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THE INTERACTION BETWEEN MASTER PRODUCTION SCHEDULING AND DETAILED CAPACITY REQUIREMENTS PLANNING: CLOSING THE LOOP IN MANUFACTURING RESOURCE PLANNING (MRPII) SYSTEMS.

PETER GUY BURCHER

Doctor of Philosophy

THE UNIVERSITY OF ASTON IN BIRMINGHAM

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SYNOPSIS

The widespread implementation of Manufacturing Resource Planning (MRPII) systems in this country and abroad and the reported dissatisfaction with their use formed the initial basis of this piece of research which concentrates on the fundamental theory and design of the Closed Loop MRPII system itself.

The dissertation concentrates on two key aspects namely; how Master Production Scheduling is carried out in differing business environments and how well the "closing of the loop" operates by checking the capacity requirements of the different levels of plans within an organisation.

The main hypothesis which is tested is that in U.K. manufacturing industry, resource checks are either not being carried out satisfactorily or they are not being fed back to the appropriate plan in a timely fashion.

The research methodology employed involved initial detailed investigations into Master Scheduling and capacity planning in eight diverse manufacturing companies. This was followed by a nationwide survey of users in 349 companies, a survey of all the major suppliers of Production Management software in the U.K. and an analysis of the facilities offered by current software packages.

The main conclusion which is drawn is that the hypothesis is proved in the majority of companies in that only just over 50% of companies are attempting Resource and Capacity Planning and only 20% are successfully feeding back CRP information to "close the loop". Various causative factors are put forward and remedies are suggested.

Key Words: MRPII, Master Production Scheduling, Capacity Requirements Planning, Rough Cut Capacity Planning, Resource Requirements Planning.

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DEDICATION

In memory of my father.

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1. INTRODUCTION

1.1 Research Area

The widespread implementation of Manufacturing Resource Planning (MRPII) systems in this country and abroad and the reported dissatisfaction with their use, (Fox 1982, Whiteside and Arbose 1984 and Waterlow and Monniot 1986), formed the initial basis of this piece of research. Whilst many researchers have concentrated on the choosing of appropriate systems (Clark P.A. et al 1990, Kochhar 1990), or the implementation phase (Frizelle 1990, Barrer, Lockett and Tanner 1989), or the organisational design for manufacturing systems (Smith, Tranfield, Bessant and Levy 1990), this piece of research concentrates on the fundamental theory and design of the Closed Loop MRPII system itself. It also tries to determine how companies are actually using their systems in practice, and, in particular, how this pattern of use might give clues to the inadequacies of the traditional MRPII system design.

This dissertation will concentrate on two key aspects of MRPII systems, namely; how Master Production Scheduling is carried out in differing business environments and how well the "closing of the loop" operates by checking the resource or capacity requirements consequences of the different levels of plans within an integrated Manufacturing Planning and Control System.

1.2 Master Scheduling and Resource and Capacity Planning

Master Scheduling has been defined in its simplest form by Burcher (Lewis et al 1980) as;

> "a management commitment to produce certain volumes of finished products in particular time periods in the future"

It is the main input to the Material Requirements Planning (MRPI) module of an MRPII system along with Inventory Status information and product structures contained in Bills Of Material. To ascertain whether the Master Production Schedule is realistic and achievable, it should be checked against the resource or capacity requirements required for the schedule. The one resource that is automatically checked is the materials via the MRPI module. To check other resources such as labour hours, machine hours, space, tooling or cash, product quantities have to be translated into these units of measure, time phased appropriately and then compared to the resources available.

There are at least three levels of planning at which resource checks might take place in a MRPII system. Figure 1.1 shows a diagrammatic representation of a MRPII system. The first is at the long term planning stage, often referred to as the Production Plan. The Resource check here is termed Resource Requirements Planning. The next check is at the Master Production Scheduling stage and this is referred to as Rough Cut Capacity Planning.

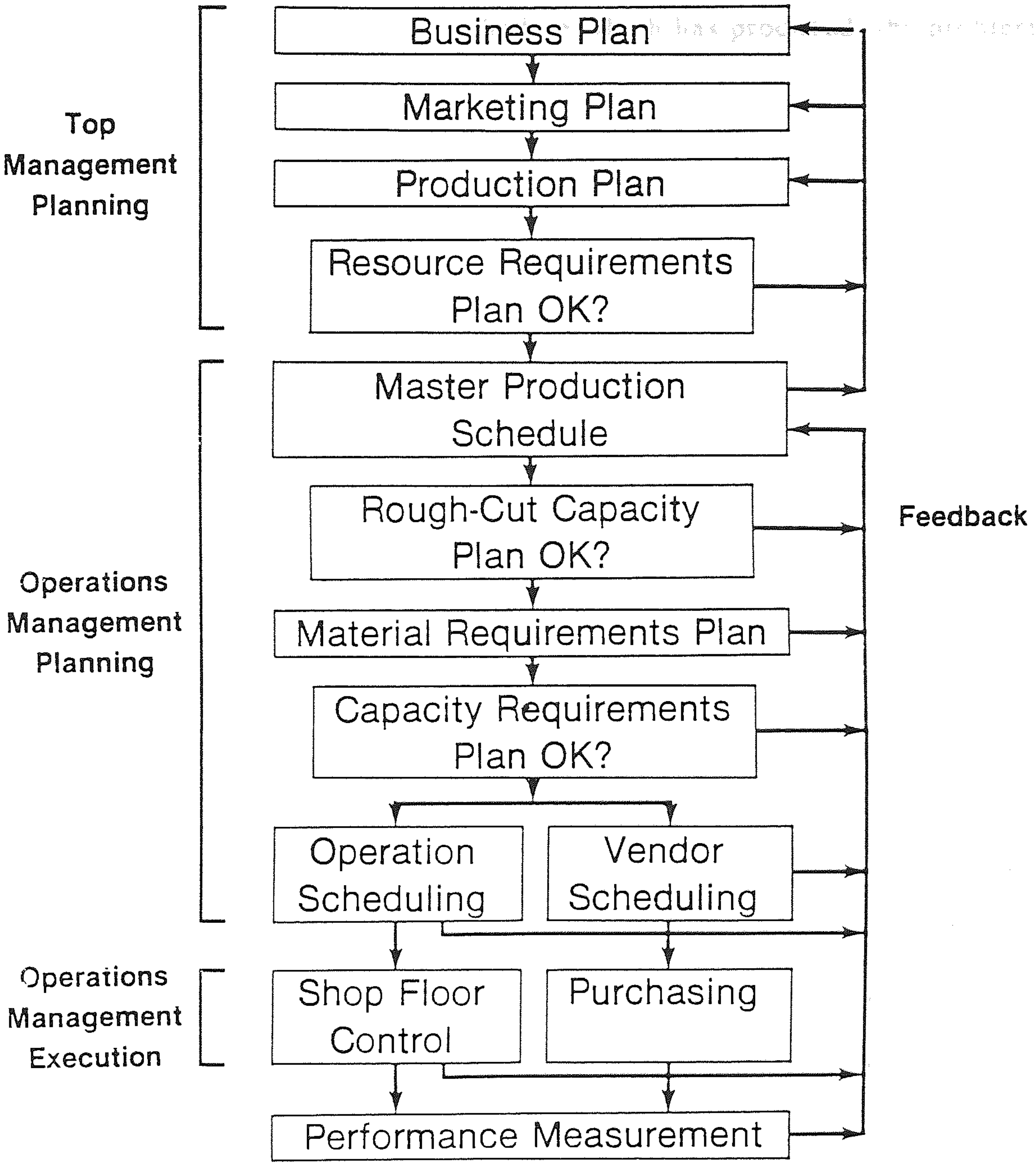


Figure 1.1 - Manufacturing Resource Planning (MRPII) System

The third level is after the MRPI module has been run and the output is obtained in terms of existing and planned orders. The check at this stage is called Capacity Requirements Planning. At each of these stages, if a significant problem is highlighted, it may be necessary to feedback a request for an amendment to the plan or schedule which has produced the problem, thus "closing the loop".

As a result of the author's experiences from many contacts with users of MRPII systems through consultancy and training, one of the main hypotheses that is put forward for testing in this dissertation is that these resource checks are either not being carried out satisfactorily or they are not being fed back to the appropriate plan in a timely fashion. Hence Master Scheduling and the whole Manufacturing Resource Planning system may not be operating properly according to the traditional theory, since the closing of the loop is not taking place.

1.3 Research Methodology

The methodology used in this research consisted of in depth investigations into Master Scheduling and Resource Planning in eight carefully chosen manufacturing organisations. These investigations were then written up as Case Studies and initial conclusions drawn from their comparative analyses. This material is covered in chapter 4.

As a result of these initial findings and to test the assertions made from this small sample, a much larger population needed to be investigated. A detailed questionnaire was then designed and sent out to a broad range of manufacturing companies throughout the United Kingdom. The replies were then analysed and conclusions drawn from the results. This material is covered in chapter 5.

To ascertain what facilities were currently being offered in Manufacturing Planning and Control software and to obtain the views of suppliers on the problems of resource planning, a questionnaire was designed and sent to all of the major suppliers in the United Kingdom. The replies were analysed and conclusions drawn from the results. An analysis was also made of the modules offered in the latest Computer Aided Production Management software by reference to secondary sources. All of this material is covered in chapter 6.

As a result of these parallel investigations, conclusions have been drawn concerning the basic hypotheses and the reasons and remedies for the lack of "closing the loop".

2. MANUFACTURING RESOURCE PLANNING (MRP II) AND MASTER PRODUCTION SCHEDULING: THE ISSUES

2.1 An Introduction to MRP II

Today's manufacturing environment in terms of manufacturing technology and variety of products offered is far more complex than it used to be. This being so, in many situations, the demand is that a suite of sophisticated information based tools be available. Furthermore, it will be shown that of the CAPM systems currently offered, Manufacturing Resource Planning (MRP II) is the most widely implemented and potentially versatile system.

2.1.1 Concepts

The origins of MRP II can be traced back to early "order point" production control systems and have been reported extensively (Orlicky (1975), Plossl and Wight (1967)). MRP II is an extension of MRPI (Materials Requirements Planning) which in turn is based on the following simple concepts:

The Master Production Schedule (MPS). The MPS extends to the "horizon" and defines manufacturing intent as product requirements, within each time bucket. Figure 2.1 represents the structure of an MPS.

Bill of Material (BOM). This defines each top level item (saleable product) in terms of the structure of each constituent part. Figure 2.2 is a schematic representation of a typical BOM for one product.

Order Quantity Per Period.

Product Type

Period	1	2	3	4	5	6
AAA	40	0	0	34	12	0
BBB	4	12	12	4	6	2
CCC	3	3	3	3	6	6
DDD	25	25	25	0	0	25
EEE	30	15	0	15	30	15
FFF	45	30	15	0	15	30
GGG	5	5	5	5	5	5
HHH	10	20	30	40	50	60
III	80	80	80	40	20	10

Figure 2.1 - A Typical MPS

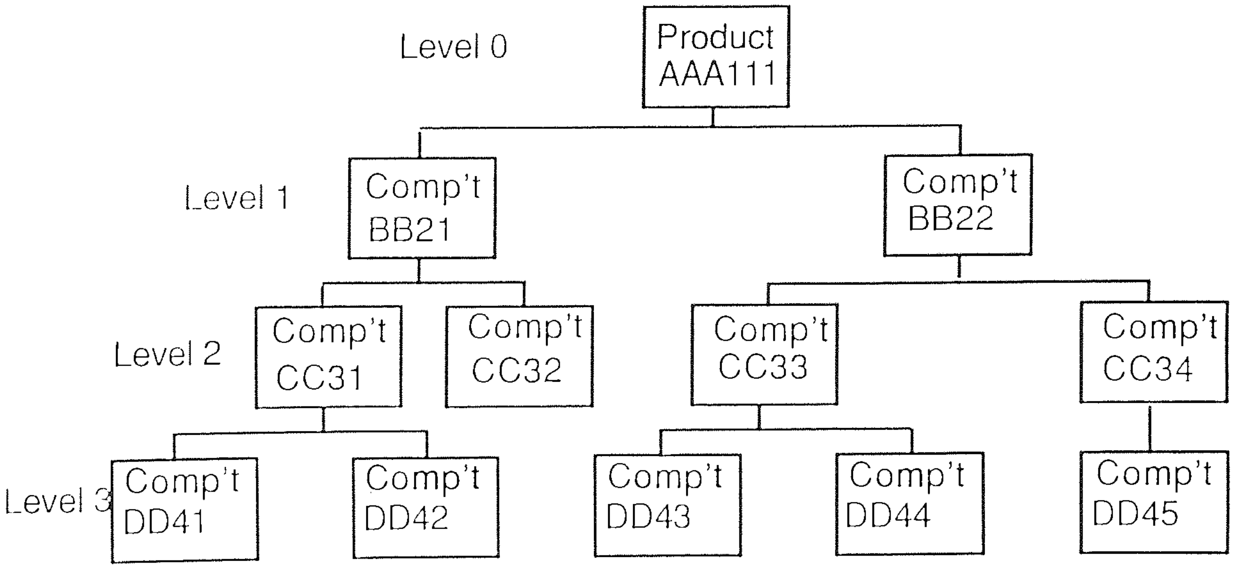


Figure 2.2 - A Typical BOM

Stock. Material held at a location prior to release, either finished stock awaiting sale or constituent stock awaiting conversion to the next level in the BOM. In MRP, work is considered to flow from one stock location to the next.

Lead time allowance. A value used to offset the requirements of each part number, by an estimate of the time required to complete the necessary work (ie, the time required for material to flow from one stock location to the next).

Work in Progress (WIP). Parts in-between stock locations.

2.1.2 Technique

The primary control mechanism of MRP II is the issue of purchase and WIP order schedules. The usefulness of all other planning and control functions (e.g. stock level per part, progress reports, financial planning, etc.) ultimately depend on the accuracy and certainty of these schedules.

In deriving WIP and purchase orders, MRP employs the following technique. First, apart from data accuracy in the Stock Status and Bill of Material files, two other assumptions are made:

> The lead time of each part under MRP control is assumed to equal a mean value (or a function of lot size) and to be independent of external influences (e.g. shop load, production route etc.).
>
> Manufacturing capacity is considered to be infinite during the order generation calculations. Consequently, effects such as the sequence

in which work flows to individual work centres (wc) and particular wc loading, is ignored.

On the basis of these two assumptions the MRP explosion and netting process looks at the MPS, BOM, lead times, stock levels and WIP to produce suggested orders which are offset by the cumulative lead times of the parts in question.

At this point the Capacity Requirements Planning (CRP) module may be run to identify capacity bottle-necks on a period by period basis. Individual demands can then be altered to balance load against capacity.

It is important to note that both the MPS and lead time contain elements of uncertainty. Consequently, the orders generated by MRP II will also be subject to uncertainty.

2.1.3 Control Policies

Modern MRP II systems are usually supplied in a generalized form with numerous options offered for each of a number of control policies. Policies and parameters form an interacting chain descending from customer demand to raw material supply. At the highest level are those, which by their nature impact on the interface between Manufacturing, Marketing, Sales and Financial groups. These relate to the policies applied to customer demand (actual and perceived) in the generation of the Master Production Schedule (MPS).

Examples include:

The extent of forecast demand in the MPS

The forecasting algorithms applied

The level in the Bill Of Materials (BOM) at which the MPS is applied.

The degree and extent of change permitted in the MPS.

At the next level are those policies which affect the translation of customer demand into production and purchase order schedules. Examples of such parameters within MRP include:

Ordering Policies

Lot Sizing rules

Lead time allowances

Safety stock/safety lead time policies

It has long been recognised that the choice of individual policies will affect aspects of the performance of the separate elements within the production system.

2.2 MRP II, Technique or Philosophy?

When examining the accumulated knowledge relating to MRP II, it is tempting to form the opinion that it is a manufacturing philosophy. Indeed the early workers in the field, (Wight, Orlicky and Plossl) suggested as much. This is not too surprising when it is considered that the 1960's into which MRP was born, represented a period of rapid development in business thinking.

The philosophy of this era was known as Corporate Planning. In manufacturing terms, end product requirements were planned against predominantly forecast demand. Long production runs were then planned to minimise standard costs and maximize individual work centre utilization. The low cost of capital was such that buffer stocks and high levels of WIP were used to negate any flow imbalances and further maintain high levels of utilization.

The objective was to achieve sales of the planned production through the market advantage offered by reduced costs. By today's standards the business environment of the time was characterised by low capital costs, minimal international trade imbalance, and long product life cycles. In addition, factors such as high levels of engineering change and customers demanding short delivery times, were not major issues.

Since these were the formative years for MRP, the Corporate Planning philosophy became embedded in the literature relating to policy design. For example, it was often suggested that once generated, the MPS could and should remain firm (e.g. Orlicky (1975)). Lot size and stock policies were often designed with the purpose of maintaining work centre utilization regardless of whether or not a particular work centre was loaded to full capacity.

Since the 1960's, international business pressures, high capital costs, explosive product diversity and reducing product life cycles, forced a shift in business philosophy away from the planned approach toward the strategic approach (strategy implies coherent objectives achieved through flexibility of tactic). The 1970's saw the adoption of Strategic Planning. By the early 1980's, this in turn had been replaced by Strategic Management in "leading edge" companies.

Operationally, the instability of the marketplace inevitably became reflected in the MPS. In many industries competition became increasingly dependent on the ability to achieve short delivery lead times. Coincidentally, the high real cost of capital and the high rate of obsolescence, discouraged the use of safety stocks and make to stock policies, against a largely forecast demand.

Unfortunately, this level of change has been ignored by many MRP researchers and implementors. Wemmerlov (1979) referred to the legacy of doctrines emanating from the troika of Orlicky, Plossl and Wight, most of which were based on 1960's thinking.

It is the author's contention that MRP II is fundamentally a production control technique, in which the assumption of independent constant lead times and infinite capacity are required. These assumptions are made primarily to simplify the computational procedures. It is arguably, both inappropriate and inadvisable to constrain the operation of a manufacturing business to the needs of the production control system. Consequently, philosophical issues should be limited to those relating to the truth of the two assumptions. If there is doubt as to their validity, then means should be employed to correct any deficiencies within the system. It is very much in this area , particularly relating to infinite capacity planning, that this research is based.

2.3 MRP's Failure

In the mid 1970's MRP II was hailed as the saviour of American Industry against the ravages of international competition. At this time the American Production and Inventory Control Society (APICS) initiated a ten year crusade to encourage its use.

However, more recently an increasing number of studies have reported widespread disillusionment with MRP. It is no longer the undisputed saviour. Reports have placed dissatisfaction with MRP implementations as high as 90% (Whiteside and Arbose 1984). Fox (1982) wrote;

> "During the past two decades, United States industries have invested heavily in manufacturing systems. It is estimated that we have spent over $10 billion for MRP alone. While we have made progress, the results have fallen far short of even our minimum goals"

MRP users have complained of; nervous systems with WIP and purchase orders in a constant state of flux, long lead times, poor due date performance, resource imbalance (ie one part of the factory idle whilst another is on full over time), low stock turn and poor return on capital employed.

Meanwhile, the MRP industry (suppliers and implementors) have answered with equally valid criticisms of users, the most common being; poor database maintenance, lack of stock control and various problems with corporate culture. The latter point has commonly resulted from disparity between the marketing, sales, production control and operations management functions.

This dichotomy has generally been resolved around the belief that if the database was maintained at 95%+ accuracy, the corporate culture was receptive, and the management structure appropriate, then MRP II would succeed.

Unfortunately this has not worked in practice. In spite of the above, a number of valid complaints remain, primarily; poor stock turn, excessive lead times and a considerable degree of order rescheduling (Whiteside and Arbose (1984), Mather (1977)). This latter point can be the most insidious, in that it results in serious disruption of manufacturing and loss of faith in the production and purchase schedules (and hence MRP II itself). Anton and Malmborg (1985) discussing a case study, noted;

> "This study was initiated in response to a specific firm's problems with direct materials procurement. The MRP system at this firm had been virtually abandoned due to its inability to react to uncertainties in demand."....
>
> ...."Invalid master production schedules translated into ineffective MRP planning and justifiably low user confidence."

Fortunately the UK's experience of MRP & MRP II has lagged somewhat behind that of America, with the result that our industry has only just begun large scale implementation. It is the author's contention that for the reasons discussed at the start of this chapter, whether or not to implement MRP II, is not an issue. The primary concern should be to learn from the American experience and to find means of ensuring that the high potential for failure is avoided.

In section 2.1 it was shown that fundamentally MRP II is reliant on two assumptions. The first being that lead time is independent of external factors and secondly that it is valid to assume infinite capacity during the MRP netting and offsetting process. The success of an MRP II system is dependent on the truth of these assumptions.

The author will argue that the truth of these assumptions is dependent on extra-system factors (such as the business and manufacturing environment of the company in question) and intra-system factors (such as the control policies used in the Master Scheduling process and the ability to check the capacity consequences of various levels of plans to ensure that plans are not made on the assumption of infinite capacity). It will be further argued that one of the reasons for the high level of failure discussed above, lies in the poor understanding of these factors.

Workers such as Goldratt (1981), (1984) and Fox (1983) have adopted a stringent view of MRP's assumptions, arguing that they are fundamentally invalid and will consequently undermine MRP's success. However the author will argue that whilst always desirable, absolute truth is often unattainable in the complexities of real world systems. Furthermore, it will be argued that a close working approximation to validity can be achieved by careful planning and control system design within defined operational boundaries.

2.4 Master Scheduling In Different Business Environments.

The Master Production Schedule (MPS) is a statement of what the company plans to manufacture in terms of items, quantities and planning periods. As will be discussed later on in this chapter, the items may be products, assemblies or individual parts.

2.4.1 The Purposes of the MPS.

The MPS serves several important purposes. (APICS 1979). First of all, it provides a manufacturing schedule for production orders for MPS items. Secondly it drives the MRPI system. Bills of Material of items in the MPS are exploded to determine the quantities of components required and when they will be needed. Next, it may serve as the basis for determining the capacities needed in terms of manpower, machine hours and other resources through a Rough Cut Capacity Planning system. Finally, for an Assemble-to-Order product, it provides the basis for making delivery promises to customers. For a Make-to-Stock product, this would only be the case when products are out of stock and cannot be shipped from inventory.

2.4.2 Inputs to the MPS.

There are three main inputs to the MPS. First of all there is the long term Production Plan which provides guide lines in terms of total quantities and mix between product families or product lines. Secondly there are various types of Demand Data which might include Sales Forecasts, Customer Orders, Field Warehouse Requirements, Inter-plant Requirements Service Demand Forecasts, Engineering Prototypes, Safety Stocks and any planned changes to MPS item inventory levels. Finally, there is the current Stock Status for each MPS item which will include any On-Hand Inventory, Released Orders (W.I.P.) and existing Firm Planned Orders.

2.4.3 Selecting Master Schedule Items.

In selecting items to Master Schedule, the following considerations might be included. First of all, each MPS item should have a bill of material. This allows the MPS to be exploded through the MRPI system to plan production or to purchase components. Secondly, since the MPS is subject to management review and decision-making, the number of MPS items should be kept small. If there are too many items on the MPS, this becomes impractical. Thirdly, the demand for the MPS items chosen may need to be forecasted, so this demand in terms of averages and trends will need to be able to be monitored. Fourthly, the MPS items should, in combination, constitute most of the required capacity. In other words, if certain products are deliberately omitted to reduce the number of MPS items scheduled, the resulting capacity checks may well be meaningless. Finally, the MPS items should be selected so as to provide flexibility and convenience in meeting customer requirements in terms of product specifications and delivery promises.

2.4.4 Planning Periods for Master Scheduling.

The choice of length of planning period or time-bucket used on the MPS is a trade-off. Short time periods increase the amount of data to be manipulated. Long time periods mean that less information on priorities is provided to manufacturing. This in turn can lead to increased manufacturing inventories due to the timing and size of MPS firm planned orders. For example, an MPS which is planned in four weekly accounting periods might have a quantity of 1,000 planned in period 10. For input to the MRPI system, this will be treated as 1,000 at the beginning of period 10. The consequence of this will be that all materials will be geared up to the first day of the period in batch multiples of 1,000. The actual final assembly situation might be that production will take place on two days of the third week of period 10. To achieve tighter planning and control, with smaller batch quantities, MPS planning might have to be done in weeks or days as shown in figure 2.3.

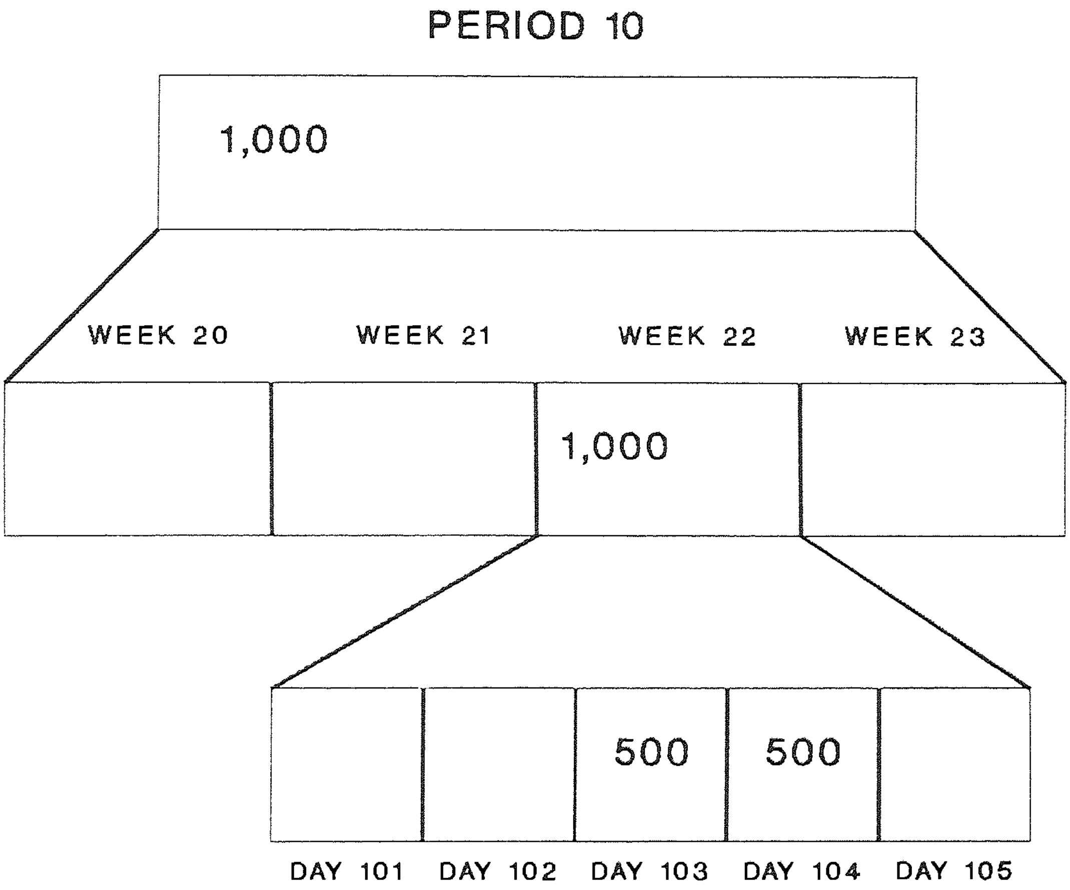
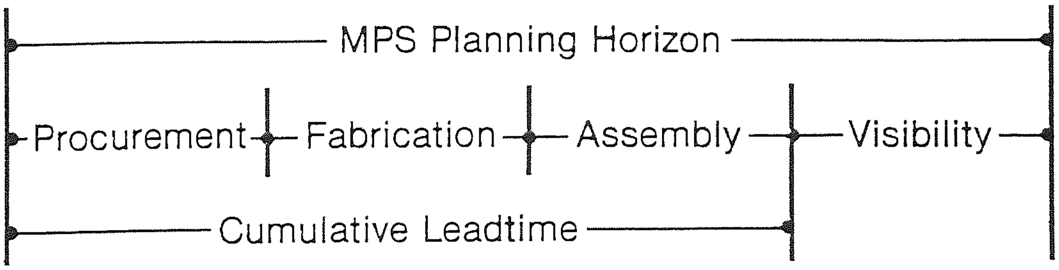


Figure 2.3 The effect of MPS planning periods.

As will be seen in Chapter 5, many companies use time buckets of one week. Others, particularly those with short leadtime, fast moving operations, use daily buckets. There appears to be a tendency towards shorter planning periods as companies move closer to the "Just-in-Time" concepts. Some companies use mixed sizes of planning periods with days for the first few weeks, moving to weeks for a further period and four-weekly periods for the remainder of the MPS.

2.4.5 Master Schedule Planning Horizons.

For the purposes of scheduling production and purchasing, it is necessary to use a MPS planning horizon at least equal to the cumulative production and purchasing leadtime. (Chung, Chen and Cheng, 1988). Furthermore, to provide additional visibility and to provide the basis for sound decisions on purchase contracts, the horizon may need to be extended even further. (see figure 2.4). If a few long leadtime items result in a very long aggregate leadtime, the MPS horizon may be shortened by stocking and controlling these items using an order point approach or by manually scheduling these items outside the MRP system. The MPS horizon may then be based on the cumulative lead time of the remaining items. It may be necessary periodically to extend the horizon further for Rough Cut Capacity Planning. For example, the normal horizon might be 12 months, but acquisition of a new special-purpose machine tool might take two years. In order to determine whether this machine should be ordered, the schedule horizon might be temporarily extended to three years.



Note: Engineering leadtime will be included for the "engineer-to-order" company.

Figure 2.4 MPS Planning Horizons.

2.4.6 Time Fences in Master Scheduling.

Schedule changes become more costly, difficult and disruptive as they become closer to the present time. For this reason, it is useful to divide the future into intervals with different procedures applicable in scheduling for each interval. These intervals are divided by Time Fences. (Figure 2.5).

One of the most important time fences is the Planning Time Fence (PTF). The PTF is usually set equal to the cumulative leadtime for the product. Beyond the PTF, changes in the planned MPS orders are made automatically by a MPS system. This operates just like a MRPI calculation, with Gross to Net and offsetting for leadtimes and taking account of any safety factors and batching rules that may have been specified. This basically automates Master Scheduling on the far horizon of the MPS. This allows the Master Scheduler to spend more time and effort in making manual changes within the PTF after consideration of feasibility and what the effects will be on costs and delays in the production of other products. These decisions may also require approval by higher levels of management. In some organisations, the first few periods of the Master Schedule are regarded as the "frozen zone". In other words, changes to the MPS in this zone should be made in emergencies only. This is done to try and prevent disruptive short leadtime MPS changes and to introduce some stability in the MPS and lower level schedules. (Sridharan and Berry, 1990).

The Demand Time Fence (DTF) is the number of periods into the future over which the demand is taken to be the actual demand (customer orders) as opposed to the forecast. Within the DTF, customer orders are no longer likely to be received or accepted, so the actual orders already booked become the demand used in calculating projected available balance and MPS orders. The DTF is often set equal to the final assembly leadtime.

A formal agreement between Manufacturing and Sales and Marketing as to what the time fences are and what procedures must be followed in making various types of changes within these fences is important in improving communication and cooperation in managing the MPS.

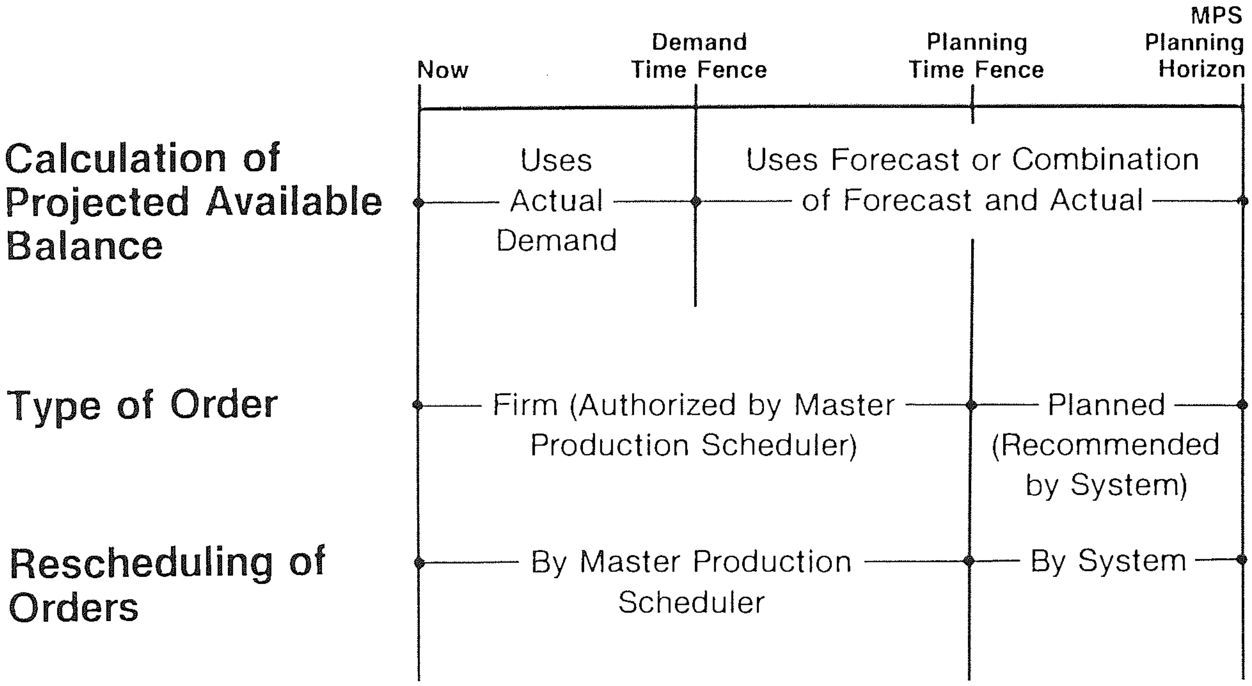


Figure 2.5 MPS Time Fences.

2.4.7 Levels of Master Scheduling.

One of the major tasks a company faces in the definition of their planning and scheduling systems is determining how and at what level a company will Master Schedule. The definition of at what level to Master Schedule will have implications in terms of the level of detail that Sales and Marketing will have to provide in their forecasts, the level in the product structure that inventory will be carried, the lead time quoted for customer delivery and whether the Master Schedule and Final Assembly Schedule will be one and the same document or whether they will be two separate and distinct processes.

The Master Production Schedule defines the detailed product mix to be produced within the production rates set in the Production Plan. It is the What, How Much and When at the product, model, feature, option or product mix level for scheduling production in manufacturing to satisfy the sales forecast or orders. The Master Production Schedule is often updated on a weekly basis and considers material and capacity in its development.

The development of the Master Schedule is based upon the classification of a company's products into categories of Make-To-Stock (MTS), Assemble-To-Order (ATO), Make-To-Order (MTO), and Engineer-To-Order (ETO), (Tincher and Buker, 1986). The first step in classifying products into the various categories is an understanding of the make up of the cumulative leadtime of each product. This is defined as the time it takes to purchase material, manufacture the parts, assemble the product and ship the product. (see figure 2.6.)

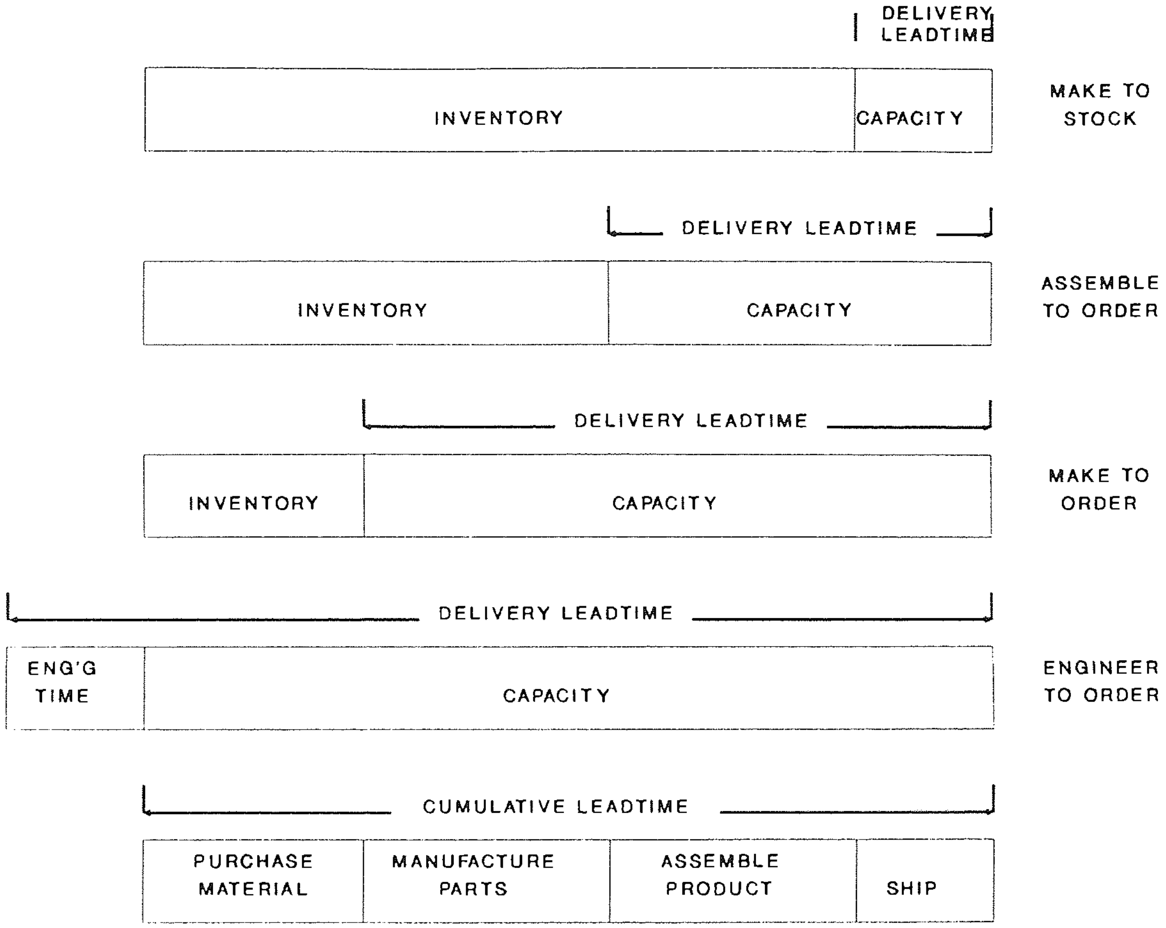


Figure 2.6 - Product categories and Leadtimes

The next step is to determine the competitive delivery leadtime required in the market place. Thus some products are Make-to-Stock, Assemble-to-Order, Make-to-Order or Engineer-to-Order and more than one product category may be present within a company. Sales and Marketing and Production must come to an agreement to properly plan inventory and capacity to produce the products to a state of completion required to meet this competitive delivery leadtime in the market place. This process is achieved by Master Production Scheduling.

2.4.8 Master Scheduling for Make-to-Stock Products.

The Make-to-Stock product is to be produced to stock and shipped off the shelf. The delivery leadtime is very short, usually a day or two. The product must be planned and produced prior to the receipt of the customer order. The longer term Production Plan usually develops the rates of production by product line or family and the Master Schedule determines the mix of the various items that are produced to stock. The Master Schedule is stated in stock-keeping units, end product items or saleable configurations. In the Make-to-Stock environment, Sales and Marketing provide a Sales Forecast or rate of sales by product line and also participate in determining the product mix forecasts at the stock-keeping level. (see figure 2.7.)

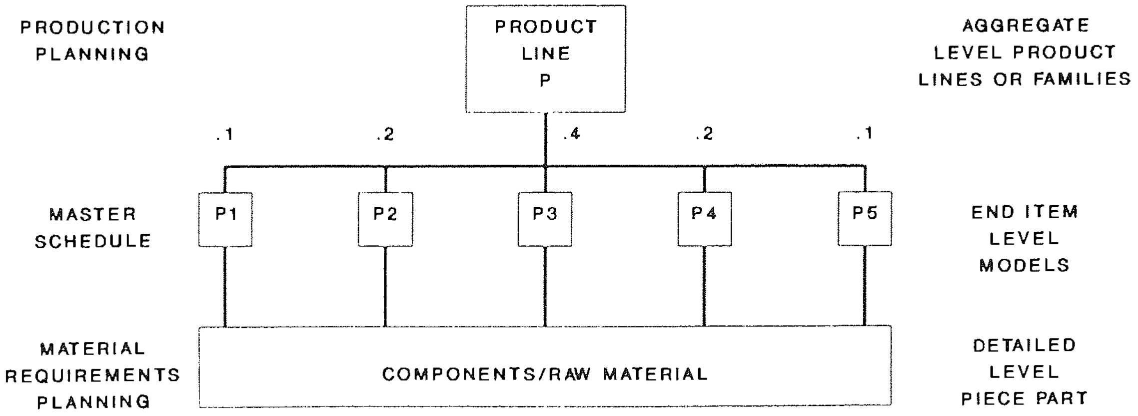


Figure 2.7 - Master Scheduling : Make-to-Stock

An example would be where Sales and Marketing provide a Sales Forecast at the product line level (Product line P) and also provide a mix forecast of the individual models (Products P1-P5). The Master Schedule is developed taking the derived Sales Forecast, often using a Forecast

Planning Bill of Material (Everdell 1983), for models P1-P5 along with the beginning finished inventory for models P1-P5 and the predetermined inventory objectives for models P1-P5. The Master Schedule would also be the Final Assembly Schedule in that the Master Schedule is developed at the top level assembly or finished product stage. It can therefore be stated that in a typical Make-to-Stock environment, the Master Schedule and Final Assembly Schedule would be one and the same.

2.4.9 Master Scheduling for Assemble-to-Order Products.

The Assemble-to-Order product is planned and produced at the component part or sub-assembly level and is assembled to order after the receipt of the customer order. The Master Schedule defines the sub-assemblies to be produced in order to be available for assembly in the Final Assembly Schedule.

The Master Schedule becomes a component or sub-assembly schedule in an environment where a customer may choose from a multitude of features and options. These features and options are then assembled into a customer chosen finished product. One of the main reasons for Master Scheduling at this level is that it may not be feasible to maintain discrete Master Schedule finished product items for every possible finished configuration. For a manufacturer with highly assemble-to-order or customer configured products, the Master Scheduling task of scheduling finished products as in the Make-to-Stock environment could become unmanageable due to the myriad of configurations.

Also, Sales and Marketing would be responsible for providing end item forecasts for each possible configuration. An example for an Assemble-to-Order product would be where the finished configurations have been disassembled into their major components or sub-assemblies. (see figure 2.8.). All of the major components can be grouped under the major heading of the hypothetical Product X using what is known as a type of MPS Planning Bill of Material, called a Common and Option Planning Bill and sometimes referred to as a Superbill. (King and Benton 1988 and Everdell 1983). This would be the top level Master Schedule item in a two level Master Schedule.

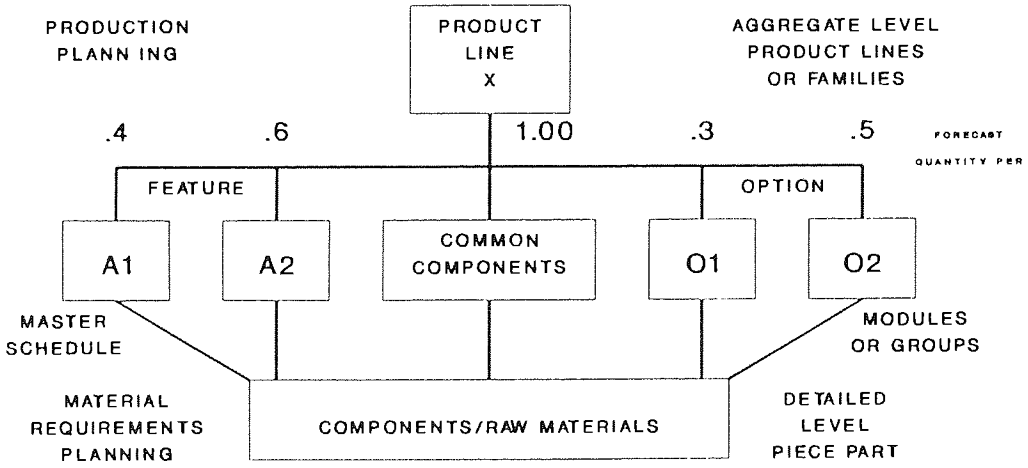


Figure 2.8 - Master Scheduling : Assemble-to-Order products

This top level Master Schedule item is a non-buildable product whose components are the aggregation of the features and options. Sales and Marketing will need to provide the monthly forecast for the top level product X. They will also need to predict the consumption rate of the second level Master Schedule items, in this case, features A1 and A2 and options O1 and O2. This second level forecast is called the mix percentage or feature and option ratio and is normally provided as a percentage of the Product X. The mix percentage forecasts for product X components are (.4) A1, (.6) A2, (.3) O1, (.5) O2 and (1.0) for the common components. As mentioned above , the mix percentage planning is most easily implemented using a type of Planning Bill of Material. Using the example in figure 2.8, if the Master Schedule called for 100 of product X, the requirements for A1=40, A2=60, O1=30, O2=50 and common components would equal 100. This mix percentage in the planning bill provides the mix of components that hopefully will be required in the Final Assembly Schedule.

Since Product X is not a buildable configuration, but is instead intended to facilitate the proper planning of all the features and options contained in Product X, the individual end item (Saleable Configuration) must be recaptured in the order entry process. Therefore, order entry to support the two level Master Schedule must create an end item part number that defines the specific configuration sold. At the time of order entry a temporary part number may be generated. This part number is associated with the specific customer order and would have in this Customer Bill of Material the major components selected by the customer. This part number and Bill of Material would be used by manufacturing for the Final Assembly Scheduling process. This link is easily established using the product family superbill as the menu for customer configuration in the order entry process.

In the Assemble-to-Order Master Schedule environment, where the major components or sub-assemblies are scheduled, the Final Assembly Schedule is used to convey the customer order through order entry and it provides the means to convert a customer configured sales order into a manufacturing order. The manufacturing order is based on the temporary part number that is created. The advantage is that a routing can then be created for works order tracking, works order costing and material control can take place for all final assemblies.

The interface between the Master Schedule, the Final Assembly Schedule and Sales Order Entry has to be dealt with very carefully, otherwise shortages or temporary overstocking of components might occur. An Available-to-Promise calculation needs to be made at the top level product and second level option and feature material stages, before customer orders are accepted and Final Assembly Scheduled. (Clay, 1990). For example for Product X (figure 2.8.), assume the quantity forecasted is 100 and 100 have been Master Scheduled for this top level assembly. (figure 2.9)

FORECAST	100
CUSTOMER ORDER	
ACTUAL PRODUCTION	
TOP LEVEL MPS	100
AVAILABLE TO PROMISE	100

Figure 2.9.

The Available-to-Promise at this time is 100. Taking orders for actual configurations of Product X of 40 would reveal the following new information in the top level Master Schedule. (figure 2.10)

FORECAST	60
CUSTOMER ORDER	40
ACTUAL PRODUCTION	40
TOP LEVEL MPS	60
AVAILABLE TO PROMISE	60

Figure 2.10

The forecast for Product X has been displaced by 40, the quantity of the actual orders. The remaining top level MPS of Product X is 60 and the Available-to-Promise of 60 is then used in the calculation of the second level forecast using the planning bill of material. The Actual Production of 40 refers to the Final Assembly Schedule of Saleable Configurations whilst the 60 top level MPS still refers to the schedule of "Average" products. If the take-up of options and features in the customer orders that have been accepted is different in percentage terms than the predicted ratios, then the Available-to-Promise situation at the second level would have to be checked before Customer Order Acceptance and Final Assembly Scheduling. Thus a Master Scheduler needs to be provided with information on the remaining forecasted quantity, actual customer orders, final assembly orders, unconsumed Master Schedule and available-to-promise for both the top level product and second level items.

A simpler MPS Planning Bill, known as an MPS Modular Planning Bill (Everdell 1983), can be used when the product is truly "modular", by which is meant that the final assembly is merely the putting together of sub-assemblies that are standard. The alternatives are only what modules are used and how they are assembled. Some automobiles and personal computers are good examples. (see Kalamazoo Case in Chapter 4.) Figure 2.11 shows the relationship of a personal computer system to the MPS modules.

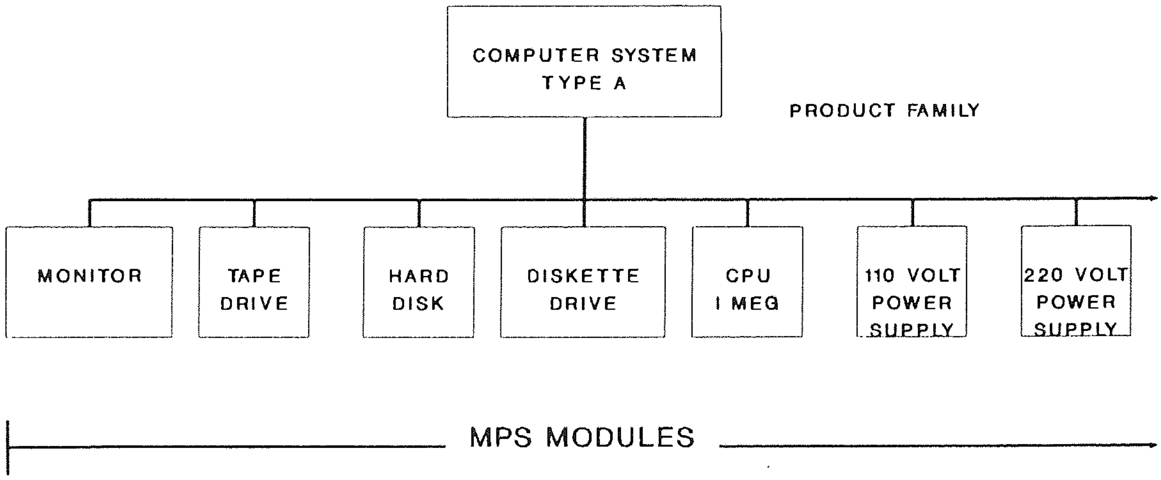


Figure 2.11

The tape drive, hard disk drive, CPU etc., are actually independently Master Scheduled as though distinct products. Customer orders are promised according to the availability of each module, but the customer configuration appears only on the Final Assembly Schedule in the period promised by the Master Scheduler. It is the bill of material for each module that is used to generate requirements in MRPI. In this instance, the modular bill is also an engineering/manufacturing bill and the MPS items can be stocked if desired since there are no further options below the first level of sub-assemblies. To generate forecast quantities for MPS modules, a Forecast Bill of Material can be used. (see figure 2.12).

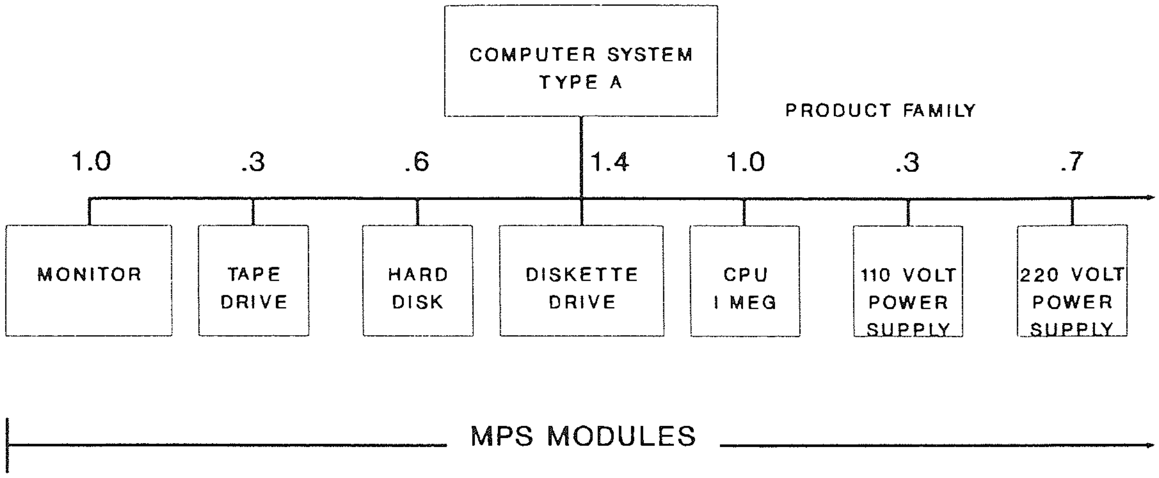


Figure 2.12

Contrasting the Assemble-to-Order Master Schedule with the Make-to-Stock Schedule it becomes clear that in the Make-to-Stock environment the Master Schedule and Final Assembly Schedule are one and the same, the Master Schedule and the Final Assembly Schedule for Assemble-to-Order are two separate or distinct processes.

2.4.10 Master Scheduling for Make-to-Order and Engineer-to-Order Products.

Make-to-Order and Engineer-to-Order products are primarily planned and produced based upon customer orders. In this environment, Master Schedules and Final Assembly Schedules would normally be based upon customer end item configurations (order backlog), and would therefore be one and the same.

However, the Master Schedule and Final Assembly Schedule are not likely to be the same at the point where customer order backlog is no longer available. The Final Assembly Schedule is still likely to be made up of customer orders only, whereas the Master Schedule for periods out beyond customer order backlog would be based upon forecast. When competitive delivery leadtimes are less than the cumulative leadtime of the product, some inventory, particularly for long leadtime materials, has to be planned in anticipation of the customer order. Again, the method used for this is a type of Planning Bill of Material in the Master Schedule. This is normally developed by product family based upon a forecast from Sales and Marketing with planning percentages developed for individual products. This is shown in figure 2.13, where the Master Schedule Planning Bill is for Family P1, with percentages for products P101-P104.

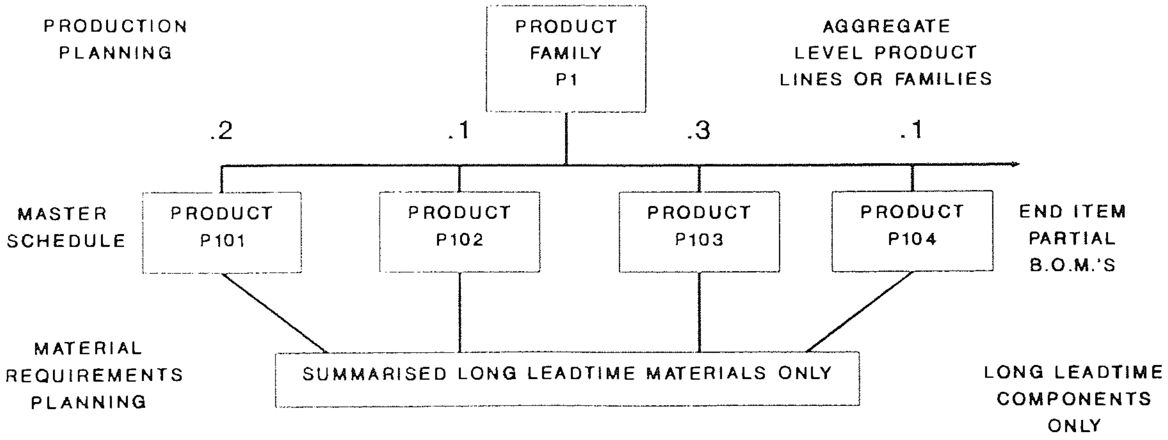


Figure 2.13

At this stage only the long leadtime items need to be included in the bills of material for products P101-P104, resulting in a single level Planning Bill in the Master Schedule. This single level Master Schedule Planning Bill is then consumed when actual customer orders are promised through order entry. At this point in time the Master Schedule for family P1 is reduced by the actual quantity and a new Master Schedule is created for items P101, P102, P103, P104 or whichever configuration has been sold. This is again where the Master Schedule and Final Assembly Schedule merge.

It should be noted that in the Engineer-to-Order environment, if the competitive delivery leadtime is less than the total cumulative leadtime, including engineering time, then considerable difficulties may arise in forecasting product family quantities and product percentages since the products might not have been designed or engineered at this stage.

2.5 Summary

In this chapter the origins and problems associated with MRPII have been discussed and the theory concerning various techniques involved in Master Production Scheduling in different business environments has been described.

Another important aspect of the Master Scheduling process and MRPII is the whole area of Resource and Capacity planning at various levels in the business. This subject will now be covered in detail in the next chapter.

3. RESOURCE AND CAPACITY PLANNING SYSTEMS.

3.1 Introduction.

This chapter outlines the current theories and reported practices of Resource and Capacity Planning systems in a MRPII environment and has been gleaned from recent books and articles written by researchers and practitioners.

The APICS Dictionary (1987) defines Capacity as " the highest reasonable output rate which can be achieved with the current product specifications, product mix, work force, plant and equipment". Capacity in the manufacturing environment is a measure of output, usually expressed as the number of hours of production available over a specific time period such as a shift, day, week, or month. This rate of output must be achievable over extended periods, and it must be reasonable. If overstated or understated, plans may be implemented that either cannot be met or result in poor utilisation of resources.

Capacity is rarely constant over time. A major function of management is to change capacity as required to meet the short, medium, and long-range plans of the company. To accomplish this, the requirements for capacity must be known, together with the available capacity. The required capacity can be derived from the business plan, production plan, master schedule and the material requirements plan if the relevant data is at hand. Available capacity must be defined for a facility or for each specific resource.

There are many factors which affect capacity that can be planned. Other factors impacting capacity cannot be planned, but must be monitored continuously. (Andreas, 1985).

Planned factors include:

Land and Space
Labour force
Facilities
Machines
Technology changes
Manufacturing/Process changes
Learning curves
Tooling
Days worked per week
Shifts per day
Overtime
Subcontracting
Alternate Routings
Preventive maintenance
Number of set-ups

Monitored factors include:

Unplanned orders
Scrap and rework
Material shortages
Excessive tooling problems.
Absenteeism
Labour performance
Machine breakdowns

The consequences of not planning and monitoring these factors carefully, result in poor capacity plans and manufacturing schedules, usually evidenced by the following problems:

Late orders
Low productivity
Higher WIP investment
Long progress meetings
Shortages
Higher labour costs
Extended leadtimes
Poor labour relations.

Within the framework of MRPII, resource and capacity management should play a vital role. By validating the feasibility of the manufacturing plans with respect to capacity at each stage of the planning process, major problems should be anticipated and avoided.

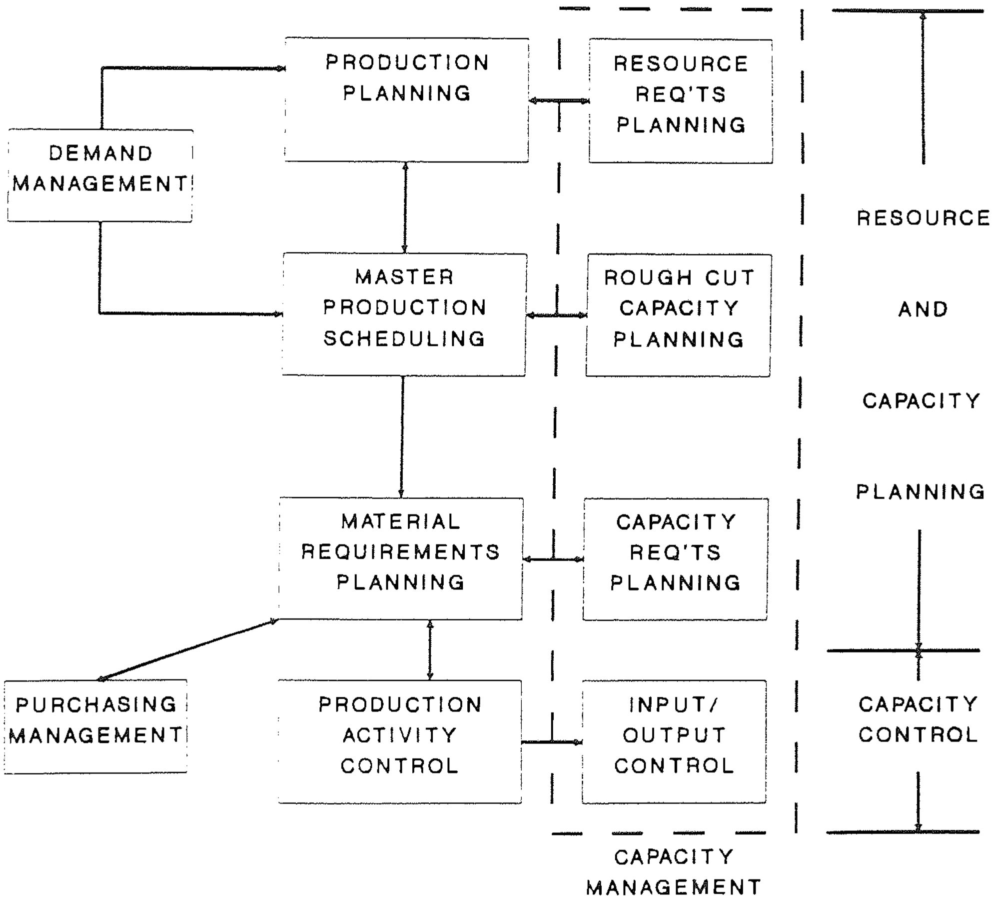


Figure 3.1 - Resource and Capacity Management in MRPII

Figure 3.1 outlines the major elements of resource and capacity management and their place in MRPII. Only the first three will be discussed in this dissertation since they are at the heart of the research, although capacity control at the Input-Output stage should be included in any closed loop MRPII system.

3.2 Resource Requirements Planning

The objective of Resource Requirements Planning (RRP) is to identify the aggregate level of major resources required to meet the long term Production Plan. The Production Plan should be used by top management to control the level of finished inventory or order backlog, the stabilisation of the work force and the long range direction of the business. These plans are usually reviewed and updated on a monthly, quarterly or annual basis, with data aggregated at the product family level in monthly or quarterly time periods, over perhaps a one to five year horizon.

Resource definition at this level is also an aggregation, with divisional, departmental, or critical groups of key resources being included in a resource profile. For example, rather than including each machining operation in the profile, the machining hours might be expressed as a total for a unit of the product family, weighted according to the average mix of the family's production. Other resource constraints which could be specified in the profile include labour hours, critical material, cubic feet of warehouse space, transportation requirements and cash flows.

The construction of resource profiles usually requires experience and judgement together with analysis of the detailed routings for the items in a product family.

By extending the Production Plan quantities over the resource profiles, top management is presented with a picture of the requirements for divisional, departmental or critical resources throughout the planning horizon. This visibility should allow management to adjust the plan or to procure additional resources with sufficient leadtime, rather than reacting to severe resource limitations later.

