The output of the decision is the final work loading for the work shop.

H/P: H = One day R = Real time

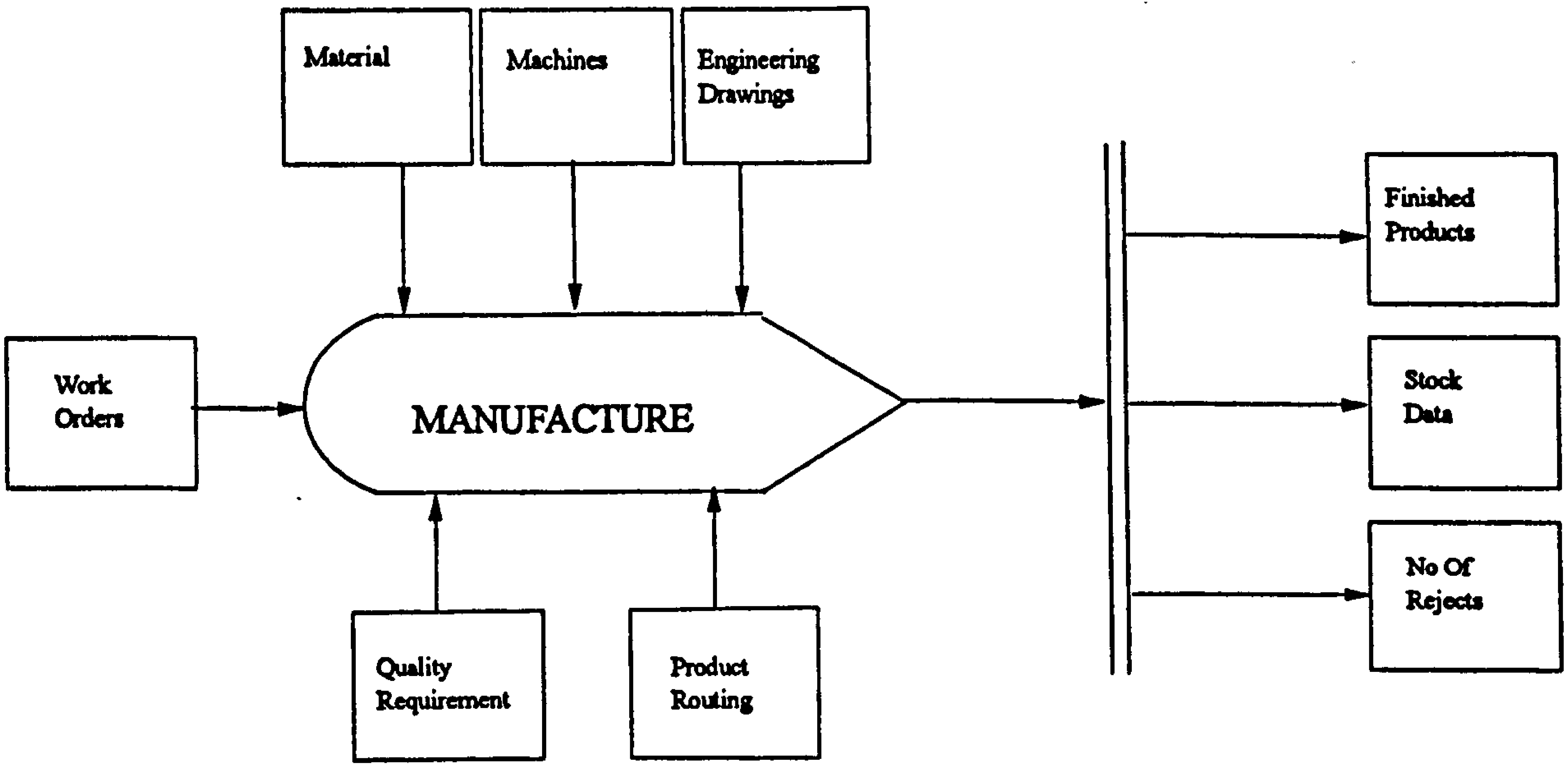
Function: To manage material (To make)

Title: Manufacture

This activity is shown in Figure 5.20. Several sources of information are required to perform the activity including work orders, engineering drawings, product routings, quality standards and product quantity. The output of the activity consists of finished products, stock data and a number of rejects.

5.2.3.4 Results of the Analysis

The overall planning period utilised by the company is relatively short being only one year. Three horizons and review periods were found. No defined group policy was identified. The production plan is only updated on a monthly basis as derived from the previous six months sales. All types of planning is carried out manually, no computers are utilised, except in the control of finished stock.



H/R Position	H = 1 Day R = Real Time
Function	To Manufacture
Title	Manufacture

FIGURE 5.20 GRAI NET FOR THE ACTIVITY OF MANUFACTURING

Due to the lack of a master production schedule, the system assumes that everything is required on the day of the planning run. Similarly, due to the lack of capacity information, the system assumes that the planning of machines and workforce is made on the same day.

No research and development section was found. The technical manager is responsible for design and research activities. The design function is active only when a special product is ordered which is relatively infrequently. This is another reason why the Company manufactures mostly standard products.

No separate inspection section exists. Operators are directly responsible to maintain product quality at the work area. This is supplemented by a visual inspection at the time of packing.

Processes routings are not clear and drawings are not available. Instructions for work are given to the operators verbally. The layout of the factory is complicated and different product shops overlap each other.

The production management team of the company is small and responsible for many jobs at the same time. There is a general lack of formal, structured meetings and consultation. The small size of the Company has led to an informal method of information transfer, which the Company considers sufficient for their needs.

5.3 COMPARISONS

The GRAI method has been applied to Footprint Tools Ltd., Presto Engineers Cutting Tools and Paramo Hand Tools. The resulting GRAI grids and nets have been drawn for each company. On the basis of these applications a comparison of the companies has been carried out. The comparison has been carried out under the following headings:

- Organisation

- Functions
- Horizons and review periods
- Activities

5.3.1 Organisation

The comparison of the organisation of the companies has been carried out as shown in Table 5.2.

	FOOTPRINT	PRESTO	PARAMO
Organisation Structure	Line Structure	Line Structure	Line Structure
Operational Objectives	'make-to-stock'	'make-to-stock'	'make-to-stock'
Size	Medium	Medium	Small
Employees	197	400	60
Factory Layout	Mixed	Mixed	Mixed
Products	Hand Tools	Engineering Cutting Tools	Hand Tools
Export	✓	✓	✓
Distributors	✓	✓	✓
BS 5750	✓	✓	✓
Production Management Team	Medium	Medium	Very Small
Strategic Level	✓	✓	✗
Tactical Level	✓	✓	✓
Operational Level	✓	✓	✓

Table 5.2 Comparison of the organisation

It can be seen that the companies are organised as line structures, as defined by Gray and Strake (1984) and their operational objectives are to 'make-to-stock'. Although all manufacture to order more than 90% of production is 'make-to-stock'. For this reason we can classify them as 'make-to-stock' manufacturing organisations. Footprint Tools Ltd. and Presto Engineers Cutting Tools are medium-sized companies, whereas Paramo Hand Tools is classified as a small company. The size of company depends on number of employees (Nelder et al, 1996). Table 5.2 shows Footprint Tools Ltd. has

197 employees, Presto Engineers Cutting Tools has 400 and Paramo Hand Tools only 60. The production layouts of the companies are of mixed type. This means both process and product layouts can be identified within the companies. Footprint Tools Ltd. and Paramo Hand Tools manufacture hand tools whilst Presto Engineers Cutting Tools manufacture engineering cutting tools. All the companies export their products all over the world through distributors and have been accredited with the BS 5750 Quality Assurance Standard. The production management team of the Footprint Tools Ltd. and Presto Engineers Cutting Tools is medium size but Paramo Hand Tools has a very small team.

5.3.2 Functions

A comparison of the basic manufacturing management functions was carried out as shown in Table 5.3. This is based on information taken from the GRAI grids constructed for the companies (Figures 4.2, 5.3 and 5.11). The Table shows that all the basic functions of manufacturing management exist in these companies. It has been observed that the design function of the companies is not very active, only being utilised when orders for a special product are received. Similarly no research and development function was identified. A quality control function exists at the Paramo Hand Tools but is provided by the operators, who inspect and maintain product quality at their workstation.

FUNCTION	FOOTPRINT	PRESTO	PARAMO
To Sell	✓	✓	✓
To Manage Material			
To Buy	✓	✓	✓
To Deliver	✓	✓	✓
To Plan Production	✓	✓	✓
To Manufacture	✓	✓	✓
To Design	✓	✓	✓
To Manage Resources			
Technical	✓	✓	✓
Human	✓	✓	
To Control Quality	✓	✓	×

Table 5.3 Comparison of the functions

5.3.3 Horizons and Review Periods

This comparison is based on the GRAI grids constructed for the companies, shown in Table 5.4. The comparison shows that all the companies use medium-term planning. The maximum planning horizon of the companies is one year but they all use different review periods, for example Presto Engineers Cutting Tool's planning horizon is one year and review period is six months. In contrast, Footprint Tools Ltd. has a one year planning horizon, but its review period is three months. Paramo Hand Tools has a one year planning horizon and its review period is one month. At the operational level, all the companies have similar horizon and review periods.

H/R	FOOTPRINT	PRESTO	PARAMO
Horizon=1 Year Review=6 Months	×	✓	×
Horizon=1 Year Review=3 Months	✓	×	×
Horizon=1 Year Review=1 Month	×	✓	✓
Horizon=3 Months Review=1 Month	✓	×	×
Horizon=1 Month Review=1 Week	✓	×	×
Horizon=1 Month Review=1 Day	×	✓	✓
Horizon=1 Week Review=1 Day	×	✓	×
Horizon=1 Week Review=1 RT	✓	×	×
Horizon=1 Day Review=RT	✓	✓	✓

Table 5.4 Comparison of horizons and review periods

5.3.4 Activities

A comparison of the different activities performed by the companies is shown in Table 5.5. All the companies produce a sales forecast. The forecast produced by Footprint Tools Ltd. is based on a market analysis, whereas Presto Engineers Cutting Tools and Paramo Hand Tools use average past sales. All the companies carry out production planning, but only on a short term basis. Similarly work orders and the priority of the work at the shop floor level can be identified in each company. They also all carry out final product inspection. Footprint Tools Ltd. and Presto Engineers Cutting Tools have a separate inspection section, whereas at Paramo Hand Tools the operators were responsible for inspection. A similar policy for workforce and machines can be identified at Footprint Tools Ltd. Paramo Hand Tools and Presto Engineers Cutting Tools have no defined policy for the machines and workforce. All the companies employ shift planning at the shop floor level regarding work orders and job priorities.

Purchase orders of the companies are based on re-orders and requisitions. Footprint Tools Ltd. and Paramo Hand Tools have manual systems to assess the re-order requirements. Presto Engineers Cutting Tools has a computerised MRP system which runs once each week. Each company carries out decision making at different levels of the management hierarchy, but the GRAI nets constructed show that the decision makers are often using limited information to make their decisions (refer to Figures 4.3-4.12, 5.4-5.9 and 5.12-5.20).

ACTIVITIES	FOOTPRINT	PRESTO	PARAMO
Sales Forecast	Based on market	Based on past sales	Based on past sales
Production Plan	✓	✗	✓
Work Orders	✓	✓	✓
Priority of Work	✓	✓	✓
Product Design	Only for special orders	Only for special orders	Only for special orders
Policy for workforce	✓	✗	✗
Policy for machines	✓	✗	✗
Shift Planning	✓	✓	✓
Policy for quality	✓	✓	✗
Inspection	✓	✓	✓
Re-order level	Manual	MRP	Manual
Inventory (Finished Goods)	✓	✓	✓
Inventory (Raw Material)	✓	✓	✓
Purchasing Order	✓	✓	✓
Suppliers Information	✓	✓	✓
Decision Making	✓	✓	✓
Shearing Information	✓	✓	✓

Table 5.5 Comparison of the activities

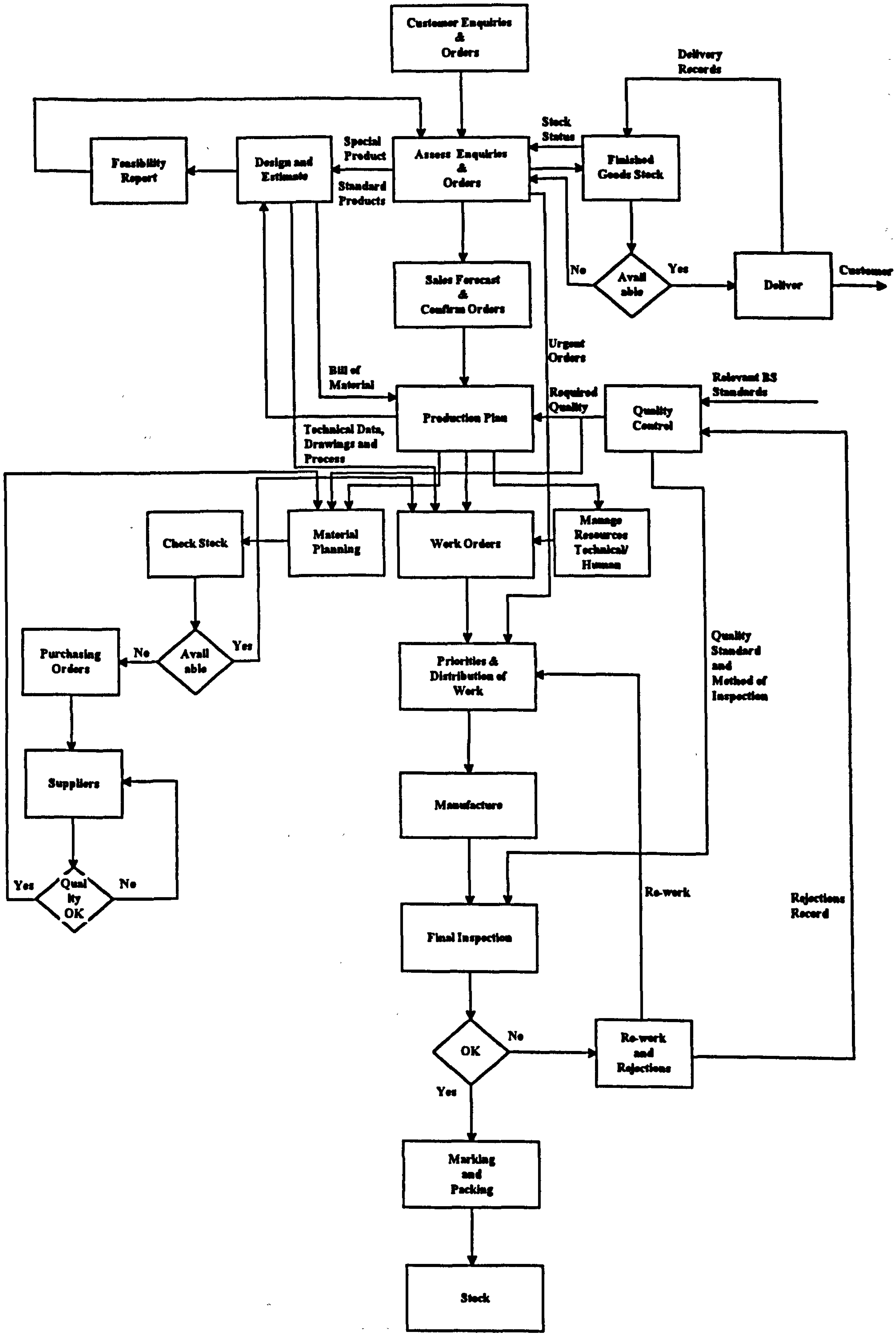


FIGURE 5.21 ACTIVITIES FLOW MODEL OF 'MAKE-TO-STOCK' MANUFACTURING ORGANISATION

5.4 CONCLUSIONS

The research is based on the hypothesis that each type of manufacturing organisation would benefit from a reference model. To prove this hypothesis, three 'make-to-stock' companies were selected for the study. The GRAI method was applied to the existing manufacturing management systems of the companies. The resulting GRAI grids and nets of each company were then drawn and analysed. In the early stages of the study, difficulties were experienced in the application of the GRAI method, some of which are highlighted in Chapter 4. The GRAI method can be difficult to understand, especially if it is new to the analyst and it can be interpreted differently by different users. The major drawback of the method is its reliance upon interviews, because the user is not told how to conduct the interviews with the synthesis group, or what type of questions to ask. To overcome these difficulties, it is necessary to develop the application of the methodology, as described in Chapter 4. Despite these difficulties, the method was used to compare of the manufacturing management systems for the three companies.

On the basis of the application of the GRAI method, comparisons of the companies were carried out. The comparisons identified several common characteristics which exist in 'make-to-stock' manufacturing organisations.

The activities flow model was developed as shown in Figure 5.21. The model shows the activities that can be identified in any 'make-to-stock' manufacturing organisation.

The comparisons and the model developed prove that 'make-to-stock' manufacturing organisations have several similar activities and characteristics. On the basis of the similarities identified, it is recommended that a generic model for 'make-to-stock' manufacturing organisations can be developed using the GRAI method. However, there is a need to develop the application of the GRAI methodology before developing a generic model.

CHAPTER-6

DEVELOPMENT OF A METHODOLOGY TO APPLY THE GRAI METHOD

6.1 INTRODUCTION

As described in previous chapters and the case studies shown in Chapter 4 and 5, the methodology used to apply the GRAI method has not been fully developed. In particular the interview techniques have not been formulated fully. During the Presto Engineers Cutting Tools case study, a member of the synthesis group associated with the development of the GRAI models and it was found that if two people apply the GRAI method to the same company, the results may be different. This is because the interviews rely on the interviewer's skill, expertise and interpretation, and sometimes, results may be biased (Oppenheim, 1992). It is difficult to assess if every interviewee has been asked the same questions, in the same manner. The author proposes that one way to minimise this problem is through the use of questionnaires to structure the interviews. The primary objective of the questionnaire would be to maintain spontaneity, similarity, control and direction of questions. A further advantage of the questionnaire would be the freedom of time for the respondent to reply. To resolve inconsistencies in interview techniques, a standardised set of interviews have been formulated for the GRAI method.

The proposed interview technique is based on a series of questionnaires (see Appendix). Questionnaire-1 relates to company background and management hierarchy, questionnaire-2 relates to the GRAI grid and questionnaire-3 relates to the GRAI nets for each decision centre. All the questionnaires are written in simple language and are easy to use and understand.

The formulation of the modified GRAI methodology comprises several steps. Each step guides the analyst and designer from analysis to design, and the implementation of a modified system.

6.2 MANAGING MODELLING ACTIVITIES

The process of modelling needs to be guided if it is to be successful. This section provides guidance on running the modelling activities, to ensure that facts are obtained in an efficient manner. The flow of the modelling activities is shown in Figure 6.1.

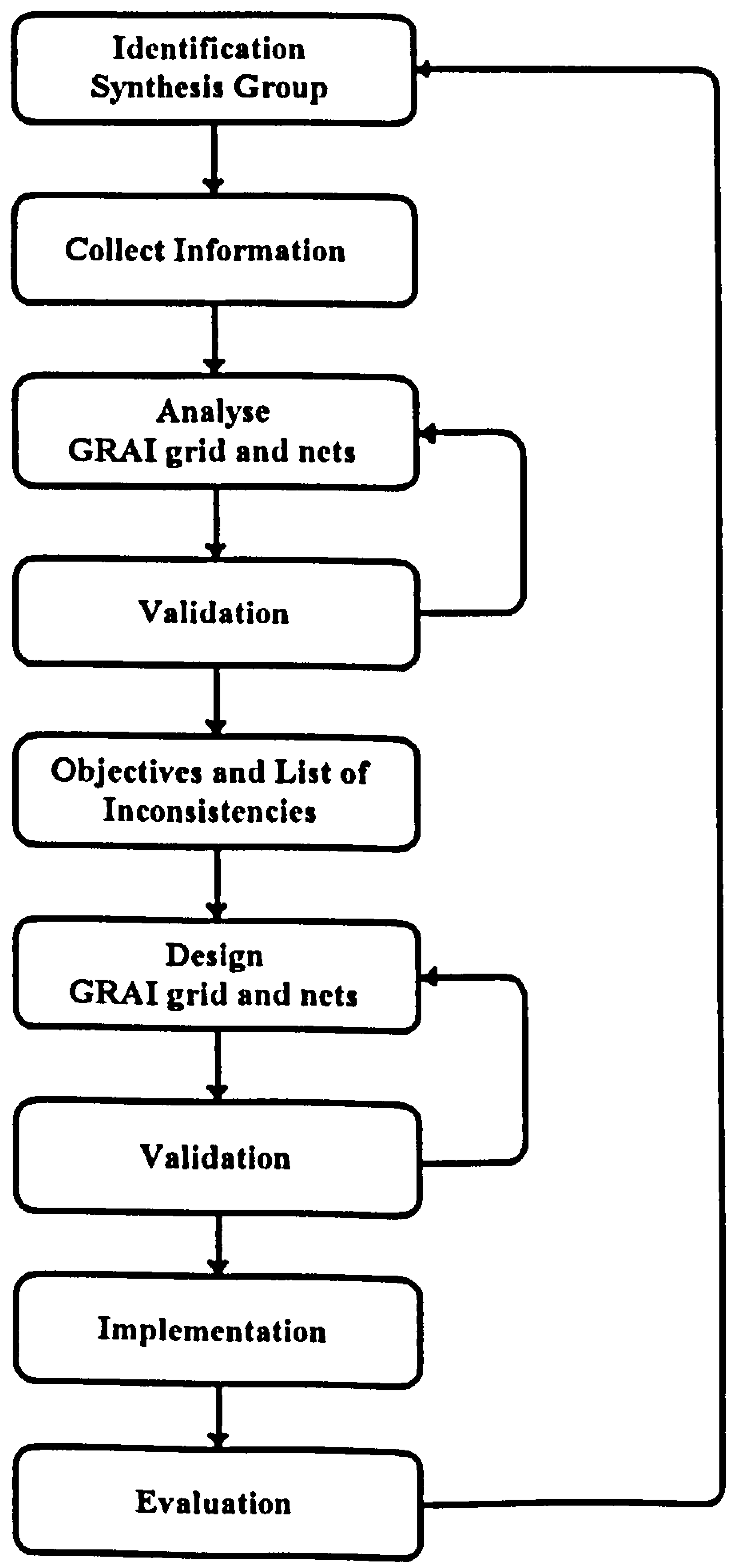


Figure 6.1 Methodology to apply the GRAI method

The application of the each of the steps in the GRAI method is explained in detail below:

Step-1: Nominate the Co-ordinator

The host company nominates a co-ordinator. The Co-ordinator should know all about the company and be able to provide detailed information upon request. The purpose of this nomination is to help the analyst. The analyst will explain the purpose and procedures used to apply the GRAI method to the existing manufacturing management system of the company.

Step-2: Send Questionnaire-1 to the Co-ordinator

When the system analyst starts work on a particular company, an informed awareness of the company's organisation is necessary. This is imperative to the analysis stage and will also assist in placing details of the current system in perspective.

Questionnaire-1 (see Appendix) consists of the following sections:

A) Company History and Background

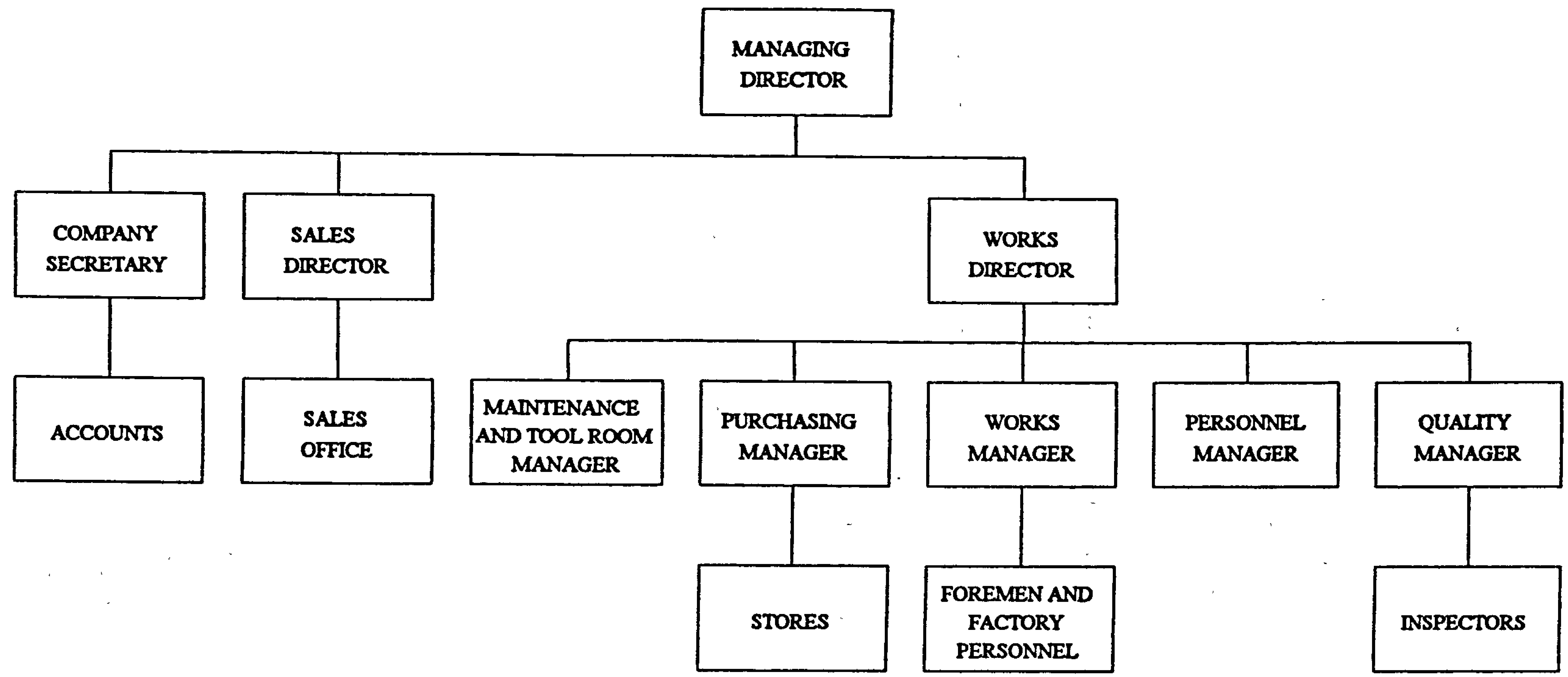
B) Management Hierarchy

- i- Departmental Hierarchy
- ii- Section Hierarchy
- iii- Subsection/Shop Hierarchy

C) Department/Section/Shop Layout

The output of the questionnaire provides a general introduction to the company. Its main purpose is to familiarise the analyst with detailed facts about the company. The analyst should then plan and analyse the manufacturing management system using the information provided by questionnaire-1.

The analyst will benefit from the knowledge of the company history. The management's overall policies should be reviewed and the annual reports, employee



TITLE:	**DRAWN BY:**	**DATE:**	**INDEX:**
COMPANY:	**VALIDATE BY:**	**DATE:**	

Figure 6.2 An Example of the Management Structure

hand books and trade literature should be examined. This background will help the analyst to appreciate the precise structure existing. At the same time an attempt should be made to discover how closely the present objectives of each function are in accord with the policies pursued.

Step-3: Draw the Management Structure

After obtaining questionnaire-1 from the co-ordinator, the analyst draws the management structure of the company indicating the hierarchy of departments, sections and sub-sections. The job title and name of all the different heads of the department, sections and sub-sections should be collated. The objectives of drawing the management structure are to obtain a brief introduction to all the members of the management team and to help to select the participants for the second questionnaire.

Step-4: Validate the Management Structure

The analyst validates the management structure with the co-ordinator. If a change is required, the structure is reviewed and validated until the co-ordinator agrees. An example of management structure is shown in Figure 6.2.

Step-5: Identification of the Synthesis Group

Using the management structure, the analyst identifies the members of the management team directly involved in decision making or responsible for different working areas within the system. These employees include the chief executive, heads of departments and heads of sections. This group is called the synthesis group.

Synthesis Group: By definition the synthesis group comprises the management team involved in the decision making process. The group is interviewed by the analyst. The responsibilities of this group are to provide the information necessary for the analyst to check and validate the results of the various steps and guide the GRAI designer in the modification or the new system.

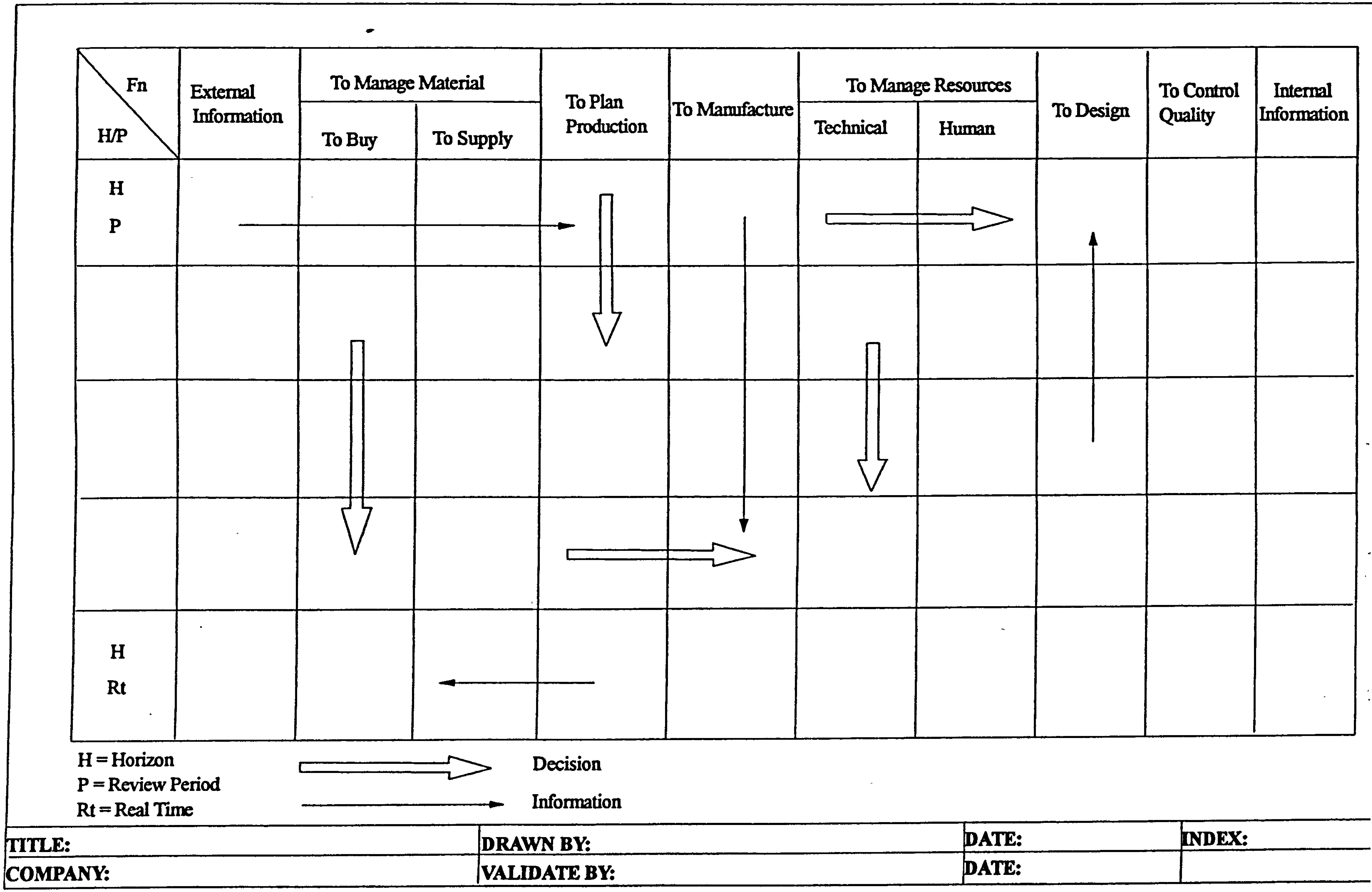


Figure 6.3 An Example of GRAI Grid

The analyst compiles the list of the members of the synthesis group identified from the management structure as shown in Table 6.1.

NO	Name	Department/Sect-ion/Sub-section	Job Title

Table 6.1 List of members of the synthesis group

Step-6: Distributes Questionnaire-2 to Synthesis Group

The co-ordinator introduces all the members of the synthesis group to the analyst, prior to interviewing. The analyst explains the GRAI method and use of the questionnaire individually to each member of the group. After this session, the questionnaire is distributed to all the members of the synthesis group.

Questionnaire-2 comprises six sections. Questions relate to the responsibilities and the decision making process within the work area of the interviewee. The questionnaire has a covering letter or notes, for the convenience of the synthesis group and to explain the terminology used.

GRAI Grid

The GRAI Grid produces a hierarchical representation of the structure of the decision centres within the system. Decision centres can be found on different levels within the organisation. According to the complexity of the system several GRAI Grids may be produced, relating to an aggregate master grid. The GRAI Grid represents the macro structure of the system, showing the links between the decision centres (see Figure 6.3). The details of a GRAI Grid are described below:

Functions: Functions are represented by the columns of the GRAI Grid. The basic functions that can be found in any manufacturing organisation include:

- To Sell
- To Plan Production
- To Manage Material
    - To Purchase
    - To Deliver
- To Manufacture
- To Design
- To Manage Resources
    - Technical
    - Human
- To Control Quality

The number of functions may vary from the above, depending on the business, organisation size and product type.

Levels: The levels are represented by different rows. Normally these levels are strategic, tactical and operational. In the GRAI method the number of rows depends on the number of horizons and the review periods.

Decision Centre: A square in the GRAI grid represents a decision centre (D C). Here a decision centre is defined as the authority capable of performing decisional activities.

Horizon(H): The Horizon is the time interval through which the decisions are valid.

Review Period (R): The Review period is the time interval at the end of which decisions are revised.

Real Time (RT): Real time (RT) shows the activities or the decisions that are made at real time.

A SUMMARY OF RULES RELATED TO GRAI METHOD

Table 6A: Rules Related to GRAI Grid

- Horizon and time period must be unique for each level.
- The horizon of any level must be equal to at least two periods of the level below.
- The levels are classified by decreasing periods, and for equal periods, decreasing horizons.
- There must be at least three levels relating to strategic, tactical and operational decisions.
- A function must contain at least one decision centre.
- A level must contain at least one decision centre.
- At any given level, the horizon must be longer than review period.
- The horizon of a decision making activity must be greater than the longest cycle of the activities which decision centre controls.
- Each level of decision must generate an action at one decision frame at lower level.
- Each decision making activity centre must receive a decision frame from an activity centre on the same or higher level.
- A decision making activity centre must not be isolated on a grid, but must be linked to at least one other activity centre.
- Every decision making activity centre must transmit a decision frame to one or more decision making activity centres on the same or lower levels, except those on the bottom level, which generate work instructions.
- Every decision making activity centre should only receive one decision frame. If more than one is received their objectives must be checked for conflict. The resources of the decision frames must also be checked.
- A decision frame should not go from a lower level to higher level.
- Every activity centre which generates a decision frame must contain a decision making activity centre.
- An activity centre should not receive a decision frame from a function which concerns basic elements (resources, products, time) not considered by the function containing that activity centre.
- A structure is coherent if all elements seek to satisfy the objectives of the overall system. Each decision frame should be linked by information chains and have similar origins.

(Source GRAI Rules, 1991)

The double arrow shows the transmission of a decision or links between decision centres at different levels. According to the GRAI method, arrows should always flow from upper level to a lower level or access the same hierarchical level, never from a lower to upper level.

The single arrow shows the informational links between decision centres. These can flow in any direction.

Decision: A decision is defined as the selection process which leads to a particular action being taken.

By analysing the questionnaire, the functions, decision centres, horizons and the review periods can be identified. This is necessary to determine whether decisions are being performed with the correct information, or whether only out-dated or incomplete information is available.

Step-7: Collect the Questionnaire

The analyst collects all the questionnaires from the synthesis group and ensures that all the relevant questions have been answered.

Step-8: Identify Functions of the Company

The analyst identifies the function of the various departments within the company from the questionnaire and compiles a list as shown in Table 6.2. The analyst adds external and internal information functions because these two functions are necessary to complete the GRAI Grid (see Table 6A).

No	Function	Department/Section

Table 6.2 List of the functions identified

Step-9: Identify Horizons and Review Periods

The decision horizons and review periods are identified from questionnaire-2 and a list is produced as shown in Table 6.3.

No	Department/ Section	Job Title	Decision	Horizon	Review Period

Table 6.3 List of the Horizons and the Review Periods

Step-10: Identify Decision Links

Identify links between the decision centres using the section of questionnaire-2 dealing with 'Instruction of the Work and Report To', and make notes.

Step-11: Identify Information Links

Identify all the information transmitted by the decision centres or functions to other decision centres or functions.

Step-12: Identify External and Internal Information

Identify the external and the internal information with an appropriate time scale from the information section of questionnaire-2. For example, important external information may concern the market, suppliers or competitors. Internal information may concern stock levels and level of Work-in-Progress.

Step-13: Draw the GRAI Grid

After collecting all the information necessary for drawing the GRAI grid from the questionnaire-2 (see Steps 8-12), the grid is drawn as shown in Figure 6.3. Firstly the columns are drawn corresponding to the number of functions identified. Then three more columns are added, the first to show horizons and review periods, the second for external information and third for internal information (see Figure 6.3). The rows are then drawn corresponding to the number of horizons and review periods identified. This is the initial grid, the columns of this grid show functions, the rows show horizons and review periods, and the grid squares represent decision centres. The columns, rows, horizons and review periods, and decision centres are labelled with reference to the functions, horizons and review periods, and decision centres identified. The horizons and review periods are arranged in descending order. Information and decision flows are linked to the decision centres as identified from questionnaire-2. The single arrows are used to show informational flow and double arrows are used for decisional flow. This grid shows a global picture of manufacturing management systems.

Step-14: Validate the GRAI Grid

The GRAI grid should be validated by the co-ordinator and the synthesis group. If changes are required the analyst should revise and re-validate the grid until the synthesis group agrees. This GRAI grid should represent the existing manufacturing management system of the company.

Step-15: Analysis of GRAI Grid

The purpose of this step is to use the GRAI grid to analyse the existing manufacturing management system of the company. This analysis should be carried out according to the rules relating to the GRAI grid (see Table 6A). During the analysis, consideration should be given to the following:

- Changes of any subsystem will effect the other subsystems

- The true underlying needs of the user and the nature of the problem itself should be identified.
- The subsystems must be integrated to give a global view

i) Analyse Functions

This includes the examination of the basic functions of the manufacturing system. The analysis determines whether all decisions or activities performed relate to the functions listed.

ii) Analyse Horizons and Review Periods

The horizons and review periods can be analysed as shown in Table 6.4. Three planning levels (strategic, tactical and operational) can be identified in any manufacturing organisation. This analysis confirms the existence of these levels and the associated time scale. The purpose of this analysis is to determine whether the horizons and review periods are appropriate for the planning levels and decisions made. The time scale may vary from company to company depending on their decisions. It should be noted that planning levels may have more than one control layer, depending upon the size of organisation and nature of decisions made.

Level	Term	Time Scale
Strategic	Long Term	1 to 5 Years
Tactical	Medium Term	1 Month to 1 Year
Operational	Short Term	1 Day to 1 Month

Table 6.4 Typical time scale for decisions

iii) Analyse Information

This analysis examines whether the functions transmit correct information to each other or to the same function at different levels of the hierarchy. The functions and the decision centres are checked to ensure that the necessary information to perform the activities is available. It is important that the information is appropriate to perform the activities within functions because misinformation can permeate and have consequences upon the entire system.

The analysis also examines the external and internal information and verifies whether the functions at different levels are using the external and internal information to perform their activities correctly.

iv) Analyse Decision Links

This analysis examines whether the decisional links are made according to the GRAI rules shown in Table 6A. For example the decision should always flow to a lower level, never upwards.

v) Make a list of all Inconsistencies Identified

The analyst makes detailed notes of all inconsistencies identified during the grid analysis.

Step-16: Identify Decision Centres and Decision Makers

The analyst identifies all the decision centres and associated decision makers from the GRAI grid. This is then tabulated as shown in Table 6.5. The decision centre and decision maker are used for further analysis using questionnaire-3.