Resource Requirements Planning may be carried out manually or with computer assistance, either using a module of a MRPII system or using a spreadsheet or similar package on a personal microcomputer.

3.3 Rough Cut Capacity Planning (RCCP)

The Rough Cut Capacity Plan translates the Master Schedule into capacity terms. Where the Production Plan involves product families, covers a long (1-5 year) horizon, and is planned in monthly or quarterly increments, the Master Schedule is much more detailed. The planning horizon is shorter and the production quantities, timing and mix of specific products is defined in the Master Schedule. With this increased level of detail, a more comprehensive capacity analysis can be made.

This capacity plan is called Rough Cut for several reasons. First of all, it is unlikely to mirror exactly the eventual workload on the shop floor since current component and sub-assembly stocks, current work in progress and arrears are not usually included in the calculation. Secondly, the effects of batching rules and safety factors which may be applied in the MRPI calculations are not simulated. Finally, some of the Master Schedule items will not be final saleable products but may be Planning Bills of average products.

Resource profiles can be constructed for each master scheduled item, similar to the profiles used in RRP, but having a finer breakdown of resource groupings and the timing of their need relative to the master scheduled item. A resource profile can be generated using bill of material explosion logic and accessing the routing for the Master Scheduled item and each of its manufactured components at all levels of the product structure. Work centres in which operations are performed may be collected together into divisions, departments or resource groups depending on the degree of detail required. As each routing is accessed, the scheduling of a standard batch size is simulated, and resource profile records created which specify the relevant work centre grouping, quantity, and timing offset relative to the master scheduled item. Alternatively, using some of the logic of Optimised Production Technology (OPT) put forward by Goldratt (Goldratt and Cox, 1984), not all resources may need to be checked against the Master Schedule, but only the Capacity Constraining Resources or "bottle-necks". In this situation, far fewer work centres would have to be analysed for their capacity and load.

Rough Cut Capacity Planning (RCCP) can now be used to verify that the Master Schedule is realistic in terms of capacity. The master schedule quantities are extended over the resource profiles, producing a time-phased analysis of the requirements for resources over the master schedule horizon, usually with work loads slotted into weekly time buckets. Again, management should be provided with enough leadtime to adjust the master schedule or change the capacity without having a disruptive impact on current operations.

As with RRP, the resources being checked might be manpower, machine hours, floor space, storage capacity, transportation requirements, cash flow or any other critical resource.

RCCP is more detailed and complex than RRP and so consequently it is less likely that the process could be tackled manually. Computer assistance is usually necessary, either using a MRPII module for the more complex calculations described above or a Spreadsheet or similar package on a personal microcomputer for the simpler Capacity Constraining Resource calculations.

3.4 Capacity Requirements Planning (CRP).

Through each of the planning stages, the amount of detail increases, while the time increments of planning and the planning horizon decrease. In the short to medium range horizon, plans are made and executed through Material Requirements Planning (MRPI), Capacity Requirements Planning

(CRP), Production Activity Control (PAC), and Input/Output Control. Although major capacity problems should have been resolved during the higher level planning processes, day-to-day capacity problems are still likely to exist. CRP is the tool used to identify those problems and to validate the material plan generated by MRPI. It is a detailed check of the time-phased load on each work centre which is generated by planned and released (open) manufacturing orders.

Capacity Requirements Planning should deal with both planned and open orders to be effective. If only one type or the other is used in CRP, an incomplete load picture will result. Exclusion of open orders distorts the analysis of capacity requirements in the short term. If planned or firm planned orders are not included, the load picture will become increasingly distorted from the present time through all future planning periods.

CRP uses the standard routing for planned orders of an item and the specific routing for open orders currently in work in progress. The routing data required by CRP includes operation sequences, planned work centres, time standards and tooling requirements (if tooling is to be included in the plan).

The status of each operation on a released order needs to be known. This status needs to be continuously updated through feedback from the shop floor, and should specify whether or not the order has arrived at the operation, is being worked on at the operation, or if the operation has been completed. If the operation is currently in progress, the quantity yet to be completed may need to be specified.

CRP determines the requirements for capacity by scheduling the operations of each order through the individual work centres. This requirement for capacity is then compared to the "available" capacity to identify potential overloads or underloads. A distinction needs to be made between several types of capacity, namely; "theoretical" capacity, "demonstrated" capacity, and "rated" capacity.

If a machining centre has 2 machines, and the company works one 8-hour shift, the "theoretical" capacity of the work centre is 16 hours per day.

By evaluating historical work centre performance, it might be found that over an extended period of time an average of only 10 standard hours of work per day have been produced by the work centre. This is sometimes used as a measure of "demonstrated" capacity, but it may be misleading. The historical average really represents output of the work centre and not necessarily capacity. Actual or average output is dependent not only on the capacity of the work centre, but also on the input of work to the work centre. If work does not exist at the work centre, there will be no output. "Demonstrated" capacity should therefore be evaluated over periods when a backlog of work was available at the work centre.

"Rated" capacity can be calculated for use by CRP, and should approximate to the "demonstrated" capacity. Figure 3.2 is used to illustrate the first step in these calculations.

WORK CENTRE: W016 EFFICIENCY: 90% UTILISATION: 80%
SCHEDULING CONSTRAINT: LABOUR

--SHIFT--		NO. OF	NO.OF	SHIFT
NO.	HOURS	EMPLOYEES	MACHINES	CAPACITY
1	8	6	6	48 HOURS
2	8	4	6	32 HOURS
3	0	0	6	0 HOURS

"THEORETICAL" CAPACITY = 80 HRS/DAY

Figure 3.2 - Calculating "Theoretical" Work Centre Capacity.

The primary scheduling constraint in this work centre is labour. Even though 6 machines are always available, an operator is needed full-time to run one machine. Therefore, only four machines are used on the second shift, and none on the third. Producing 80 standard hours of work per day in this work centre over any length of time is likely to be an unrealistic expectation. To determine an achievable "rated" capacity, performance factors must be applied.

The first factor is Utilisation, where:

$$\text{Utilisation} = \frac{\text{Direct Labour Hours}}{\text{Attendance Hours.}}$$

Again, a common mistake in determining utilisation based on historical data is the inclusion of time when no work was available. In the calculation of "rated" capacity, "planned" utilisation should be used, taking into account the monitored factors mentioned previously, such as absenteeism, machine breakdowns, rework, and training but not "waiting for work".

The second factor is Efficiency, where:

$$\text{Efficiency} = \frac{\text{Standard Hours Produced}}{\text{Direct Labour Hours}}$$

Efficiency can be monitored through feedback from the shop floor. Efficiency for both the current production period and an average over time can be maintained. In calculating "rated" capacity, however, a "planned" efficiency is often used. This allows management to use efficiency as a policy variable, and to plan increases (or decreases) in efficiency. These changes obviously need to be realistic, otherwise the capacity plan will be unworkable.

If the primary constraint in a work centre is machine time rather than labour, then the direct labour hours should be replaced by machine hours used in direct production and the available machine hours in the formulas for utilisation and efficiency.

Thus, applying utilisation and efficiency factors to the "theoretical" capacity yields the "rated" capacity which can be used by CRP. Using the data from figure 3.2, the calculation of "rated" capacity is shown in figure 3.3.

THEORETICAL CAPACITY	=	80 HOURS/DAY
X UTILISATION (80%)		.80
		64 HOURS/DAY
X EFFICIENCY (90%)		.90
= RATED CAPACITY		57.6 HOURS/DAY

Figure 3.3 - Calculation of "rated" capacity.

Another piece of information required for CRP is the leadtime offset for each operation, to enable the workload to be allocated to the appropriate time bucket (usually a week). This may be tackled in a relatively simple manner by allowing a fixed inter-operation leadtime. A more sophisticated approach is to use data on setup time, run time, wait time, move time and planned queue time to produce individual inter-operation lead times per order and per operation. Account may also need to be taken of the planned use of multiple resources per order, for example, two machines per order in a work centre rather than one.

Finally, to allocate work load into time buckets, operations have to be either forward scheduled from the current date or backward scheduled from the order due date. Theoretically it might seem more logical to carry out forward scheduling, however, this approach does not take account of the required due dates and does not give users any direct information on arrears or required capacity to overcome an arrears situation. Consequently, because of the importance of due date performance in a MRPII environment, Backward Scheduling is the most common method used in CRP. An example of backward scheduling for an individual order is shown in figure 3.4, with the order due date having been set as the Net Requirement date from a MRPI system.

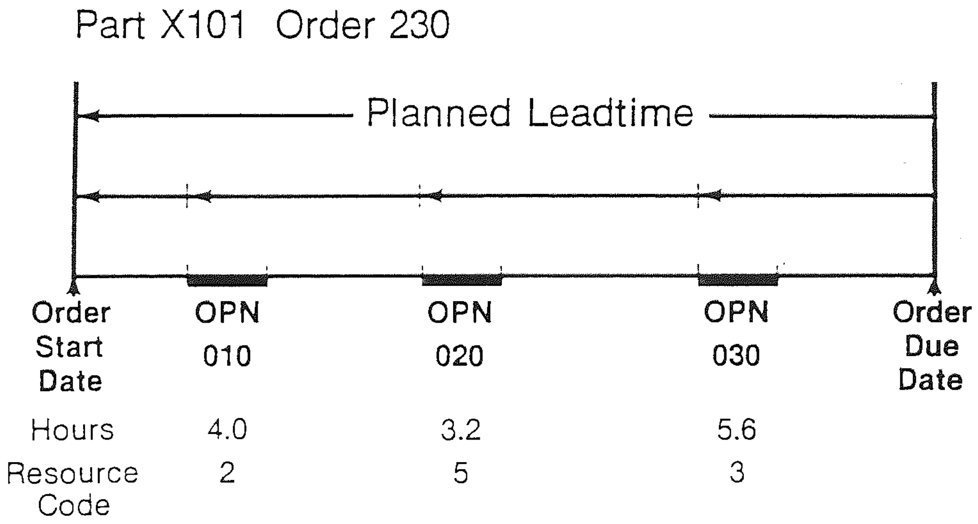


Figure 3.4 - Backward Scheduling for CRP.

Work loads from each order in terms of machine hours, labour hours, or setting hours are then accumulated for each work centre or resource for each time period and usually shown graphically with a comparison against rated or demonstrated capacity as in figure 3.5.

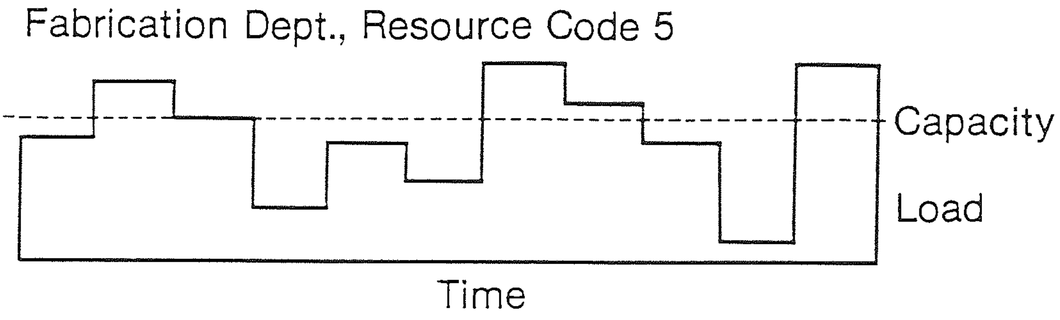


Figure 3.5 - Capacity Plan for Resource Code 5.

One important aspect to note is that CRP, as with RRP and RCCP, is not a "finite" capacity planning system. "Infinite" loading refers to the approach in which CRP schedules individual orders without regard to order priority, other orders planned or in process, or the load generated on any work centre by other orders. In other words, when an overload or underload situation is predicted by CRP, as in the figure 3.5 example, there is nothing in the scheduling approach which automatically reschedules orders to overcome these problems. If an effective job of managing capacity has been done at the higher levels of planning (RRP and RCCP), the problems identified through CRP should be minor. The overload or underload conditions discovered using CRP should usually be resolved by the "fine-tuning" of capacity or orders on the shop floor. Only occasionally should the remedy be to feedback the problem to the Master Scheduler to enable the MPS to be altered, so as to change the due dates of the orders concerned.

3.5 Finite Capacity Loading and Scheduling.

According to Vollmann (1986), finite loading, at least in some software packages, is shown as an activity proceeding from detailed CRP to Production Activity Control (PAC). Finite loading is better seen as a Production Activity Control (PAC) technique than as an alternative to CRP. It goes beyond the usual CRP approach of infinite loading , using the detailed information already generated. In so doing, it smooths the load at each work centre so that capacity is exceeded in no time bucket, but is fully utilised. The result is a detailed daily schedule for each work centre; in effect, a Production Activity Control system.

Consultants, users and researchers (Goddard, 1985, and Thorne, 1986), have debated the usefulness and appropriateness of finite loading techniques, primarily because MRPI already produces a set of consistent shop order due dates for matching parts which serve as priorities to drive PAC. Unfortunately, MRPI assumes that infinite capacity exists during this process, and this can result in shop order due dates not being met. On the other hand, finite loading can easily come up with conflicting due dates because work centres are loaded to capacity. Most finite loading procedures, moreover, also incorporate additional priority schemes to determine relative importance ranking, usually based on managerial judgement or internally computed indices on job lateness.

Compounding the problem of finite loading is the question of for how long a produced schedule is valid. If the finite schedule is produced only once per week, by the end of the week it will usually be meaningless, since it was based on a set of assumptions in which changes compound the errors. Most firms making finite loading work do so with a daily processing cycle, which has often taken several hours of computer time.

Finite loading and scheduling systems come in various forms ranging from those incorporating Artificial Intelligence (Perrier and Cross, 1987), detailed shop floor simulation models as used in Pratt and Witney (Mirto and Lehman, 1987) and Rolls-Royce (Rolls-Royce Case study in Chapter 4.), and P.C. based interactive planning board systems such as CIM Manager supplied by Hoskyns U.K. and Manufacturing Manager supplied by RWT U.K.

A particular version of finite loading and scheduling is the Optimised Production Technology (OPT) software, which basically replaces the RCCP, MRPI, CRP and PAC modules of a traditional MRPII system. OPT utilises a mixture of forward finite scheduling through Capacity Constraining Resources and beyond and traditional priority index based infinite capacity scheduling for all resources feeding the capacity constraints. (Goldratt, 1984 and Vollum, 1985).

Some authors (Ben-Ari, 1989 , Muegel and Ryan, 1986 and Archer, 1990) suggest the use of finite capacity planning at the Master Schedule stage, thus replacing RCCP.

3.6 Summary

In this chapter, the theory of Resource and Capacity planning has been discussed in some detail and the assumptions have been made that these procedures and calculations need to take place if a truly "closed loop" MRPII system is to operate.

In the following chapters, the author tries to determine whether the Master Production Scheduling techniques described in Chapter 2 and the Resource and Capacity Planning procedures described here are used in practice in specific companies and in U.K. manufacturing industry in general.

4. DETAILED INVESTIGATIONS OF MASTER PRODUCTION SCHEDULING IN U.K. MANUFACTURING ORGANISATIONS.

4.1 Introduction and Objectives.

To ascertain the state of the art of Master Production Scheduling in the U.K., from the mid 1980's onwards, eight manufacturing organisations, which operated in quite different business environments, were investigated.

The objectives at this stage were to:

i) Identify what information companies actually use to create their Master Production Schedule and how they use it.

ii) Identify what measures are actually used to judge the success of the Master Production Scheduling process and which of these are the most useful.

iii) Identify the MPS methodologies which appear to be successful.

iv) Identify any common problems encountered in Master Scheduling across the organisations.

v) Compare current practice with MPS theory.

4.2 Method of Investigation

An Interview Check-list (questionnaire), was developed and refined after the first pilot investigation and used by the author whilst interviewing at the companies. A copy of this Check-list can be found in Appendix 1. The model of the relationship of Master Production Scheduling to other Manufacturing Planning and Control activities which formed the basis of the check list is shown in figure 4.1 and is attributed to Berry, Vollmann and Whybark (1979).

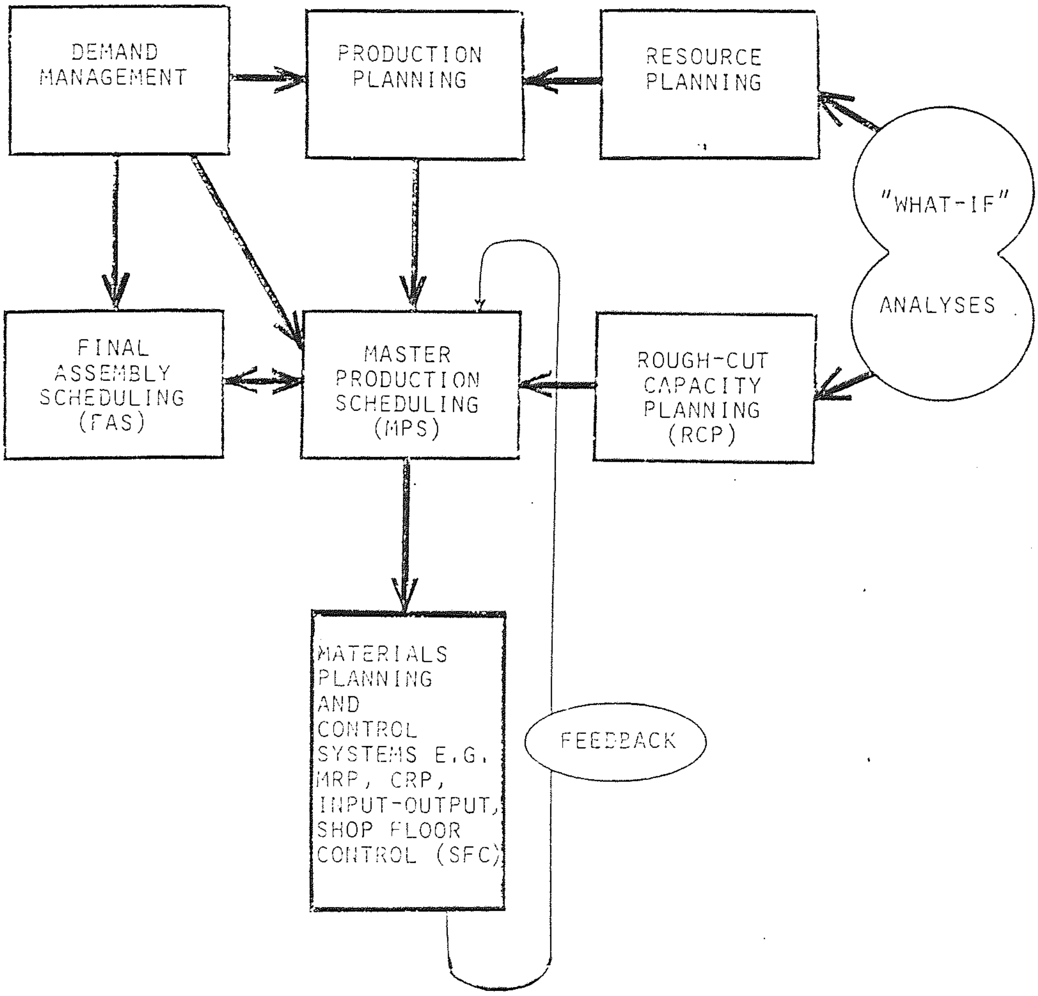


Figure 4.1 Relationship of Master Production Scheduling to Other Manufacturing Planning and Control Activities.

Interviews were carried out using a tape recorder to speed up the process of information gathering and to ensure that no details were missed. Several visits were often required to one organisation to enable all the relevant personnel to be interviewed. The interviewees usually included the Master Scheduler, Production Control Manager, Production Manager, Materials Manager, Systems Manager and occasionally Sales and Marketing Manager and Managing Director. Examples of documents used in the Master Scheduling process were also collected at these interviews.

After each investigation, tapes were transcribed and an investigation report produced in case study form. In doing this, further visits or telephone calls were necessary to answer queries and to obtain "missing" information.

When a final draft company investigation report was produced, this was sent to the main contact at the company for checking for factual accuracy and for clearance of sensitive information. Copies of the eight company case studies can be found in Appendices 2 to 9.

4.3 Collaborating Organisations

The collaborating organisations were chosen, wherever possible, to represent a spectrum of types of business in terms of size, business environment e.g. Make-to-Stock, Make-to-Order, Assemble-to-Order and Engineer-to-Order, product complexity and manufacturing leadtimes.

The following is a list of the companies which were investigated, together with brief details of their products and markets. Full details regarding these companies can be found in Appendices 2 to 9.

4.3.1 Marathon Alcad, Redditch, Worcs.

Manufacturers of nickel cadmium batteries, mostly to customer order for the industrial battery market.

4.3.2 Riker Laboratories (3M Health Care), Loughborough, Leics.

Manufactures and markets pharmaceuticals in the form of packaged tablets, capsules, sachets and aerosols. It makes to stock for the Home Market and to order for the Export Market, selling to over 75 countries throughout the world.

4.3.3 Kalamazoo Business Systems, Birmingham.

The Small Business Systems Division manufactured a range of micro computers to stock which were then sold as part of a business system and installed on site.

4.3.4 Rolls Royce Ltd., Derby and Glasgow.

Manufacturers of aero engine components to support the final assembly of aircraft engines and spare parts requirements, the majority of which are made to customer order.

4.3.5 Cincinnati Milacron, Birmingham.

Manufacturers of complex, high value, Machine Tools, Machining Centres and Flexible Manufacturing Systems with many options, strictly to customer order.

4.3.6 Midland Electric Manufacturing Co. Ltd., Birmingham.

Manufacturers of relatively standard industrial and commercial switchgear and accessories, mostly to stock.

4.3.7 Quinton Hazell Transmission Division, Redditch, Worcs.

Manufacturers of a wide range of motor vehicle clutches and allied components, many under own-brand labels, to stock, mainly for the aftermarket.

4.3.8 Pye Telecommunications, Cambridge.

Manufacturers of a range of portable radio equipment with many options and accessories, mostly to customer order.

The following figures, 4.2 to 4.5 compare the differences in the companies in terms of company size (employees), business and market environment, product complexity, and manufacturing leadtimes. (Rolls-Royce refers to component and sub-assembly and not final engine manufacture).

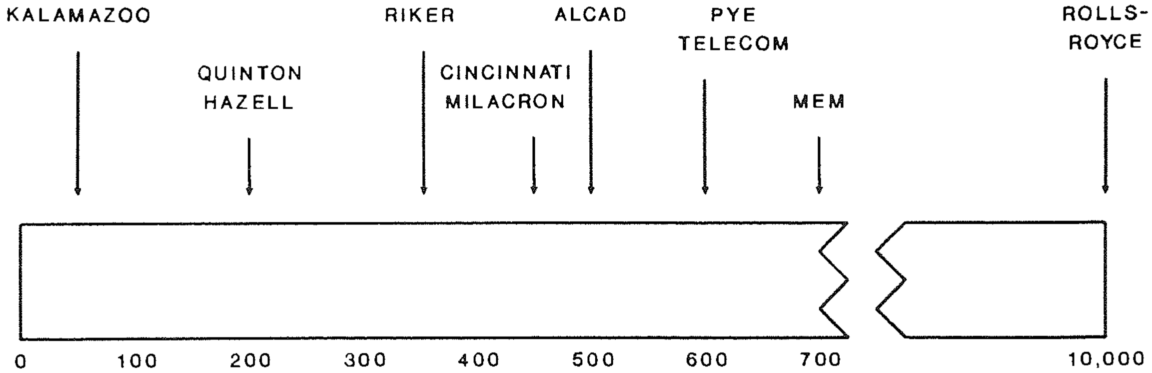


Figure 4.2 Comparison of company sizes (no. of employees)

MAKE-TO-STOCK	ASSEMBLE-TO-ORDER	MAKE-TO-ORDER	ENGINEER-TO-ORDER
QUINTON HAZELL	PYE TELECOM	ROLLS-ROYCE	ROLLS-ROYCE
KALAMAZOO	MARATHON ALCAD	CINCINNATI	
RIKER	KALAMAZOO		
MEM	RIKER		

Figure 4.3 Comparison of company business and market environments.

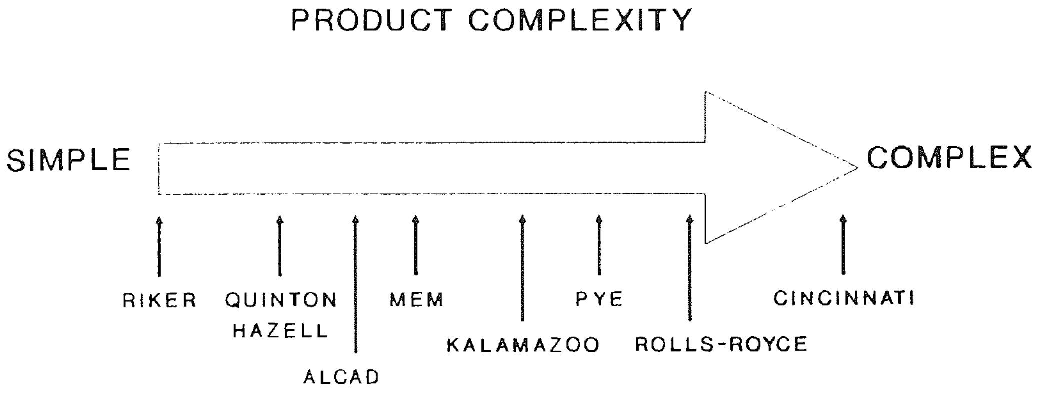


Figure 4.4 Comparison of companies by product complexity.

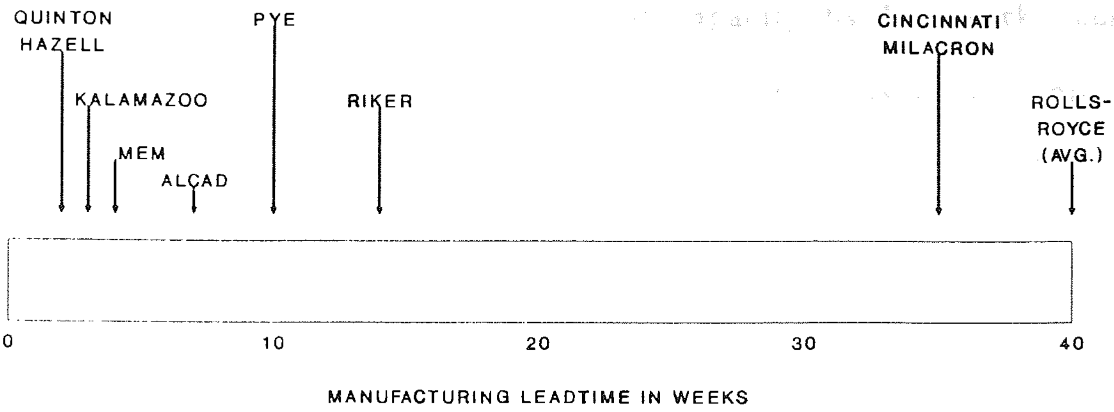


Figure 4.5 Comparison of companies by length of manufacturing leadtimes.

4.4 Significant Features of Companies' MPS Systems and Procedures

Whilst each company's systems have been separately compared against a theoretical model (figure 4.1) and the details outlined in the company case studies in appendices 2 to 9, in this section, only the significant existence or lack of parts of the model are discussed here.

4.4.1 Marathon Alcad [May 1984]

Forecasting is currently carried out on a microcomputer using a company developed program. For forecasting and Master Scheduling, 33 "key" representative cell types were used out of a range of 800. These were not planning bills of material but actual cells. An on-line allocation system was used which was linked to a Rough Cut Capacity Planning system such that no despatch dates were confirmed to customers until the orders had been Master Scheduled. The Rough Cut Capacity Planning system gave on-line screen displays of load against capacity by key work centre (machine or labour) and by week. This was created using load profiles which were updated twice a week from the routing files. Detailed Capacity Requirements Planning was not carried out.

4.4.2 Riker Laboratories (3M Health Care) [May 1984]

Much effort was given to forecasting all of the 500 finished products and to creating closer links with customers, particularly those overseas. Master Scheduling was carried out for the finished products and then for up to four manufacturing stages down through the product structures. This was usually completed over three weekly MRP runs. This was because of strict capacity limits on process type facilities and the need to sequence products to minimise changeover and clean-down times. In effect, finite capacity planning, based on manual bar charts was being carried out down through the manufacturing stages. Data was also being downloaded from the main system onto P.C.'s for capacity planning calculations. Detailed reports were produced on stock coverage and service to production and used as measures of MPS effectiveness.

4.4.3 Kalamazoo Business Systems. [August 1984]

The Master Production Schedule was stated in modules, for example, keyboards, terminals, and central processing units. No formal capacity planning either at the Rough Cut or detailed level was carried out. The first month of the MPS was adjusted depending on the installation schedule of complete business systems. (Note: microcomputers ceased to be produced by Kalamazoo nine months after the author's investigation).

4.4.4 Rolls-Royce Ltd. [September 1984]

Master Scheduling in its true sense was not carried out at Rolls Royce manufacturing plants. This was because the total manufacturing requirements were not looked at as one schedule. Requirements may have been generated directly from Engine Programmes or for replenishing stocks of spare parts at airlines and overhaul and repair plants. The only parts which were scheduled were high value, high volume parts on which decisions were based on information from Provisioning Conferences with the major airlines. Much work was done on long term Resource Planning in great detail. There were also detailed computer simulations of individual workshops and manufacturing facilities developed by an Operational Research group. Some Rough Cut Capacity Planning was being carried out by downloading data from the main system onto P.C.'s and using standard hour contents for average products.

4.4.5 Cincinnati Milacron [February 1985]

Basic models for machine tools were forecast using a six month moving average and then "dummy" orders for machines , including the most popular options were Master Scheduled. The material required for the other possible options were catered for by safety stocks in the MRPI system. The MPS was calculated and displayed using a Multiplan Spreadsheet program on a P.C.. No detailed Capacity Requirements Planning was carried out other than the allocation of work on final assembly. Regular MPS meetings were held at director level.

4.4.6 Midland Electric Manufacturing Co. Ltd. [September 1985]

Programming meetings were held every month to update and agree the Master Schedule. Rough Cut Capacity Planning was carried out using a micro computer based spreadsheet with data downloaded from the main system. Historical line running rates were used as the units of measure. The main MPS system provided visibility of the "Projected Available Balance" and "Available to Promise" for every end item. No detailed Capacity Requirements Planning was carried out.

4.4.7 Quinton Hazell Transmission Division. [January 1986]

Sales forecast schedules received from the Distribution Division were converted into a Master Schedule by grouping like finished products together into family bills of material and making comparisons against historical capacities in terms of daily output rates "in one's head". The MPS was being developed, amended and displayed on a P.C. based spreadsheet. No formal Rough Cut or detailed Capacity planning was carried out.

4.4.8 Pye Telecommunications. [December 1985]

Super Bills of Material were used for Master Scheduling a wide variety of options to the basic products. Customer Bills of Material were then created at order entry by using a product sales code which called up the relevant second level sets of option materials as well as the basic product common materials. In the order entry and promising system, available-to-promise information was used (for up to five items simultaneously) so that the products on a customer order could be promised and scheduled at the date of earliest availability of all the models and option materials. The concept of Master Planning over and above Master Scheduling had recently been introduced which involved setting the Manufacturing and Inventory Strategies in and across plants and providing the necessary logistics systems. Rough Cut Capacity Planning was being carried out using a Multiplan spreadsheet for labour requirements and labour capacity in three main manufacturing areas. Detailed Capacity Requirements Planning was not undertaken.

4.5 Conclusions Drawn from the Detailed Cases.

Referring to the list of objectives set at the beginning of this chapter, the following conclusions can be drawn.

i) The information that companies actually use to create their Master Schedules depends on the business environment and may include a mixture of forecasts and orders. In some firms the forecasting is done at the end product stage, in others it is done at the product family and option mix stages. Some businesses have relatively sophisticated order entry and order promising systems (e.g. Pye Telecom and Marathon Alcad), in others it was fairly rudimentary (e.g. Kalamazoo).

ii) In terms of the measures used to judge the success of the Master Scheduling process, the most common, mentioned by all companies, was delivery performance or customer service levels. This was followed by stock level measures used by six out of eight and comparisons against longer term production or financial plans mentioned by four. Forecast error, labour utilisation, machine utilisation and service to production measures were only mentioned by one out of eight companies.

iii) There were examples of the successful use of some of the MPS methodologies which were described in chapter two. In particular, the use of various types of planning bill of material was simplifying the forecasting and Master Scheduling task in several of the companies. For example, Super Bills were being used in Pye Telecom, Family Bills in Quinton Hazell, Modular Bills in Kalamazoo and Option Bills (for safety stocks) in Cincinnati Milacron. There were also examples of multi-level Master Scheduling in Riker and Pye Telecom. Available-to-Promise calculations and displays were used in several companies, namely, Pye Telecom and MEM. The

Master Schedule was being tested out by means of Rough Cut Capacity Planning in varying degrees of sophistication in five of the eight companies, namely; Marathon Alcad, Riker, Pye Telecom, Rolls-Royce and Cincinnati Milacron.

iv) The only common problems mentioned were concerning the inability to measure work load in terms of Standard Hours. This was either because time standards did not exist at all or were thought to be too unreliable to be used. The companies involved in these problems were Marathon Alcad, Cincinnati Milacron, MEM, Quinton Hazell and Kalamazoo.

v) Comparing MPS theory with the current practice as described in the eight organisations investigated, the conclusion that can be drawn is that many of the aspects of the theory are in use and are assisting companies in the Master Scheduling process particularly in the areas of bill of material structuring, Rough Cut Capacity Planning and links to order entry and order promising through the use of Available-to-Promise calculations.

The most significant area where practice did not seem to be following MPS theory was the lack of use of detailed Capacity Requirements Planning (CRP) and the lack of closing of the loop by feeding back from this check to the MPS process. Six out of the eight companies were not carrying out CRP for various reasons, many because of the lack of time data, but some deliberately choosing not to carry it out because of the perceived lack of benefit to be obtained for the time and effort required.

One other aspect where practice and theory were not in line, was the lack of monitoring and collection of Utilisation and Efficiency (or Performance) factors in the majority of companies. This could have been because of the initial lack of time standards in the first place but could also have been because of the lack of shop floor data collection systems or procedures. If these Utilisation and Efficiency factors are not available, the theory as outlined in chapter 3, would suggest that available capacities cannot be calculated for Rough Cut or Detailed Capacity Requirements Planning.

Another interesting feature that arose from these investigations was the apparent widespread use of Spreadsheet or similar packages on micro computers (P.C.'s) for such tasks as Rough Cut Capacity Planning and Master Scheduling (6 companies). There was also one company carrying out forecasting using a micro computer. In some companies this was explained as being because the main MRPII software did not have the facilities or that the queue for programming work on the main system was too long. Some companies saw the use of P.C.'s as merely a stop-gap measure or to act as a test-bed for ideas and report layouts prior to getting the function working on the main system. Others saw the P.C. solution as a long term one which was much more flexible than the use of a module on the main system.

As a result of these detailed investigations, the hypothesis was formed that the link between Capacity Requirements Planning and Master Production Scheduling was not operating successfully and that, therefore, "the loop" was not being "closed" satisfactorily in the majority of manufacturing organisations.

Since this was a very small sample on which to base such a statement, the next step was to carry out a much larger survey of U.K. manufacturing industry to test out this assertion. The analysis of such a survey together with a survey and analysis of software suppliers is covered in chapters 5 and 6.

5. NATIONAL USER SURVEY OF THE USE OF CAPACITY REQUIREMENTS PLANNING IN MANUFACTURING PLANNING AND CONTROL SYSTEMS.

5.1 Introduction.

In order to test the hypothesis put forward at the end of chapter four and also to ascertain some of the reasons for the suspected lack of use of Capacity Requirements Planning, a detailed questionnaire was developed and sent out in November 1990 to manufacturing organisations throughout the United Kingdom.

5.2 Methodology

The questionnaire was developed to elicit sufficient information to justify or refute the main hypothesis as well as to provide information that might explain the reasons for the current situation. The User Questionnaire sample had also to be shown to be representative of U.K. manufacturing organisations in terms of size and type of business.

Before detailed design of the questionnaire document, several statistical and survey analysis packages were reviewed and eventually SNAP-2, a Survey Analysis Package and General Data Analyser by Mercator Computer Systems, was chosen as being most suitable to the task. The questionnaire was then designed with the eventual analysis method in mind.

A pilot questionnaire document was produced and tested on a small number of companies, well-known to the author. After relatively few amendments the final questionnaire was produced.

The User Questionnaire, shown in Appendix 10, is divided into four main sections. Section A is concerned with obtaining general information such as company size, turnover, industry and type of operation. Section B deals with computer hardware and software and specifically the software modules in place and planned. Section C asks the detailed questions about Resource Requirements Planning (RRP), Rough Cut Capacity Planning (RCCP) and Capacity Requirements Planning (CRP). Section D is concerned with the availability of information for capacity and resource planning such as standard times and utilisation and efficiency measures and how this information is collected.

The population for the User Survey was carefully chosen. The author was given access to the membership database of the British Production and Inventory Control Society (BPICS) and was able to categorise the members into several groups, one of which was Manufacturing Practitioners. This list from BPICS together with the author's personal contacts built up over a number of years, produced a total of 2,700 people to which the User Survey was posted. In interpreting the results of this survey, it should be borne in mind that answers were received from people holding quite different positions in their companies and this may well bring with it certain biases regarding the perceived success of Capacity Planning.

The basic analysis of all the questions asked in the User Survey is covered in the next section of this chapter. A summary of the analysis of the User survey is discussed in section 5.4.

5.3 Analysis and Results.

Of the 2,700 questionnaires sent out, 400 replies were received, a response rate of 14.8% which was regarded as good. Of the 400 replies, 349 (12.9%) were usable; most of the unusable responses being because of duplication of information from the same factory, where more than one BPICS member had replied from that company. The following is a question-by-question analysis of the responses. (Note that in some cases, replies to certain questions may add up to more than 100% since respondents could choose more than one answer).

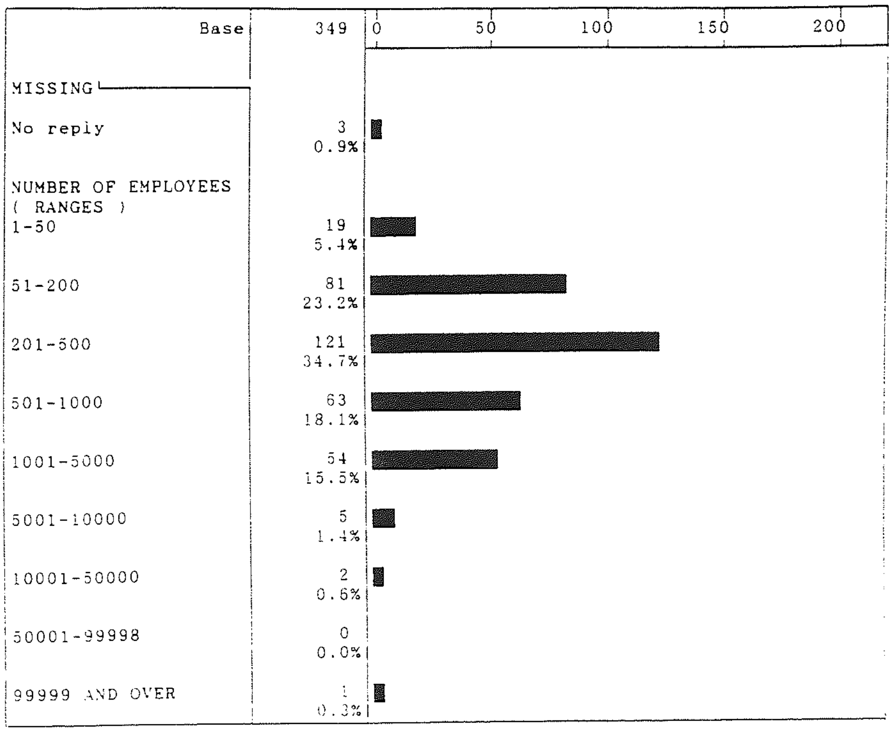
5.3.1 Section A - General

Question 1 concerned the size of company in terms of number of employees which revealed the distribution shown overleaf.

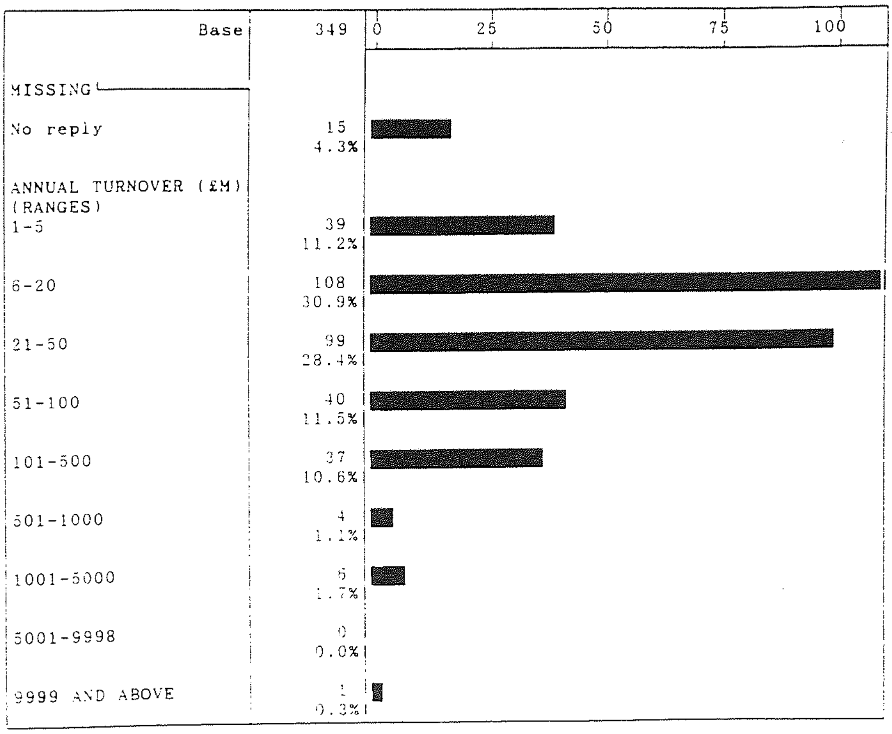
Whilst this sample is not fully representative of the total population of UK manufacturing organisations, it may well be a good cross section of the users of computerised manufacturing planning systems.

Question 2 asked about the size of company in terms of annual turnover, giving the distribution shown overleaf. As with question 1, this again shows a good spread of respondents.

Bar chart...: NUMBER OF EMPLOYEES (RANGES)
Cells.......: Absolute, Total %

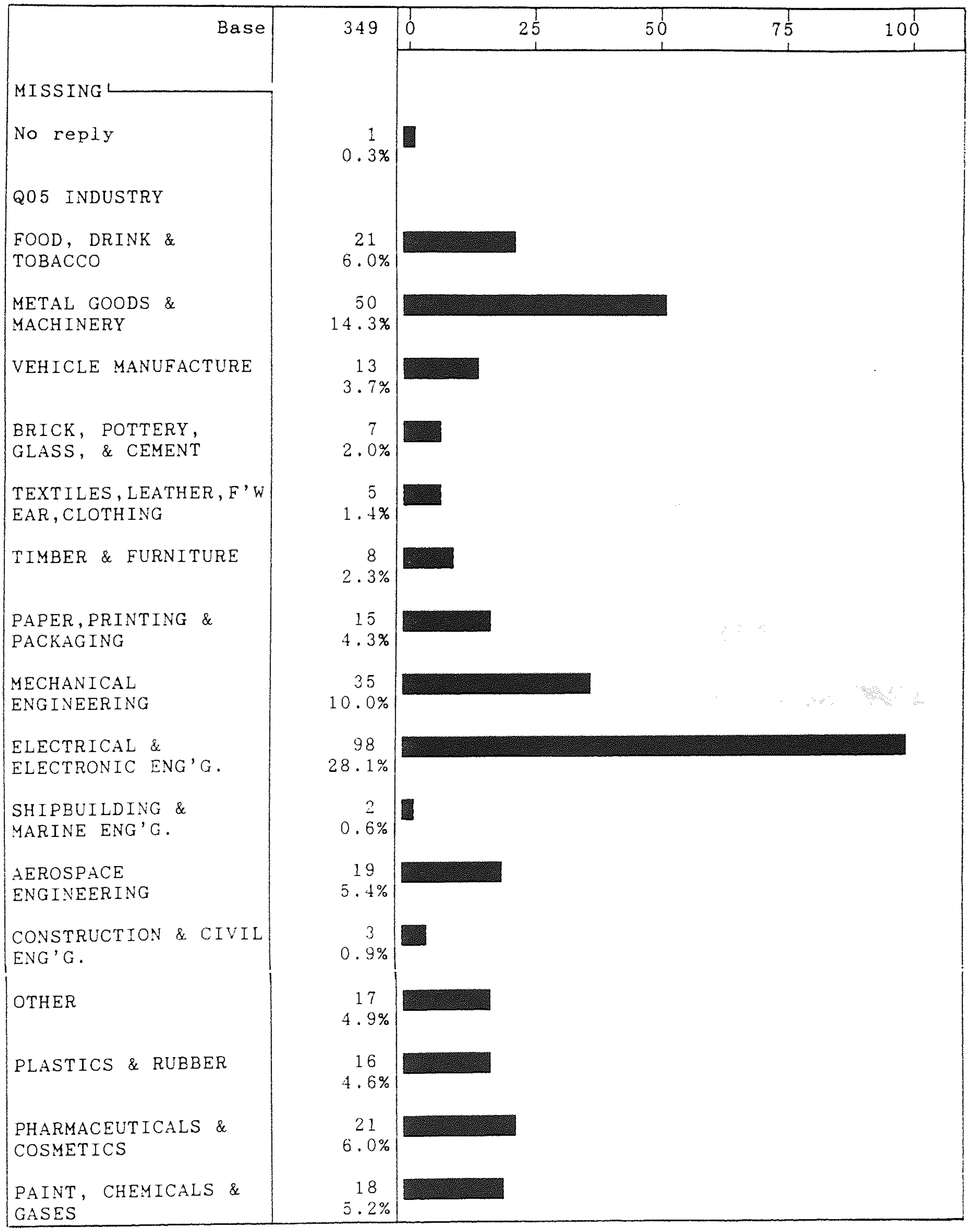


Bar chart...: ANNUAL TURNOVER (£M) (RANGES)
Cells.......: Absolute, Total %



Question 3 deals with the type of industry in which the respondents' companies are placed:

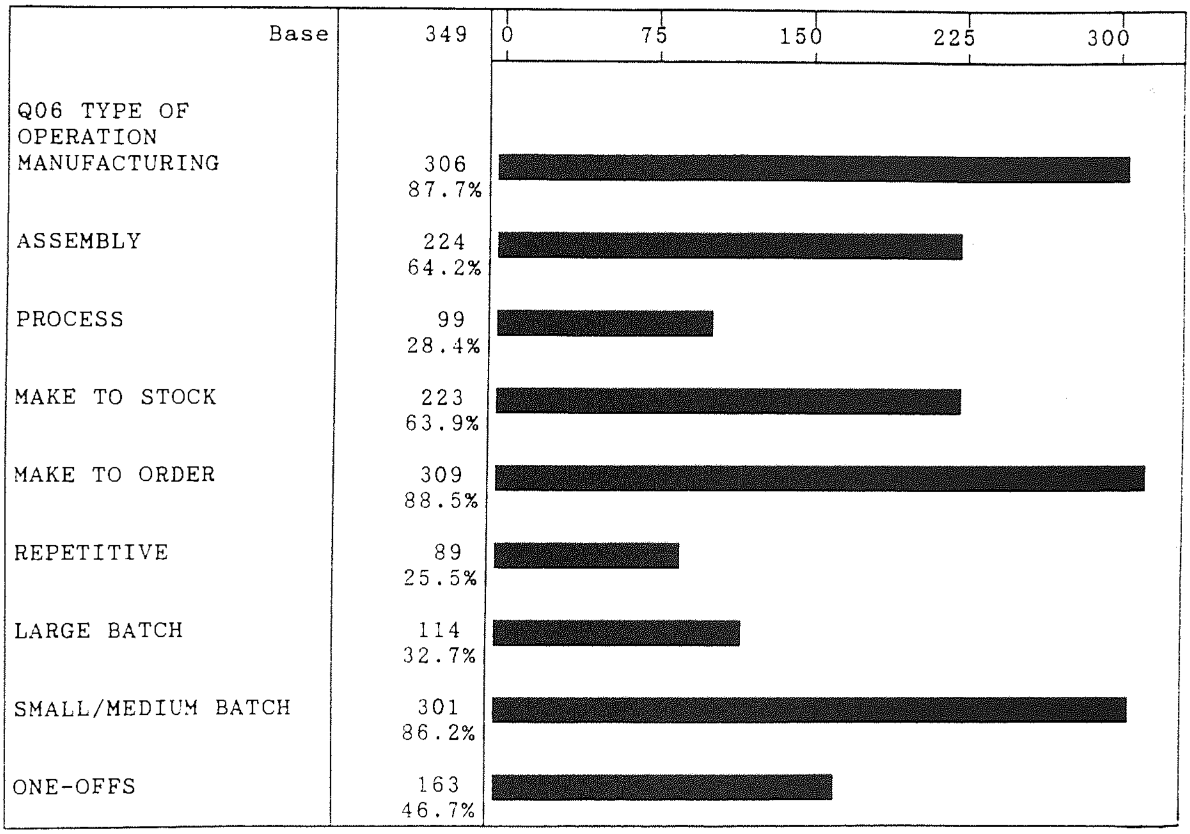
```
Bar chart...: Q05 INDUSTRY
Cells.......: Absolute, Total %
```



This again shows a good spread with a preponderance in Electrical and Electronic Engineering (28.1%), followed by Metal Goods and Machinery (14.3%). This again cannot be shown to be a true representation of U.K. manufacturing as a whole but is a good spread of users.

Question 4 is concerned with the type of operation in which the companies are involved:

```
Bar chart...: Q06 TYPE OF OPERATION
Cells.......: Absolute, Total %
```



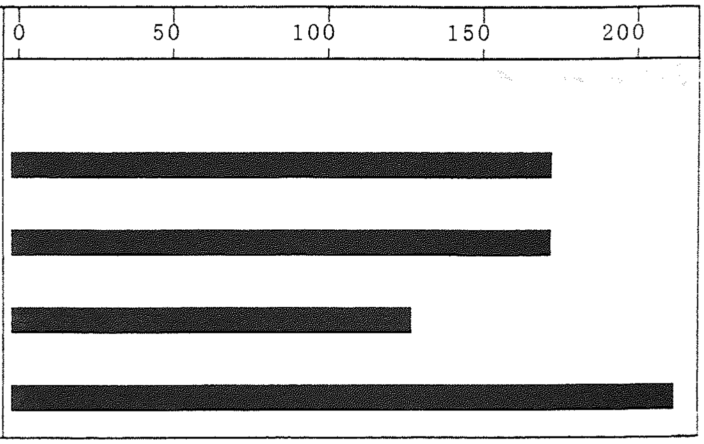
This shows that many of the companies are operating in very much of a mixed environment across the spectrum of all the categories of type of operation mentioned.

5.3.2 Section B. - Computer Hardware and Software

Question 7 asks about the use of different types of hardware:

```
Bar chart...: TYPE OF HARDWARE
Cells.......: Absolute, Total %
```

Base	348
TYPE OF HARDWARE	
MAIN FRAME	170 48.9%
MINI	173 49.7%
P.C.'S (NETWORKED)	126 36.2%
P.C.(S)(STAND-ALONE)	214 61.5%

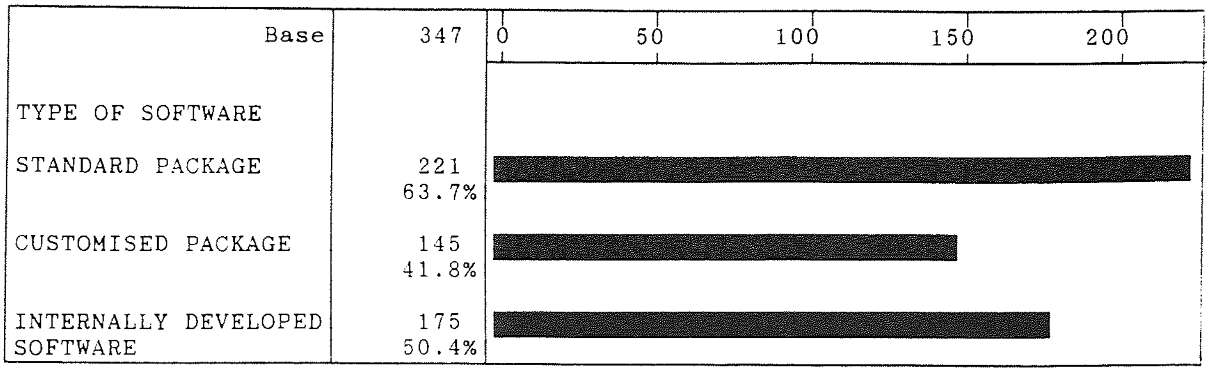


In reply, the use of Mini and Mainframe computers is fairly evenly divided, although it should be pointed out that respondents may not have been using a clear definition of the difference between these two categories (even the "experts" are no longer clear). There appears to be a large use of stand-alone P.C.'s (61.5%), mostly as adjuncts to the main hardware systems.

Question 8 moves on to the area of software and asks the respondents to classify the type of software used and replies were as shown overleaf.

This shows that the largest category is the use of the standard package, followed by internally developed software. This overall categorisation could be misleading, however, since the majority of respondents were using more than one type of software and the internally developed part of it may have been only one or two modules. (This is covered in more detail in the next question)

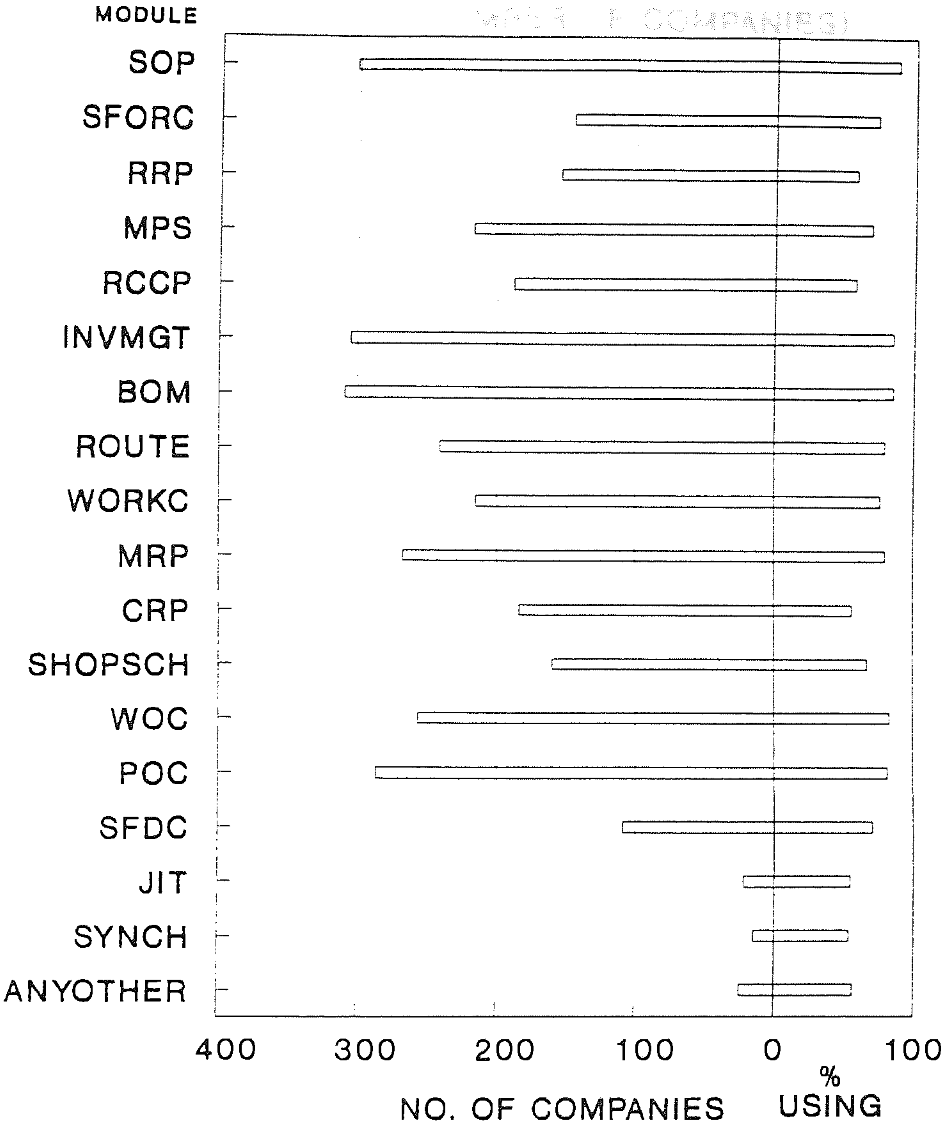
```
Bar chart...: TYPE OF SOFTWARE
Cells.......: Absolute, Total %
```



Question 9 is a very detailed one concerning the purchase, development and use of all the possible Production Management Modules together with timings and future plans. The responses are probably firstly best shown by the following three summary charts.

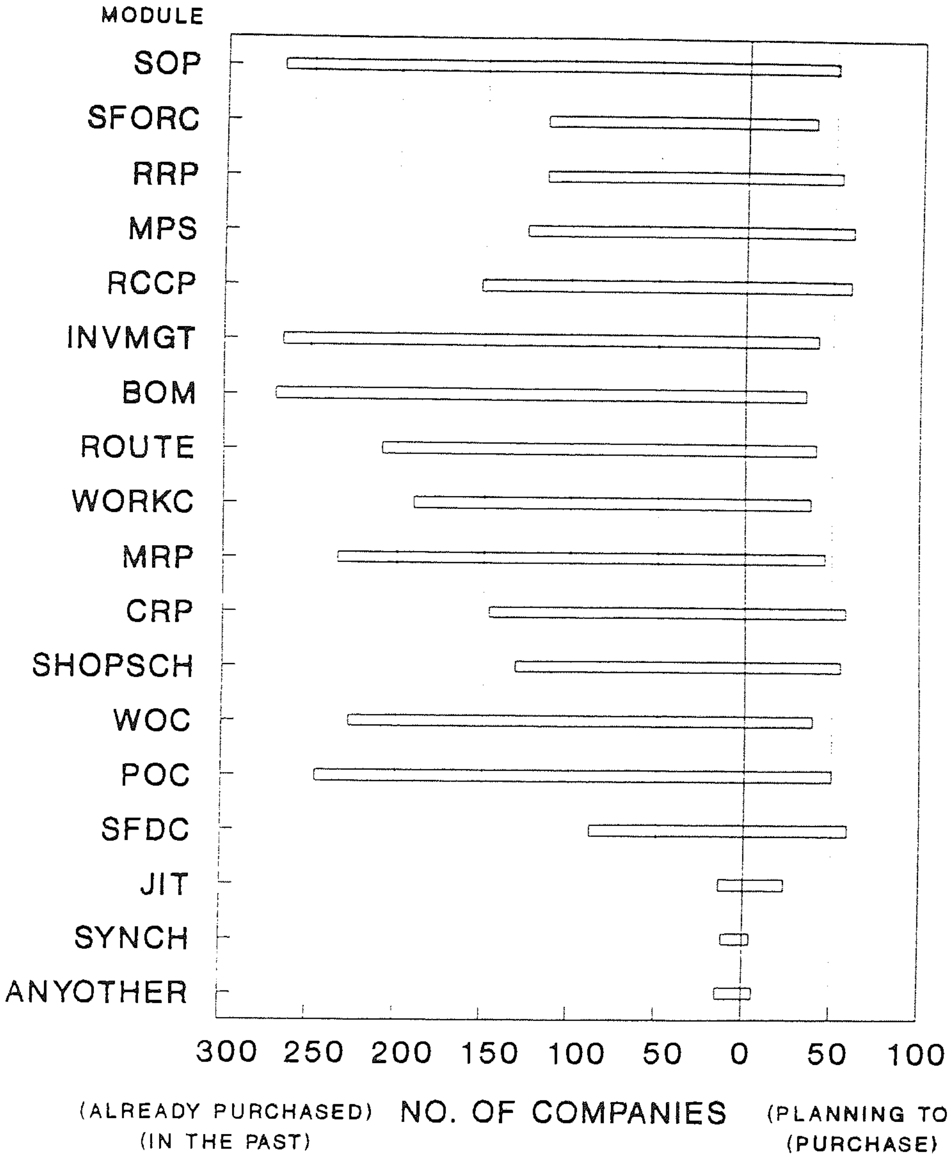
The first chart shows that apart from JIT and Synchronised Manufacturing software, which only a handful of companies have purchased, Capacity Requirements Planning is the least routinely used of the software modules that have been purchased or developed. CRP is followed closely by Rough Cut Capacity Planning and Resource Requirements Planning.

The second chart depicts the number of companies which have purchased or developed certain modules in the past or are planning to do so in the future.