No	Decision Maker	Function	Decision	Horizon	Review Period

Table 6.5 List of decision makers identified

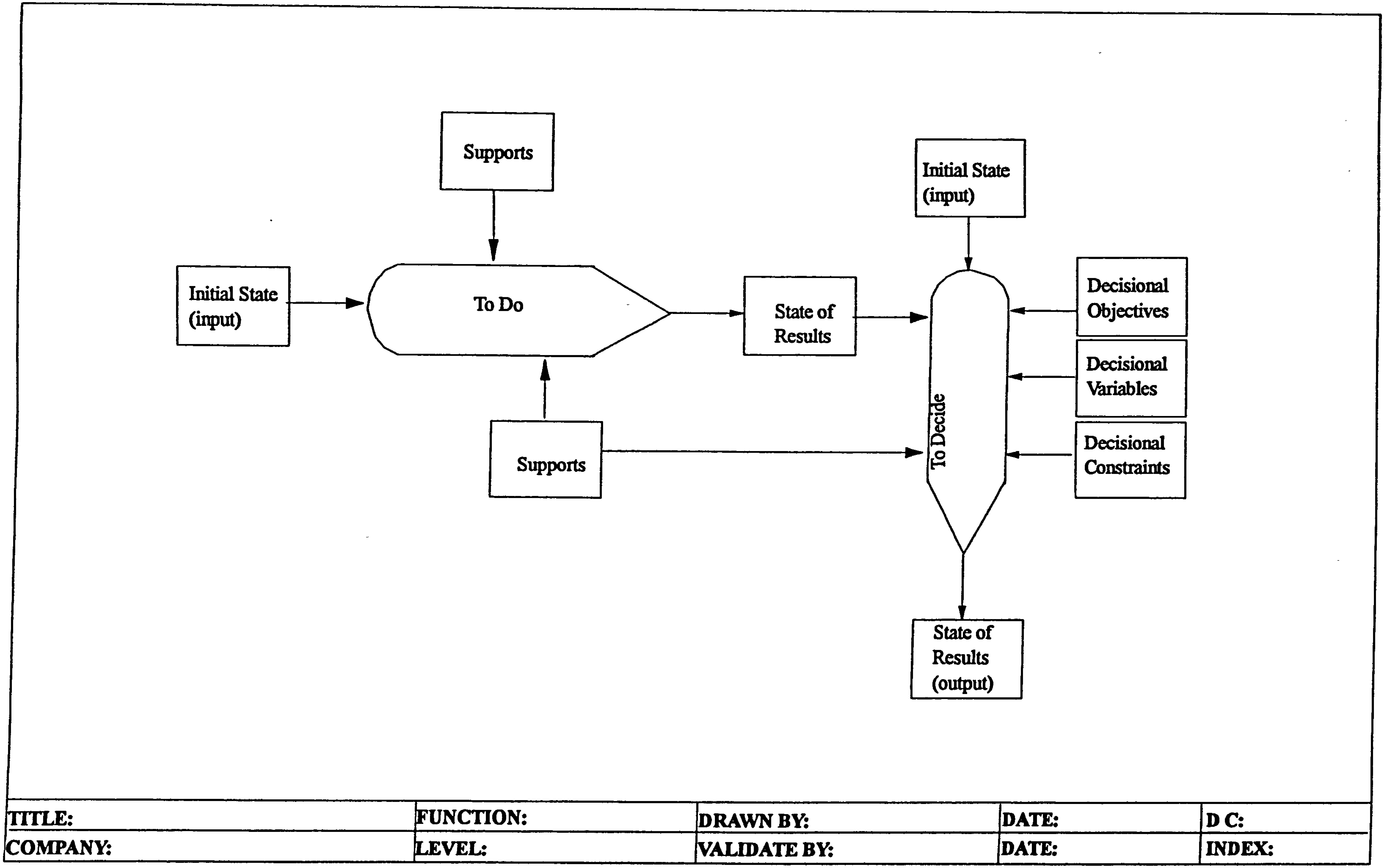


Figure 6.4 An Example of GRAI Net

Step-17: Deliver Questionnaire-3 to all Decision Makers Identified

Questionnaire-3 (see Appendix) must be distributed to all the decision makers identified during step-16. These decision makers are members of the synthesis group and are involved in the decision making process at all levels of the hierarchy of the system i.e. the strategic, tactical and operational. The analyst should record the delivery and the receipt of the questionnaires using Table 6.6.

No	Decision Maker	Function	Decision	Horizon	Review Period	Delivered Date	Received Date

Table 6.6 Record of questionnaire delivered and received

The questionnaire focuses on all the decision making activities at each decision centre. The terminology used in the questionnaire is explained as follows:

GRAI Net

The GRAI net is based on the micro structure of the system and examines the detailed activities of each decision centre. It is a symbolic representation of the chain of activities within a decision centre, showing the relationship to other centres and the support they require.

The basic net is shown in Figure 6.4. By using the GRAI net, the result of one discrete activity can be connected with the combined support of another discrete activity. In the GRAI net, five fundamental elements can be identified:

- to do (executing activity name)
- to decide (decisional activity name)
- initial state of activity
- supports (information, decision frame, method and material)

- results (results of an activity)

These elements are represented using the symbols shown in Figure 6.4. The vertical flow shows decisional activities and horizontal flow denotes executing activities.

To Do (Executing Activity name): This represents the initial activity to be performed for a particular decision. The GRAI net may consist of more than one activity.

Initial State (Input): This represents the input of any activity. All activities start at this initial state.

Supports: Supports represent the information used to perform both the activity and decision. The information includes the objectives, constraints, criteria and decision variables.

Output: This is the result of the activity performed. There may be more than one output from an activity.

To Decide (Decisional Activity): This represents the main decision frame of the decision centre based upon the results of the executing activities. All activities, information, objectives, constraints and decisional variables are analysed and decisions are made accordingly.

Decisional Variable (D V): Decisional variables are the parameters on which the decision is based. A decision variable flows into or out of a model process and is significant enough not be ignored in the opinion of the decision maker. Variables can be further classified as input and output (results).

Decisional Objectives: These are the objectives upon which the decision is based. They direct the decision to achieve the desired goals.

Table 6B: Rules Related to GRAI Net

- Every piece of information sent by a net, must appear somewhere in another net.
- The support of a decision making activity must include an objective, some constraints, and some decisional variables.
- The decision variables are the parameters on which the decision is based.
- Each activity must have a unique label in the same net.
- Each activity must produce results.
- The results of a decisional activity must be used by another activity.
- The results of an activity must not be used as a support of the same activity.
- All relationships existing in the grid must appear on the net.

(Source GRAI Rules, 1991)

Decisional Constraints: These constraints represent the limitation of the decision. The decision maker should consider the constraints before performing the decision.

For the convenience of the decision maker and to explain the terminology used in the questionnaire, block diagrams and an example of a GRAI net can be illustrated at the end of questionnaire-3. It is worth noting that some decision makers may be involved in more than one decision. The questionnaires must be delivered according to the number of decisions made.

Step-18: Collect Questionnaire-3 from all the Decision Makers

This step involves the collection of the questionnaire from each decision maker. The analyst should confirm that all relevant questions have been answered before collection and provide assistance where required.

Step-19: Draw the GRAI Net for each Decision Centre

After collecting all the necessary information from questionnaire-3, the analyst draws the GRAI net for each decision centre. An example of the GRAI net is illustrated in Figure 6.4 and summary of the diagrammatic representation used in the GRAI net is shown in Table-6C.

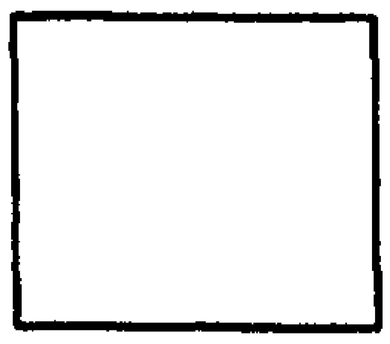
Step-20: Validate the GRAI Net

The GRAI net produced should be validated by the decision maker. If changes are required, the analyst must redraw and revalidate it until the decision maker agrees.

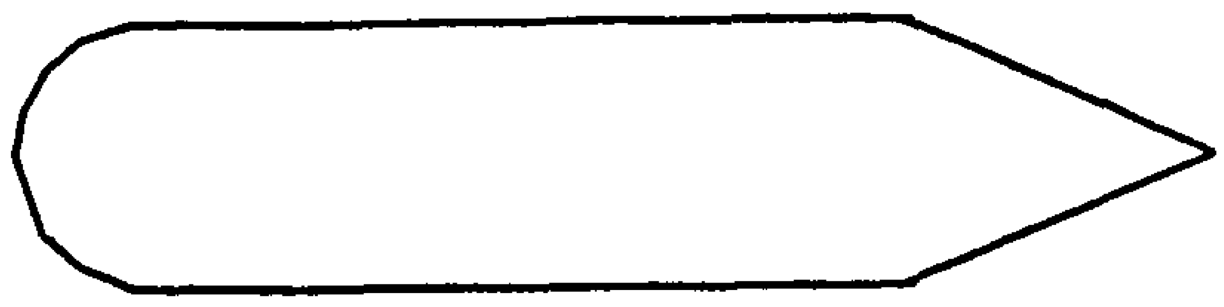
Step-21: Analysis of GRAI Net

This is the analysis of the information obtained using the rules related to the GRAI net shown in Table-6B. The rules analyse each decision centre in detail for:

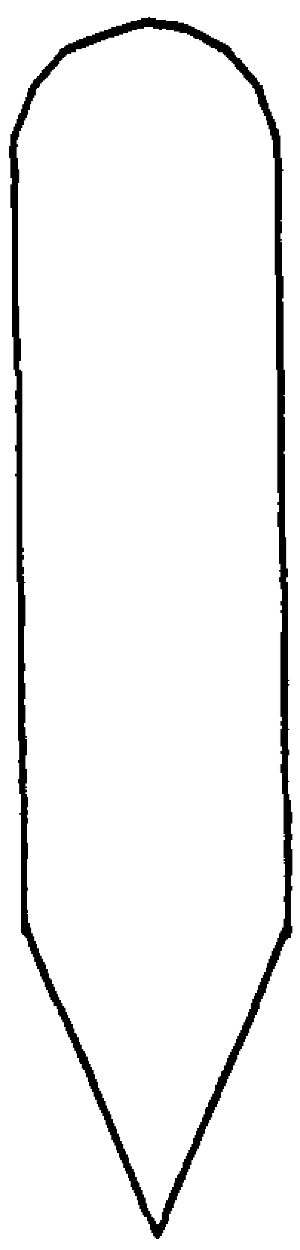
Table-6C Summary of Diagrammatic Representation Used on the GRAI Nets



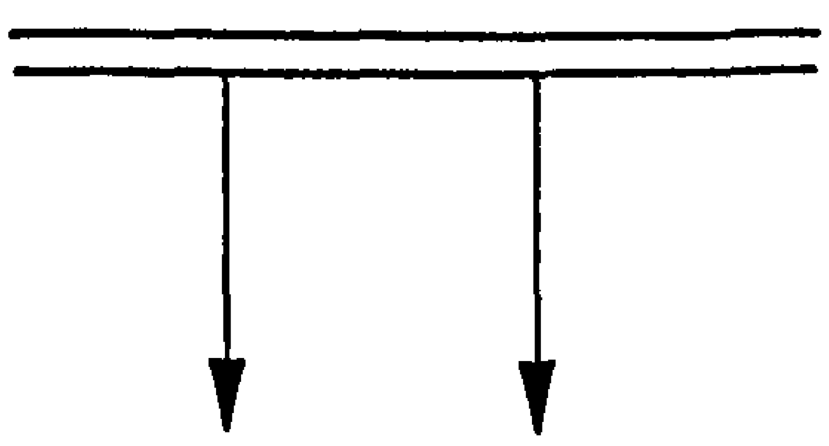
The square represents support, input and output



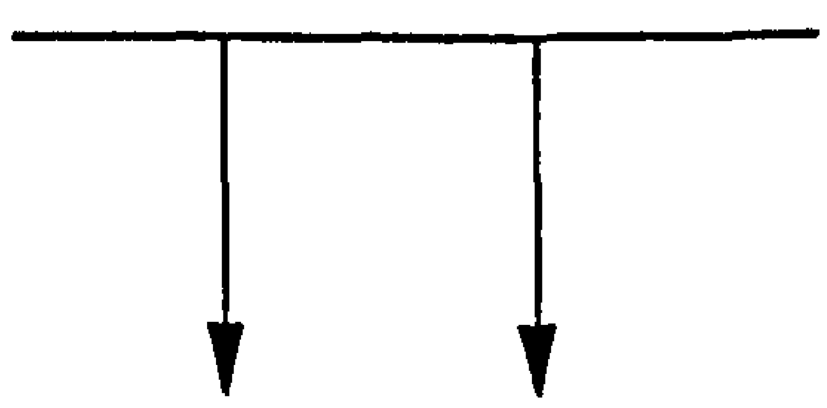
This symbol represents an executing activity



This symbol represents decisional activity



This symbol represents the logic AND operator



This symbol represents the logic OR operator

(Source GRAI Rules, 1991)

- the specific or particular decision made in each decision centre
- any constraints, variables or criteria used to make the decision
- whether the information required is used to make the decision
- the rules between the inputs and outputs
- the frame of the decision
- the flow of the decision and the associated information
- the level of the decision centre

i) Analyse Horizon and Review Period

The analysis checks that the horizon and review period of a particular decision centre are matched to the GRAI grid. The horizons and review periods are then checked for suitability to the particular decision.

ii) Analyse the Executing Activities

This analysis is carried out to check whether all the executing activities performed by the decision maker are appropriate to the decision made. The suitability of the information or supports used to perform the related activities is also checked.

iii) Analyse Decisions

The analysis examines whether the decision made is suitable to the particular function or environment, and how it affects the system. It also verifies that the objectives and constraints are defined and the decision made accordingly. Furthermore it critically examines whether the correct information and support activities are used to perform the decision.

iv) Make the List of Inconsistencies

The analyst compiles a list of all the inconsistencies observed. Any weaknesses and the strengths of the system are identified. This information should then be verified by the synthesis group.

Step-22: Design Phase

The design phase aims to solve the inconsistencies and weaknesses identified during the analysis phase. This begins from two points:

- The economic and technical objectives set by the synthesis group
- The list of inconsistencies identified

The design phase has two steps:

- A frame is drawn using the GRAI grid tool to represent the new structure of the manufacturing management system.
- The decisional frame of each decision centre is constructed using the GRAI net tool. The nets show the detailed activities of each decision centre at different levels.

The design phase of the method is based upon the two conceptual models of the GRAI: macro structure and micro structure. These models guide the designer to resolve the inconsistencies in the context of company specific objectives and the environment. The result of the design phase is a set of GRAI grids and nets that define the new or modified manufacturing management system.

i) Draw Modified GRAI Grid

The designer draws the modified or new GRAI grid using the rules listed in Table 6A.

ii) Validate the GRAI Grid

The designer should validate the modified GRAI grid with the synthesis group. If the group agrees the corresponding GRAI nets can then be produced.

iii) Draw the Modified GRAI Nets

After the GRAI grid is approved, the analyst designs the GRAI nets for each decision centre shown in the GRAI grid. The analyst should follow the rules related to the GRAI net (see Table 6B) and attention should be paid to information provided by the decision centre regarding decision making.

iv) Validate the GRAI Nets

The designer should validate each GRAI net with the decision maker. When all the members of the synthesis group have agreed, the design can be implemented.

Step-23: Implementation

The objective of this step is to obtain a fully documented and operational system. The models of the GRAI grid and nets should not be operational until proven to be free from error and the synthesis group familiar with its operation. This is employed throughout the testing and implementation phase.

Guidelines for the model testing are to:

- Test the GRAI grid
- Test each GRAI net separately
- Use live data as well as test data
- Perform parallel runs before going solo
- Test the GRAI grid and its related nets as a unit
- Allow the synthesis group to test the system

The best way to test the model is by carrying out a pilot study. First the model should be implemented to one department or section of the organisation, to see if results run successfully over the desired period. If so, the full implementation should be recommended.

Step-24: Evaluation of the Models

The evaluation step takes place after the system has been running error free for the desired period. The purposes of this step are:

- To examine the efficiency of the model to see where improvements can be made
- To compare the results of the models with the manufacturing objectives
- For the analyst to evaluate the feedback received in order to benefit from identifying both good and bad points within the model.

The feedback session with the synthesis group is used to check the consistency of the model. The analyst should examine the performance with respect to the following aspects:

- Synthesis group satisfaction
- Error rates
- Problem areas

Any significant variances should be investigated to determine the cause. In this way, areas for improvement can be swiftly identified. The findings of the evaluation should be documented and achievements of the system, together with recommendations for improvements summarised. Once the analyst has identified the areas for improvement, the relevant GRAI nets or grid should be modified.

6.3 CONCLUSIONS

A thorough analysis of an existing system and careful design for the future must precede the transformation of present day companies in the manufacturing environment. Such a task cannot be successful without a systematic and comprehensive methodology, which allows manufacturing functions, decision centres and their relationships to be identified prior to the creation of a new and improved model. The GRAI method is such a methodology. The existing methodology used to apply the GRAI method, however has a number of shortcomings as detailed in Chapter 4. Nevertheless, it provides a sound base which can be utilised for the study and improvement of manufacturing management systems.

The methodology to apply the GRAI method was developed. The objectives of this development were:

1. To remove shortcomings from the existing method
2. To provide guidelines to the user to ease its application and interpretation.

Interview techniques have been formulated and as a result a series of questionnaires were developed. The objective of the questionnaires is to remove any subjectivity within the interview and therefore maintain a consistent application of the methodology. The questionnaires cover all the aspects of the analysis of the system.

The methodology developed provides a systematic approach towards the analysis and the design of manufacturing management systems. The next step is validation of the methodology using a case study.

CHAPTER-7

VALIDATION OF THE METHODOLOGY TO APPLY THE GRAI METHOD

7.1 INTRODUCTION

This Chapter presents the validation of the methodology developed in Chapter-6 to apply the GRAI method using a case study. The manufacturing organisation selected is a mainly 'make-to-stock' company, Edward Pryor Ltd., situated in Sheffield. The objectives of the case study are:

1. to validate the methodology developed
2. to obtain feedback specifically regarding the questionnaires developed and to test that they successfully structure interviews
3. to identify any inconsistencies within the management system
4. to present a solution for any inconsistencies identified

The Company is divided into three Divisions which work independently. The new methodology has been applied to the existing management system of one of the Divisions of the Company. As a result of the application, the GRAI grid and GRAI nets have been drawn. An analysis of the GRAI grid and the GRAI nets has been carried out and validated. Several inconsistencies within the system were identified.

Consequently, modifications to the system are presented in the form of modified GRAI grid and GRAI nets.

The research found that this methodology easy to use and can be applied to any manufacturing management system. It was also found that the questionnaires are more effective than interviews. The methodology resolves the problems of interview subjectivity and presents a new systematic approach to the modelling of a manufacturing management system.

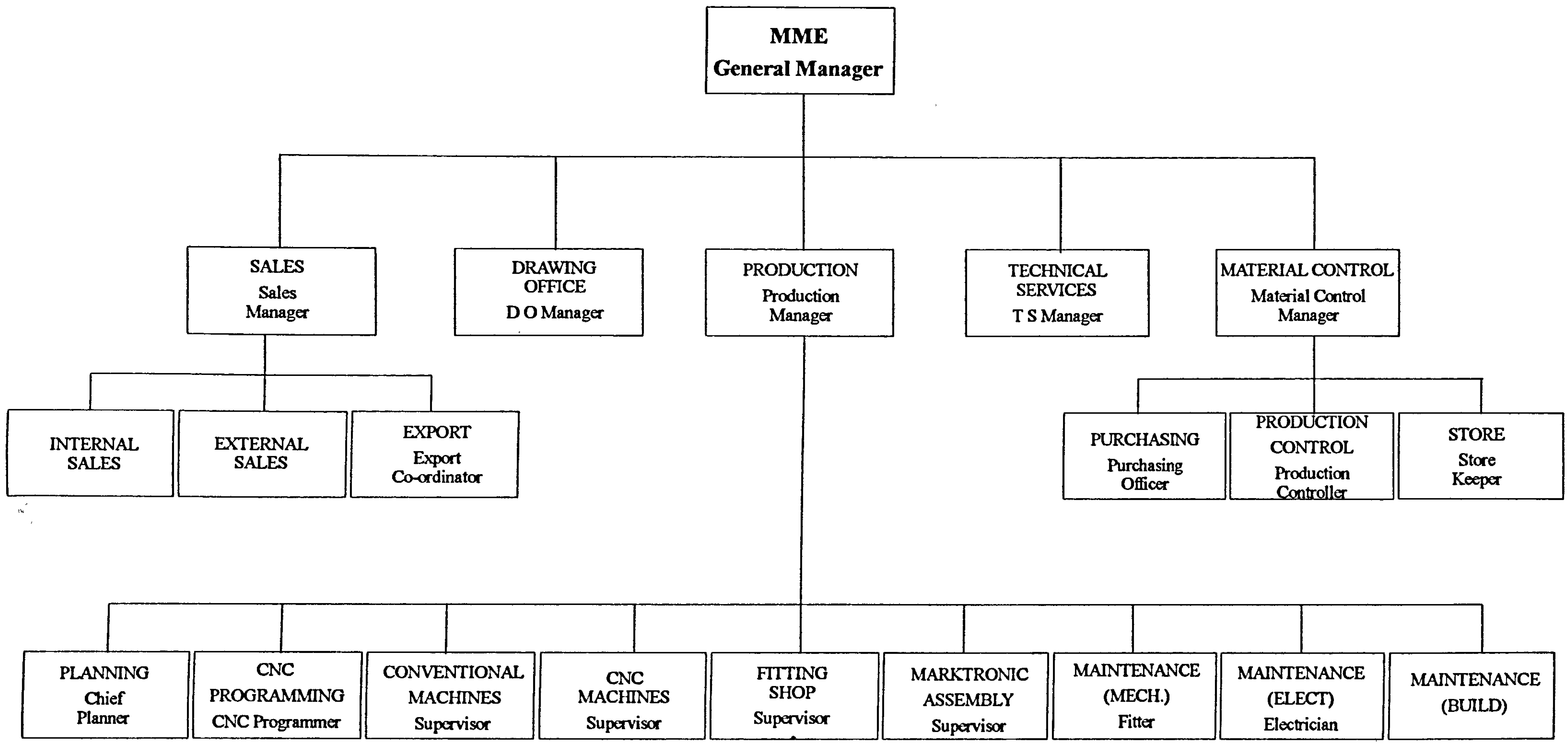
7.2 APPLICATION OF THE METHODOLOGY

The application of the methodology to apply the GRAI method consists of several steps as detailed in Chapter 6. It is the combination of a top-down and bottom-up approach and has two phases which are: analysis and design. The application is structured using well-defined procedures, beginning with the collection of information relating to the existing system using the top-down approach. The GRAI grid can then be constructed. Here it is necessary to determine the contents of the GRAI grid such as the horizons and review periods, information, decision centres and the decisional links between decision centres. The bottom-up approach is used to drawn the GRAI nets of the decision centres identified. Here it is necessary to identify the contents of the GRAI net such as its activities, supports, decisional variables, decisional constraints and decisional objectives.

Once the analysis phase is complete, the design phase begins with the examination of any inconsistencies identified during the analysis phase. The objectives of the design phase are to remove inconsistencies from the system and present a modified system.

7.2.1 Introduction to the Company

Edward Pryor & Son Ltd. was established in 1849, and has grown from a family engraving business. The Company operates mainly as a 'make-to-stock' and



TITLE: MANAGEMENT HIERARCHY	DRAWN BY: M A CHODARI	DATE: 12-4-1996	INDEX: 1/1
COMPANY: EDWARD PRYOR & SON LTD. (MME GROUP)	VALIDATE BY: General Manager	DATE: 15-4-1996	

Figure 7.1 Organisational Structure

manufactures dies, assay markers, standard punches and types. The turnover of the Company is £10M per year and it shares 50% of the UK market. The Company exports 50% of its output to European countries and the USA. The Company ranks as one of the largest marking equipment suppliers in the world. It is situated in Sheffield because the marking industry has been closely allied to the steel industry and is generally found in the same geographical areas. The Company has 250 employees and achieved BS5750 part 1 accreditation in 1993.

7.2.1.1 Organisational Structure

In 1991 the UK operation of the Company was formally Divisionalised into three business units which are MME (Machinery Division), Consumables and Signage. MME and Consumable are situated in Sheffield, whilst Signage is situated in Rotherham. The turnover of each Division is approximately £3.5 M. The General Manager of each Division is responsible for the production of a business plan, including a strategy for the development of the Division's business to achieve around 15% return on sales within 3 years. Each Division is responsible for its own performance and acts as an independent organisation.

For the case study one Division of the Company was selected, the MME Division. The turnover of the Division is approximately £3.5 M and it has 80 employees including 50 direct and 30 indirect employees. The direct workforce of the Division is divided into 50% skilled, 30% semiskilled and 20% unskilled. The wage system operates on an hourly basis with operators paid weekly. The main product of the MME Division is the family of computerised Dot Marker products called Marktronics. The organisational structure of the MME Division in shown in Figure 7.1.

7.2.1.2 Layout of the Division

The shops layout of the Division is shown in Table 7.1.

Section	Layout
Conventional Machines	Process
CNC Machines	Process
Fitting Shop	Process
Marktronic Assembly	Product

Table 7.1 Layout of the Sections.

7.2.2 Identification of the Synthesis Group

The synthesis group was chosen from the management structure (Figure 7.1). The group chosen is shown in Table 7.2. As previously described, the synthesis group consists of management staff who are involved in decision making, or are responsible for their working areas. Normally these people are the heads of the departments or sections.

No	Department/Section	Job Title
1	M M E	General Manager
2	Sales	Sales Manager
3	Production	Production Manager
4	Drawing Office	D O Manager
5	Technical Services	T S Manager
6	Material Control	Material Control Manager
7	Purchasing	Purchasing Officer
8	Material Control	Store Keeper
9	Production Control	Production Controller
10	Production Planning	Senior Planner
11	Conventional Machines	Supervisor
12	CNC Machines	Supervisor
13	Fitting Shop	Supervisor
14	Marktronics	Supervisor

Table 7.2 Synthesis Group of the Division.

First the author met all the members of the synthesis group individually for approximately thirty minutes. In each session, the GRAI method, its purposes and operation were explained. At the end of each session questionnaire-2 (Ref. Appendix) was distributed to each member of the group. Two members of the synthesis group refused to participate in the exercise. The reason for this was the resistance to change in their working areas. They were satisfied with current working practises because, in their opinion, there were no perceivable problems and they did not want any external help. For this reason, the group was reduced to fourteen members, as shown in Table 7.2. (The fact that these two members were allowed to withdraw was an indication of the management control within the Company. The information relating to the working area of these staff members was obtained from the General Manager.)

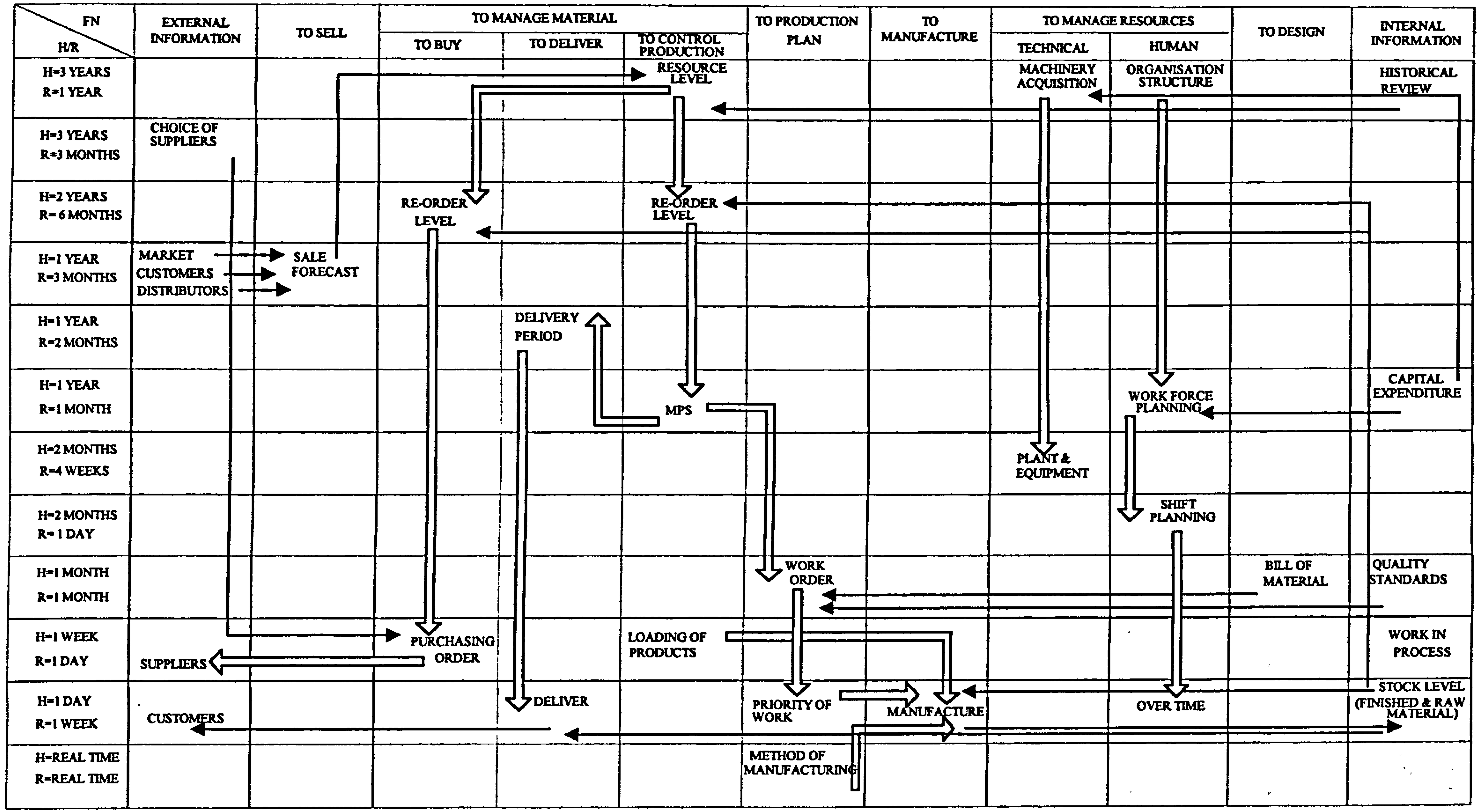
7.2.3 Identification of the Functions

The following functions of the Division were identified:

- To Sell
- To Manage Material
    - To Buy
    - To Deliver
    - To Control Production
- To Production Plan
- To Manufacture
- To Manage Resources
    - Technical
    - Human

7.2.4 Identification of the Horizons and Review Periods

Horizons and review periods of the decisions identified are shown in the Table 7.3.



TITLE: GRAI GRID	DRAWN BY: M A CHODARI	DATE: 26-5-1996	INDEX: 1/1
COMPANY: EDWARD PRYOR & SON LTD	VALIDATE BY: MR MIKE BROOK (G MANAGER)	DATE: 28-5-1996	

FIGURE 7.2 GRAI GRID OF THE MANUFACTURING MANAGEMENT SYSTEM OF THE DIVISION

No	Department/Section	Job Title	Decision	Horizon	Review Period
1	MME	General. Manager	Resource Level	3 Yr.	1 Yr.
2	MME	General Manager	Machinery Acquisition	3 Yr.	1 Yr.
3	MME	General Manager	Organisation Structure	3 Yr.	1 Yr.
4	Technical Services	T.S. Manager	Software Purchasing	4 Wk.	1 Wk.
5	Technical Services	T.S. Manager	Project Management	6-12 M	2 Wk-1M
6	Technical Services	T.S. Manager	Potential Order	3 M	1 M
7	Sales	Sales Manager	Sales Forecast	1 Yr.	3 M
8	Sales	Sales Manager	Personnel Training	1 Yr.	6 M
9	Sales	Sales Manager	Daily Routine Matters	1 Wk.	RT.
10	Sales	Sales Manager	Choice of Advertising	1 Yr.	6 M
11	Production	Production Manager	Work Overtime	1 Day	1 Wk.
12	Production	Production Manager	Priority of Work	1 Day	1 Wk.
13	Production	Production Manager	Workforce Planning	1 Yr.	1 M
14	Production	Production Manager	Capital Expenditure	1 Yr.	1 M
15	Material Control	M. C. Manager	MPS	1 Yr.	1 M
16	Material Control	M. C. Manager	Re-order Level	2 Yr.	6 M
17	Material Control	M. C. Manager	Delivery Period	1 Yr.	2 M
18	Purchasing	Purchasing Officer	Choice of Supplier	3 Yr.	3 M
19	Production Control	Production Controller	Loading of Products	1 Wk.	1 Day
20	Production Planning	Senior Planner	Work Order	1 M	1 M
21	Machine Shop	Supervisor	Shift Planning	2 M	1 Day
22	Machine Shop	Supervisor	Method of Manufacturing	RT.	RT.
23	Machine Shop	Supervisor	CNC Programming	1 Day	RT.
24	Machine Shop	Supervisor	Plant & Equipment	2 M	4 Wk.

Table 7.3 Horizons and Review Periods

7.2.5 Identification of Decisional and Informational links

From the sections of information on work and work instruction, the decisional and informational links were identified (Figure 7.2).

7.2.6 Construction of the GRAI Grid

Following the initial collection of data from questionnaire-2, concerning functions, horizons and review periods and rules relating to the GRAI grid construction, the GRAI grid was drawn. After a few iterations, the GRAI grid was validated by the Co-ordinator as shown in Figure 7.2. The Following activities and decisions were not considered for the GRAI grid: software purchasing, project management, potential order, personnel training, daily routine matter and choice of advertisement. The

A SUMMARY OF RULES RELATED TO GRAI METHOD

Table 7A: Rules Related to GRAI Grid

- Horizon and time period must be unique for each level.
- The horizon of any level must be equal to at least two periods of the level below.
- The levels are classified by decreasing periods, and for equal periods, decreasing horizons.
- There must be at least three levels relating to strategic, tactical and operational decisions.
- A function must contain at least one decision centre.
- A level must contain at least one decision centre.
- At any given level, the horizon must be longer than review period.
- The horizon of a decision making activity must be greater than the longest cycle of the activities which decision centre controls.
- Each level of decision must generate an action at one decision frame at lower level.
- Each decision making activity centre must receive a decision frame from an activity centre on the same or higher level.
- A decision making activity centre must not be isolated on a grid, but must be linked to at least one other activity centre.
- Every decision making activity centre must transmit a decision frame to one or more decision making activity centres on the same or lower levels, except those on the bottom level, which generate work instructions.
- Every decision making activity centre should only receive one decision frame. If more than one is received their objectives must be checked for conflict. The resources of the decision frames must also be checked.
- A decision frame should not go from a lower level to higher level.
- Every activity centre which generates a decision frame must contain a decision making activity centre.
- An activity centre should not receive a decision frame from a function which concerns basic elements (resources, products, time) not considered by the function containing that activity centre.
- A structure is coherent if all elements seek to satisfy the objectives of the overall system. Each decision frame should be linked by information chains and have similar origins.

(Source GRAI Rules, 1991)

reason for this is that the decision made by the technical services such as software purchasing, is an activity of the purchasing department; potential order is an activity of the sales department and project management is only incurred with certain software products which are developed in-house. Similarly, personnel training and choice of advertisement are not activities of manufacturing management systems.

7.2.7 Analysis of the GRAI Grid

This analysis is based on the top-down approach and was carried out according to the rules relating the to GRAI grid (Table-7A). The objective of the analysis was to identify the elements and the organisation of the manufacturing management system. This identifies any inconsistencies within the existing system.

7.2.7.1 Analysis of Functions

This is the analysis of the basic functions within the Division. The analysis examines whether decision or activities performed are appropriate to the function. All the basic functions of the manufacturing system were identified. The Master Production Schedule is identified on a yearly basis but it does not exist in reality because the Division operates on a re-order level. There is no information available for the quality and design functions. The design function is only active when the order for a special product arrives from the sales department. Although the Company spends a small, undisclosed percentage of the returns on research, no separate research and development function exists within the Division. The production planning and the production control functions perform similar types of planning, which leads to some confusion between the functions.

7.2.7.2 Analysis of Horizons and Review Periods

- Many horizons and review periods have been identified. In reality most of the members of the management team were unaware of all the horizon and review periods, because most of the decisions are non-structured and made in real time.

- No formulation between the horizon and the review periods was identified.
- The formal establishment of a horizon and review period only exists at the strategic level. No others were identified.
- At row-9 of the GRAI grid (Figure 7.2) the review period is the same as the horizon.
- At row-10 of the GRAI grid (Figure 7.2) the horizon is 1 day and the review period is 1 week. This does not agree with the GRAI rules (Table-7A).

7.2.7.3 Analysis of Information

- No proper utilisation of external and internal information was identified.
- Poor co-ordination between the departments was identified.
- No formal meetings with subordinates were found.
- No information regarding Work-in-Progress was identified.

7.2.7.4 Analysis of the Decision Links

- The decisional link from the decision centre "MPS" is flowing towards the decision centre of "delivery period" (Figure 7.2). This breaks the GRAI grid rule (Table-7A), which states that decisional links should always flow to a lower level.
- Similarly the decisional link of the decision centre "method of manufacturing" is flowing towards the decision centre termed "manufacturing" (Figure 7.2). This again breaks the GRAI grid rule (Table-7A), which states that decisional links must always flow downwards.

7.2.8 Identification of Decision Makers and Decisions

From the GRAI grid (Figure 7.2) the following decision makers and decisions were identified (Table 7.4)

Table 7B: Rules Related to GRAI Net

- Every piece of information sent by a net, must appear somewhere in another net.
- The support of a decision making activity must include an objective, some constraints, and some decisional variables.
- The decision variables are the parameters on which the decision is based.
- Each activity must have a unique label in the same net.
- Each activity must produce results.
- The results of a decisional activity must be used by another activity.
- The results of an activity must not be used as a support of the same activity.
- All relationships existing in the grid must appear on the net.

(Source GRAI Rules, 1991)

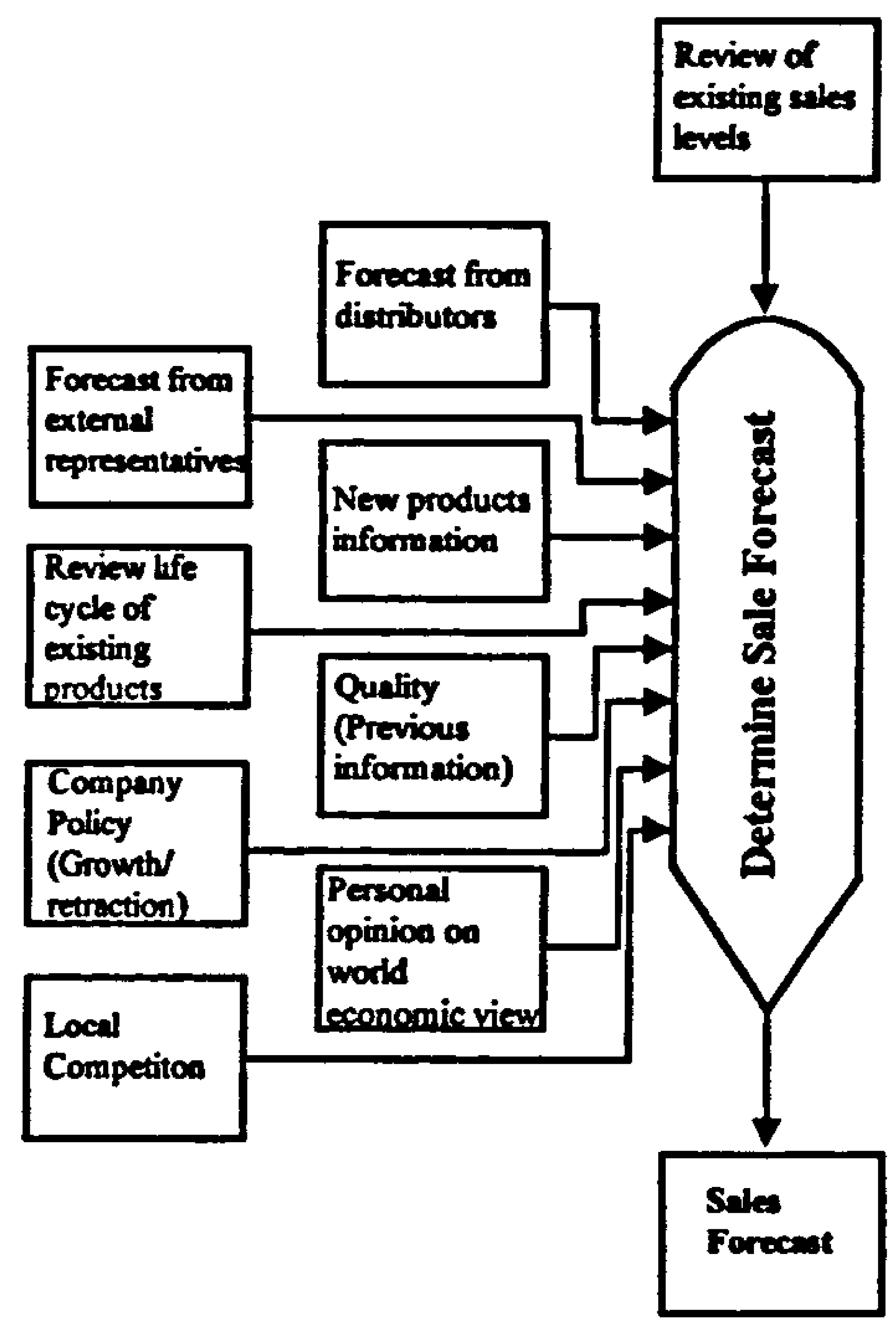
No	Function	Decision Maker	Decision	Horizon	Review Period
1	To Manage Material (To Control Production)	General. Manager	Resource Level	3 Yr.	1 Yr.
2	To Manage Resources (Technical)	General Manager	Machinery Acquisition	3 Yr.	1 Yr.
3	To Manage Resources (Human)	General Manager	Organisation Structure	3 Yr.	1 Yr.
4	To Manage Material (To Buy)	M. C. Manager	Re-order Level (Raw Material)	2 Yr.	6 M
5	To Manage Material (To Control Production)	M. C. Manager	Re-order Level (Finished Products)	2 Yr.	6 M
6	To Sell	Sales Manager	Sales Forecast	1 Yr.	3 M
7	To Manage Material (To Deliver)	M. C. Manager	Delivery Period	1 Yr.	2 M
8	To Manage Material (To Control Production)	M. C. Manager	MPS	1 Yr.	1 M
9	To Manage Resources (Human)	Production Manager	Workforce Planning	1 Yr.	1 M
10	To Manage Resources (Technical)	Supervisor	Plant & Equipment	2 M	4 Wk.
11	To Manage Resources (Human)	Supervisor	Shift Planning	2 M	1 Day
12	To Production Plan	Senior Planner	Work Order	1 M	1 M
13	To Manage Material (To Buy)	Purchasing Officer	Purchasing Orders	1 Wk	1 Day
14	To Manage Material (To Control Production)	Production Controller	Loading of Products	1 Wk.	1 Day
15	To Production Plan	Production Manager	Priority of Work	1 Day	1 Wk.
16	To Manage Resources (Human)	Production Manager	Work Overtime	1 Day	1 Wk.
17	To Production Plan	Supervisor	Method of Manufacturing	RT.	RT.

Table 7.4 List of decision makers and decisions identified

After identification of the decisions and decision makers, questionnaire-3 (Ref. Appendix) was delivered to all decision makers. This questionnaire focuses on all the decision making activities.

7.2.9 Collection of Questionnaire-3

The questionnaires were collected from the synthesis group, but several members did not understand the questionnaire completely. To solve this problem, the author met them individually and explained the questionnaire.



TITLE: SALES FORECAST	FUNCTION: TO SELL	DRAWN BY: M A CHODARI	DATE: 14-6-1996	D C: (4,2)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=1 YEAR, R=3 MONTHS	VALIDATE BY: SALES MANAGER	DATE: 18-6-1996	INDEX: 1/1

Figure 7.3 GRAI Net for Sales Forecast

7.2.10 Construction of GRAI Net for each Decision Centre

After collecting all the relevant information such as horizons, review periods and functions, for each decision centre the GRAI nets were constructed and validated (Figures 7.3-7.17).

7.2.11 Analysis of the GRAI Nets

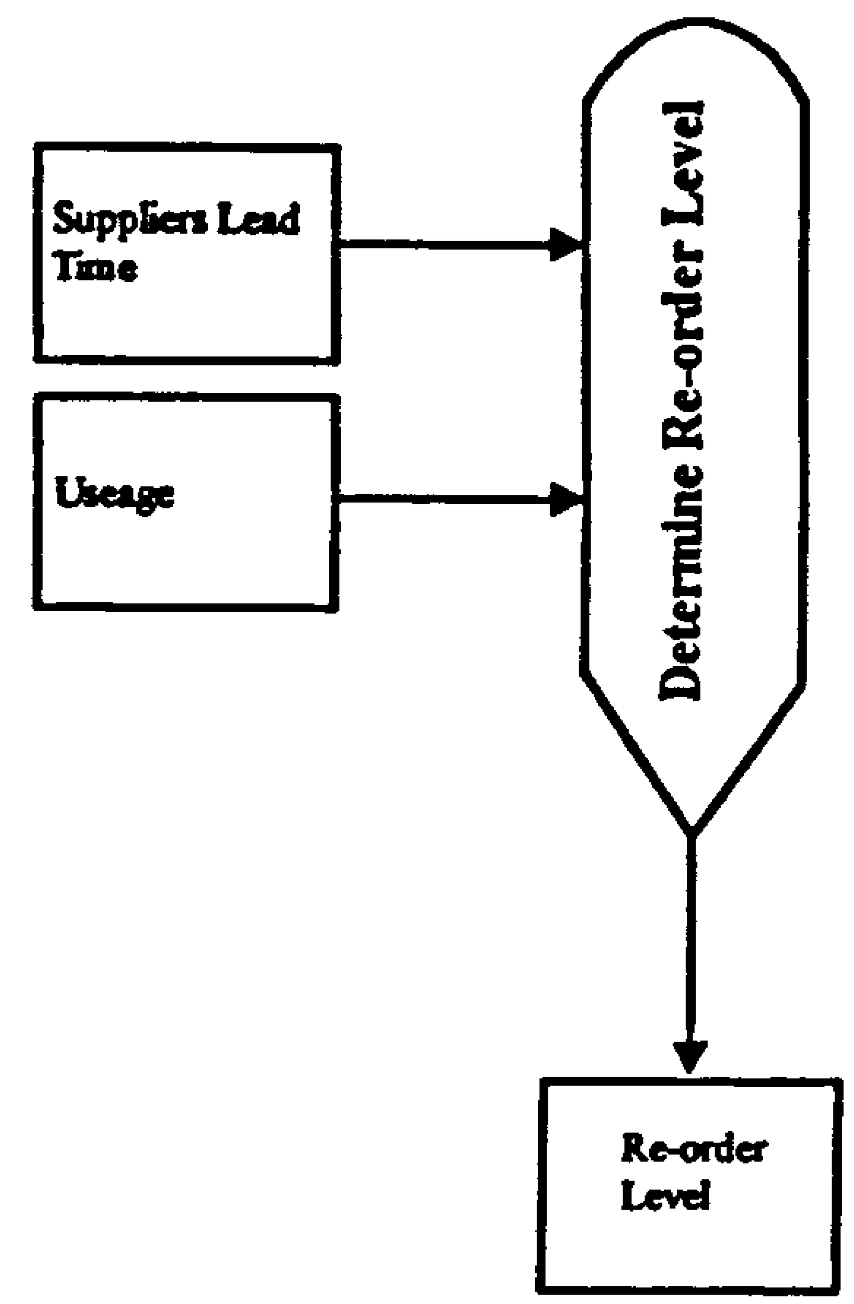
The analysis is carried out on the information provided by the GRAI net and the rules relating to GRAI nets shown in Table-7B.

Title: Sales Forecast
Function: To Sell
H/R: H=1 Year, R=3 Months

The GRAI net is shown in Figure 7.3. This net relates to the production of the annual sales forecast. It can be seen that there is no activity to support the decision identified. Similarly no decisional objectives, criteria or constraints have been identified. The decision is made using little information and no utilisation of market information or future trends.

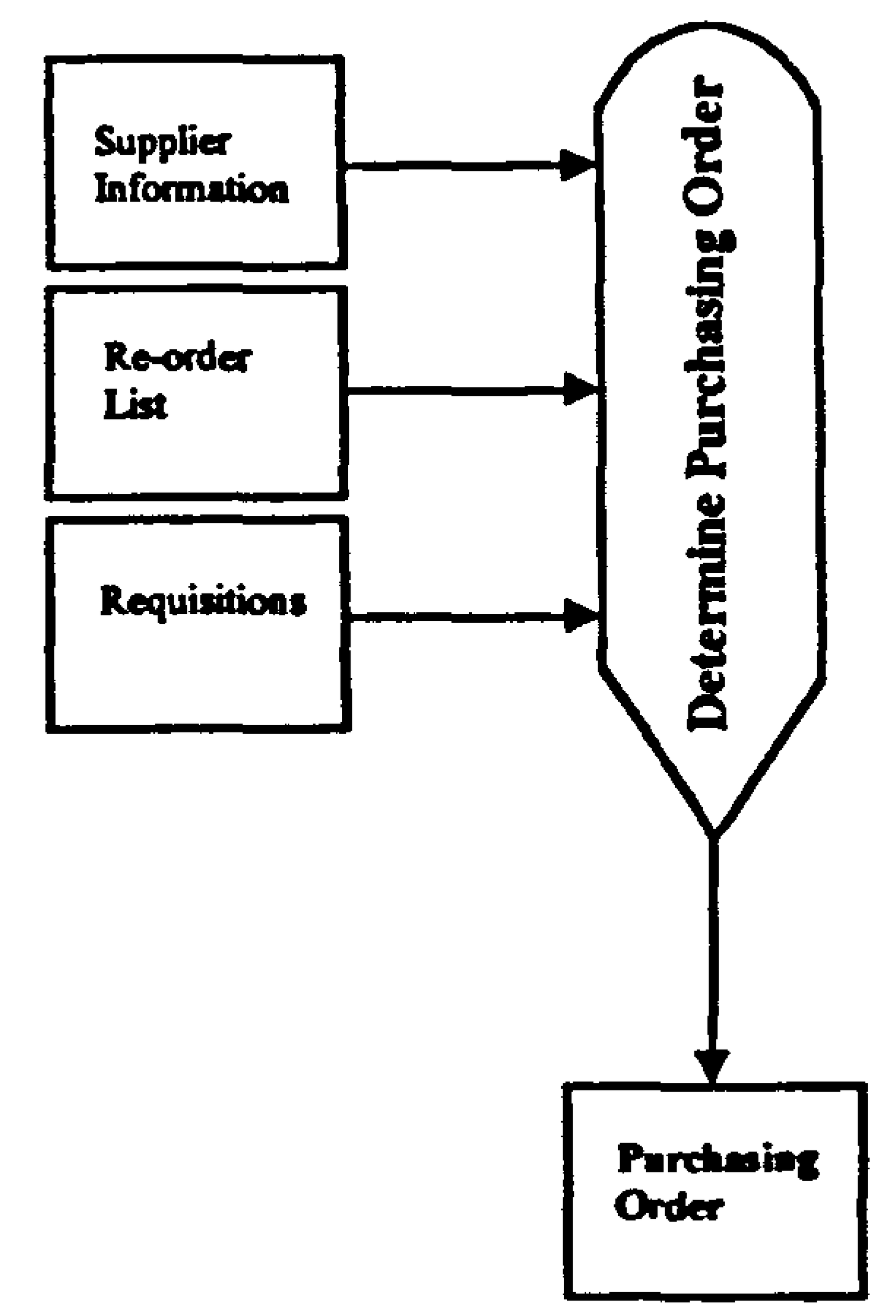
Title: Re-order Level (Raw material)
Function: To Manage Material (To Buy)
H/R: H=2 Year, R=6 Months

The GRAI net is shown in Figure 7.4. This GRAI net details the setting of the re-order level for the raw material. It can be seen that there is no activity to support the decision identified. Similarly no decisional objectives, criteria or constraints to perform the decision have been identified. Only two supports have used been to make the decision. No other relevant information, such as stock level and the "MPS" are considered.



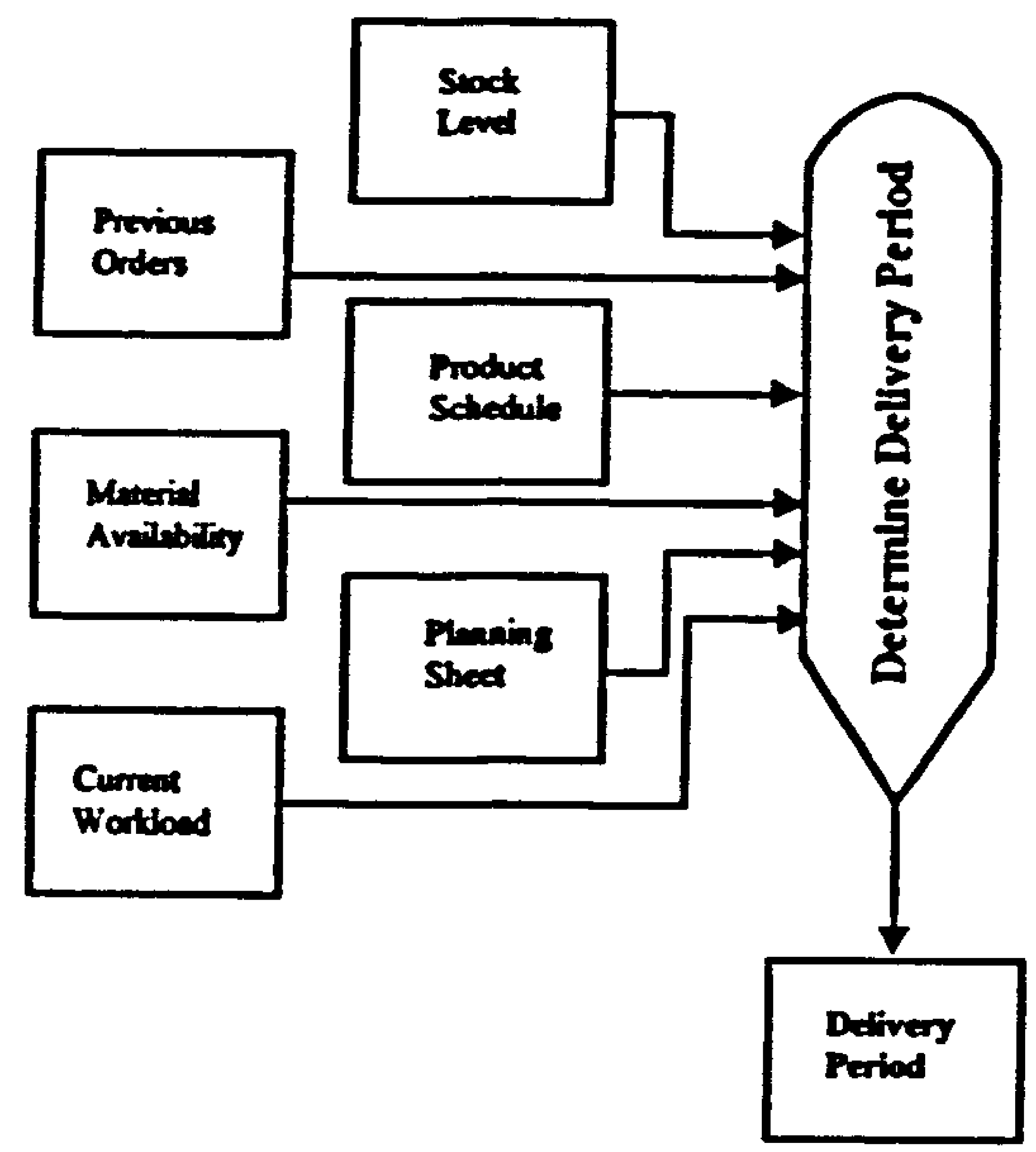
TITLE: RE-ORDER LEVEL	FUNCTION: TO MANAGE MATERIAL (TO BUY)	DRAWN BY: M A CHODARI	DATE: 14-6-1996	D C: (3,3)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=2 YEARS, R=6 MONTHS	VALIDATE BY: Material Control Manager	DATE: 18-6-1996	INDEX: 1/1

Figure 7.4 GRAI Net for Re-order Level (Raw Material)



TITLE: Purchasing Order	FUNCTION: To Manage Material (To Buy)	DRAWN BY: M A CHODARI	DATE: 14-6-1996	D C: (3,9)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=1 Week, R=1 Day	VALIDATE BY: Purchasing Officer	DATE: 18-6-1996	INDEX: 1/1

Figure 7.5 GRAI Net for Purchasing Order



TITLE: Delivery Period	FUNCTION: To Manage Material (To Deliver)	DRAWN BY: M A CHODARI	DATE: 14-6-1996	D C: (5,4)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=1 Year, R=2 Months	VALIDATE BY: Material Manager	DATE: 18-6-1996	INDEX: 1/1

Figure 7.6 GRAI Net for Delivery Period

Title: Purchasing Order
Function: To Manage Material (To Buy)
H/R: H=1 Week, R=1 Day

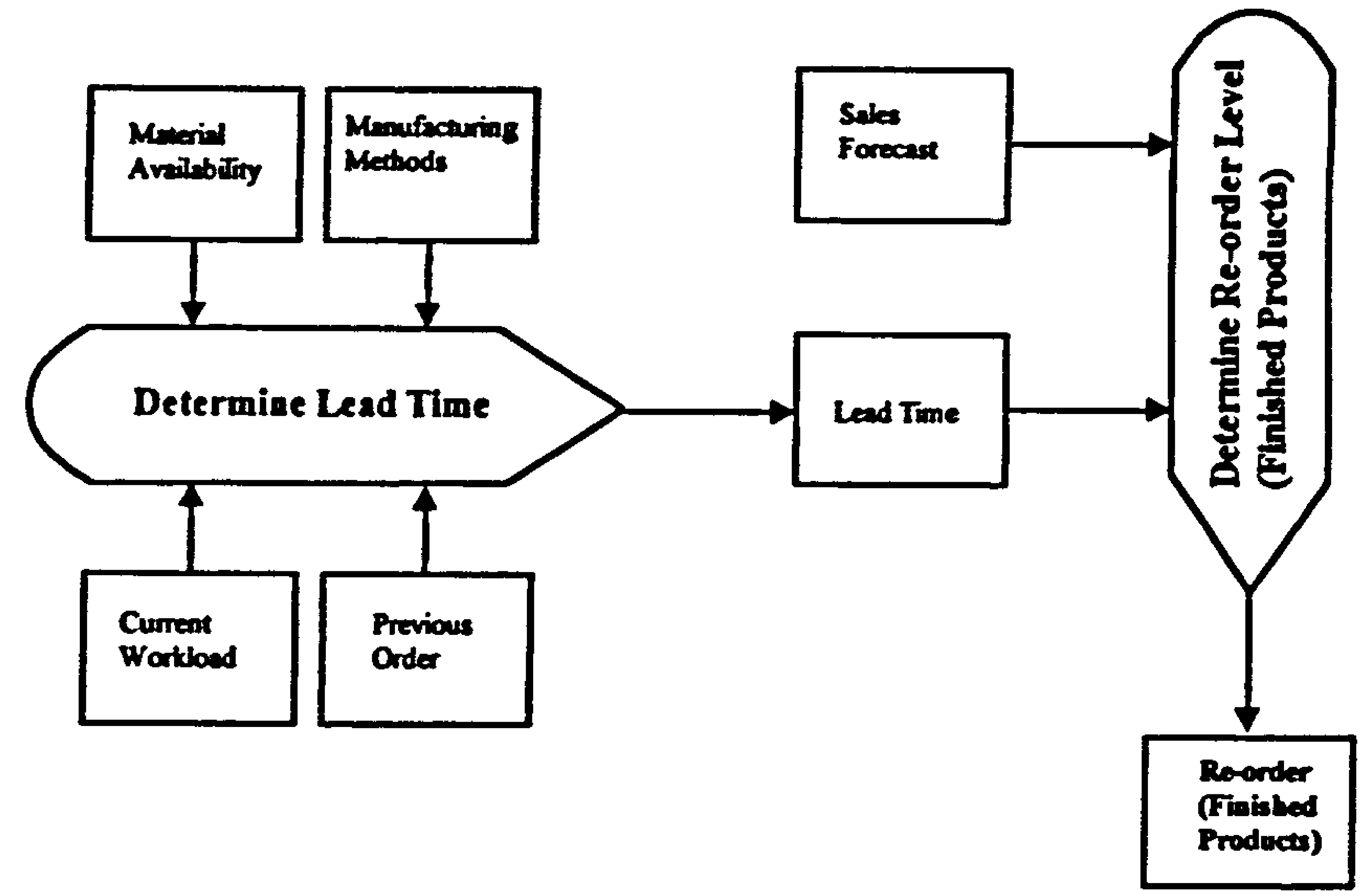
The GRAI net constructed shown in Figure 7.5 relates to the issuing of purchase orders. The MME Division works on the requisition system, but no activity to analyse the requisition has been identified. Only three types of supports or information (supplier information, re-order list and requisitions) are used to make this decision. No decisional objective, criteria or constraints were identified. No information of stock levels and lead times were observed. Furthermore the horizon of the decision is disproportionately short for the long lead items.

Title: Delivery Period
Function: To Manage Material (To Deliver)
H/R: H=1 Year, R=2 Months

The GRAI net drawn shown in Figure 7.6. and refers to the determination of the delivery period for finished products. No supporting activities to perform the decision were identified and no decisional objectives, and variables were observed. Limited support information is used to make the decision. No reference to sales forecasts, stock levels or customer orders was identified.

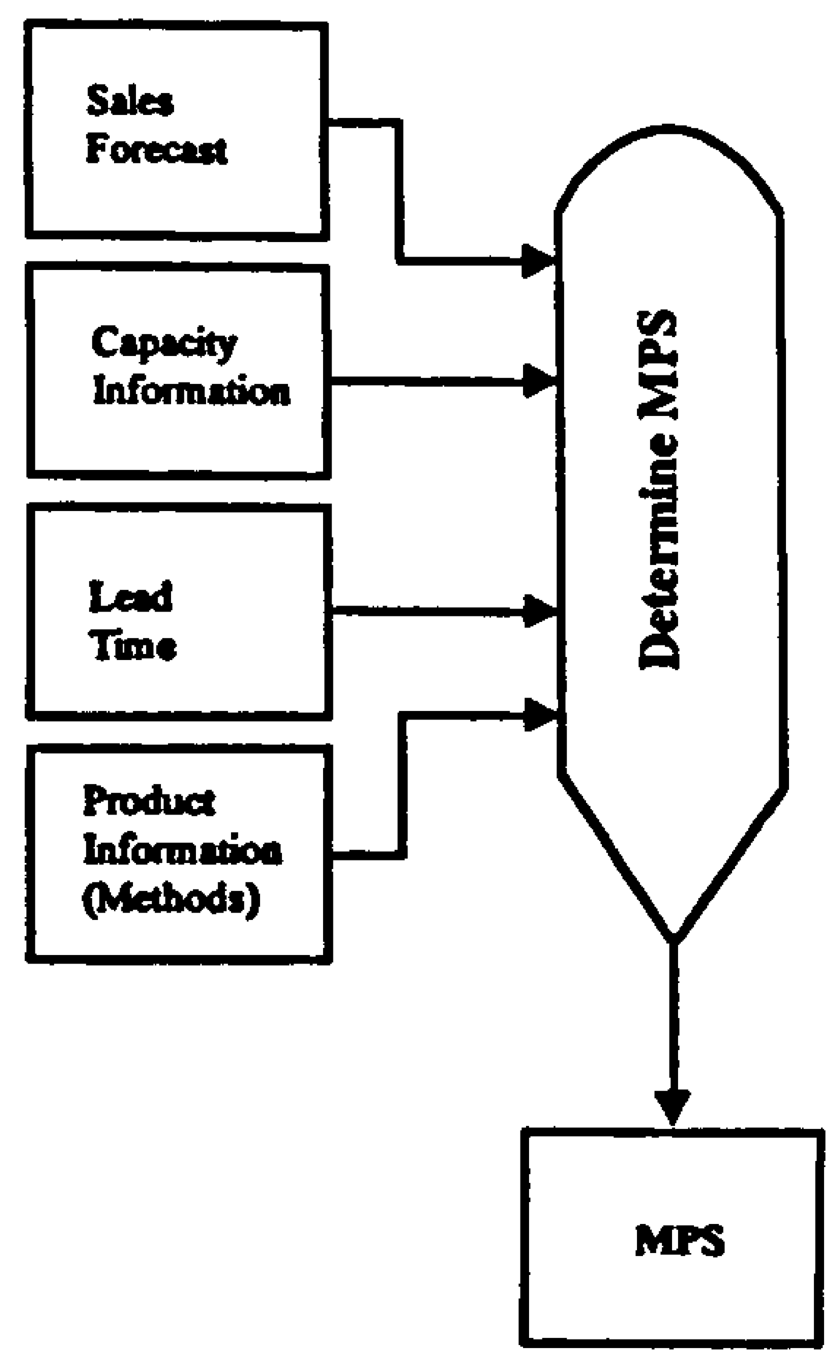
Title: Re-order level for finished products
Function: To Manage Material (To Control Production)
H/R: H=2 Year, R=6 Months

The GRAI net drawn shown in Figure 7.7 relates to the setting of the re-order levels for finished products. Only one activity that determines the lead time is used to perform the decision. No decisional objectives, variables or constraints have been identified. No other relevant information such as the current stock status, a historical review of stock level and the Company policy for holding inventory was identified as being used by the decision maker.



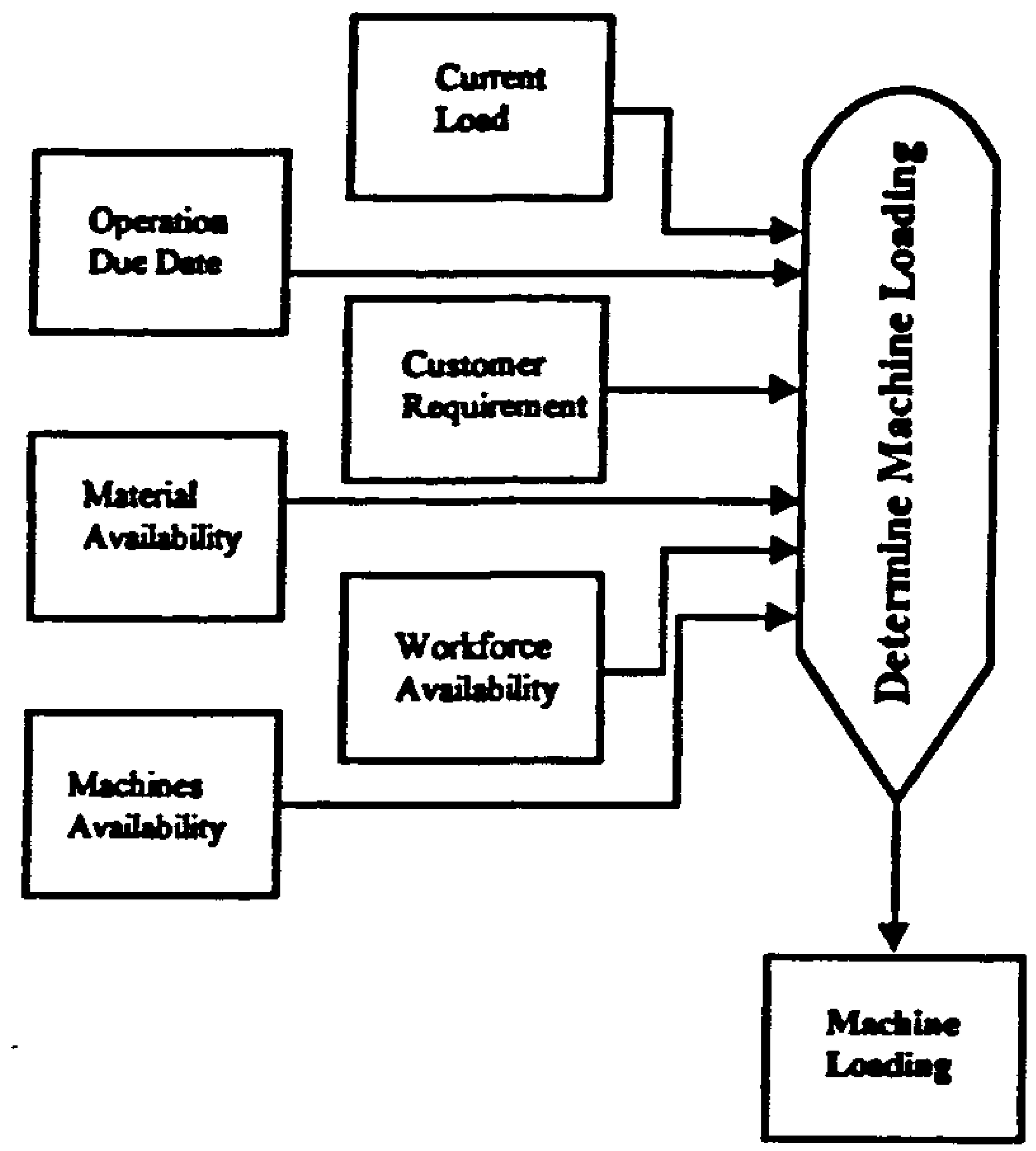
TITLE: Re-order Level For Finished Products	FUNCTION: To Manage Material (To Control Production)	DRAWN BY: M A CHODARI	DATE: 14-6-1996	D C: (3,5)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=2 Years, R=6 Months	VALIDATE BY: Material Control Manager	DATE: 18-6-1996	INDEX: 1/1

Figure 7.7 GRAI Net for Re-order Level (Finished Products)



TITLE: Master Production Plan	FUNCTION: To Manage Material (To Control Production)	DRAWN BY: M A CHODARI	DATE: 14-6-1996	D C: (6,5)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=1 Year, R=1 Month	VALIDATE BY: Material Manager	DATE: 18-6-1996	INDEX: 1/1

Figure 7.8 GRAI Net for MPS



TITLE: Machines Loading	FUNCTION: To Manage Material (To Production Control)	DRAWN BY: M A CHODARI	DATE: 14-6-1996	D C: (10,5)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=1 Week, R=1 Day	VALIDATE BY: Material Manager	DATE: 18-6-1996	INDEX: 1/1

Figure 7.9 GRAI Net for Machines Loading

Title: Master Production Schedule

Function: To Manage Material (To Control Production)

H/R: H=1 Year, R=1 Month

The GRAI net shown in Figure 7.8 refers to the annual formulation of the Master Production Schedule. In reality the MPS of the Division does not exist, although the Company has plans to develop this in the future. The reason for this is that the Division is based mainly on a re-ordering system. No supporting activity to perform this decision has been identified and little relevant information was used to make the decision. No decisional objectives, variables or constraints were identified.

Title: Machine Loading

Function: To Manage Material (To Control Production)

H/R: H=1 Week, R=1 Day

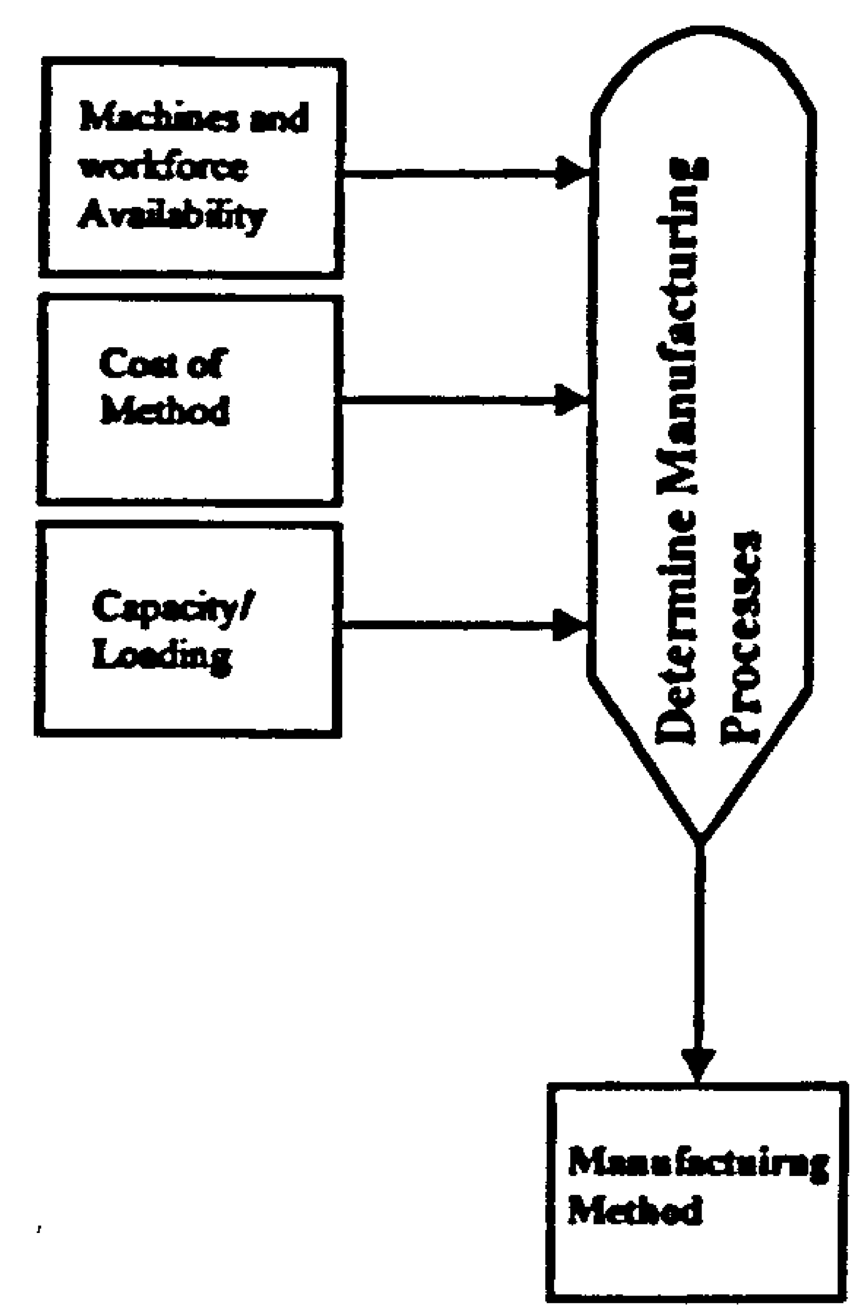
The GRAI net shown in Figure 7.9 relates to the issue of work orders. In reality, work orders are based on job "priority" and issued on a weekly basis. No supporting activity to make the priority was identified. Little information is used to support the decision. No decisional objectives, variables or constraints were identified. Similarly no utilisation of relevant information such as Work-in-Progress and urgent order requirements have been identified. A complex relationship between production control and production was observed, as production planning decisions are divided between these two departments.

Title: Work Order

Function: To Production Plan

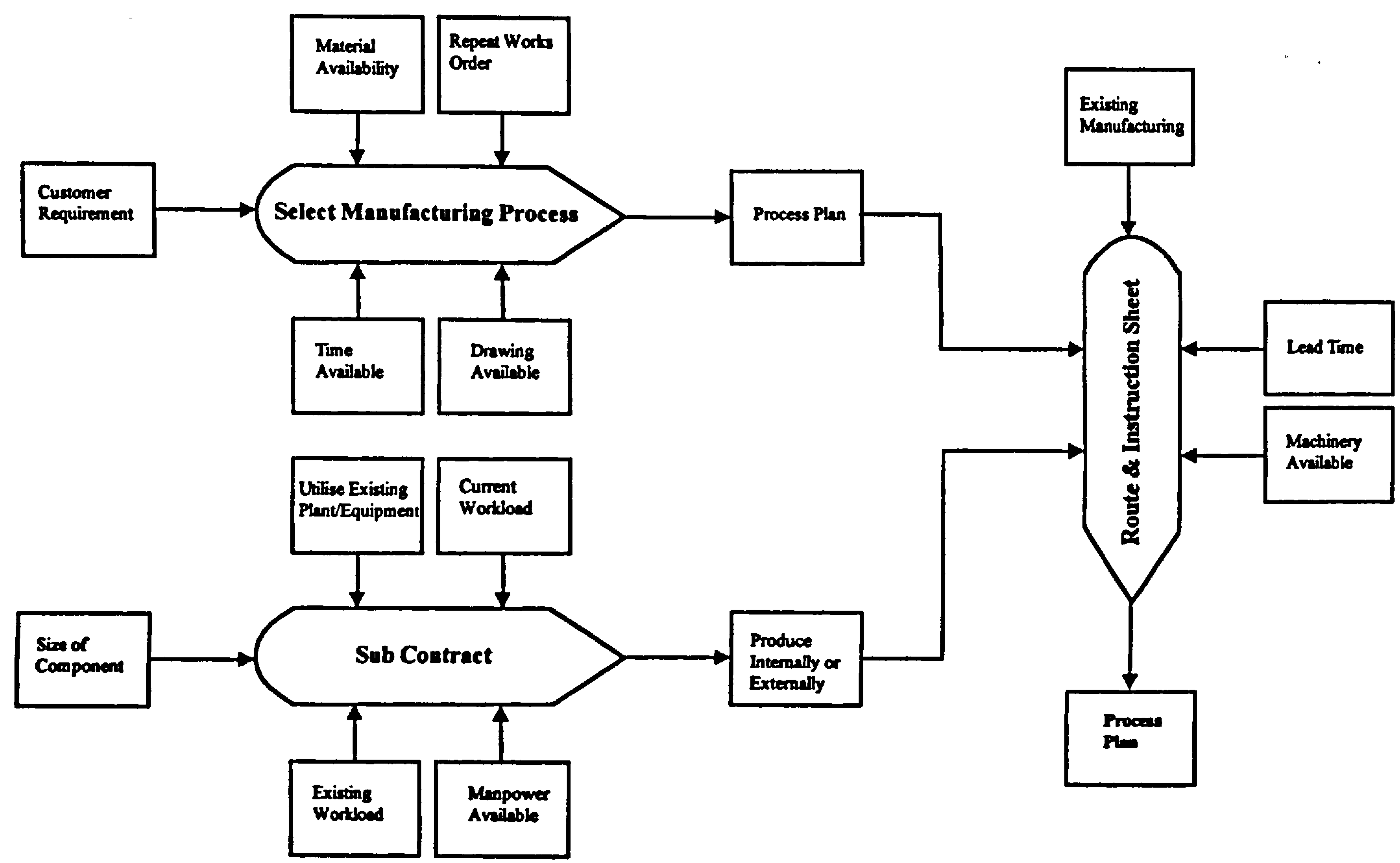
H/R: H=1 Month, R=1 Month

The GRAI net for this decision as shown in Figure 7.10 relates to the issue of work orders. No activity to support the decision was identified. The work order consists of process planning and the decision is only active when orders for special products are delivered by the sales department. The horizon and the review period are identical in



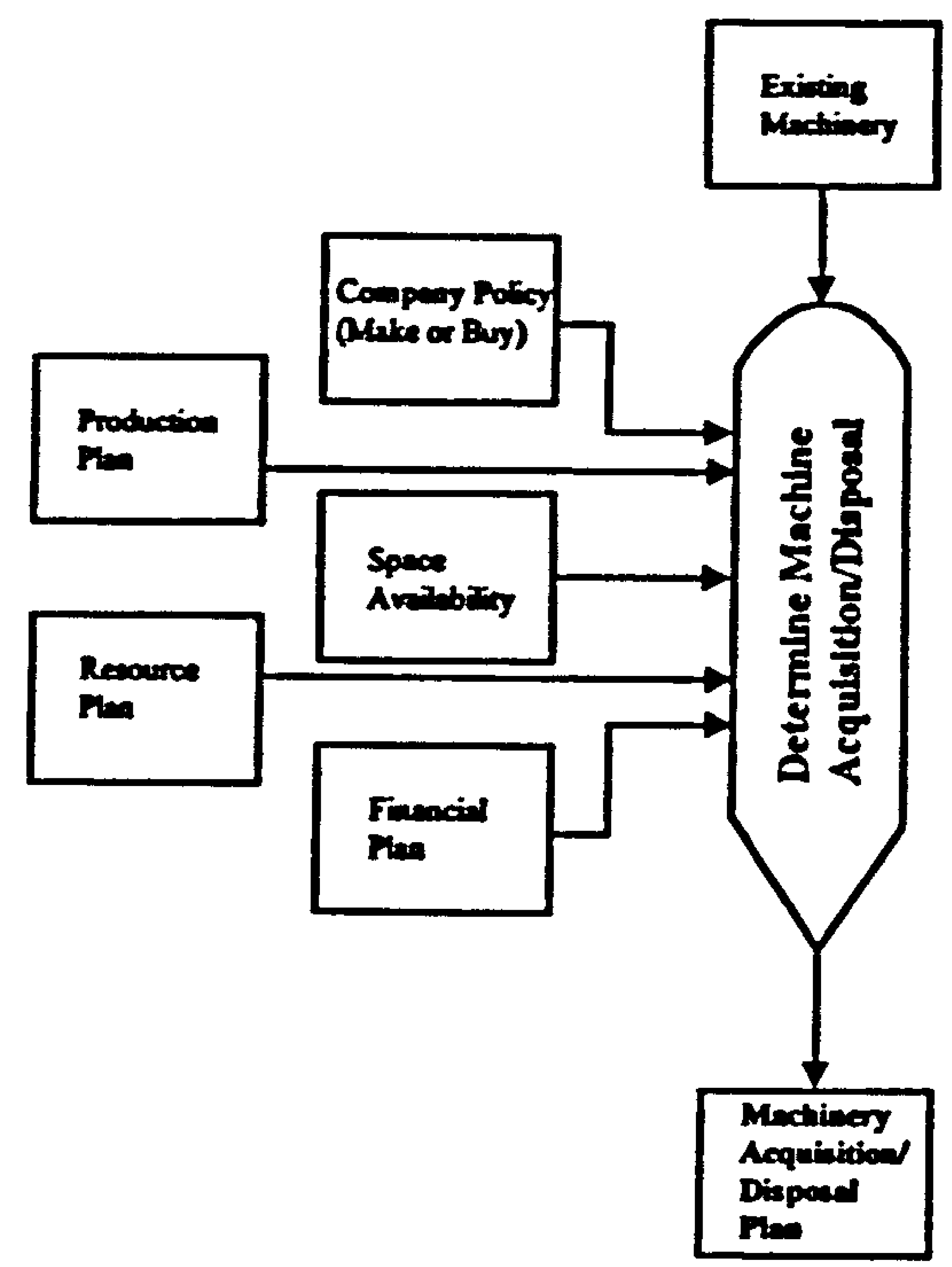
TITLE: Work Order	FUNCTION: To Production Plan	DRAWN BY: M A CHODARI	DATE: 20-6-1996	D C: (9,6)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=1 Month, R=1 Month	VALIDATE BY: Senior Planner	DATE: 23-6-1996	INDEX: 1/1

Figure 7.10 GRAI Net for Work Order



TITLE: Process Plan	FUNCTION: To Production Plan	DRAWN BY: M A CHODARI	DATE: 20-6-1996	D C: (12,6)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=1 Month, R=1 Day	VALIDATE BY: Production Manager	DATE: 24-6-1996	INDEX: 1/1

Figure 7.11 GRAI Net for Process Plan (Method of Manufacturing)



TITLE: Machinery Acquisition Plan	FUNCTION: To Manage Resources(Technical)	DRAWN BY: M A CHODARI	DATE: 20-6-1996	D C: (1,8)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=3 Years, R=1 Year	VALIDATE BY: General Manager	DATE: 24-6-1996	INDEX: 1/1

Figure 7.12 GRAI Net for Machinery Acquisition

this case. This breaks the GRAI net rule that, the review period of the decision should always be less than the horizon of the decision. No utilisation of relevant information was observed.