SOFTWARE MODULE PURCHASE & DEVELOPMENT (NO. OF COMPANIES) & ROUTINE USE (%)

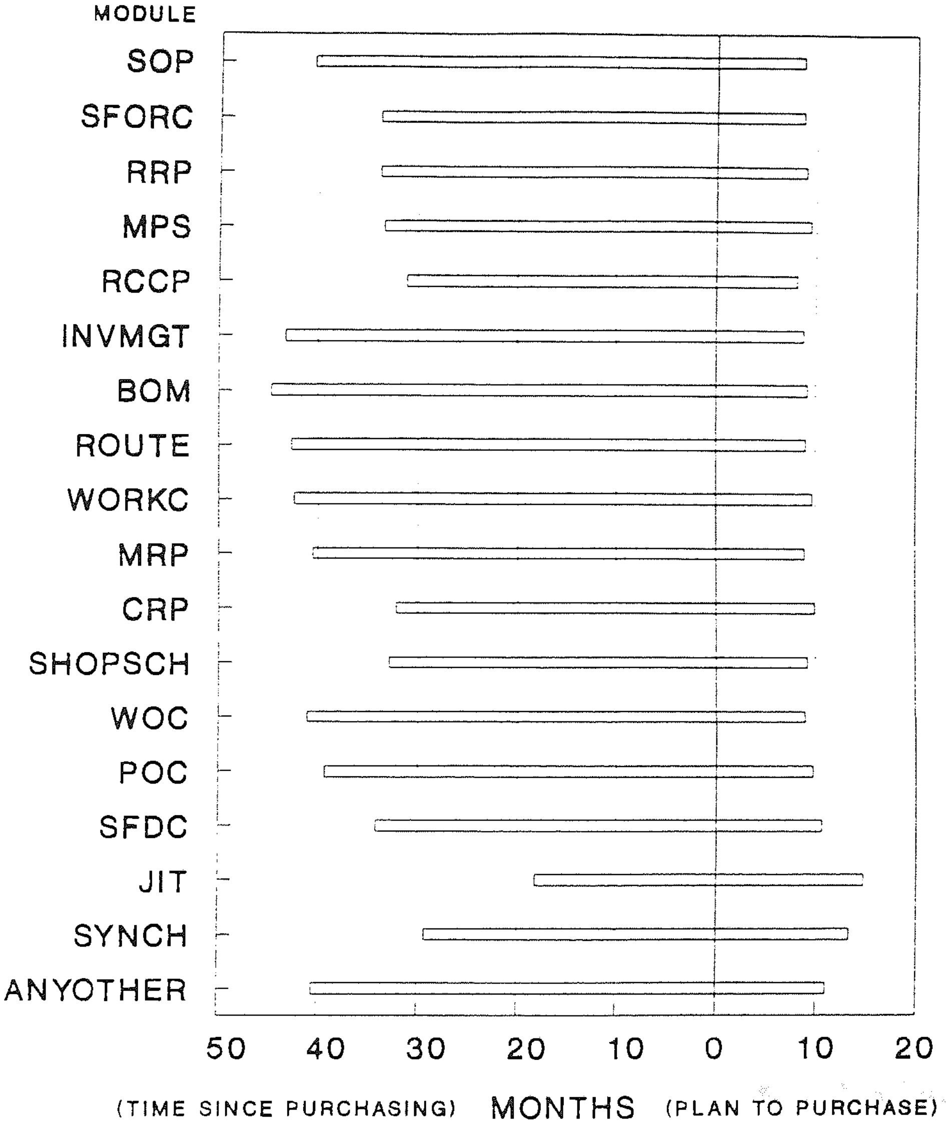
Historically, of the modules expected in an integrated MRPII system, computerised Shop Floor Data Collection has been the least popular followed by Sales Forecasting, Resource Requirements Planning, Master Production Scheduling, Shopfloor Scheduling and Capacity Requirements Planning. In the future, companies are planning to implement Master Production Scheduling, Rough Cut Capacity Planning, Shop Floor Data Collection and Capacity Requirements Planning in that order of popularity.

SOFTWARE MODULE PURCHASE & DEVELOPMENT, PAST AND FUTURE (NUMBER OF COMPANIES)



The next summary chart shows how long, on average, each module has been in existence in a company or how far in the future it is planned to be implemented. Of the normal MRPII modules, RCCP followed closely by CRP have been in existence for the shortest time, albeit by a relatively small margin over the other modules.

SOFTWARE MODULE PURCHASE & DEVELOPMENT, PAST AND FUTURE (AVERAGE TIMES)

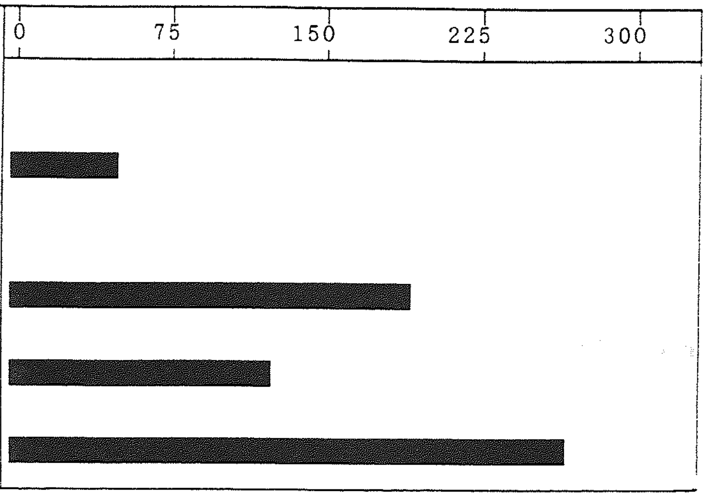


There now follows the detailed analyses of each part of question 9, in terms of whether each module was purchased, developed internally, is being used routinely, how long since it was purchased or developed or when it is planned to purchase or develop.

Sales Order Processing.

Bar chart...: Q09-1A SALES ORDER PROCESSING
Cells.......: Absolute, Total %

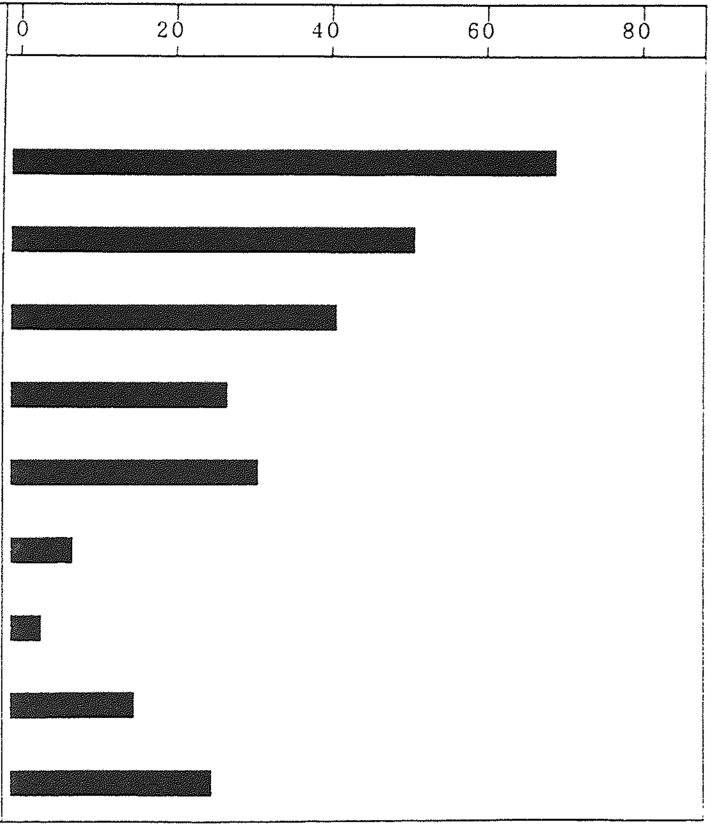
Base	349
MISSING	
NOT PURCH' OR DEV'D OR NO REPLY	47 13.5%
Q09-1A SALES ORDER PROCESSING PACKAGED MODULE PURCHASED	190 54.4%
MODULE DEVELOPED INTERNALLY	121 34.7%
MODULE IS BEING USED ROUTINELY	267 76.5%



	Base	NOT PUR-CH'D OR DEV'D OR NO REPLY	Valid	Mean	Standard Dev
HOW LONG SINCE SOP PURCH? (MTHS)	349	82	267	40.51311	30.28112

Bar chart...: NO.OF MONTHS SINCE SOP PURCHASED
Cells.......: Absolute, Total %

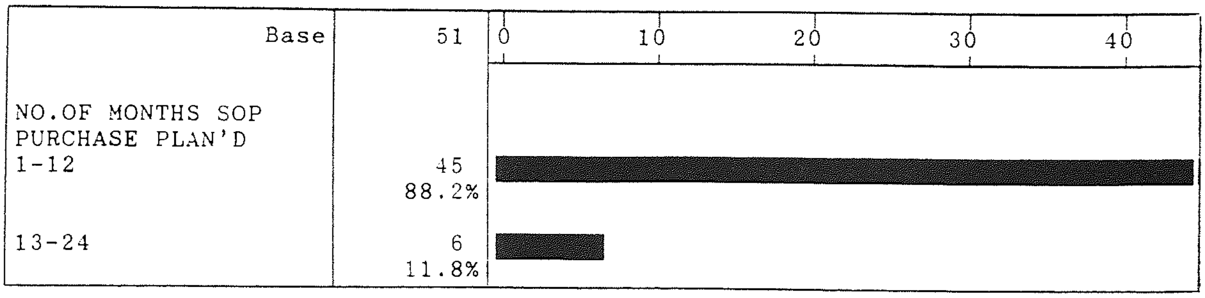
Base	267
NO.OF MONTHS SINCE SOP PURCHASED 1-12	68 25.5%
13-24	51 19.1%
25-36	41 15.4%
37-48	27 10.1%
49-60	30 11.2%
61-72	7 2.6%
73-84	3 1.1%
85-98	15 5.6%
99 AND ABOVE	25 9.4%



Statistics..: Q09-1C WHEN PLAN TO PURCH SOP?
Cells.......: Absolute

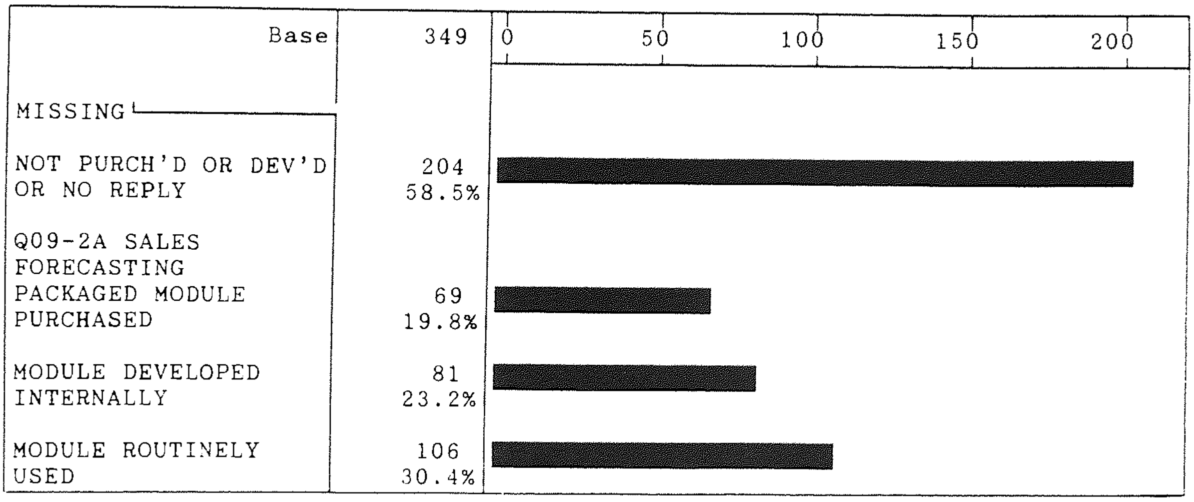
	Base	NOT PLANNED OR NO REPLY	Valid	Mean	Standard Dev
Q09-1C WHEN PLAN TO PURCH SOP?	349	298	51	8.666667	5.429284

Bar chart...: NO.OF MONTHS SOP PURCHASE PLAN'D
Cells.......: Absolute, Total %, Zeros suppressed



Sales Forecasting.

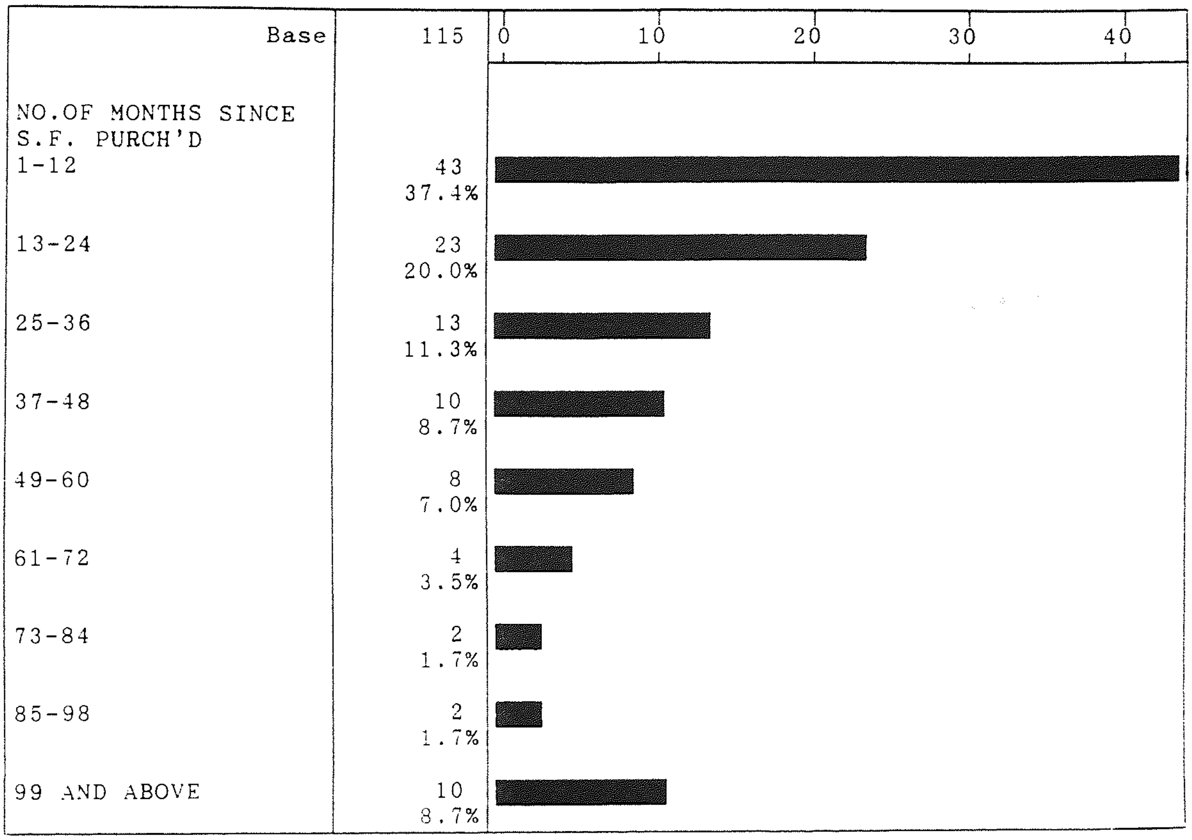
Bar chart...: Q09-2A SALES FORECASTING
Cells.......: Absolute, Total %



Statistics..: HOW LONG SINCE SFORC. PURCH(MTH)
Cells.......: Absolute

	Base	NOT PURCH'D OR DEV'D OR NO REPLY	Valid	Mean	Standard Dev
HOW LONG SINCE SFORC. PURCH(MTH)	349	234	115	33.83478	29.75784

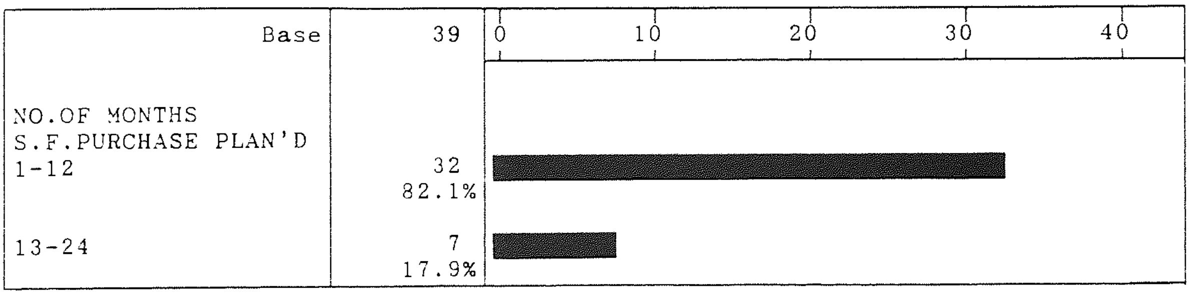
Bar chart...: NO.OF MONTHS SINCE S.F. PURCH'D
Cells.......: Absolute, Total %



Statistics..: WHEN PLAN TO PURCH SFORC (MTHS)
Cells.......: Absolute

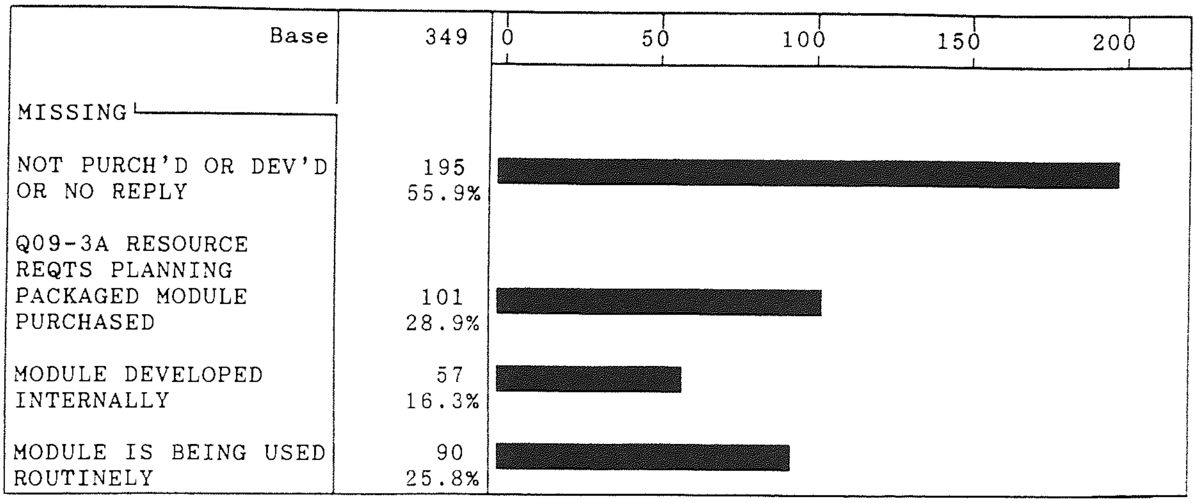
	Base	NOT PLANNED OR NO REPLY	Valid	Mean	Standard Dev
WHEN PLAN TO PURCH SFORC (MTHS)	349	310	39	8.717949	6.025368

Bar chart...: NO.OF MONTHS S.F.PURCHASE PLAN'D
Cells.......: Absolute, Total %, Zeros suppressed



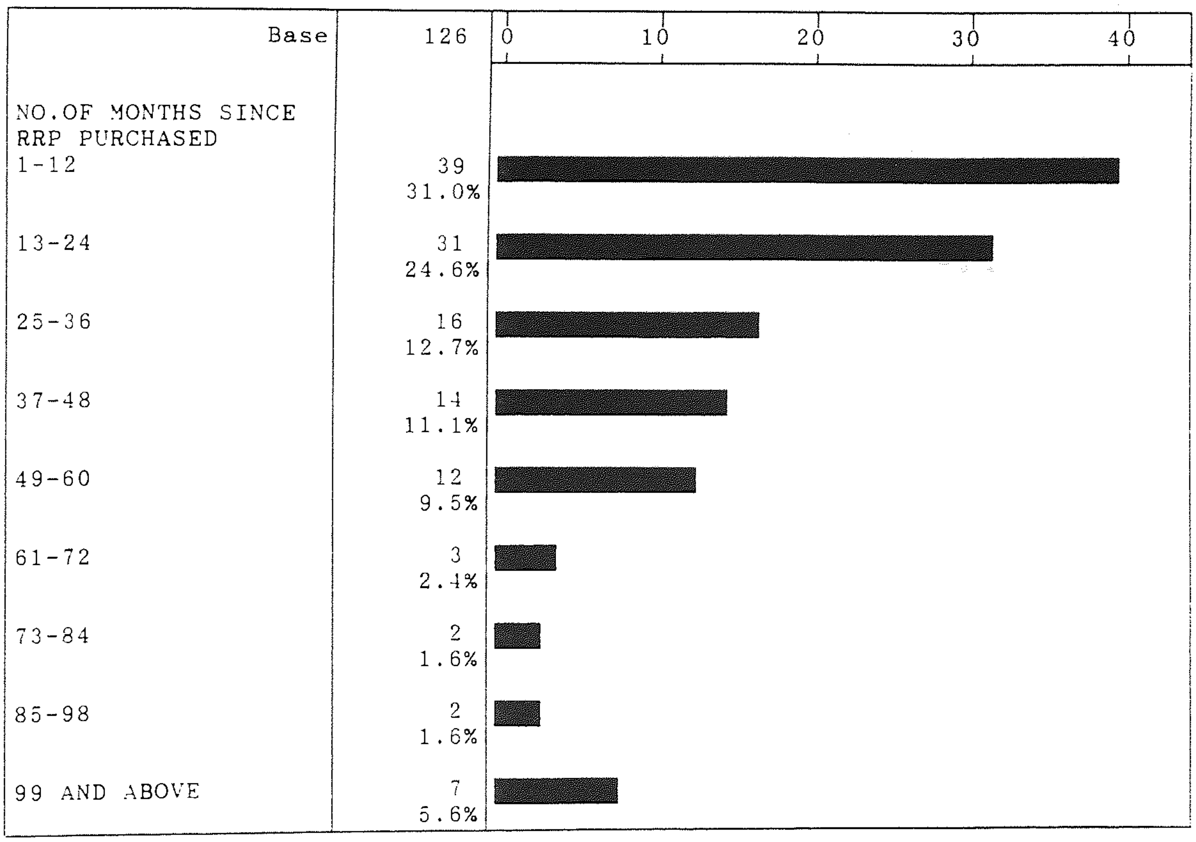
Resource Requirements Planning.

Bar chart...: Q09-3A RESOURCE REQTS PLANNING
Cells.......: Absolute, Total %



	Base	NOT PURCH'D OR DEV'D OR NO REPLY	Valid	Mean	Standard Dev
HOW LONG SINCE RRP PURCH? (MTHS)	349	234	115	33.83478	29.75784

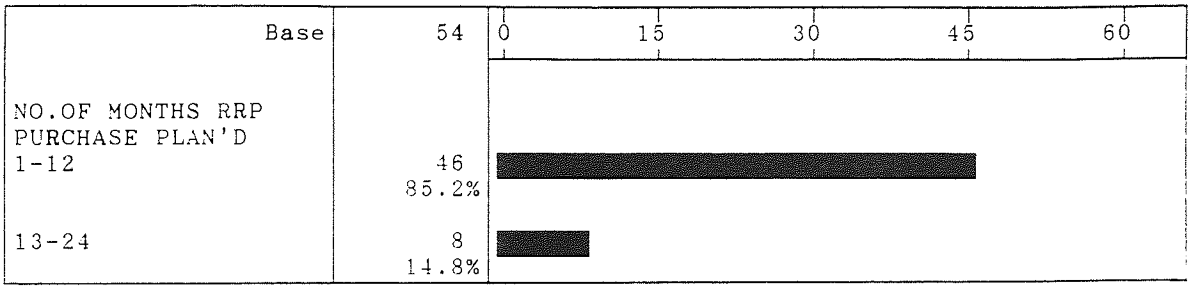
Bar chart...: NO.OF MONTHS SINCE RRP PURCHASED
Cells.......: Absolute, Total %



Statistics..: WHEN PLAN TO PURCH RRP (MTHS)
Cells.......: Absolute

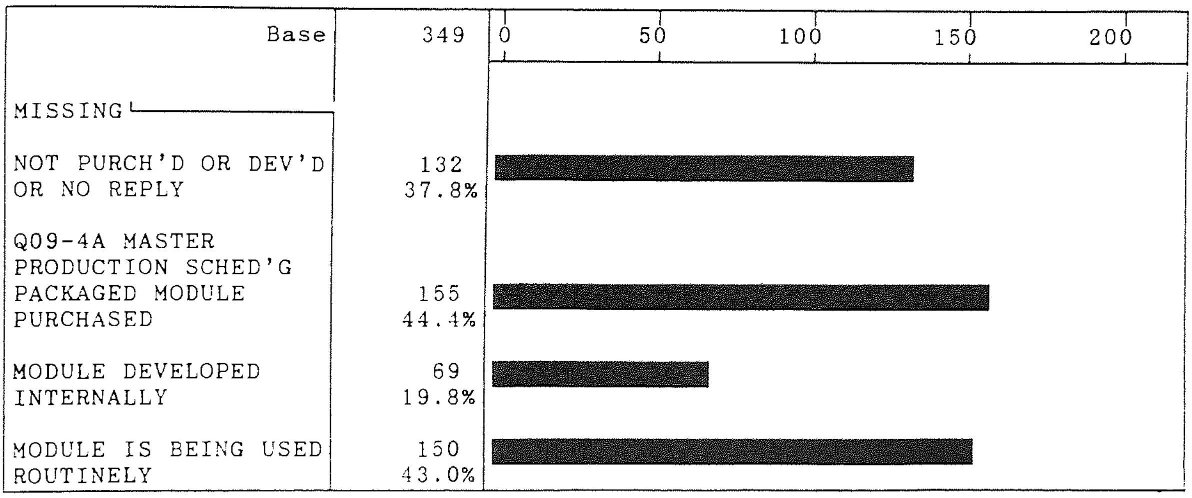
	Base	NOT PLANNED OR NO REPLY	Valid	Mean	Standard Dev
WHEN PLAN TO PURCH RRP (MTHS)	349	295	54	9.037037	5.560985

Bar chart...: NO.OF MONTHS RRP PURCHASE PLAN'D
Cells.......: Absolute, Total %, Zeros suppressed



Master Production Scheduling.

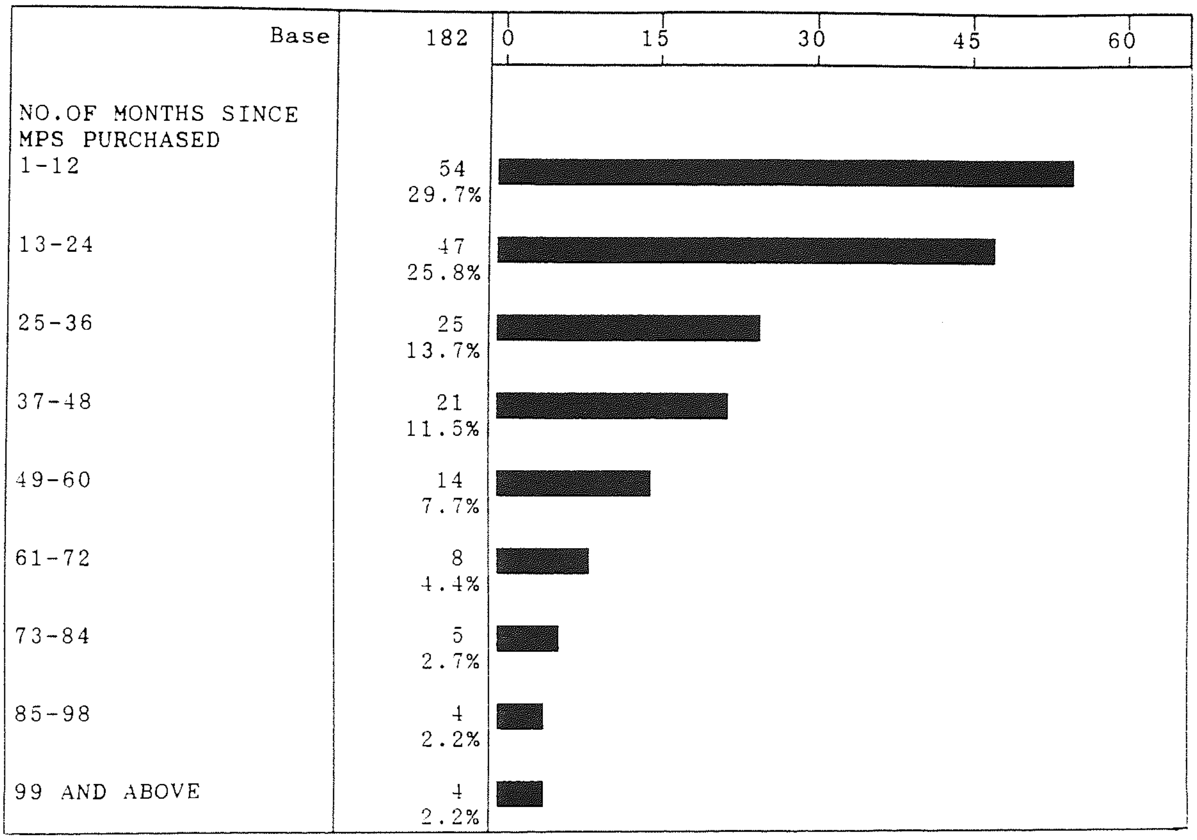
Bar chart...: Q09-4A MASTER PRODUCTION SCHED'G
Cells.......: Absolute, Total %



Statistics..: HOW LONG SINCE MPS PURCH? (MTHS)
Cells.......: Absolute

	Base	NOT PURCH'D OR DEV'D OR NO REPLY	Valid	Mean	Standard Dev
HOW LONG SINCE MPS PURCH? (MTHS)	349	223	126	33.4127	26.70125

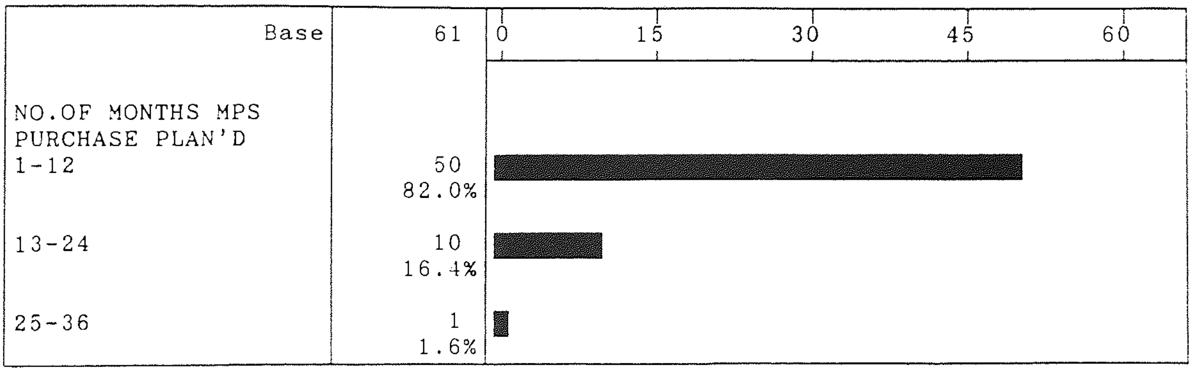
Bar chart...: NO.OF MONTHS SINCE MPS PURCHASED
Cells.......: Absolute, Total %



Statistics..: WHEN PLAN TO PURCHASE MPS (MTHS)
Cells.......: Absolute

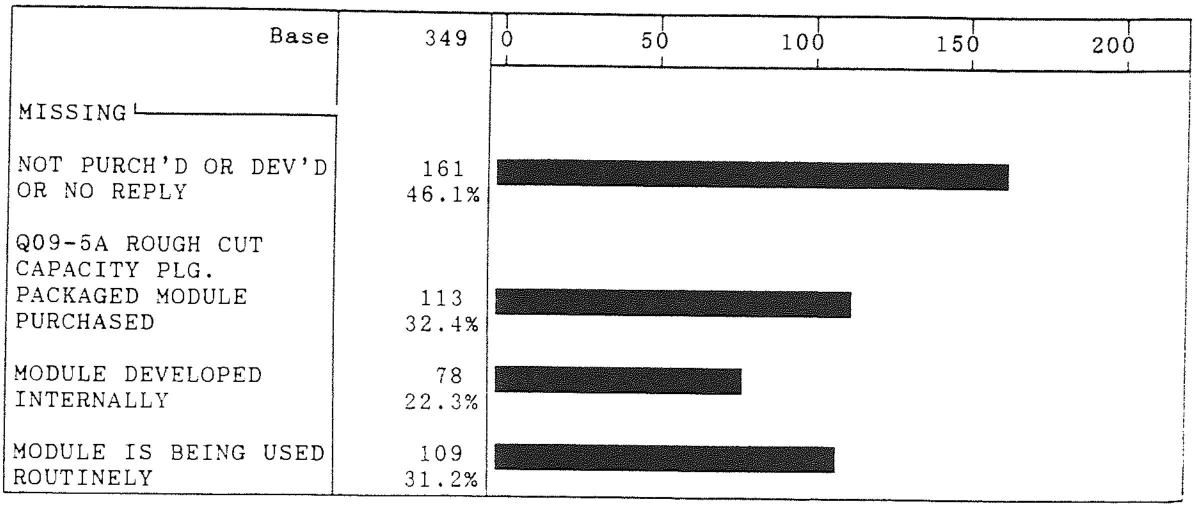
	Base	NOT PLANNED OR NO REPLY	Valid	Mean	Standard Dev
WHEN PLAN TO PURCHASE MPS (MTHS)	349	288	61	9.459016	6.456852

Bar chart...: NO.OF MONTHS MPS PURCHASE PLAN'D
Cells.......: Absolute, Total %, Zeros suppressed



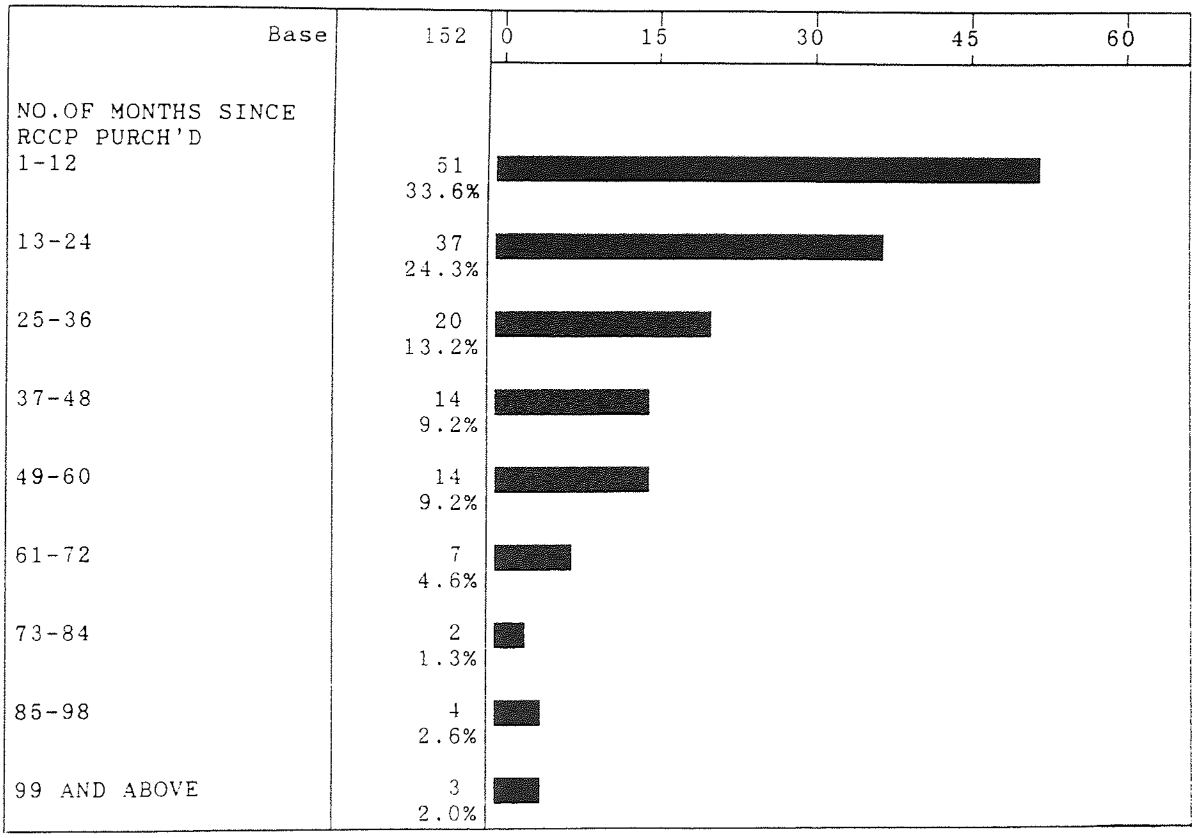
Rough Cut Capacity Planning.

Bar chart...: Q09-5A ROUGH CUT CAPACITY PLG.
Cells.......: Absolute, Total %



	Base	NOT PUR-CH'D OR DEV'D OR NO REPLY	Valid	Mean	Standard Dev
HOW LONG SINCE RCCP PURCH?(MTHS)	349	197	152	31.08553	24.98287

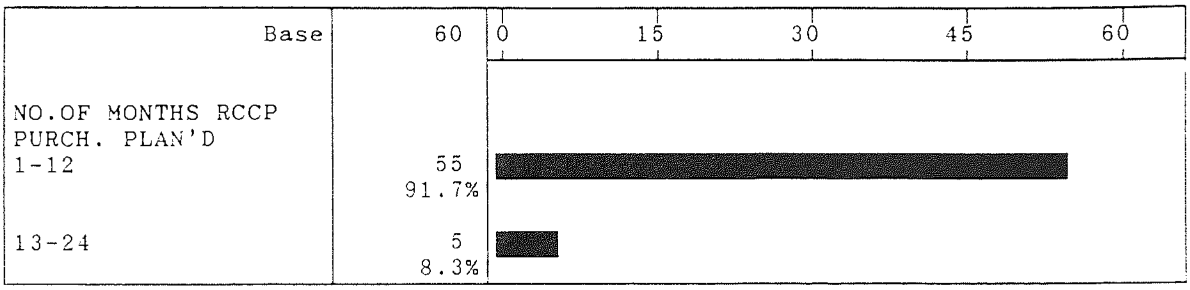
Bar chart...: NO.OF MONTHS SINCE RCCP PURCH'D
Cells.......: Absolute, Total %



Statistics..: WHEN PLAN TO PURCH RCCP? (MTHS)
Cells.......: Absolute

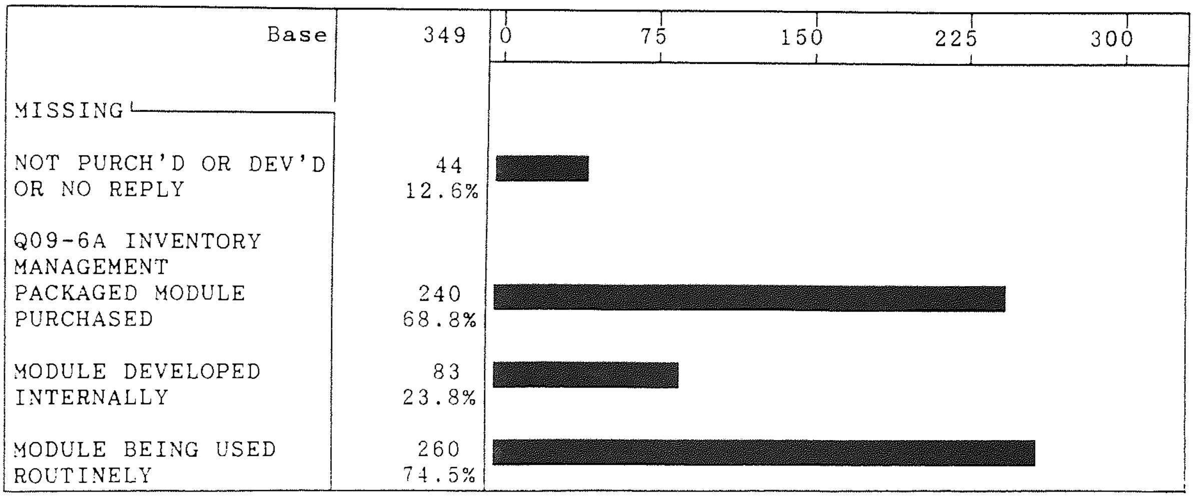
	Base	NOT PLANNED OR NO REPLY	Valid	Mean	Standard Dev
WHEN PLAN TO PURCH RCCP? (MTHS)	349	289	60	8.1	4.624932

Bar chart...: NO.OF MONTHS RCCP PURCH. PLAN'D
Cells.......: Absolute, Total %, Zeros suppressed



Inventory Management.

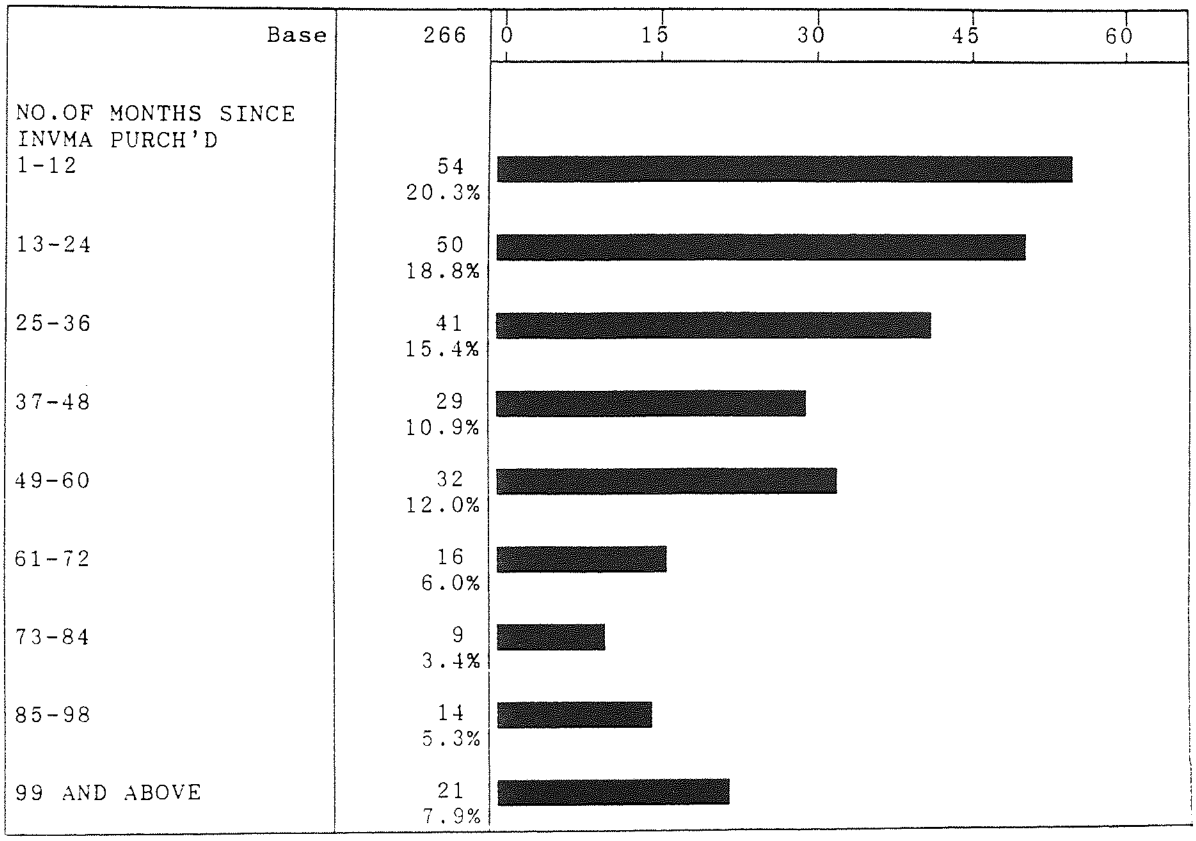
Bar chart...: Q09-6A INVENTORY MANAGEMENT
Cells.......: Absolute, Total %



Statistics..: HOW LONG SINCE INVMAN PURCH(MTH)
Cells.......: Absolute

	Base	NOT PUR-CH'D OR DEV'D OR NO REPLY	Valid	Mean	Standard Dev
HOW LONG SINCE INVMAN PURCH(MTH)	349	83	266	43.2594	29.74194

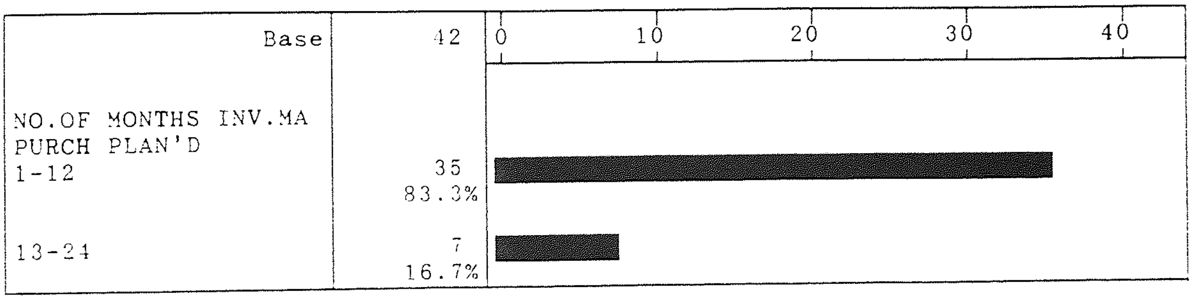
Bar chart...: NO.OF MONTHS SINCE INVMA PURCH'D
Cells.......: Absolute, Total %



Statistics..: WHEN PLAN TO PURCH INVMAN (MTHS)
Cells.......: Absolute

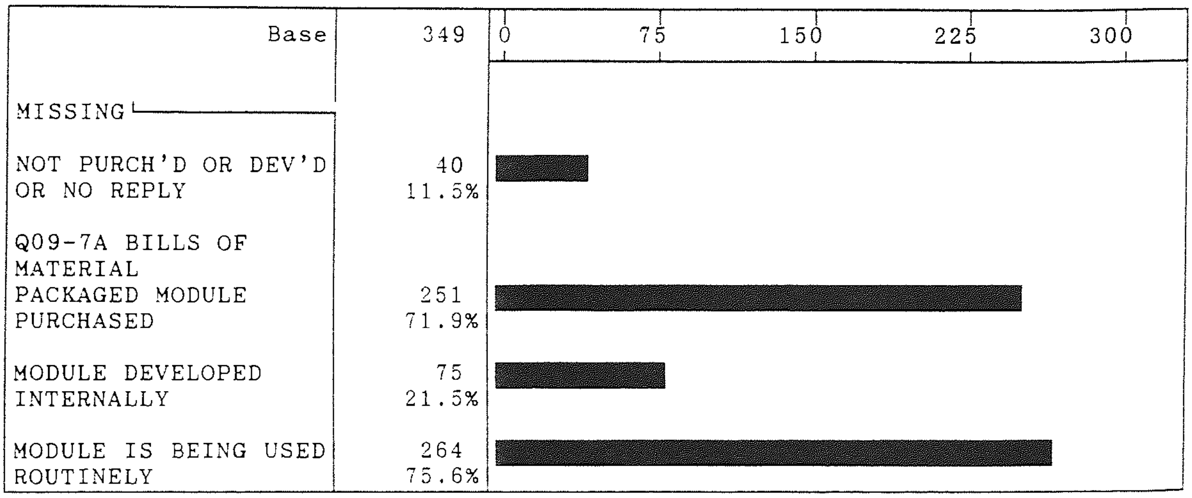
	Base	NOT PLANNED OR NO REPLY	Valid	Mean	Standard Dev
WHEN PLAN TO PURCH INVMAN (MTHS)	349	307	42	8.809524	5.430242

Bar chart...: NO.OF MONTHS INV.MA PURCH PLAN'D
Cells.......: Absolute, Total %, Zeros suppressed



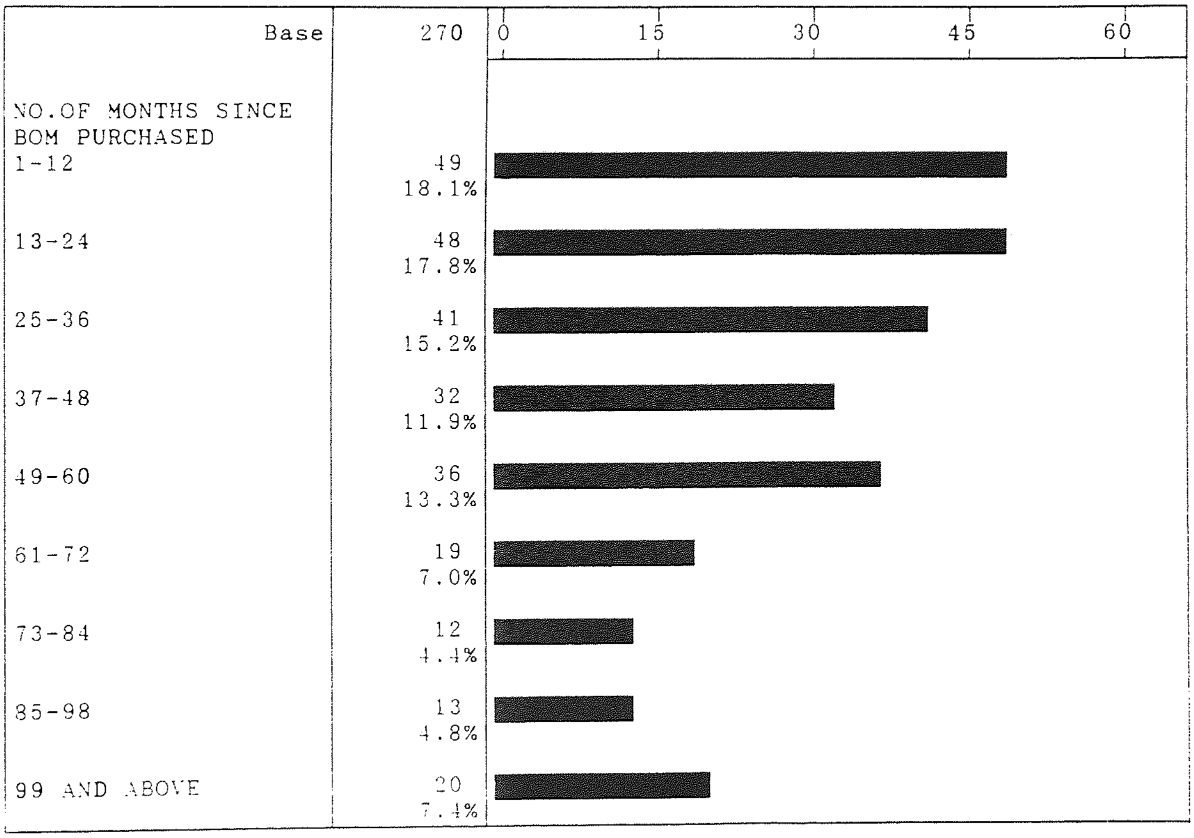
Bills Of Material.

Bar chart...: Q09-7A BILLS OF MATERIAL
Cells.......: Absolute, Total %



	Base	NOT PUR-CH'D OR DEV'D OR NO REPLY	Valid	Mean	Standard Dev
HOW LONG SINCE BOM PURCH? (MTHS)	349	79	270	44.67778	29.24842

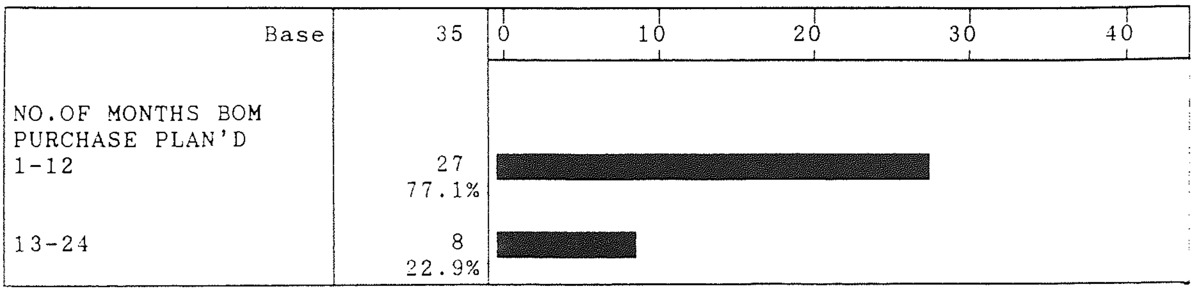
Bar chart...: NO.OF MONTHS SINCE BOM PURCHASED
Cells.......: Absolute, Total %



Statistics..: WHEN PLAN TO PURCH BOM? (MTHS)
Cells.......: Absolute

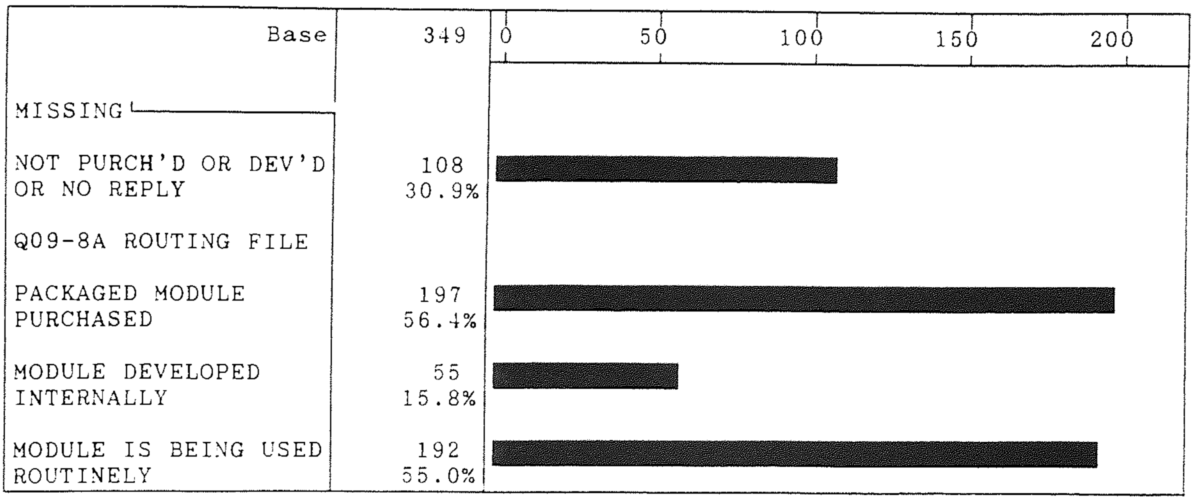
	Base	NOT PLANNED OR NO REPLY	Valid	Mean	Standard Dev
WHEN PLAN TO PURCH BOM? (MTHS)	349	314	35	9.171429	5.838227

Bar chart...: NO.OF MONTHS BOM PURCHASE PLAN'D
Cells.......: Absolute, Total %, Zeros suppressed



Routing File.

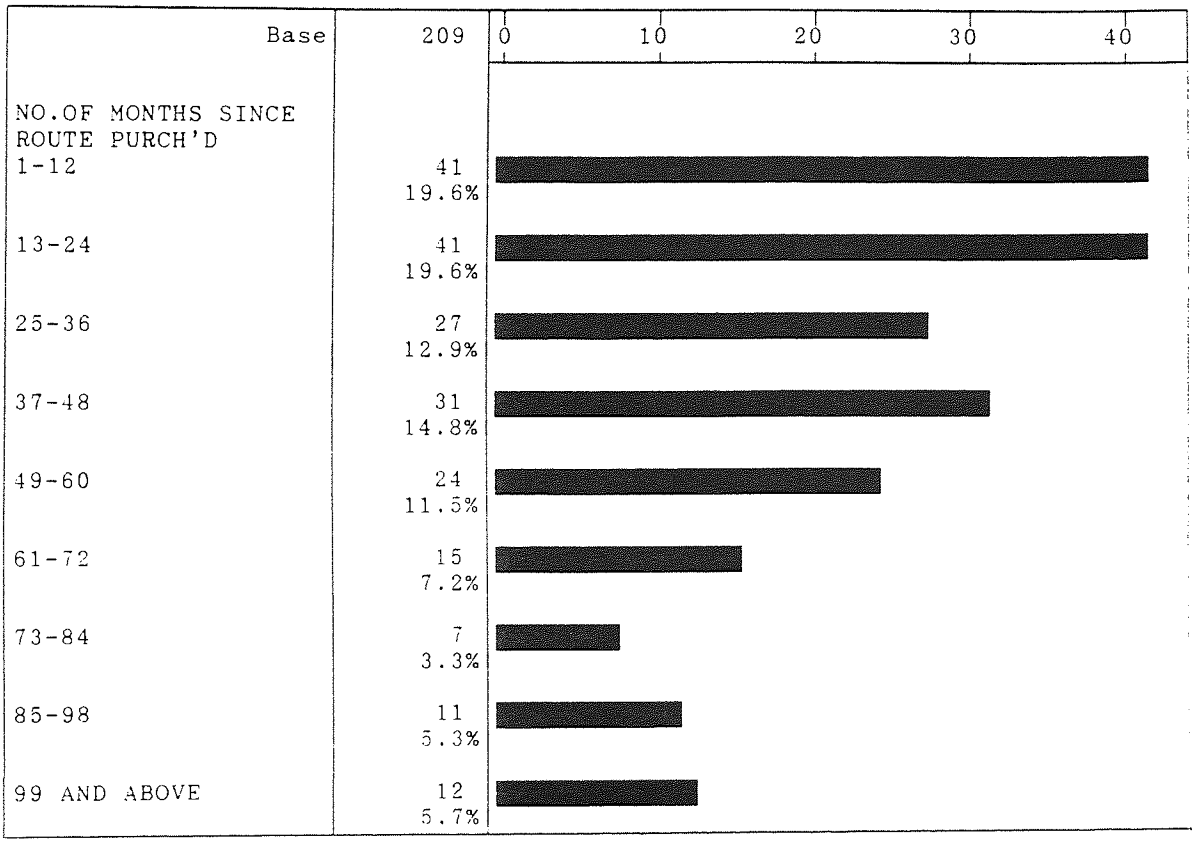
Bar chart...: Q09-8A ROUTING FILE
Cells.......: Absolute, Total %



Statistics..: HOW LONG SINCE ROUTE PURCH?(MTH)
Cells.......: Absolute

	Base	NOT PURCH'D OR DEV'D OR NO REPLY	Valid	Mean	Standard Dev
HOW LONG SINCE ROUTE PURCH?(MTH)	349	140	209	42.70813	28.65528

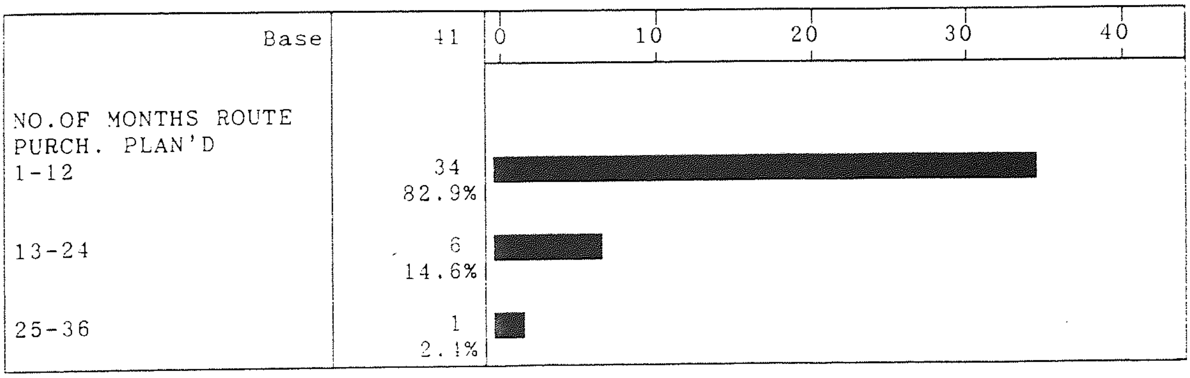
Bar chart...: NO.OF MONTHS SINCE ROUTE PURCH'D
Cells.......: Absolute, Total %



Statistics..: WHEN PLAN TO PURCH ROUTE? (MTHS)
Cells.......: Absolute

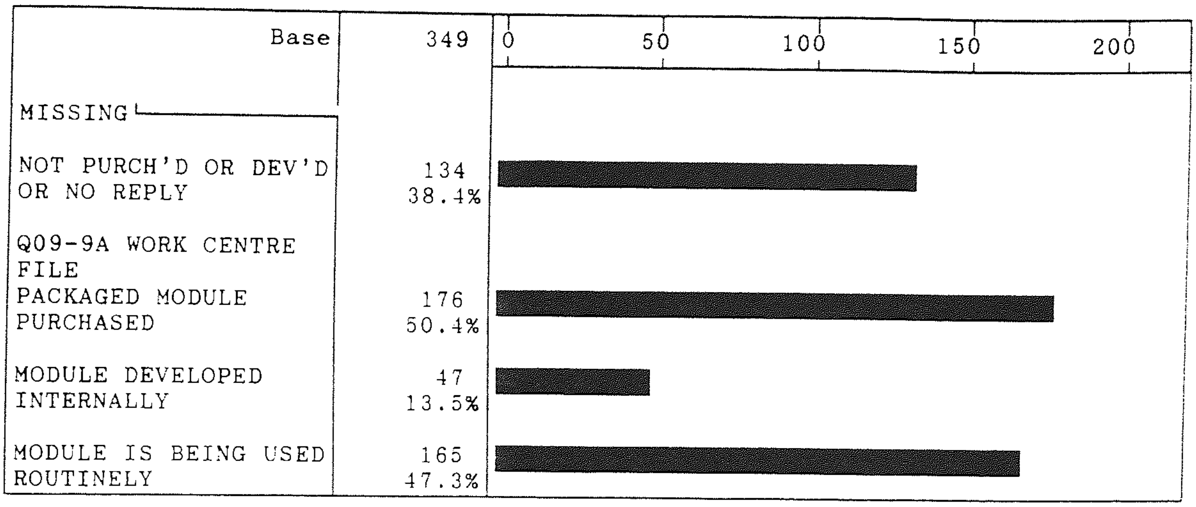
	Base	NOT PLANNED OR NO REPLY	Valid	Mean	Standard Dev
WHEN PLAN TO PURCH ROUTE? (MTHS)	349	308	41	8.97561	5.874657

Bar chart...: NO.OF MONTHS ROUTE PURCH. PLAN'D
Cells.......: Absolute, Total %, Zeros suppressed



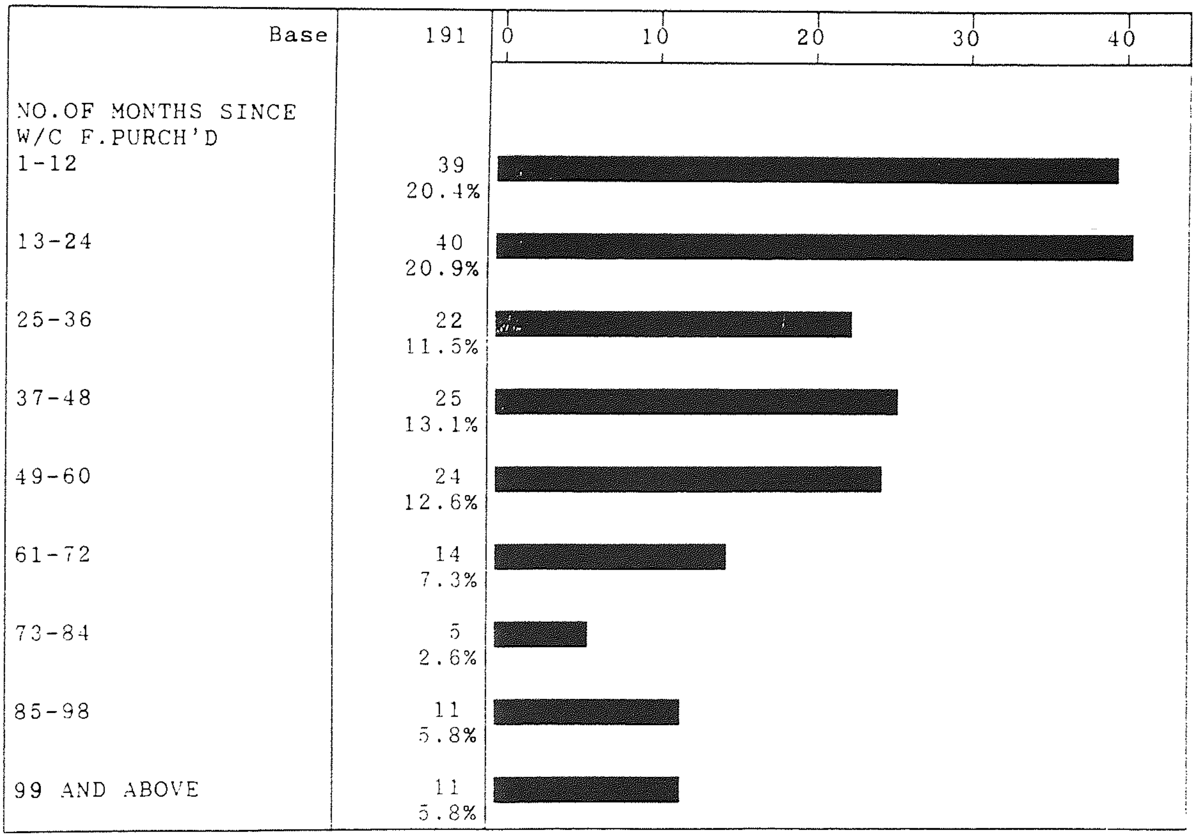
Work Centre File.