Title: Process Plan (Method of Manufacturing)
Function: To Production Plan
H/R: H=1 Month, R=1 Day

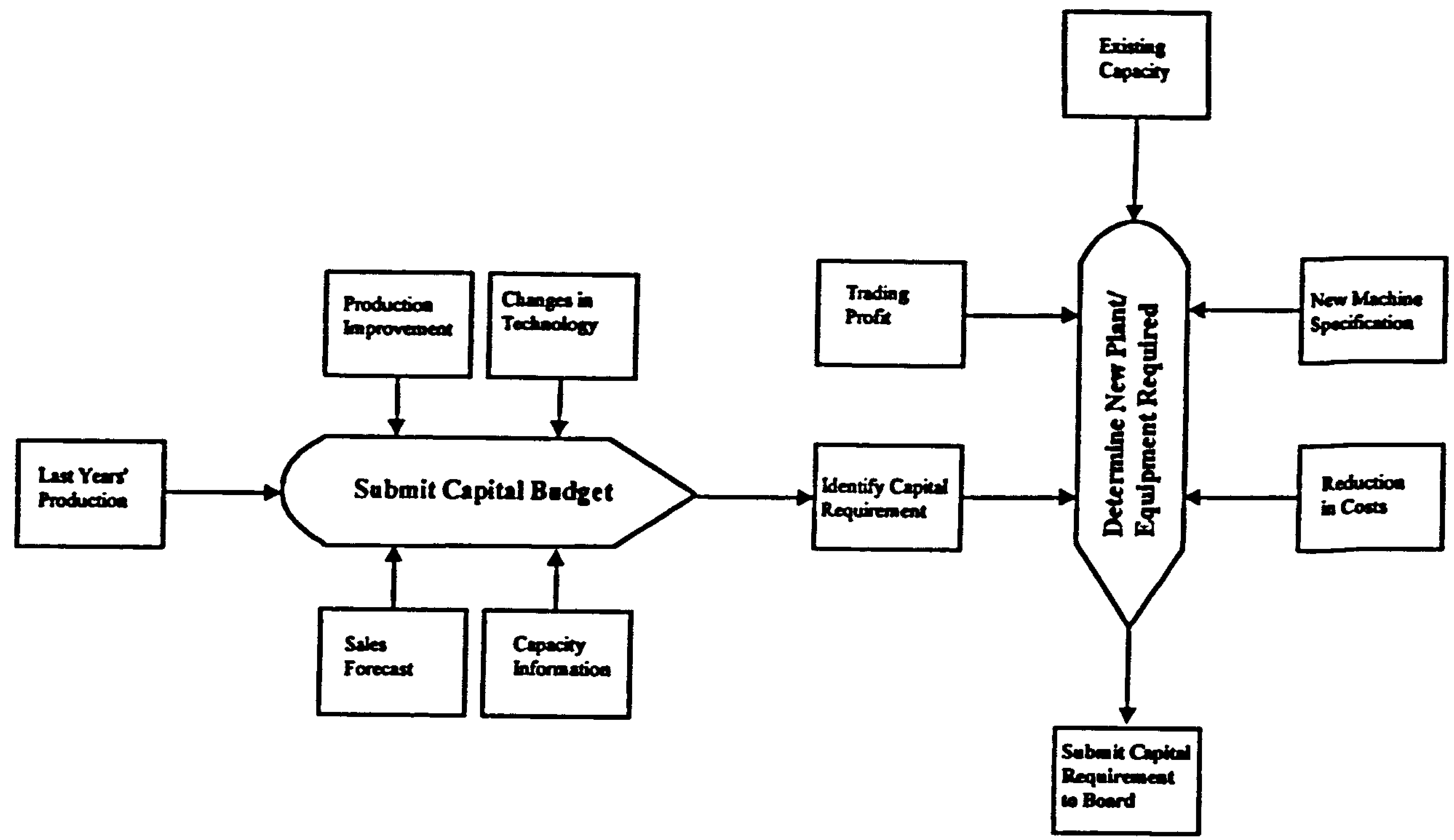
The GRAI net constructed as shown in Figure 7.11. The net details the development of process plan, which contains the method of manufacturing. Two supporting activities were identified: the "select manufacturing process" and "sub-contract". The first activity analyses the manufacturing process, whilst the second analyses whether the product or sub-assembly would be produced in house or sub-contracted. The decisional objective and constraints are also identified. The horizon and the review period of the GRAI net are different from the horizon and the review period that appeared in the GRAI grid for a similar decision (Figure 7.2). It was observed that other people were also involved in performing a similar decisional activity.

Title: Machinery Acquisition Plan
Function: To Manage Resources (Technical)
H/R: H=3 Years, R=1 Year

The GRAI net for the decision of machinery acquisition is shown in Figure 7.12. No supporting activities to perform the decision were identified. The decision relies on intuition. No decisional objectives, variables or constraints were identified.

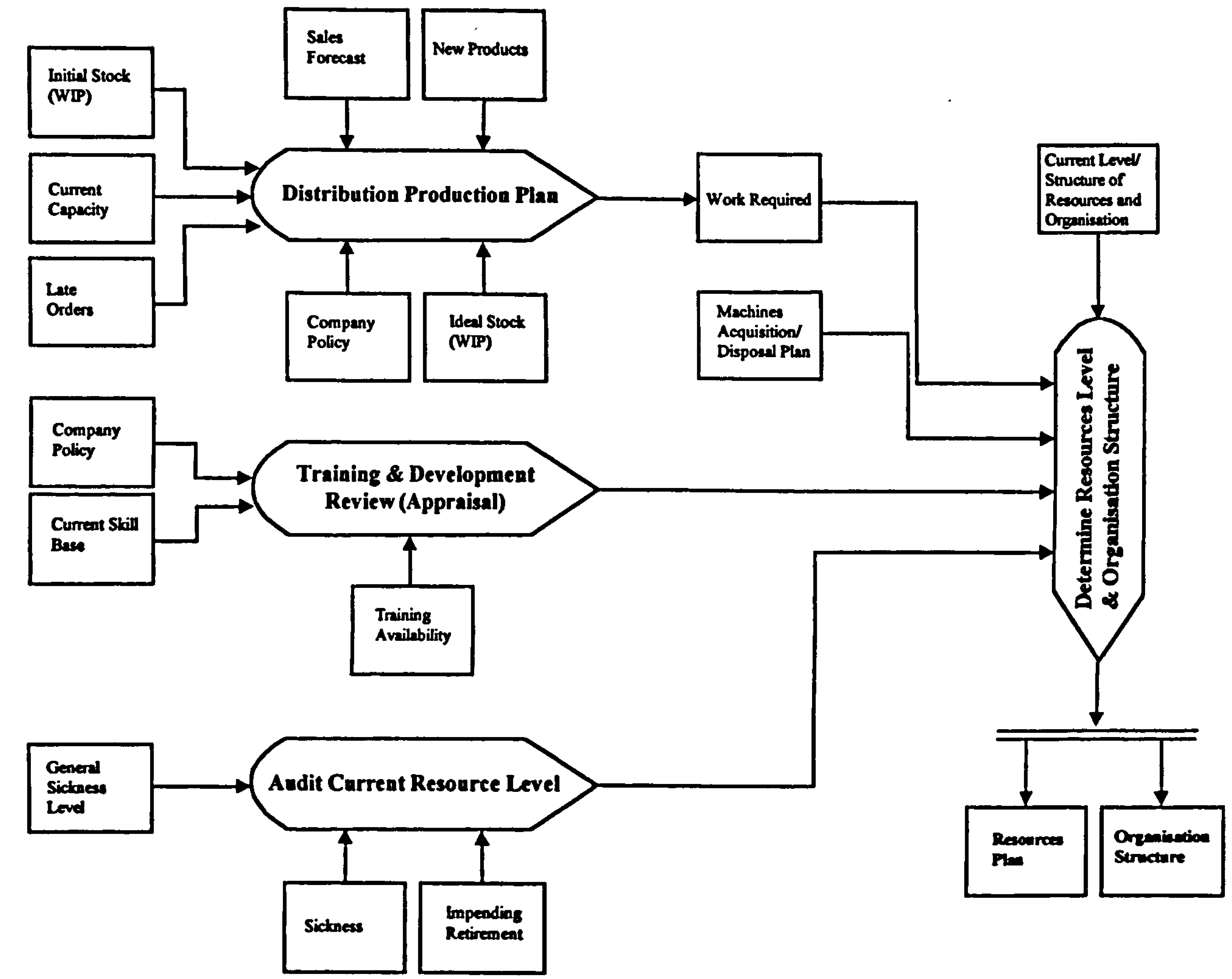
Title: New Plant and equipment
Function: To Manage Resources (Technical)
H/R: H=1 Year, R=1 Month

The GRAI net for the decision of machinery acquisition is shown in Figure 7.13. Only one supporting activity to perform the decision was identified. The decisional



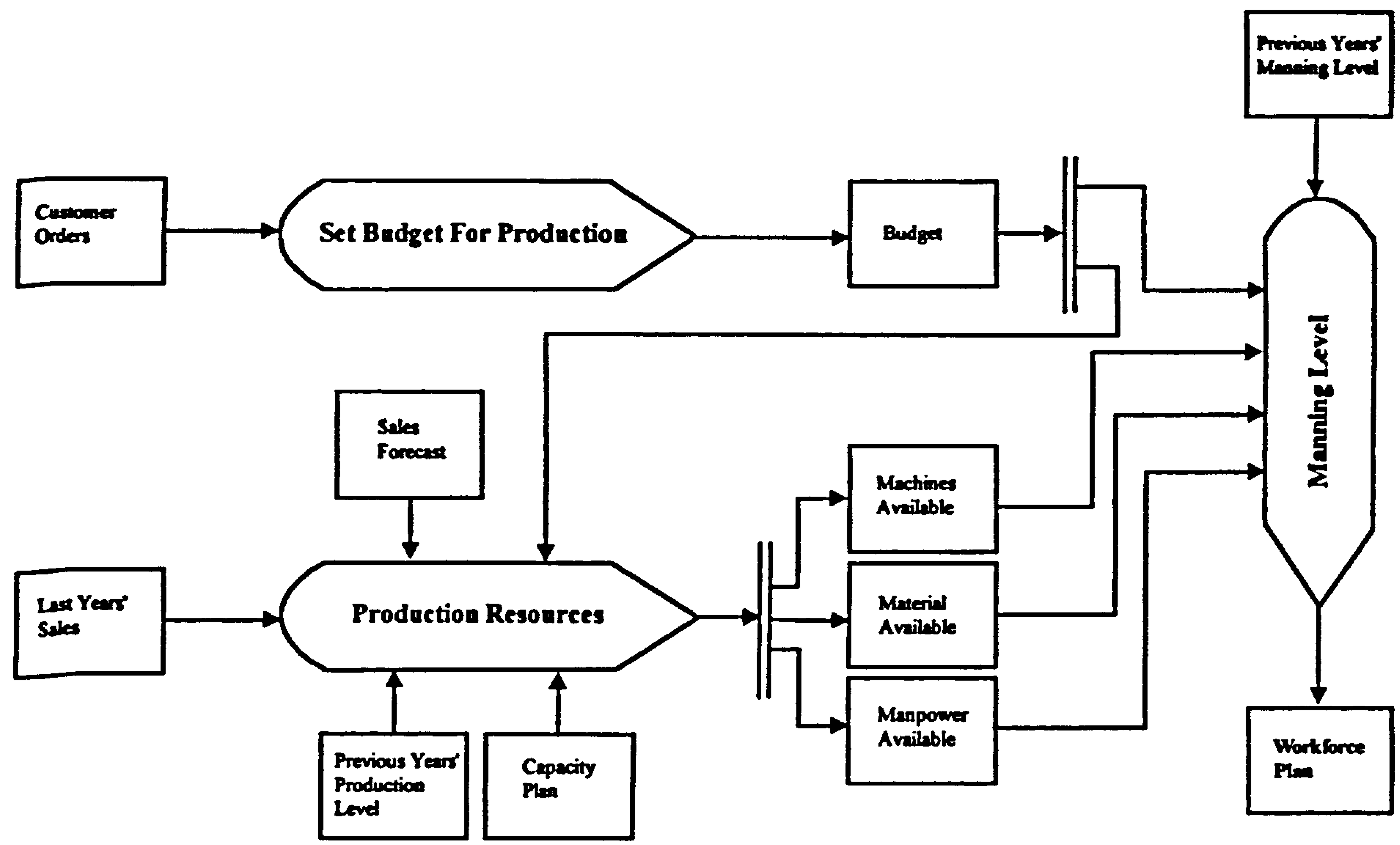
TITLE: New Plant & Equipment	FUNCTION: To Manage Resources(Technical)	DRAWN BY: M A CHODARI	DATE: 20-6-1996	D C: (7,8)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=1 Year, R=1 Month	VALIDATE BY: Production Manager	DATE: 26-6-1996	INDEX: 1/1

Figure 7.13 GRAI Net for New Plant/Equipment



TITLE: Resource Plan & Organisation Structure	FUNCTION:To Manage Resources(Tech & Human)	DRAWN BY: M A CHODARI	DATE: 20-6-1996	D C: (1,9 & 1,5)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=3 Years, R=1 Year	VALIDATE BY: General Manager	DATE: 24-6-1996	INDEX: 1/1

Figure 7.14 GRAI Net for Resource Level & Organisation



TITLE: Workforce Planning	**FUNCTION:** To Manage Resources(Human)	**DRAWN BY:** M A CHODARI	**DATE: 20-6-1996**	**D C:** (6,9)
COMPANY: EDWARD PRYOR & SON LTD.	**H/R:** H=1 Year, R=1 Month	**VALIDATE BY:** Production Manager	**DATE: 26-6-1996**	**INDEX:** 1/1

Figure 7.15 GRAI Net for Workforce Plan

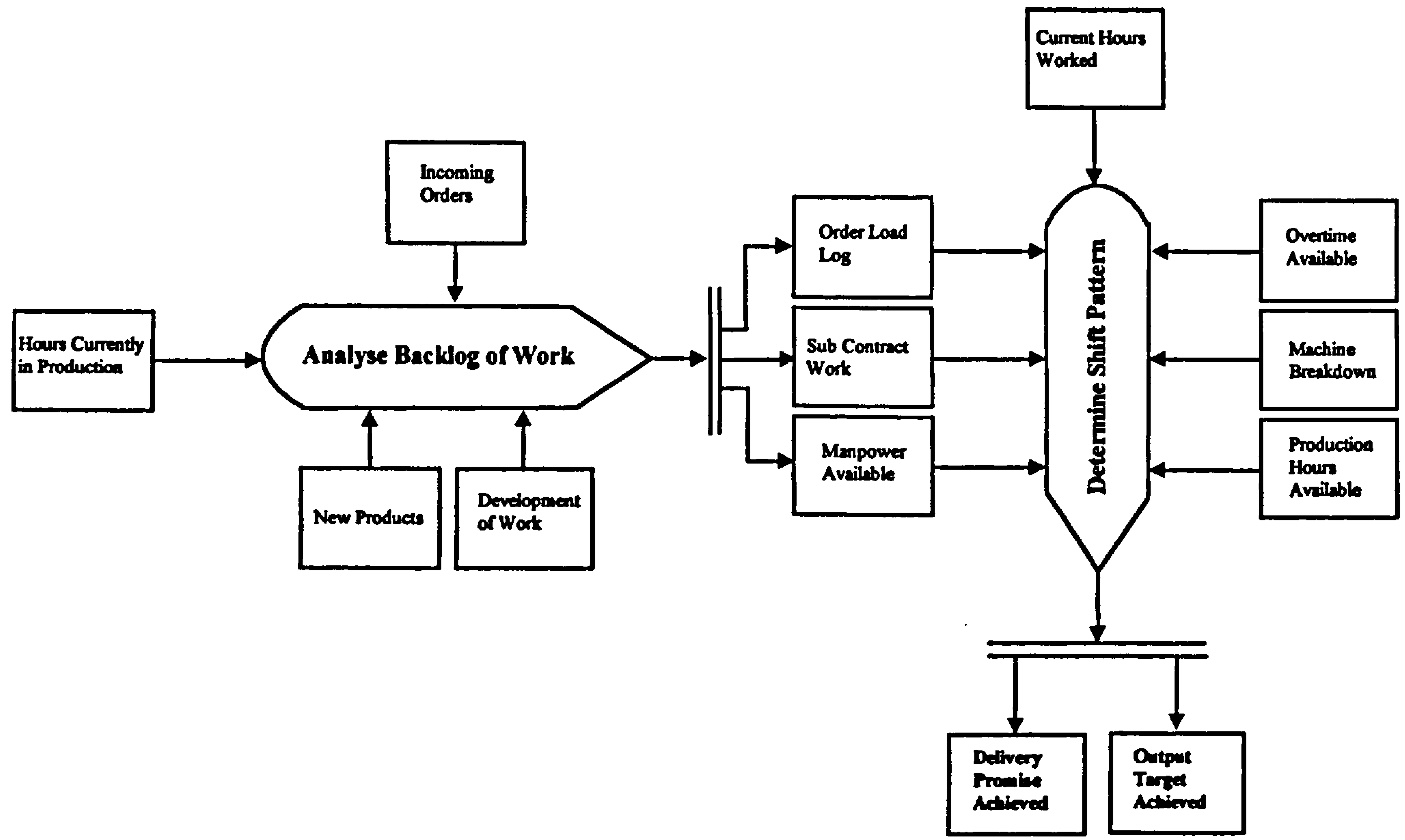
objective has also been identified. The horizon and the review period of this net are different from the horizon and the review period that has appeared in the GRAI grid for a similar decision (Figure 7.2).

Title: Resource Plan and Organisation
Function: To Manage Resources (Technical & Human)
H/R: H=3 Years, R=1 Year

The GRAI net drawn is shown in Figure 7.14 and concerns the development of plans for resource usage and the organisation structure. The resources plan sets the stock level of finished products for a three years period. The decision for the organisation structure shows the future requirements of the employees. The three types of supporting activity identified to perform the decision are: distribution of production plan, review of training and development, and audit current resource levels. The first activity produces a result, whilst other activities do not. This goes against the GRAI net rule which state that each activity must produce some results which must then be used as a support to perform the decision. Similarly the decisional activity is performed without considering the decisional objectives, variables or constraints.

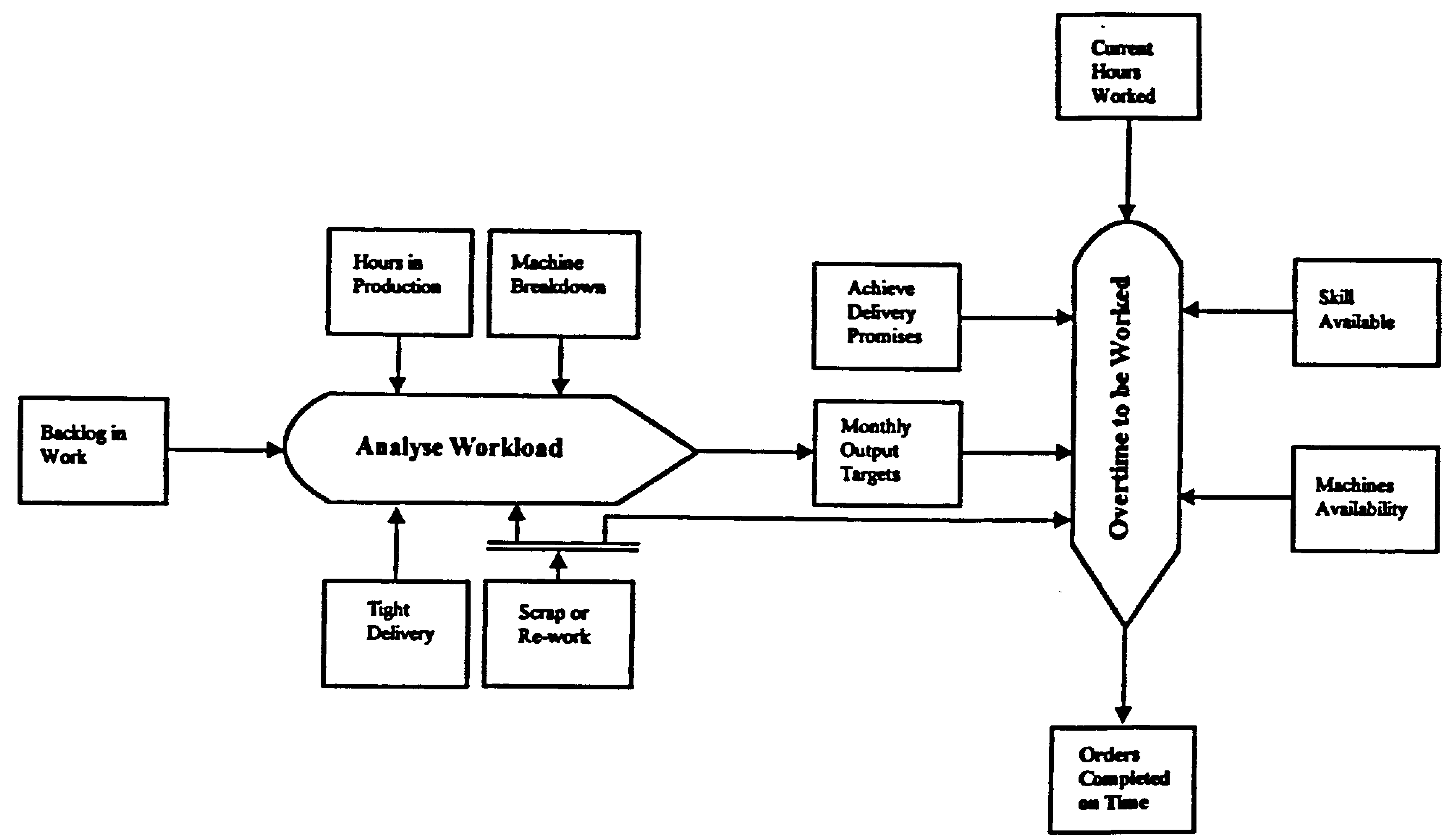
Title: Workforce Planning
Function: To Manage Resources (Human)
H/R: H=1 Year, R=1 Month

The GRAI net constructed for workforce planning is shown in Figure 7.15. The workforce plan shows the utilisation of the existing workforce of the Division. Two supporting activities to perform the decision were identified are: "setting a budget for the production" and "production resources". The decision is performed without considering the decisional objectives and constraints. The title of this decisional activity is the manning level but the result is the workforce plan. The manning level should be considered as supporting information.



TITLE: Shift Planning	FUNCTION: To Manage Resources(Human)	DRAWN BY: M A CHODARI	DATE: 20-6-1996	D C: (8,9)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=3 Months, R=1 Month	VALIDATE BY: Production Manager	DATE: 26-6-1996	INDEX: 1/1

Figure 7.16 GRAI Net for Shift Planning



TITLE: Overtime Planning	FUNCTION: To Manage Resources(Human)	DRAWN BY: M A CHODARI	DATE: 20-6-1996	D C: (8,12)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=1 Week, R=1 Day	VALIDATE BY: Production Manager	DATE: 26-6-1996	INDEX: 1/1

Figure 7.17 GRAI Net for Overtime Planning

Title: Shift Planning

Function: To Manage Resources (Human)

H/R: H=3 Months, R=1 Month

The GRAI net drawn for the decision is shown in Figure 7.16. The decision is related to the issue of a shift plan for the workforce. One supporting activity to perform the decision was identified. This activity analyses any backlog of work. Results of this activity are sent to the decisional activity which determines the shift plan.

Title: Overtime Planning

Function: To Manage Resources (Human)

H/R: H=1 Week, R=1 Day

The GRAI net constructed for overtime planning is shown in Figure 7.17. Only one supporting activity to perform the decision was identified. No decisional objectives, decisional constraints or decisional variables were identified. The horizon and the review period of this GRAI net are different from the horizon and the review period which appeared in the GRAI grid for a similar decision (Figure 7.2).

7.2.12 Other Inconsistencies

The following list indicated other inconsistencies identified during the course of this case study:

- The objectives of the Division are not defined
- Although the Division has been accredited with BS5750 part-1, no documentation relating to the system and job responsibilities was identified
- The quality policy cannot be correctly applied to organisation because of the current status of the production management system
- The manufacturing routes of the products are complex and descriptions of the routes are not available

- The manufacturing workshops are congested and manufacturing routes are not easy to understand.
- The relationship between capacity and machine loading cannot be identified.
- The product scheduling cannot be studied due to lack of planned information.
- The culture and politics of the Division are dominant and certainly very visible. Some members are not satisfied with the current working practice and they are not satisfied with the open office environment.
- At the shop floor level, supervisors feel that managers issue work orders relatively late, making scheduling and production difficult to coherence.

7.3 Recommendations

In light of the inconsistencies identified within the manufacturing management system of the Division the following recommendations were made:

- The GRAI Grid of the manufacturing management system of the Division needs to be re-structured, i.e.
    - Functions should be adjusted
    - Horizons and review periods should be adjusted
    - The transfer of information and basic communication between departments should be improved
    - More decision centres must be identified within the manufacturing management system of the Division
- The programmed decisions need to be restructured in more detail
- The quality management system needs to be reviewed with reference to BS5750. Every procedure and management responsibility must be documented. Each person within the Division should have a clear understanding of their job objectives and responsibilities.
- Work orders and priorities of production should be issued as a work plan, not in real time.

- The manufacturing routing of each product must be clear and relate to the plant layout. The manufacturing process of each standard product needs to be documented and records maintained.

7.4 CONCLUSIONS

The main objective of this case study was to validate the methodology developed to apply the GRAI method as described in Chapter 6. The methodology has been successfully applied to the existing manufacturing management system of the Division.

The methodology has several steps and is based on a series of the questionnaires. For the case study, each step of the methodology was followed. First, a meeting between of the author and the co-ordinator was arranged, to describe and explain the purposes and operation of the study. A further reason for this meeting was to obtain background information concerning the progress and problems with in the Company. At the end of the meeting, questionnaire-1 was delivered to the co-ordinator. The questionnaire provided information about the Division with respect to the management structure, plant layout, etc.. In light of this information, the management structure of the Division was constructed and validated (Figure 7.1). This was the basic source used to identify the members of the synthesis group. After identification of the synthesis group, meetings with each member of the group were arranged. Each session lasted approximately thirty minutes. In these sessions, the purposes of the study and the GRAI method were explained, at the end of the meeting, questionnaire-2 was distributed. After collecting the completed questionnaire-2 from each member of the synthesis group, the GRAI grid was constructed and validated (Figure 7.2). Decision centres from the GRAI grid were then identified. The next step was to deliver questionnaire-3 to the decision makers to analyse their decisions. At this stage some difficulties were experienced because most members of the synthesis group did not fully understand the questionnaire. This was partly due to the terminology used in the questionnaire. To remove this shortcoming, the covering letter was modified to include definitions of each specific term used and an example of a GRAI net was also supplied. The author met members of the group individually again and delivered the modified questionnaire. This approach met with greater success. The questionnaires were later collected from the group and the GRAI nets were constructed for each decision centre. These nets were validated by the relevant decision maker (Figures 7.3-7.17). An analysis of the GRAI grid and nets was carried out, the results of which showed several inconsistencies within the system. These inconsistencies were discussed with the co-ordinator and recommendations for the modification of the system were presented.

This case study has illustrated the benefit of employing questionnaires for structuring interviews and gaining information for modelling using the GRAI method. Much of the ambiguity and subjectivity was removed, although questionnaire-3 had to be modified to make sense to the lay person. The advantage of the questionnaires is that it is easy to collect relevant information and control the direction of questions, unlike conventional interviews. Before the questionnaires, the gathering of information was totally dependent on the skill of the interviewer and the method of questioning adopted. Another advantage of using these questionnaires is that the iterative nature of model construction is eliminated, because the correct and relevant information can be obtained in a single application. For to this reason, the overall model building time has been reduced, which will be of great benefit for future GRAI analysis.

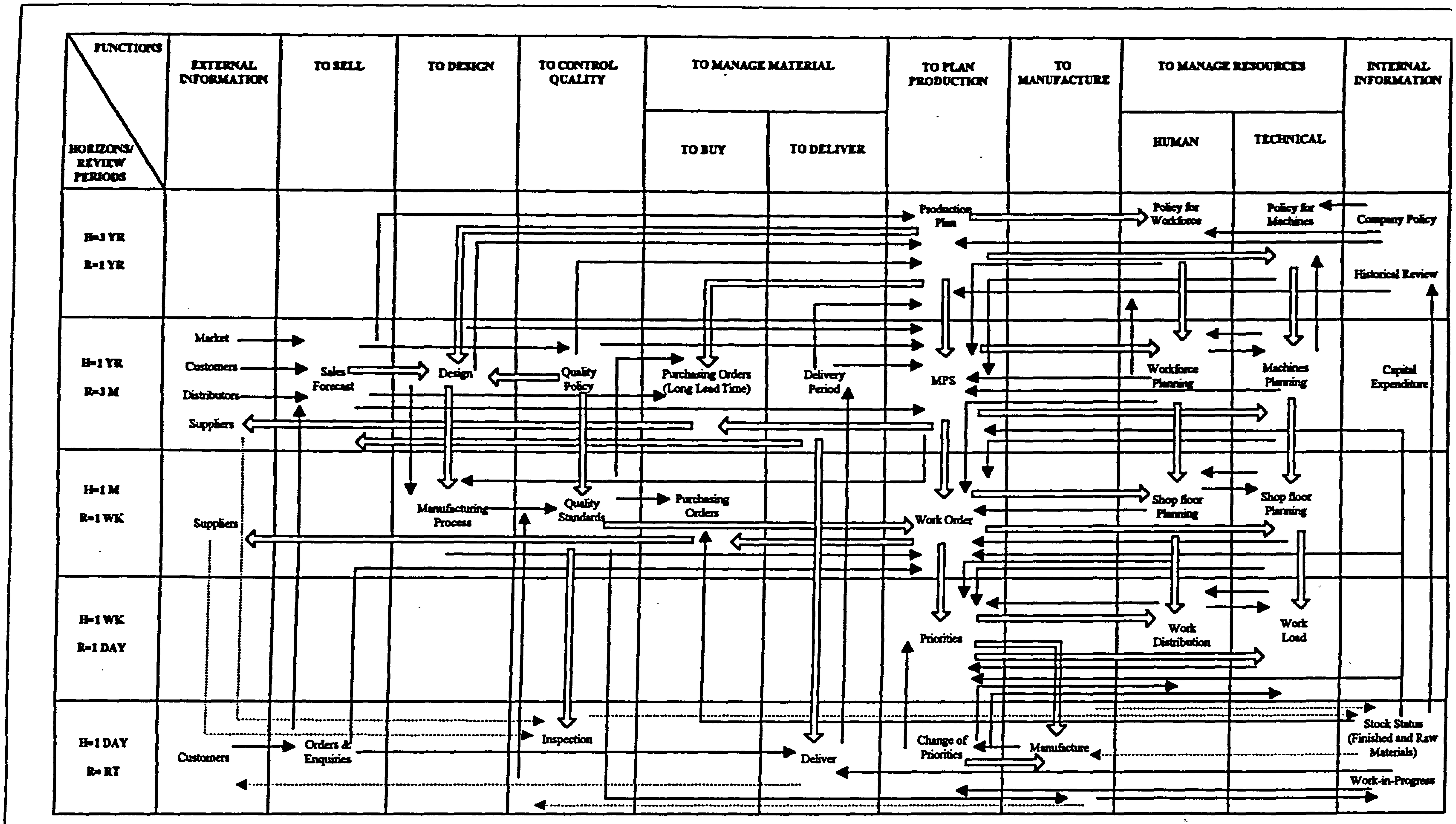
CHAPTER-8

DEVELOPMENT OF A MODEL FOR A 'MAKE-TO-STOCK' MANUFACTURING MANAGEMENT SYSTEM

8.1 INTRODUCTION

The aim of this chapter is to develop a generic model for a 'make-to-stock' manufacturing management system which could be adopted to suit a particular application. In this case Edward Pryor & Son Ltd. have been selected as a case study application. This chapter presents the development of a model for the manufacturing management system of the MME Division, Edward Pryor & Son Ltd. The methodology developed to apply the GRAI method has been used to further this model. The model was constructed from the results of the analysis carried out and the recommendations made in Chapter-7. The development of the model is based on the design phase of the methodology. The design phase consists the development of the modified GRAI grid and GRAI nets. The GRAI grid will present the overall picture of the new manufacturing management system, including the management hierarchy with layers of control, different functions, decision centres, information flows, decisional flows and material flows. The GRAI nets describe the structure of the programmed decisions and illustrate the activities carried out to perform each decision. The decisions are made by considering the decisional objectives and any constraints.

Once the GRAI grid and GRAI nets were completed, they were validated by the synthesis group (who are identified in Table 7.2, Chapter 7). Iterations of the model



TITLE: NEW GRAI GRID	**DRAWN BY:** M A CHODARI	**DATE:** 10-7-96	**INDEX:** 1/1
COMPANY: EDWARD PRYOR & SON LTD.	**VALIDATE BY:** GENERAL MANAGER	**DATE:** 12-7-96	

Legend: Decisional Flow: Informational Flow: Material Flow:

FIGURE 8.1 NEW GRAI GRID FOR THE MANUFACTURING MANAGEMENT SYSTEM

then took place until the synthesis group reached agreement. Once the model had been validated, it was recommended for implementation.

8.2 CONSTRUCTION OF THE NEW GRAI GRID

Functions of manufacturing management, suitable horizons, review periods and decision centres are essential elements in the construction of a GRAI grid. Decisional links and information flow show the relationship between the decision centres at different levels of the hierarchy. After collection of the above mentioned essential elements and identification of decisional and information flows, it was possible to construct the new GRAI grid. This is shown in Figure 8.1.

The GRAI grid shows the management hierarchy of the Division. Three levels, (strategic, tactical and operational), with five layers of control have been established. These layers are presented in the rows of the grid (Figure 8.1). The first row shows the strategic level of the Division. This level has the responsibility to produce the objectives and develop the strategies necessary to achieve these objectives, based on long term planning. The second and the third rows of the GRAI grid show the tactical level. This level is based on the decisions made at the strategic level and adopts relatively medium term policies. The last two rows of the GRAI grid represent the operational level. The operational level is the routine execution of work based on decision made at the tactical level and involves in the decisions made at the shop floor level. Further details of the GRAI grid are shown below:

8.2.1 Functions

The functions of the Division have been constructed and are shown in the columns of the GRAI grid in Figure 8.1:

- To Sell
- To Design
- To Control Quality
- To Manage Material

    - To Buy
    - To Deliver
- To Plan Production
- To Manufacture
- To Manage Resources
    - Human
    - Technical
- External Information
- Internal Information

Two fundamental changes can be seen between the GRAI grid of the existing manufacturing management system (Figure 7.2, Chapter 7) and the modified GRAI grid (Figure 8.1). Firstly, the 'To Control Production' function has been removed and secondly the 'To Control Quality' function has been introduced. The reasons for this are that production can be controlled if the production plans are implemented correctly and promptly. The 'To Control Quality' function is a fundamental function for any manufacturing company, which was missing in the original management system.

8.2.2 Horizons and Review Periods

The decisions made at each level of the management hierarchy have different horizons and review periods, depending on the policies involved and nature of the decisions. Too many horizon and review periods were identified in the existing management system (Figure 7.2, Chapter 7). These original periods show the complex and cluttered hierarchy of the system. To avoid this complexity and present a systematic model, the following horizons and review periods have been selected:

- Horizon=3 Years, Review Period=1 Year
- Horizon=1 Year, Review Period=3 Months
- Horizon=1 Month, Review Period=1 Week
- Horizon=1 Week, Review Period=1 Day
- Horizon=1 Day, Review Period=Real Time

8.2.2.1 Horizon=3 Years, Review Period=1 Year

The three year planning horizon represents the strategic level which directs and controls the Division. The horizon is related to the Divisional business plan, made with respect to the objectives and strategies necessary to achieve the Company policy. The business plan also shows the manufacturing objectives. The manufacturing objectives must be made by considering the company policy, resources available and external information such as the market and the competitors. The manufacturing objectives must be consistent with the business strategy, for example a business strategy for growth will a have different manufacturing implication to one for short term profit maximisation and reducing the lead time.

The three year horizon level also shows the annual meetings. On these occasions matters arising from the monthly review and feedback can be analysed, and changes to the planned program are implemented if necessary. The following decision centres can be identified at this level:

- Production Planning
- Policy for the Workforce
- Policy for the Machines

i) Production Planning

The production plan provides key information links from the top management to the shop floor manufacturing. It determines the basis for focusing the detailed production resources required to achieve the Company's strategic objectives, by providing the framework within which the master production schedule is developed. It enables, the management to control and develop other plans such as those for resources and capacity loading. The production plan is not a forecast of demand, but plan, stated on an aggregate basis, for which manufacturing management is held responsible.

ii) Policy for the Workforce

This policy aims to increase the potential output. It includes investment grants for employee recruitment, training and a bonus scheme to motivate the workforce.

Another aim of the policy is to establish a working environment that is suitable for the whole organisation.

iii) Policy for the Machines

This policy aims to increase the potential output. It includes investment grants for purchasing new machines and equipment to increase capacity or change the plant layout. The policy is made with respect to the future production requirements.

8.2.2.2 Horizon=1 Year, Review Period=3 Months

The one year planning horizon represents the tactical level of the Division. The main responsibilities at this level are to generate alternative policies for the medium term, which will yield better results. This requires a knowledge of manufacturing at several levels, ranging from management principles to detail of specific technologies employed. The following decision centres can be identified at this level:

- Sales Forecast
- Design Product
- Quality Policy
- Purchasing Orders (long procurement lead time)
- Delivery Period
- Master Production Schedule (MPS)
- Workforce Planning
- Machine Planning

i) Sales Forecast

The sales forecast concerns the potential and prospective sales volume for individual products and defines a sales target in the respective markets within the generic economic environment. This is an important function, because it identifies the size and value of individual markets, and the current market share of the Company. The desired market share can then be identified as part of the Company strategy, against which performance can be measured.

ii) Design Product

Design is the translation of a concept into a form suitable for production. It also includes the re-design of existing products, for ease of production or modification in light of customer feedback. Design operates between the marketing and production function. Its purpose is essentially to fulfil the needs of the market, as identified by the marketing department and translate them into production "language". Decisions made during design can have significant and long-term effects on the whole organisation.

iii) Quality Policy

The quality of products, services and the operating system is not only important for manufacturing, but also for customers and suppliers. Quality deficiencies result in additional costs of inspection, testing and re-work, and scrap. This affects both the sales and the efficiency of the organisation. The decision to improve product quality must be supported by top management in the company. It must be based upon the consideration of both the external environment and internal availability of resources. The decision to establish a quality policy must consider the following:

- The customers' needs and perception of need.
- Bought-in material must meet the required quality standards.
- Reviewing the quality management system to maintain the progress.
- Education and training for quality improvement
- Concentrating on prevention rather than detection of quality problems after they occur.
- Establishing a system for quality.

iv) Purchasing Orders

The purchasing orders are a contractual document which bind the originating company to expenditure. It can be an important and expensive decision and therefore the process should be clear and unambiguous. The decision centre makes sure that all long procurement lead time items are bought before manufacturing begins on the shop floor. It is important that the purchasing orders are only issued to recommended suppliers.

v) Delivery Period

This period anticipates the delivery dates of products to finished stock or customers, using stock level information and the sales forecast. The delivery period or 'due date' is the point from which the MPS calculates the schedule. The decision centre is also responsible for providing any delivery and packing instructions.

vi) Master Production Schedule (MPS)

The master production schedule is an anticipated build schedule for the manufacturing of end products. The MPS is not a sales forecast. The sales forecast has a critical input to the planning process used to determine the MPS. The schedule (MPS) takes into account capacity limitations as well as the desire to utilise capacity to the full. This often results in items being built before they are needed for sale. The MPS should state the product specification in part numbers, identified from the bill of materials, and must state the anticipated delivery dates. The MPS must be reliable and firm, because it is used to derive the capacity requirements.

vii) Workforce Planning

Workforce planning aims to maintain and improve the ability of production to achieve its manufacturing objectives through the development of the tactical strategies. The production plan and MPS are the basic inputs to plan the workforce.

viii) Machine Planning

Machine planning aims to achieve the optimum utilisation of machines and meet production targets through the tactical strategies developed. The production plan and MPS are the basic inputs to plan machine loading.

8.2.2.3 Horizon=1 Month, Review Period=1 Week

The one month horizon level also represents tactical activities. It is a relatively short term planning horizon with a review period of one week. The level represents a monthly meeting where matters arising from weekly meetings are reviewed. The following decision centres can be identified at this level:

- Process Plan
- Quality Standards
- Purchasing Orders
- Work Orders
- Shop Floor Planning (Workforce)
- Shop Floor Planning (Machines)

i) Process Plan

Manufacturing process plan transforms the design information into working instructions. It looks critically at all the facilities available and the layout of the manufacturing organisation. It involves the interpretation of drawings, the selection of raw material in the specific shapes and form, the selection of machine tools, manufacturing methods and the sequencing of operations. The objectives of the decision are to produce a process plan that enables parts to be manufactured to the correct specification, determine an optimal manufacturing sequence and operate in the most economical manner.

ii) Quality Standards

Based on the quality objectives, the quality specification and standards must be defined for each product range and bought-in materials and parts. The quality control standards take account the accuracy that individual processes can achieve and the level of quality which management desires, based on the product's net sales revenue and customers' quality expectations. The quality standards of products will determine the method and degree of inspection, the equipment required and general process control principles.

iii) Purchasing Orders

This is the routine decision of issuing purchasing orders. The decision centre analyses the requisitions and collects the detail of stock levels from the computer or manually. If the re-order point occurs, the purchasing orders are generated automatically for the material.

iv) Work Orders

At this level, the most basic decision concerns how to construct and update the MPS and part re-order levels. This involves processing the MPS and re-order point transactions, maintaining the MPS and re-order record. The work orders are reviewed weekly, to assess any exceptional circumstances and the general effectiveness of the MPS. On a day to day basis, sales and production are co-ordinated in terms of orders placed. This is where customers' order requests receive information of shipment dates. The decision resolves any backlog problems and converts the MPS and re-order information into manufacturing work orders.

v) Shop Floor Planning (Workforce)

Shop floor planning aims to produce feasible plans for utilisation of the workforce to complete the work orders. This is based upon factors such as wage rates (for overtime for example) and staff availability.

vi) Shop Floor Planning (Machines)

Machine planning aims to produce plans for the effective utilisation of machine capacity to fulfil the work orders.

8.2.2.4 Horizon=1 Week, Review Period=1 Day

The one week horizon level represents the operational activities, based on short-term planning. The review period for this level is one day. The following decision centres can be identified:

- Priority Allocation
- Work Distribution
- Work Load

i) Priorities

The priority is the conversion of a work order into an actual orders for manufacturing, in the desired sequence. The priority sheet must be issued one week in advance and must consist of a product number (with the bill of materials), quality standards and manufacturing routes, including loading and unloading time.

ii) Work Distribution

Distribution of work to operators can actually provide an improvement in productivity. Ideally, every operator should know the task that has to be undertaken. It is a responsibility of the supervisor to distribute the work with regard to the skills of the operators.

iii) Work Load

The optimum loading of work to the machines is capable of providing a substantial improvement in productivity. It is the responsibility of the supervisor to load work to the machines in the right sequence, according to machine capacity and capabilities. The supervisor must compare the load and capacity, to avoid overloading or excessive under-utilisation of the machines.

8.2.2.5 Horizon=1 Day, Review Period=Real Time

This level represents the day-to-day manufacturing activities performed by the workforce. It involves the physical processing of the raw material into finished products, according to the work instructions. The review period of this level is real time which is related to individual tasks. To make decisions, the parameters of time, physical progress and resources must be considered. The following decision centres can be identified at this level:

- Customer Orders/Enquiries
- Inspection
- Delivery
- Change of Priorities
- Manufacture

i) Customer Orders/Enquiries

The decision centre assesses customer orders and enquiries and prepares a proposal that includes the variables such as technical specification, price and delivery date.

ii) Inspection

The objective of this activity is to verify whether bought-in material and all manufactured products conform to the specified quality standards.

iii) Delivery

The objective of this activity is to deliver the right product to the right customer according to the delivery and packing instructions.

iv) Change of Priorities

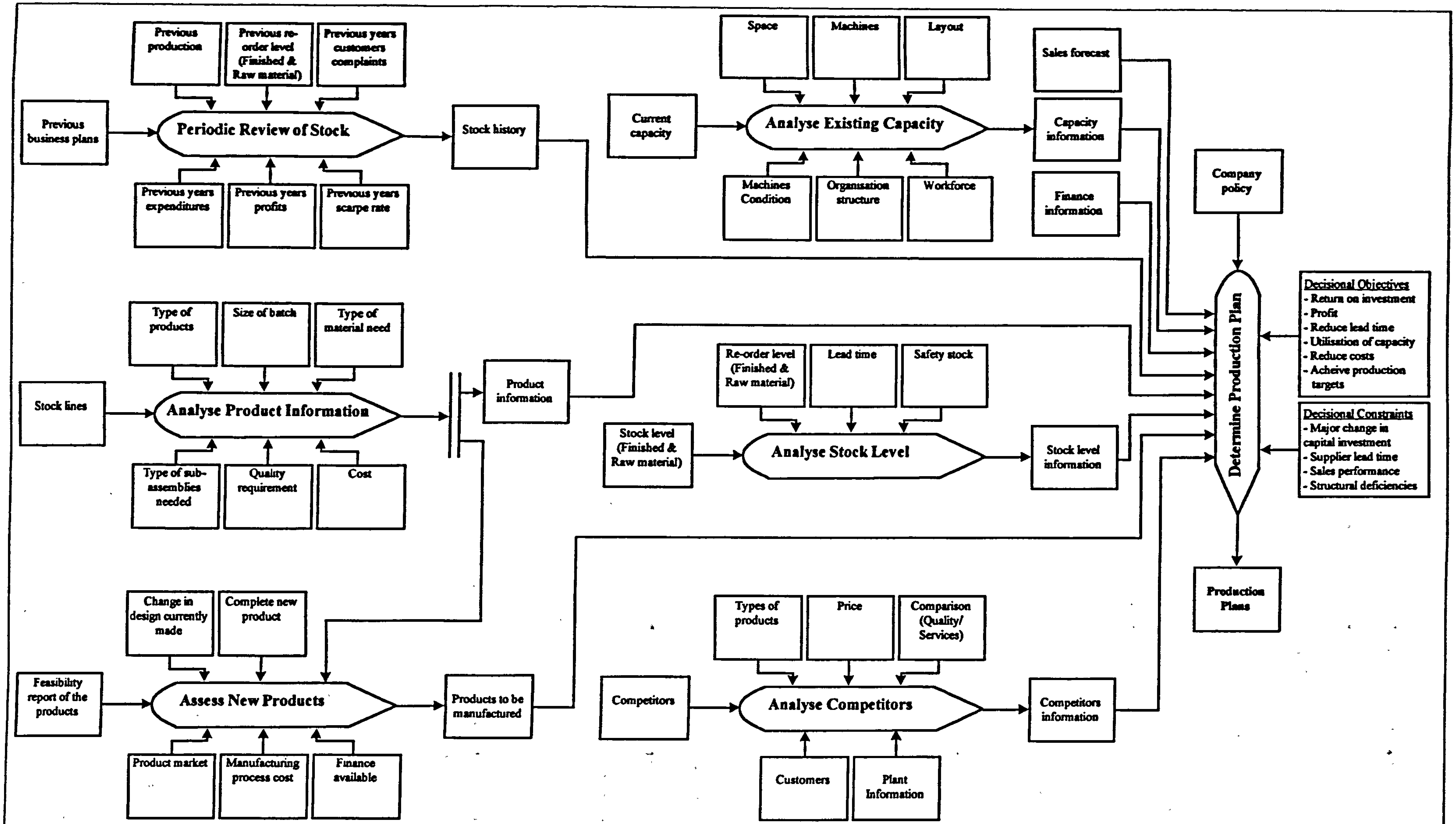
This decision centre assesses any urgent requirements and changes the priorities accordingly.

v) Manufacture

This is the transformation of raw material into finished products using various machine tools and process according to the manufacturing instructions.

8.3 CONSTRUCTION OF GRAI NETS

The identification of the decision centres is the first step in the construction of GRAI nets. Each net presents the structure of the programmed decision of the decision centre in detail. The structure of the decision shows the flow of activities and supporting information required to carry out the decision. The decision is made by considering the activities carried out, the supporting information and any decisional objectives and constraints. After identification of the decision centres from the GRAI grid (Figure 8.1) and the essential elements, the GRAI nets were constructed according to the rules relating to GRAI nets (Table-7B) for each decision centre. The



TITLE: PRODUCTION PLAN	FUNCTION: TO PLAN PRODUCTION	DRAWN BY: M A CHODARI	DATE: 20-7-96	D C: (1,7)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=3 YEARS R=1 YEAR	VALIDATE BY: General Manager	DATE: 23-7-96	INDEX: 1/1

FIGURE 8.2 GRAI NET FOR PRODUCTION PLAN

GRAI nets are shown in Figures 8.2-8.27. Each GRAI net constructed is discussed in the following section with reference to the level of control in the management hierarchy.

8.3.1 GRAI Net for the Production Plan

This GRAI net represents the structure of the production plan decision, performed at the strategic level. The GRAI net is shown in Figure 8.2. The horizon of this decision is three years and the review period one year. This is an important decision because it provides the basic input to plan the resources. The following activities have been used to support this decision:

a) Periodic Review of Stock

This activity is performed to assess what has been produced in the past. This is the collection of periodic data from stock and production. The output of the activity is stock history.

b) Analyse Product Information

This activity collects all the information of different products including types, batch size, quality requirements and the cost of manufacture.

c) Assess New Products

This activity assesses any new products to be manufactured. The input of this activity is a feasibility report, issued by the design department. The activity analyses the product information and the cost of manufacture.

d) Analyse the Existing Capacity

This activity analyses the existing capacity of the company, which includes the total number of machines, machine capacities, layout, workforce and organisational structure. The objective of the activity is to provide capacity data necessary to perform the decision.

e) Analyse the Stock Level

This activity analyses the stock level of each product and raw material. The main objective of the activity is to set the re-order level, and production requirements in light of the stock level.

f) Analyse the Competitors

This is the collection of information regarding the company's competitors, it includes product information, price, customers and plant facilities.

g) Determine the Production Plan

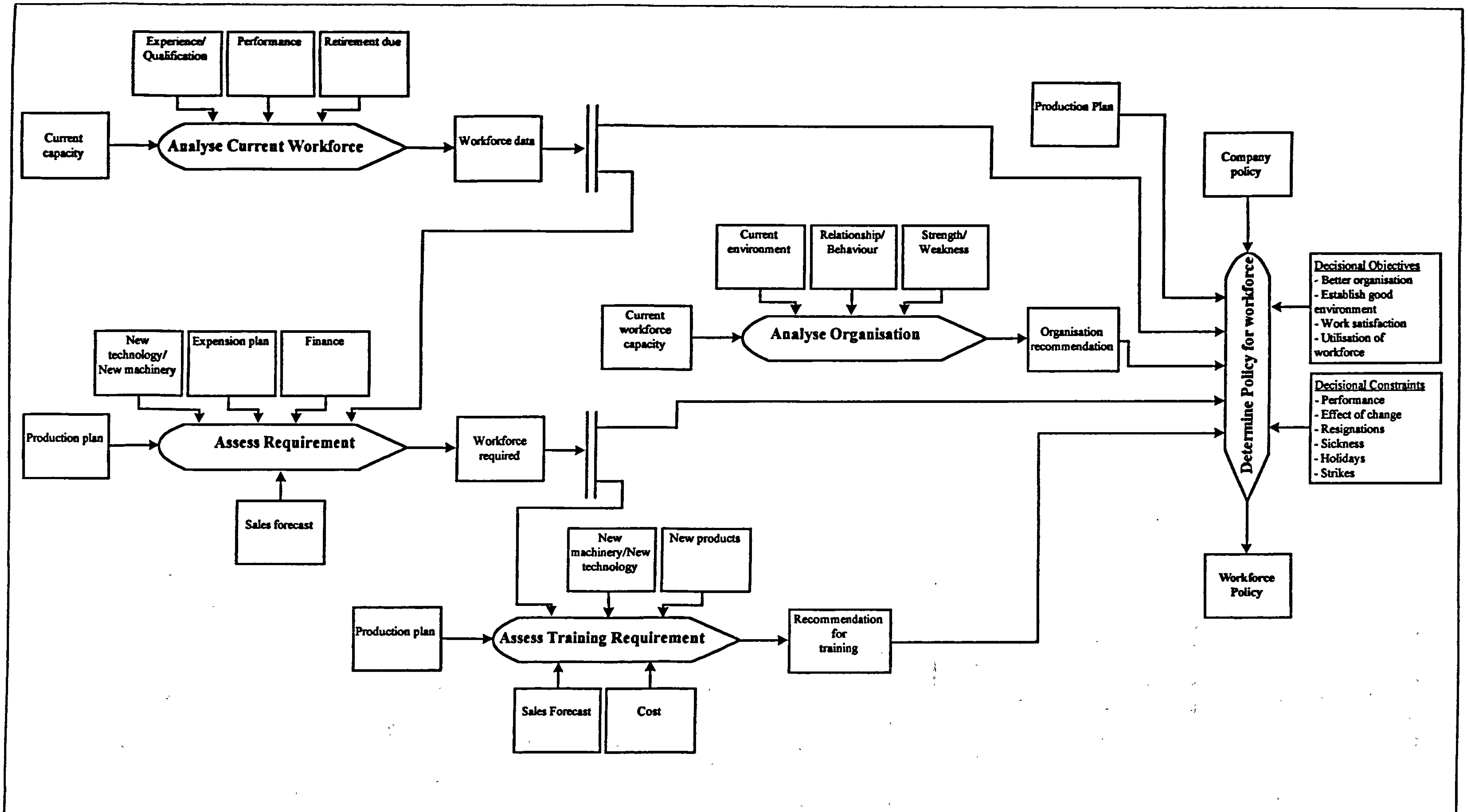
First this decisional activity collects all the relevant information required to perform the decision. The information consists of the outputs from all the different activities performed and other supporting information, such as sales forecasts and financial information. Secondly, the decisional activity considers the decisional objectives and constraints. The objectives of the decision are to:

- Maximise the return on the investment
- Maximise profit
- Reduce the manufacturing lead time
- Optimise utilisation of capacity
- Achieve the production targets

Possible constraints include:

- Major changes in the capital investment
- Procurement lead time
- Sales performance

After collection of all the information, the decision is performed with reference to the decisional objectives and the constraints. The output of the decision is the production plan which contains detail of the desired stock level of each product, products to be manufactured (with batch sizes) and re-order levels.



TITLE: POLICY OF WORKFORCE	**FUNCTION:** TO MANAGE RESOURCES (HUMAN)	**DRAWN BY:** M A CHODARI	**DATE:** 20-7-96	**D C:** (1,9)
COMPANY: EDWARD PRYOR & SON LTD.	**H/R:** H=3 YEARS R=1YEAR	**VALIDATE BY:** General Manager	**DATE:** 23-7-96	**INDEX:** 1/1

FIGURE 8.3 GRAI NET FOR WORKFORCE POLICY

8.3.2 GRAI Net for Policy for Workforce

This GRAI net represents the structure of the decision concerning the workforce policy performed at the strategic level. The GRAI net is shown in Figure 8.3. The horizon of this decision is three years and the review period is one year. The following activities have been used to support the decision:

a) Analyse the Current Workforce

This activity collects all the information regarding the workforce, which includes factors such as qualifications and skill.

b) Assess Requirement of the Production Plan

The input for this activity is the production plan. It assesses the needs of the production plan and indicates the workforce requirement to achieve production targets.

c) Assess Training Requirements

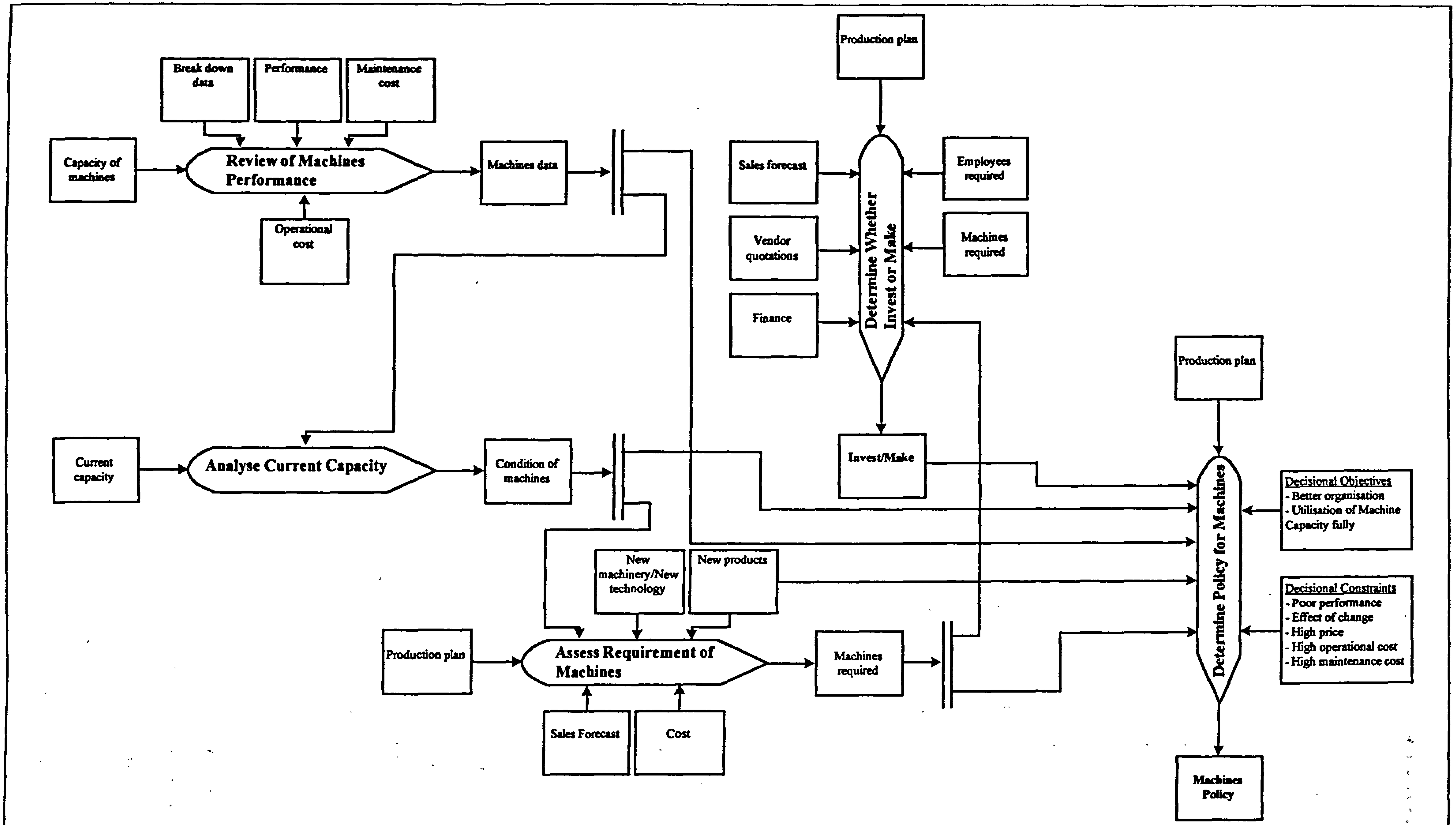
This activity assesses the training requirements with respect to product complexity and new machine acquisitions. The input of the activity is the production plan and the output is recommendations for training.

d) Analyse the Organisation

This activity analyses the organisational structure and behaviour of the workforce. The output of this activity recommends improvements to the organisational structure, based on an analysis of strengths and weaknesses within the organisation.

e) Determine the Workforce Policy

This decisional activity collects all the relevant information to perform the decision. The information comprises the outputs of all the different activities performed and other supporting information such as the budget, the production plan and the sales forecast. It considers the objectives of the decision and any constraints. The objectives of the decision are to:



TITLE: POLICY OF MACHINES	**FUNCTION:** TO MANAGE RESOURCES (TECH)	**DRAWN BY:** M A CHODARI	**DATE:** 20-7-96	**D C:** (1,10)
COMPANY: EDWARD PRYOR & SON LTD.	**H/R:** H=1 YEARS R=1 YEAR	**VALIDATE BY:** General Manager	**DATE:** 23-7-96	**INDEX:** 1/1

FIGURE 8.4 GRAI NET FOR MACHINES POLICY

- Improve the organisation
- Establish a good working environment
- Increase work satisfaction
- Appropriate utilisation of workforce regarding their skills

Possible constraints include:

- Low performance
- The effects of change
- Resignations
- Sickness
- Holidays
- Retirements

The output of this decision is the policy for the workforce. The policy consists of an organisational structure, salary structure, bonuses, and the number and expertise of employees required.

8.3.3 GRAI Net for Policy for Machines

This GRAI net represents the structure of the decision for the machines policy, performed at the strategic level. The GRAI net is shown in Figure 8.4. The horizon of this decision is three years and the review period one year. The following activities have been used to support the decision:

a) Review of Machine Performance

This is the periodic review of the performance of the company's machines. The objective of this activity is to collect periodic data on the machines. The data consists of the machines' condition, performance, breakdowns and capacity. The output of this activity is sent both to the decisional activity and to the activity which analyses current capacity.

b) Analyse the Current Capacity

This activity analyses the current capacity and the layout of machines. The purpose of this activity is to check whether the current capacity and the condition of the machines meets the requirements of the production plan. The output is sent to the activity that assess these requirements (Figure 8.4).

c) Determine Whether to Invest or Make

This decisional activity decides whether the company utilises sub-contractors or manufactures in-house. It compares vendor quotations with the expenditure involved in producing in-house. This is performed with reference to supporting information including sales forecasts and production plans. The output of this activity acts as supporting information that is sent to other decisional activities (Figure 8.4).

d) Determine the Policy for Machines

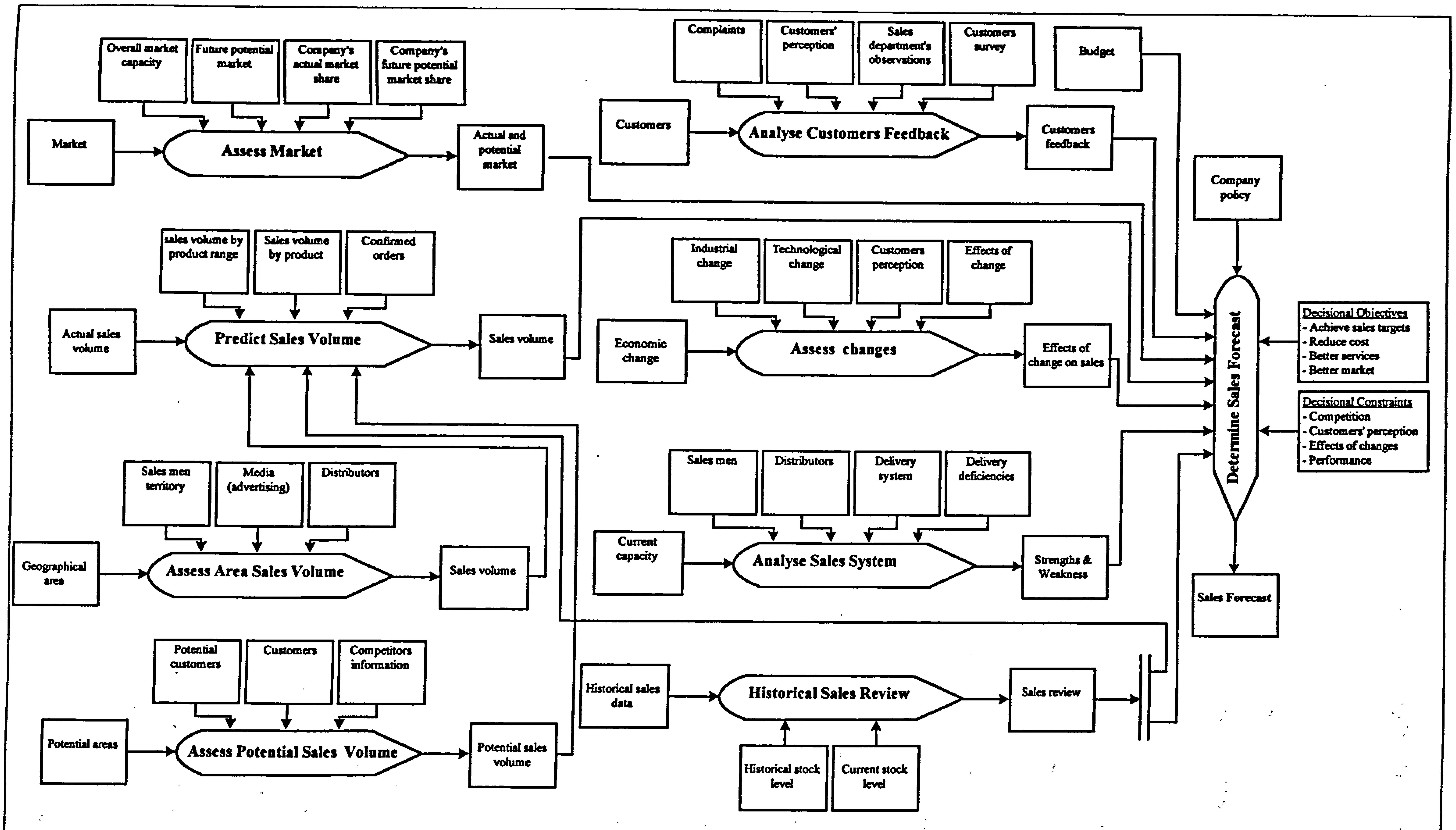
This decisional activity collects all the relevant information to perform the decision. The information consists of outputs from all the different activities performed and of other supporting information such as the budget, the production plan and the sales forecast. The decisional activity considers the objectives and constraints of the decision. The objectives of the decision are to:

- Improve the organisation of the machines
- Fully utilise the machines

Possible constraints include:

- Poor performance of machines
- Higher operational cost
- Higher maintenance cost

After collection of all the relevant information, the decision is performed with consideration of the objectives and constraints of the decision. The output of the decision is the policy of the machines which includes the number of machines required, the budgets and the procedure for buying new machines.



TITLE: SALES FORECAST	**FUNCTION:** TO SELL	**DRAWN BY:** M A CHODARI	**DATE:** 29-7-96	**D C:** (2,2)
COMPANY: EDWARD PRYOR & SON LTD.	**H/R:** H=1 YEAR R=3 MONTHS	**VALIDATE BY:** Sales Manager	**DATE:** 2-8-96	**INDEX:** 1/1

FIGURE 8.5 GRAI NET FOR SALES FORECAST

8.3.4 GRAI Net for the Sales Forecast

This GRAI net represents the structure of the decision for sales forecasts which is performed at the tactical level. The GRAI net is shown in Figure 8.5. The horizon of this decision is one year and the review period is three months. The following activities have been used to support this decision:

a) Assess Market

This activity assesses the market of the products that the company manufactures. This includes market capacity and potential market. The company's actual and potential market share are used as supporting information to perform this activity.

b) Predict Sales Volume

This activity predicts the sales volume using supporting information such as the sales volume by product range and the results of different activities performed, such as the assessment of the potential sales volume, the area sales volume and the historical review of sales (Figure 8.5).

c) Analyse Customers' Feedback

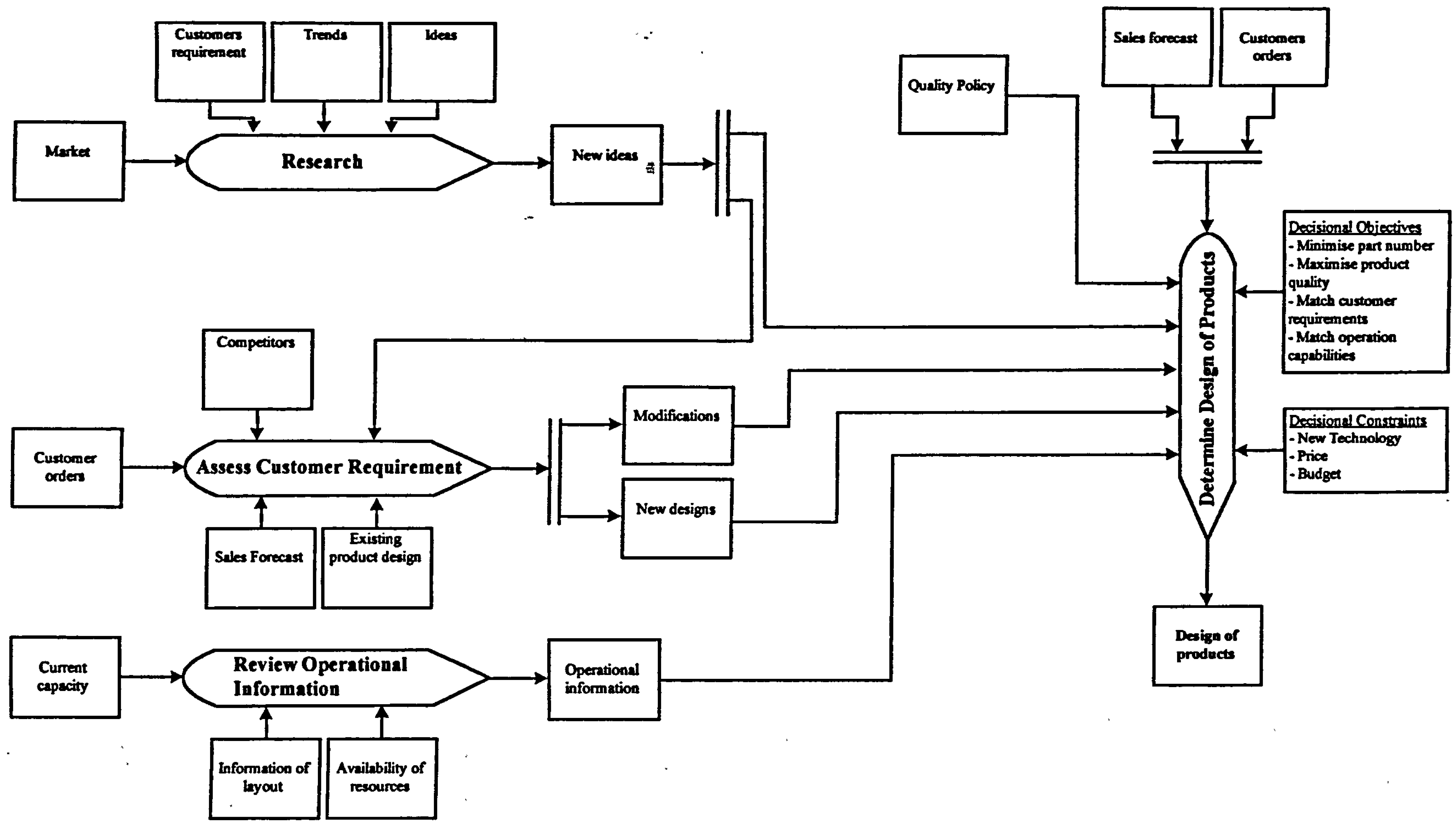
This activity analyses the customers' feedback. There are different methods of collecting feedback from the customers such as observation of the market, questionnaire surveys and the analysis of customer complaints.

d) Assess Change

This activity analyses the potential variables such as economic change, change in technology, change in the market and the effect of the changes on the market or the company. The result is sent to the decisional activity for further consideration.

e) Analyse the Sales System

This activity analyses the sales management system. This includes performance of the distributors, the salesmen, the delivery system and delivery deficiencies. The result of this analysis highlights the strengths and weaknesses of the system.



TITLE: RESEARCH & DEVELOPMENT	FUNCTION: TO DESIGN	DRAWN BY: M A CHODARI	DATE: 20-7-96	D C: (2,3)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=1 YEAR R=3 MONTHS	VALIDATE BY: General Manager	DATE: 23-7-96	INDEX: 1/1

FIGURE 8.6 GRAI NET FOR PRODUCT DESIGN

f) Historical Review of the Sales

This activity reviews past sales. The supporting information to perform the activity comprises the historical stock levels, sales levels and the re-order level. The result of this activity are sent both to the decisional activity and the activity that predicts the sales volume.

g) Determine the Sales Forecast

This decisional activity collects all the relevant information to perform the decision. The information consists of outputs from all the different activities performed and other supporting information, such as the sales budget. The decisional activity considers the objectives of the decision and the constraints. The objectives of the decision are to:

- Predict sales as accurately as possible
- Achieve sales targets
- Reduce costs
- Provide a better service

Possible constraints include:

- Competition
- The effect of change
- Product quality losses
- Performance of the salesmen

The result of the decision is the sales forecast, which consists of sales volumes with expected delivery dates and the quality requirements.

8.3.5 GRAI Net for Design

The GRAI net represents the structure of design decisions performed at the tactical level. The GRAI net is shown in Figure 8.6. The horizon of this decision is one year and the review period is three months. The following activities have been used to support the decision:

a) Research

Research is used to discover novel techniques or new ideas. This provides the basic input to carry out the design activities, incorporating possible new improvements.

b) Assess Customer Requirements

This activity assesses the customers' perceptions of the company, the product and the market. The customers' orders can also be the source of the quality requirement. The result of the activity is the recommendation of modifications to the existing product design or a completely new design.

c) Review Operational Information

This activity reviews the existing operational manufacturing facilities of the company including its layout, the machine capacity and resources. The objective of this activity is to collect the operational information necessary for consideration during the design phase.

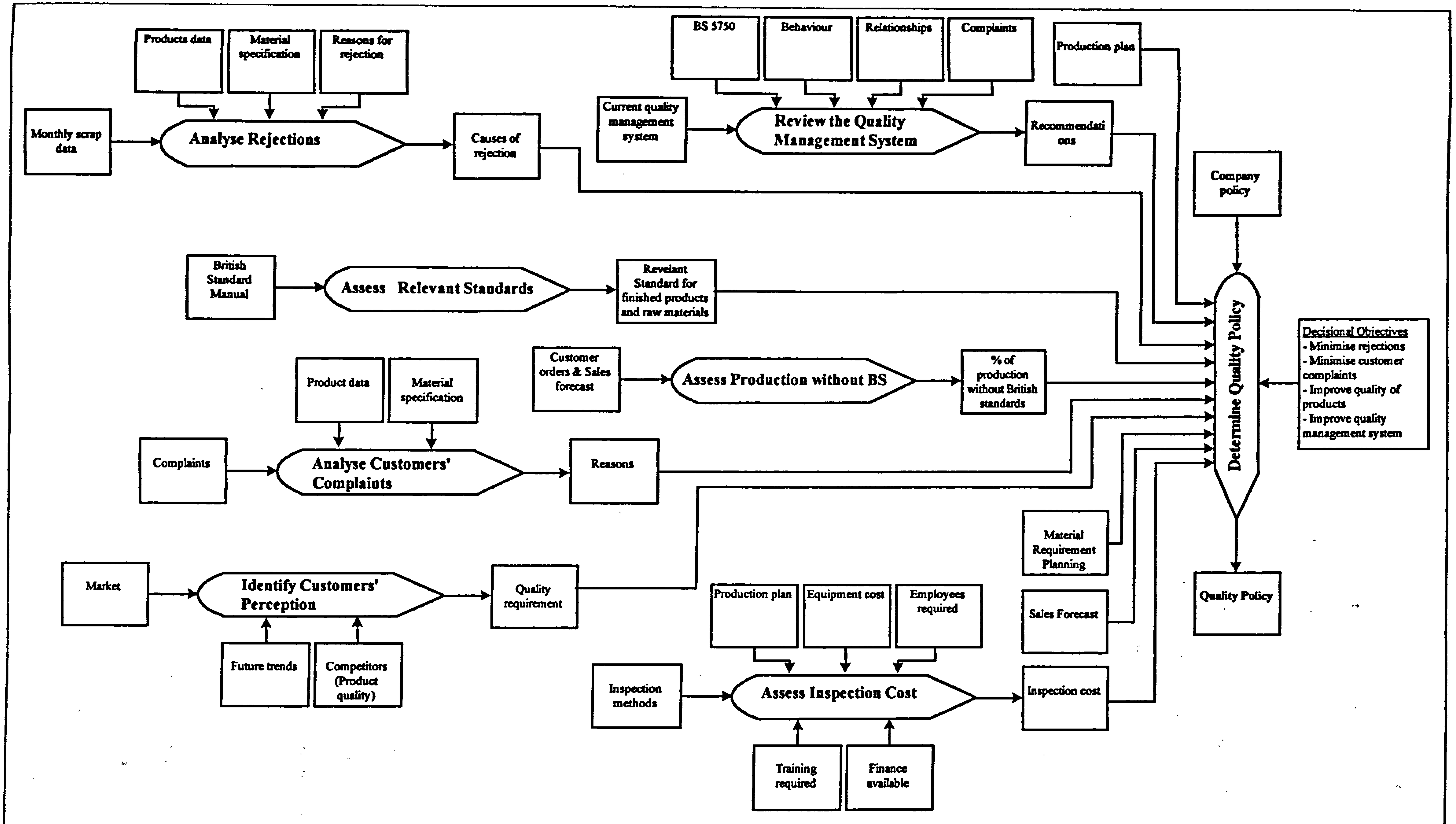
d) Determine the Design

This decisional activity collects all the relevant information to perform the decision. The information consists of the outputs of all the different activities performed and other supporting information, such as the budget and the quality policy. The decisional activity considers the objectives and constraints. Objectives of the decision are to:

- Minimise part numbers
- Optimise product quality
- Identify customers' requirements
- Design products that matched the operational capabilities

Possible constraints include:

- New technology employed by competitors, not available in the company
- Limited finance
- Products price



TITLE: QUALITY CONTROL	**FUNCTION:** TO CONTROL QUALITY	**DRAWN BY:** M A CHODARI	**DATE:** 29-7-96	**D C:** (2,3)
COMPANY: EDWARD PRYOR & SON LTD.	**H/R:** H=1 YEAR R=3 MONTHS	**VALIDATE BY:** General Manager	**DATE:** 2-8-96	**INDEX:** 1/1

FIGURE 8.7 GRAI NET FOR QUALITY POLICY

The inputs of this decisional activity are the sales forecast and the production plan and the result is the final product design. The final design consists of the engineering drawings, technical specifications of parts and subassemblies, and the specification of the materials.

8.3.6 GRAI Net for the Quality Policy

This GRAI net represents the structure of the decision for the quality policy, performed at the tactical level. The GRAI net is shown in Figure 8.7. The horizon of this decision is one year and the review period is three months. The following activities are used to support this decision:

a) Analyse Rejections

This activity analyses and determines the causes of rejections. This activity is helpful in improving the quality, because it acts as a feedback mechanism.

b) Assess Relevant Standards

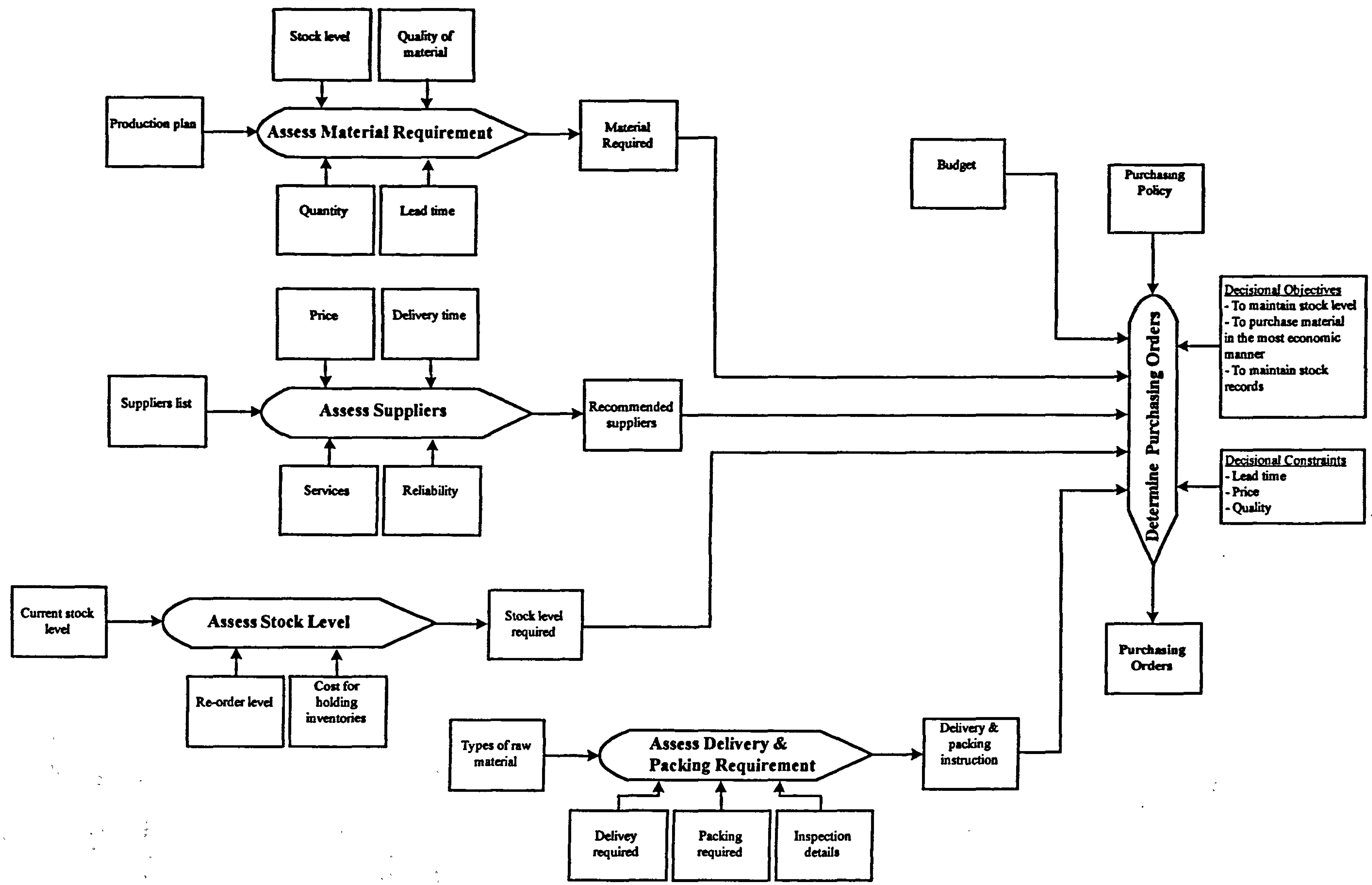
The main objective of this activity is to update the quality standards with reference to the relevant standards, for both products and materials. The input for the activity is the relevant standards reference manual.

c) Analyse Customers' Complaints

This activity analyses the customers' complaints and quality problems. It uses the product data and material specification for support. Material testing is also carried out to detect causes. The objective of the activity is to identify the reasons for a complaint and the results are then sent to the decision centre for further consideration.

d) Review Quality Management System

Ideally a quality management system should be documented and each procedure should be absolutely clear. It is the responsibility of senior management to have a clear understanding of quality and ensure that the correct systems are implemented in



TITLE: PURCHASING ORDERS	**FUNCTION:** TO MANAGE MATERIAL (TO BUY)	**DRAWN BY:** M A CHODARI	**DATE:** 30-7-96	**D C:** (2,5)
COMPANY: EDWARD PRYOR & SON LTD.	**H/R:** H=1 YEAR R=3 MONTHS	**VALIDATE BY:** Material Control Manager	**DATE:** 6-8-96	**INDEX:** 1/1

FIGURE 8.8 GRAI NET FOR PURCHASING ORDERS (Long lead time)

the organisation. The quality system is reviewed against BS5750 and recommendations for improvements to the system are presented.

e) Assess Inspection Cost

This activity assesses the inspection cost. The costs comprise of equipment, material testing, employees and the training needed to carry out inspection. The result of the activity is sent to the decision centre for further consideration.

f) Determine the Quality Policy

This decisional activity collects all the relevant information to perform the decision. The information comprises the results of all the different activities performed and other supporting information such as the budget and material requirement planning, sales forecasts and production plan. The decisional activity considers the objectives and constraints of the decision. The objectives of the decision are to:

- Minimise rejections
- Minimise customer complaints
- Improve the quality of both the product and the quality management system

The result of the decision represents the company's quality policy. The policy consists of recommendations of the quality standards and documentation of the quality management system.