Bar chart...: Q09-9A WORK CENTRE FILE
Cells.......: Absolute, Total %



	Base	NOT PURCH'D OR DEV'D OR NO REPLY	Valid	Mean	Standard Dev
HOW LONG SINCE WORKC PURCH?(MTH)	349	158	191	42.40314	29.10155

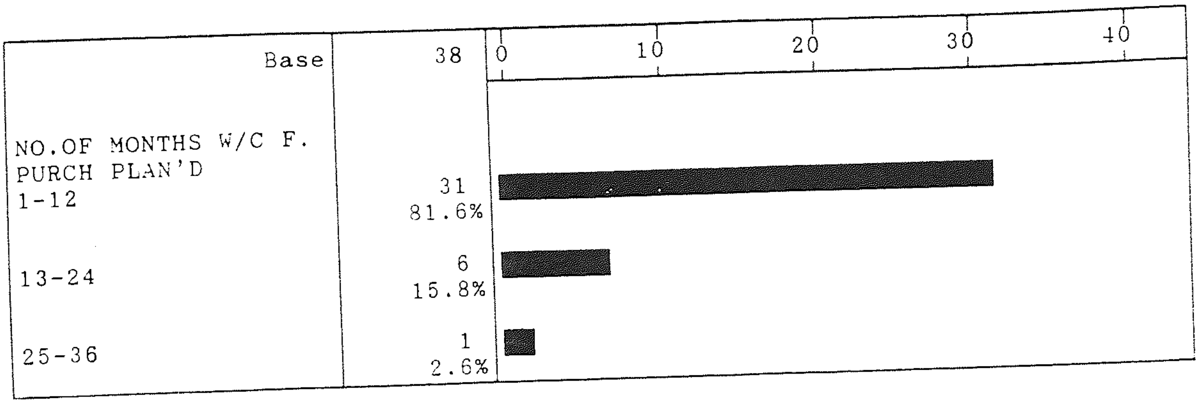
Bar chart...: NO.OF MONTHS SINCE W/C F.PURCH'D
Cells.......: Absolute, Total %



Statistics..: WHEN PLAN TO PURCH WORKCFIL(MTH)
Cells.......: Absolute

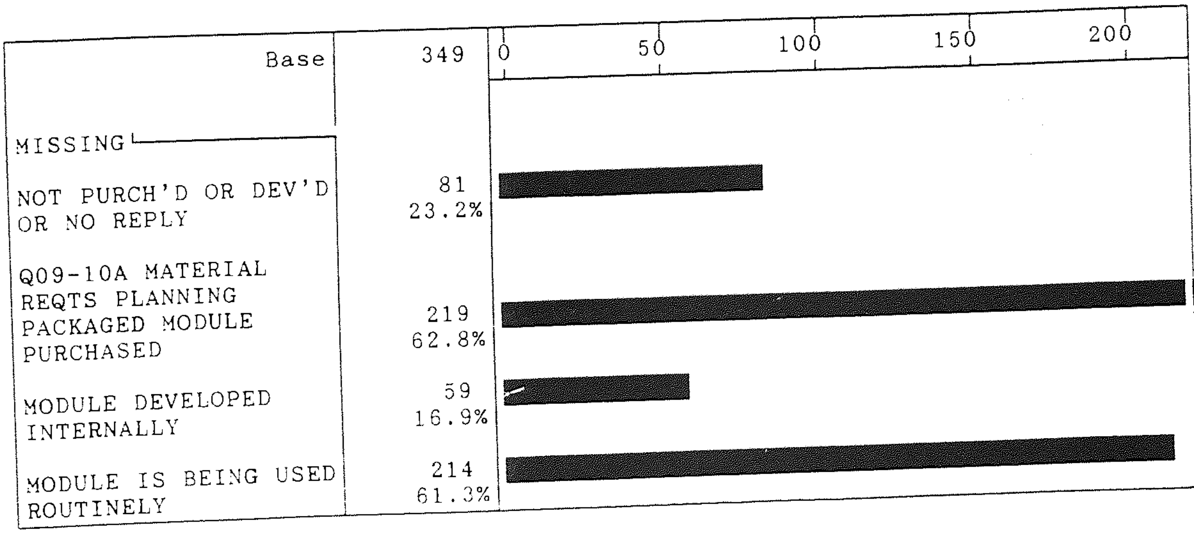
	Base	NOT PLANNED OR NO REPLY	Valid	Mean	Standard Dev
WHEN PLAN TO PURCH WORKCFIL(MTH)	349	311	38	9.736842	6.197131

Bar chart...: NO.OF MONTHS W/C F. PURCH PLAN'D
Cells.......: Absolute, Total %, Zeros suppressed



Material Requirements Planning.

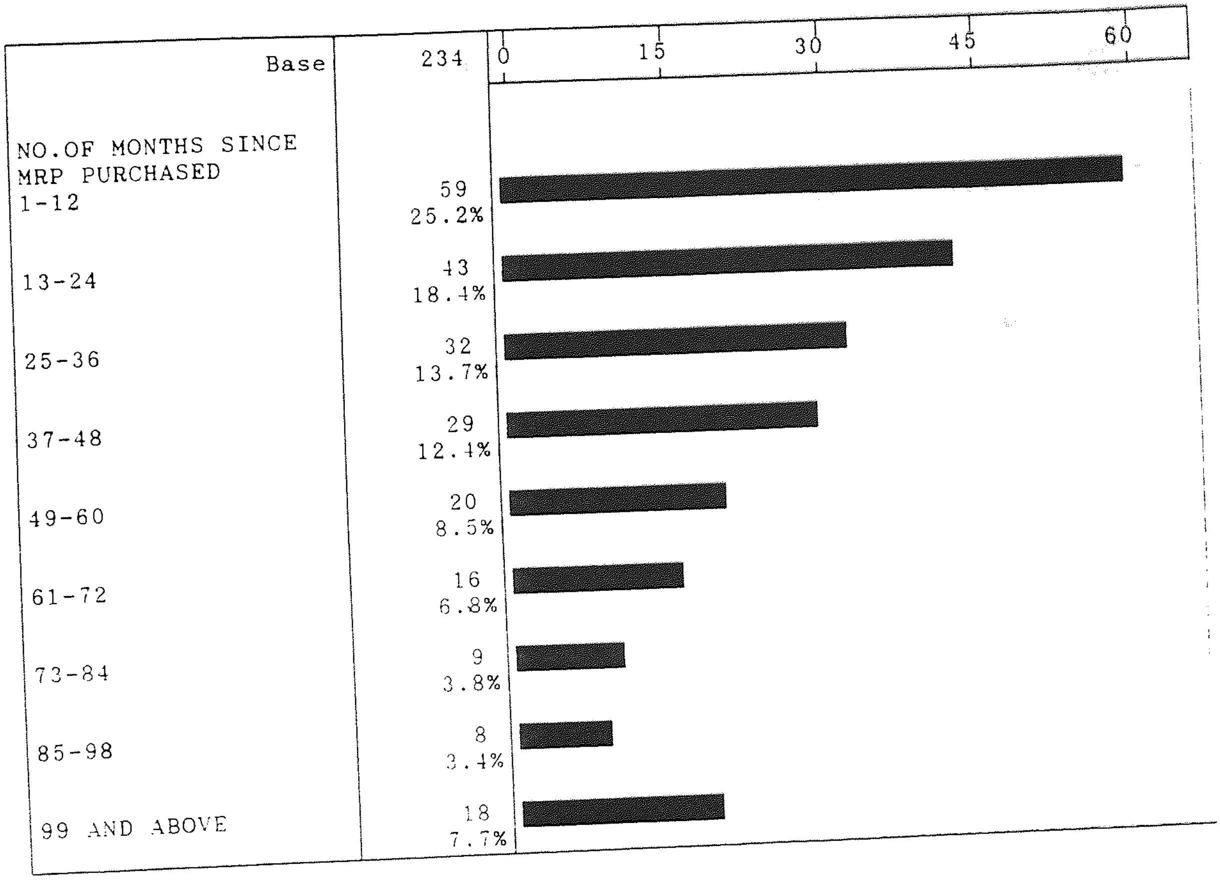
Bar chart...: Q09-10A MATERIAL REQTS PLANNING
Cells.......: Absolute, Total %



Statistics..: HOW LONG SINCE MRP PURCH? (MTHS)
Cells.......: Absolute

	Base	NOT PUR-CH'D OR DEV'D OR NO REPLY	Valid	Mean	Standard Dev
HOW LONG SINCE MRP PURCH? (MTHS)	349	115	234	40.46154	30.0595

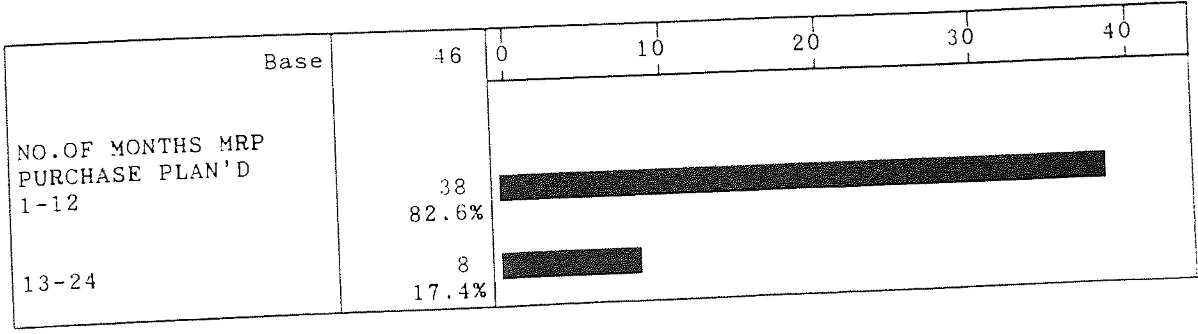
Bar chart...: NO.OF MONTHS SINCE MRP PURCHASED
Cells.......: Absolute, Total %



Statistics..: WHEN PLAN TO PURCH MRP? (MTHS)
Cells.......: Absolute

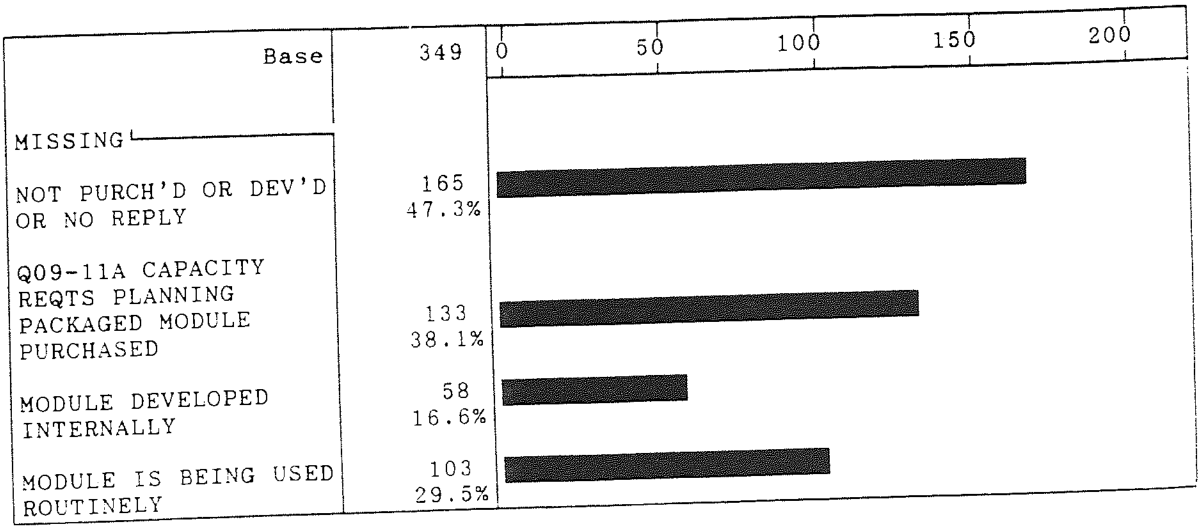
```
                               NOT
                             PLANNED
                                OR                           Standard
                        Base|NO REPLY|   Valid|       Mean|       Dev
WHEN PLAN TO PURCH       349      303       46  8.934783  4.936123
MRP? (MTHS)
```

Bar chart...: NO.OF MONTHS MRP PURCHASE PLAN'D
Cells.......: Absolute, Total %, Zeros suppressed



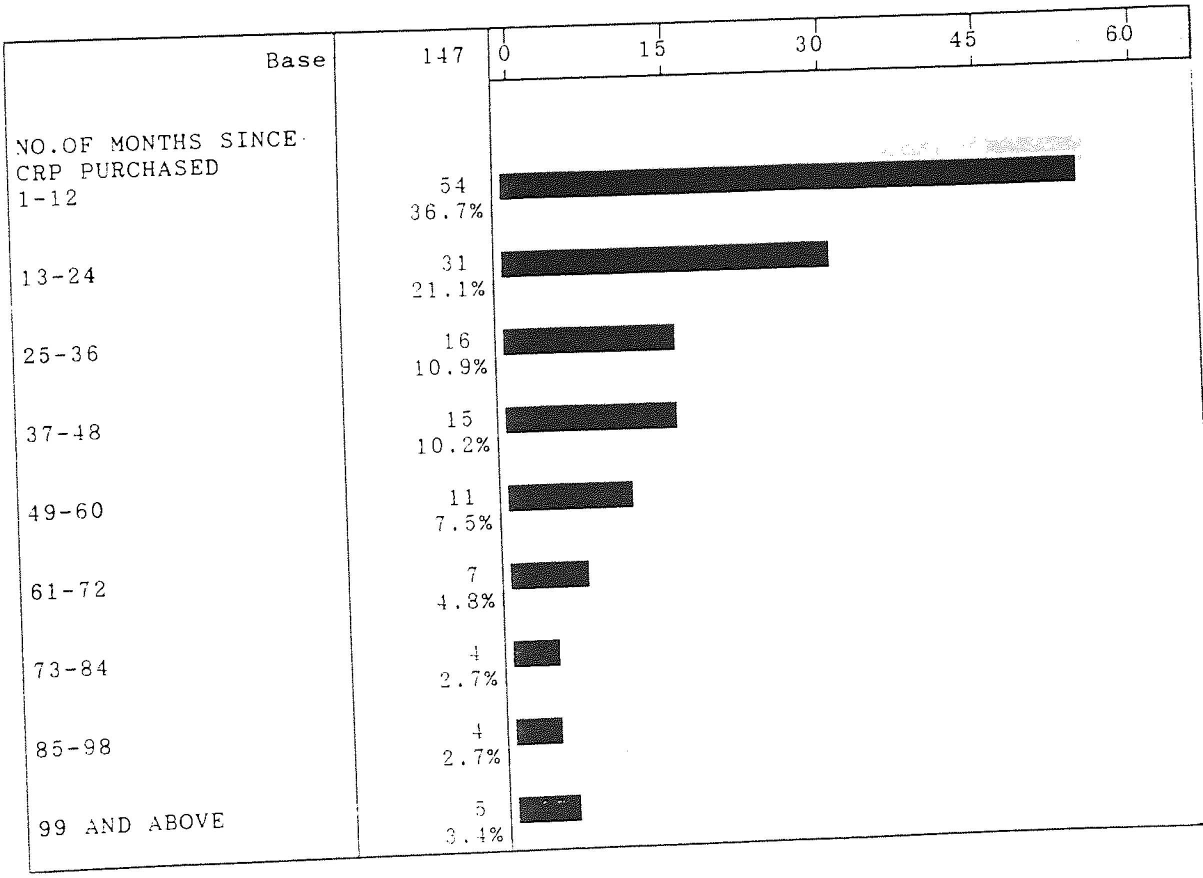
Capacity Requirements Planning.

Bar chart...: Q09-11A CAPACITY REQTS PLANNING
Cells.......: Absolute, Total %



	Base	NOT PURCH'D OR DEV'D OR NO REPLY	Valid	Mean	Standard Dev
HOW LONG SINCE CRP PURCH? (MTHS)	349	202	147	32.19048	27.05935

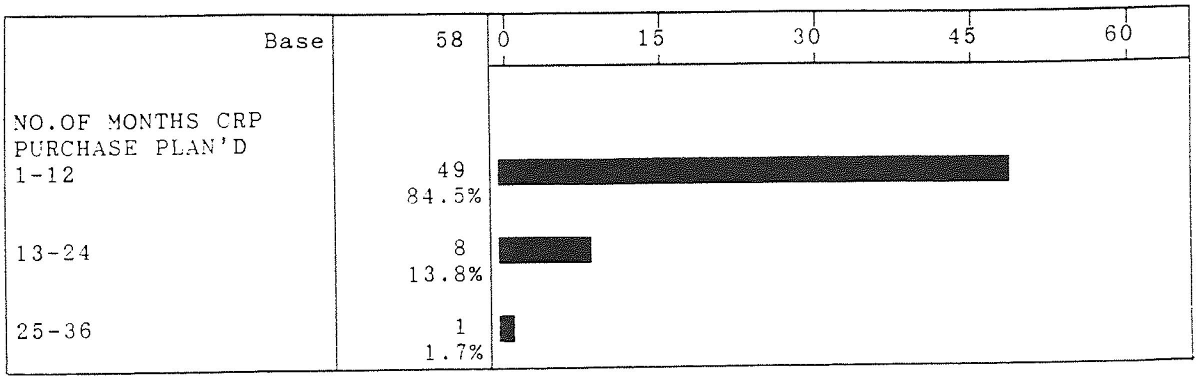
Bar chart...: NO.OF MONTHS SINCE CRP PURCHASED
Cells.......: Absolute, Total %



Statistics..: WHEN PLAN TO PURCHASE CRP? (MTH)
Cells.......: Absolute

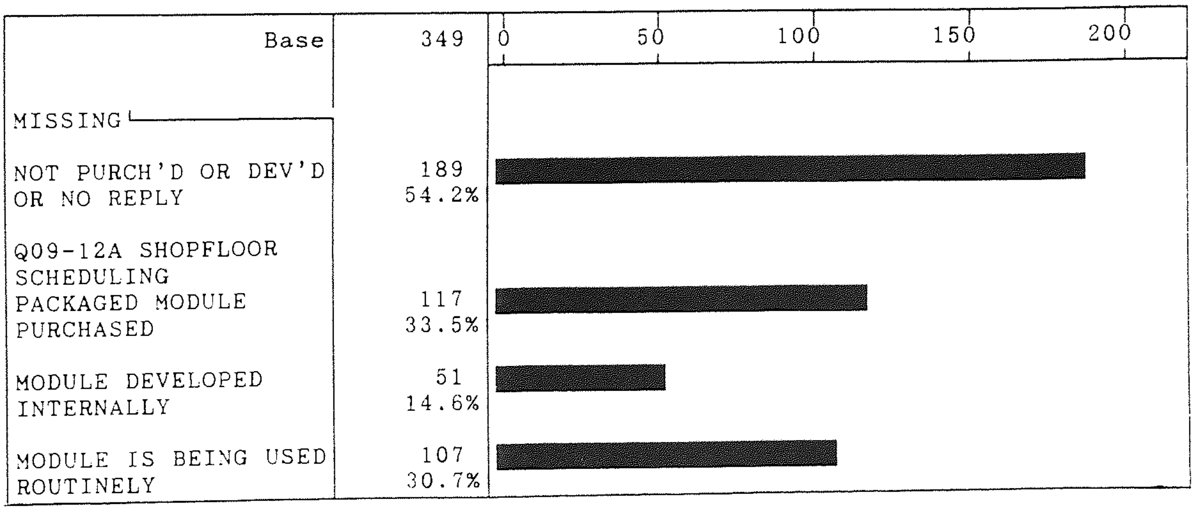
	Base	NOT PLANNED OR NO REPLY	Valid	Mean	Standard Dev
WHEN PLAN TO PURCHASE CRP? (MTH)	349	291	58	9.896552	6.210918

Bar chart...: NO.OF MONTHS CRP PURCHASE PLAN'D
Cells.......: Absolute, Total %, Zeros suppressed



Shop Floor Scheduling.

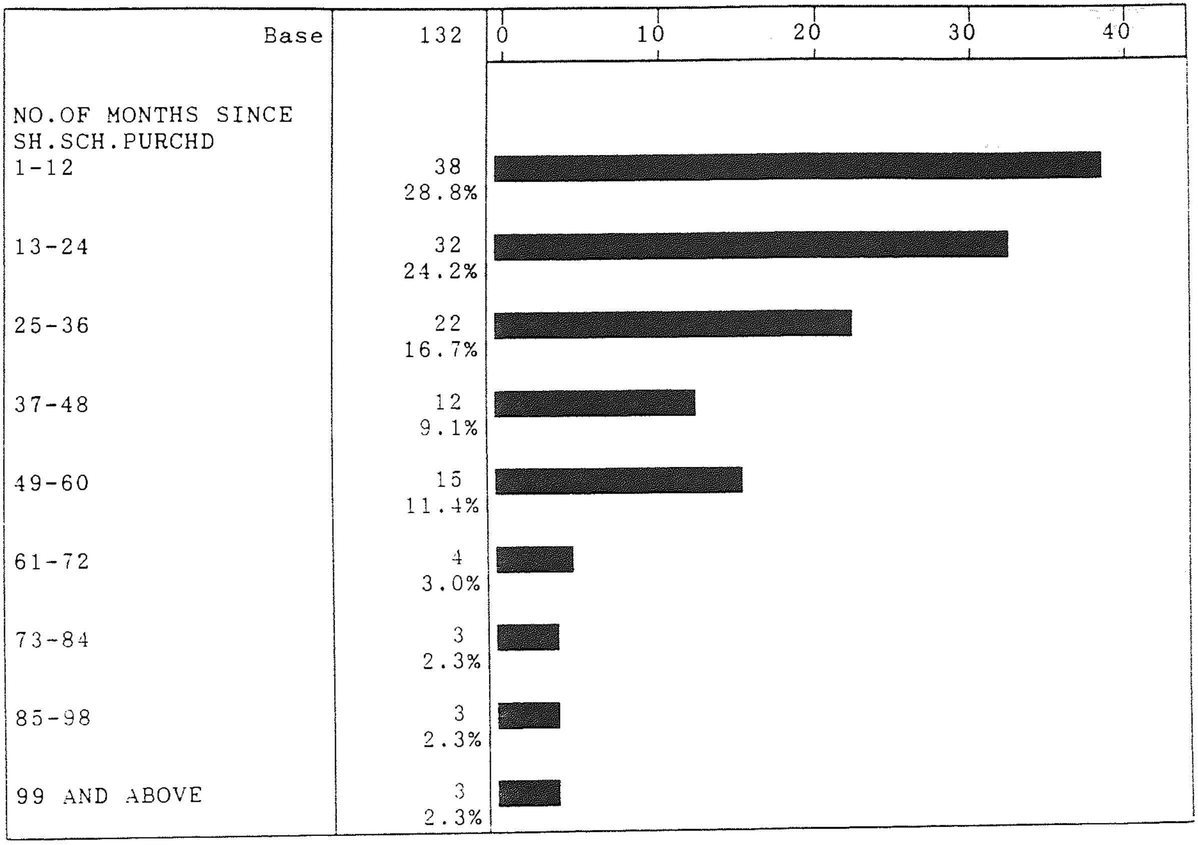
Bar chart...: Q09-12A SHOPFLOOR SCHEDULING
Cells.......: Absolute, Total %



Statistics..: HOW LONG SINCE SFS PURCH? (MTHS)
Cells.......: Absolute

	Base	NOT PURCH'D OR DEV'D OR NO REPLY	Valid	Mean	Standard Dev
HOW LONG SINCE SFS PURCH? (MTHS)	349	217	132	32.93939	24.4744

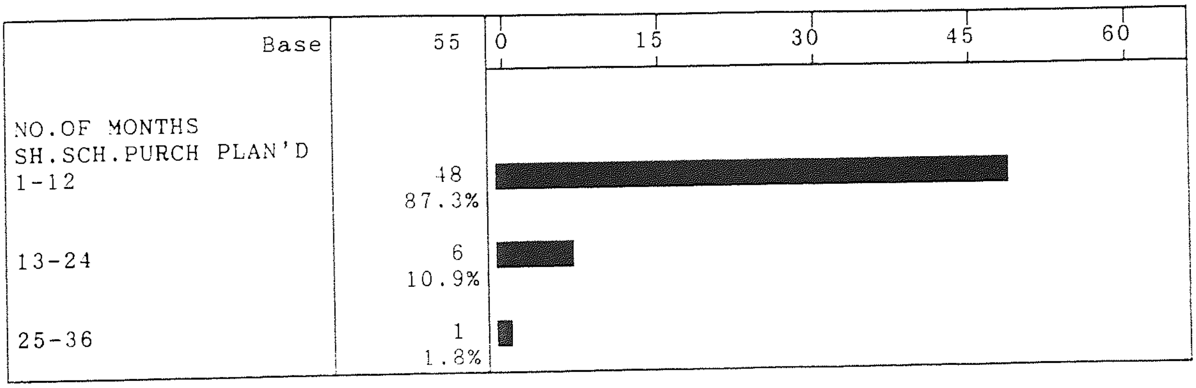
Bar chart...: NO.OF MONTHS SINCE SH.SCH.PURCHD
Cells.......: Absolute, Total %



Statistics..: WHEN PLAN TO PURCH SHOPSCED(MTH)
Cells.......: Absolute

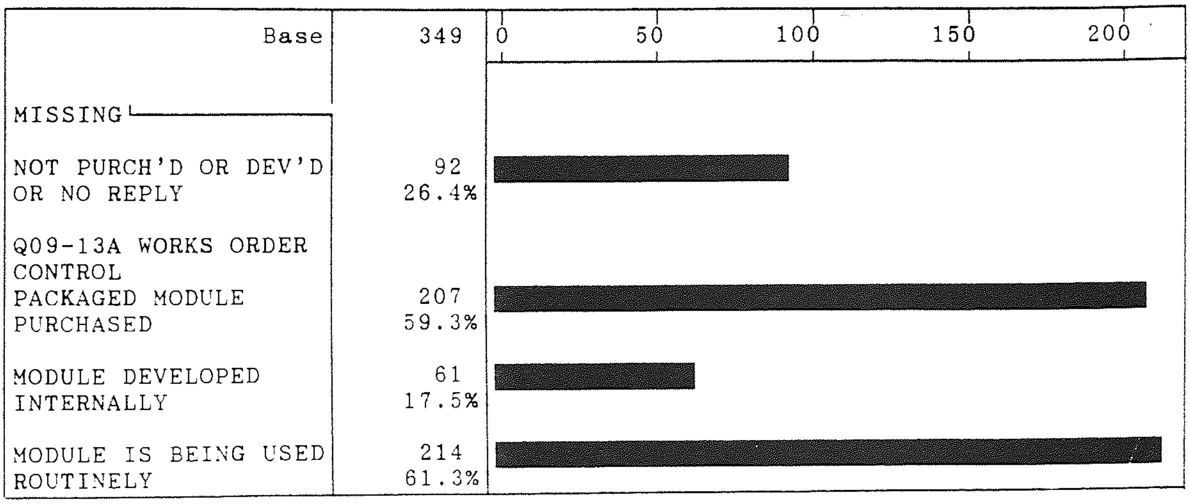
	Base	NOT PLANNED OR NO REPLY	Valid	Mean	Standard Dev
WHEN PLAN TO PURCH SHOPSCED(MTH)	349	294	55	9.218182	5.864193

Bar chart...: NO.OF MONTHS SH.SCH.PURCH PLAN'D
Cells.......: Absolute, Total %, Zeros suppressed



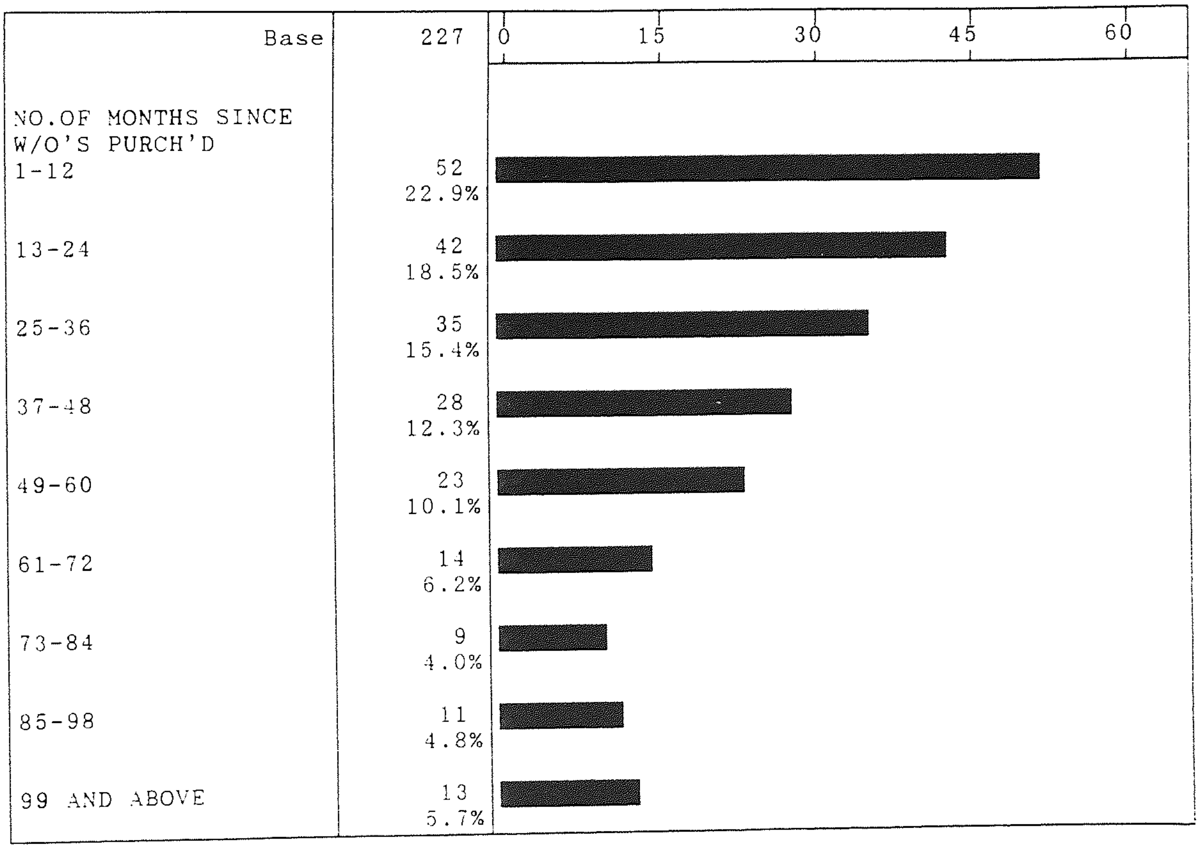
Works Order Control.

Bar chart...: Q09-13A WORKS ORDER CONTROL
Cells.......: Absolute, Total %



	Base	NOT PURCH'D OR DEV'D OR NO REPLY	Valid	Mean	Standard Dev
HOW LONG SINCE WOC PURCH? (MTHS)	349	122	227	41.07489	28.93908

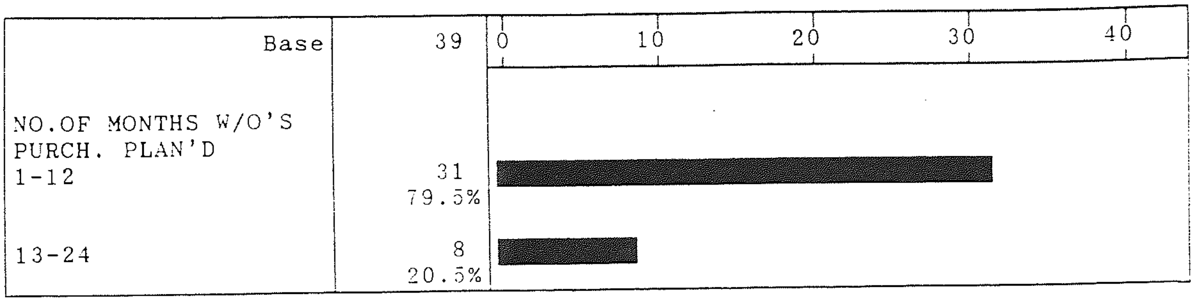
Bar chart...: NO.OF MONTHS SINCE W/O'S PURCH'D
Cells.......: Absolute, Total %



Statistics..: WHEN PLAN TO PURCH WOC? (MTHS)
Cells.......: Absolute

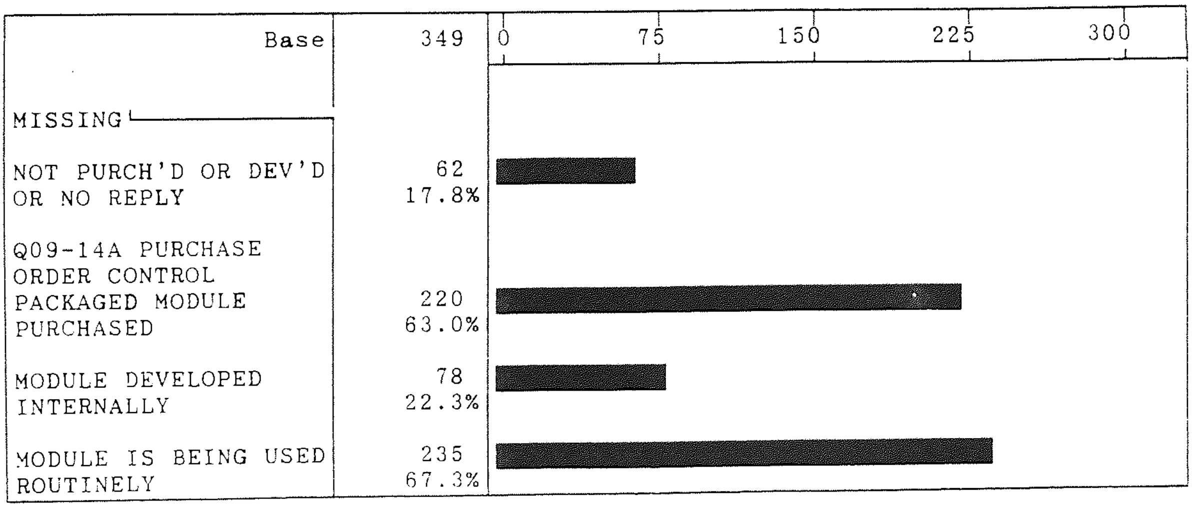
	Base	NOT PLANNED OR NO REPLY	Valid	Mean	Standard Dev
WHEN PLAN TO PURCH WOC? (MTHS)	349	310	39	8.871795	5.684795

Bar chart...: NO.OF MONTHS W/O'S PURCH. PLAN'D
Cells.......: Absolute, Total %, Zeros suppressed



Purchase Order Control.

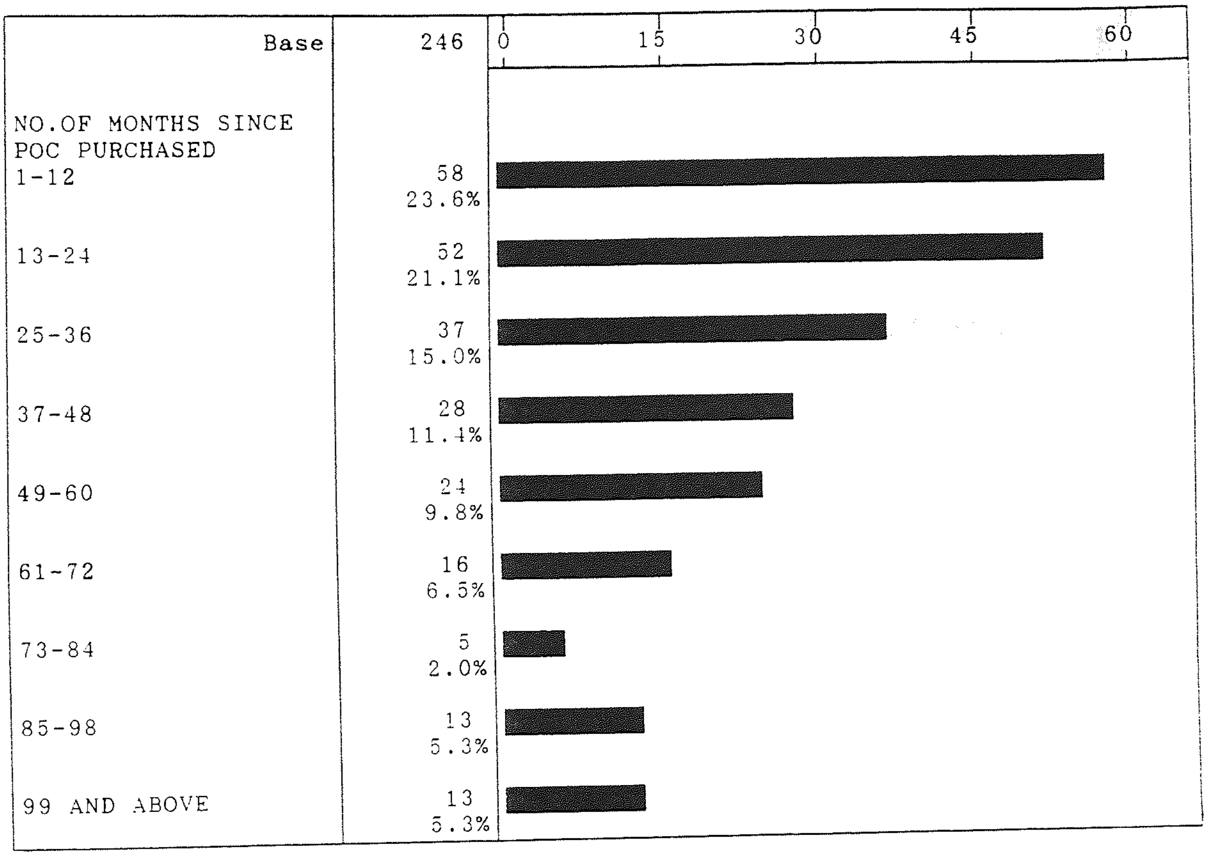
Bar chart...: Q09-14A PURCHASE ORDER CONTROL
Cells.......: Absolute, Total %



Statistics..: HOW LONG SINCE POC PURCH? (MTHS)
Cells.......: Absolute

	Base	NOT PURCH'D OR DEV'D OR NO REPLY	Valid	Mean	Standard Dev
HOW LONG SINCE POC PURCH? (MTHS)	349	103	246	39.32114	28.92362

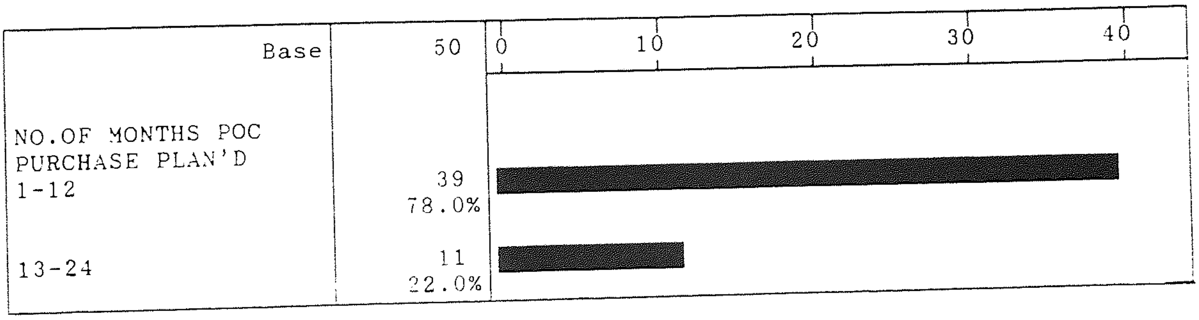
Bar chart...: NO.OF MONTHS SINCE POC PURCHASED
Cells.......: Absolute, Total %



Statistics..: WHEN PLAN TO PURCH POC? (MTHS)
Cells.......: Absolute

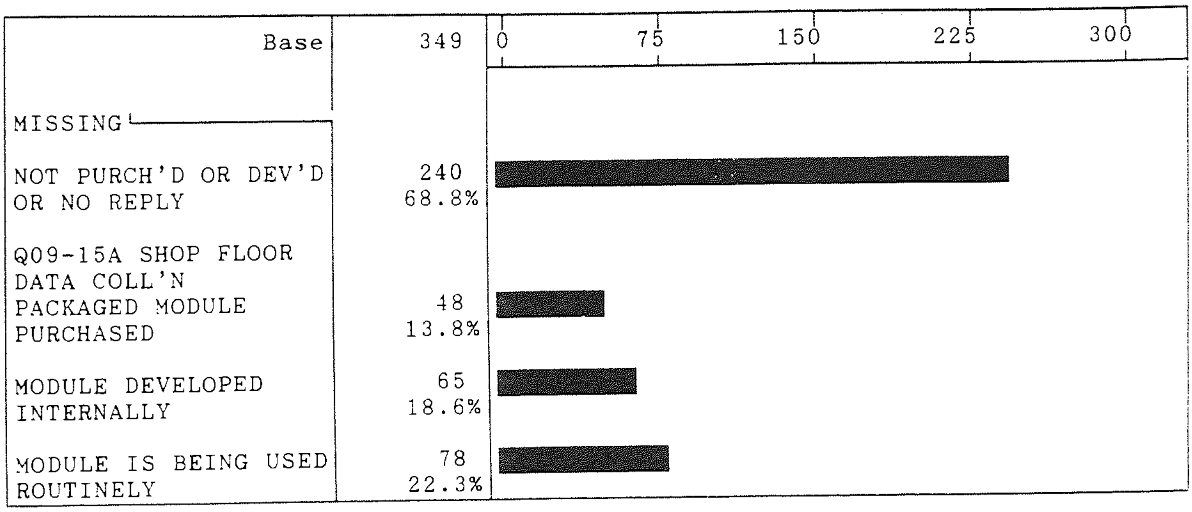
	Base	NOT PLANNED OR NO REPLY	Valid	Mean	Standard Dev
WHEN PLAN TO PURCH POC? (MTHS)	349	299	50	9.72	6.409493

Bar chart...: NO.OF MONTHS POC PURCHASE PLAN'D
Cells.......: Absolute, Total %, Zeros suppressed



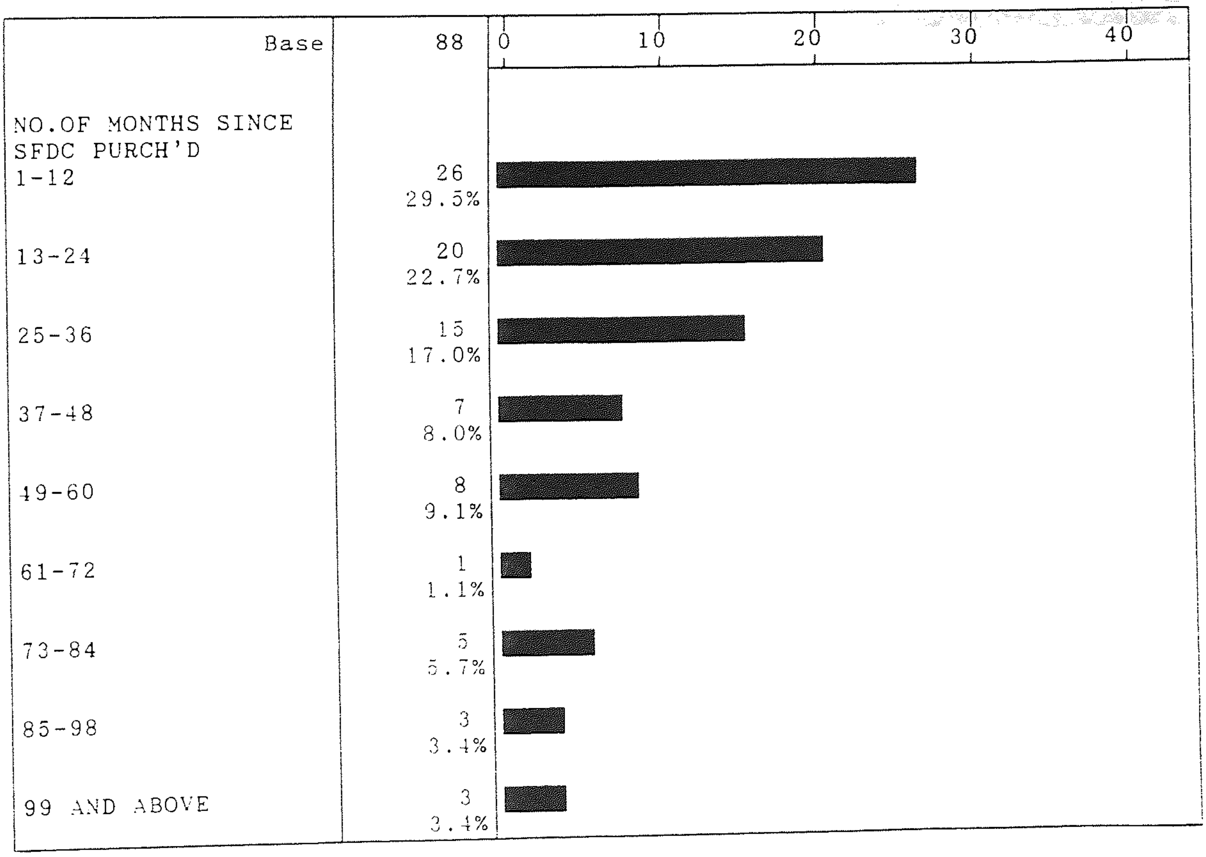
Shop Floor Data Collection.

Bar chart...: Q09-15A SHOP FLOOR DATA COLL'N
Cells.......: Absolute, Total %



	Base	NOT PURCH'D OR DEV'D OR NO REPLY	Valid	Mean	Standard Dev
HOW LONG SINCE SFDC PURCH?(MTHS	349	261	88	34.17045	27.59909

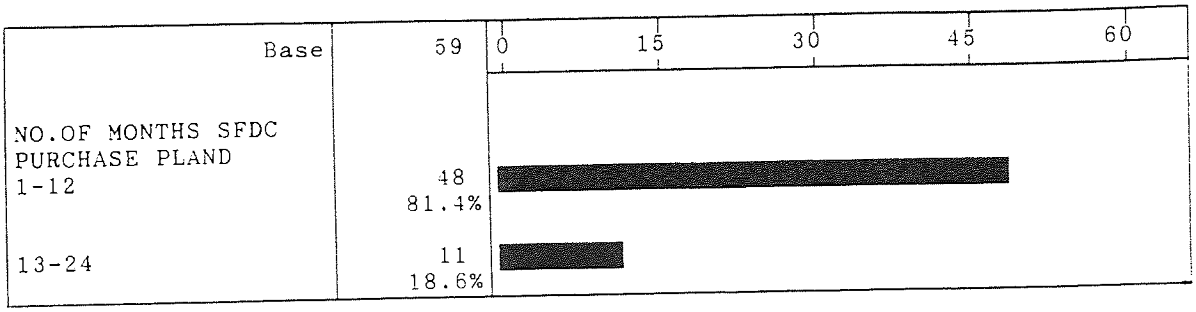
Bar chart...: NO.OF MONTHS SINCE SFDC PURCH'D
Cells.......: Absolute, Total %



Statistics..: WHEN PLAN TO PURCH SFDC? (MTHS)
Cells.......: Absolute

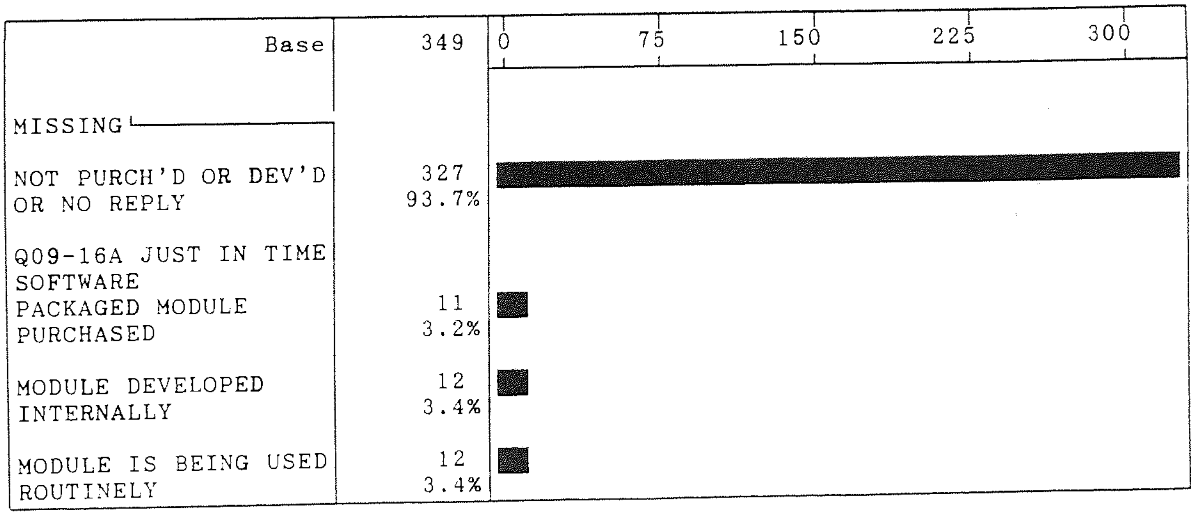
	Base	NOT PLANNED OR NO REPLY	Valid	Mean	Standard Dev
WHEN PLAN TO PURCH SFDC? (MTHS)	349	290	59	10.61017	5.505058

Bar chart...: NO.OF MONTHS SFDC PURCHASE PLAND
Cells.......: Absolute, Total %, Zeros suppressed



JIT Software.

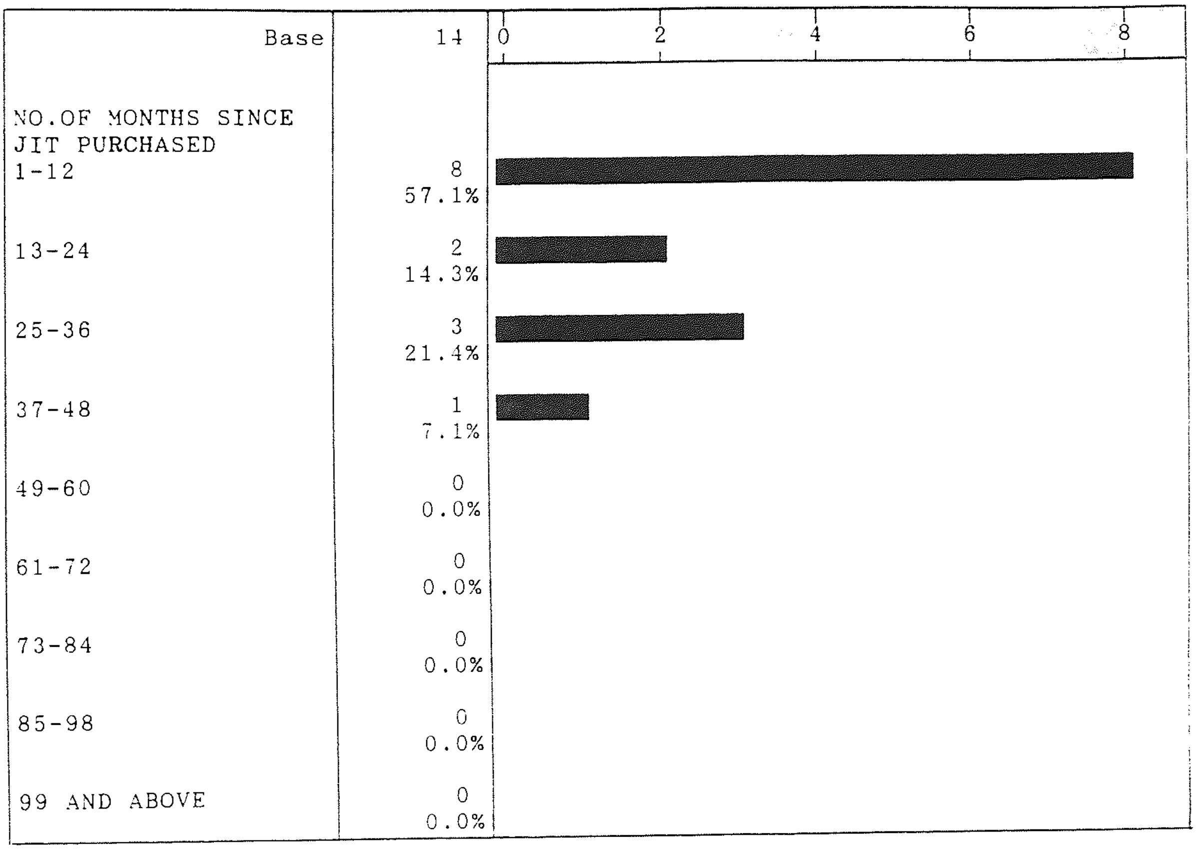
Bar chart...: Q09-16A JUST IN TIME SOFTWARE
Cells.......: Absolute, Total %



Statistics..: HOW LONG SINCE JIT PURCH? (MTHS)
Cells.......: Absolute

	Base	NOT PURCH'D OR DEV'D OR NO REPLY	Valid	Mean	Standard Dev
HOW LONG SINCE JIT PURCH? (MTHS)	349	335	14	18.21429	14.09244

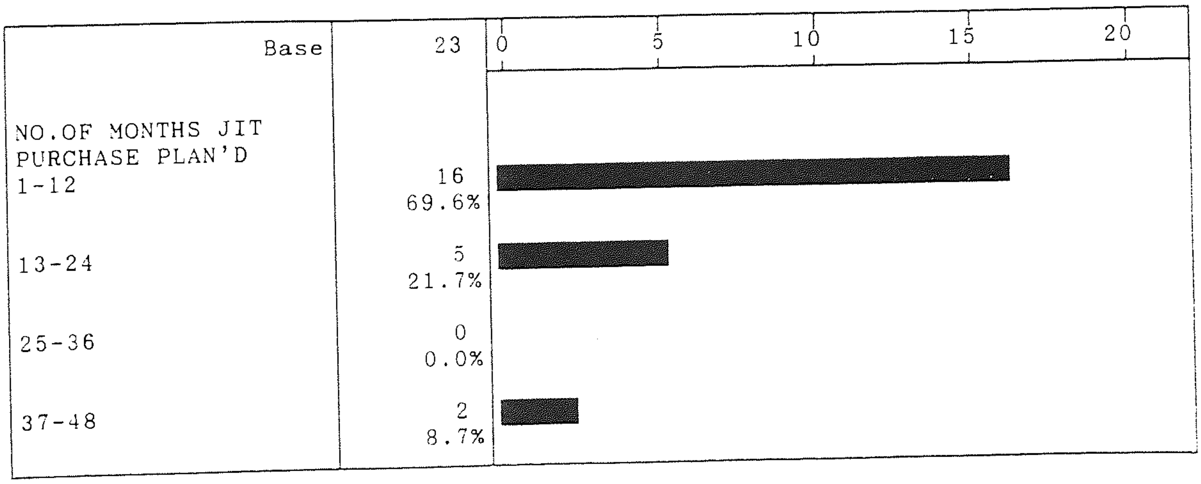
Bar chart...: NO.OF MONTHS SINCE JIT PURCHASED
Cells.......: Absolute, Total %



Statistics..: WHEN PLAN TO PURCH JIT? (MTHS)
Cells.......: Absolute

	Base	NOT PLANNED OR NO REPLY	Valid	Mean	Standard Dev
WHEN PLAN TO PURCH JIT? (MTHS)	349	326	23	14.73913	11.55786

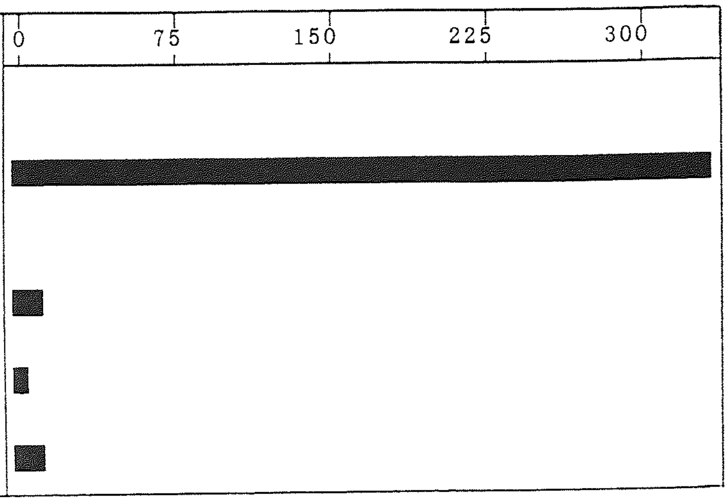
Bar chart...: NO.OF MONTHS JIT PURCHASE PLAN'D
Cells.......: Absolute, Total %



Synchronised Manufacturing Software. (e.g. OPT)

Bar chart...: Q09-17A SYNCHRONISED MFG S'WARE
Cells.......: Absolute, Total %

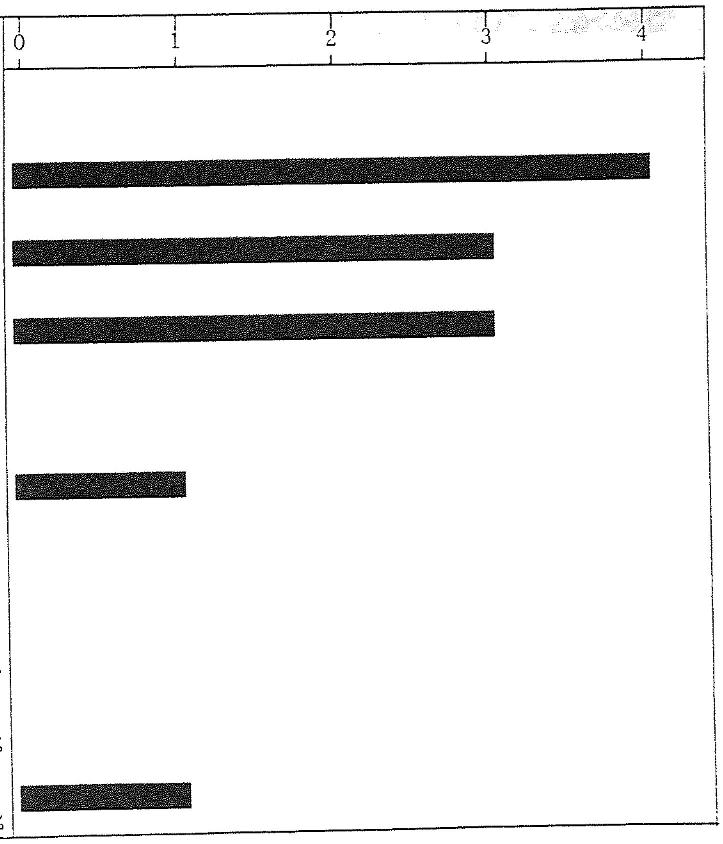
Base	349
MISSING	
NOT PURCH'D OR DEV'D OR NO REPLY	334 95.7%
Q09-17A SYNCHRONISED MFG S'WARE	
PACKAGED MODULE PURCHASED	12 3.4%
MODULE DEVELOPED INTERNALLY	4 1.1%
MODULE IS BEING USED ROUTINELY	8 2.3%



	Base	NOT PURCH'D OR DEV'D OR NO REPLY	Valid	Mean	Standard Dev
HOW LONG SINCE SYNCH PURCH?(MTH)	349	337	12	29.33333	25.94974

Bar chart...: NO.OF MONTHS SINCE SYNCH PURCH'D
Cells.......: Absolute, Total %

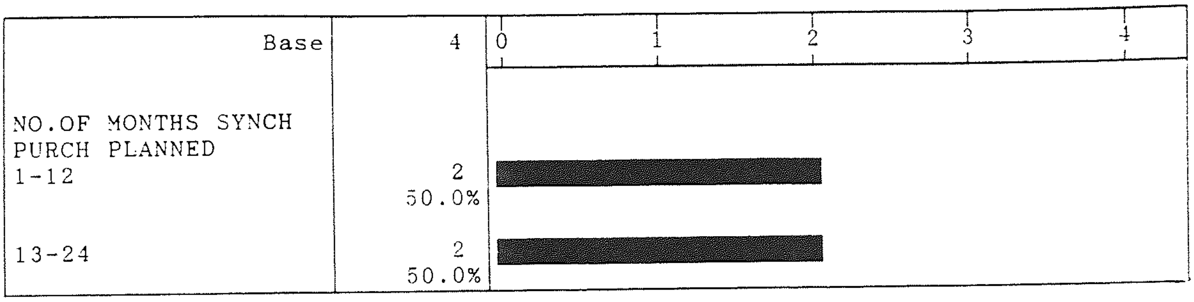
Base	12
NO.OF MONTHS SINCE SYNCH PURCH'D	
1-12	4 33.3%
13-24	3 25.0%
25-36	3 25.0%
37-48	0 0.0%
49-60	1 8.3%
61-72	0 0.0%
73-84	0 0.0%
85-98	0 0.0%
99 AND ABOVE	1 8.3%



Statistics..: WHEN PLAN TO PURCH SYNCH? (MTHS)
Cells.......: Absolute

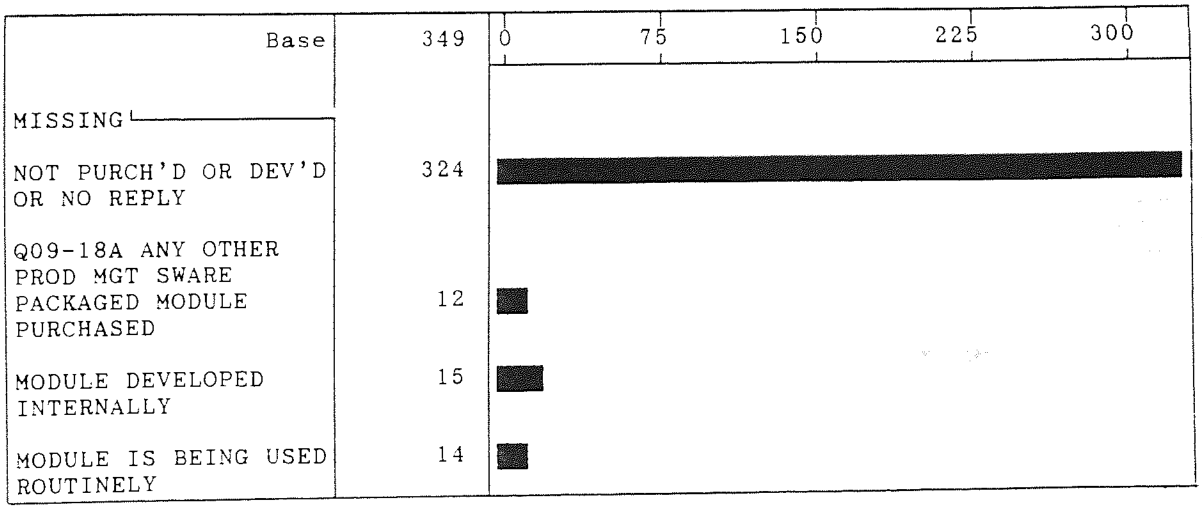
	Base	NOT PLANNED OR NO REPLY	Valid	Mean	Standard Dev
WHEN PLAN TO PURCH SYNCH? (MTHS)	349	345	4	13.25	10.75581

Bar chart...: NO.OF MONTHS SYNCH PURCH PLANNED
Cells.......: Absolute, Total %, Zeros suppressed



Any Other Production Management Software.