8.3.7 GRAI Net for Purchase Orders (Long Procurement Lead Time)

This GRAI net represents the structure of the decision for issuing the purchasing orders for raw material. The GRAI net is shown in Figure 8.8. The horizon of this decision is one year and the review period is three months. The following activities are used to support the decision:

a) Assess Material Requirements

This activity assesses the material requirements regarding the production plan. First, the activity determines the quantity of the material needed before checking whether the required material is already available in stock. The discrepancy between these quantities indicates the material requirements.

b) Assess Re-order Level

This activity assesses the re-order level against the material requirements. If material is required, the purchasing order is issued accordingly.

c) Assess Suppliers

This activity assesses the suppliers and their quotations using information such as prices, delivery time, service offered and reliability. The result of the activity is a recommended list of suppliers.

d) Assess Delivery and Packing Requirements

The activity assesses the delivery and packing requirements with reference to demand. The result of the activity issues the instructions for delivery and packing.

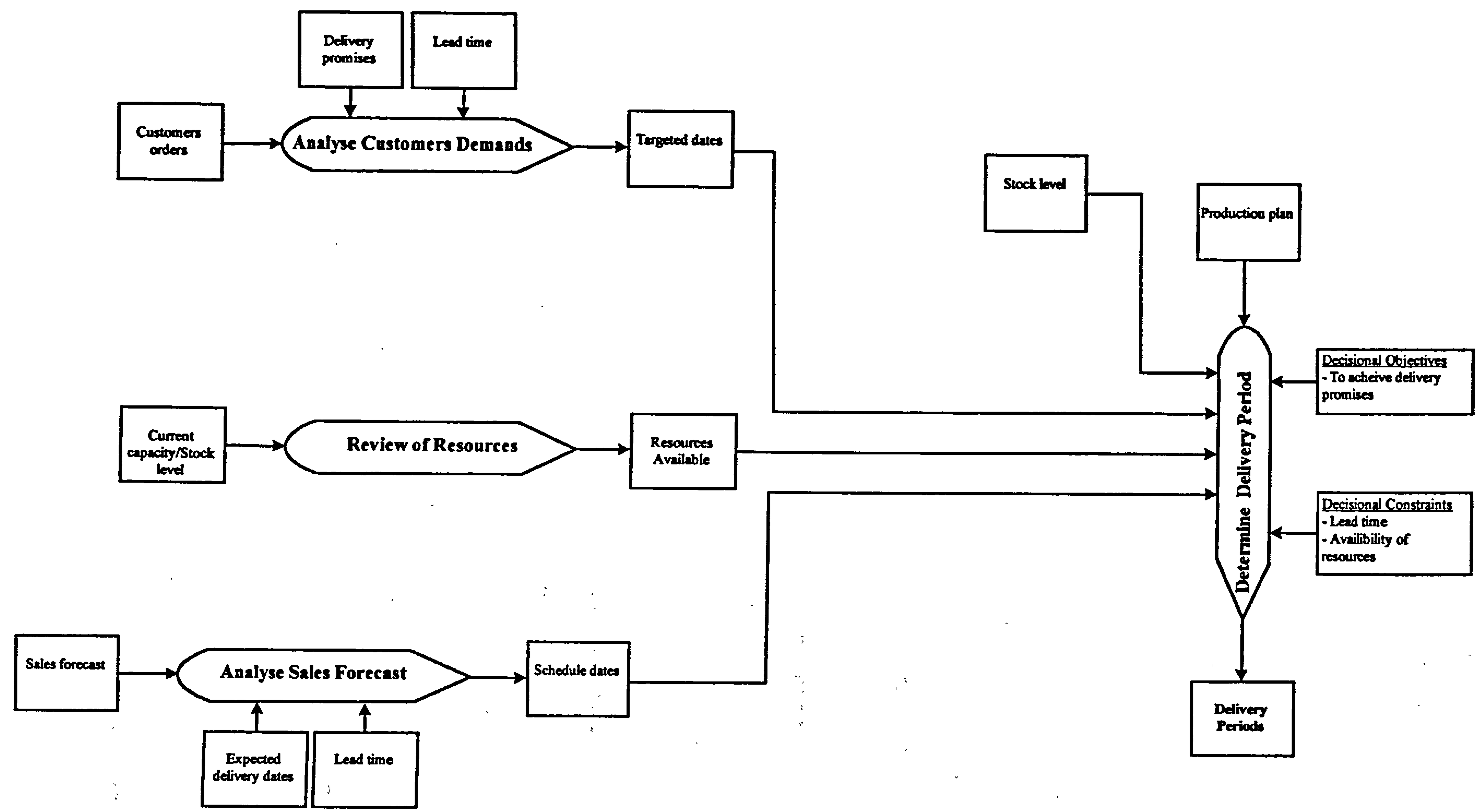
e) Determine the Purchasing Order

This decisional activity collects all the relevant information to perform the decision. The information comprises the results of all the different activities performed and other supporting information, such as the budget, material requirement planning, sales forecasts and the production plan. The decisional activity considers the objectives of the decision and any other constraints. The objectives of the decision are to:

- Maintain the stock level
- Purchase the material in the most economic manner
- Maintain the stock record

Possible constraints include:

- Purchasing lead time



TITLE: DELIVERY PERIODS	FUNCTION: TO MANAGE MATERIAL (TO DELIVER)	DRAWN BY: M A CHODARI	DATE:30-7-96	D C: (2,6)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=1 YEAR R=3 MONTHS	VALIDATE BY: Material Control Manager	DATE:6-8-96	INDEX: 1/1

FIGURE 8.9 GRAI NET FOR DELIVERY PERIOD

- Material price
- Quality

The output of this decisional activity are the purchasing orders which are issued to recommended suppliers. The purchasing orders consist of the accepted price, the quality required, the required delivery time, and delivery and packing instructions.

8.3.8 GRAI Net for the Delivery Period

This GRAI net represents the structure of the decision for the delivery period of the finished products to customers and stock. This decision is performed at the tactical level and is shown in Figure 8.9. The horizon of this decision is one year and the review period is three months. The following activities have been used to support the decision:

a) Analyse Customers Demand

This activity analyses the customers' delivery requirements. The input to the activity is from the customers' orders. The manufacturing lead time is determined and an estimate of the delivery target date is made.

b) Analyse Sales Forecast

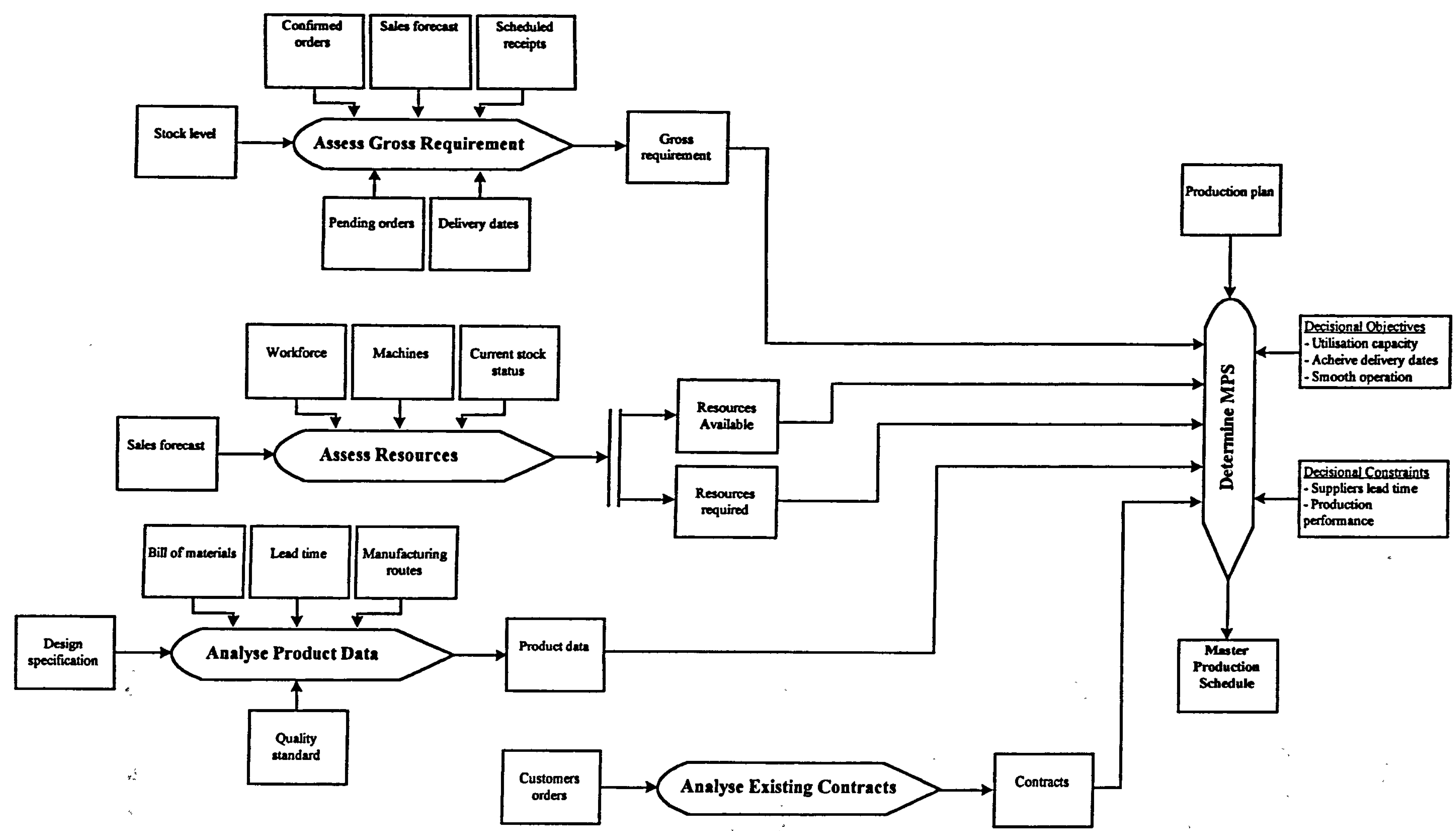
The activity analyses the sales forecast and to estimates the schedule dates for manufacturing.

c) Review the Resources

This activity reviews the existing resources of the company including the machine capacity, raw material and the workforce.

d) Determine the Delivery Period

This decision estimates the delivery period for the finished products to reach the customers or stock. The decisional activity collects all the relevant information to perform the decision. The information consists of results from all the different



TITLE: MASTER PRODUCTION SCHEDULE	FUNCTION: TO PLAN PRODUCTION	DRAWN BY: M A CHODARI	DATE: 31-7-96	D C: (2,7)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=1 YEAR R=3 MONTHS	VALIDATE BY: Material Control Manager	DATE: 6-8-96	INDEX: 1/1

FIGURE 8.10 GRAI NET FOR MPS (MASTER PRODUCTION SCHEDULE)

activities performed and other supporting information, such as the budget, material requirement planning, sales forecast, stock levels, re-order level and the production plan. The decisional activity considers the objectives of the decision and any other constraints. The objectives of the decision are to:

- Maintain the stock level
- Achieve the delivery dates

Possible constraints include:
- Manufacturing lead time
- Availability of resources

The output of this decisional activity are estimated delivery dates, which are then sent to the MPS decision centre.

8.3.9 GRAI Net for the Master Production Schedule (MPS)

The MPS must be a firm plan because it acts as the driving force and provides the basic input to plan the manufacturing activities such as capacity planning, resources planning and material requirement planning. The GRAI net represents the structure of the decision of the MPS that is performed at the tactical level. The GRAI net is shown in Figure 8.10. The horizon of this decision is one year and the review period three months. The following activities have been used to support the decision:

a) Assess Gross Requirements

The activity assesses the gross requirements for production. The input of this activity is the stock level because the Division operates using a re-ordering system. The activity is carried out depending on the sales forecast and customers' confirmed and pending orders. The result of the activity shows the gross production requirements for one year.

b) Assess Resources

The objective of this activity is to assess the availability of resources. The input is the sales forecast and the analysis refers to existing loading of the resources. The results of the activity show the availability and potential loading of resources.

c) Analyse Product data

The objective of the activity is to collect product information such as the bill of materials, quality standards, subassemblies and material specifications. The result of the activity is sent to the decisional activity.

d) Determine the MPS

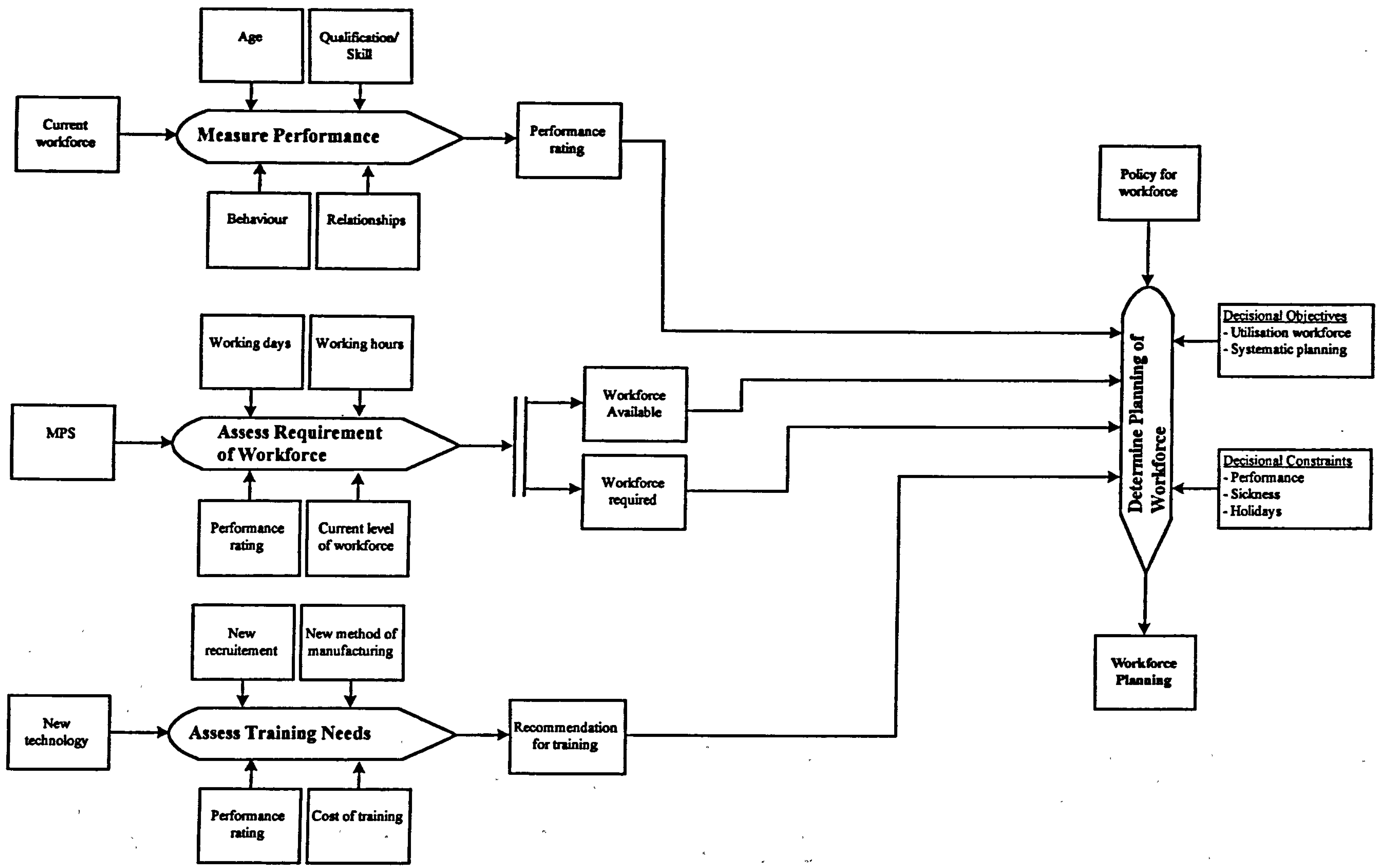
This decisional activity collects all the relevant information to perform the decision. The information consists of the results of all the different activities carried out and other supporting information, such as the budget, sales forecast, stock level details, re-order level and production plan. The decisional activity considers the objectives of the decision and the constraints. The objectives of the decision are to:

- Achieve the delivery dates
- Ensure smooth operation
- Improve the utilisation of capacity

The constraints of the decision are:

- The procurement lead time
- Possible lapses in production performance
- Machines breakdowns

The output of this decisional activity is the master production schedule, issued for one year. The MPS consists of all the products and sub-assemblies to be manufactured, together with the bill of materials, expected completion dates and batch sizes.



TITLE: WORKFORCE PLANNING	**FUNCTION:** TO MANAGE RESOURCES (HUMAN)	**DRAWN BY:** M A CHODARI	**DATE:** 5-8-96	**D C:** (2,9)
COMPANY: EDWARD PRYOR & SON LTD.	**H/R:** H=1 YEAR R=3 MONTHS	**VALIDATE BY:** Production Manager	**DATE:** 7-8-96	**INDEX:** 1/1

FIGURE 8.11 GRAI NET FOR WORKFORCE PLANNING

8.3.10 GRAI Net for Workforce Planning

This GRAI net represents the structure of the decision for workforce planning which is performed at the tactical level. The GRAI net is shown in Figure 8.11. The horizon of this decision is one year and the review period is three months. The following activities are used to support the decision:

a) Measure Performance

This activity measures the performance of the workforce regarding their job commitment, behaviour and relationships. The resulting performance rating helps when assigning jobs to the workforce.

b) Assess Requirements of the Workforce

The requirements of the workforce are assessed with reference to the master production schedule. The activity collects all the information such as current workforce levels and the total number of working days and hours available in one year. The results of the activity show the availability of the workforce and the requirements necessary to achieve the production target.

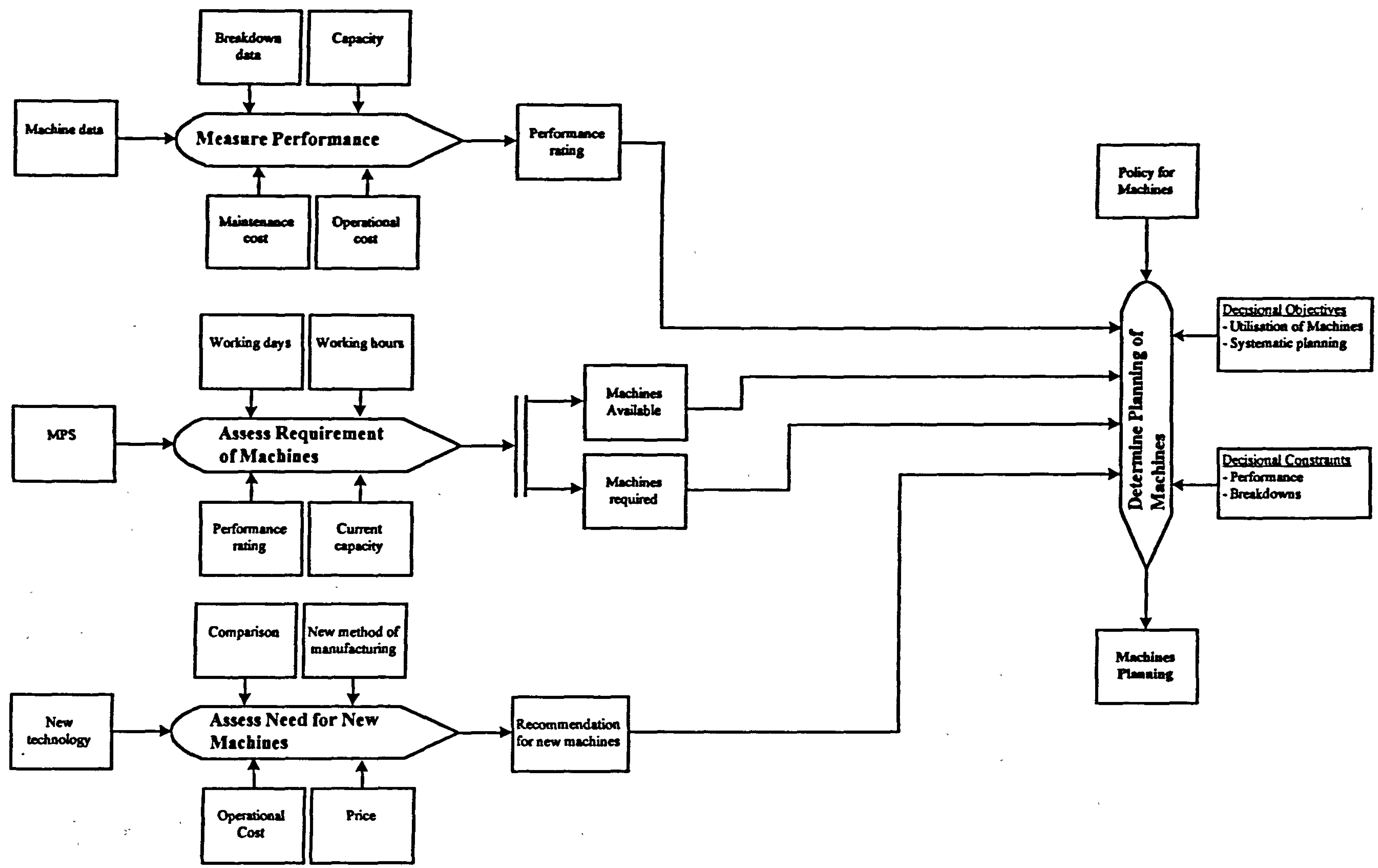
c) Assess Training Needs

This activity assesses the need for training resulting from the introduction of new technologies and the increasing complexity of manufacturing operations. Information regarding cost, recruitment and new methods of manufacturing are used to carry out this activity. The results of this activity are the recommendations for training.

d) Determine the Workforce Planning

This decisional activity collects all the relevant information to perform the decision. The information consists of the results of all the different activities carried out and other supporting information such as the budget and the MPS. The decisional activity considers the objectives and constraints of the decision. The objectives of the decision are the:

- Effective utilisation of the workforce



TITLE: MACHINES PLANNING	FUNCTION: TO MANAGE RESOURCES (TECH)	DRAWN BY: M A CHODARI	DATE: 5-8-96	D C: (2,10)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=1 YEAR R=3 MONTHS	VALIDATE BY: Production Manager	DATE: 7-8-96	INDEX: 1/1

FIGURE 8.12 GRAI NET FOR MACHINES PLANNING

- Systematic planning

Possible constraints include:

- Poor workforce performance
- Sickness
- Holidays

The decisional activity is carried out with reference to the policy for the workforce and the output of this activity is the plan of workforce loading. The output consists of the workforce availability and the allocation of the jobs.

8.3.11 GRAI Net for Machine Planning

This GRAI net represents the structure of the decision for planning the machine loading, performed at the tactical level. The GRAI net is shown in Figure 8.12. The horizon of this decision is one year and the review period three months. The following activities are used to support this decision:

a) Measure Performance

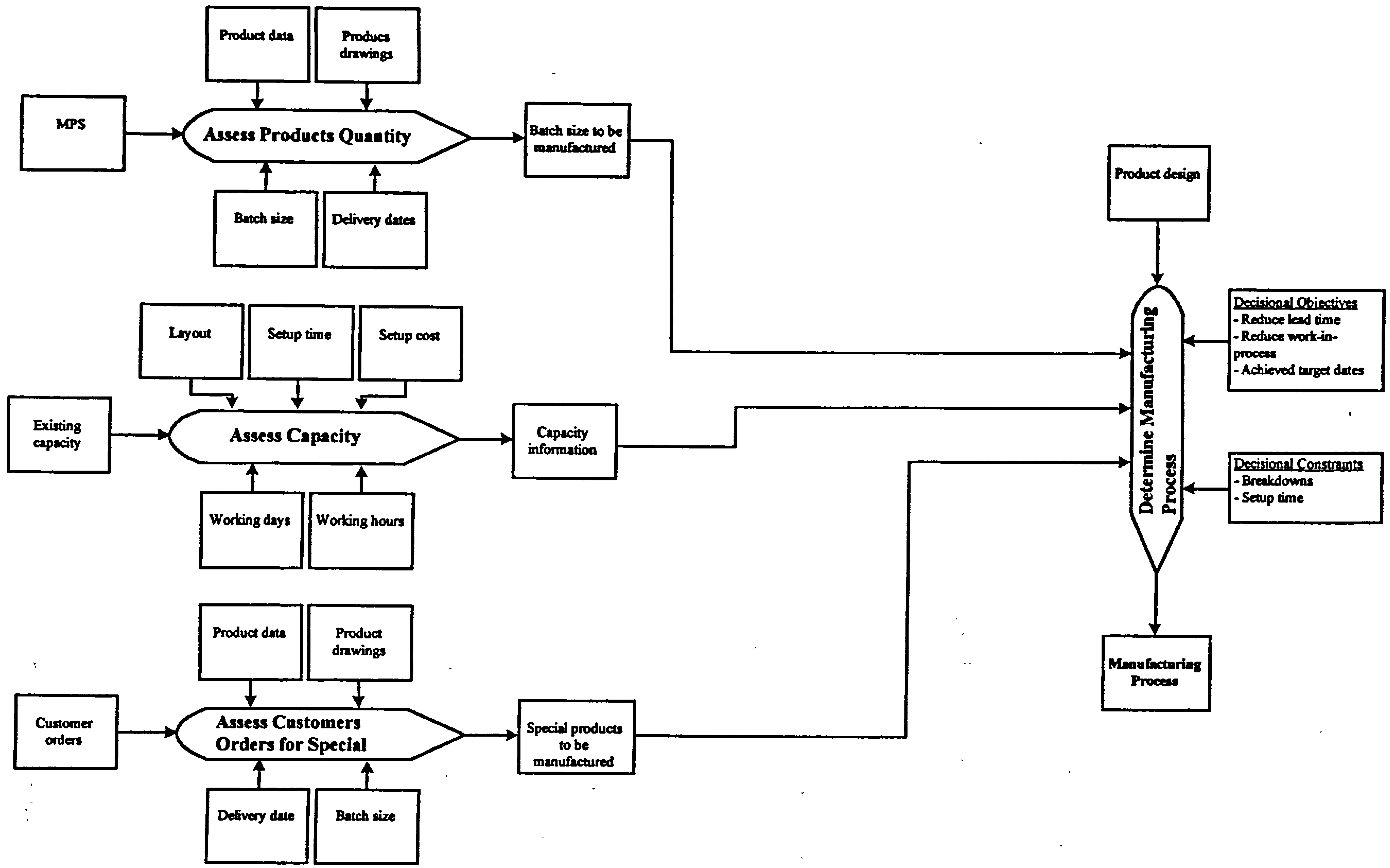
This activity measures the performance of the machines and calculates the operational costs, the number of breakdowns and the machine capacities. The result of the activity aids the assignment of jobs to the machines.

b) Assess Requirements

The requirements of the machines is assessed using the MPS. The activity collects the information such as the level of machine capacities, and total number of the working days and hours available in one year. The results of the activity show the availability and number of machines required to achieve the production targets.

c) Assess the Need for New Machines

This activity assesses the need for new machines using the MPS or simply the need to replace existing machinery due to its poor condition or performance. The result of this activity is sent to the decisional activity for further consideration.



TITLE: MANUFACTURING PROCESS & ROUTES	**FUNCTION:** TO DESIGN	**DRAWN BY:** M A CHODARI	**DATE:** 10-8-96	**D C:** (3,3)
COMPANY: EDWARD PRYOR & SON LTD.	**H/R:** H=1 MONTH R=1 WEEK	**VALIDATE BY:** Chief Planner	**DATE:** 14-8-96	**INDEX:** 1/1

FIGURE 8.13 GRAI NET FOR MANUFACTURING PROCESS

d) Determine the Planning of the Machines

This decisional activity collects all the relevant information to perform the decision. The information consists of the results of all the different activities carried out and other supporting information, such as the budget and the MPS. The decisional activity considers the objectives and constraints of the decision. The objectives of the decision are to:

- Improve the utilisation of the machines
- Introduce systematic planning

Possible constraints of the decision include:

- A reduction in performance of the machines
- Machine breakdowns

The decisional activity operates in view of the policy for the machines, and the output of this activity is the machine planning schedule. The output consists of detail of the machines available and allocation of jobs.

8.3.12 GRAI Net for the Manufacturing Process

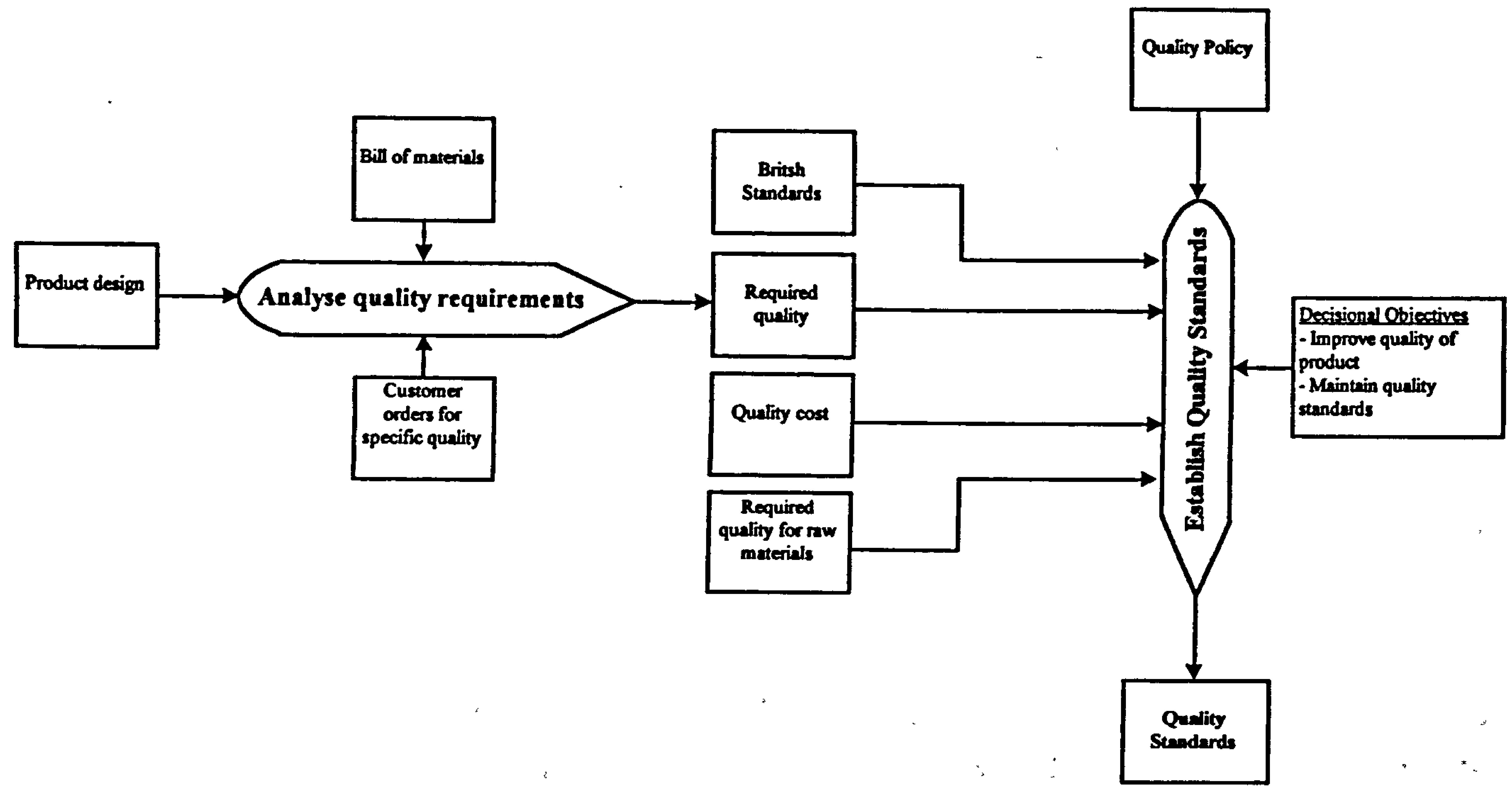
This GRAI net represents the structure of the decision to establish the manufacturing process for the company's products. The GRAI net is shown in Figure 8.13. The horizon of this decision is one month and the review period one week. The following activities are used to support this decision:

a)Assess Quantity of Products

The objective of this activity is to divide the master production schedule into the desired monthly production. The activity assesses the batch size of the standard products to be manufactured in one month.

b) Assess Customer Orders for Special Products

This activity consults the sales and design departments about customer orders placed for any special product. If the design has been completed and the product is due for the production, the activity will consider it for the process.



TITLE: QUALITY STANDARDS	**FUNCTION:** TO CONTROL QUALITY	**DRAWN BY:** M A CHODARI	**DATE:** 10-8-96	**D C:** (3,4)
COMPANY: EDWARD PRYOR & SON LTD.	**H/R:** H=1 MONTH R=1 WEEK	**VALIDATE BY:** Chief Planner	**DATE:** 14-8-96	**INDEX:** 1/1

FIGURE 8.14 GRAI NET FOR QUALITY STANDARDS

c) Assess Capacity

This activity collects the capacity information, including the layouts of the machines, set-up times and working days and hours available in one month.

d) Determine the Manufacturing Process

The decisional activity collects all the relevant information to perform the decision. The information consists of the results of all the different activities carried out and other supporting information, such as the product design and MPS. The decisional activity considers the objectives of the decision and any other constraints. The objectives of the decision are to:

- Reduce the manufacturing lead time
- Reduce Work-in-Progress
- Create smooth and flexible manufacturing routes, that match the layout

The constraints of the decision are:

- Machine breakdowns
- Machine set-up times

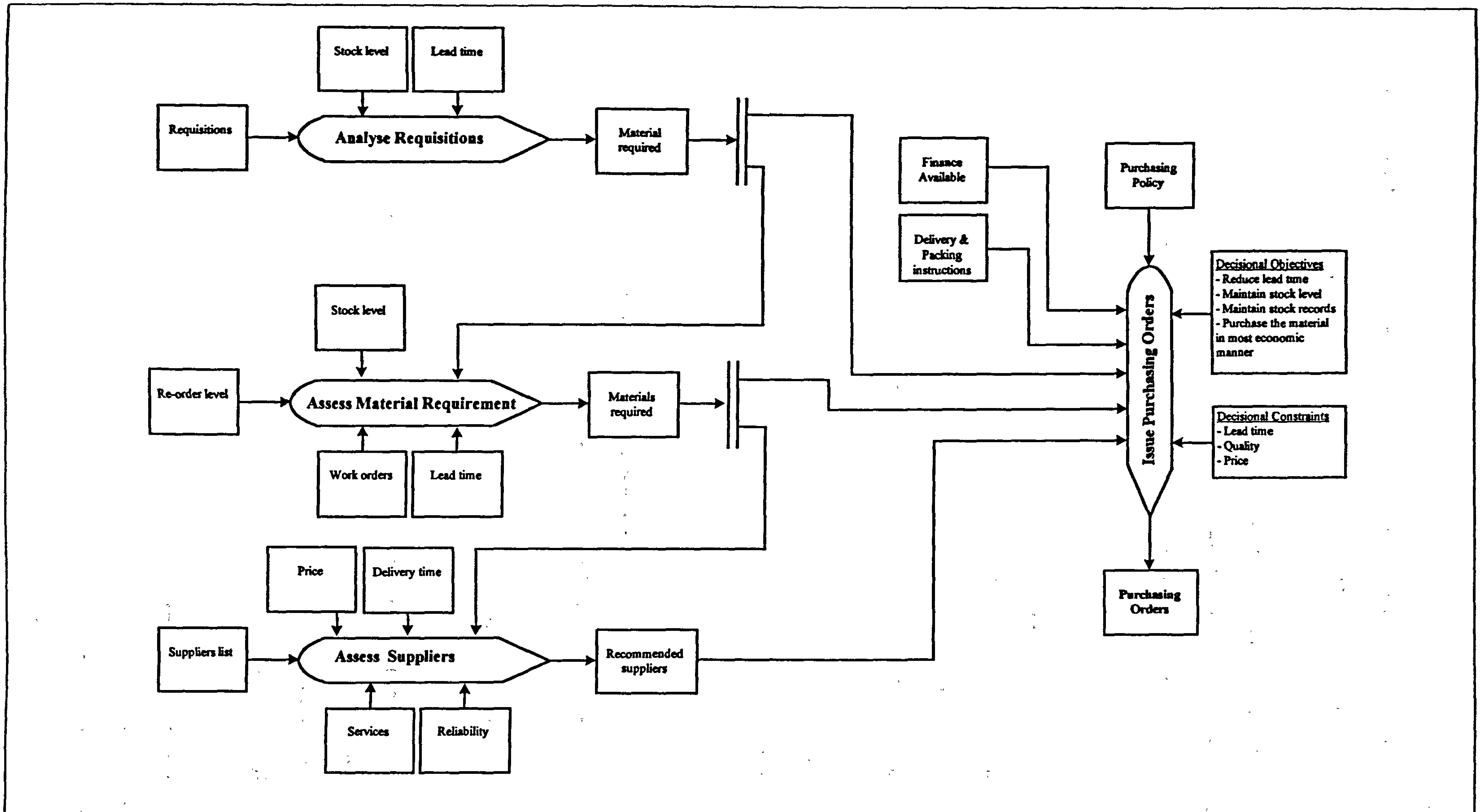
The output of the decision is the manufacturing process sheet that consists of the manufacturing instructions, lead time and product routes.

8.3.13 GRAI Net for Quality Standards

This GRAI net represents the structure of the decision to establish quality standards for finished products and the raw material. The GRAI net is shown in Figure 8.14. The horizon of this decision is one month and the review period is one week. The following activities have been used to support the decision:

a) Analyse Quality Requirements

This activity analyses the quality requirements. It consults the marketing and design departments to obtain information about the quality specifications for both finished products and raw materials. It also assesses any special customer requirements.



TITLE: PURCHASING ORDERS	**FUNCTION:** TO MANAGE MATERIAL (TO BUY)	**DRAWN BY:** M A CHODARI	**DATE:** 11-8-96	**D C:** (3,5)
COMPANY: EDWARD PRYOR & SON LTD.	**H/R:** H=1 MONTH R=1 WEEK	**VALIDATE BY:** Purchasing Officer	**DATE:** 14-8-96	**INDEX:** 1/1

FIGURE 8.15 GRAI NET FOR PURCHASING ORDERS

b) Determine the Quality Standards

This decisional activity collects all the relevant information to perform the decision. The information consists of the result of the activity carried out and other supporting information such as the product design, quality costs and the British Standards. The decisional activity considers the objectives of the decision and any constraints. The objectives of the decision are to:

- Improve the quality of the products
- Maintain the quality standards

8.3.14 GRAI Net for the Purchasing Orders

The GRAI net represents the structure of the decision to issue purchasing orders for raw materials. The GRAI net is shown in Figure 8.15. The horizon of this decision is one month and the review period is one week. The following activities have been used to support the decision:

a) Analyse Requisition

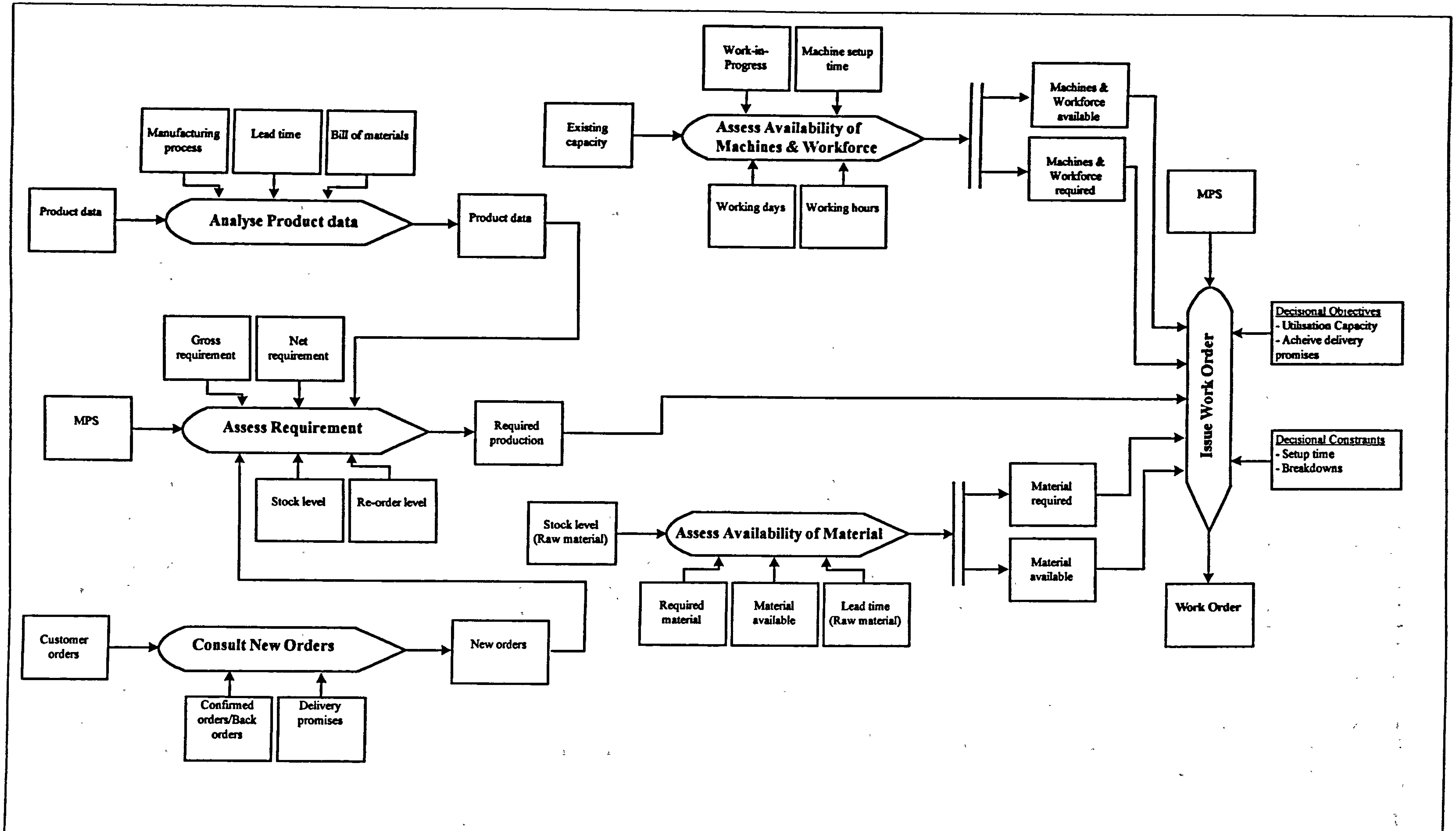
This activity analyses the requisitions that come from the production department. The activity assesses the type of material, the quantity and quality required. The resulting information is sent to the material assessment activity.

b) Assess Material Requirements

This activity assesses the material requirements. It first checks the re-order level, the requisitions and then the stock level. The result shows the requirement for the material which is sent to the decisional activity for further consideration.

c) Assess Suppliers

This activity assesses the suppliers in terms of their quotations, services, lead time, quality of the material and reliability. The result of the activity recommends particular suppliers according to the material specifications and any other requirements.