Bar chart...: Q09-18A ANY OTHER PROD MGT SWARE
Cells.......: Absolute



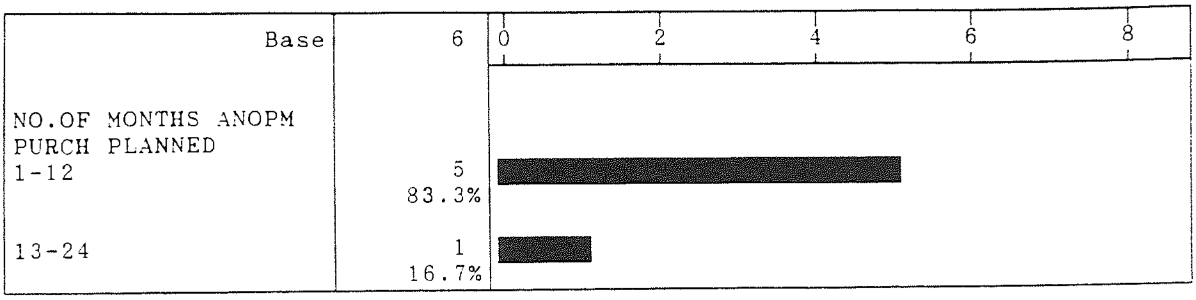
Statistics..: HOW LONG SINCE ANOPM PURCH (MTH)
Cells.......: Absolute

	Base	NOT PUR-CH'D OR DEV'D OR NO REPLY	Valid	Mean	Standard Dev
HOW LONG SINCE ANOPM PURCH (MTH)	349	334	15	40.46667	27.8995

```
Statistics..: WHEN PLAN TO PURCH ANOPM? (MTHS)
Cells.......: Absolute
```

	Base	NOT PLANNED OR NO REPLY	Valid	Mean	Standard Dev
WHEN PLAN TO PURCH ANOPM? (MTHS)	349	343	6	11	4.123106

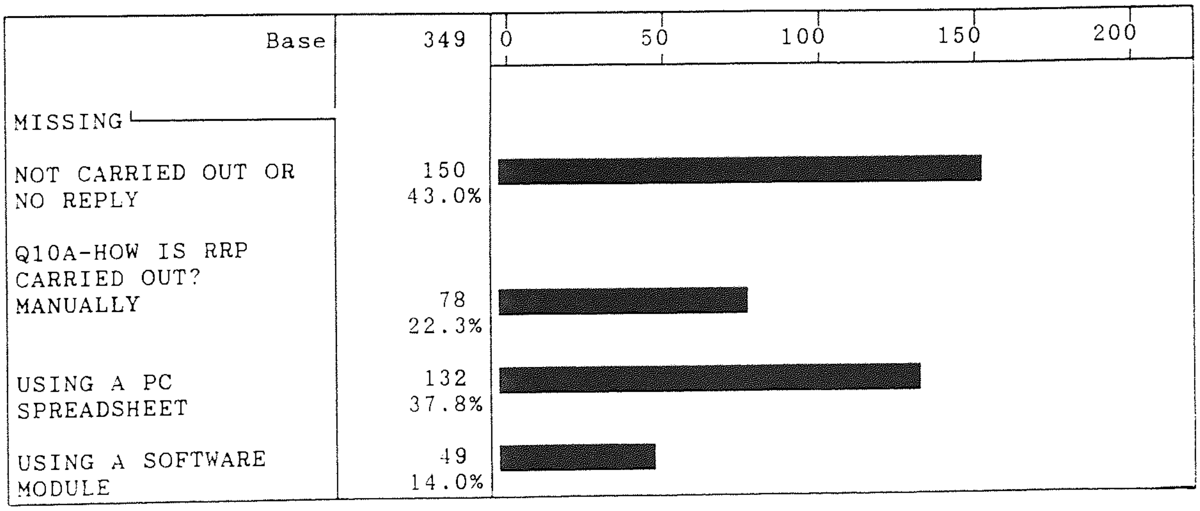
```
Bar chart...: NO.OF MONTHS ANOPM PURCH PLANNED
Cells.......: Absolute, Total %, Zeros suppressed
```



5.3.3 Section C. - Use of Capacity or Resource Planning

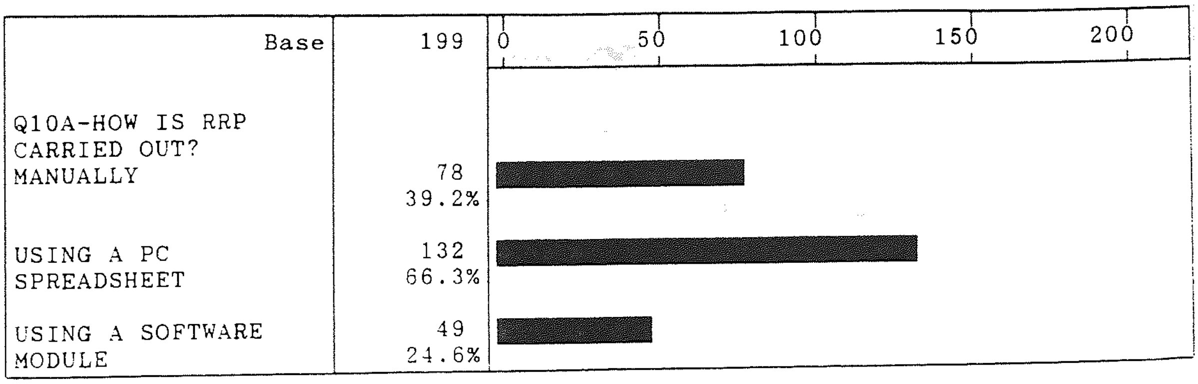
Question 10 a) asks how Resource Requirements Planning (RRP) is being carried out.

```
Bar chart...: Q10A-HOW IS RRP CARRIED OUT?
Cells.......: Absolute, Total %
```



This chart reveals that only 57% of respondents were carrying out RRP. Of these companies, the following chart reveals the split between methods of RRP, showing a large use (66.3%) of P.C. spreadsheets in this area.

```
Bar chart...: Q10A-HOW IS RRP CARRIED OUT?
Cells.......: Absolute, Total %
```



Question 10 b) concerns the planning horizon used for RRP. The replies show an average of approximately 20 months with a large spread.

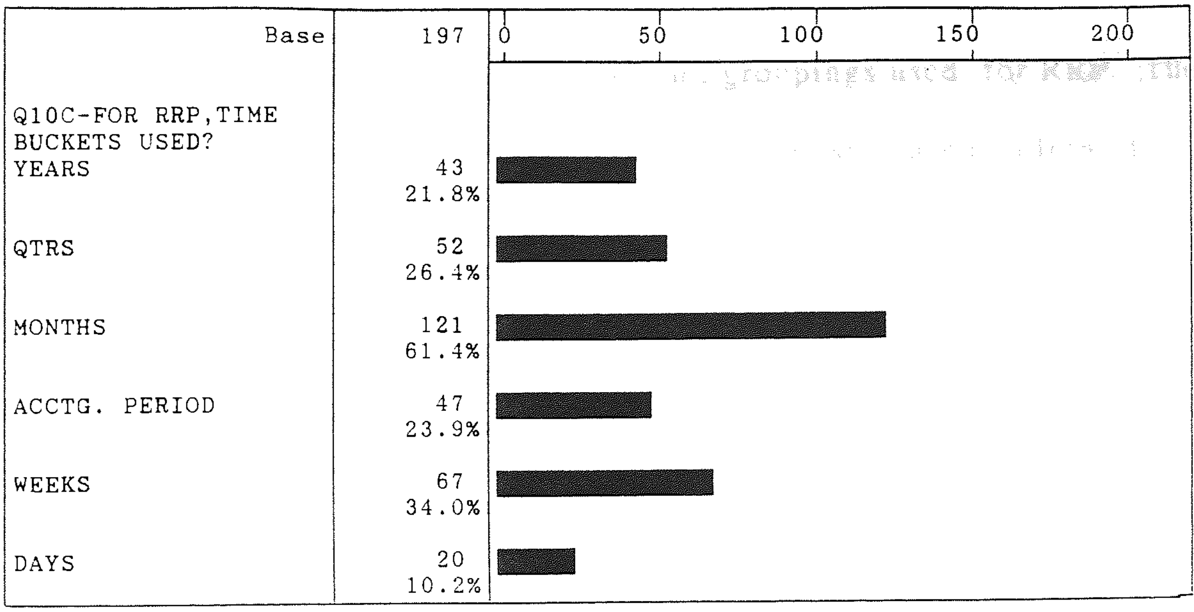
```
Statistics..: Q10B-FOR RRP WHAT HORIZON ?(MTH)
Cells.......: Absolute

                     Base|    Valid|     Mean| Minimum| Maximum|
Q10B-FOR RRP WHAT     349       193 19.89637        1      180
HORIZON ?(MTH)

                               Standard
                     Base|         Dev
Q10B-FOR RRP WHAT     349    20.35818
HORIZON ?(MTH)
```

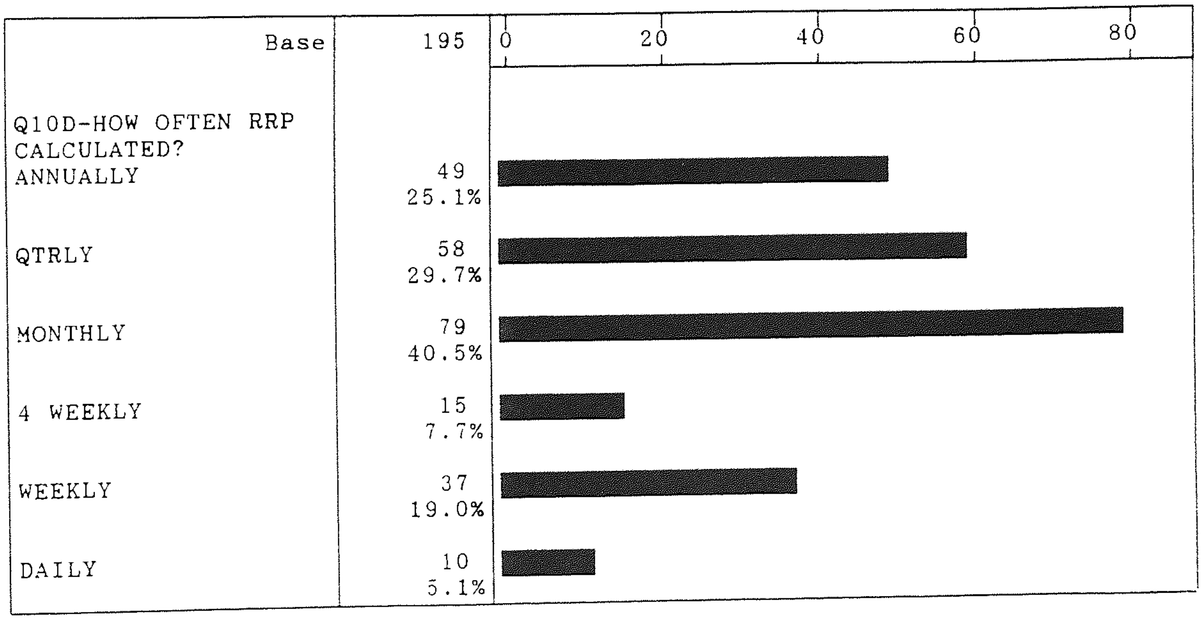
Question 10 c) asks what planning periods (buckets) were used for RRP. The following chart shows that months were the most common, with many companies using several different periods to aggregate work load.

Bar chart...: Q10C-FOR RRP,TIME BUCKETS USED?
Cells.......: Absolute, Total %



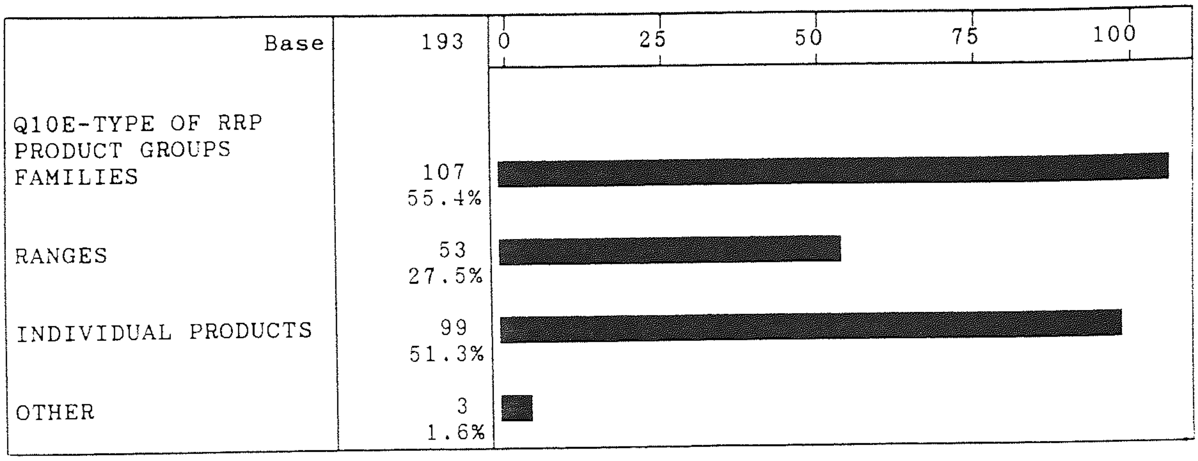
Question 10 d) concerns the frequency of calculation of RRP. The replies show that monthly is the most common, with a surprising 5% calculating daily, which might suggest a basic misunderstanding of the term RRP by some respondents.

Bar chart...: Q10D-HOW OFTEN RRP CALCULATED?
Cells.......: Absolute, Total %



Question 10 e) deals with the type of product groupings used for RRP. The replies show that Product Families are the most used followed by Individual Products (i.e. no grouping).

```
Bar chart...: Q10E-TYPE OF RRP PRODUCT GROUPS
Cells.......: Absolute, Total %
```



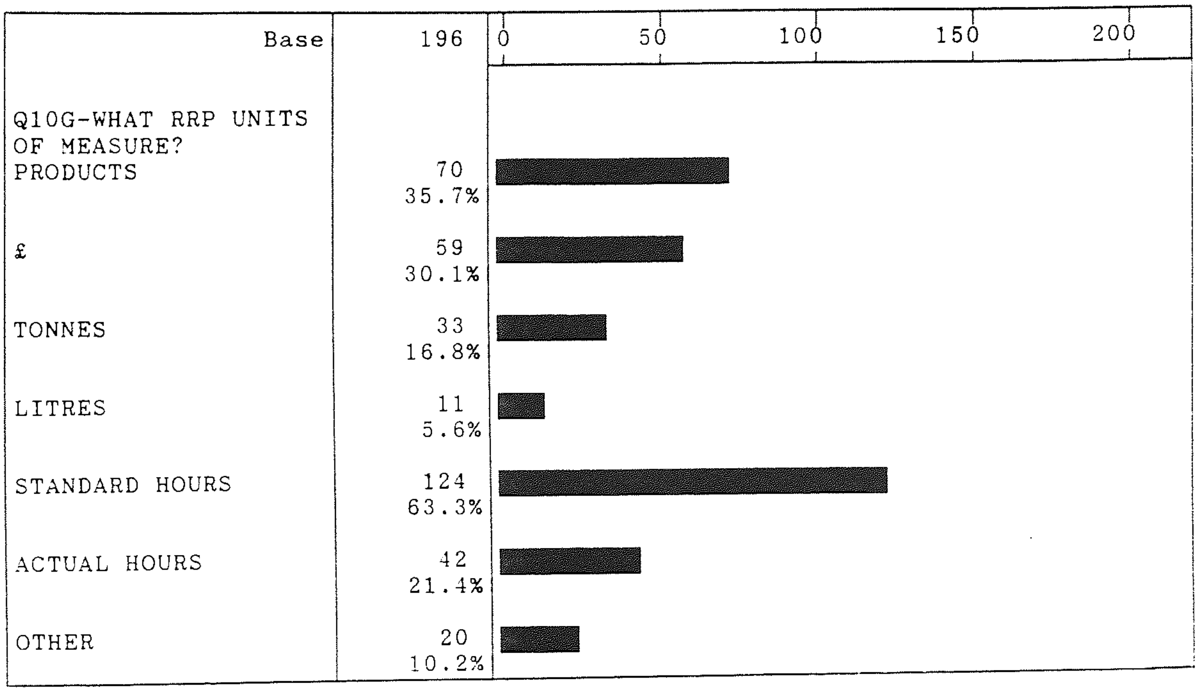
Question 10 f) concerns the number of product groupings which are planned at the RRP stage and replies show an average of 72 with a large standard deviation.

```
Statistics..: Q10F-HOW MANY RRP GROUPS PLANNED
Cells.......: Absolute

                          Base|    Valid|     Mean| Minimum| Maximum|
Q10F-HOW MANY RRP         349        176 72.38636        1     1500
GROUPS PLANNED

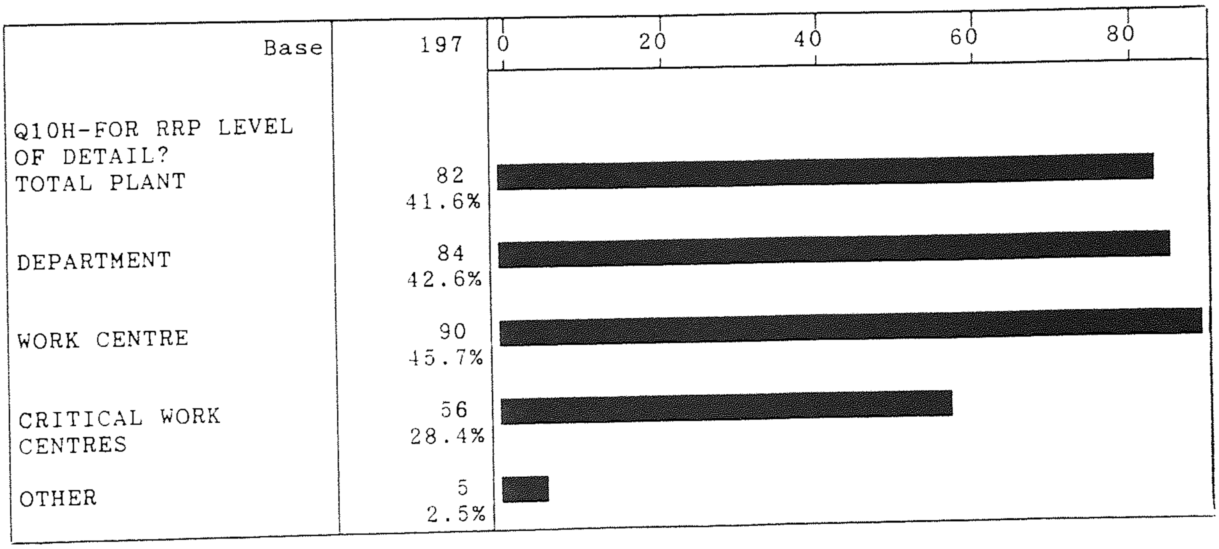
                                    Standard
                          Base|          Dev
Q10F-HOW MANY RRP         349    166.371
GROUPS PLANNED
```

Question 10 g) asks about the units of measure used for RRP. The replies indicate a wide variety with a predominance of the use of Standard Hours.



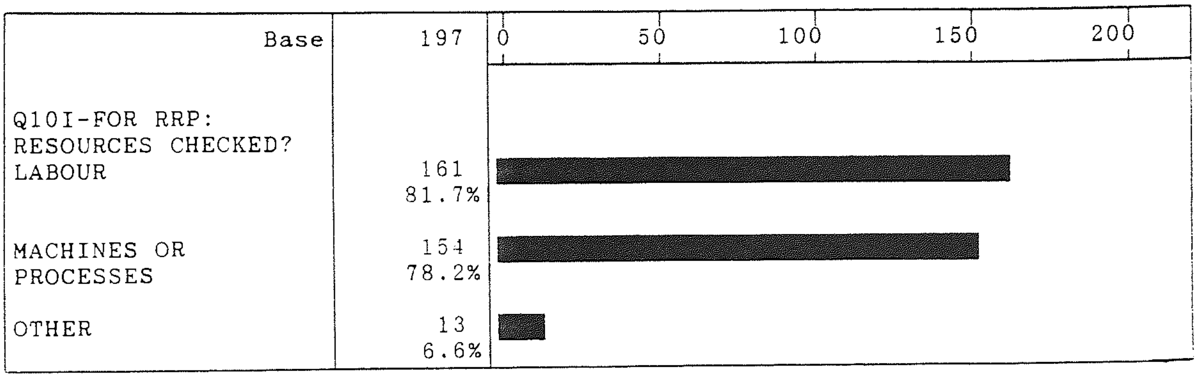
Question 10 h) concerns the level of detail to which RRP is taken. Results reveal an almost even mix between Total Plant, Department and Individual Work Centre, with Work Centre being slightly ahead.

Bar chart...: Q10H-FOR RRP LEVEL OF DETAIL?
Cells.......: Absolute, Total %



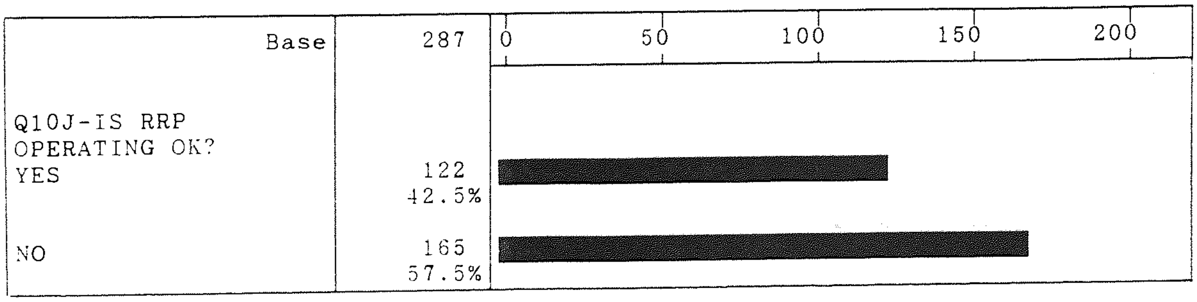
Question 10 i) asks about the type of resources checked in RRP and replies show an almost even split between labour and machine/process resources.

```
Bar chart...: Q10I-FOR RRP:RESOURCES CHECKED?
Cells.......: Absolute, Total %
```

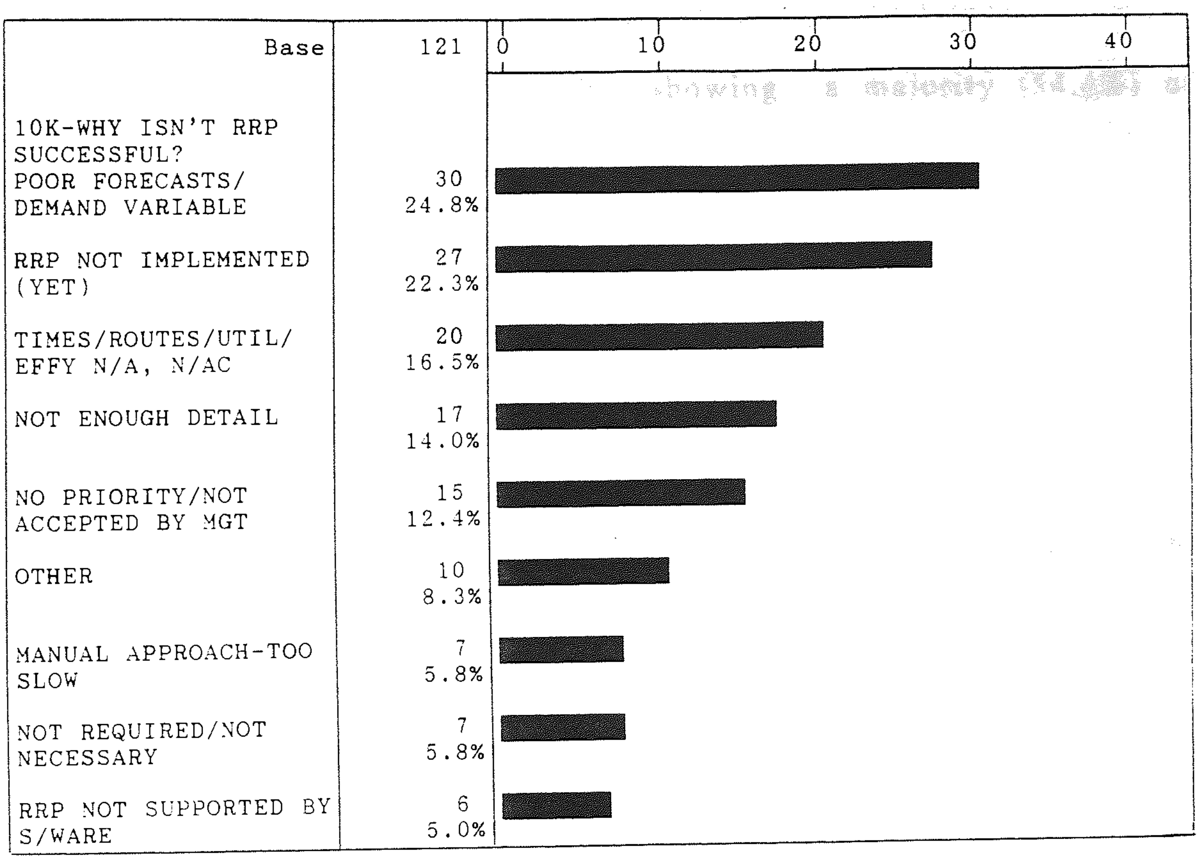


Question 10 j) asks whether RRP is operating successfully. Of those answering, the majority (57.5%) said NO.

```
Bar chart...: Q10J-IS RRP OPERATING OK?
Cells.......: Absolute, Total %
```

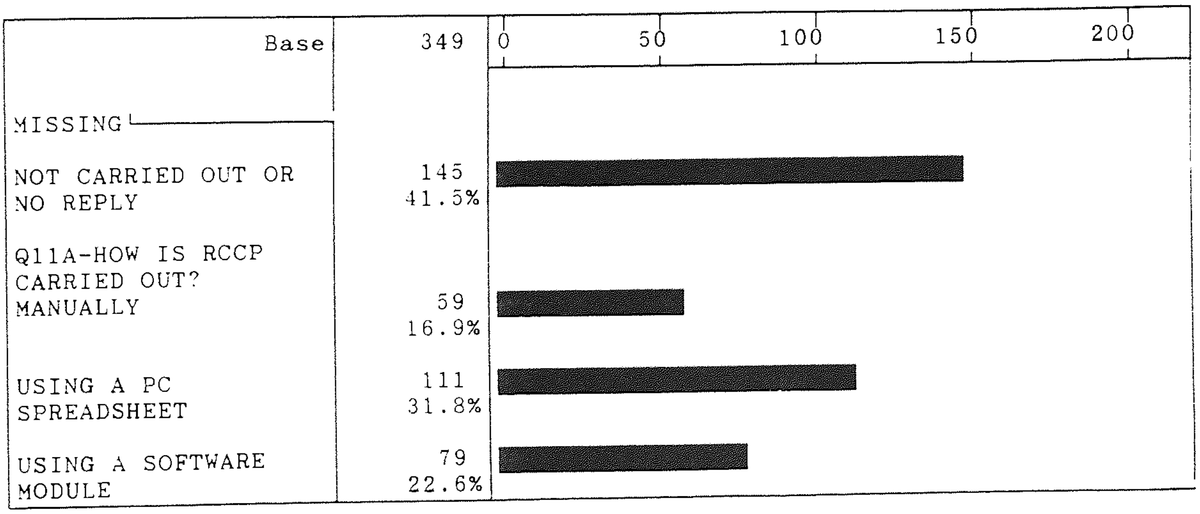


Question 10 k) is an open question asking why RRP may not be operating successfully. Replies were post-classified, giving the following results.



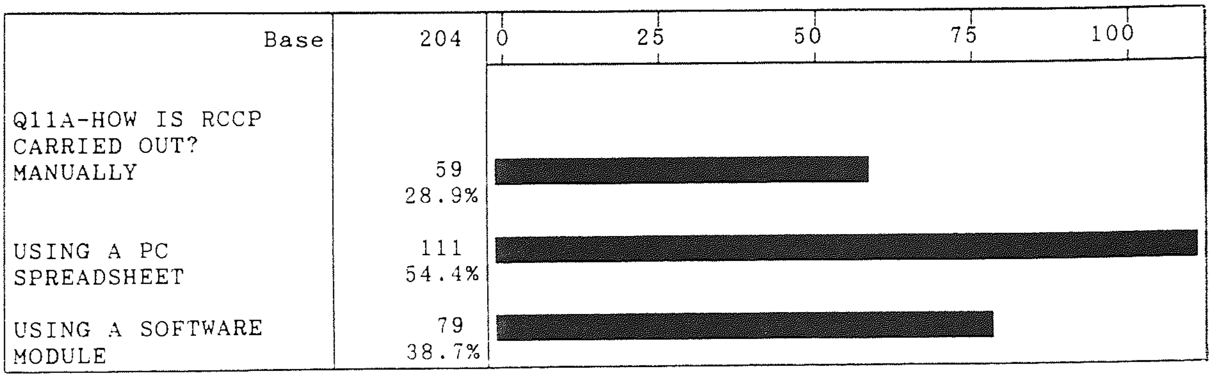
Question 11 a) asks how Rough Cut Capacity Planning (RCCP) is being carried out.

Bar chart...: Q11A-HOW IS RCCP CARRIED OUT?
Cells.......: Absolute, Total %



This chart reveals that only 58.5% of companies were carrying out RCCP. Of these companies, the following chart reveals the split between different methods of carrying out RCCP, showing a majority (54.4%) of respondents using P.C. spreadsheets.

```
Bar chart...: Q11A-HOW IS RCCP CARRIED OUT?
Cells.......: Absolute, Total %
```



Question 11 b) concerns the planning horizon used for RCCP. The replies show an average of 33 weeks with a large range.

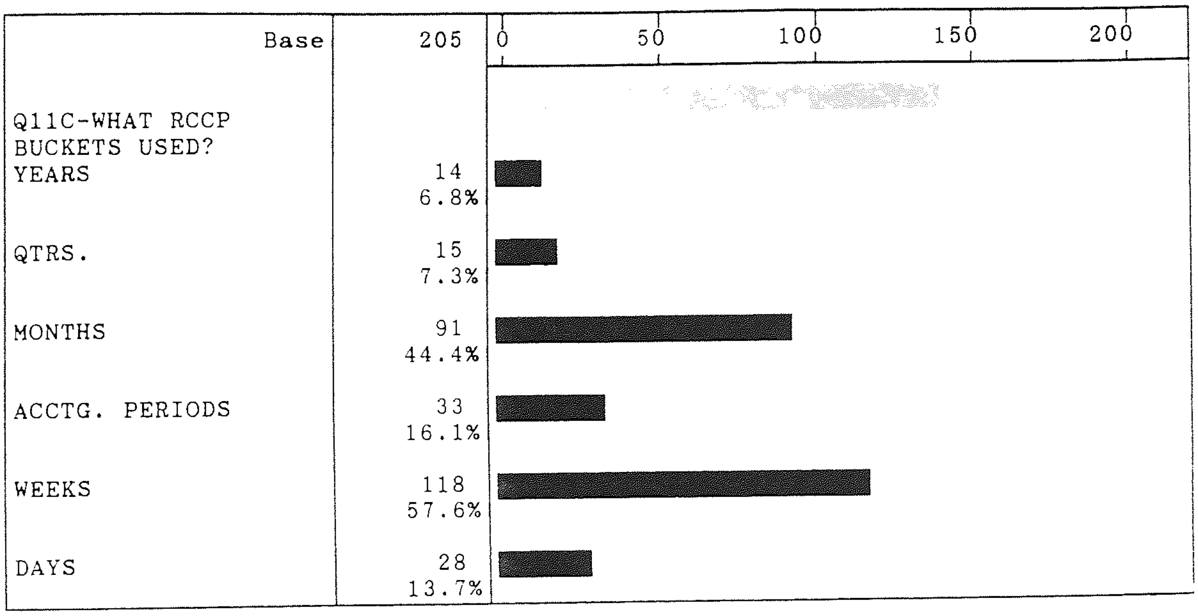
```
Statistics..: Q11B-WHAT IS RCCP HORIZON? (WKS)
Cells.......: Absolute

                          Base|     Valid|      Mean| Minimum| Maximum|
Q11B-WHAT IS RCCP          349       202 33.49505         2      603
HORIZON? (WKS)

                               Standard
                          Base|     Dev|
Q11B-WHAT IS RCCP          349  55.7301
HORIZON? (WKS)
```

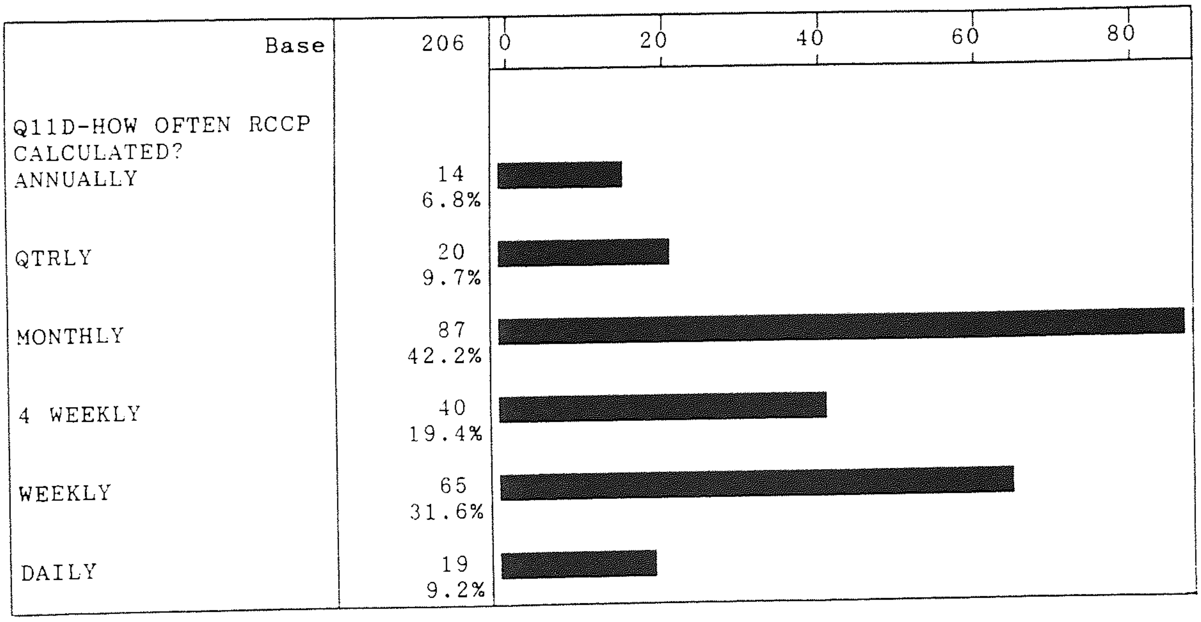
Question 11 c) asks what planning periods (buckets) are used for RCCP. The following chart shows a predominance of companies using weeks (57.6%) followed by months.

Bar chart...: Q11C-WHAT RCCP BUCKETS USED?
Cells.......: Absolute, Total %

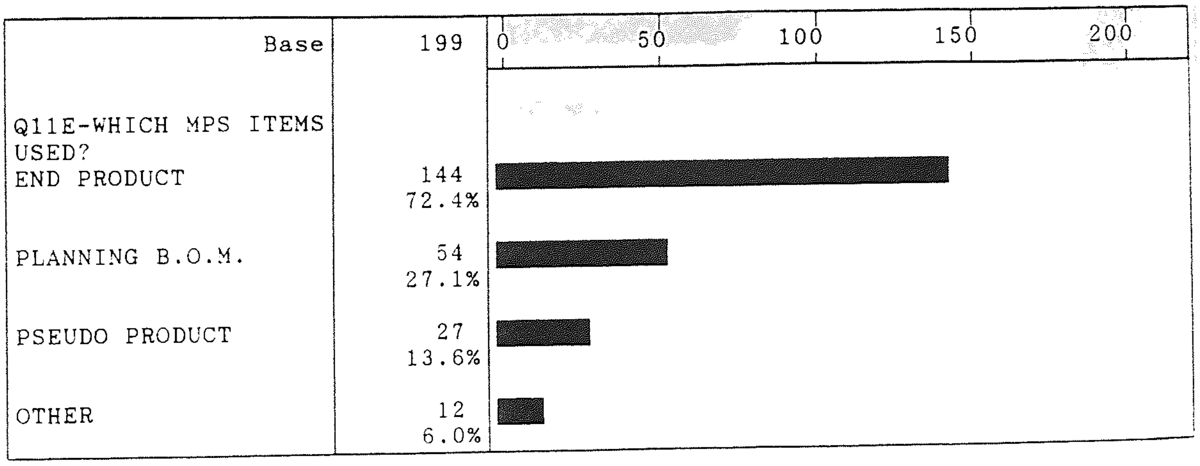


Question 11 d) concerns the frequency with which RCCP is calculated. Replies show that monthly is the most common.

Bar chart...: Q11D-HOW OFTEN RCCP CALCULATED?
Cells.......: Absolute, Total %



Question 11 e) asks which type of MPS items are used in RCCP. The vast majority (72.4%) were using end products.



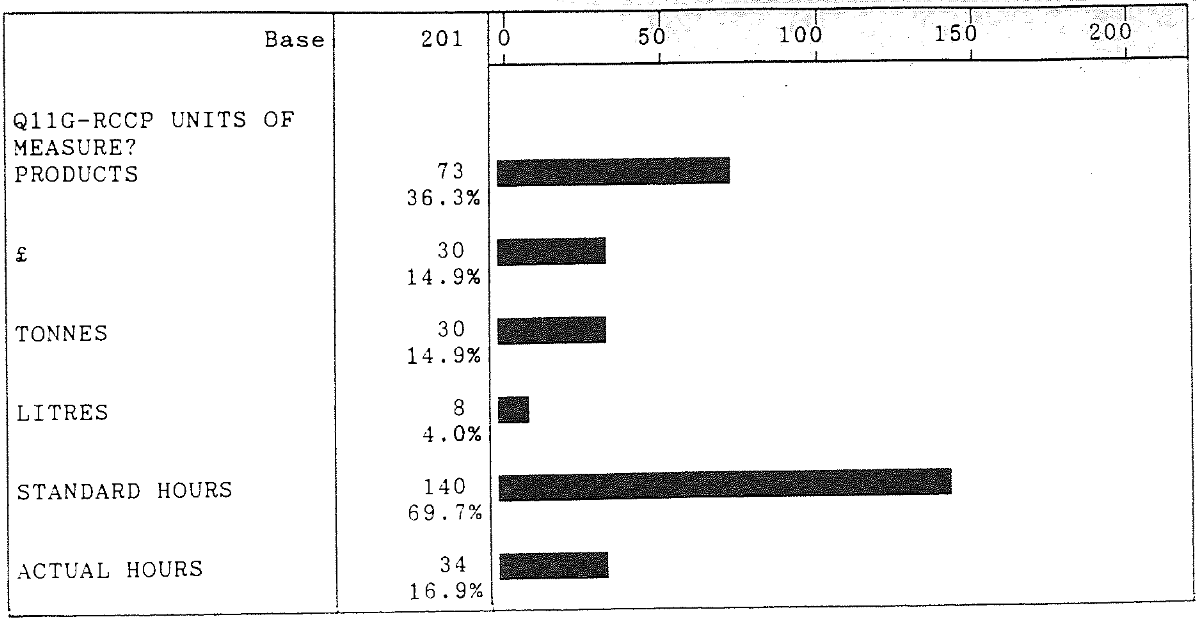
Question 11 f) concerns how many items are Master Scheduled, revealing an average of 703.

```
Statistics..: Q11F-HOW MANY MPS ITEMS?
Cells.......: Absolute

                            Base|    Valid|      Mean| Minimum| Maximum|
Q11F-HOW MANY MPS           349      195 702.6051          1     9999
ITEMS?

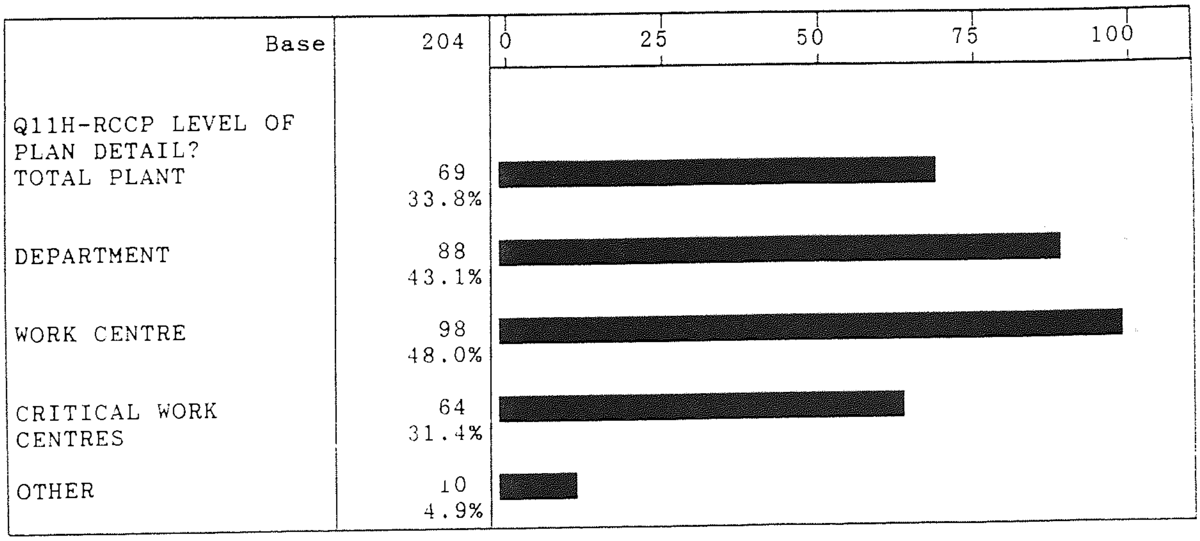
                                 Standard
                            Base|     Dev
Q11F-HOW MANY MPS           349  1399.524
ITEMS?
```

Question 11 g) asks about the units of measure used for RCCP. The replies show that Standard Hours are the most used.

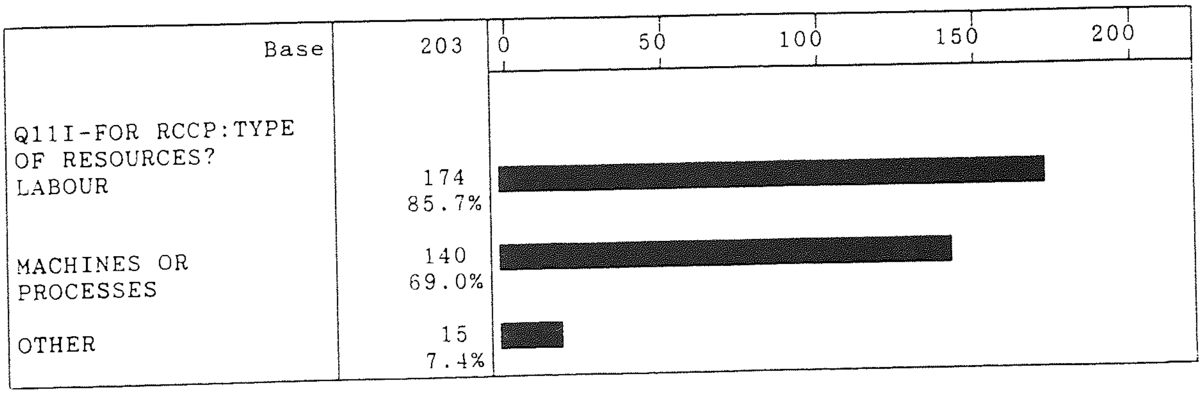


Question 11 h) concerns the level of detail to which RCCP is taken. Replies reveal that the Work Centre is the most common, with Department and Total Plant following.

Bar chart...: Q11H-RCCP LEVEL OF PLAN DETAIL?
Cells.......: Absolute, Total %

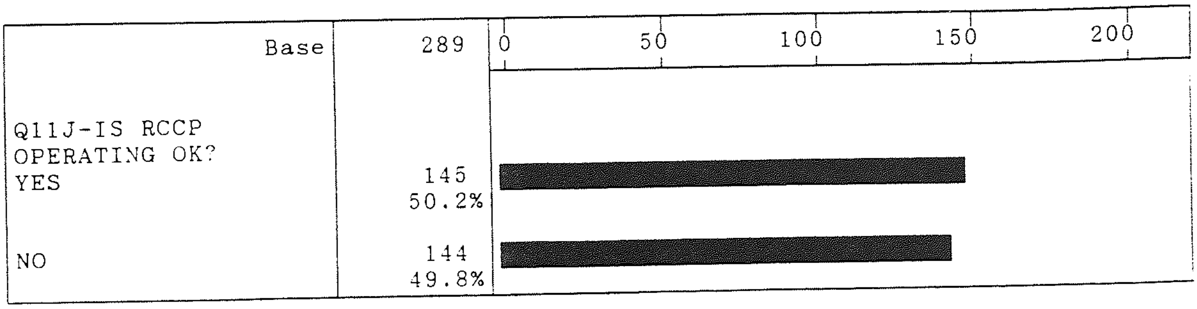


Question 11 i) asks about the type of resources checked in RCCP, the replies revealing that labour is checked slightly more often.

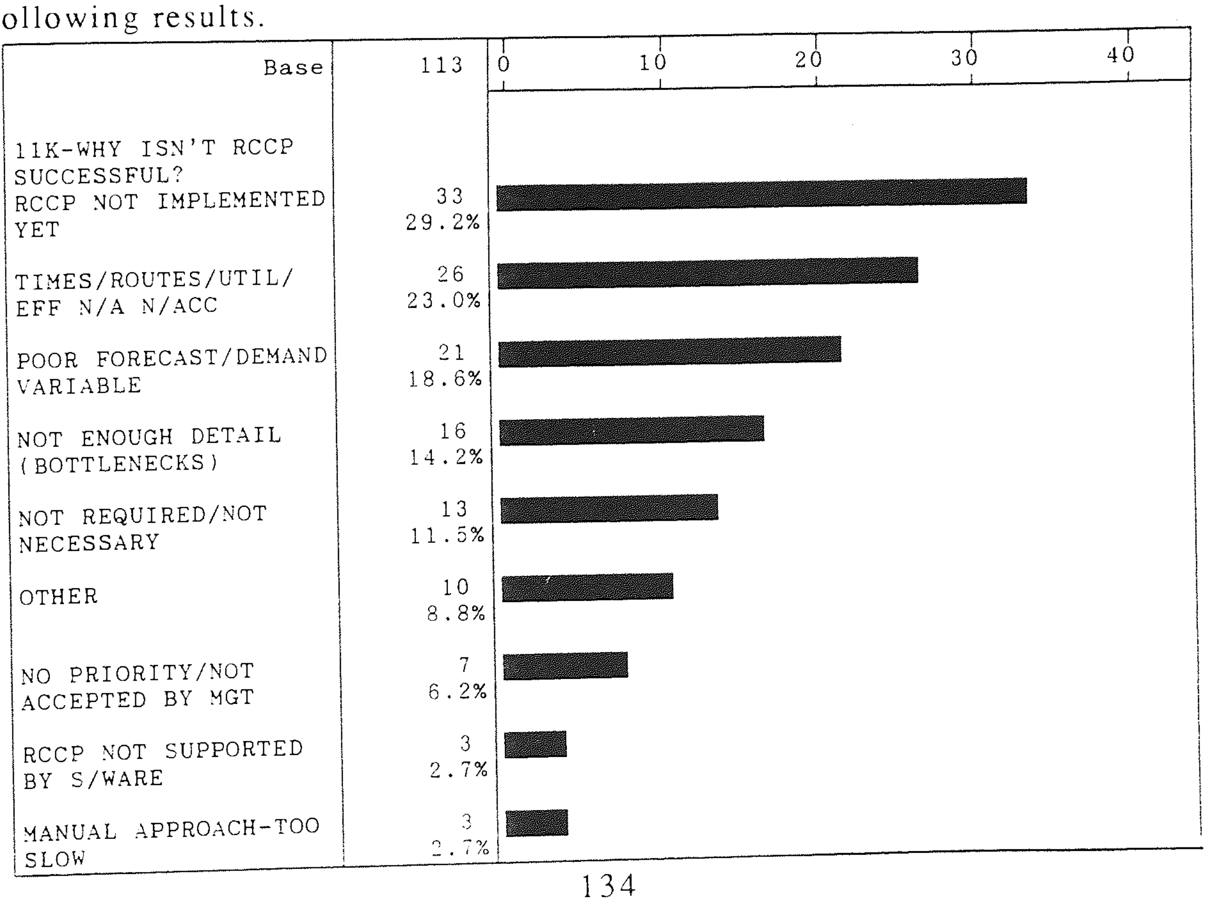


Question 11 j) asks whether RCCP is operating successfully. The result shows an almost even split between YES and NO.

```
Bar chart...: Q11J-IS RCCP OPERATING OK?
Cells.......: Absolute, Total %
```

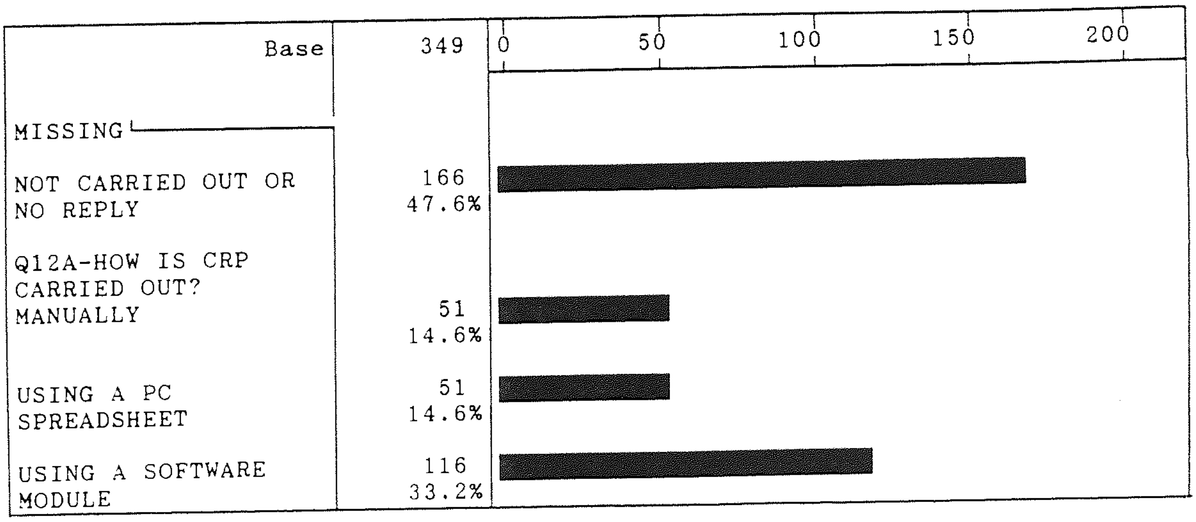


Question 11 k) is an open question asking why RCCP may not be operating successfully. The replies were post-classified, giving the following results.

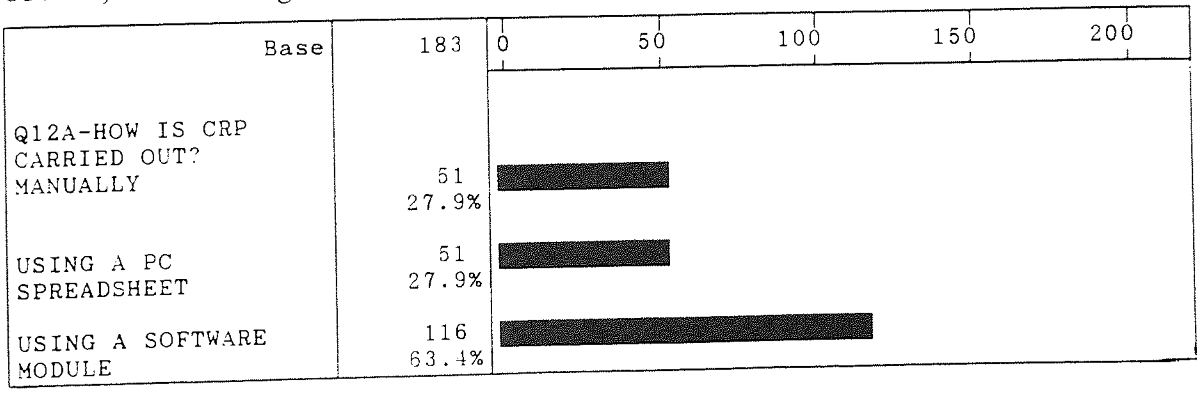


Question 12 a) asks how Capacity Requirements Planning is carried out.

```
Bar chart...: Q12A-HOW IS CRP CARRIED OUT?
Cells.......: Absolute, Total %
```



This chart shows that only 52% of respondents carried out CRP and of those companies, the methods used were as follows, indicating that the majority (63.4%) were using a software module.



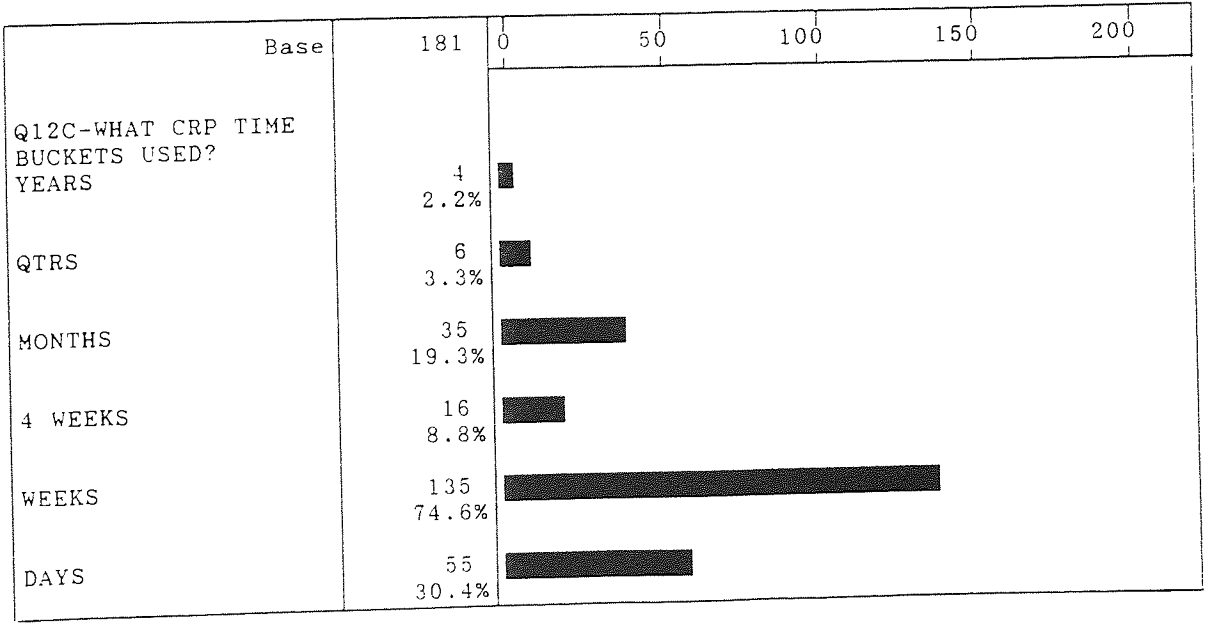
Question 12 b) refers to the CRP planning horizon. Replies show an average of 23 weeks with a standard deviation of 37 weeks.

```
Statistics..: Q12B-WHAT IS CRP HORIZON? (WKS)
Cells.......: Absolute

                                Base|    Valid|     Mean| Minimum| Maximum|
Q12B-WHAT IS CRP                349       179 22.76536        1      300
HORIZON? (WKS)

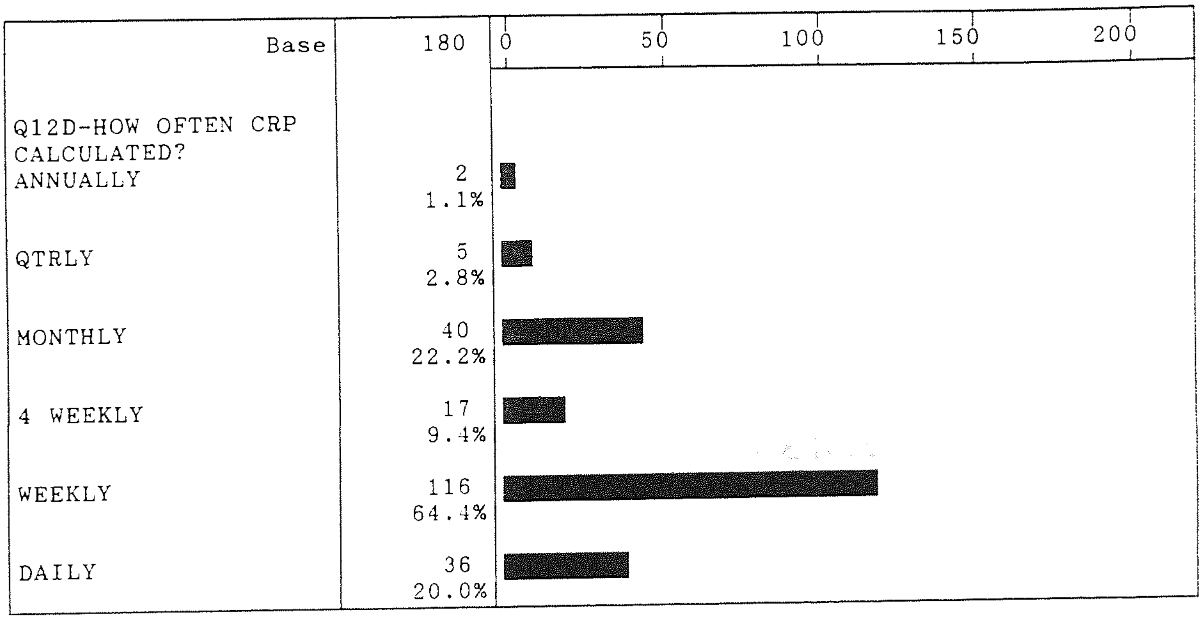
                                      Standard
                                Base|      Dev
Q12B-WHAT IS CRP                349   37.44569
HORIZON? (WKS)
```

Question 12 c) concerns the planning periods (buckets) used in CRP. The results show that Weeks is the most used period.



Question 12 d) refers to the frequency with which CRP is calculated. The following chart shows that Weekly is the most common.

```
Bar chart...: Q12D-HOW OFTEN CRP CALCULATED?
Cells.......: Absolute, Total %
```



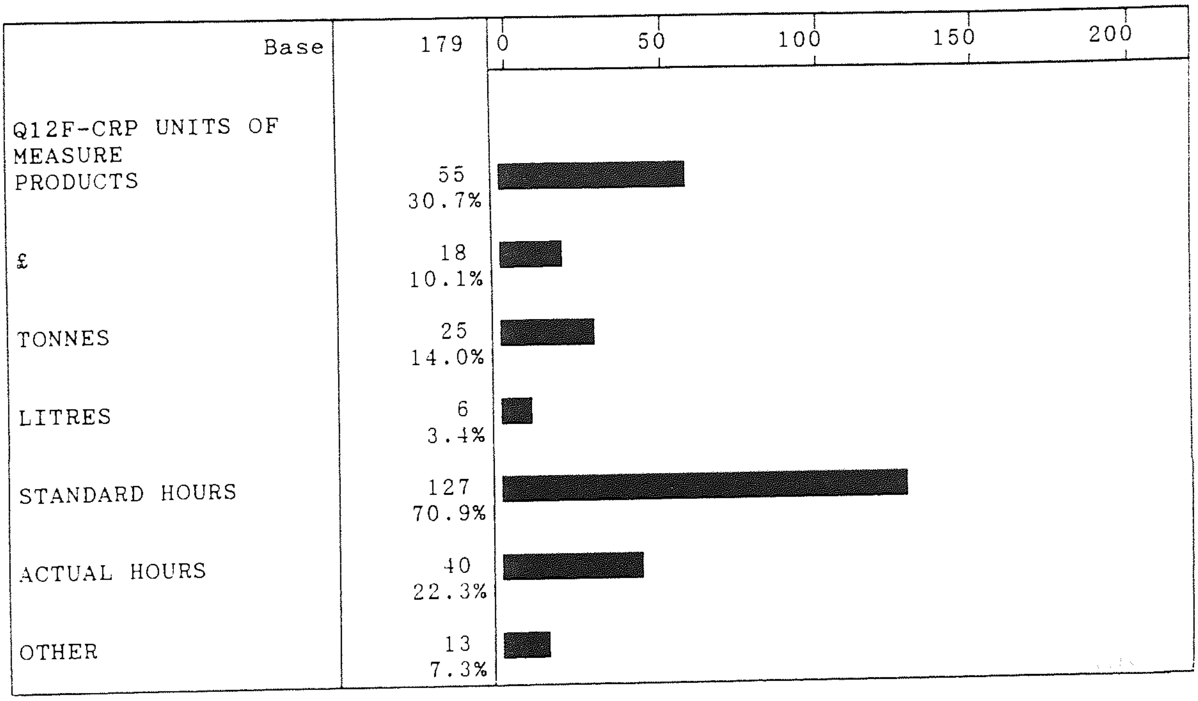
Question 12 e) asked how many live and planned orders are included in the CRP. The replies show an average of 3,821 with a standard deviation of 12,204.