TITLE: WORK ORDERS PLANNING	**FUNCTION:** TO PRODUCTION PLAN	**DRAWN BY:** M A CHODARI	**DATE:** 5-8-96	**D C:** (3,7)
COMPANY: EDWARD PRYOR & SON LTD.	**H/R:** H=1 MONTH R=1 WEEK	**VALIDATE BY:** Production Manager	**DATE:** 7-8-96	**INDEX:** 1/1

FIGURE 8.16 GRAI NET FOR WORK ORDERS

d) Determine the Purchasing Orders

This decisional activity collects all the relevant information to perform the decision. The information consists of the results from all the different activities carried out and other supporting information such as the budget, and delivery and packing instructions. The decisional activity considers the objectives and constraints of the decision. The objectives of the decision are to:

- Maintain the stock level
- Maintain stock records
- Issue orders to the recommended supplier
- Purchase the material in most economic manner

The constraints of the decision include:

- Procurement lead time
- Product quality
- Material price

The output of the decision is the purchasing orders, which are issued to the recommended suppliers. The orders consist of the agreed price, the quality required, the quantity specification the delivery date, and delivery and packing instructions.

8.3.15 GRAI Net for the Work Order

The GRAI net represents the structure of the decision for work orders in production. The GRAI net is shown in Figure 8.16. The horizon of this decision is one month and the review period one week. The following activities are used to support the decision:

a) Analyse Product Data

The objective of this activity is to collect the relevant information on the different products to be manufactured. This includes the bill of materials, process plan and estimated lead time. The resulting information is sent to the activity that assesses the production requirement.

b) Assess Requirements

The main input of the activity is the master production schedule. It divides the MPS into monthly production plan regarding the requirements and schedules. The supporting information to carry out the activity includes the gross and net production requirements, stock levels, the re-order level and customer orders.

c) Consult New Orders

This activity consults the sales department for details of any new orders and their delivery date. If the delivery date is set, they are considered for manufacturing. The resulting information is sent to the requirement assessment activity.

d) Assess Availability of the Material

This activity assesses the availability of materials. It first checks the stock status of the material required. If the material is not available, it issues a requisition to the purchasing department.

e) Assess Availability of Machines and Workforce

This activity assesses the machines and the operators available for manufacturing. The resulting information is sent to the decisional activity for further consideration.

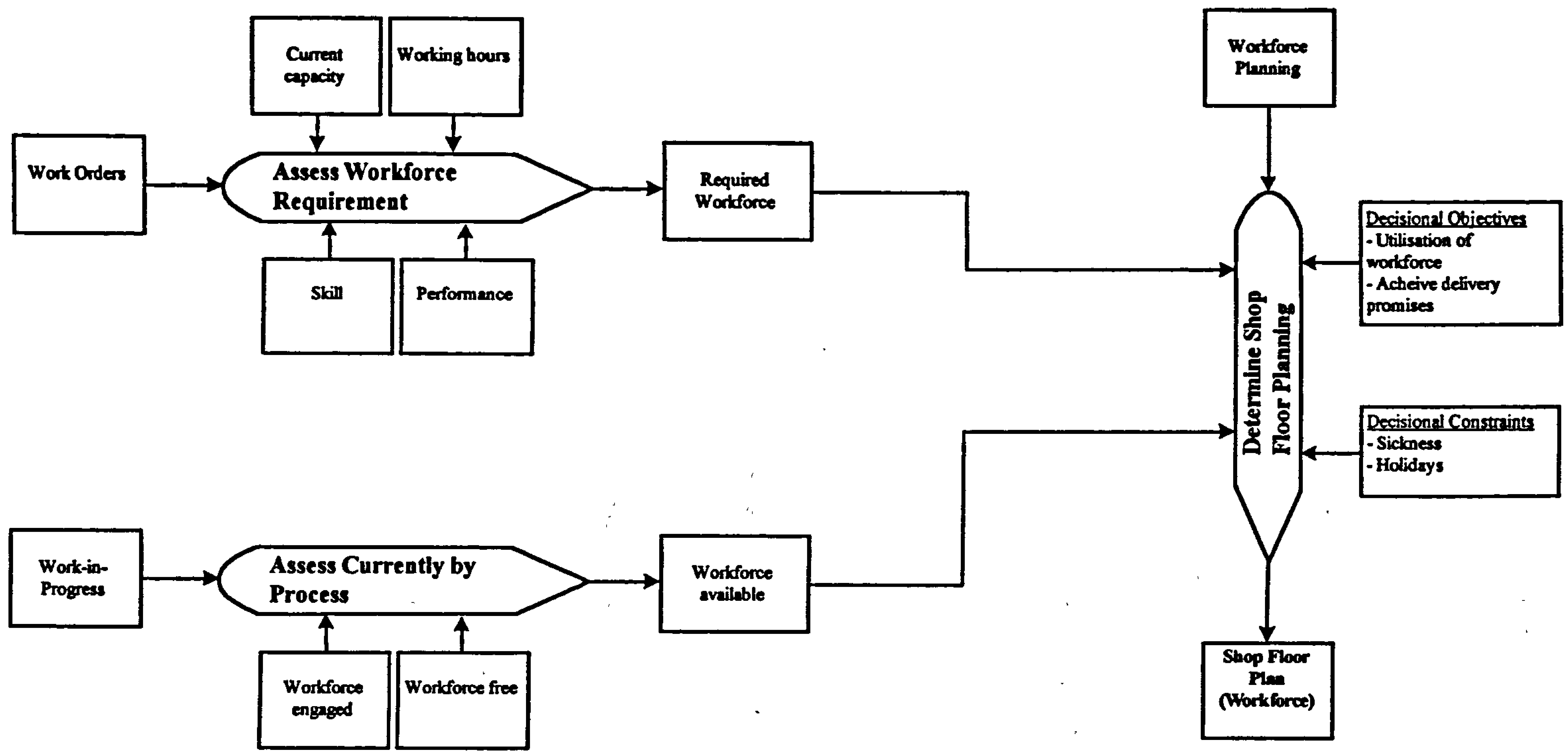
f) Determine the Work Orders

This decisional activity collects all the relevant information to perform the decision. The information consists of the results of all the different activities carried out and other supporting information, such as the layout. The decisional activity considers the objectives and constraints of the decision. The objectives of the decision are to:

- Utilise full capacity
- Achieve the delivery promises

The potential constraints of the decision include:

- Set-up times
- Machine breakdowns



TITLE: SHOP FLOOR PLANNING	FUNCTION: TO MANAGE RESOURCE(HUMAN)	DRAWN BY: M A CHODARI	DATE: 18-8-96	D C: (3,9)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=1 MONTH R=1 WEEK	VALIDATE BY: Production Manager	DATE: 19-8-96	INDEX: 1/1

FIGURE 8.17 GRAI NET FOR SHOP FLOOR PLANNING (WORKFORCE)

The output of the decision is the work orders for manufacturing. Each work order contains information regarding the products to be manufactured, with their scheduled start and finish dates.

8.3.16 GRAI Net for the Shop Floor Planning (Workforce)

This GRAI net represents structure of the decision for the shop floor plan for the workforce. The plan is carried out with reference to the works orders for production. The GRAI net is shown in Figure 8.17. The horizon of this decision is one month and the review period one week. The following activities are used to support the decision:

a) Assess Workforce Requirements

The input of this activity is the works orders showing the production plan for one month. The objective of this activity is to assess the exact requirements for the workforce to achieve the works orders. The activity helps the decision centre with shift and overtime planning.

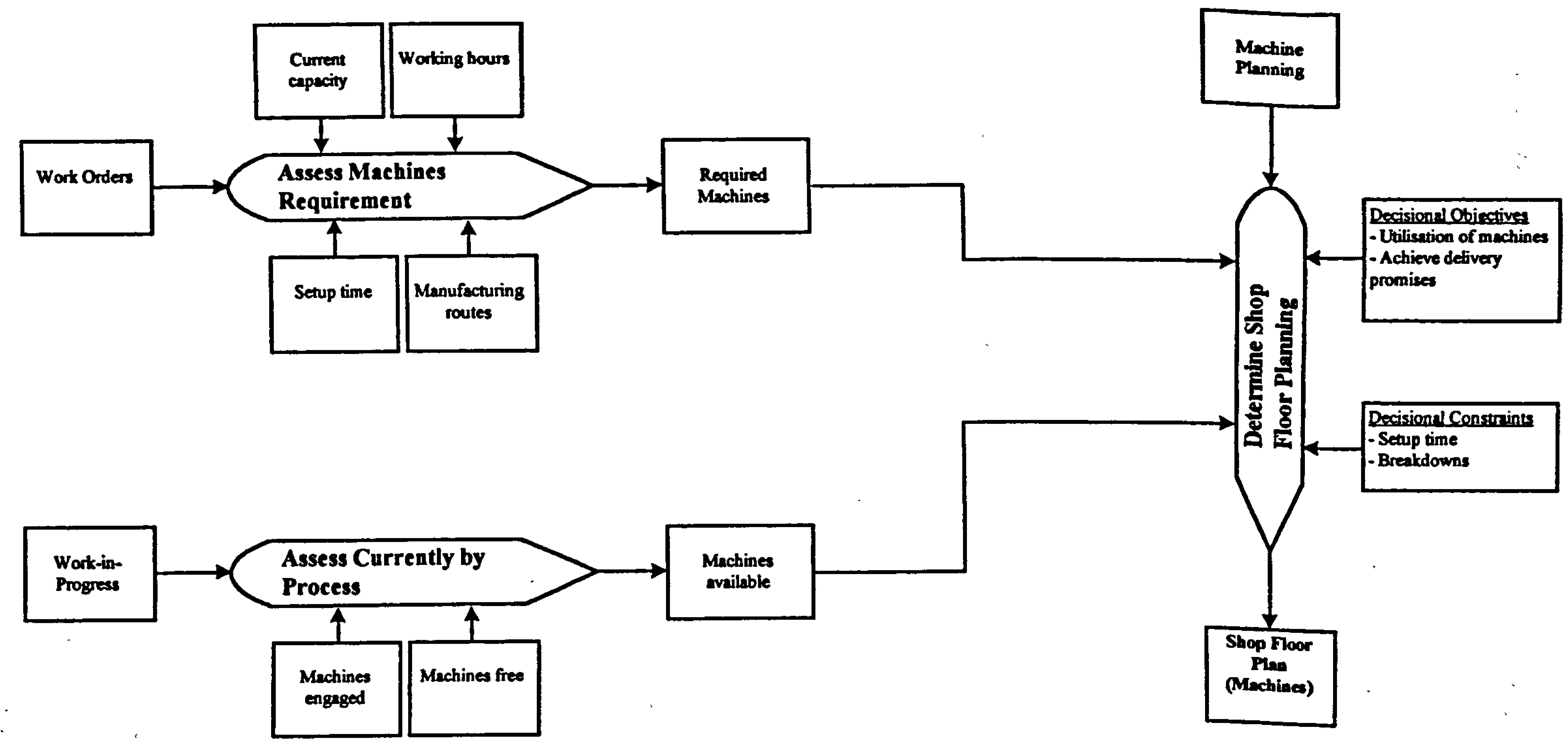
b) Assess Work-in-Progress

This activity assesses how many operators are currently engaged and how many are free. The resulting information is sent to the decisional activity for further consideration.

c) Determine the Shop Floor Plan

This decisional activity collects all the relevant information to perform the decision. The information consists of the results of all the different activities carried out and other supporting information, such as the skill and the performance of the operators. The decisional activity considers the objectives and constraints of the decision. The objectives of the decision are to:

- Utilise of the workforce
- Achieve the target date for manufacture



TITLE: SHOP FLOOR PLANNING	**FUNCTION:** TO MANAGE RESOURCE (TECH)	**DRAWN BY:** M A CHODARI	**DATE:** 18-8-96	**D C:** (3,10)
COMPANY: EDWARD PRYOR & SON LTD.	**H/R:** H=1 MONTH R=1 WEEK	**VALIDATE BY:** Production Manager	**DATE:** 19-8-96	**INDEX:** 1/1

FIGURE 8.18 GRAI NET FOR SHOP FLOOR PLANNING (MACHINES)

Potential constraints of the decision include:

- Sickness
- Holidays

The output of the decision is the shop floor plan for the workforce to meet the requirement of manufacturing works orders.

8.3.17 GRAI Net for Shop Floor Planning (Machines)

This GRAI net represents the structure of the decision of the shop floor plan, for the machines. The plan is carried out with reference to the works orders for production. The GRAI net is shown in Figure 8.18. The horizon of this decision is one month and the review period one week. The following activities are used to support the decision:

a) Assess Machines Requirement

The input of this activity is the work order which details the production plan for the month. The objective of this activity is to assess the exact requirements for the machines to achieve the works orders. The activity helps the decision centre in shift and overtime planning.

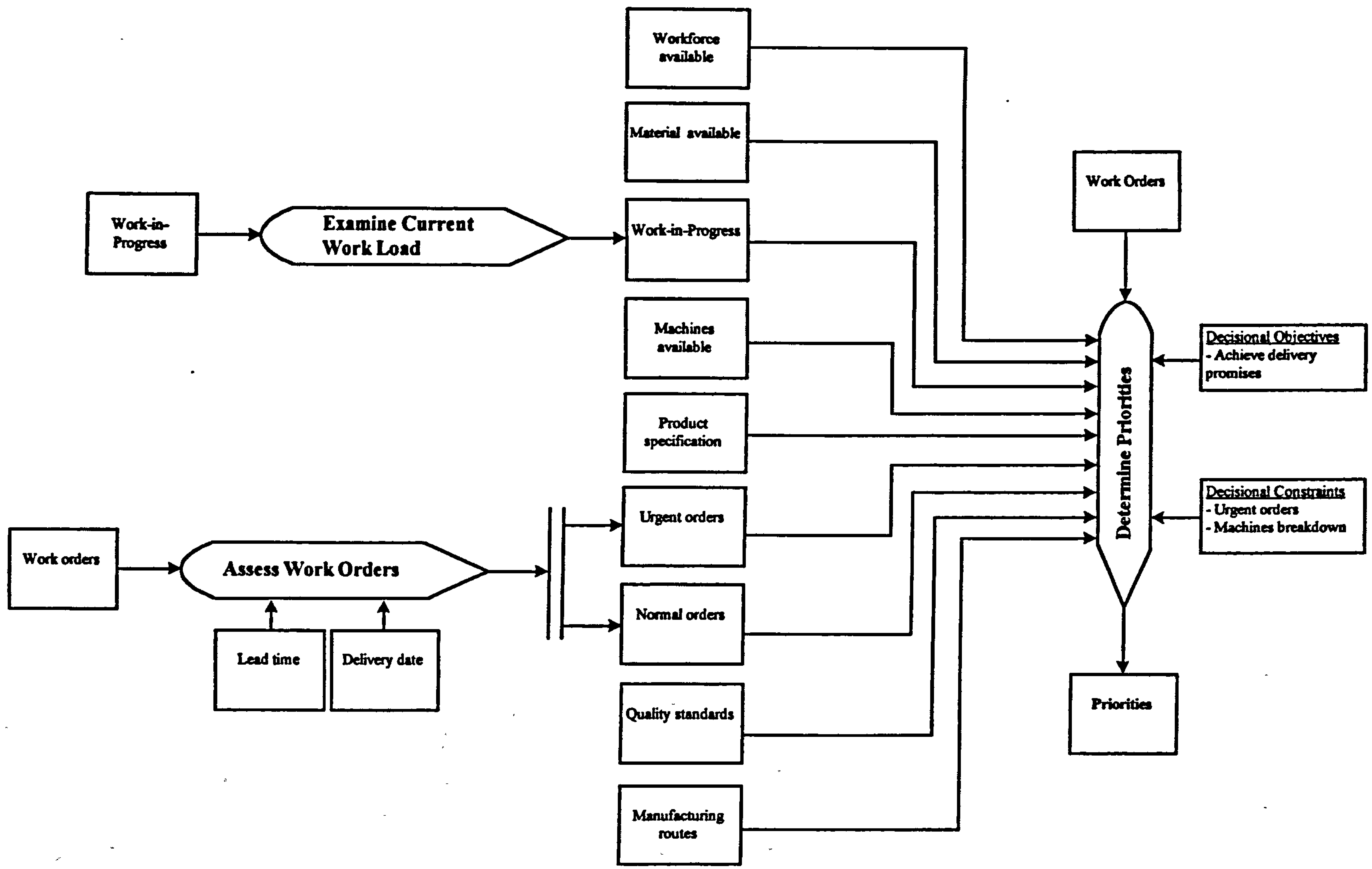
b) Assess Work-in-Progress

The activity assesses how many machines are engaged currently and how are free. The resulting information is sent to the decisional activity for further consideration.

c) Determine the Shop Floor Plan

The decisional activity collects all the relevant information to perform the decision. The information consists of the results of all the different activities carried out and other supporting information, such as performance data. The decisional activity considers the objectives and constraints of the decision. The objectives of the decision are to:

- Optimise the utilisation of the machines
- Achieve the production target dates



TITLE: PRODUCTION PRIORITIES	**FUNCTION:** TO PRODUCTION PLAN	**DRAWN BY:** M A CHODARI	**DATE:** 20-8-96	**D C:** (4,7)
COMPANY: EDWARD PRYOR & SON LTD.	**H/R:** H=1 WEEK R=1 DAY	**VALIDATE BY:** Production Controller	**DATE:** 23-8-96	**INDEX:** 1/1

FIGURE 8.19 GRAI NET FOR PRIORITIES

Potential constraints of the decision include:

- Machine set-up times
- Machine breakdowns

The output of the decision is the shop floor plan for machines to meet the requirements of the manufacturing works orders.

8.3.18 GRAI Net for Priorities

The GRAI net represents the structure for the decision to priorities work orders for production. The GRAI net is shown in Figure 8.19. The horizon of this decision is one week and the review period one day. The following activities are used to support this decision:

a) Assess Work Orders

This activity assesses the work orders with reference to delivery schedules for orders to customers and to stock. It consults the sales department for the delivery date requirements. The result of the activity indicates both urgent and routine orders.

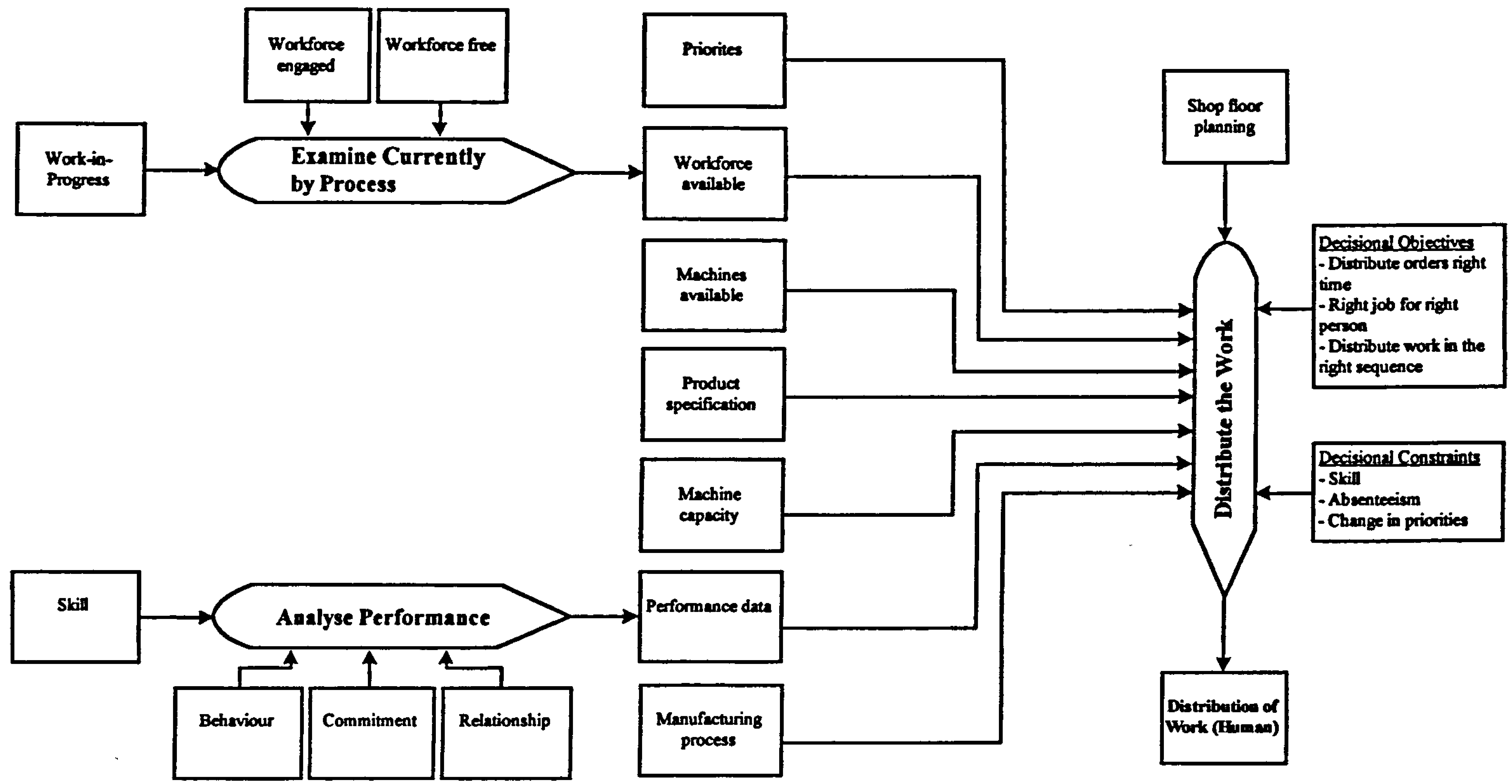
b) Examine the Current Work Load

The objective of this activity is to assess the Work-in-Progress and to determine the current work load. The resulting information is sent to the decisional activity.

c) Determine the Priorities

The decisional activity collects all the relevant information to perform the decision. The information consists of the results from all the different activities carried out and other supporting information, such as the availability of the workforce, material, machines, product specification, quality standards and the manufacturing process. The decisional activity considers the objectives of the decision and other constraints. The objectives of the decision are to:

- Achieve the delivery promises



TITLE: DISTRIBUTION OF WORK	**FUNCTION:** TO MANAGE RESOURCE(HUMAN)	**DRAWN BY:** M A CHODARI	**DATE:** 20-8-96	**D C:** (4,8)
COMPANY: EDWARD PRYOR & SON LTD.	**H/R:** H=1 WEEK R=1 DAY	**VALIDATE BY:** Supervisor	**DATE:** 23-8-96	**INDEX:** 1/1

FIGURE 8.20 GRAI NET FOR WORK DISTRIBUTION (WORKFORCE)

Possible constraints of the decision include:

- Any urgent requirements (Urgent orders)
- Machine breakdowns

The output of the decision is the priority sheet which details the products to be manufactured in order of priority.

8.3.19 GRAI Net for Work Distribution (Operators)

This GRAI net represents structure of the decision for distributing of work with reference to their production priority. The GRAI net is shown in Figure 8.20. The horizon of this decision is one week and the review period one day. The following activities have been used to support the decision:

a) Examine Currently by Process

The activity assesses the availability of the operators with respect to Work-in-Progress and the production priorities. The result shows how many operators are engaged and how many will be free. This information is sent to the decisional activity for further consideration.

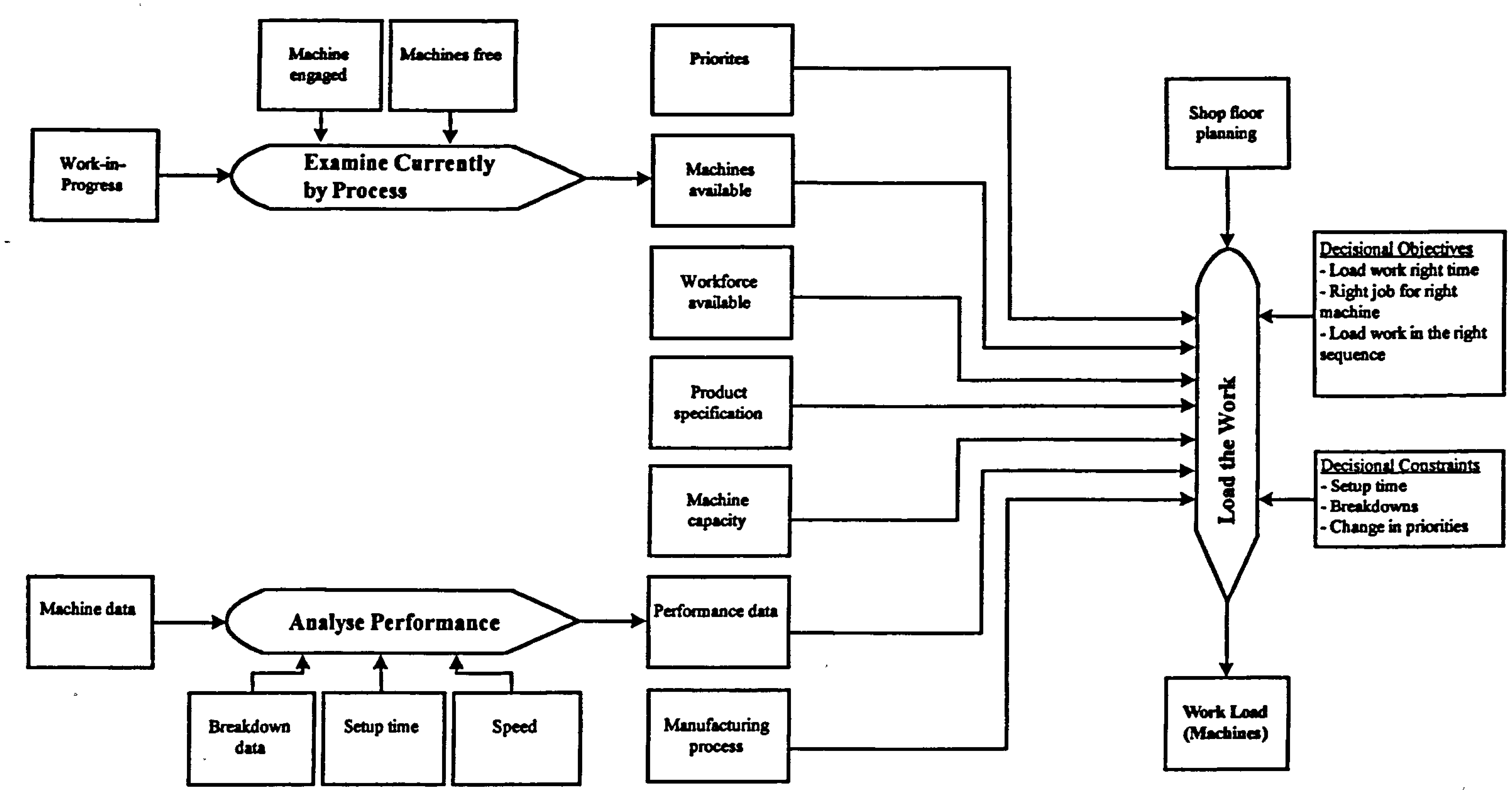
b) Analyse the Performance

This activity analyses the operators performance and skill. The objective of activity is to distribute the work after considering these factors.

c) Determine the Distribution of Work for the Operators

The decisional activity collects all the relevant information to perform the decision. The information consists of the results of all the different activities carried out and other supporting information, such as the availability of the workforce, materials, machines, product specification, quality standards, the manufacturing process and machine capacities. The decisional activity considers the objectives and constraints of the decision. The objectives of the decision are to:

- Distribute the work at right time



TITLE: WORK LOAD	**FUNCTION:** TO MANAGE RESOURCE(TECH)	**DRAWN BY:** M A CHODARI	**DATE:** 20-8-96	**D C:** (4,9)
COMPANY: EDWARD PRYOR & SON LTD.	**H/R:** H=1 WEEK R=1 DAY	**VALIDATE BY:** Supervisor	**DATE:** 23-8-96	**INDEX:** 1/1

FIGURE 8.21 GRAI NET FOR LOAD WORK (MACHINES)

- Allocate the right job to the right operator
- Distribute work in the right sequence

Possible constraints of the decision include:

- Unmatched skills
- Low performance
- Absenteeism
- Changes in priorities

The output of the decision is the distribution of work to the operators and the allocation of overtime if necessary.

8.3.20 GRAI Net for the Work Load (Machines)

This GRAI net represents the structure of the decision to load the work with reference to production priorities. The GRAI net is shown in Figure 8.21. The horizon of this decision is one week and the review period one day. The following activities have been used to support the decision:

a) Examine Currently by Process

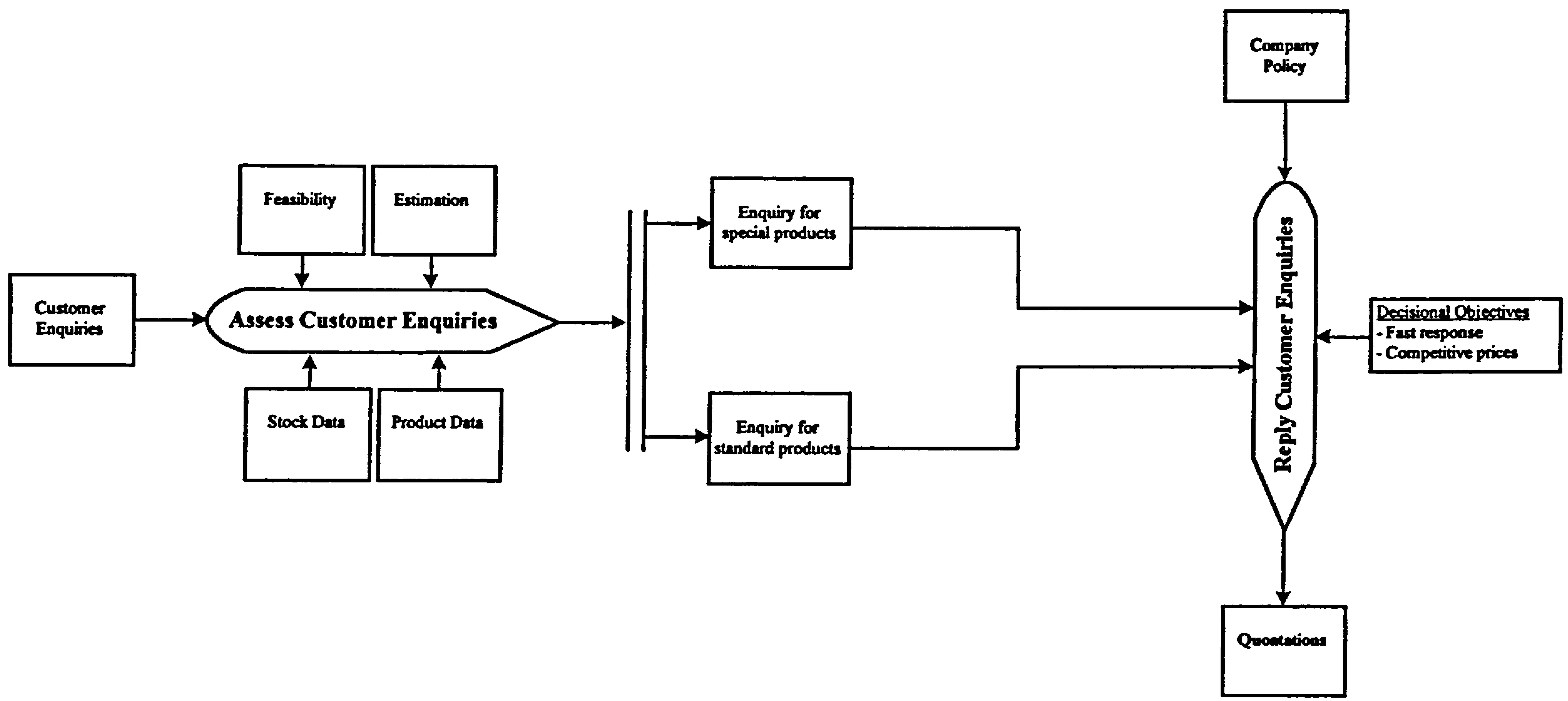
This activity assesses the availability of machines regarding Work-in-Progress and the work priorities within production. The result shows how many machines are engaged and how many will be free. This information is sent to the decisional activity for further consideration.

b) Analyse the Performance

This activity analyses the machines performance and capacity. The objective of this activity is to load the work with reference to both machine capacity and performance.

c) Determine Allocation of the Work Load to Machines

This decisional activity collects all the relevant information to perform the decision. The information consists of the results from all the different activities carried out and



TITLE: CUSTOMERS ENQUIRIES	FUNCTION: TO SELL	DRAWN BY: M A CHODARI	DATE: 24-8-96	D C: (5,2)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=1 DAY R=1 REAL TIME	VALIDATE BY: Sales Manager	DATE: 26-8-96	INDEX: 1/1

FIGURE 8.22 GRAI NET FOR CUSTOMER ENQUIRY

other supporting information, such as the availability of the workforce, material, machines, product specification, quality standards, the manufacturing process and machine capacity. The decisional activity considers the objectives of the decision and any additional constraints. The objectives of the decision are to:

- Load the work at the right time
- Allocate right job to the right machine
- Load the work in the right sequence

Possible constraints of the decision include:

- Machine set-up times
- Poor performance
- Breakdowns
- Changes in priorities

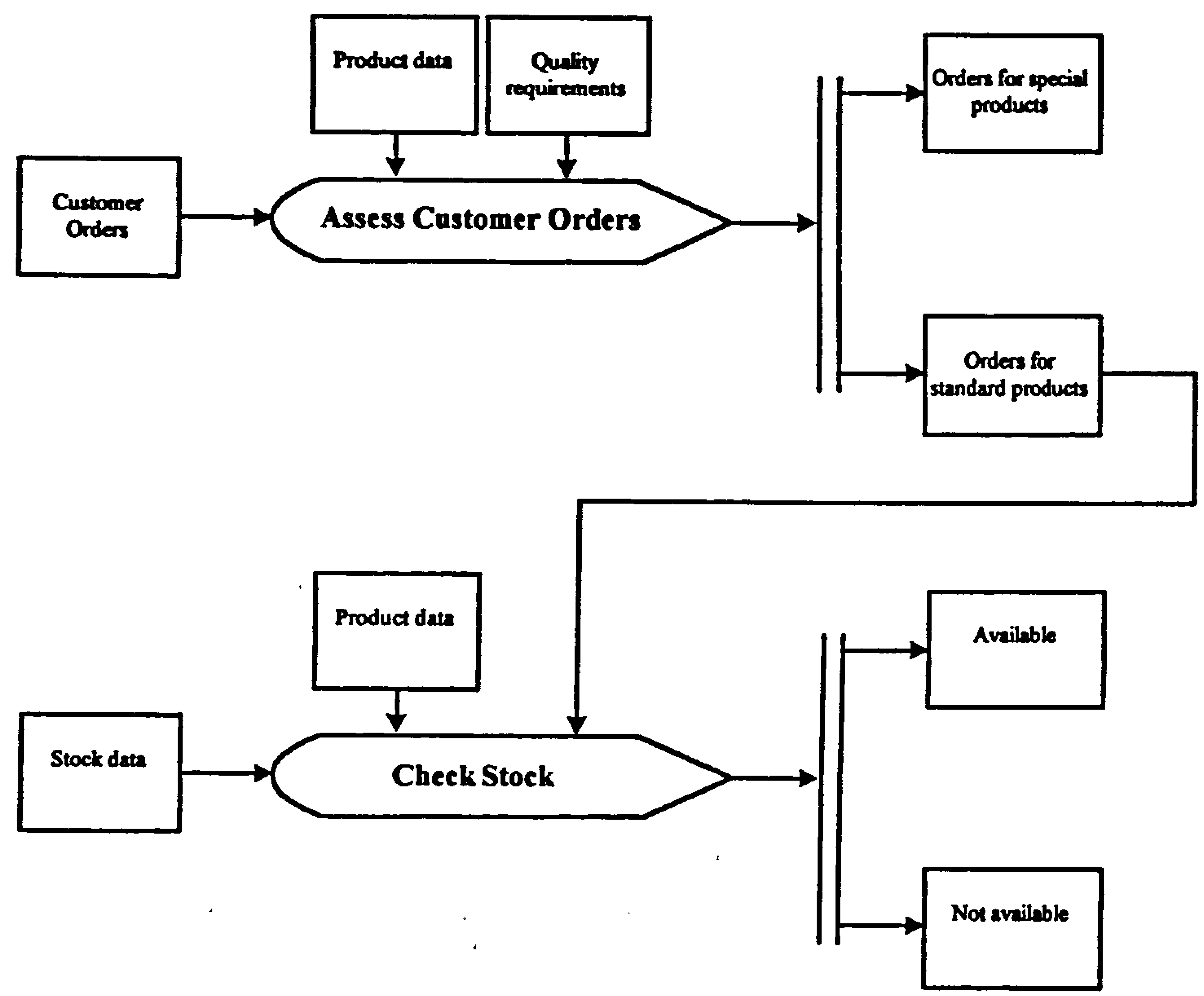
The output of the decision is the allocation of work to the machines and the identification of any necessary overtime.

8.3.21 GRAI Net for Customer Enquiries

The GRAI net represents the structure of the decision to reply to customers enquiries. The GRAI net is shown in Figure 8.22. Horizon of this decision is one day and the review period is real time. The following activity is used to support the decision:

a) Assess Customer Enquiries

This activity assesses the customer's enquiry, whether it is for a standard or special product. Standard products are assessed regarding their product information. If the enquiry is for a special product, the information is sent to the design department for separate design and cost estimation.



TITLE: CUSTOMERS ORDERS	**FUNCTION:** TO SELL	**DRAWN BY:** M A CHODARI	**DATE:** 24-8-96	**D C:** (5,2)
COMPANY: EDWARD PRYOR & SON LTD.	**H/R:** H=1 DAY R=1 REAL TIME	**VALIDATE BY:** Sales Manager	**DATE:** 26-8-96	**INDEX:** 1/1

FIGURE 8.23 GRAI NET FOR CUSTOMER ORDERS

b) Determine the Response to the Customer Enquiry

The decisional activity collects all the relevant information to perform the decision. The information consists of the result of the activity carried out and other supporting information, such as product data and stock status. The decisional activity is carried out under the company policy and considers the objectives of the decision. These are:

- Fast response to the enquiry
- Competitive pricing

The output of the decision is a quotation that contains the product price, quality, warranty, after sale services details and an estimated delivery date.

8.3.22 GRAI Net for the Processing of Customer orders

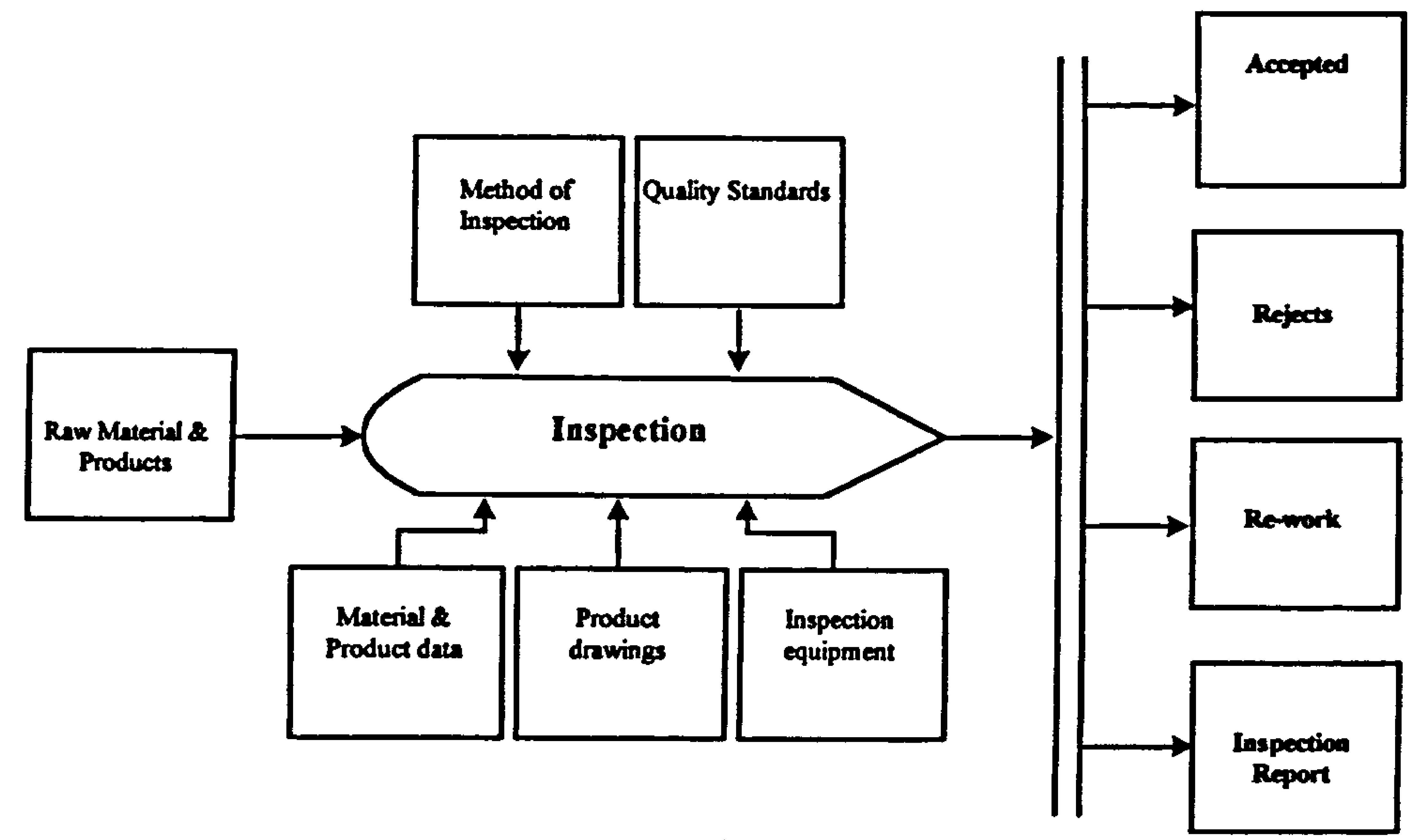
The GRAI net represents the structure the activities for processing a customer orders. The GRAI net is shown in Figure 8.23. The horizon of this activity is one day and the review period is real time. Two activities are carried out to process the customer order:

a) Assess Customer Orders

When the customers' orders arrive in the sales department, the order processing section assesses the orders for standard or special products. If the order is for a special product, the instruction for a new design is sent to the design department. If the order is for a standard product, the relevant information is sent to the check stock activity (Figure 8.23).

b) Check Stock

When customer orders for standard products arrive in the sales department, the activity checks the stock status to see whether the required product is already available in stock. If it is available, the instructions for its delivery are issued to the material control department. If the product is not available, instructions for its manufacture are issued.



TITLE: INSPECTION	**FUNCTION:** TO CONTROL QULAITY	**DRAWN BY:** M A CHODARI	**DATE:** 10-8-96	**D C:** (5,4)
COMPANY: EDWARD PRYOR & SON LTD.	**H/R:** H=1 DAY R=1 REAL TIME	**VALIDATE BY:** Chief Planner	**DATE:** 14-8-96	**INDEX:** 1/1

FIGURE 8.24 GRAI NET FOR INSPECTION

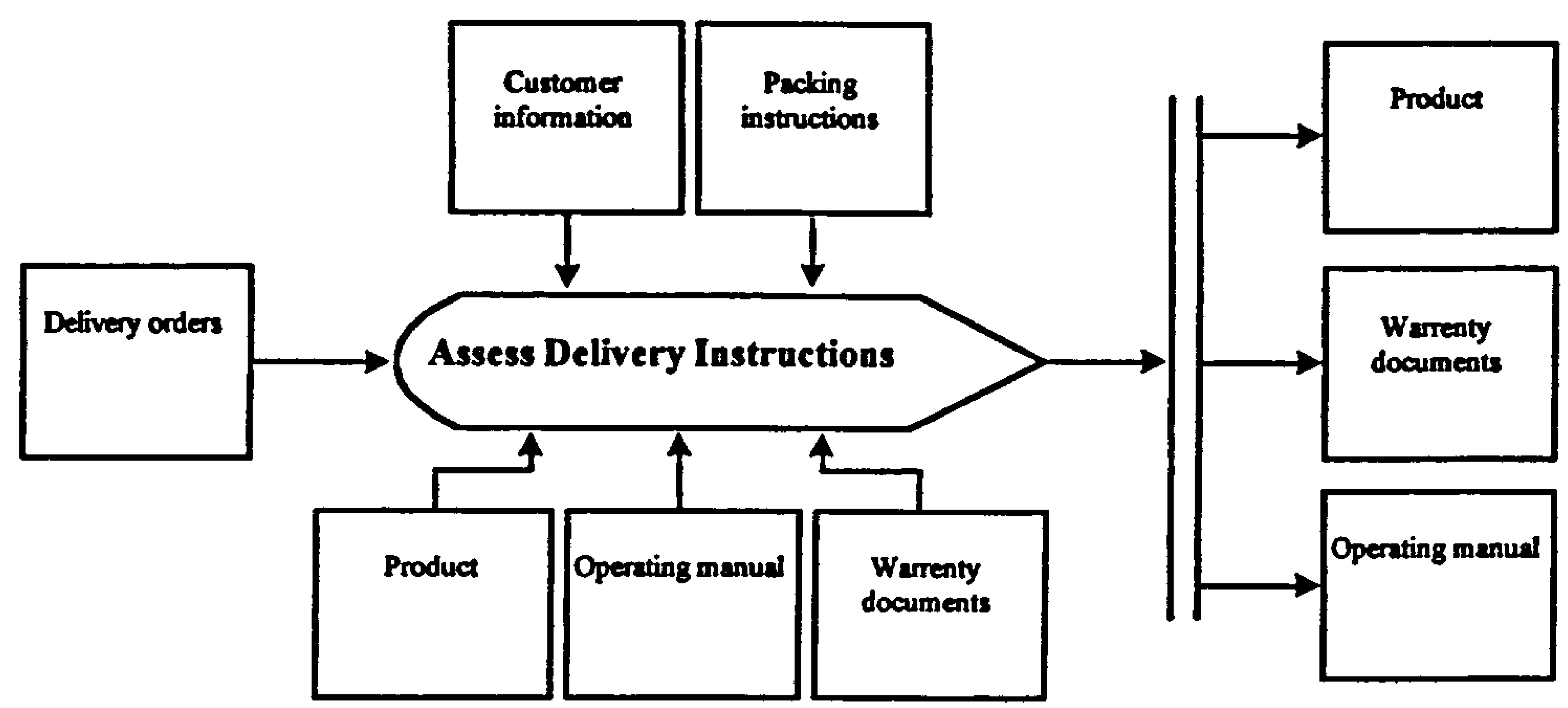
8.3.23 GRAI Net for Inspection

This GRAI net presents the structure of the inspection activity. The GRAI net is shown in Figure 8.24. The horizon of this activity is one day and the review period is real time. The inspection is carried out according to the relevant quality standards and design specifications of the products. The methods used to carry out the inspection involve specific inspection equipment and visual inspection. It is carried out on both bought-in material and products manufactured in-house. The outputs of this activity are:

1. Acceptance of the raw material or finished product. The raw materials are sent to the stores as inventory and the finished products are sent for packing.
2. Rejection of the raw material or finished products due to poor quality. The raw material is sent back to the suppliers and the finished product is considered as scrap.
3. Instructions for re-working are issued to the production department.
4. Inspection report. This daily report indicates the number of accepted and rejected items and reasons for their rejection.

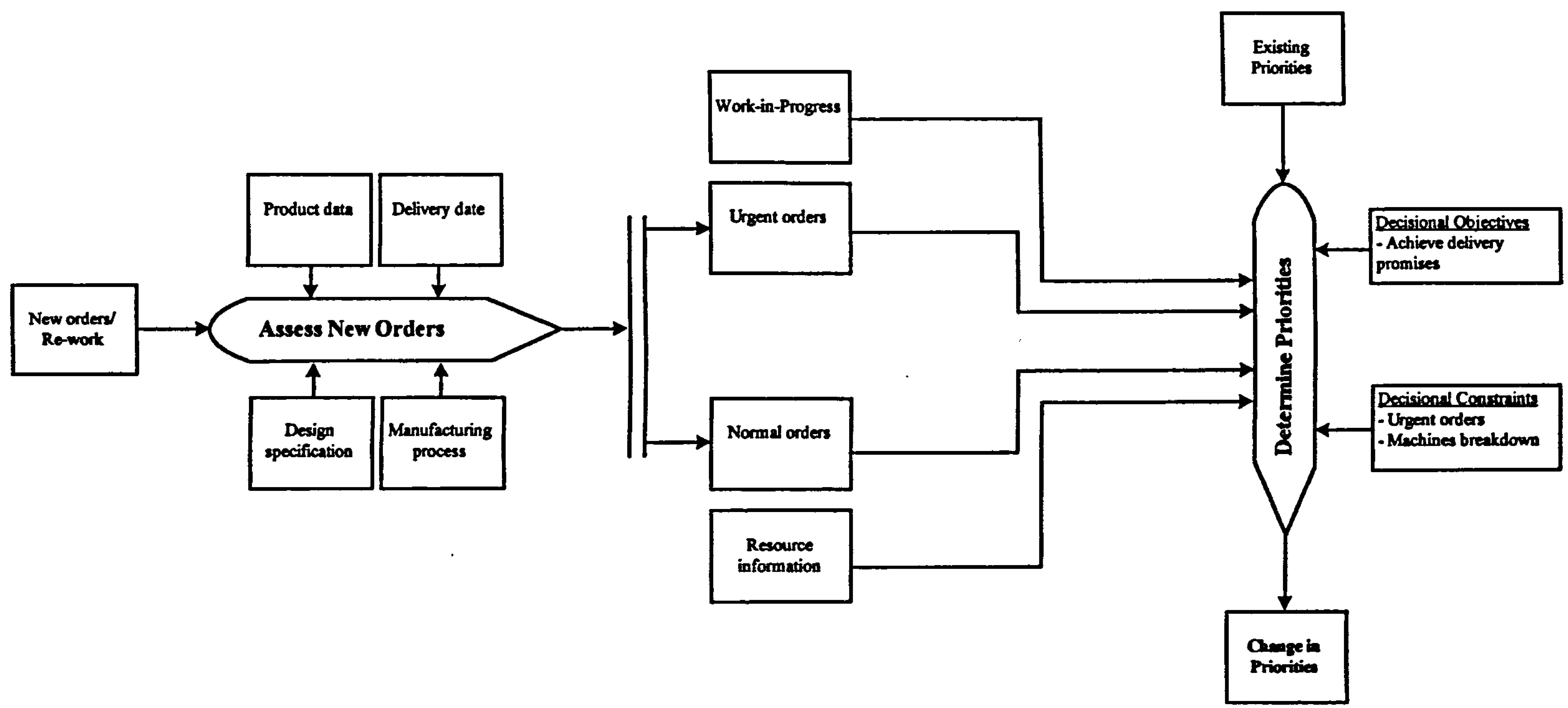
8.3.24 GRAI Net for Delivery

This GRAI net presents the structure for the delivery of products to customers. The GRAI net is shown in Figure 8.25. The horizon of this activity is one day and the review period is real time. The objective of this activity is to deliver the product to the customer. The inputs of the activity are the delivery orders issued by the sales department. The activity assesses the delivery instruction with reference to support information, such as customer information and packing instructions. It checks that the required products are sent with the correct documentation, such as the operating manual, warranty and after sales service, and that they are delivered to the right customer.



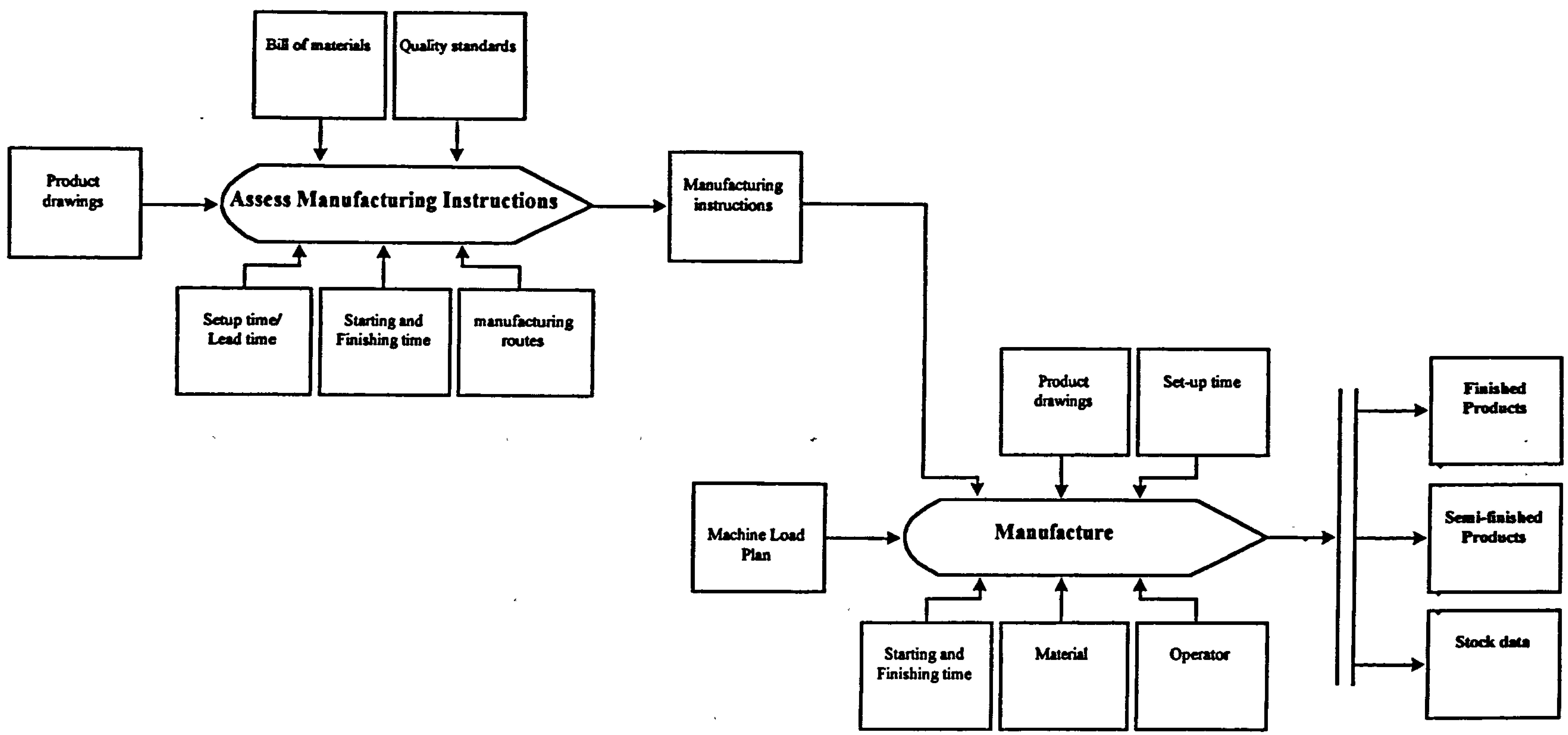
TITLE: DELIVER	FUNCTION:TO MANAGE MATERIAL(DELIVER)	DRAWN BY: M A CHODARI	DATE: 24-8-96	D C: (5,5)
COMPANY: EDWARD PRYOR & SON LTD.	H/R: H=1 DAY R=1 REAL TIME	VALIDATE BY: Store Keeper	DATE: 26-8-96	INDEX: 1/1

FIGURE 8.25 GRAI NET FOR DELIVER



TITLE: CHANGE IN PRIORITIES	**FUNCTION:** TO PRODUCTION PLAN	**DRAWN BY:** M A CHODARI	**DATE:** 20-8-96	**D C:** (5,6)
COMPANY: EDWARD PRYOR & SON LTD.	**H/R:** H=1 DAY R=1 REAL TIME	**VALIDATE BY:** Production Controller	**DATE:** 23-8-96	**INDEX:** 1/1

FIGURE 8.26 GRAI NET FOR CHANGE OF PRIORITIES



TITLE: MANUFACTURE	**FUNCTION:** TO MANUFACTURE	**DRAWN BY:** M A CHODARI	**DATE:** 20-8-96	**D C:** (5,7)
COMPANY: EDWARD PRYOR & SON LTD	**H/R:** H=1 DAY R=1 REAL TIME	**VALIDATE BY:** Supervisor	**DATE:** 23-8-96	**INDEX:** 1/1

FIGURE 8.27 GRAI NET FOR MANUFACTURE

8.3.25 GRAI Net for the Change of Priorities

This GRAI net presents the structure of the decision to change priorities. The GRAI net is shown in Figure 8.26. The horizon of this activity is one day and the review period is real time. One activity is carried out to perform the decision.

a) Assess New Orders

This activity consults the sales and production departments for new orders and assesses them as being urgent or normal, according to the delivery date. The product data, design specifications and manufacturing process are used as support information.

b) Determine the Change of Priorities

The decisional activity assesses the priority requirements for the product with reference to the delivery date. It analyses the existing priorities, Work-in-Progress and availability of resources, and if necessary a change in priority is implemented. The objective of this decision is to achieve the delivery quoted.

8.3.26 GRAI Net for Manufacture

The GRAI net presents the structure of the manufacturing activity. The GRAI net is shown in Figure 8.27. The horizon of this activity is one day and the review period is real time.

a) Assess Manufacturing Instructions

The activity assesses the manufacturing instructions, whether they are appropriate to the machine or the product to be manufactured. The instructions consist of the products to be manufactured together with the loading and unloading time, engineering drawings and the bill of materials.

b) Manufacture

This involves the conversion of the raw material into a finished product, by the utilisation of physical resources. Before making the product, the activity assesses that everything agrees with the product plan, such as the correct material being loaded onto the right machine, the right engineering drawings supplied with a valid bill of materials and quality standards, and the skills of the operator are appropriate to the operation. The outputs of this manufacturing activity are finished products that are sent to quality control for final inspection, semi-finished products that are sent for other operations and stock data that is updated with all the records of manufacturing.

8.4 CONCLUSIONS

A model of the manufacturing management system has been developed. The objective of developing this model was to remove the inconsistencies identified in the existing manufacturing management system of the MME Division of the Company and present it in a convenient way which was acceptable to the users. The new methodology to apply the GRAI method designed in Chapter-6 was used to develop this model. As a result, a GRAI grid and several GRAI nets have been constructed. The GRAI grid presents the overall picture of the manufacturing management system including the functions, management hierarchy, layers of control, and informational and decisional flows. The GRAI nets show the detailed activities of individual decision centres identified within the GRAI grid. In total, twenty-six decision centres were identified and a GRAI net constructed for each of them. The activities shown are related to the decision making process and illustrate the structure of the programmed decision.

Although the model was specifically developed for the MME Division of the Company, it has a generic nature. It can be used as a reference model to analyse and design the manufacturing management system of 'make-to-stock' companies. It works as a framework model and it is recommended that any 'make-to-stock' company can 'benchmark[1]' its existing management system against this model.

[1] "Benchmarking is a method of improving operations. In essence it consists in *looking* and *learning* from others by comparing yourself with them. It involves the whole organisation in searching for the best practice outside the company" (Karlof, 1995).
"Benchmarking is the process by which organisation learn, modelled on human learning process" (Watson, 1993).

CHAPTER-9

CONCLUSIONS

9.1 DISCUSSION

Throughout this thesis, specific conclusions relating to the findings and recommendations of each chapter are presented. This chapter presents an overview of these conclusions and summarises the main findings and novel aspects of the research. This includes details of the work carried out, the deliverables, achievements, recommendations and proposals for future work.

The need to develop a generic model for a specific classification of manufacturing company was the driving force behind this research. The initial motivation was obtained from a review of different methods of modelling manufacturing management systems. Several authors such as Levery (1996), Harrison and Burns (1991), Owen (1989) and Carrie et al (1993) have identified the need to change a manufacturing system by developing the appropriate modelling techniques (see Chapter-1). The need for change in manufacturing systems is driven by global competition, where new methods and technologies are introduced, which offer a competitive advantage to their employer. To meet this global competition, a modelling method must be developed to help analyse and design more competitive manufacturing systems. This method should identify the shortcomings within the system and suggest solutions to solve these shortcomings.

A model can illustrate how a new system will appear once redesigned, allowing various aspects of the manufacturing system, such as planning and decision making systems to be investigated, at no risk to the physical system. The decision making system is a vital aspect of the manufacturing management system and should be comprehensively structured. Two types of decision making systems have been observed: programmed and non-programmed. A programmed decision has a structure, such as to establish a Master Production Schedule (MPS). Conversely, non-programmed decisions have no structure. These decisions are performed on the basis of the knowledge and skill of the decision maker, gained through their experience. There was a need to develop a model that would support the decision making process and also present a structure of programmed decisions.

On the basis of the above background, the aims and objectives of the research were established.

9.2 ACHIEVEMENT OF THE RESEARCH AIMS AND OBJECTIVES

To achieve the objectives of the research, it was necessary to review the basic concepts behind manufacturing systems. This review provided the necessaries background knowledge and understanding of manufacturing systems. A model of the basic structure of a manufacturing system was constructed (Figure 2.1, Chapter 2). This model exhibits the "procedural[1]" and "transformational activities[2]" of a manufacturing system. The manufacturing management system is responsible for controlling these activities. The system has a hierarchical nature, comprising three types of control level, namely strategic, tactical and operational. These control levels use long, medium and short-term planning periods accordingly. Basic functions of the

[1] Procedural activities refers to procedures such as planning, control and implementation in a manufacturing system.
[2] Transformational activities convert the raw material into finished items and present the material flow.

system were identified from the literature survey of manufacturing systems. These functions include; to plan production, to control quality, to design, to sell, to manage material and to manage resources. The existence of these functions depends on the size, nature and policies of the manufacturing organisation.

It is possible to categorise manufacturing organisations against various common operating characteristics. Traditionally, manufacturing organisations are classified into three types (Johnson and Montgomery, 1974). These types are project, intermittent process and continuous process, but the existence of other classification systems has also been identified (Chapter 2). The survey conducted of various classification systems indicated the structure, characteristics and operational objectives of manufacturing organisations. The classification of 'make-to-stock' companies defined by Marucheck and McClelland (1986) was adopted for this research because it demonstrates many fundamental issues of the industry, such as production planning, sales, scheduling, material management, human resource management and production shop floor activities. These are required for accurate decision making, because inadequate decisions may lead to costly and ineffective use of resources. The type of classification has had a significant impact upon the generic model applied to help improve this category of manufacturing companies.

Based upon this classification, it is believed that a generic model would benefit all companies possessing the same 'make-to-stock' characteristics and assist them to improve the information and decisional system. To achieve this, the objectives outlined were approached and completed as following:

1) Identification of Suitable Modelling Methods

A modelling method is a set of principles, which guides the analyst towards the solution of a problem. The method identifies the problems within a system and provides guidelines to improve the operating efficiency of the system. A literature survey identified several methods available to analyse and design a system (Chapter 3). Only methods which incorporate graphical tools and a structured approach to problem solving were selected for this research. The methods selected as being suitable for further investigation were: SSADM, SADT, IDEF0, MERISE, STRIM and GRAI. All the methods selected have been applied in several different cases (Chapter 3), except for the STRIM and GRAI methods. These two methods are comparatively new and few records of their application were found.

2) Comparison of the Methods

The methods selected were reviewed in detail and a comparison was carried out. An assessment of the capability of each methods for modelling manufacturing management system is presented in Table 3.1 (Chapter 3). The objective of this comparison was to identify the most suitable method for modelling manufacturing systems and select one which could be investigated for further research. Results of the comparison show that the GRAI and IDEF0 methods are the most suitable methods for such analysis and design work. The GRAI method has some advantages over IDEF0 because it supports the decision making systems and portrays the structure of the management hierarchy with the appropriate decision horizons and review periods.

3) Testing the Methods

The method used to further compare and contrast the GRAI and IDEF0 methods involved their detailed application in a manufacturing organisation. The purpose of this was:

- To examine the methods within a manufacturing environment and identify how appropriate each was to the application. This is the first time that the GRAI and IDEF0 methods have been directly compared and contrasted.
- To examine the feasibility of developing a generic model for one particular classification of company, 'make-to-stock'.
- To compare the methods directly and identify any shortcomings regarding their application.

- To identify any inconsistencies in the case study manufacturing management system.

For this research, the manufacturing organisation selected was a 'make-to-stock' company, where end items are produced or assembled in anticipation of customer orders. Both the GRAI and IDEF0 methods were applied to the existing manufacturing system of Footprint Tools Ltd. The GRAI model (comprising a GRAI grid and GRAI nets) and the IDEF0 model were constructed and several inconsistencies were identified within the system.

Practical comparisons of GRAI and IDEF0 were carried out throughout the application. This comparison highlighted several major differences between the two methods. IDEF0 only concentrates on the flow of material and information, and the methods of conducting interviews has not been developed. In addition the method does do not consider decision making systems. There are some restrictions on the use of the method, such as the decomposition of functional blocks, which need to be broken down into between three and six levels (Chapter 4). The GRAI method is more capable of system analysis and design. The GRAI method considers each aspect of the manufacturing system including the functions, information flows, decisional flows, management hierarchy and most importantly, the decision making system with the decision structure. The results of the comparison demonstrates that the GRAI method is the most appropriate method of analysing and designing manufacturing systems. However, the methodology used to apply the GRAI method has some limitations. These limitations have been highlighted in this research and conclude:

a) The lack of clear defined methodology
b) The lack of a structure for the interview sessions which are a major feature of the method.
c) The lack of a computerised tool.

From these observations it was concluded that the GRAI method does not meet the definition and requirement of a methodology. Then 'a' and 'b' have been addressed in this research and 'c' will be addressed by future research programmes.

4) Comparison of GRAI Models

The GRAI method was further applied to two 'make-to-stock' manufacturing companies, Presto Tools and Paramo Tools, and the appropriate GRAI models constructed. The objective of this was a further investigation of the GRAI method and the study of the 'make-to-stock' manufacturing environment. Comparisons of the GRAI models constructed were carried out and are presented in Chapter 5. The comparisons show that 'make-to-stock' manufacturing organisations have several similar functions, activities and characteristics. On the basis of these comparisons, an activity relationships model for 'make-to-stock' companies was developed (Figure 5.21, Chapter 5).

The comparison and the GRAI models developed support the hypothesis of this research, that 'make-to-stock' companies would benefit significantly from a generic model. It was therefore recommended that a generic model for 'make-to-stock' manufacturing organisations be developed. The case studies also confirmed that there was a need to develop the methodology to apply the GRAI method prior to the development of a generic model.

5) Development of the New Methodology

Difficulties were experienced with the consistency of application of the GRAI method, particularly regarding the subjectivity of the synthesis group interviews. It was necessary to remove these difficulties and develop a methodology that would be both acceptable to each user and easy to use. This is presented in Chapter 6.

Formulation of techniques for the interviews

An observed shortcoming of the GRAI method was the potential subjectivity of two analysts applying the method to the same manufacturing organisation, the results of which could vary. This could lead to completely different recommendations for improvement, dependent primarily upon the style of interviewing technique employed.

To remove this subjectivity and optimise the results gained from the modelling technique, questionnaires were introduced. These questionnaires removed any bias from the interview and structure and control the direction of the questions. Another advantage is that the questionnaire allows the synthesis group to respond in their own time, allowing them to gain access to other information as required rather than simply using memory. The questionnaires are written in simple language and wherever necessary, explanations of the terminology used are presented.

The formulation of the interview is based on a series of three questionnaires. These are included in Appendix and are described below:

- Questionnaire-1 relates to the company background and organisation.

- Questionnaire-2 relates to the construction of a GRAI grid to model the existing management system of the organisation.

- Questionnaire-3 relates to the construction of GRAI nets, illustrating the structure of the decision.

The methodology can be presented in the form of a workbook. It is recommended that companies can use this workbook to analyse and design their manufacturing system without external help. This is particularly important to smaller companies, who may not be able to afford external consultants or analysts. The methodology guides the user through the analysis, design, implementation through to consistency checks of the system.

6) Validation of the Methodology

It was necessary to validate the methodology against the hypothesis, to verify the benefits of the research and to identify if the framework could be improved in any way. The method used to validate the methodology was a case study. This case study was used for two purposes. Firstly, to validate the methodology, and secondly to help identify any shortcomings within the manufacturing system of the Company. The GRAI method was applied to the existing manufacturing system of Edward Pryor & Son Ltd., using the methodology developed. The analysis then identified several inconsistencies within the system. Recommendations for future improvements were suggested to the Company in light of this analysis.

The use of questionnaires made the interview process far more reliable. The data gathering and collection phase was greatly improved and it is believed that the additional time given to the synthesis group aided the accuracy of the data collected. The methodology resolves the problem of subjectivity when applying the GRAI method.

7) Development of a Model

A model of the manufacturing system was constructed. This model was developed according to the flaws identified within the existing management system, the recommendations identified during the analysis and general information provided by the methodology. The purpose of developing the model was:

a) To design a new system which could fulfil the future requirements of the company
b) To validate the design phase of the methodology.

The model was specifically developed for the MME division of the Company, but can be used as a reference model to analyse any manufacturing system with 'make-to-stock' characteristics. Another advantage of the model is that it can help smaller companies who cannot afford external consultancy and analysts. The companies can compare their manufacturing system against that of the model and modify the system according to the constraints and irregularities identified.

9.3 RECOMMENDATIONS

The following are recommendations for further research in this area of system modelling:

- Develop a pilot study of the model developed
- Develop a computerised tool supporting the GRAI method
- Develop a generic model for manufacturing systems other than make-to stock
- Use of the GRAI method as a tool for BPR (Business Process Re-engineering)
- Apply the GRAI method to other industries

1) Develop a Pilot Study of the Model Developed

A pilot study should be conducted of the new model developed, to implement the model in other companies but of the same manufacturing category i.e. 'make-to-stock'. This should be monitored over a three year period, to study the behaviour of horizons and review periods and the relationship with different functions and decision centres. The objective of this pilot study would be to establish the rules regarding horizon and review periods, as the setting of horizon and review periods currently relies on the skill and knowledge of the designer. There are no existing rules regarding this activity or mathematical formulas to guide it. Empirical research would be an effective approach to establish such rules.

2) Develop a Computerised Tool Supporting the GRAI Method

Difficulties were experienced when drawing the GRAI models. This is could be the iterative process necessary to produce valid GRAI models which often require numerous modifications and redrawing. This is time consuming, as it often requires the re-construction of the whole model. Similar problems were faced when positioning activities and text in the GRAI nets. These difficulties were experienced due to unavailability of software for drawing GRAI models. To overcome this, software supporting the construction of GRAI models should be developed. The software should be user friendly, have its own data dictionary and contain a library of symbols used in the GRAI model. It is recommended that the Visual Basic programming language should be used to write the programming codes. A survey of different programming languages carried out by Binns (1993) shows that Visual Basic is the most appropriate language to develop such a graphical tool, because it supports graphical functions, requires little programming codes and is simpler than the 'C' language. It is estimated that such a tool would reduce the current drawing time for a model by at least 50%.

Recently, a computerised tool (IMAGIM) based on the GRAI method has been developed by the GRAI laboratory France. An evaluation copy has been requested. A computerised tool based on the GRAI method is also under development at the University of Sheffield.

3) Develop a Generic Model for Manufacturing Systems other than 'make-to-stock'

It has been shown that 'make-to-stock' manufacturing organisations have similar characteristics and activities. Hence one generic model would benefit all companies possessing the same characteristics. This then develops the need for a generic model for other classifications of manufacturing system, which would enable other companies to perform the same comparison with an 'ideal' model using the GRAI method. It is recommended that the methodology developed and the questionnaires can easily be adopted for this application.

4) Use of the GRAI method as a tool for BPR (Business Process Re-engineering)

Business Process Re-engineering (BPR) aims towards significant organisational improvements through the re-organisation of a traditional functional hierarchy

(Hammer and Champy, 1993). BPR can involve the transformational change of entire organisations or of specific functions. It restructures the organisation to produce inter-functional areas which perform processes more effectively, efficiently, in less time and with less expense (Davenport et al, 1990).

In short, it is a method of significant and often radical change. The process and system perspectives of BPR readily enable a technique such as GRAI to be incorporated into the re-engineering framework. Within the framework, objectives exist to integrate the functions and achieve an effective process. The GRAI method accomplishes this by considering all the manufacturing functions requiring control and their inter-relationship.

The GRAI method is a powerful modelling tool based on a decision perspective and developed primarily for the redesign of manufacturing systems. It is also appropriate to use as a tool for BPR to rationalise the decision making process and information systems.

5) Apply the GRAI Method to other Industries

The literature reports that the GRAI method has mostly been applied to manufacturing industry, with only one application to project management identified (Ridgway, 1992). The general concept of the method has been specifically developed for the requirements of manufacturing management systems. After a detailed study and applications of the method, the author proposes that this is not the case and it can be applied to other industries such as the service sector. The method supports the information and decision making process and includes detail of the management hierarchy. These characteristics can be identified in any industry. It is therefore recommended that the GRAI method should also be used to analyse and design operating systems for other industries.

9.4 CONCLUDING REMARKS

The original hypothesis of this research was that each type of manufacturing system would benefit from a generic model, allowing the analysis and design of systems without external help. The 'make-to-stock' category of manufacturing system was adopted for this research. The reason for this was that it is a fundamental class of manufacturing system that represents all related activities and is therefore ideal for modelling. This type of classification has a significant impact upon the generic model to improve the category of manufacturing companies.

A review of various modelling methods were conducted and the GRAI method was identified as the most appropriate for modelling manufacturing management systems. This was because the method considers all aspects of manufacturing systems to be modelled, specifically decision making. Subsequently, the method was applied to various 'make-to-stock' companies to model their manufacturing management systems. These models indicated that several similarities exist in 'make-to-stock' companies that support the hypothesis of the research. As a result of the application, limitations of the method were identified and comprehensively examined. The most significant drawbacks of the method were conducting the interviews and the potential for subjectivity. This was resolved by developing a series of questionnaires and a methodology to apply the GRAI method.

The methodology was then applied to another 'make-to-stock' company to model its manufacturing management system and validate the authenticity of the methodology and questionnaires. The application of the methodology developed was successful. Consequently an operative generic model for 'make-to-stock' manufacturing management systems was developed.

It is anticipated that this type of general model will benefit all companies possessing similar 'make-to-stock' characteristics. It is also anticipated that companies who may not able to afford consultants and analysts would benefit from the structured guidance and simple application that this methodology affords.

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APPENDIX

QUESTIONNAIRE 1

MANAGEMENT STRUCTURE

A-Company History and Background

Name of the Company.			
When was the Company established.			
Is the Company a subsidiary of any group?			
What is the turnover of the Company?			
Does the Company export?	□ Yes □ No		
If yes, What % of turnover is exported?			
What is the product range?			
What is the best selling product?			
Who are the main customers?			
How many people work in the Company?	Direct	Indirect	
What % of the direct workforce are skilled, semiskilled and unskilled?	Skilled	Semiskilled	Unskilled
What employee remuneration system is used?			
Does the Company have any other manufacturing site?			
Who is the controller of the site?			
Does the Company have accreditation to the BS 5750, ISO EN 9000 series?			

B-Departmental/Management Hierarchy

Name of the Company: ....

Name of Chief executive: ....

Job Title of Chief executive: ....

Name of Co-ordinator: ....

Job Title of Co-ordinator: ....

Please provide a Management Structure of the Company.

Section-1 Departments

Name of Department	Head of the Department (Name)	Head of the Department (Job Title)

Section-2 Section Hierarchy

Name of the Department	Name of the Section	Head of the Section (Name)	Head of the Section (Job Title)

Section-3 Subsection/Shops Hierarchy

Name of the Section	Name of the Subsection/Shop	Head of the Subsection/Shop (Name)	Head of the Subsection/Shop (Job Title)

C- Department/Section/Shop Layout

Please indicate the name of the section/subsection/shop and tick the appropriate form of layout, as defined below:

Fixed Position Layout: Material and manufacturing resources move but the product remains stationary during the manufacturing operations.

Product Layout: Machines are grouped sequentially to produce a specific product.

Process Layout: Similar processes which perform similar functions are located together.

Section/ subsection/ shop	**Fixed Position**	**Product**	**Process**	**Any other** (Please mention)

QUESTIONNAIRE 2

GRAI GRID

General Information

Name of the Company:...

Name of Employee:...

Job Title:..

Department/Section/Subsection:..

Report to:..

What are your job responsibilities?

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What are the functions of your department?

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Decision Making

A decision is defined as the selection process, leading to a particular course of action being taken. An action is the realisation of a decision.

Are you involved in any decision making process. ☐ Yes ☐ No

If yes, what decisions do you make?

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At what level do you think your decisions affect the Company?

- ☐ Strategic (input to the business development planning)
- ☐ Tactical (input on the way the business aims are achieved)
- ☐ Operational (input on the way the plans are operated)

What are the horizon and review periods of your decisions?

(The terms 'horizon' and 'review period' are use in this questionnaire. The 'horizon' refers to the time interval through which decisions are valid. For example decisions regarding the Master Production Schedule may be taken on a yearly basis, so the horizon period is one year. The 'review period' is the time interval at which decisions are revised, for example the Master Production Schedule may be reviewed every three month.)

What are the horizon and review period of the action/decision initiated?

Decision	Horizon Period	Review Period

Who acts as a result of your decisions?

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How independent do you feel when making your decisions?
□ Very Strong □ Strong □ Average □ Poor □ Very Poor

Do you experience any difficulties in decision making within the system. Please describe what kind of difficulties you face?
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Information of Work

Do you exchange or share information regarding your work with any other department/section? □ Yes □ No
If yes, what kind of information is exchanged and how often?
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Do you have any computerised information systems? □ Yes □ No
If yes, name the packages employed. ....

Do you experience any problems when giving or receiving information from other departments/sections?
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Do you receive feedback from your colleagues regarding work problems or other difficulties?

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Do you receive information from outside the company concerning your work and how often?

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Do you have any formal meetings with your manager, and if so, why and how often?

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Do you have any formal meetings with your subordinates, and if so, why and how often?

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Work Instruction

Do you receive instructions or orders concerning your work from other people within the company? ☐ Yes ☐ No

If yes, what do they most commonly relate to, who do they come from (job title) and how often?

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Do you issue instructions/orders concerning work to other people within the company? ☐ Yes ☐ No

If yes, what kind of instructions do you issue, who do they go to (job title) and how often?

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Change/Modification

What kind of change or modification do you consider would benefit the company within your work area.

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Comments

Please add any comments or information that you feel would contribute to this project.

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QUESTIONNAIRE 3

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Name of the Company: ....

Name of Employee: ....

Job Title: ....

Department/Section/Subsection: ....

Horizon Period of the decision: ....

Review Period of the decision: ....

Section-1 Executing Activities

Executing Activity-1

To Do (Executing Activity Name): ....

Initial State (Input): ....

Support (Information used to perform the executing activity)

1-:..
2-:..
3-:..
4-:..
5-:..
6-:..

Procedures to perform the activity

1-:..
2-:..
3-:..
4-:..

Results of the executing activity (Output): ....

Executing Activity-2

To Do (Executing Activity Name): ....

Initial State (Input): ....

Support (Information used to perform the executing activity)

1-:..
2-:..
3-:..
4-:..
5-:..
6-:..

Procedures to perform the activity
1-:..
2-:..
3-:..
4-:..

Results of the executing activity (Output): ....

Executing Activity-3

To Do (Executing Activity Name): ....

Initial State (Input): ....

Support (Information used to perform the executing activity)

1-:..
2-:..
3-:..
4-:..
5-:..
6-:..

Procedures to perform the activity
1-:..
2-:..
3-:..
4-:..

Results of the executing activity (Output): ....

Executing Activity-4

To Do (Executing Activity Name): ....

Initial State (Input): ....

Support (Information used to perform the executing activity)

1-:..
2-:..
3-:..
4-:..
5-:..
6-:..

Procedures to perform the activity

1-:..
2-:..
3-:..
4-:..

Results of the executing activity (Output): ....

Executing Activity-5

To Do (Executing Activity Name): ....

Initial State (Input): ....

Support (Information used to perform the executing activity)

1-:..
2-:..
3-:..
4-:..
5-:..
6-:..

Procedures to perform the activity

1-:..
2-:..
3-:..
4-:..

Results of the executing activity (Output): ....

Executing Activity-6

To Do (Executing Activity Name): ....

Initial State (Input): ....

Support (Information used to perform the executing activity)

1-:..
2-:..
3-:..
4-:..
5-:..
6-:..

Procedures to perform the activity

1-:..
2-:..
3-:..
4-:..

Results of the executing activity (Output): ....

Executing Activity-7

To Do (Executing Activity Name): ....

Initial State (Input): ....

Support (Information used to perform the executing activity)

1-:..
2-:..
3-:..
4-:..
5-:..
6-:..

Procedures to perform the activity

1-:..
2-:..
3-:..
4-:..

Results of the executing activity (Output): ....

Section-2 Decision Making

Decision Activity-1

To Decide (Decision to be made):..

Input:..

Decisional Objectives:

1-:..
2-:..
3-:..
4-:..
5-:..
6-:..

Decisional Variables:

1-:..
2-:..
3-:..
4-:..
5-:..
6-:..

Decisional Constraints:

1-:..
2-:..
3-:..
4-:..
5-:..
6-:..

Support (Relevant information used to decide, if any):

1-:..
2-:..
3-:..
4-:..
5-:..
6-:..

Procedures to be used to make decision:

1-:..
2-:..
3-:..
4-:..

Output (results):..

Decision sent to (Please specify job title):...

Decision Activity-2(if any)

To Decide (Decision to be made):..
Input:..
Decisional Objectives:
1-:...
2-:...
3-:...
4-:...
5-:...
6-:...
Decisional Variables:
1-:...
2-:...
3-:...
4-:...
5-:...
6-:...
Decisional Constraints:
1-:...
2-:...
3-:...
4-:...
5-:...
6-:...
Support (Relevant information used to decide, if any):
1-:...
2-:...
3-:...
4-:...
5-:...
6-:...
Procedures to be used to make decision:
1-:...
2-:...
3-:...
4-:...
Output (results):..
Decision sent to (Please specify job title):...

Please add any remarks or other useful information:

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