	Base	Valid	Mean	Minimum	Maximum
Q12E-HOW MANY ORDERS IN CRP?	349	158	3821.551	12	99999

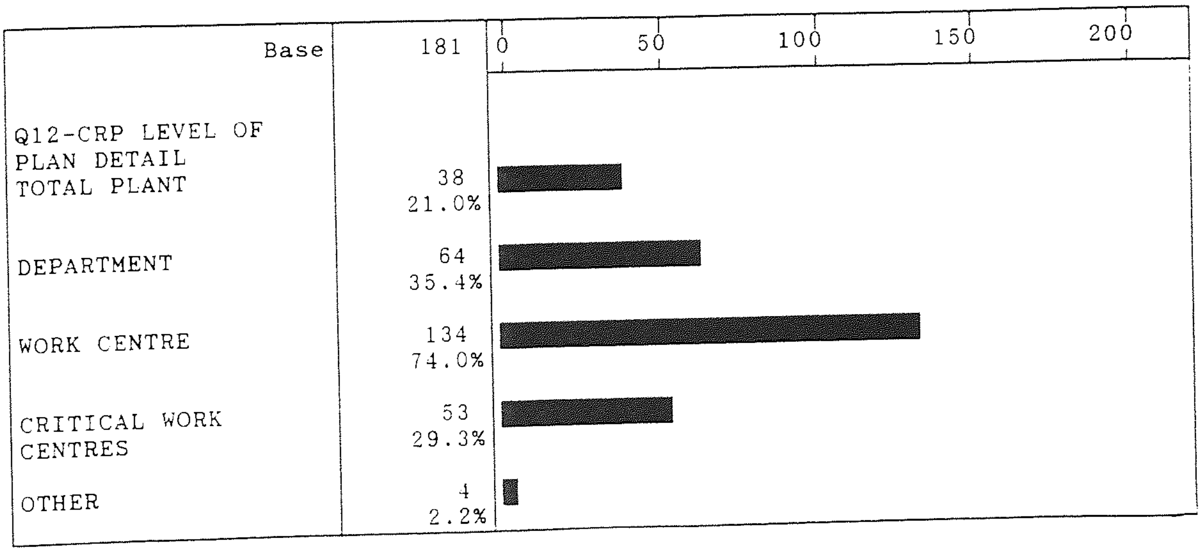
	Base	Standard Dev
Q12E-HOW MANY ORDERS IN CRP?	349	12204.05

Question 12 f) concerns the units of measure used in CRP. The following chart shows that Standard Hours is the most common followed by individual products.

Bar chart...: Q12F-CRP UNITS OF MEASURE
Cells.......: Absolute, Total %

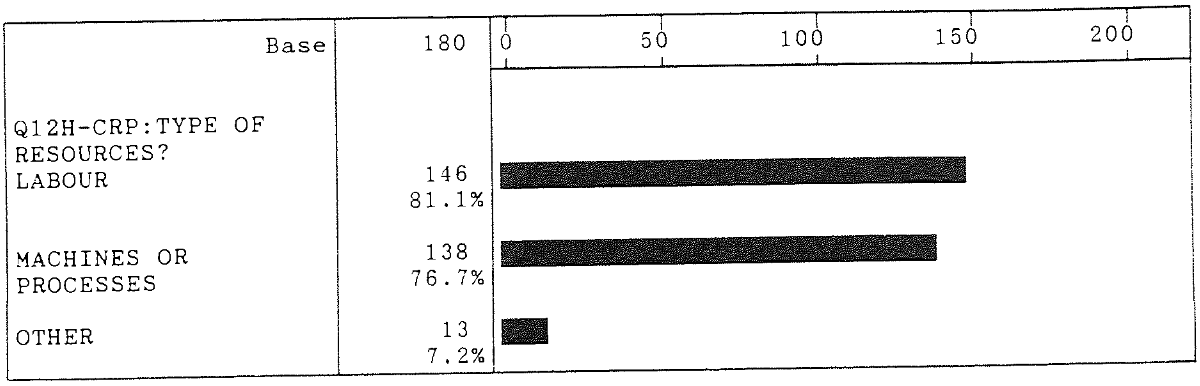


Question 12 g) refers to the level of detail to which CRP is taken and replies show that the Work Centre is the most used (74%).



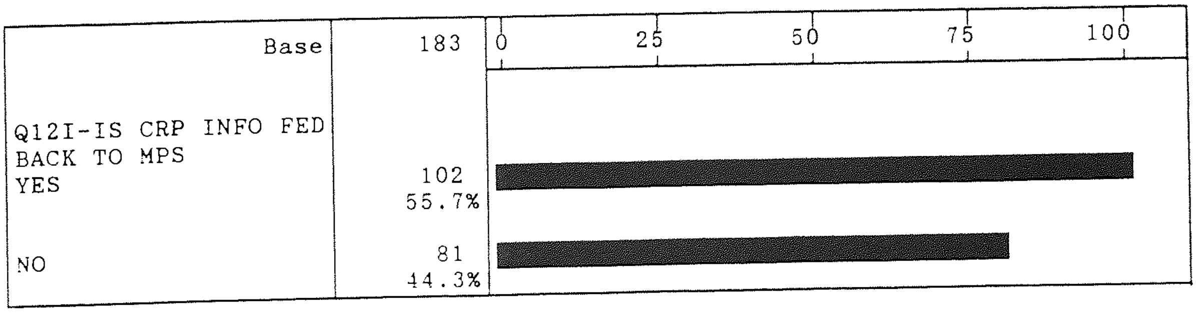
Question 12 h) asks which type of resources are checked in CRP. The results show that labour is checked slightly more often than machines or processes.

```
Bar chart...: Q12H-CRP:TYPE OF RESOURCES?
Cells.......: Absolute, Total %
```



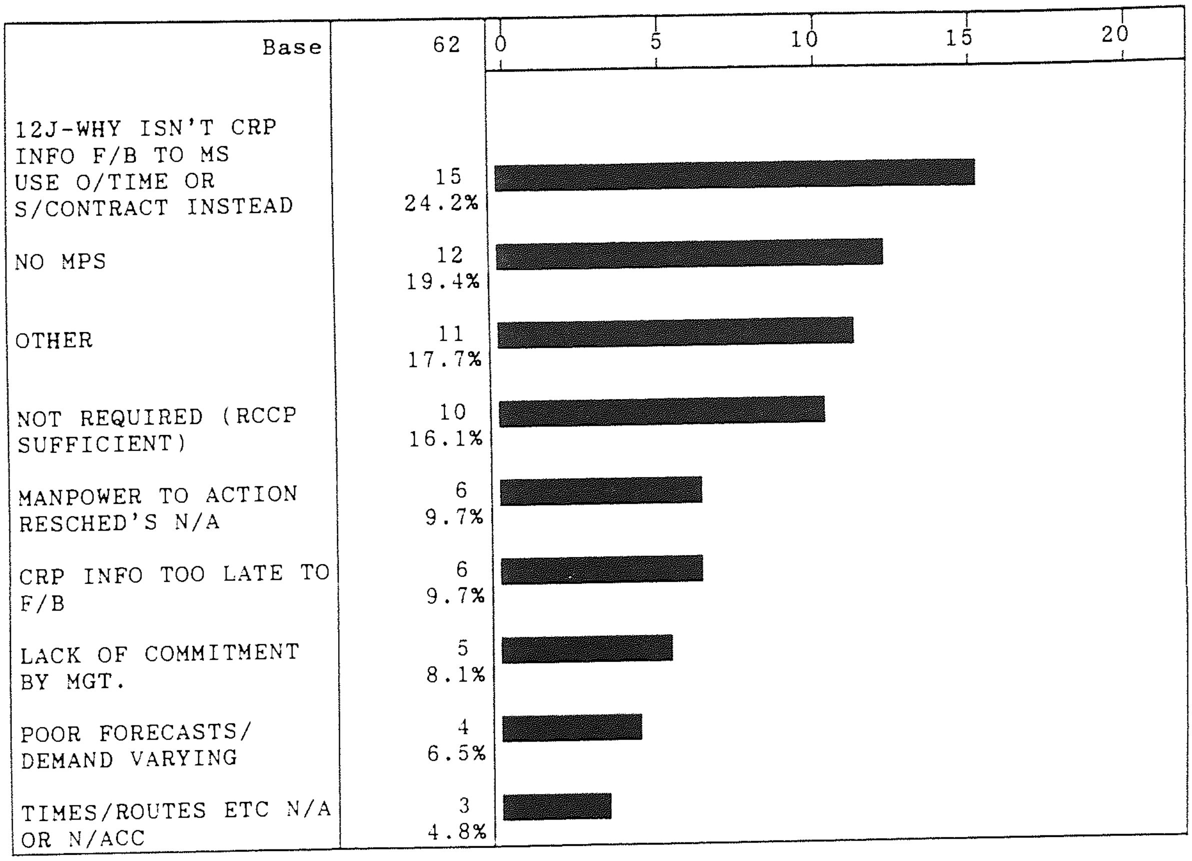
Question 12 i) asks whether CRP information is fed back to the MPS for rescheduling. The chart shows that of those replying (52.4%), slightly more (55.7%) were feeding back to the MPS than were not.

```
Bar chart...: Q12I-IS CRP INFO FED BACK TO MPS
Cells.......: Absolute, Total %
```

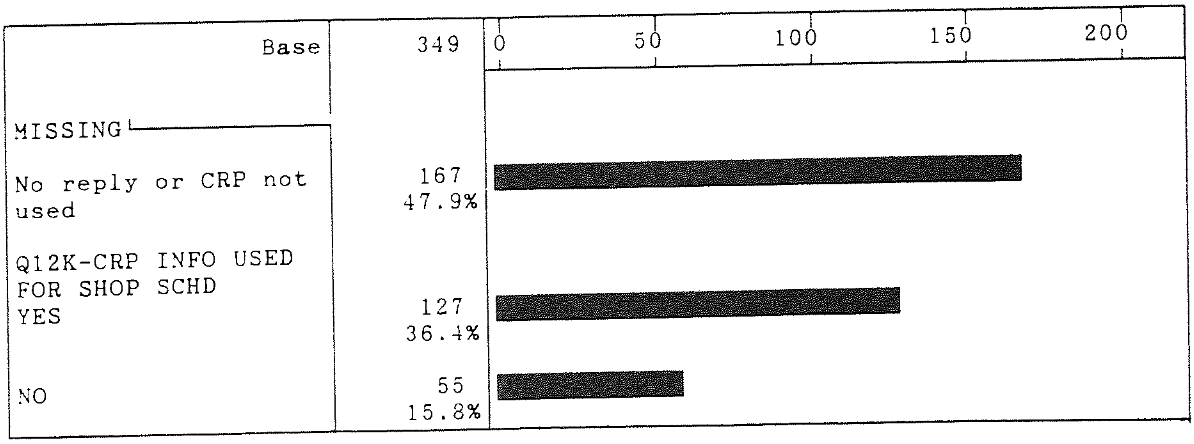


Question 12 j) asks respondents to explain why CRP information is not being fed back to the MPS. This is an open question which was post-categorised to give the following results.

Bar chart...: 12J-WHY ISN'T CRP INFO F/B TO MS
Cells.......: Absolute, Total %, Rows ordered

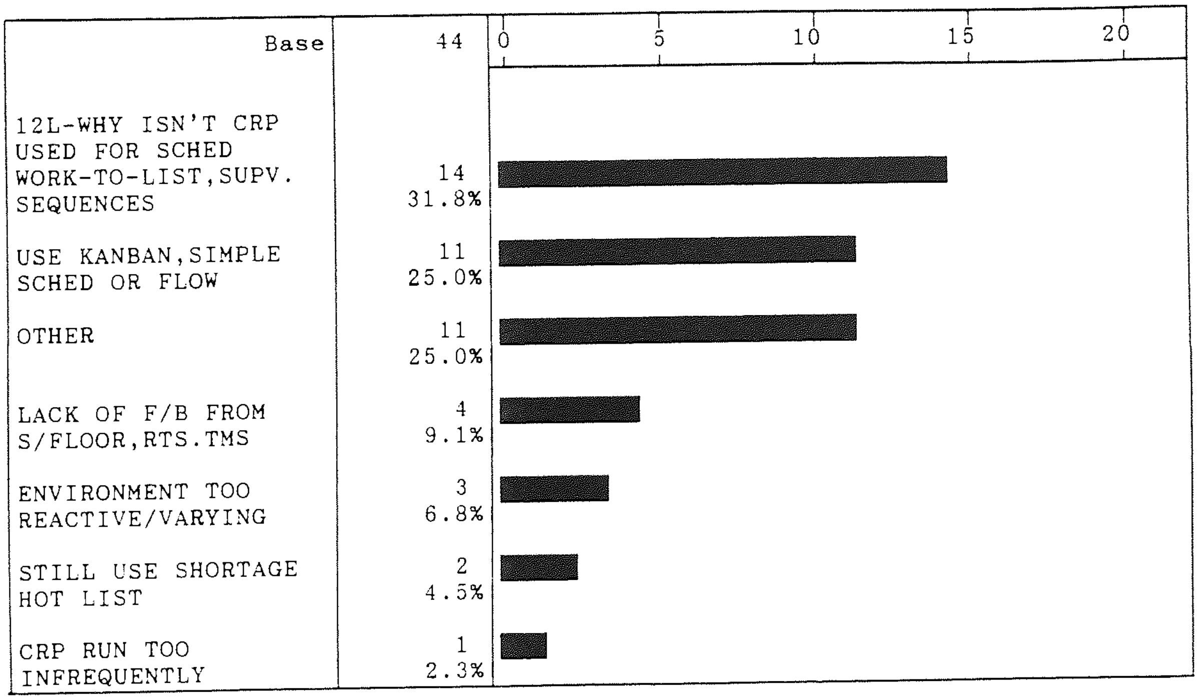


Question 12 k) asks whether CRP information is used for detailed shop floor scheduling. The following chart shows that for those who replied (52.1%), the majority did use it for scheduling.

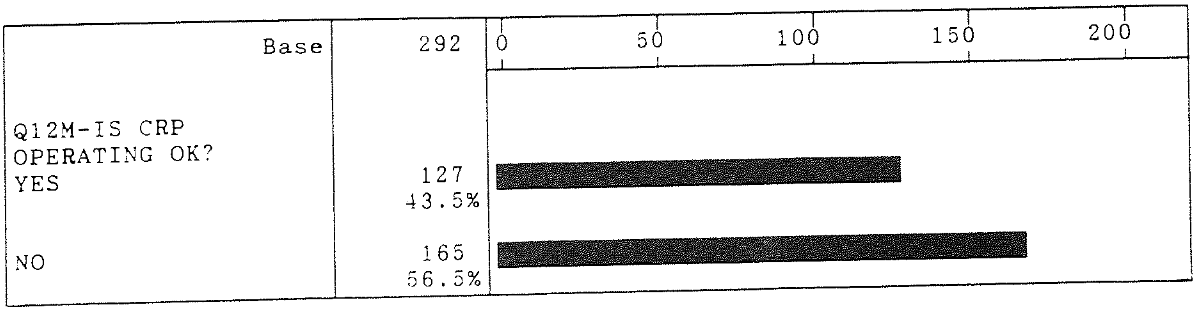


Question 12 l) tries to determine why CRP information is not used for shop floor scheduling. With only a limited response (44), the following responses were found (post-categorised).

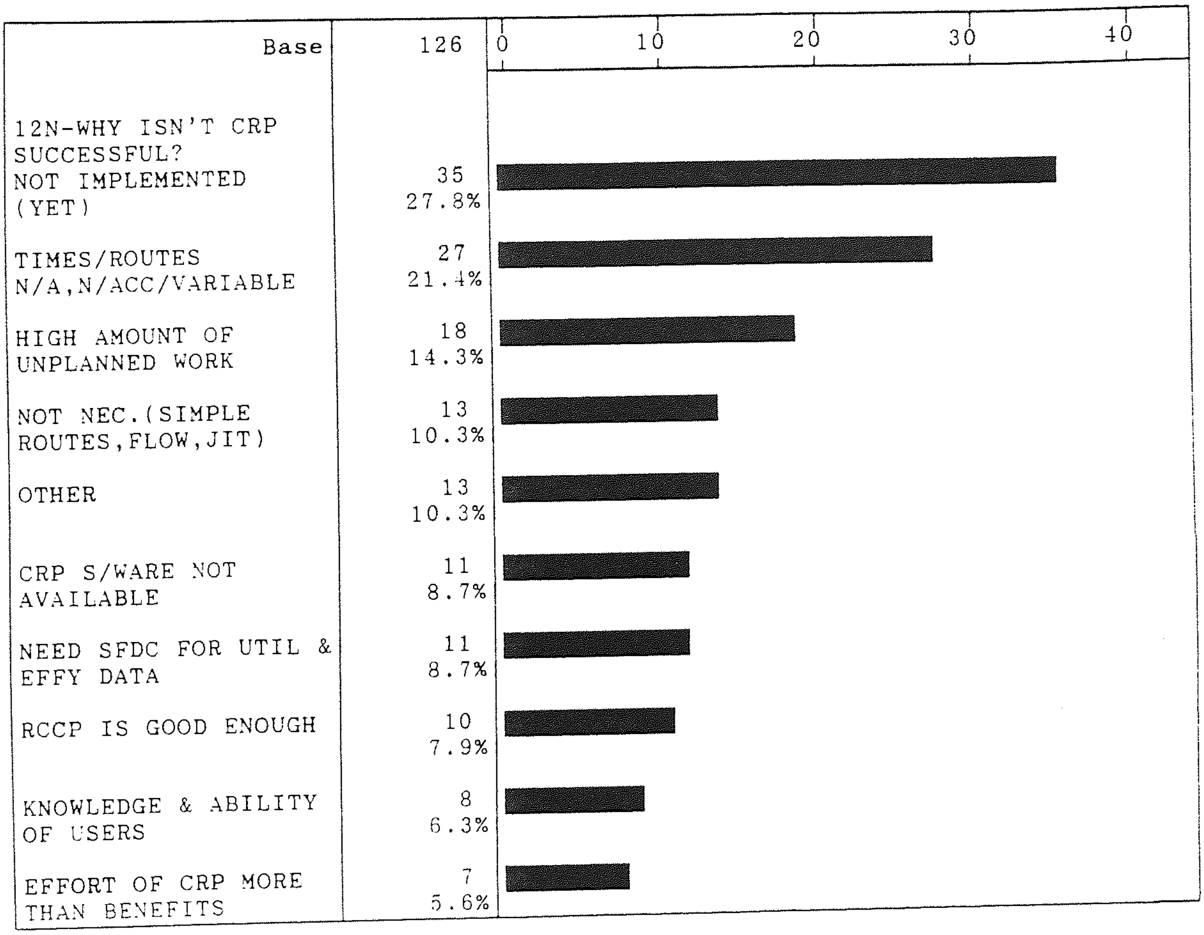
```
Bar chart...: 12L-WHY ISN'T CRP USED FOR SCHED
Cells.......: Absolute, Total %, Rows ordered
```



Question 12 m) asks whether CRP is operating successfully. The following chart of replies shows that the majority answering (56.5%) said NO.



Question 12 n) is an open question referring to the possible reasons as to why CRP may not be operating successfully. The replies were post-categorised and are as follows.



5.3.4 Section D. - Availability of Information for Capacity and Resource Planning.

This section tries to determine the availability of time, utilisation and efficiency information which is needed for capacity planning calculations.

Question 13 asks what proportion of current workload has standard times or estimates on it. The responses from virtually all respondents (346 out of 349) show that the average is 81% with a standard deviation of 31%.

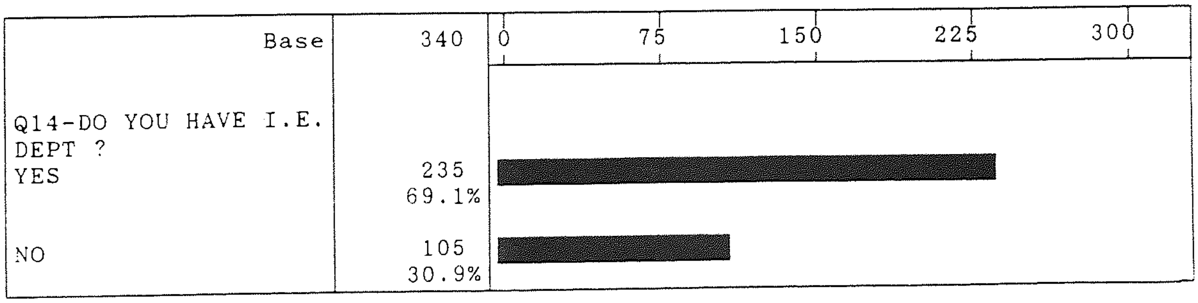
Statistics..: Q13-WHAT % OF WORK HAS TIMES?
Cells.......: Absolute

	Base	Valid	Mean	Minimum	Maximum
Q13-WHAT % OF WORK HAS TIMES?	349	346	80.72832	0	100

	Base	Standard Dev
Q13-WHAT % OF WORK HAS TIMES?	349	30.97148

Question 14 tries to determine the proportion of companies which have a specific department responsible for providing times for operations. The replies show that the vast majority do (69.1%).

Bar chart...: Q14-DO YOU HAVE I.E. DEPT ?
Cells.......: Absolute, Total %



Question 15 a) tries to determine the number of people involved in setting times in the companies replying. The responses show an average of 6.5 with a standard deviation of 12.8.

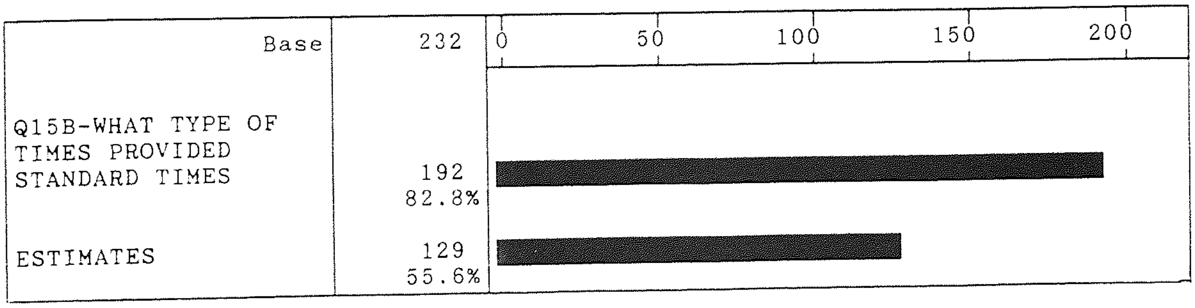
```
Statistics..: Q15A-HOW MANY I.E. STAFF?
Cells.......: Absolute

                         ____________________________________________________
                        |
                        |     Base|     Valid|       Mean| Minimum| Maximum|
 _______________________|____________________________________________________
|Q15A-HOW MANY I.E.     |     349        226 6.486726          1        99
|STAFF?                 |

                         _____________________
                        |
                        |           Standard|
                        |     Base|      Dev|
 _______________________|_____________________
|Q15A-HOW MANY I.E.     |     349  12.81462
|STAFF?                 |
```

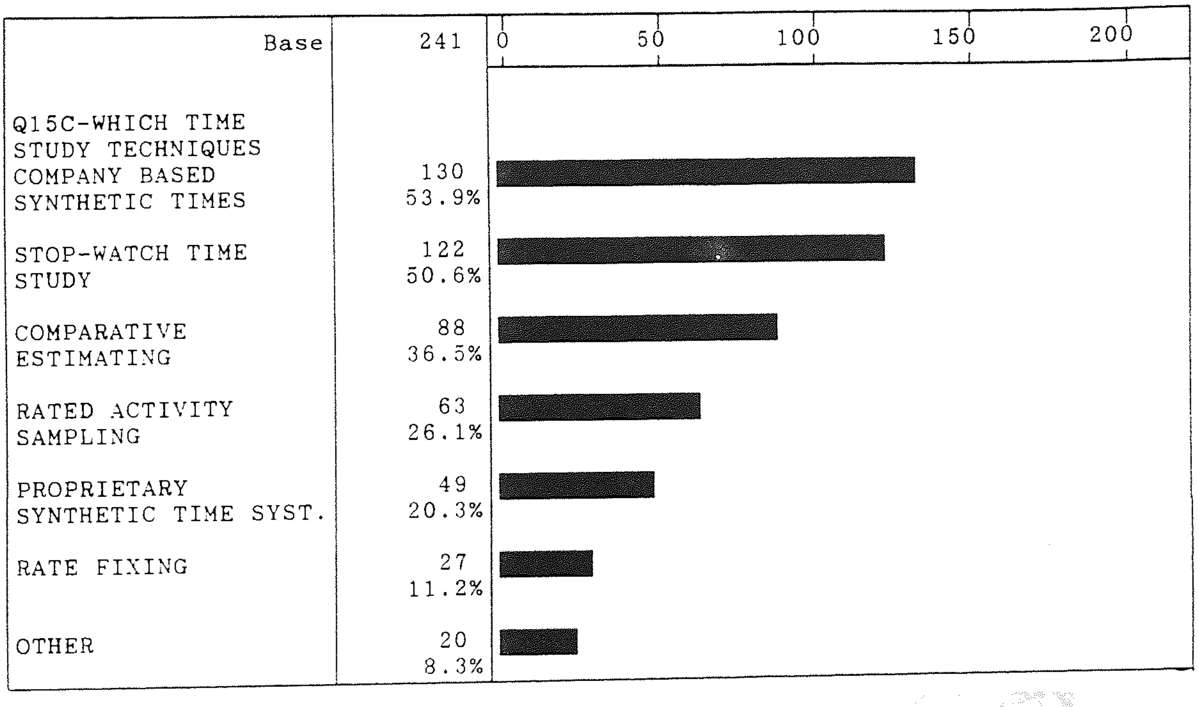
Question 15 b) asks whether Standard Times or Estimates (or both) are provided. The following chart shows in the majority of cases Standard Times are provided, but with many providing a mixture of both.

```
Bar chart...: Q15B-WHAT TYPE OF TIMES PROVIDED
Cells.......: Absolute, Total %, Rows ordered
```

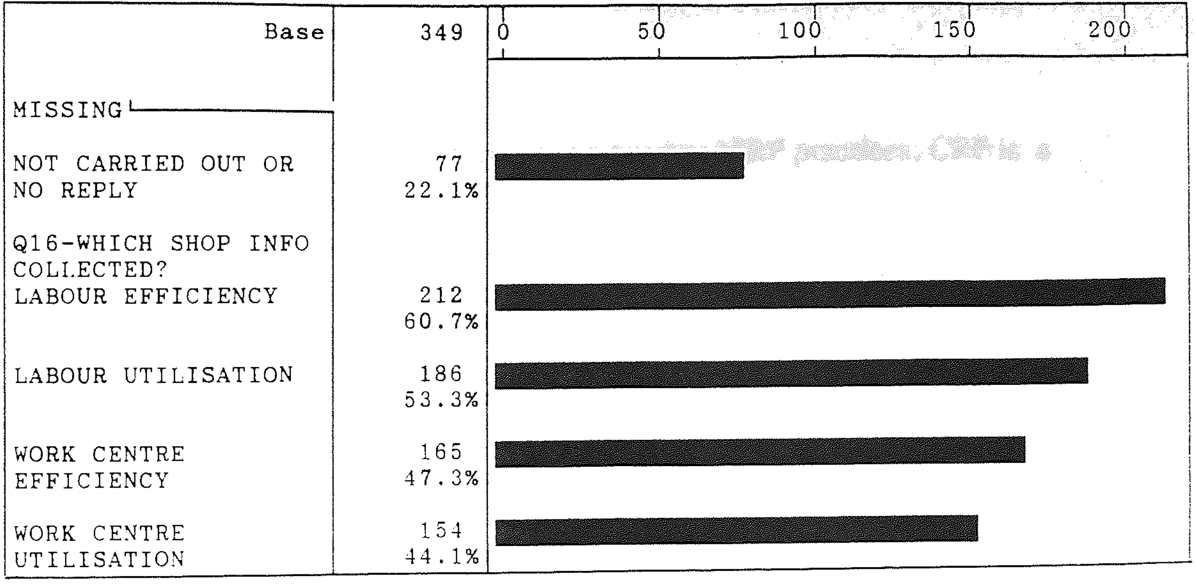


Question 15 c) tries to determine the Time Study techniques currently being used to provide times. The responses indicate that Company Based Synthetic Times are most used followed closely by Stop Watch Time Study.

```
Bar chart...: Q15C-WHICH TIME STUDY TECHNIQUES
Cells.......: Absolute, Total %, Rows ordered
```

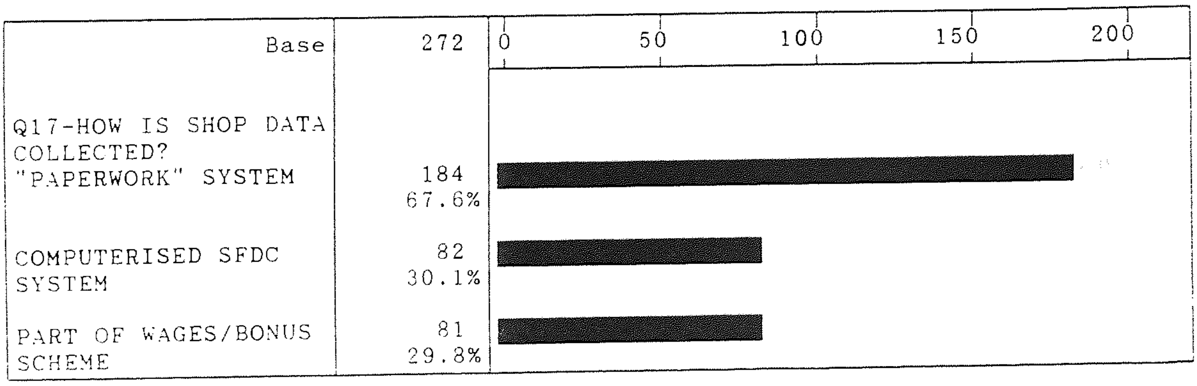


Question 16 moves on to the collection of Utilisation and Efficiency information for use in Capacity and Resource planning. The replies show that measures concerning labour are more likely to be collected than for work centres.



Question 17 tries to establish how the information above is collected and whether it is part of a wages/bonus system or whether it is collected for other reasons. The replies show that the majority of companies (67.6%) are still using paperwork collection systems and overall about a third are collecting the information as part of a wages/bonus scheme.

Bar chart...: Q17-HOW IS SHOP DATA COLLECTED?
Cells.......: Absolute, Total %, Rows ordered



Question 18 is an open question which tries to elicit any other comments regarding Resource and Capacity Planning. The replies were extremely varied and difficult to categorise. Below is a small sample of the type of responses received, in no particular order.

"Could not quote without RCCP."

"Main priority is to continue to develop MRP practices; CRP is a low priority."

"As MPS and RCCP allows smoother production scheduling, so the need for CRP decreases."

"Quality of data only capable of supporting RCCP."

"Due to complexity of purchased CRP module, have not implemented it, preferring to develop P.C. based program for RRP and CRP."

"RCCP is vital and provides a wonderful basis on which to plan."

"CRP is not used because it consistently shows the factory cannot achieve what it routinely does achieve - errors in lead time assumptions?"

"CRP can only work where the true reliability and capacity of the shop is understood in terms of bottle-neck resources."

"Need for CRP nullified by planning the RRP and MPS against a fixed (finite) production rate."

"Lack of CRP makes scheduling impossible, with the implementation of SFDC I hope this will improve."

"Major problem - capture of accurate Shop Floor Data."

"Before CRP the shop floor was out of control. SFDC was essential for data accuracy. Finite capacity planning has proved to be very successful."

"Level of complexity and variety makes anything other than RCCP impractical."

"With critical work centres capacity planned, benefits in ability to offer customer available capacity 'real time'".

> "Purchased MRPII five years ago - never used capacity planning and scheduling side. This year purchased finite capacity scheduler - fits better with moves to JIT."

> "Lack of formal CRP has resulted in appalling service level and consequent loss of sales and sales contracts."

> "Capacity planning is an essential process, difficult to crack but still trying hard" (One of the earliest UK OPT users).

5.4 Summary.

From the wealth of information generated by this survey, it is perhaps useful to try and summarise some of the main findings.At this point it probably worth adding a caveat regarding the state of the U.K. business environment in late 1990 in terms of the recession and its effect on spare capacity and perhaps, therefore, a reduction in the emphasis on the need for Capacity Planning.

In terms of the number of companies claiming to carry out Resource and Capacity planning, Rough Cut Capacity Planning appears to be used the most as shown in figure 5.1.

Another result which is as important , if not more important, is the percentage of respondents who regarded a particular capacity planning approach as being operating successfully in their plant. Figure 5.2 shows that Rough Cut Capacity Planning is thought to be more successful than the others.

To interpret the results in terms of how many organisations have successfully operating capacity planning systems, the total sample base should perhaps be taken as more representative, since many respondents did not answer these particular questions since they did not carry out the capacity planning approach at all. Figure 5.3 shows the summary of these results.

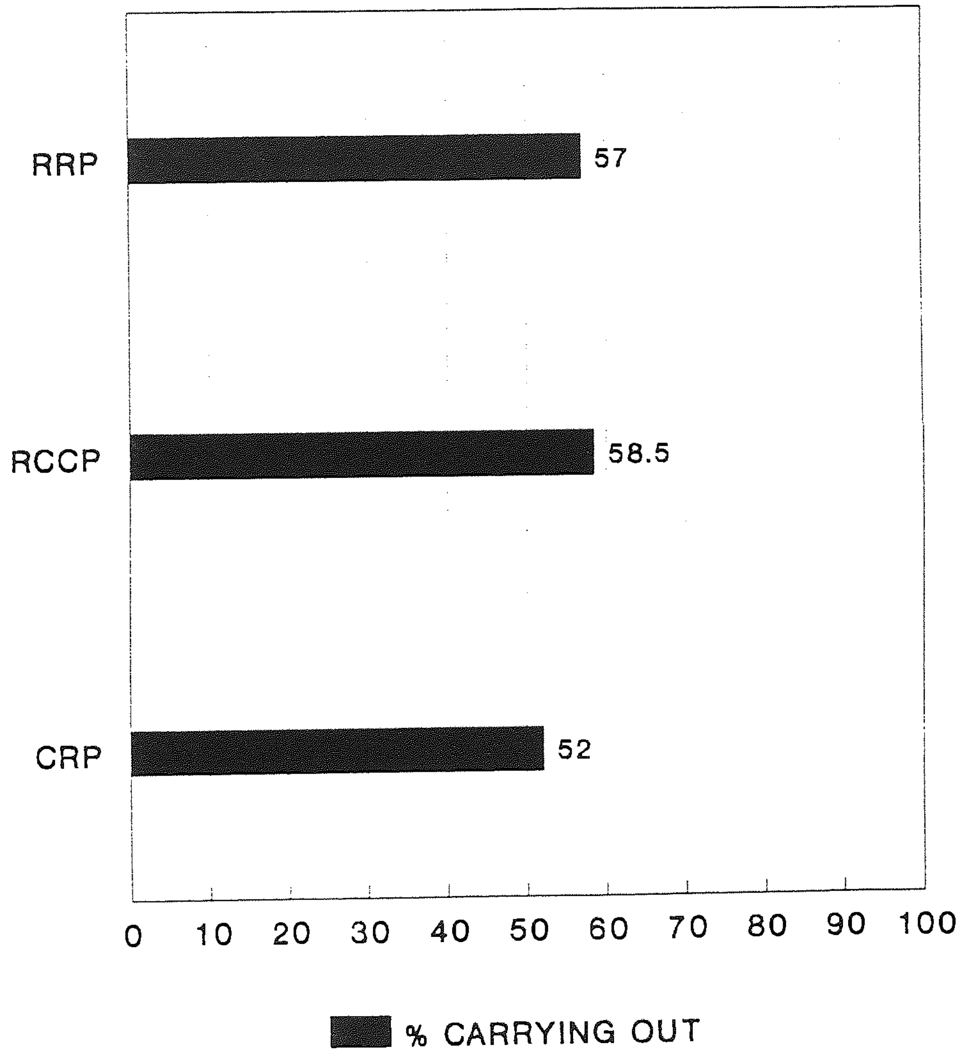
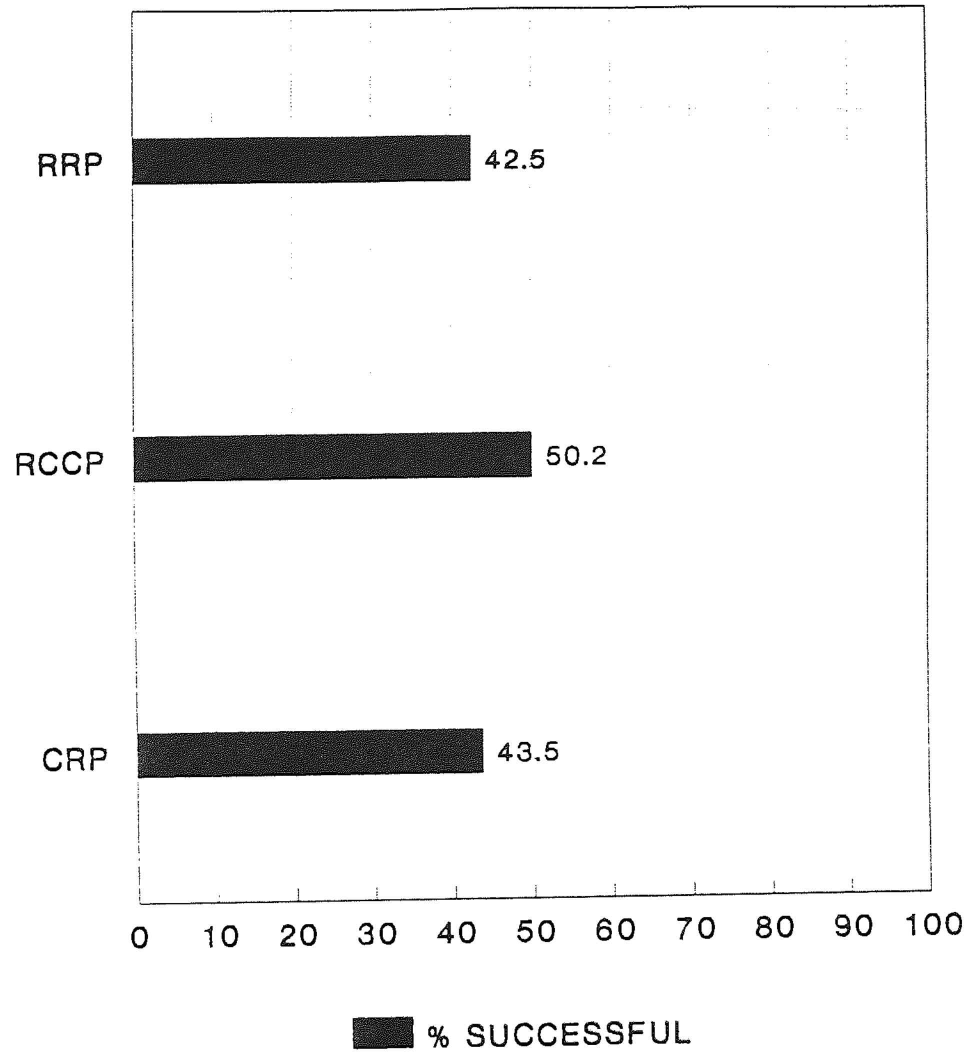
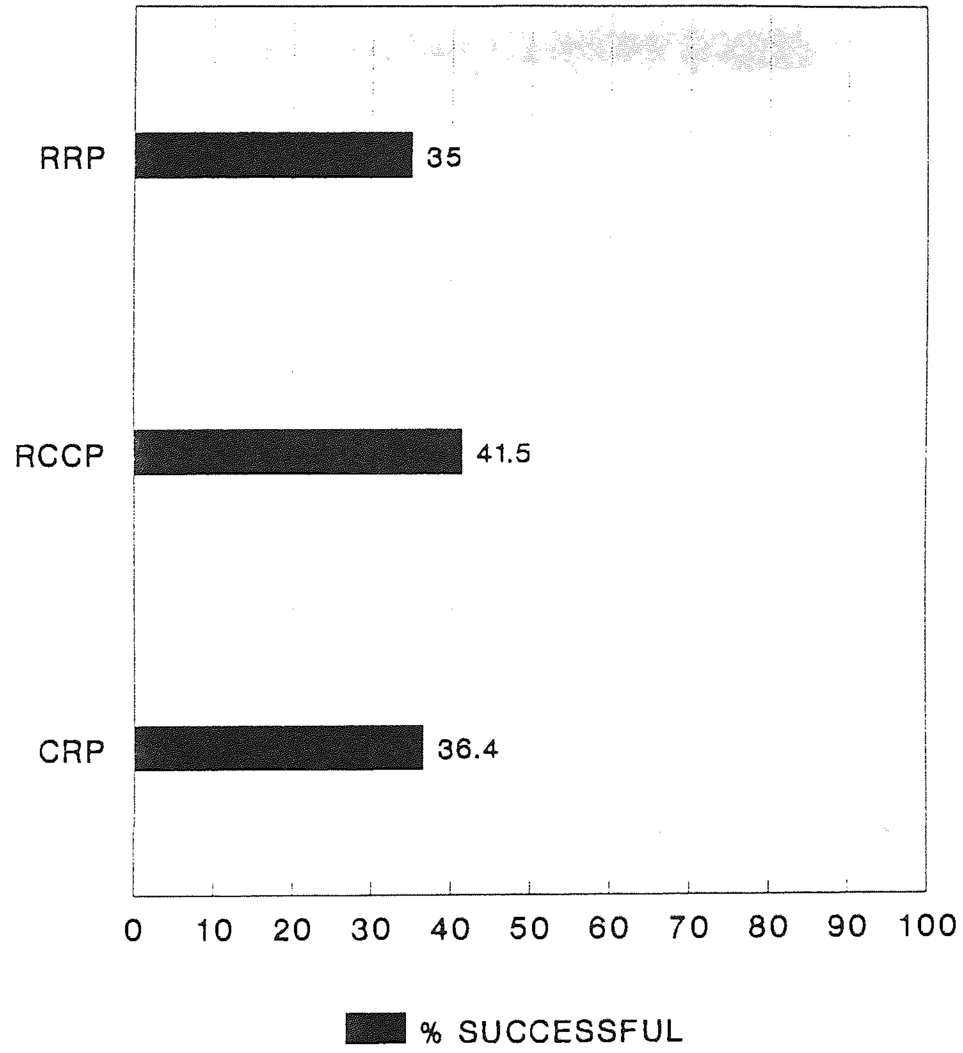


Figure 5.1 Percentage of Companies carrying out different levels of capacity planning.



(BASE: THOSE ANSWERING)

Figure 5.2 Percentage of Companies regarding capacity planning approaches as successful. (based on companies answering question)



(BASE: TOTAL SAMPLE)

Figure 5.3 Percentage of Companies regarding capacity planning approaches as successful. (based on total sample).

In looking at the detailed procedures involved in the various planning approaches, the following conclusions can be drawn.

Firstly, the average planning horizon used is shown in figure 5.4.

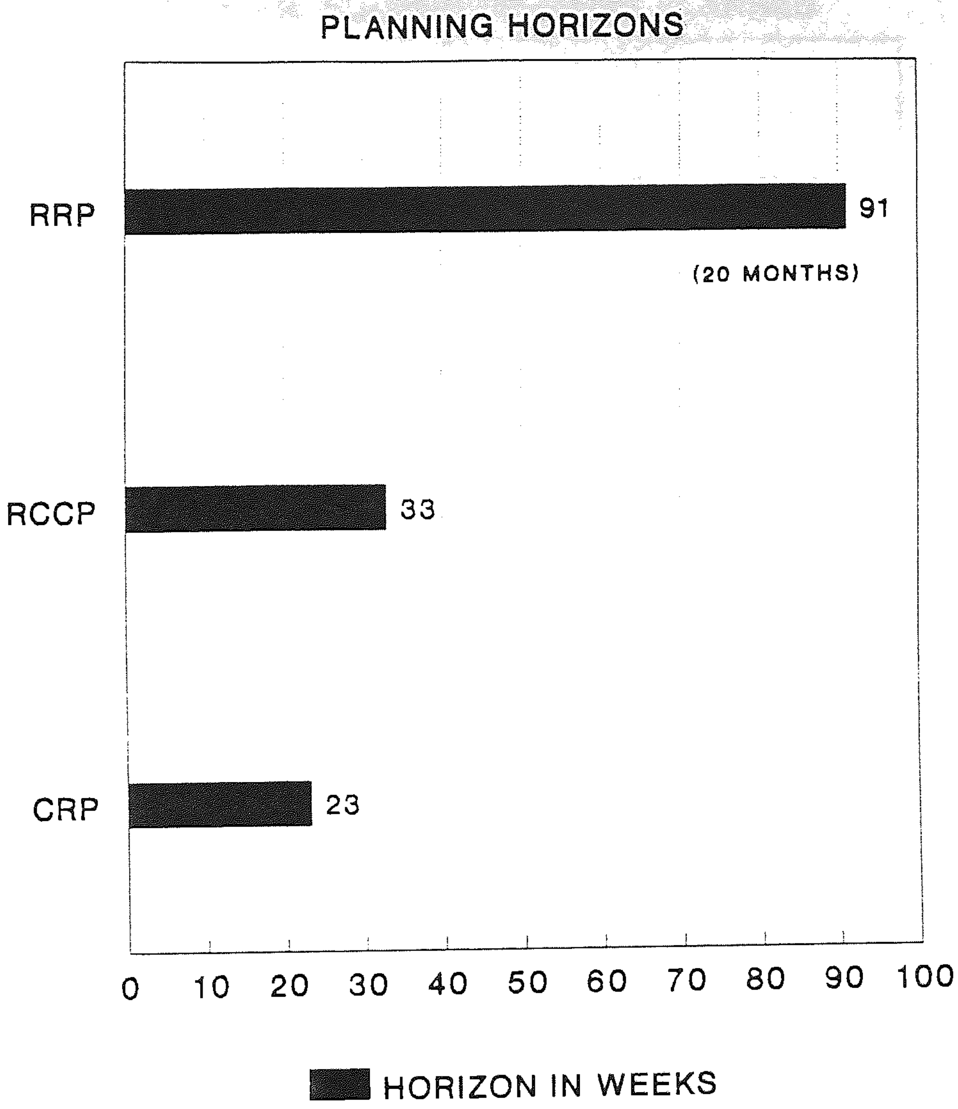


Figure 5.4 - Average Planning Horizons.

Secondly, the most used planning periods are months for RRP, changing to weeks for RCCP and CRP. Next the frequency of calculation changes from monthly for RRP and RCCP to weekly for CRP.

The average number of items planned in each of the three planning approaches is shown in figure 5.5.

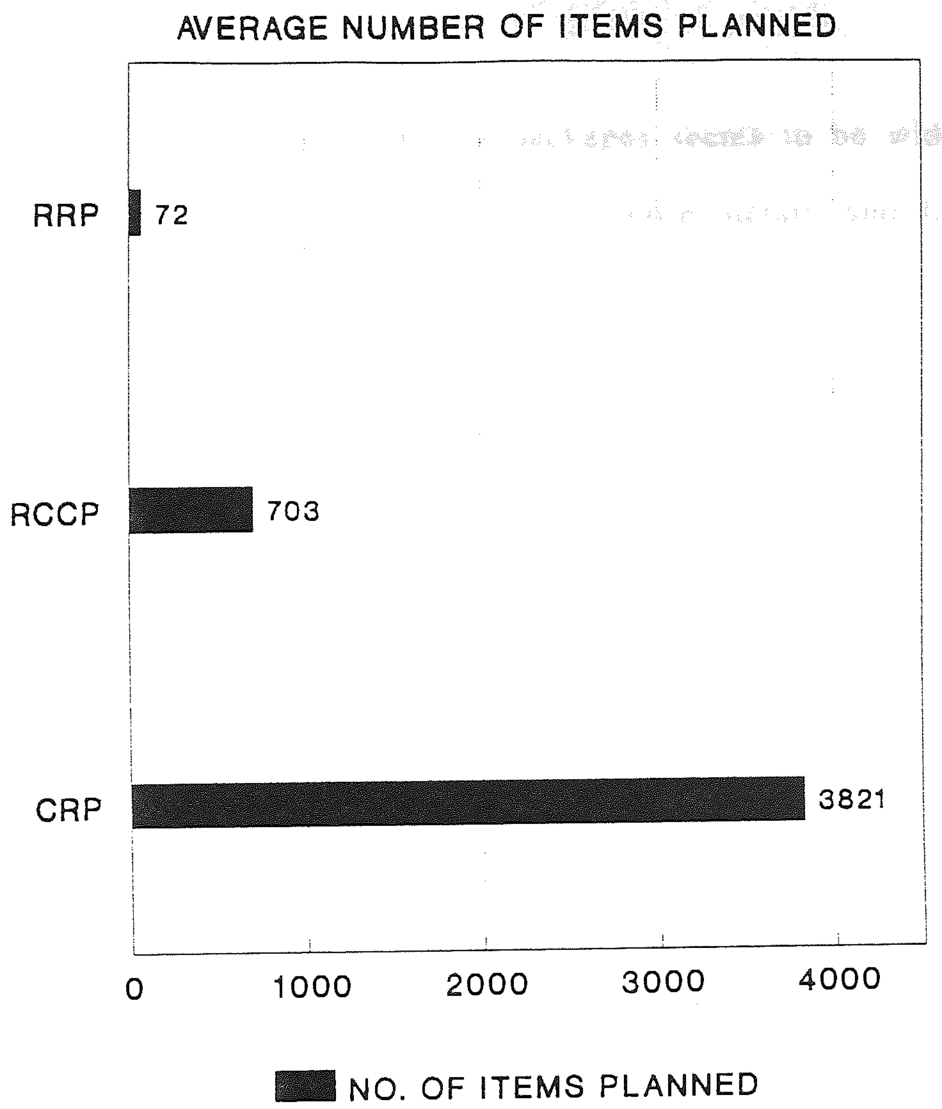


Figure 5.5 - Average number of items planned.

In all three approaches, Standard Hours are the most commonly used units of measure. In terms of level of detail, for RRP, Total Plant, Department and Work Centre are almost equally popular whilst for RCCP and CRP the Work Centre is the most common.

Of the 52% who answered the particular questions, approximately 56% fed back CRP information to the MPS and 71% used CRP information for shop floor scheduling. The corresponding percentages of the total sample are 29% feeding back and 36% using for shop scheduling.

The use of P.C. based Spreadsheet packages seems to be widespread for capacity planning, with diminishing use as more detail and data becomes necessary as shown in figure 5.6.

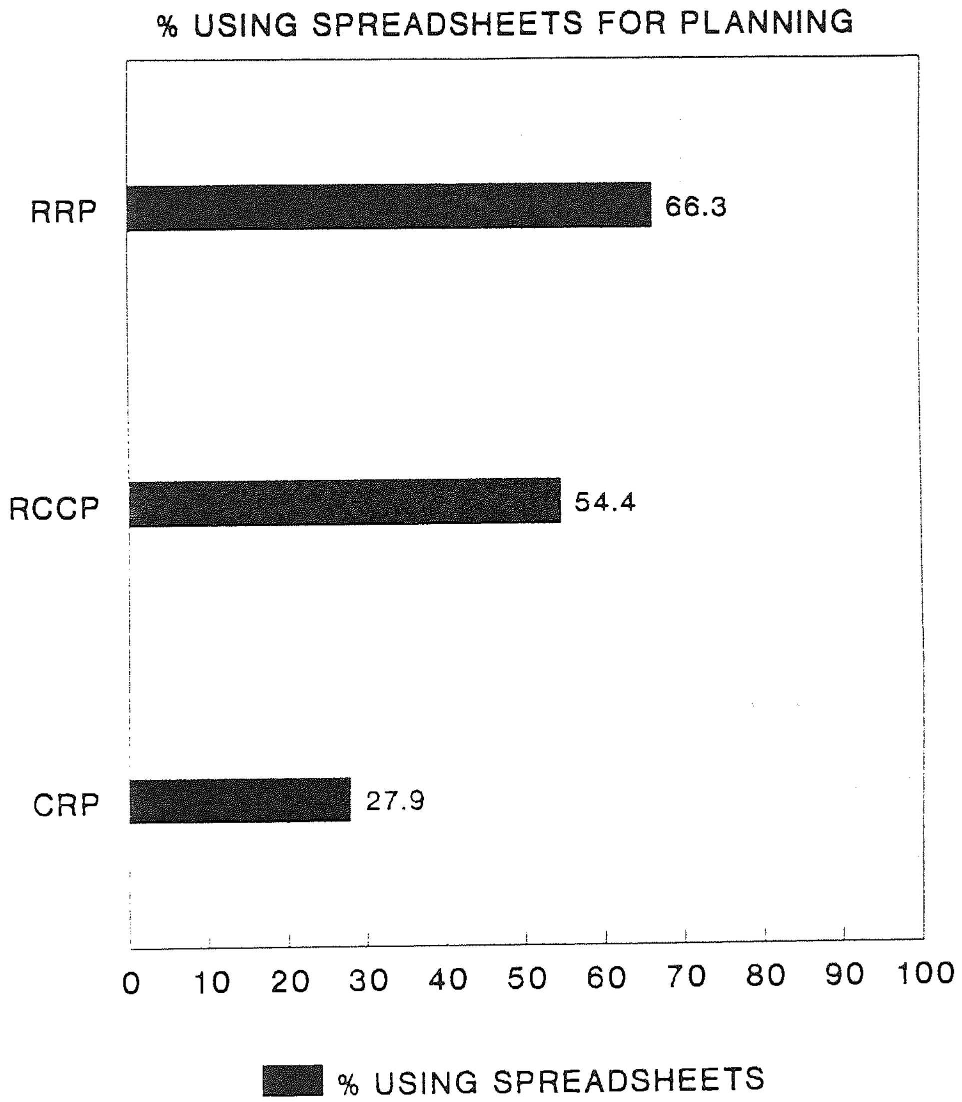


Figure 5.6 - Use of Spreadsheet Packages for capacity planning.

In chapter 7 comparisons with MPS and Capacity Planning theory will be made with the detailed and summarised findings of actual practice outlined in this chapter. In chapter 8, overall conclusions will be drawn.

6. NATIONAL SUPPLIER SURVEY OF CAPACITY REQUIREMENTS PLANNING IN MANUFACTURING PLANNING AND CONTROL SYSTEMS AND ANALYSIS OF AVAILABLE SOFTWARE.

6.1 Introduction

In order to obtain the views of suppliers on this subject, to ascertain the take-up of resource and capacity planning modules by users and to determine the facilities offered by the latest software packages, a detailed, two part questionnaire was developed and sent out in November 1990 to the major software suppliers in the United Kingdom.

6.2 Methodology

As with the User Questionnaire, the SNAP-2 package was chosen for analysis purposes and a draft questionnaire developed and tested in a pilot study on three software houses. A final version was then produced.

The Supplier Questionnaire, shown in Appendix 11, is split into two parts. The first is concerned with the supplier's current sales of capacity and resource planning modules and also their views on the barriers to successful use of RRP, RCCP and CRP. The second part deals with the modules included in each of the packages sold by the supplier and specifically the capacity planning facilities offered.

The population for the Supplier Survey was taken from the suppliers of Production Management packages in the BPICS/Industrial Computing Sourcebook 1990/91 (1990) and numbered 90.

In order to validate some of the responses to the supplier survey in terms of modules offered from a relatively small sample size (27), a further analysis of the 124 Production Management Software packages described in the BPICS/Industrial Computing Sourcebook 1990/91 (1990) was undertaken.

The basic analysis of part one of the questionnaire is covered in the next section. The basic analysis of part two of the questionnaire is dealt with in section 6.4 and the analysis of the available software packages is covered in section 6.5. Finally, a summary of the these analyses is dealt with in section 6.6.

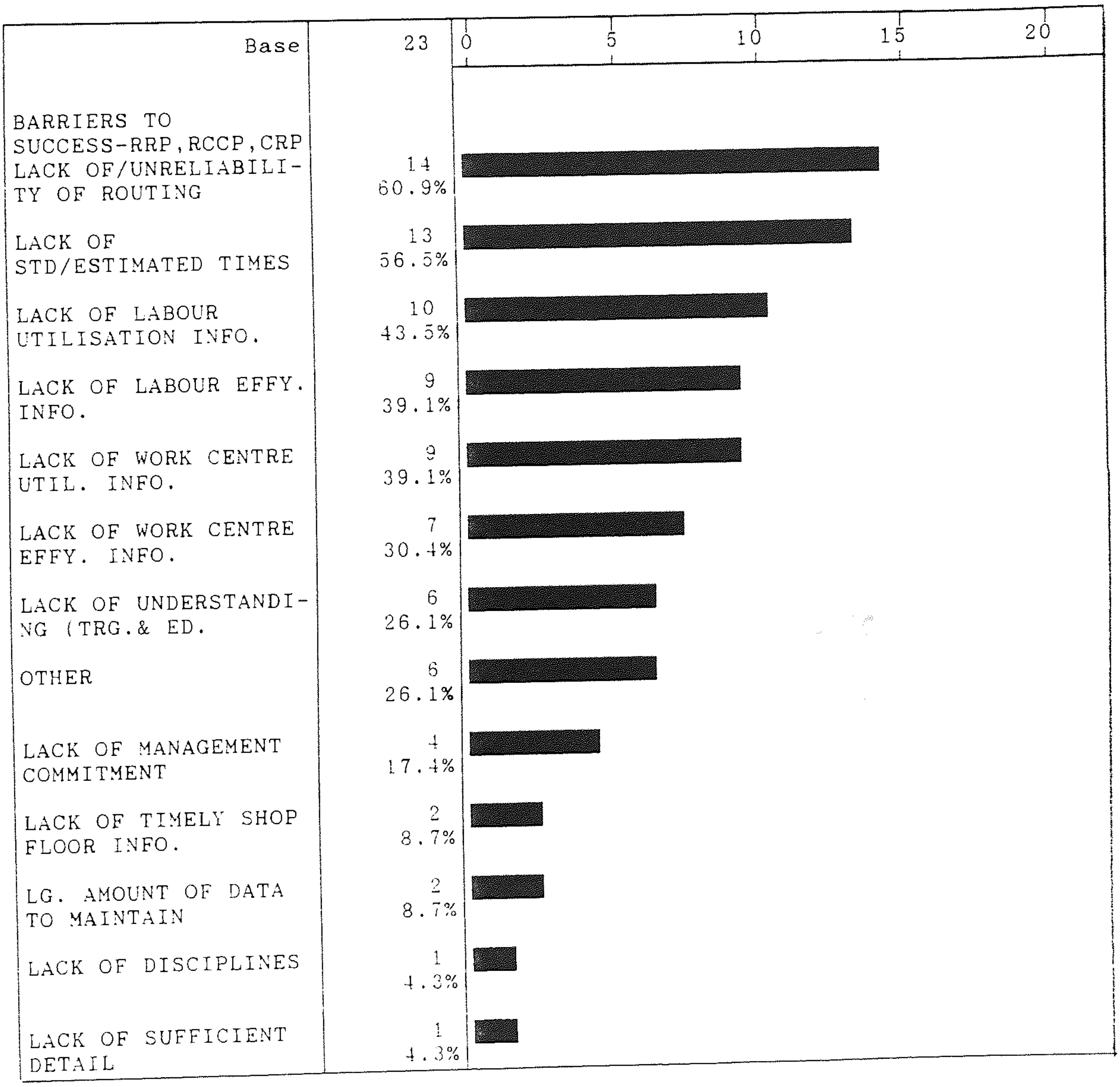
6.3 Analysis and Results (Part 1.)

Of the 90 questionnaires sent out, 23 replies were received, a response rate of 26% which was regarded as good.

The following is a question-by-question analysis of the responses.

Question 1 concerned the proportion of system sales which included RRP, RCCP and CRP. The responses revealed that 55.5% included RRP with a standard deviation of 38.3%, 52.4% included RCCP with a standard deviation of 36.9% and 54.4% included CRP with a standard deviation of 35.5%.

Question 2 asked suppliers to give their views on the main barriers to the successful use of RRP, RCCP and CRP in user companies. The following is an analysis of the replies.



As can be seen, the lack of routing information or its unreliability was the reply most often given, followed closely by the lack of standard or estimated times.

6.4 Analysis and Results (Part 2.)

Of the 90 questionnaires sent out, replies were received from 23 software companies, giving 27 Part 2 responses concerning the Production Management packages sold by them.

The following is a question-by-question analysis of the responses.

Question 1 concerned the type of production operations to which the package was best suited. As can be seen from the following responses, all packages were suited to small and medium batch manufacturing and only 63% were suited to repetitive operations.

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Bar chart...: TYPE OF OPS IS PACKAGE SUITED?
Cells.......: Absolute, Total %, Rows ordered
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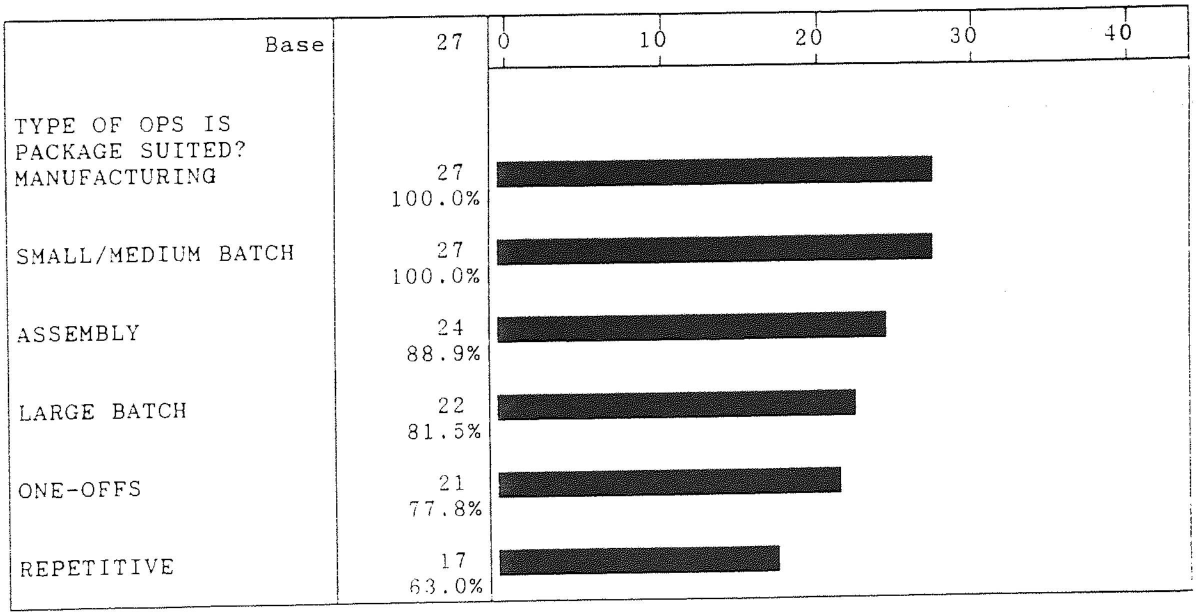

Question 2 asked which type of hardware the package was designed to run on. The replies show that mini based systems are most offered.

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Bar chart...: TYPE OF H/WARE DESIGNED FOR?
Cells.......: Absolute, Total %, Rows ordered
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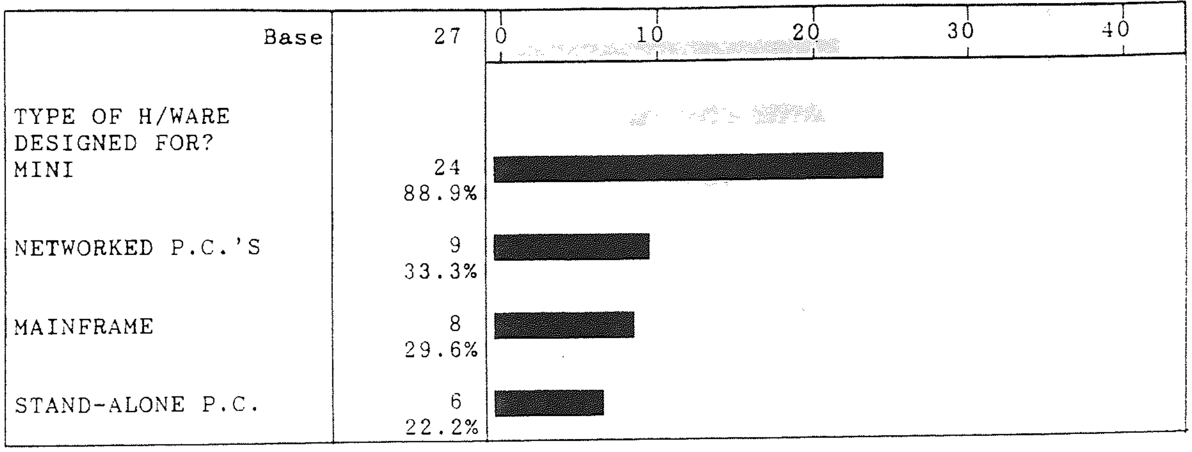
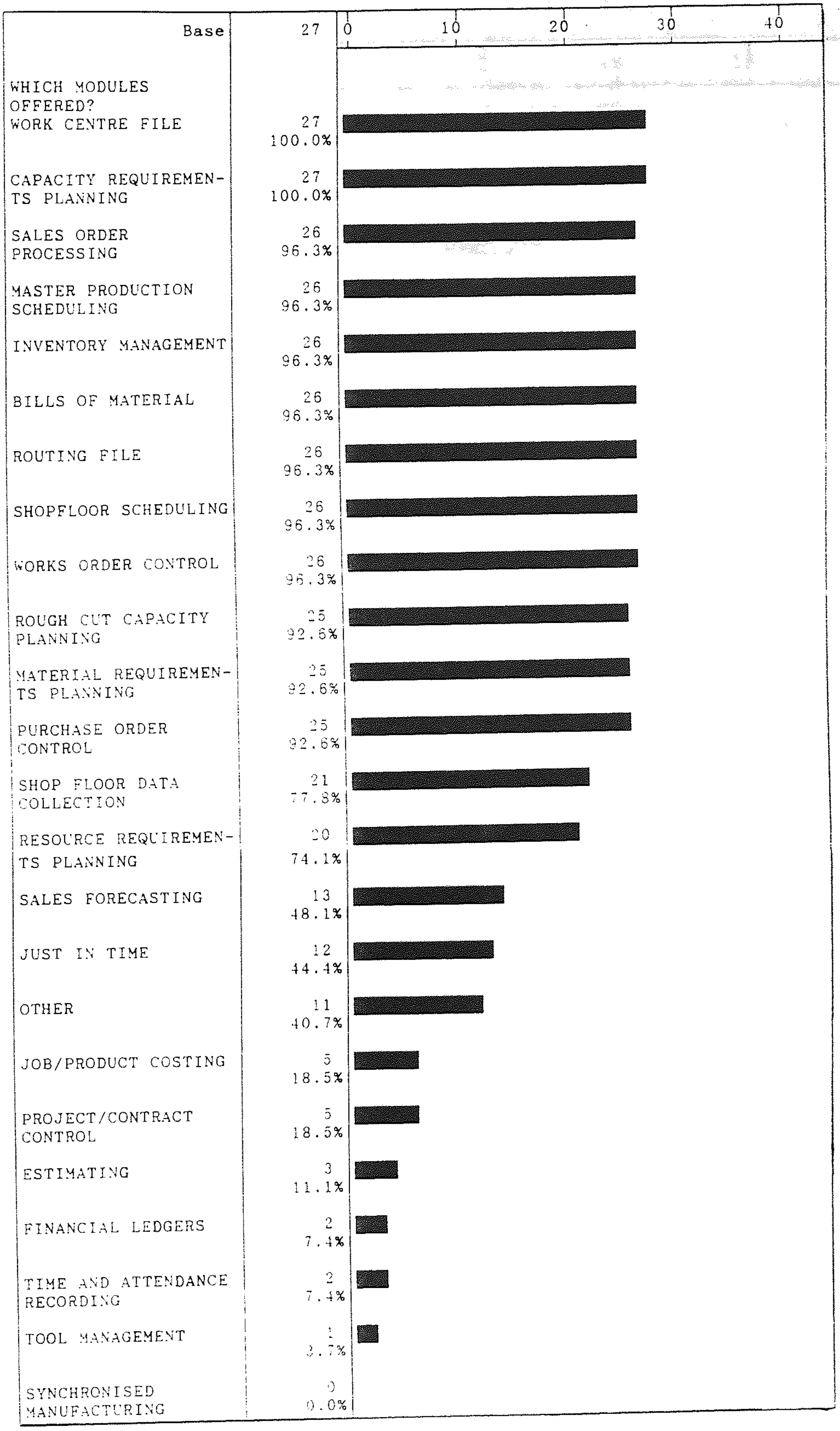


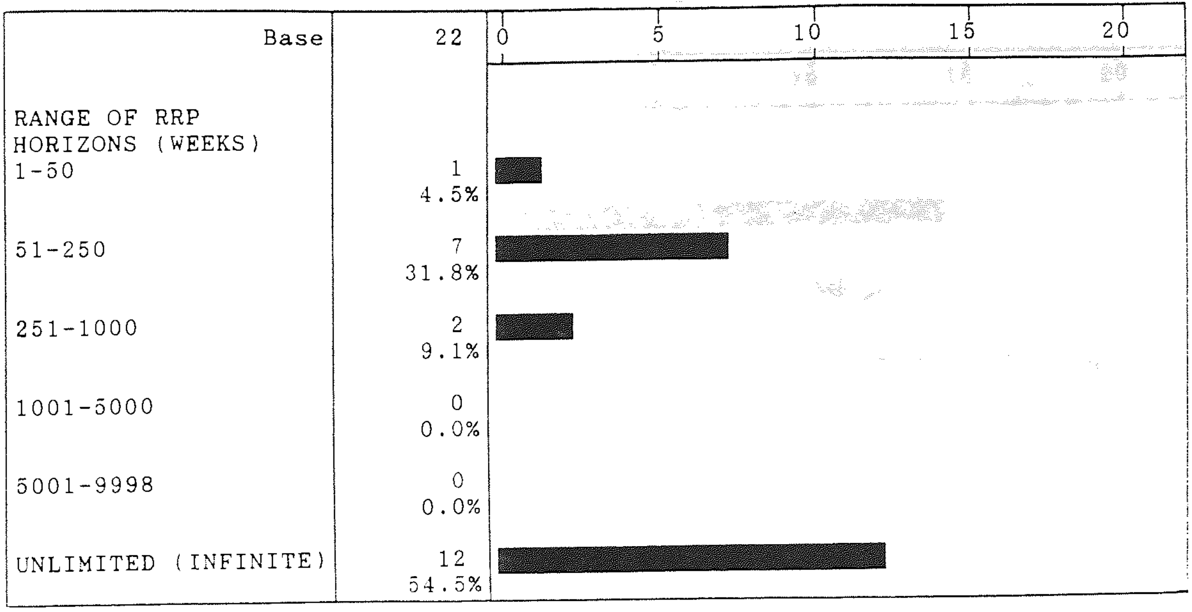
Question 3 tried to ascertain which modules were offered as part of the package. The replies are as shown overleaf.

Question 4 asked whether the package offered the facility of downloading data into P.C. spreadsheets. The replies show that 100% of the packages do offer this.

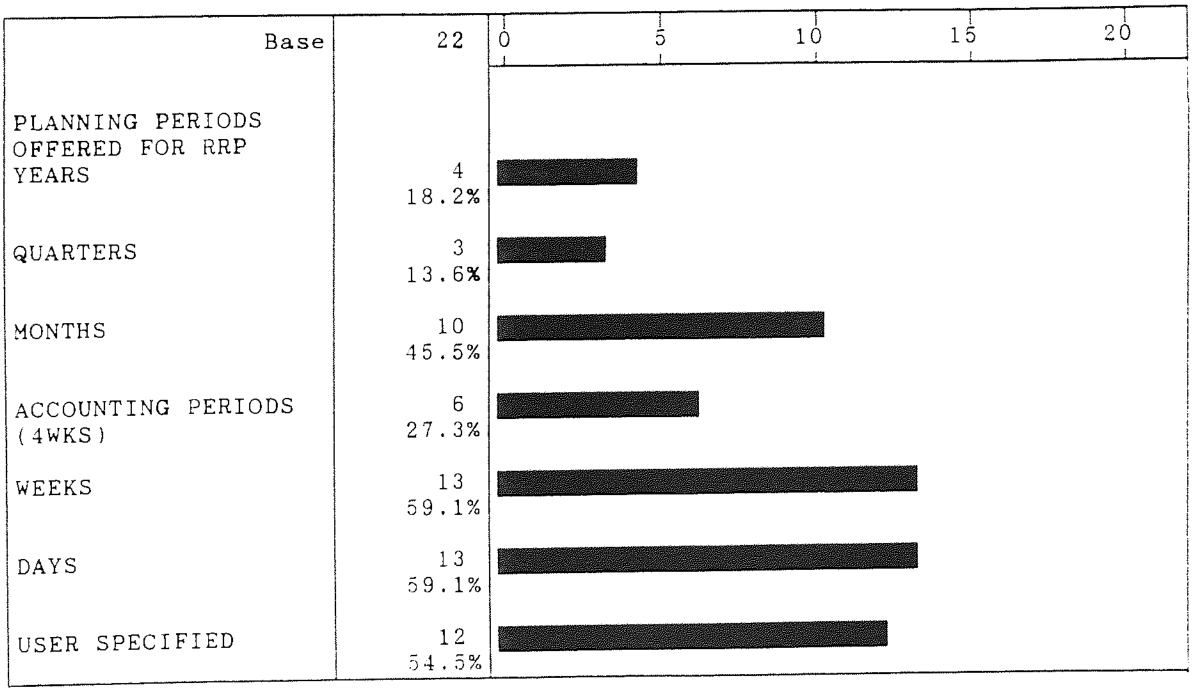
The following seven questions concern the detailed features offered for Resource Requirements Planning (RRP).



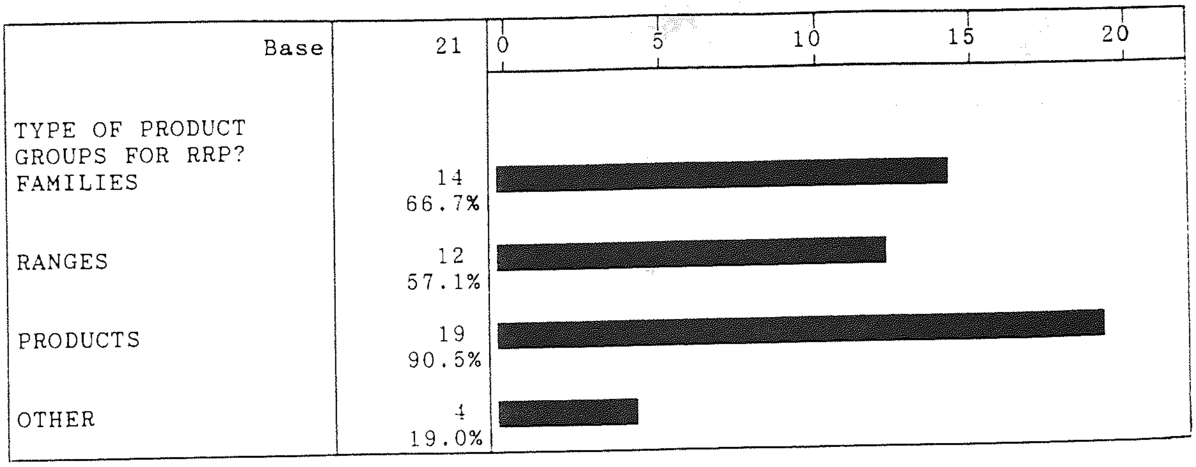
Question 5 asked what was the longest planning horizon offered for RRP. The replies show that the majority of packages offer an unlimited horizon.



Question 6 concerned the planning periods (buckets) offered for RRP. The responses show that weeks and days and user specified periods are most often offered.

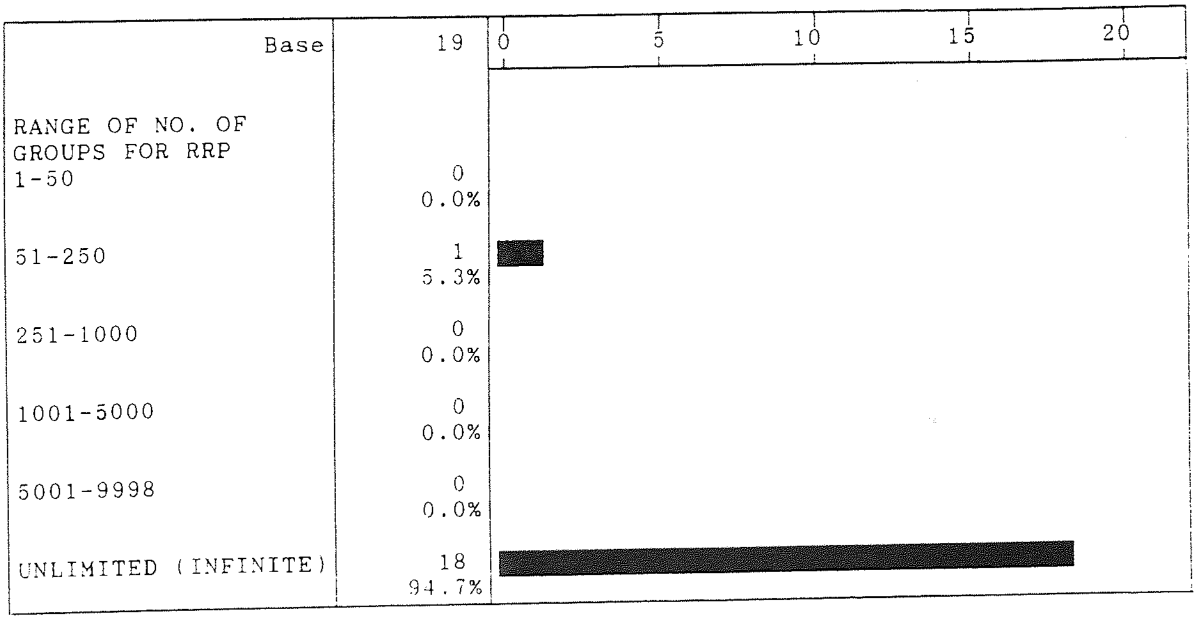


Question 7 asked what type of product groupings can be accommodated for RRP. The most common answer was "products".



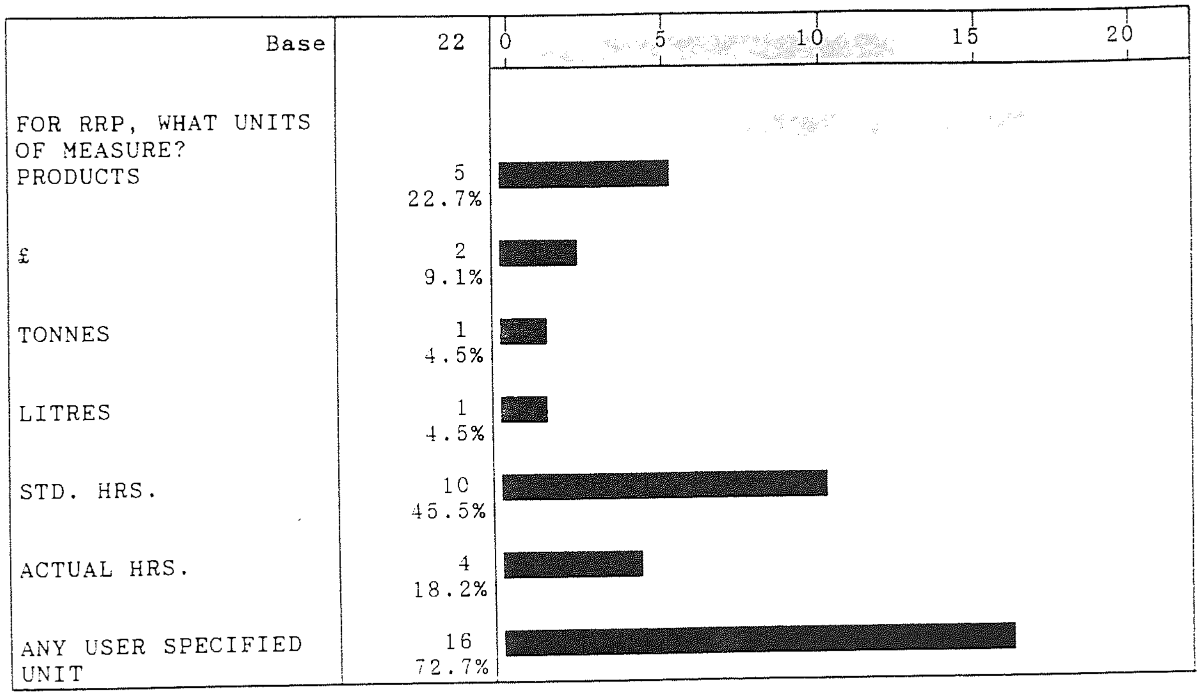
Question 8 concerned the maximum number of product groups that can be accommodated for RRP. As can be seen, virtually all packages offered an unlimited number.

Bar chart...: RANGE OF NO. OF GROUPS FOR RRP
Cells.......: Absolute, Total %

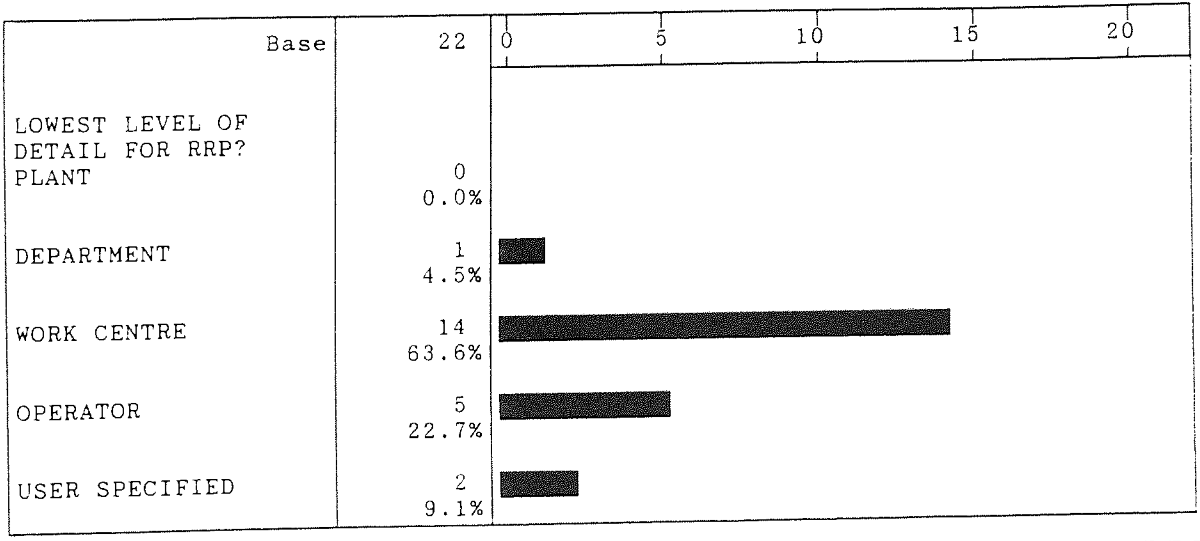


Question 9 asked which units of measure the package supported for RRP. Most often, any "user specified unit" could be used followed by "Standard Hours".

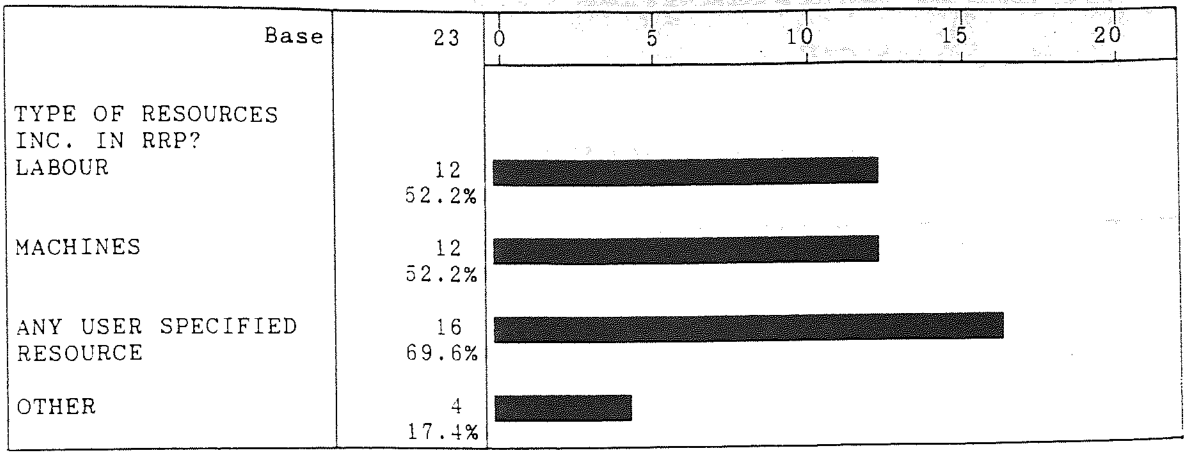
Bar chart...: FOR RRP, WHAT UNITS OF MEASURE?
Cells.......: Absolute, Total %



Question 10 concerned the lowest level of detail to which RRP could be taken. Results show that the "Work Centre" is the reply given most often.

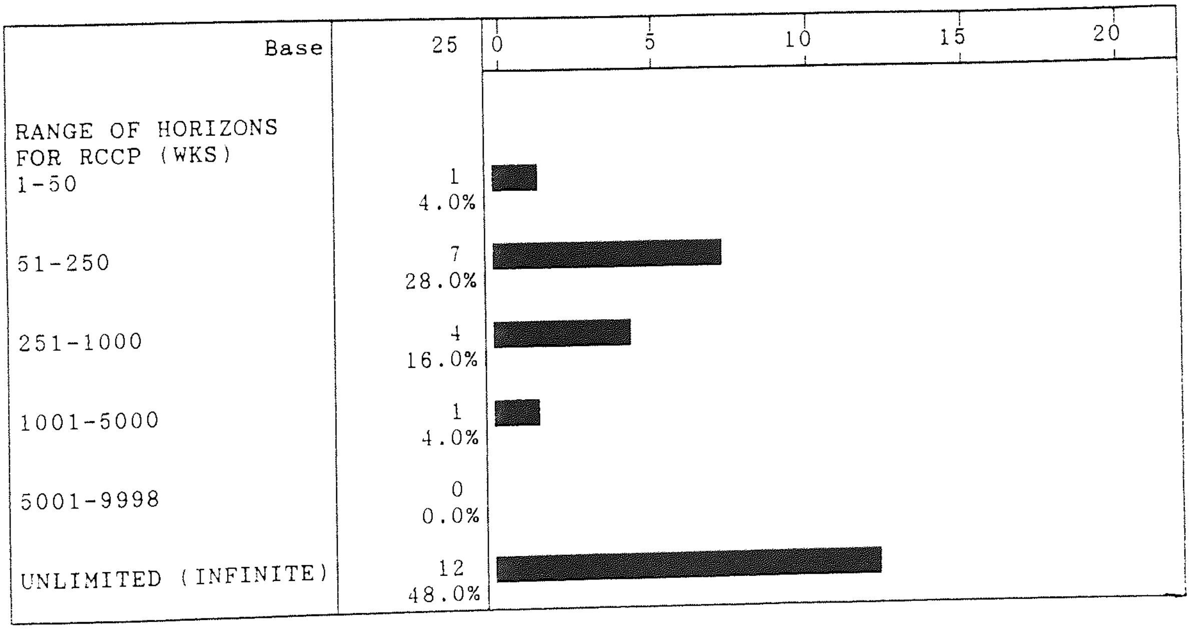


Question 11 asked which type of resources could be included in RRP. The replies show that "any user specified resource" is the reply most often given.



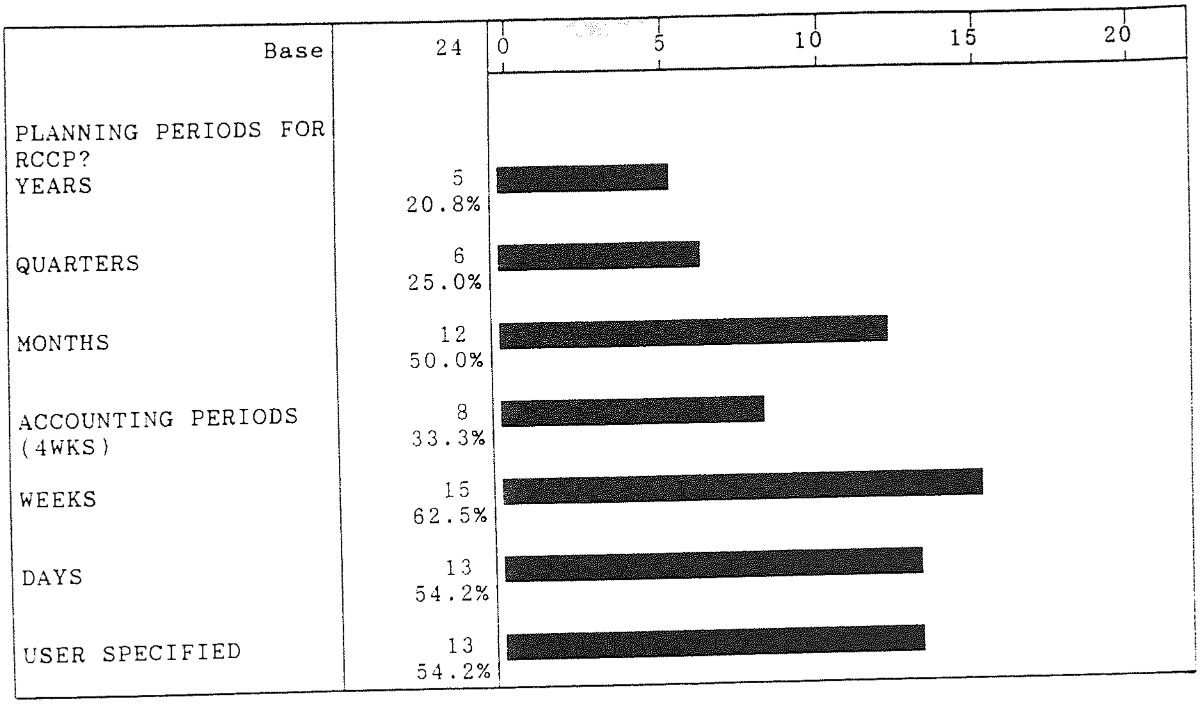
The following seven questions relate to the detailed features offered for Rough Cut Capacity Planning (RCCP).

Question 12 concerned the longest planning horizons allowed for RCCP. The following analysis of replies shows that many packages offer an unlimited horizon.

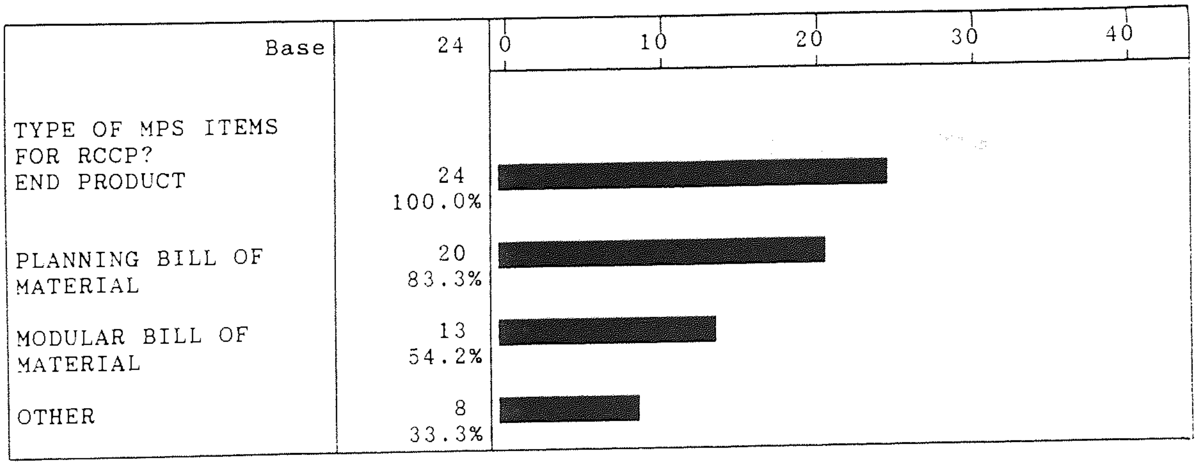


Question 13 asks which planning periods (buckets) are offered for RCCP. The replies show that "weeks" is most often offered.

Bar chart...: PLANNING PERIODS FOR RCCP?
Cells.......: Absolute, Total %

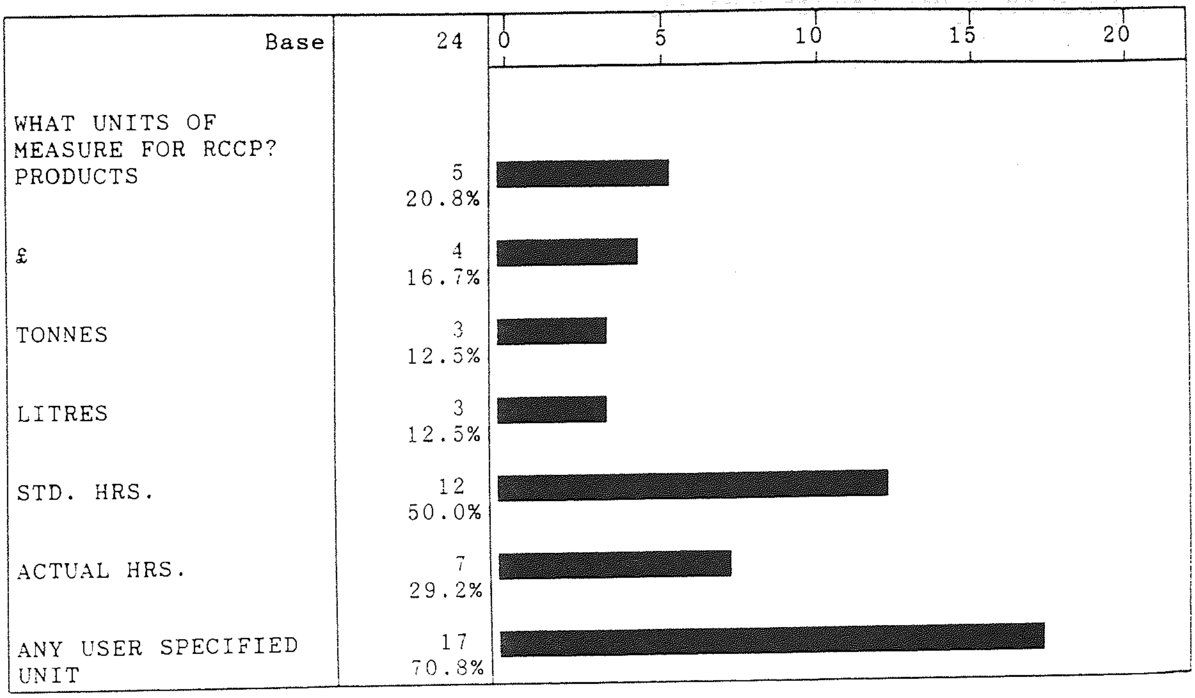


Question 14 concerned the type of MPS items accommodated in RCCP.

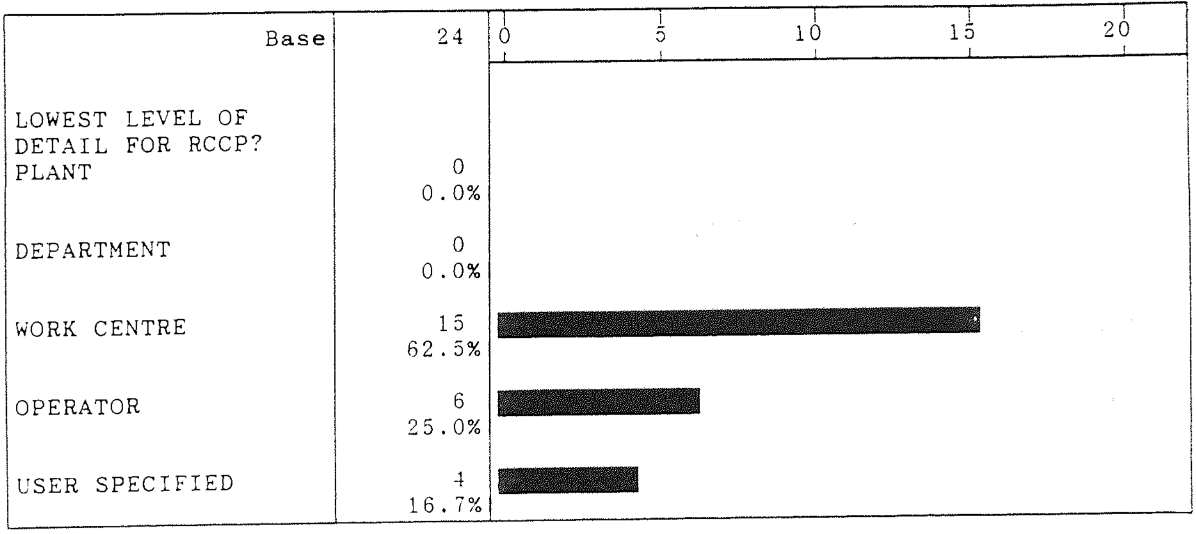


Question 15 asked what was the maximum number of MPS items that could be accommodated in the package for RCCP. The replies show that all packages cater for an unlimited number of items.

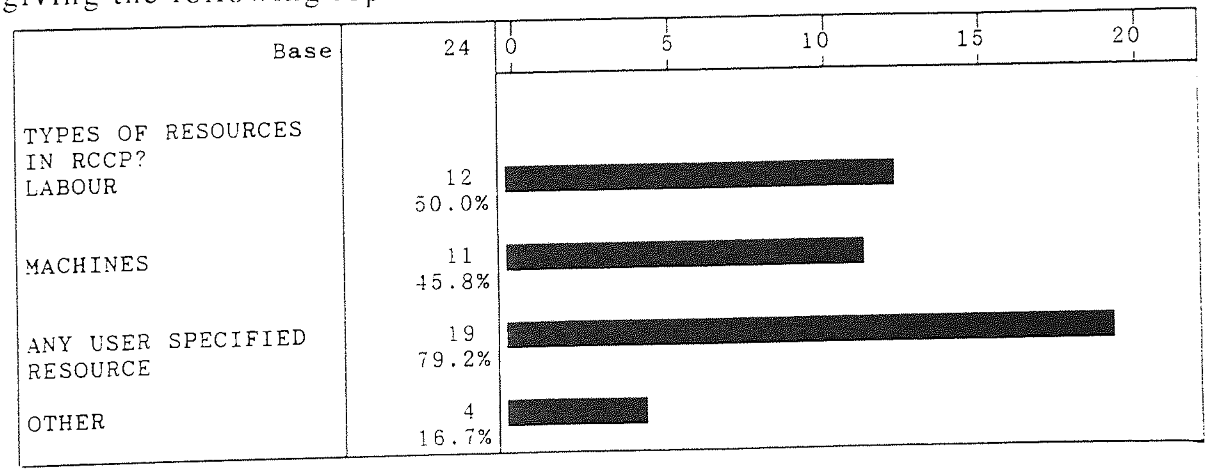
Question 16 asked what units of measure the package supports for RCCP. The replies show that most often the user can specify the unit.



Question 17 concerned the lowest level of detail to which RCCP could be taken. Replies show that the "Work Centre" is the most common answer.

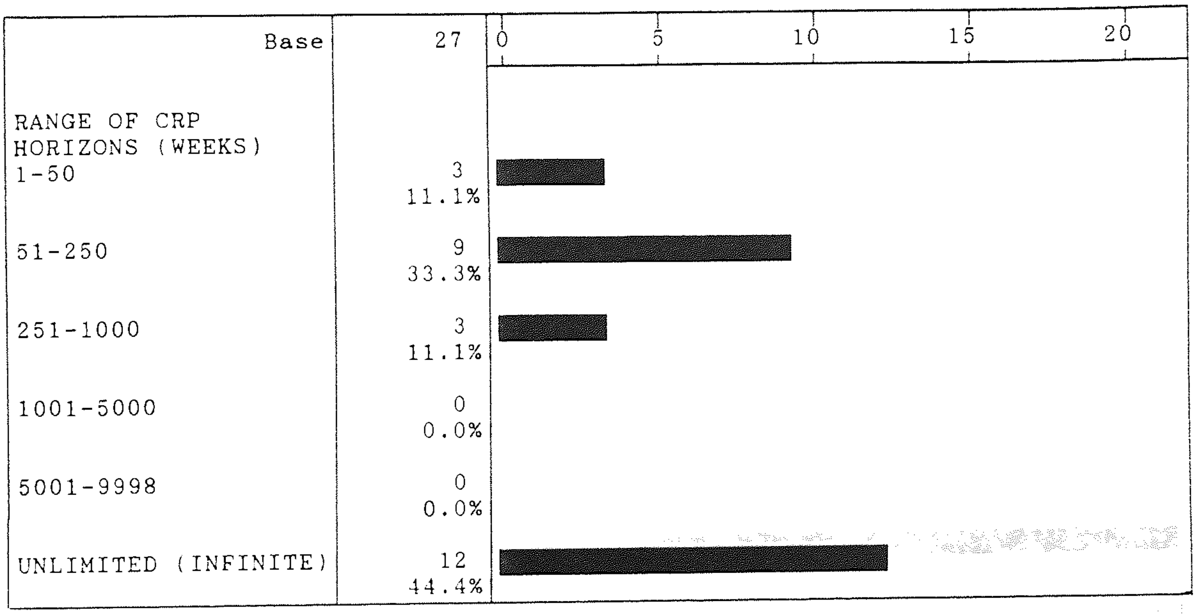


Question 18 asked which type of resources could be included in RCCP, giving the following replies.

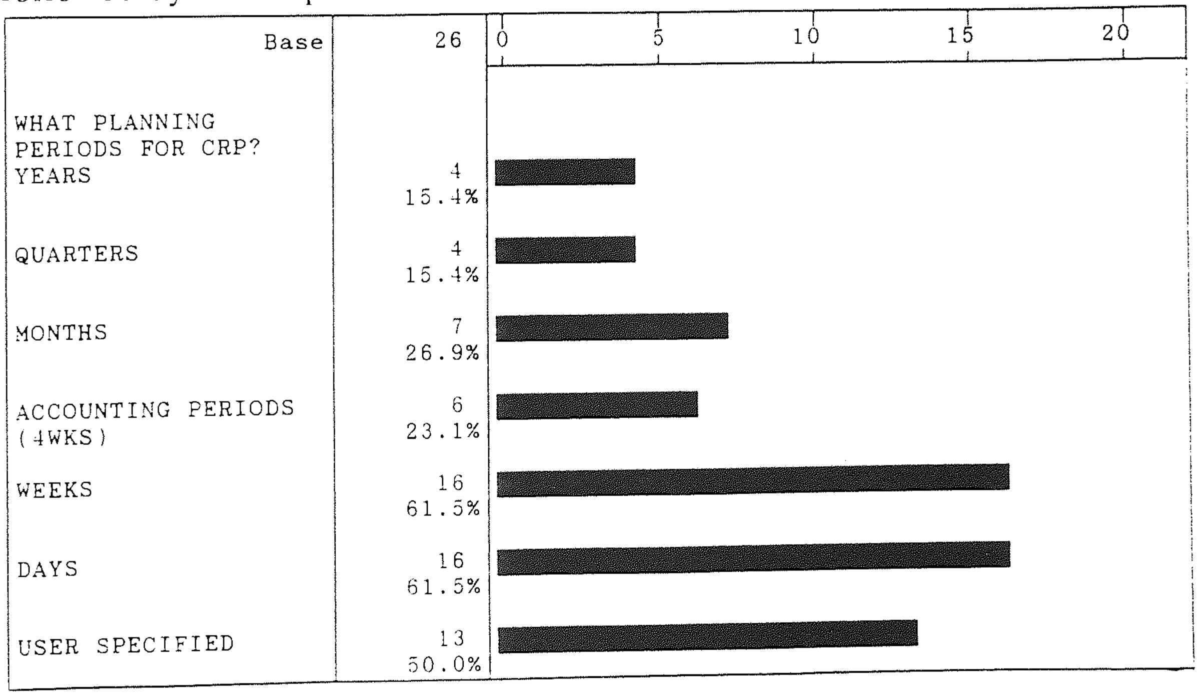


The following six questions concern the detailed features offered for Capacity Requirements Planning (CRP).

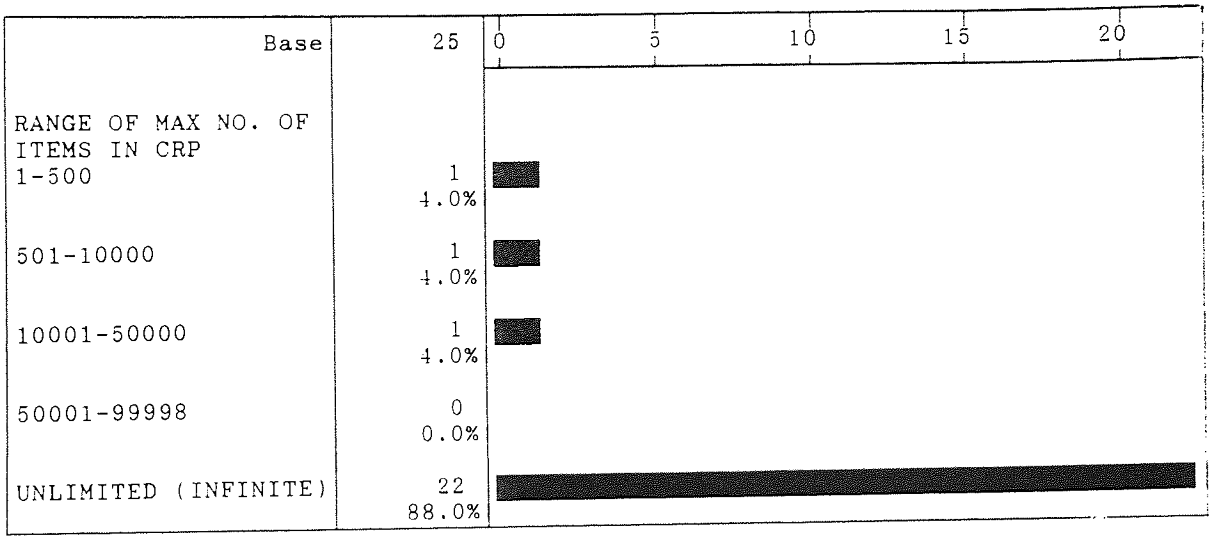
Question 19 concerned the longest planning horizon allowed for CRP.



Question 20 asked what planning periods (buckets) were offered for CRP. The replies show that "weeks" and days" are the most common, followed by "user specified".

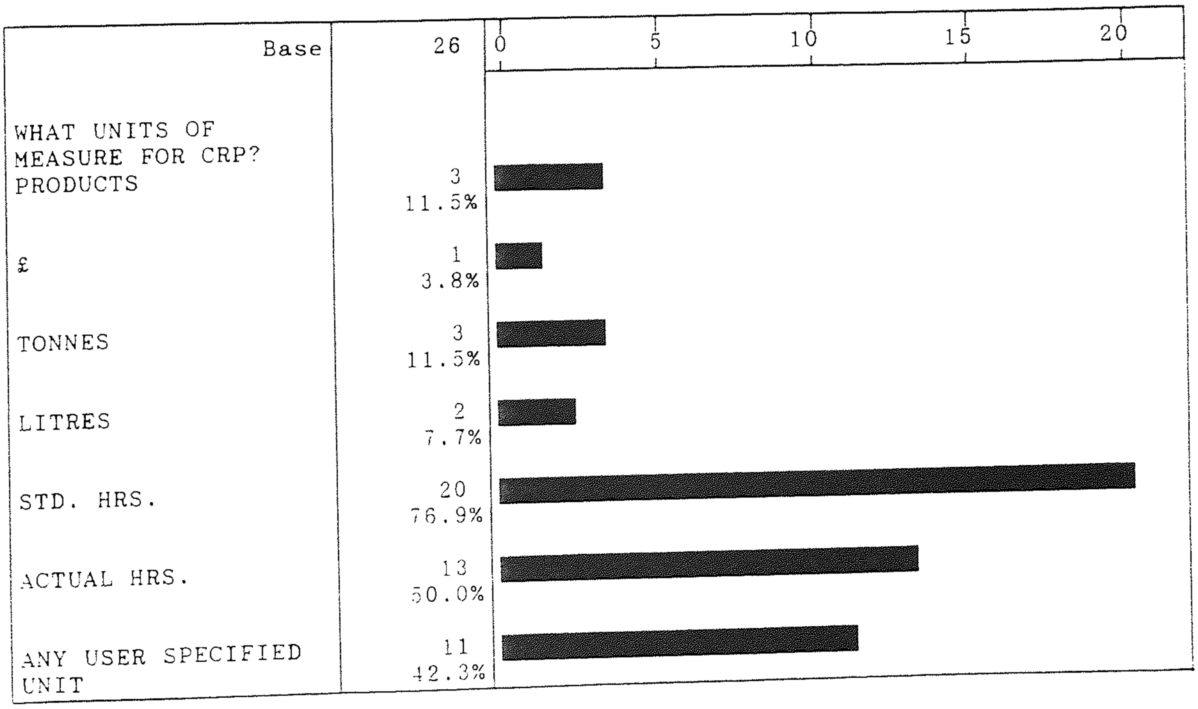


Question 21 concerned the maximum number of live and planned orders that could be accommodated for CRP. The most frequent reply was "unlimited".



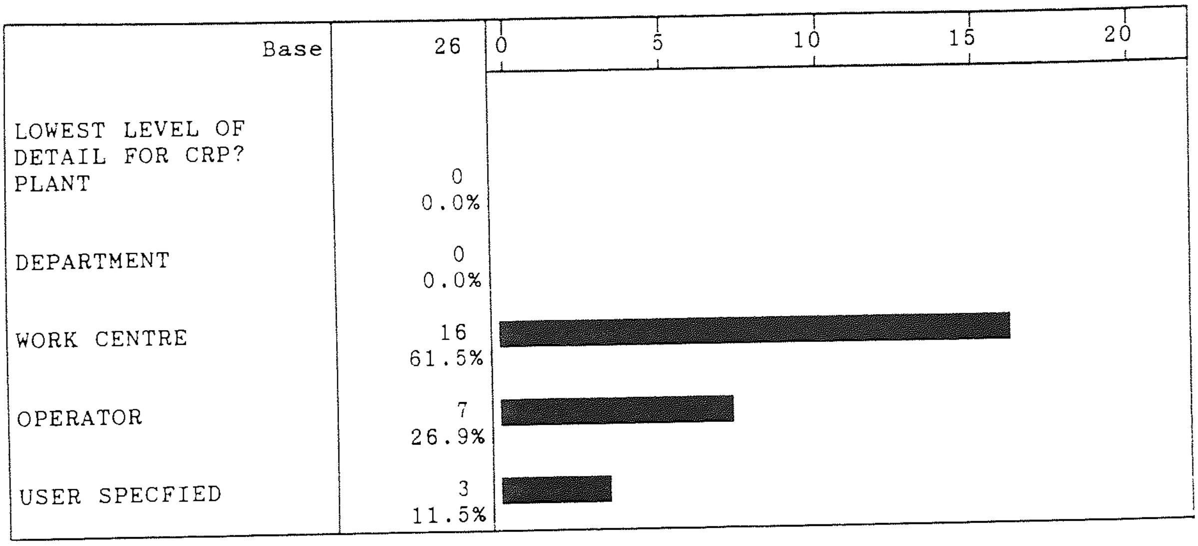
Question 22 asked what units of measure the package supported for CRP. The replies show that "Standard Hours" was the most popular.

Bar chart...: WHAT UNITS OF MEASURE FOR CRP?
Cells.......: Absolute, Total %



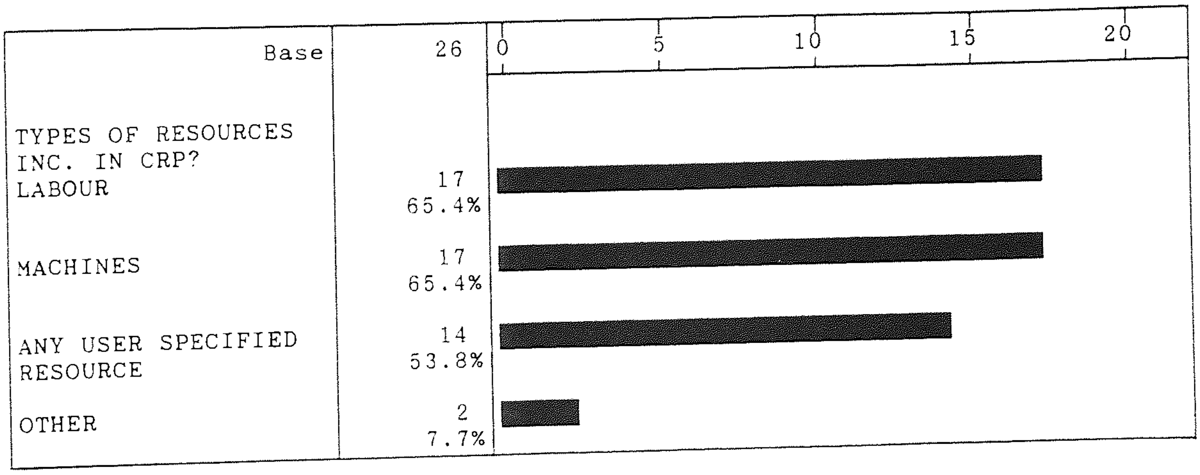
Question 23 concerned the lowest level of detail to which CRP could be taken. The "Work Centre" is the most common reply.

Bar chart...: LOWEST LEVEL OF DETAIL FOR CRP?
Cells.......: Absolute, Total %



Question 24 asked which type of resources could be included in the CRP.

Bar chart...: TYPES OF RESOURCES INC. IN CRP?
Cells.......: Absolute, Total %



Question 25 asked respondents to include any other features of their product which concerned capacity planning. Five packages (18.5% of

replies) offered Finite Capacity Planning and Scheduling. Three packages (11.1% of replies) offered On-line Capacity Requirements Planning.

6.5 Analysis of Production Management Software Packages.

In an attempt to validate some of the replies from the Supplier Survey concerning the modules offered in the packages, an analysis was undertaken of 124 Production Management packages using the BPICS/Industrial Computing Sourcebook 1990/91 (1990) as a secondary source.

The analysis is as shown overleaf.

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Bar chart...: SOFTWARE MODULES OFFERED
Cells.......: Absolute, Total %, Rows ordered, Zeros suppressed
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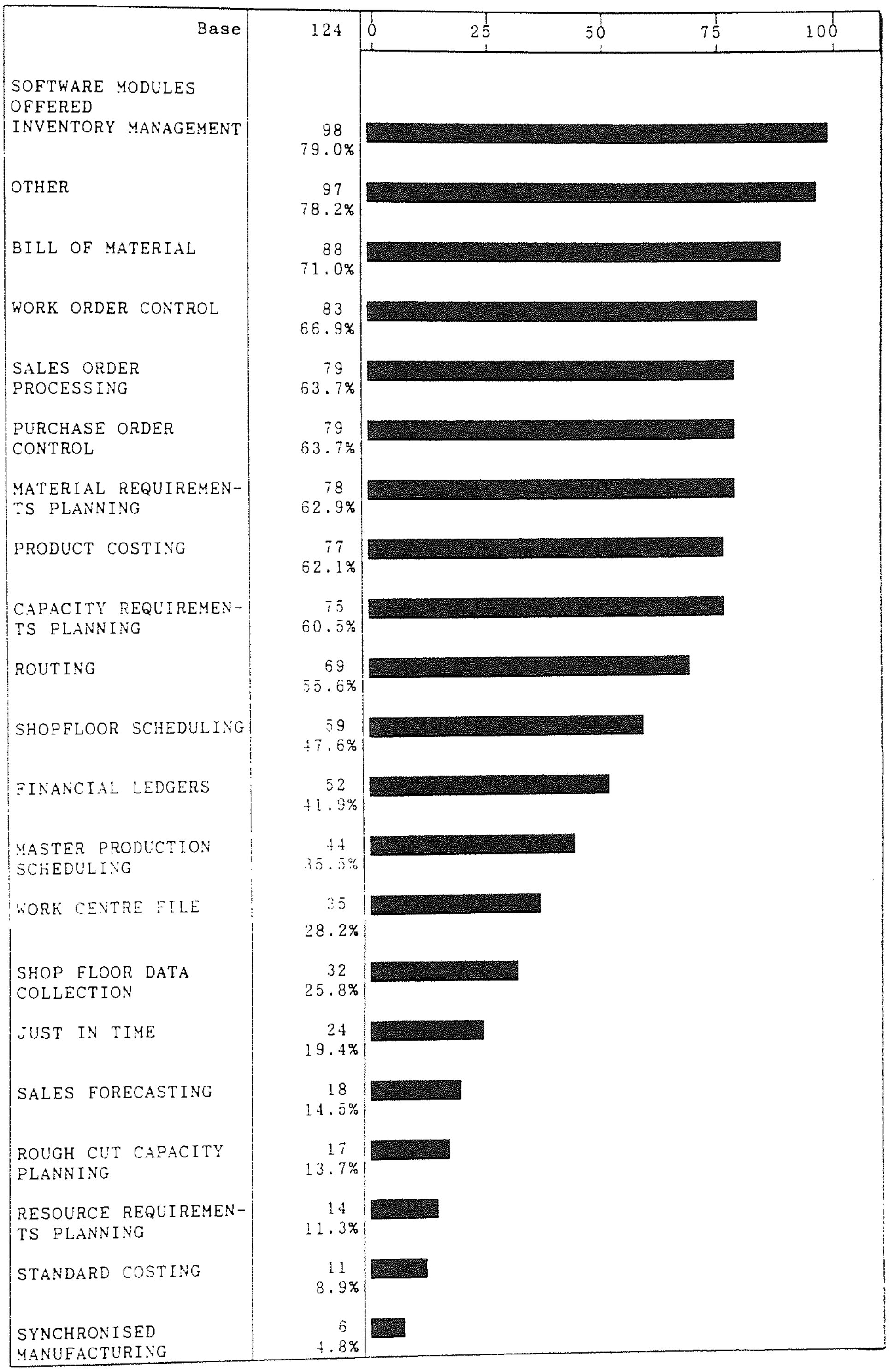


6.6 Summary

The main results of the analyses in this chapter are as follows.

Only just above 50% of system sales include RRP, RCCP and CRP modules, despite the fact that 100% of the packages surveyed offer CRP, 93% offer RCCP and 74% offer RRP.

The main reasons for the lack of successful use of RRP, RCCP and CRP by users is seen by suppliers to be the lack of or unreliability of routing and time information.

The overall impression of the facilities offered for capacity planning by the current packages, is one of a great deal of flexibility and a lack of size constraints. This is borne out by the unlimited planning horizons, user specified planning periods, units of measure and resources and unlimited numbers of items that can be dealt with for RRP, RCCP and CRP by many of the packages. Also, all the packages offered the facility of downloading data into P.C. Spreadsheets.

The analysis of the 124 packages in the Sourcebook may show that the respondents to the Supplier Survey may have been a somewhat biased sample in that the Supplier Survey showed 100% of packages offering CRP whereas the Sourcebook analysis showed only 60.5% offering CRP. The explanation is probably that the respondents to the Supplier Survey were self selected in as much as the survey was concerning capacity planning, therefore it would be less likely for suppliers who did not offer capacity planning as part of their package to reply at all. The low percentage offerings of RCCP (13.7%) and RRP (11.3%) in the Sourcebook analysis may be because of the lack of space for description of the package modules in the book and perhaps because of an assumption by the authors of the Sourcebook that RCCP and RRP might be included under the "umbrella" title of Capacity Requirements Planning.

Another interesting feature is the relatively few packages (18.5%) which were specifically offering Finite Capacity Planning and Scheduling.

As promised to respondents to both the User and Supplier Surveys, a summary of each of the two survey analyses is in preparation and will be sent to over 300 companies who have requested a copy.

The comparisons with Master Scheduling and Capacity Planning theory which can be drawn from the analyses in this chapter, chapter 5 and the case studies in chapter 4 are dealt with in the following chapter. The overall conclusions as to whether the original hypotheses have been proven are put forward in chapter 8.

7. COMPARISONS OF MASTER PRODUCTION SCHEDULING AND CAPACITY PLANNING THEORY WITH ACTUAL PRACTICE.

7.1 Introduction

In this chapter the various findings outlined in previous chapters are brought together to create an overall picture of the current state of the art of Master Production Scheduling and Capacity Planning in the U.K.. This position is then compared to the theoretical approaches which have been put forward for the operation of Manufacturing Resource Planning (MRPII) systems and the deficiencies in current operations are highlighted. Some of the causes of these inadequacies are suggested and comparisons are made with the results of previous surveys and investigations.

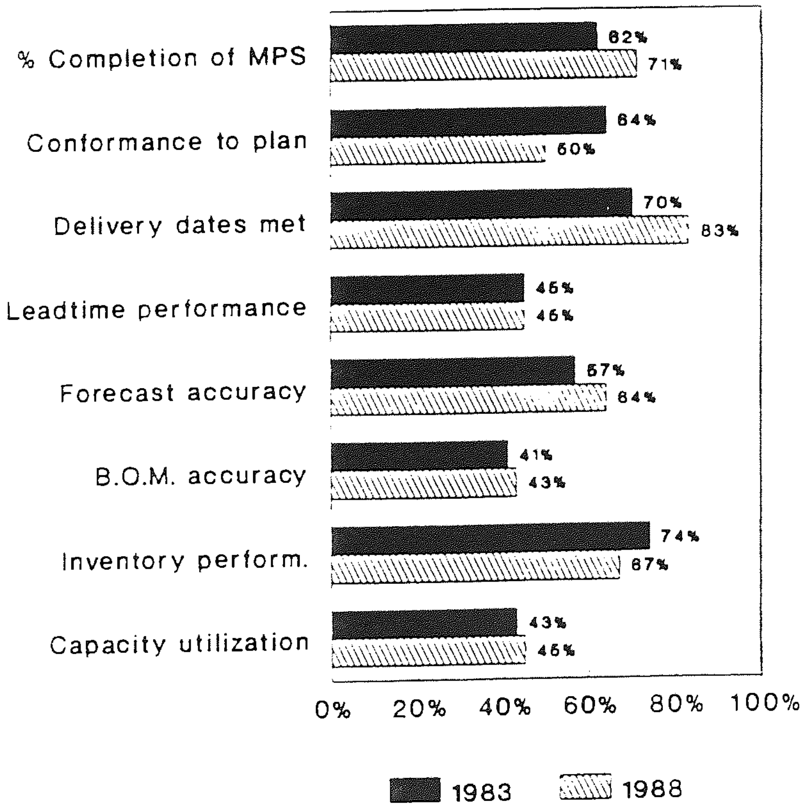
The next section deals with the findings of the detailed company investigations discussed in chapter 4. Section 7.3 covers the results of the User Survey which was dealt with in chapter 5 and section 7.4 concerns the Supplier survey which was described in chapter 6. A final section provides a summary.

7.2 Detailed Company Investigations.

The main conclusions of the investigations into the eight companies were put forward at the end of chapter 4 and were basically that Master Production Scheduling is very specific to the type of company in question but that many of the basic principles of Master Scheduling were in use.

These included the use of various types of Planning Bills of Material, multi-level Master Scheduling, Available-to-Promise calculations and Rough Cut Capacity Planning.

In terms of the measures used to judge the success of the Master Scheduling process, the most common was delivery performance or customer service, followed by stock level measures and conformance to plans. Forecast accuracy and capacity utilisation measures were only mentioned by one out of eight companies. These findings from such a small sample compare very well with the results of a recent survey into the use of manufacturing planning and control performance measures in 169 U.S. companies as shown in figure 7.1.(Wharton T.J. and Reid R.D., 1990).



(Source: Wharton and Reid 1990)

Figure 7.1 - Use of Performance Measures

One of the most significant findings of these investigations was that Capacity Requirements Planning was not being carried out in six of the eight companies and that one of the main reasons for this was thought to be the lack of reliable time standards. This lack of time standards was also put forward as one of the major overall problems which was preventing the measure of workload at various levels of planning in the companies.

Another unexpected feature was that six out of the eight companies were using P.C. based Spreadsheet or similar packages as aids in Master Scheduling or Rough Cut Capacity Planning. The main reasons given were that the main MRPII systems did not provide the facilities required or were not flexible enough.

7.3 User Survey.

A great deal of data was obtained through the User Survey and the more important findings are discussed and compared with the results of previous research studies in the next sub sections.

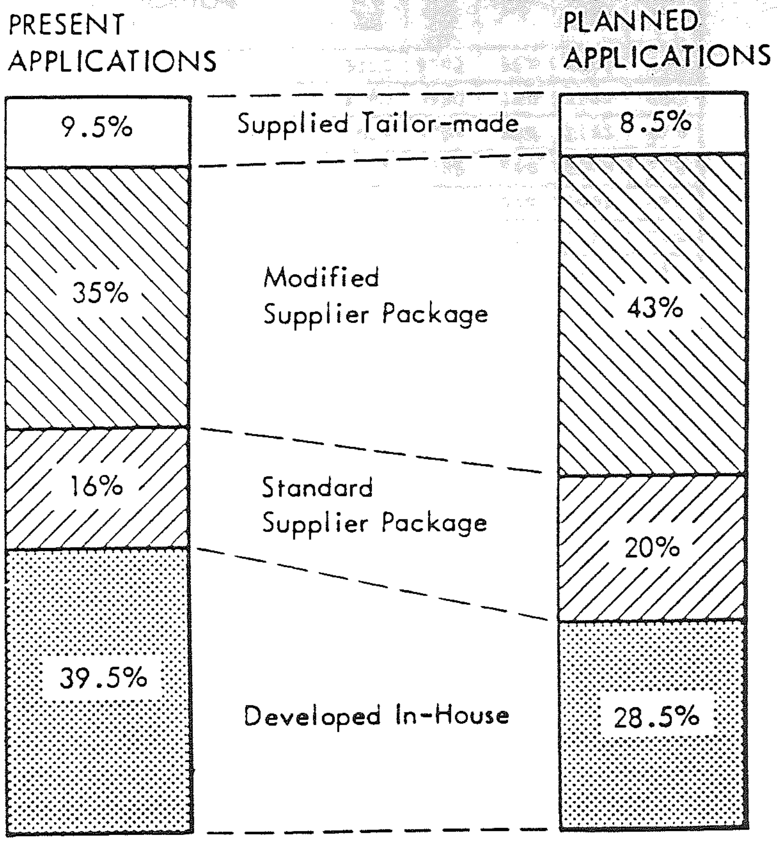
It should perhaps be pointed out that whilst every effort has been made to ensure that the survey is representative of U.K. manufacturing companies in general, the fact that the sample population was mainly taken from manufacturing practitioner members of the British Production and Inventory Control Society, could mean that there is an overall bias towards companies who are more aware of Computer Aided Production Management systems and may well be more advanced in their use than the average UK company. This could suggest that results for the use of MPS and capacity planning in the UK as a whole may be slightly worse than the survey shows.

7.3.1 The Use of Computers in Master Scheduling and Capacity Planning.

One of the findings was that in terms of the type of computer software being used for Production Management, the largest category (64%) was the use of standard packaged software followed by internally developed software (50%) with the modified standard package coming a close third. In comparing this result with an earlier survey (Butler Cox, 1985 - see figure 7.2 overleaf), the growth in standard packages seems to have been greater than was predicted in the mid 1980's and the use of in-house developed software has not decreased as expected.

One possible explanation for this could be that the definition of in-house development has changed over the years from the writing of code in low level languages to the use of packages such as spreadsheets and databases for the production of application programs.

In terms of particular software modules, the low take-up of RRP (46%), RCCP (54%), and CRP (53%) can be compared to the use and predicted use of Capacity Planning back in the mid 1980's in two surveys. (Butler Cox, 1985 - see table 7.1 and DTI, 1984 - see table 7.2).



(Source: Butler Cox Survey, 1985)

Figure 7.2 - How Applications will be developed.

APPLICATIONS (IN GENERAL SEQUENCE OF IMPLEMENTATION)	ESTIMATED CURRENT INSTALLATION LEVELS	PLANS BY END 1985
Sales order	64%	70%
Stock control	76%	83
Bill of materials	60%	72%
Shopfloor data collection (turnaround documents)	20%	28%
Purchase order	58%	75%
Material requirements Planning	48%	62%
Master schedule	45%	62%
Shopfloor data collection (terminals and scanners)	23%	35%
Routing	40%	52%
— Standard costing*	45%	60%
— Capacity planning*	28%	50%
— Labour costing*	19%	30%

*Estimates based on partial sample only

Table 7.1 Adoption Levels for Production Control Applications.

(Source: Butler Cox Survey, 1985)

APPLICATION AREAS	1983 NO OF PLANTS USING	1984 NO OF PLANTS USING NOW	ANNUAL GROWTH RATE	NO OF PLANTS PLANNING TO USE	PROJECTED GROWTH 1985
Stock control	3350	5192	55%	2295	44%
Costing	3180	4530	42%	2264	50%
Sales order processing	2624	3783	44%	2155	57%
Purchase ordering	2185	3365	54%	2376	71%
MRP	2002	3070	53%	1984	65%
Estimating	1805	2460	36%	1824	74%
Document/word proc.	1351	2387	77%	917	38%
Master scheduling	1465	2132	45%	1382	65%
Design calculations	1493	2116	42%	705	33%
Shopfloor loading	1357	2069	52%	1705	82%
NC/CNC programming	1165	1938	66%	616	32%
Capacity planning	1093	1641	50%	1610	98%
Data capture	851	1144	34%	936	82%
Engineering analysis	754	1085	44%	386	36%
QC/Inspection	784	1073	37%	534	50%
Draughting	506	908	79%	1124	124%
Design graphics	376	617	64%	301	49%
Process control	523	621	19%	390	63%
Tool control	398	602	51%	528	88%
Elec design calcs/sim.	318	504	58%	62	12%
Process planning	246	468	90%	186	40%
Maintenance	309	376	22%	356	95%
PCB design	142	288	102%	90	31%
Surface modelling	153	228	49%	170	75%
Shape nesting	108	220	103%	95	43%
Solid modelling	139	217	56%	190	88%

(Source: Engineering Computers Survey, DTI, 1984)

Table 7.2 Software Users League Table.

Both of these earlier surveys show that the largest projected annual growth rate was expected to be in Capacity Planning systems; 79% (Butler Cox) and 98% (DTI).

It can be seen that this growth either did not take place or certainly could not be extrapolated over the following five years.

As far as Master Scheduling systems are concerned, the prediction by the Butler Cox survey (1985)(table 7.1) that the use of MPS would be the same as MRP by the end of 1985 has not proved to be the case by 1990. The prediction by the DTI survey (1984)(table 7.2) for 1985 for MPS as 70% of MRP users is closer to the actual picture in 1990,(81%).

For Shop Floor Data Collection systems (Data Capture) the predictions for 1985 were much closer to the 1990 position, showing 35% of all companies (table 7.1) and 41% of MRP users (table 7.2) compared to the situation in 1990 of 31% of all users having SFDC (41% of MRP users).

The low take up of MPS and CRP in particular has been commented on in the past by researchers such as Doumeingts (1984) whose comparative analysis of 433 MRP users in the USA and France showed that only 52.2% had an MPS module and only 37.7% had CRP. A more recent survey in the USA, (Pohlen and Ticknor, 1989) showed that of the companies surveyed, only 5% of them were using a standard package for Master Scheduling compared to 95% for Inventory Management and MRP. In another U.S. survey, Machon and Young (1986) report;

> "Computer support for Capacity Management was variable with most of the RRP being performed manually. RCCP and CRP was split between manual and computer processing. Input Output control was mostly computerised. Only one respondent used a standard software package for RRP, while all other computer models were developed with customised software."

7.3.2 The Use of Hierarchical Resource and Capacity Planning.

The results in chapter 5 show that planning in most companies does take place in a top-down hierarchical fashion as put forward in the MRPII theory. Specifically, average planning horizons range from 91 weeks for RRP through 33 weeks for RCCP down to 23 weeks for CRP. There is evidence of the use of aggregate product groupings such as product families (average number 72) for RRP, finished products and Planning

Bills of Material at the RCCP stage (average 703) and much larger numbers of live and planned orders (average 3822) for CRP. Monthly planning periods are most often used for RRP and weeks for RCCP and CRP.

7.3.3 "Closing the Loop".

As a percentage of the total number of respondents, relatively few companies claim to be trying to close the loop by feeding back information from CRP to the Master Production Schedule, (29%).

For those respondents who answered the question whether CRP information is fed back to the MPS, several cross-tabulations were analysed to determine whether there were any significant relationships between these answers and other factors. No significant relationships were found with type of industry, size of company, type of operation, type of software, number of live and planned orders, proportion of workload with times on and methods of Shop Floor Data Collection. There was a relationship, however, with those companies who also used CRP information for Shop Floor Scheduling, indicating that those companies who were more fully integrated in their planning systems were more likely to be closing the loop. (See Table 7.3).

```
Rows........: Q12I-IS CRP INFO FED BACK TO MPS
Columns.....: Q12K-CRP INFO USED FOR SHOP SCHD
Cells.......: Absolute

----------------------------------------------------------
Chi-squared value: 2.9886148
Number of degrees of freedom: 1
There is a significant relationship at the 10% level
----------------------------------------------------------
```

		Q12K-CRP INFO US	
	Base	YES	NO
Base	175	124	51
Q12I-IS CRP INFO FED BACK TO MPS YES	100	76	24
NO	75	48	27

Table 7.3 - Cross Tabulation of "CRP used for Shop Scheduling" and "CRP Information fed back to the MPS".

As might be expected, there was a very strong correlation between whether CRP information was being fed back and whether CRP was viewed as operating successfully in the plant. (see table 7.4 overleaf).

```
Rows........: Q12I-IS CRP INFO FED BACK TO MPS
Columns.....: Q12M-IS CRP OPERATING OK?
Cells.......: Absolute

---------------------------------------------------------
Chi-squared value: 8.3214929
Number of degrees of freedom: 1
There is a significant relationship at the 1% level
---------------------------------------------------------
```

		Q12M-IS CRP OPER	
	Base	YES	NO
Base	178	111	67
Q12I-IS CRP INFO FED BACK TO MPS YES	99	71	28
NO	79	40	39

Table 7.4 - Cross Tabulation of "Is CRP Operating O.K." and "CRP Information fed back to MPS".

7.3.4 The Success or Lack of Success of the Use of Capacity Planning.

As was shown in chapter 5, the rate of successful use of RRP (35%), RCCP (42%) and CRP (36%) is less than what might be described as satisfactory.

Some of the main reasons given by respondents are the lack of reliable time standards and routing data. However, replies also suggest that, on average, a relatively large proportion (81%) of the workload on the shop floor has standard or estimated times on it.

Other reasons suggested include; poor forecasts, the need for SFDC systems and planning not going into enough detail to identify bottle-necks.

These results are very similar to those reported by Machon and Young (1986) regarding a survey of twenty U.S. manufacturing companies, namely:

> "Problems encountered in developing capacity plans centered mostly around the lack of standard data, bottle-necks, no formal business or production plan, and lack of timely information."

In an attempt to try and discover causative factors for the lack of success of RRP, RCCP and CRP, various cross-tabulations against potential factors were tried.

No significant relationships were found with size of company, type of industry, type of operations, whether an industrial engineering department is in existence , or how long since the modules had been purchased or developed.

There was a weak relationship found between the number of live and planned orders and whether CRP is operating successfully as shown in table 7.5., suggesting that the fewer the orders that have to be dealt with, the more likely CRP is to be successful. However, no corresponding relationship was found for RRP and RCCP.

```
Rows........: NO. OF ORDERS IN CRP (RANGE)
Columns.....: Q12M-IS CRP OPERATING OK?
Cells.......: Absolute, Expected

-----------------------------------------------------------
Chi-squared value: 9.9428735
Number of degrees of freedom: 5
There is a significant relationship at the 10% level
-----------------------------------------------------------
```

		Q12M-IS CRP OPER	
	Base	YES	NO
Base	155	104	51
NO. OF ORDERS IN CRP (RANGE)			
1-100	26	13 17	13 9
101-1000	69	54 46	15 23
1001-5000	38	22 25	16 13
5001-10000	13	10 9	3 4
10001-50000	7	4 5	3 2
50001-99999	2	1 1	1 1

Table 7.5 - Cross-tabulation of "Number of Orders in CRP" and "Is CRP Operating O.K.?".

Relationships were found between the percentage of workload with times on and the success rate of resource and capacity planning. For RRP there was a relationship found as shown in table 7.6.

```
Rows........: % OF WORK WITH TIMES ON.
Columns.....: Q10J-IS RRP OPERATING OK?
Cells.......: Absolute

--------------------------------------------------------------
Chi-squared value: 16.547523
Number of degrees of freedom: 9
There is a significant relationship at the 10% level
--------------------------------------------------------------
```

		Q10J-IS RRP OPER	
	Base	YES	NO
Base	260	110	150
% OF WORK WITH TIMES ON. 1-10%	2	0	2
11-20%	2	0	2
21-30%	3	0	3
31-40%	2	0	2
41-50%	10	1	9
51-60%	7	1	6
61-70%	8	3	5
71-80%	26	9	17
81-90%	41	19	22
91-100%	159	77	82

Table 7.6 - Cross-tabulation of "% of workload with times on" and "Is RRP Operating O.K.?".

A strong relationship was found for RCCP as shown in table 7.7.

```
Rows........: % OF WORK WITH TIMES ON.
Columns.....: Q11J-IS RCCP OPERATING OK?
Cells.......: Absolute

-----------------------------------------------------------
Chi-squared value: 18.367631
Number of degrees of freedom: 9
There is a significant relationship at the 5% level
-----------------------------------------------------------
```

		Q11J-IS RCCP OPE	
	Base	YES	NO
Base	261	134	127
% OF WORK WITH TIMES ON.			
1-10%	2	1	1
11-20%	3	1	2
21-30%	3	0	3
31-40%	3	0	3
41-50%	8	0	8
51-60%	8	3	5
61-70%	8	4	4
71-80%	25	12	13
81-90%	43	22	21
91-100%	158	91	67

Table 7.7 - Cross-tabulation of "% of workload with times on" and "Is RCCP Operating O.K.?"

A very strong relationship was found between the percentage of workload with times on and whether CRP was viewed as being successful, indicating, as might be expected, that CRP depends on having times on virtually everything on the shop floor.(See Table 7.8)

```
Rows........: % OF WORK WITH TIMES ON.
Columns.....: Q12M-IS CRP OPERATING OK?
Cells.......: Absolute

----------------------------------------------------------
Chi-squared value: 21.890441
Number of degrees of freedom: 9
There is a significant relationship at the 1% level
----------------------------------------------------------
```

		Q12M-IS CRP OPER	
	Base	YES	NO
Base	268	118	150
% OF WORK WITH TIMES ON. 1-10%	2	1	1
11-20%	2	0	2
21-30%	3	0	3
31-40%	3	0	3
41-50%	8	0	8
51-60%	7	1	6
61-70%	7	1	6
71-80%	25	9	16
81-90%	45	21	24
91-100%	166	85	81

Table 7.8 - Cross-tabulation of "% of workload with times on" and "Is CRP operating O.K.?".

A very strong correlation was found between whether CRP is operating successfully and how shop floor data is collected, indicating that the use of computerised SFDC suggests success in CRP, whereas data collected as part of a wages or bonus scheme is less likely to lead to a successful CRP system. (see table 7.9).

```
Rows........: Q12M-IS CRP OPERATING OK?
Columns.....: Q17-HOW IS SHOP DATA COLLECTED?
Cells.......: Absolute

-------------------------------------------------------------
Chi-squared value: 9.5485448
Number of degrees of freedom: 2
There is a significant relationship at the 1% level
-------------------------------------------------------------

                                 ┌─Q17-HOW IS SHOP DATA COLL─┐
                                 │         PART OF       COMP-│
                                 │         WAGES/  "PAP- UTERISED│
                                 │          BONUS ERWORK"    SFDC│
                                 │    Base│SCHEME│ SYSTEM│ SYSTEM│
                      Base│     235      74     157      69│
 Q12M-IS CRP
 OPERATING OK?
 YES                      │     114      27      78      43│

 NO                       │     121      47      79      26│
```

Table 7.9 - Cross-tabulation of "How is shop data collected" and "Is CRP operating successfully?".

A much weaker relationship was found for RRP (see table 7.10 overleaf) and no significant relationship was found between RCCP success and shop floor data collection method, suggesting that higher level planning does not depend to such an extent on the feedback of shop floor data.

Finally, relationships were found between RRP and CRP success and the method of carrying out the planning; whether it is manual, using a P.C. Spreadsheet or using a software module. No significant relationship was found for RCCP. The relationship for RRP is shown in table 7.11 and the strong correlation for CRP is shown in table 7.12. In both cases, computerised methods of planning and, in particular, using a module for CRP seem to point to greater success.

```
Rows........: Q10J-IS RRP OPERATING OK?
Columns.....: Q17-HOW IS SHOP DATA COLLECTED?
Cells.......: Absolute

------------------------------------------------------------
Chi-squared value: 5.115165
Number of degrees of freedom: 2
There is a significant relationship at the 10% level
------------------------------------------------------------

                                   Q17-HOW IS SHOP DATA COLL
                                   PART OF               COMP-
                                    WAGES/     "PAP-  UTERISED
                                     BONUS   ERWORK"      SFDC
                             Base  SCHEME|   SYSTEM|    SYSTEM

                     Base     232       74       159        67

Q10J-IS RRP
OPERATING OK?
YES                           110       28        72        38


NO                            122       46        87        29
```

Table 7.10 - Cross-tabulation of "How is Shop Data collected?" and "Is RRP operating O.K.?".

```
Rows........: Q10A-HOW IS RRP CARRIED OUT?
Columns.....: Q10J-IS RRP OPERATING OK?
Cells.......: Absolute, Expected

------------------------------------------------------------
Chi-squared value: 5.6433811
Number of degrees of freedom: 2
There is a significant relationship at the 10% level
------------------------------------------------------------

                                   Q10J-IS RRP OPER


                             Base        YES|        NO

                     Base     191        112         79


Q10A-HOW IS RRP
CARRIED OUT?                   73         34         39
MANUALLY                                  42         31

                              128         81         47
USING A PC                                74         54
SPREADSHEET

USING A SOFTWARE               47         29         18
MODULE                                    27         20
```

Table 7.11 - Cross-tabulation of "How is RRP carried out?" and "Is RRP operating O.K.?".

```
Rows........: Q12A-HOW IS CRP CARRIED OUT?
Columns.....: Q12M-IS CRP OPERATING OK?
Cells.......: Absolute, Expected

-----------------------------------------------------------
Chi-squared value: 8.6796512
Number of degrees of freedom: 2
There is a significant relationship at the 5% level
-----------------------------------------------------------
```

		Q12M-IS CRP OPER	
	Base	YES	NO
Base	177	111	66
Q12A-HOW IS CRP CARRIED OUT? MANUALLY	48	21 30	27 18
USING A PC SPREADSHEET	50	35 31	15 19
USING A SOFTWARE MODULE	113	74 70	39 43

Table 7.12 - Cross-tabulation of "How is CRP carried out?" and "Is CRP Operating O.K.?".

7.4 Supplier Survey and Analysis of Software Packages.

7.4.1 Part 1.

The proportion of sales of RRP, RCCP and CRP modules by suppliers as a percentage of total sales were 56% (RRP), 52% (RCCP) and 54% (CRP). These were remarkably close to the take-up of the same modules by users in the User survey; 46% (RRP), 54% (RCCP) and 53% (CRP). This indicates that each survey is, to some extent, validating the results of the other, showing that a representative picture of the use of resource and capacity planning software has been obtained.

The views of suppliers on the barriers to use of capacity planning software are very similar to those of the users, namely that the lack of reliable routing and time data followed by the lack of feedback of shop floor utilisation and efficiency information are the main reasons.

7.4.2 Part 2 and Analysis of Packages.

The analysis of replies concerning the packages offered from the Supplier Survey shows that modern MRPII packages are, in general, very flexible and offer the facilities required for capacity planning at the RRP, RCCP and CRP levels. Even if users believe that more speed and flexibility is required for RRP and RCCP calculations than is available in the packaged software, all packages offered the facility of downloading information into P.C. spreadsheets so that these tasks could be carried out.

Whereas some of the reasons given for the lack of success of capacity planning in the User Survey and in the detailed case studies was that the software was not available or not flexible enough, this is unlikely to be the case in the majority of the latest MRPII software on the market.

It is also interesting that 18.5% of respondents specifically mentioned that their packages offered Finite Capacity Planning and Scheduling, although this category was not offered as a choice. This may suggest that more packages are now offering this facility, perhaps as a result of the impetus provided by the advent of Optimised Production Technology (OPT), although no previous data is available to substantiate this assertion.

The analysis of the 124 packages described in the Source Book (BPICS 1990), confirmed the view that current software packages offer a wide variety of modules, many of which (61%) offer capacity planning.

7.5 Summary.

The findings from the various parts of this research have been brought together in this chapter and, where possible, comparisons have been made with Master Scheduling and Capacity Planning theory. An attempt has also been made to determine the causative factors for the lack of success of capacity planning and the lack of "closing the loop".

On the basis of these findings, several articles are in preparation: one for the British Production and Inventory Control Society, focussing on the results of the User Survey, one for the journal, Integrated Manufacturing Systems, concentrating on the link between Master Scheduling and Resource Planning and a third is planned for the Institute of Management Services journal based on the results of the User Survey, especially regarding the sources of information for resource planning, the employment of Industrial Engineers and the techniques of time measurement used.

In the next and final chapter, conclusions are drawn as to whether the initial hypothesis has been proved and the possibilities for further research in this area are discussed.

8. Overall Conclusions and Suggestions for Further Research.

8.1 Proof of Hypothesis.

It is the author's contention that the main hypothesis of this thesis which was outlined in chapter 1. has been proved, namely; that throughout U.K. manufacturing industry, "resource and capacity checks are either not being carried out satisfactorily or they are not being fed back to the appropriate plan in a timely fashion". Whilst this has not been proved in absolute terms, that is, it cannot be said that no companies are "closing the loop" satisfactorily, but that, rather, the majority of U.K. companies are not operating satisfactorily in this area.

This can be shown first of all by the proportions of companies from the User Survey actually attempting to carry out Resource Requirements Planning, Rough Cut Capacity Planning and Capacity Requirements Planning, namely; 57% (RRP), 58.5% (RCCP) and 52% (CRP). However, the more important proof is the number of companies claiming that the particular capacity planning approach is successful, namely; 35% (RRP), 41.5% (RCCP) and 36.4% (CRP). In terms of using CRP information to feed back to the Master Schedule, only 29% of the total number of respondents to the User Survey claimed to be doing this.

After further analysis of the replies, it can be shown that of those companies carrying out CRP and judging it to be operating successfully, only 70 were feeding the information back to update the Master Schedule. This represents only 20% of the total sample population.

Thus, with only approximately just over 50% of companies carrying out Resource and Capacity Planning and only 20% of companies successfully feeding back CRP information to "close the loop", the hypothesis appears to be proved.

8.2 Causative Factors.

The main reason put forward by users for the lack of successful use of Resource and Capacity Planning was the absence of time standards and routing information or unreliability of this data. This was true both in the detailed company investigations and in the User Survey responses. This was also the view of the suppliers who answered the Supplier Survey. As shown in chapter 7, correlations were found between the proportion of workload with times on and the successful use of capacity planning; indeed, a very strong relationship was found for CRP.

The second most proffered reason was the lack of availability of Efficiency and Utilisation information which prevents the realistic calculation of net "rated" capacities in the factory. The possible cause of this is the low rate of usage of computerised Shop Floor Data Collection systems (22% of all companies routinely using computerised SFDC). Cross tabulation analyses also show that there is a very strong relationship between the method of shop floor data collection and the success of CRP, with computerised SFDC leading to success and paperwork collection systems as part of a wages or incentive scheme leading to a lack of success.

The third most popular reason given was poor sales forecasts or the consequential large volumes of unplanned work.

The main reason given for not feeding CRP information back to update the Master Schedule was that the capacity was changed by using overtime or sub-contracting rather than changing the schedule. The second most popular reason given was that there was no Master Schedule in existence. There was also a view that feedback was not required since Rough Cut Capacity Planning was sufficient.

8.3 Remedies.

Because of the main barriers to the successful use of capacity planning mentioned above, it would appear that a greater emphasis on more accurate times and routes is necessary. This is likely to be easier to put into place in some industries and business environments than others. For example there appears to be a correlation between the proportion of workload with standard times on and the type of industry, with the Brick, Pottery, Glass and Cement industry currently having an average of 95%, the Pharmaceutical and Cosmetics industry having 92%, ranging down to the Textiles, Leather, Footwear and Clothing industry with 68%. This would appear to be as might be expected as the move is made from relatively standard, process-type products to fast moving fashion items. Similarly, companies involved in repetitive manufacturing currently have a higher proportion of work with times on (83%) than those involved in the production of one-offs (73%).

There could perhaps be an argument put forward for the use of more Industrial Engineers than are currently employed; the current situation being an average of just over six per company which represents on average 0.5% of the total number of employees per company. There is, however, no data in this thesis which could support this argument on a cost-benefit basis, since it cannot be proved that more Industrial Engineers would lead to an improvement in the proportion of work with times on and even if it did, this may not result in increases in company performance which would offset the cost of employing the extra staff.

The other conclusion which might be drawn is that there should be a greater take-up of computerised shop floor data collection (SFDC) since it can be shown that this leads to greater success in capacity planning. Again, it would have to be up to the individual company to decide whether the cost of a SFDC system could be justified from the benefits of having better capacity planning.

Perhaps a more realistic remedy would be for companies to concentrate on the Rough Cut Capacity Planning (RCCP) stage and in particular on checking only the critical or bottle-neck work centres. Currently only 31% of companies who carry out RCCP, plan against critical work centres. The concentration on bottle-necks as put forward by Goldratt (1984) would mean that more accurate time standards would only be needed for relatively few work centres.

Similarly, shop floor data collection systems could be aimed solely at the Capacity Constraining Resources (bottle-necks). Such an approach of close monitoring and control of bottle-neck processes has proved very successful at the Cummins Engine plant at Shotts in Scotland, described in the training video, "Just in Time Manufacturing" (E.I.T.B. 1985).

Having to determine capacity plans for relatively few work centres and needing to collect and monitor utilisation and efficiency data for the same resources, would mean that most companies could achieve this in a speedy and flexible fashion by using P.C. based spreadsheet packages, especially if they were not in a position to use an MRPII software module for the task. As shown in the Supplier Survey, all the Production Management packages offered the facility of downloading data into P.C. spreadsheets for this purpose.

A remedy for poor sales forecasts and high levels of unplanned work may lie in the area of improved forecasting techniques, particularly for the Make-to-Stock business environment. Another possibility might be the better use of Master Scheduling techniques such as Planning Bills of Material and Available-to-Promise calculations for order promising; the User Survey suggests that only 22% of companies use Planning Bills or Pseudo Products in their planning. Finally it may be possible, in some companies, to reduce the overall Master Schedule planning horizon by tackling the individual manufacturing and purchase lead times using many of the Just in Time concepts (Schonberger, 1986), thus leading to less reliance on forecast information.

8.4 Discussion.

The overall findings of this research suggest that at the critical interface between the market place and production, namely the Master Production Schedule, much has been developed to manage and control the demand side of the equation in terms of forecasting approaches and the use of techniques such as Planning Bills and Available-to-Promise calculations. It is on the supply side that deficiencies are apparent in terms of checking the validity of plans and schedules in terms of available capacity.

Several of the respondents to the User Survey and some of the managers interviewed in the detailed company case studies put forward the view that Capacity Requirements Planning in its current infinite capacity planning form is not necessary or even desirable. The reasons given included stating that RCCP was sufficient or that because the company had moved down the JIT path, CRP was not necessary because of rate-based planning, simplified routes and flow production operations. Similarly, CRP information was not being used for shop floor scheduling because Kanban control or simple scheduling approaches were in place.

Following on from the lead given by Optimised Production Technology (OPT), several software suppliers and consultants have developed and marketed finite capacity scheduling packages. These can either be added on to an existing MRPII system to carry out the final shop floor schedule, for example "CIM Manager" from Hoskyns, or, in other cases, such as Capability Based Scheduling (Archer, 1990) can be used for both the Master Scheduling and shopfloor scheduling stages. Whilst these approaches may well claim to overcome one of the major criticisms of the MRPII logic, namely the use of predetermined lead times, their effective use could be equally affected by the current lack of reliable time standards and routing information as outlined in this thesis.

8.5 Suggestions for Further Research.

As a result of this piece of research, several questions remain unanswered and their investigation could well form the basis for some substantial research projects.

The first question is how companies have evolved in their use of capacity planning techniques and whether improvements in capacity planning leads to enhanced "bottom-line" results for the organisations. A project here would have to entail the longitudinal study of a group of companies over at least a five year period and would involve the reconstructing of previous planning approaches and comparing various business measures over the same period.

Another investigation could be into the use and success of the more recent finite capacity planning packages that have been mentioned earlier in this chapter. This would entail determining whether they are as dependent on accurate times and routes as traditional CRP and whether these packages do offer a solution to the main MRPII criticisms of the assumptions of infinite capacity planning and predetermined planning leadtimes.

Some useful research could also be carried out into the choice of appropriate MPS items to schedule in different business environments with particular respect to Delivery Lead Times, Manufacturing Lead Times and Time Fence policies.

Finally it might be interesting and beneficial to find out why so many companies are using P.C. based Spreadsheet packages for capacity planning and Master Scheduling instead of the available MRPII modules. Is it that the MRPII software really is too slow and inflexible or is it the case that users feel that they own and control applications that they have developed themselves, even if the solution may not be as efficient as it could be?

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Appendix 1.

Detailed Case Study Interview Check List.

S.E.R.C. MASTER PRODUCTION SCHEDULING RESEARCH. P.G. BURCHER

COMPANY INFORMATION SHEET

Company Name ....

Division ....

Master Scheduling Unit (Note: All data are to be prepared for the unit or units that are being master scheduled. This may or may not correspond to a division plant, or entire company. Describe the master scheduling unit and record the remaining data for that unit.)

....

Master Scheduling Unit differs from full company or division yes... no...

Description or products:

....

Industry ....

Annual Sales (£) ....

Number of Employees ....

Plants: single .... multiple ....

Multi-National yes .... no ......

Branch Warehouse or Distribution Centres used yes ...... no ......

PRODUCTION PROCESS DATA

What portion of the sales value is produced by:

A)	Process		B)	Fab/Assembly	
	Batch	.......%		Fabrication	.......%
	Continuous	.......%		Assembly	.......%
				Fabric. and Assembly	.......%

Typical Production lead time ....

Typical finish or assembly lead time ....

Number of engineering changes issued per week ....

Number of end items ....

Percent of end items that account for 90% of sales value ....

Percent of sales value that is:
made to stock ....%
made to order ....%

Number of Part and Subassembly numbers ....

Number of levels in a typical bill of material ....

Degree of part commonality (i.e. part numbers that are used on more than one parent)

High (> 75%) .... Med. ...... Low (< 25%) ......

Percent of purchased parts ....%

Typical number of weeks backlog of orders (Length of order book) ....

Typical number of weeks of supply of finished goods inventory ....
Work in process inventory ....
Raw material inventory ....

Percent of orders that require special engineering (design/customising) ....

Rough flow diagram of Manufacturing Process.

Rough organization chart that positions the master scheduling function with respect to purchasing, materials management, production planning and control, manufacturing management, marketing/sales etc.

MARKET DATA

Percent of customers that are industrial ....% OEM ....%
Consumer ....% Other ....%
(Describe)

Number of customers ....
Percent of customers that account for 90% of sales value ....%

Typical customer requested delivery time ....

Average number of orders per day ....

Average number of items per order ....

Percent of orders that are changed between receipt and shipping ....%

Percent of sales value that comes from:
- Export customers ....%
- Domestic customers ....%
- Distribution warehouse replenishments ....%
- Service Parts ....%

Percent of shipping dates specified by customer ....%
company ....%

COMPUTER SYSTEMS

Name of computer manufacturer..

Type of computer (i.e. Model No.) ....

Is your production control system
i) on line data entry, real time update YES/NO
ii) on line data entry, batch update YES/NO
iii) batch data entry and update YES/NO

Was your production control system
i) developed entirely in house YES/NO
ii) based on an externally-supplied package YES/NO

If based on a package,
i) has the package been modified to suit? YES/NO
ii) package name ....

How long has your M.R.P. system been in operation ....

(Any other aspects of the company, organisation systems or market which affect master scheduling and not covered in the company information questions.)

I. **Production Planning**

1. Does the master production scheduling function get direction from top management in overall (aggregate) terms?

    a) If no - Why not and would this type of information be useful?

    b) If yes - How is this information provided?

        1) In what units is the production output expressed, e.g. £, tons, hours, etc.?

        2) Over what time period is the production output specified?

        3) How is the production plan related to financial plans and budgets?

        4) How is the production plan related to marketing requirements, e.g. service level goals, etc.?

        5) How often is the production output information provided? How often is this information received and revised? What circumstances cause an unscheduled review? When the production plan is missed, what is done about it?

        6) Who are the participants in providing the production planning information?

2. How is the production plan specified in terms of product item units, e.g. what is a meaningful aggregate grouping for production planning purposes? Is the production plan expressed in terms of:

   a) product characteristics, e.g. overall production by product line or by individual products?

   b) manufacturing resources, e.g. by plant, manufacturing division or individual machine or assembly stations?

3. Give us an example of your production plan and explain how it was prepared and what sources of information were used in its preparation. Explain the steps in its preparation.

II. Master Production Scheduling

1. Describe the features of the master production schedule, e.g.:

   a) What is the unit that is being master scheduled (what is the build unit of the master schedule)?

   b) What is the length of time covered by the master schedule?

   c) What is the time period size in the master schedule?

   d) How is forecast information used in preparing the master schedule?

   e) How is backlog (open order) information used in preparing the master schedule?

   f) If product groupings are master scheduled, how are the product options handled (scheduled)?

   g) Are firm planned orders used in the master schedule? If so, how?

   h) What is the frequency with which the master schedule is updated?

   i) What kind of time fencing is used?

2. In general, all product items in a company need to be scheduled using one of the following procedures: Time-Phased Order Point, MRP, Order Point Systems, Master Production Scheduling, or Final Assembly Scheduling.

   a) What types of product configurations are to be used for master scheduling purposes, e.g. end product items, major assemblies, planning bills, product modules, etc. How did you arrive at the particular vehicle (product configuration) that you are using and give an example of how it is being used in preparing the master schedule.

   b) Do you use a two level master scheduling approach?

   c) Given the product configuration that you are using for master scheduling, are all of the product items in the company included in the master-schedule? Are any product items excluded? If so, why are they being excluded and how are they being scheduled?

3. a) Do you hold formal master production scheduling meetings?

   b) If yes; how often and who attends?

4. Is the master schedule prepared using the computer? If yes:

   a) To what extent is the computer being used in preparing the master schedule?

   b) Is the computer being allowed to adjust the master schedule automatically?

   c) Does the computer calculate action messages for the master scheduler? Example action messages include:

      - re-schedule in or out
      - need to add additional items or quantities to the master schedule
      - need to cancel orders
      - indicate past due

   d) What standard software packages are being used for master scheduling

5. Is there a specific job title and description of the master scheduler's job? If yes:

   a) How many product items does he handle?

   b) Is the master scheduler's job organized by product line or by manufacturing function?

   c) Does the master scheduler perform any other jobs than master scheduling, e.g.

      - Materials Planning (MRP)
      - Forecasting
      - Order Processing
      - Lower Lever material planning
      - Order Entry
      - Customer liaison

   d) Who does the master scheduler report to?

   e) How many master schedulers do you have? If more than one, how are they organized and coordinated?

6. Lay out a typical master production schedule report, indicating:

   - how it is prepared
   - how it is rolled through time
   - the sources and types of information

   Explain the steps involved in preparing the master schedule using an example master schedule.

7. How frequently is your MRP system run and how does the frequency of the MRP system run relate to the task of master scheduling?

III. Resource Requirements Planning

1. Do you use one or more of the following capacity planning procedures to evaluate and to predict the consequences of the master schedule before preparing a detailed materials plan (MRP run)?

   - Capacity Bills
   - Resource Profiles
   - Other

2. What types of manufacturing facilities are included in your Resource Requirements Plan? How are they included?

   - work stations (machines)
   - departments
   - assembly station processes
   - other

3. How frequently is this information prepared?

4. Who uses this information and for what specific purposes?

5. Does your Resource Requirements Planning function provide estimates of long range facility needs for capital budgeting decisions? How?

6. Please present an example of your Resource Requirements Planning reports and explain how they are developed and used.

IV. Capacity Requirements Planning

1. What detailed information do you pull off the detailed materials (MRP) plan to estimate work centre (or other work stations) capacity plans?

2. How frequently is this information prepared?

3. Who uses this information and for what specific purposes?

4. Do you use Capacity Requirements Planning to determine what each department will spend (or budget) each month?

5. Please present an example of your Capacity Requirements Planning reports and explain how they are developed and used.

V. Order Entry

1. Describe how your order entry system operates at your firm, including:

   a) How are customer orders matched up against the master schedule (if at all)?

   b) What is the length of time between customer inquiry and the delivery commitment?

   c) How is the delivery commitment decided?

   d) When you give a customer due date, how often is it moved forward by you?

   e) How do you decide whether material is available to produce the customer order?

   f) What is the role of engineering and marketing in the order entry system performance?

   g) What performance measurements describe the order entry system performance?

2. Please present the types of information (reports, etc) used by order entry personnel and describe how they are prepared and used.

VI. Final Assembly Scheduling

1. How does the Final Assembly Schedule relate to the master production schedule?

2. How does the Final Assembly Schedule operate when the product configuration used in the master schedule is not the end product item saleable configuration?

3. Please present any reports (information) that are used in preparing the Final Assemoly Schedule. Please describe how this information is developed and used.

VII. Forecasting

1. Who is reponsible for preparing forecasts?

2. What types of forecasts are being prepared for use in master scheduling. Please show examples of this information.

3. How frequently is the forecast updated?

4. What techniques are being used to prepare the forecasts, e.g. statistical techniques, management forecasts, field sales forecasts, etc.?

5. Is there a routine forecast error measurement?

6. To what extent is the master scheduling function allowed to modify the forecast?

VIII. Management Use of the Master Schedule

1. To what extent is the master schedule used by top management to consider what-if questions?

   What types of what-if questions are being considered?

2. If it is being used in this manner, can the what-if questions be analyzed without changing (disturbing) the current plan, e.g. by a separate simulation?

IX. Master Scheduling Feedback Loops

1. How does the MRP system feed information back to the Master Scheduling System?

2. How does the Capacity Requirements Planning System feed information back to the Master Scheduling System?

3. How does the Shop Floor Control System feed information back to the Master Scheduling System?

4. How does the Purchasing System feed information back to the Master Scheduling System?

5. How does the Master Scheduling System feed information back to the Production Planning System?

6. To what degree is your Master Schedule realistic, e.g. to what extent does one have the material and the capacity when needed to meet the master schedule?

7. How effective is the feedback process in maintaining the master schedule?

8. To what extent is your management policy "as a last resort change the master schedule"? Is this the first or last thing that you do to solve a problem?

X. Measuring the Master Scheduling Effectiveness

1. How are the following items measures, who measures these items, and what other items (not listed) are measured?

   - Delivery performance (actual versus policy or promise)
   - Capacity utilization (input, output, overtime, etc.)
   - Frequency of changes in order promise dates
   - Inventory and backlog performance (number of turns, backorders, etc.)
   - Actual Production to Master Schedule relationship (pieces, hours, past due, etc.)
   - Conformance of the Master Schedule to policy/plans, e.g. budget goals, capital plans, expense plans, etc.

2. What top management policies guide the preparation and the revision of the master production schedule? Please list these policies.

3. To what extent is the performance against these policies reviewed by top management, and how is this accomplished?

4. To what extent are the performance measures listed above in question 1 used to measure the performance of the firm against the management policies for master scheduling (question 2 and 3)? Is there any mismatch between the performance measures and the management policies?

Appendix 2.

Marathon Alcad Case Study.

[May 1984]

MARATHON ALCAD, REDDITCH, WORCS. [1984]

THE COMPANY, PRODUCTS AND MARKETS.

Marathon Alcad Ltd, part of the world wide Marathon Battery Company, produces nickel cadmium alkaline batteries with an annual sales value of approximately £14 million for the industrial battery market.

The Redditch factory employs about 500 people producing a range of over 800 different cell types, the cells being put together at the final assembly stage in various combinations to provide finished batteries. The product range is split between the use of plastic or steel containers and by the applications of the batteries namely, High Performance (e.g. Engine Starting), Medium Performance (e.g. Process Control and Telemetry), General Purpose (e.g. Emergency Lighting) and Cycling (e.g. Train Lighting and Air Conditioning). A typical cell is shown in Figure 1.

Approximately 80% of the cells are made to customer order, the remainder being made for stock, with typical inventory levels of 3 weeks finished stock, 10 weeks work-in-progress and 3 weeks raw materials. The company deals with about 400 customers, about 85% of which are industrial users, the remaining 15% being mostly O.E.M.'s. About 150 of these customers account for 90% of the annual sales value and the typical delivery times quoted are 2 weeks for stocked cells, (to allow for final assembly and despatch) and between 6 and 12 weeks for non stocked items.

On average, 30 orders per day are received, approximately 15% of which might be changed by the customer between receipt and shipping in terms of specification, quantity or date required. The split between export and domestic customers is approximately 70/30 and products are shipped direct to customers without using branch warehouses or distribution centres. The current length of the order book averages between 8 and 12 weeks.

THE PRODUCTION PROCESS.

A simplified manufacturing sequence for a typical stainless steel cell is shown in Figure 2. It should be noted that purchasing activities for raw materials (e.g. chemicals and steel) and for bought-out components take place before week 1 as do machine shop operations (e.g. manufacture of pole bolts).

It can therefore be seen that the typical manufacturing lead time is 5 weeks for a cell and 6 or 7 weeks for a completed battery depending on whether it is for a domestic or export customer.

The manufacturing system is essentially a batch production organisation with the majority of value being added in the fabrication stages prior to final battery assembly. Of the 800 cell types produced, approximately 120 account for 90% of the sales value and very few require special design or customising work.

COMPUTER SYSTEMS.

The company currently uses an ICL 2904 computer with a customised version of the P.A. PACS package. This includes modules for Part Master File, Product Costing, M.R.P., Routing and Product Structures which are run weekly in batch mode together with company developed modules for Cell Allocation and Master Production Scheduling which are run on-line. The current M.R.P. system has been in operation for eight years, previous to that, an IBM bureau service was used.

An Apple II microcomputer is used for forecasting and final assembly progressing. A multi-workstation Hytec microcomputer is used for sales order processing.

The company is now evaluating alternative hardware and software to replace the ICL 2904 and to incorporate the functions carried out by the microcomputers.

The current systems are coping with approximately 20,000 different part numbers, bills of material for finished products having about 5 levels of breakdown and a relatively low rate of engineering/design changes (10-20 per week). There is a high degree of part commonality.

THE MASTER PRODUCTION SCHEDULE - OVERVIEW.

The Master Production Schedule (MPS) which is input to MRP is stated in cells, in weekly time periods usually over a 25-30 week time span. The

MPS file can cater for 104 weeks, the later weeks only being used if there are customer orders that far out. However, the MRP system only looks out 20 periods; periods being defined by the user usually as a mixture of weeks and fortnights.

The first five weeks of the MPS are regarded as firm, this period corresponding to the major manufacturing stages shown in Figure 2, one week's MPS (five weeks out) being "closed" every Monday afternoon. This first section of the MPS is made up of firm customer orders and stock orders for any of the range of cells.

Beyond the five week section, the MPS contains any firm orders that have been allocated to the MPS and forecast requirements for 33 "key" representative cells.

Master Scheduling is carried out by one person with the title of Production Scheduler who also has the tasks of forecasting and cell allocation. The Production Scheduler reports to a Production Planning Manager who also has the responsibility for Customer Order Processing and Customer Liaison as can be seen in Figure 3.

The constraints on Master Scheduling are in terms of Production Capacity, Product Mix and the Annual Production Plan together with the actual customer delivery requirements and finished stock policies. All of these features are catered for in the MPS system at Alcad which will be described in detail in later sections.

PLANNING AND CONTROL SYSTEM INTERACTIONS.

Using the basic model of MPS and its relationship with other planning and control activities as shown in Figure 4.1 , this section describes how these relationships operate at Marathon Alcad.

Demand Management.

This incorporates the activities of forecasting, order entry, order promising and physical distribution, all of which come under the responsibility of the Supplies Manager at Alcad, (see Figure 3).

Forecasting is carried out by the Production Scheduler using a company developed program on an Apple II microcomputer. The program uses a single exponential smoothing model which is updated monthly using the previous month's production of the 33 "key" cell type groups. This produces a new forecast once a month which is then pro-rated every fortnight to "top-up" the actual orders on the MPS to be in line with product mix constraints from the Production Plan in terms of seven major cell application groups and the plastic/steel container production. This has been introduced during the past year and is a considerable improvement on the old method of forecasting all the cell types every month. The main problem was in the choice of the 33 "key" cell types to give a representative spread across the product range.

Sales Order Entries are dealt with by the Home and Export Customer Liaison Officers using a dedicated multi-workstation microcomputer. An order document is produced from this system which is passed to the Production Scheduler who enters the details of cells required, relevant lead times and a "required to stores" date on to an Unallocated Orders file. From this file, orders are checked against stock and work in process using the on-line Cell Allocation system. If cells are found to be unavailable, Factory Assembly Orders for the required cells are automatically generated and passed over to the Master Production Scheduling system. No despatch dates are confirmed to customers until orders have been through the Cell Allocation and MPS routines.

Production Planning.

The annual Production Plan or Budget is produced once a year several months before the beginning of the calendar year. The Production Planning process begins with an annual total sales forecast produced by the Marketing Manager for each of 33 product groups. This is in terms of numbers of cells as well as the capacity of the cells measured in "Cell Ampere Hours". The product mix forecast for 1984 is shown in Figure 4. This forecast is checked for acceptability against expected production capacity by entering the requirements as a fictitious MPS in a future period and assessing the resulting factory load derived using the Product Profiles. (See following section on MPS preparation). Once this Production Plan has been accepted by the Manufacturing Director, the revenues and costs associated with it are calculated and form the basis for the annual Financial Budget. This process is of course iterative and several amendments are likely to be made before a final Production Plan or Budget is agreed.

The measuring of output, load and capacity in terms of Cell Ampere Hours is traditional at Alcad. The Ampere-Hour rating of a cell does not relate directly to its work content but if the product mix remains fairly constant, it can be used as a reasonable global measure.

Currently there are projects in hand to change over from planning and measuring in Cell Ampere Hours to Standard Hours of work content.

Resource Planning.

The longer term planning of manufacturing resources in terms of plant, equipment and labour is currently carried out manually although the facility of using the Product Profiles and dummy MPS's could be used to assist in this area.

Final Assembly Scheduling.

Final assembly at Marathon Alcad consists of joining the required number of cells together, both mechanically and electrically to produce a battery. Lead times of 1 week for domestic and 2 weeks for export batteries requiring extra packing are allowed.

It is assumed that sufficient labour and time is available in the Final Assembly area and this has not caused too many problems in the past.

Each Sales Order is monitored in the Final Assembly area by entering its details on to a file held on an Apple II microcomputer system in the Final Assembly and Despatch area, and recording its status in terms of its readiness for assembly.

An Overdue Order Report (Figure 5) is produced from this system sorted by Order Status (e.g. CELL - awaiting cells, OINS - waiting Outside Inspection, QUEU everything available and kitted ready for assembly) and by number of weeks late.

The list of orders with status "QUEU" therefore acts as a Final Assembly "Work-to-list".

Rough Cut Capacity Planning.

The Product Profiles used in the Master Production Scheduling system are not in fact "Rough Cut" loads. The Product Profile loads are generated directly from the Product Routing file and represent the aggregated load on 29 key work centres in five major departments.

These Product Profiles were originally set up and maintained manually separately from the Routing file. This represented an excessive clerical workload and therefore the profiles soon became out of date. Consequently, routines were programmed into the system to automatically update the Product Profiles twice a week with any changes that had been made to the Routing files.

These Product Profiles are for machine or process loads as well as total labour loads for each department and form the basis of the on-line Master Production Scheduling routines.

Material Requirements Planning.

At Alcad, MRP is run once a week on a Monday night. On alternate weeks a full MPS of about 25-30 weeks is input to MRP. On the other weeks, only firm orders are used as the MPS input. Consequently on one week the Net requirements generated by MRP are "real" and the next week they may be "real" plus "forecast". This identification of "real" requirements to users of the system has proved useful although it does mean that requirements for items down at the bottom of the product structures are only produced every fortnight.

The MRP run provides Suggested Orders for components which have to be confirmed back to MRP to provide Works Orders and Job Tickets for manufactured items and Purchase Orders or Supplier Schedules for bought out items.

Works Order sets for the assembly of cells are initiated by the MPS system for each new week entering the firm period.

All production material is on the Bill of Material.

Requirements for components used in the battery final assembly are produced by using a battery part number which has a Bill of Material calling for the required number of cells and a subassembly which represents a kit of assembly components.

MASTER PRODUCTION SCHEDULE PREPARATION.

This section outlines the detailed use of the on-line Master Scheduling routines at Alcad which were introduced about two and a half years ago.

The details of the suggested Factory Orders generated from the Cell Allocation System are input to the MPS system and at this stage individual customer orders may have been split down into smaller batch sizes to enable greater flexibility in the MPS process. If two or more orders for an individual cell eventually become loaded in a particular week, the system is programmed to automatically merge these into one order as that week moves into the firm period.

These orders appear initially on the VDU screen, PS02 screen 2, on the right hand side (see Figure 6). This screen is for a particular week number which is displayed in the top left hand corner.

The orders which are identified by cell type, quantity, total ampere hours and required date are given temporary alphabetic identifiers (A-J) which are used on following screens to show individual order loads on histograms. The orders may first be tentatively loaded to that week of the MPS by assigning a 'T' against them in the final right hand column. If this loading appears satisfactory, the status of the orders may be changed from tentative ('T') to firm ('F'). The left hand side of Screen 2 shows the weekly total of ampere hours represented by firmly loaded orders against targets set by the annual Production Plan or Budget.

Thus Actuals and Targets for each of the seven main cell groups are shown in thousands of cell ampere hours (KCAH) in the bottom left hand quadrant of the screen together with weekly totals for Steel and Plastic Cells in KCAH and the quantity of cells and the Platemaking load expressed in KCAH. The number of different cell types planned to be produced and the average amps per cell are also displayed.

At present these targets are regarded more as Marketing targets rather than Production ones and as such are not strictly adhered to.

What is more important is the Work Content of the cells being allocated to the MPS and this is shown on the next screen display, PS02 Screen 3, (Figure 7).

This terminal display shows the Work Centre loading for a particular MPS week for 29 key work centres across 5 main departments in histogram form, expressed as a percentage of the capacity available in the relevant weeks, taking account of lead times.

The capacities used in this display are net figures derived from a knowledge of the permanent capacity available and an appropriate efficiency factor. This factor is monitored by the Production Scheduler by taking account of feedback from Production on Departmental Efficiencies, absentee rates and machine breakdown rates.

Therefore, capacities can be changed week by week to more closely reflect the actual situation in terms of machine maintenance or planned labour re-allocations.

If serious arrears accumulate in a department or work centre, the production supervision have to quantify the arrears in hours (e.g. 1,000 hours) and an agreement is reached to catch up over a period of weeks (e.g. 250 hrs/week). The Production Scheduler would then change the capacity available for the work centres in question for the required period.

The load figures are generated by using Product Profiles across the 29 work centres being monitored. As has already been described, these Product Profiles are automatically derived from the Routing File.

The PS02 Screen 3 display (Figure 7) shows work centres on the horizontal axis, those with asterisks below being total labour for the preceding group of work centres. The vertical axis shows load between 52% and 108% of capacity, asterisks denoting the load generated by firmly loaded orders. The effect of tentatively loaded orders is shown by using the alphabetic identifiers from the previous screen display (Figure 6).

Hence the effect of orders A, B and C can be seen in Figure 7. Loads exceeding 108% of capacity are shown with a > at the top of the relevant column.

If during the MPS loading process a serious overload is predicted on a work centre, then the effect of moving factory orders between weeks can be seen by viewing another screen display, PS02 Screen 4 (Figure 8). This screen uses a similar histogram display, this time for a particular work centre with weeks either side of the current week (shown with an asterisk underneath) along the horizontal axis.

The loading of orders to the MPS continues during the week in this fashion, firstly tentative then firm until by the Monday afternoon a fully loaded week of the MPS can be "closed" in agreement with Production.

Once this agreement has been reached, a Weekly Factory Programme is produced (Figure 9) which shows the number and ampere hour equivalent of "cells to stores" for the week in question together with the work loads on the key work centres in the preceding weeks. The example given shows an overall load of 114% of capacity which could be catered for by using overtime. A Forward Production Programme for the next 13 weeks showing firmly loaded orders is also produced (Figure 10).

PLANNING AND CONTROL SYSTEM EVALUATION.

In this section the performance measures which are used to evaluate planning and control systems at Marathon Alcad are briefly described and some of the improvements to the current systems which are in the process of implementation are mentioned.

Measures.

Delivery performance is monitored in terms of the percentage of customer orders delivered on time and the % delivered within two weeks of the promised date.

Labour and machine utilisations are also monitored.

The main MPS evaluation is in terms of the quantity of cells and cell ampere hours produced against the Annual Production Plan.

Improvements.

The major improvements to the systems are in the area of changing over planning, displays and reports from using cell ampere hours as a measure to using hours of work content. Consequently, the Forward Production Programme report (Figure 10) is being supplemented with a report also showing hours loading on the key work centres.

The PS02 Screen 2 (Figure 6) is being altered to write out the Marketing targets in terms of KCAH's and replace them with hours available and planned load for the five major departmental labour work centres. This display is being supplemented with another giving capacity, planned load and tentative load for each of the 29 key work centres in a tabular form so as to give information on those work centres loaded at less than 52% or more than 108% of capacity.

Future improvements are also envisaged with the implementation of replacement hardware and software systems.

Construction

Cell Group Assembly

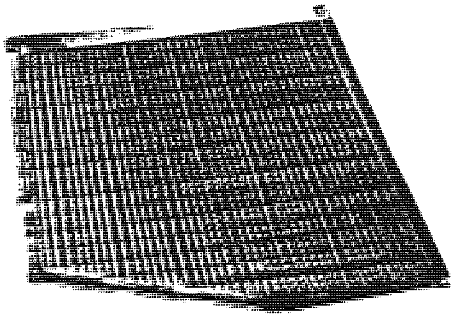
ALCAD nickel cadmium cells are of perforated steel pocket plate construction employing nickel hydrate as the major constituent of the positive active material and cadmium hydrate for the negative active material. The manufacturing process includes the nickel-plating of components of the negative and positive plates in the cells.

Plates are solidly bolted on their group bolts except for the smaller capacity cell sizes which have welded assemblies. Terminal pillars are machined from mild steel of ample section, but for large high performance cells they are of multi pole design to ensure adequate current carrying capability. For plastic cased cells the solidity of the plate group is an important contribution to the rigid construction of ALCAD cells.

The ALCAD patented double positive plate construction consists of two thin plates placed in the same frame and consolidated under high pressure.

The effect is to double the surface area of the active material and lower the internal resistance.

ALCAD double positive plate.



Separation

The design of separation of plates is essential to the life and performance of any cell. Separation in ALCAD cells is by sheet or pin type separators between the plates together with channel edge insulation.

Electrolyte

The electrolyte used in ALCAD cells is a solution of potassium hydroxide and lithium hydroxide in deionised water. Its function is to provide an adequate supply of ions and water to support the reactions at the plates. There is no significant change in specific gravity related to state of charge of the battery.

A typical specific gravity (SG) of an ALCAD cell is 1.200 at 20°C and may be used safely at operating temperatures of −20°C.

Under normal float voltage applications it is not necessary to change the electrolyte during the lifetime of the battery.

Cell Containers

ALCAD cells are available in either plastic or steel containers. The suffix 'P' in the cell designation indicates a plastic case e.g. LP, and the suffix 'S' a steel case. The choice of steel or plastic containers depends on the applications and operating conditions and the advantages of each construction is summarised below.

■ Plastic Cases

Translucent containers allow electrolyte levels to be checked at a glance. Other advantages include complete freedom from corrosion in wet and saline atmospheres and easy assembly.

Polypropylene, with its high impact resistance, is used for the majority of the ALCAD ranges.

■ Steel Cases

Great strength for conditions of high shock and vibration. The cells are capable of operating in wide temperature extremes, not possible with ordinary batteries. Steel cells are housed in insulated wood crates of robust construction.

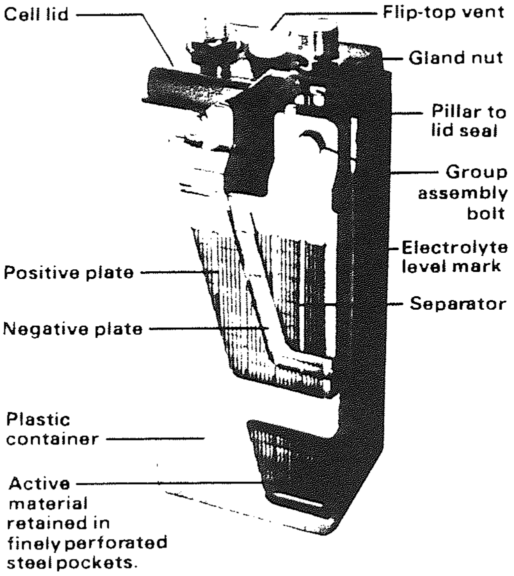


Figure 1. - Typical Cell

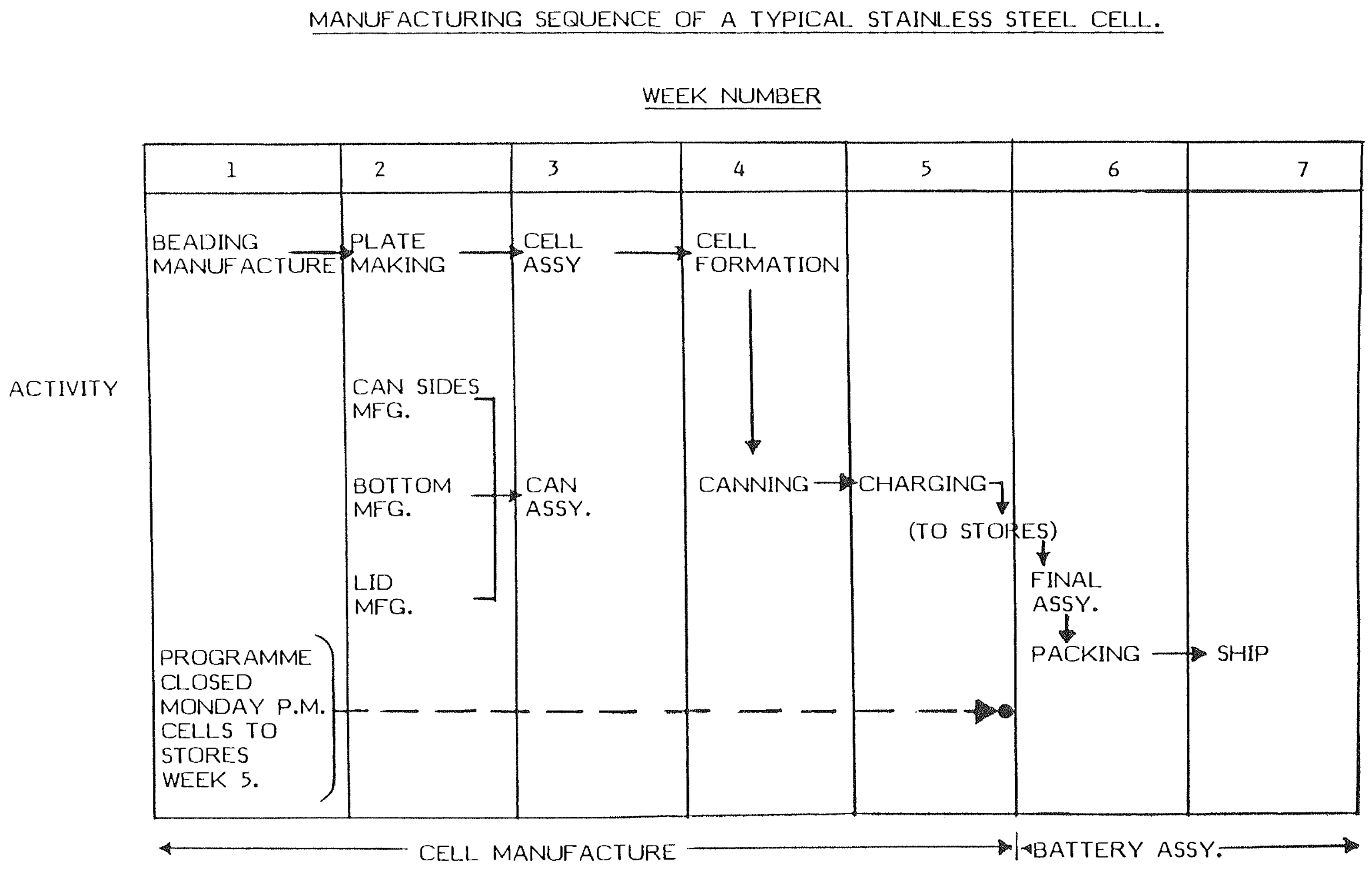


Figure 2. - Manufacturing Sequence.

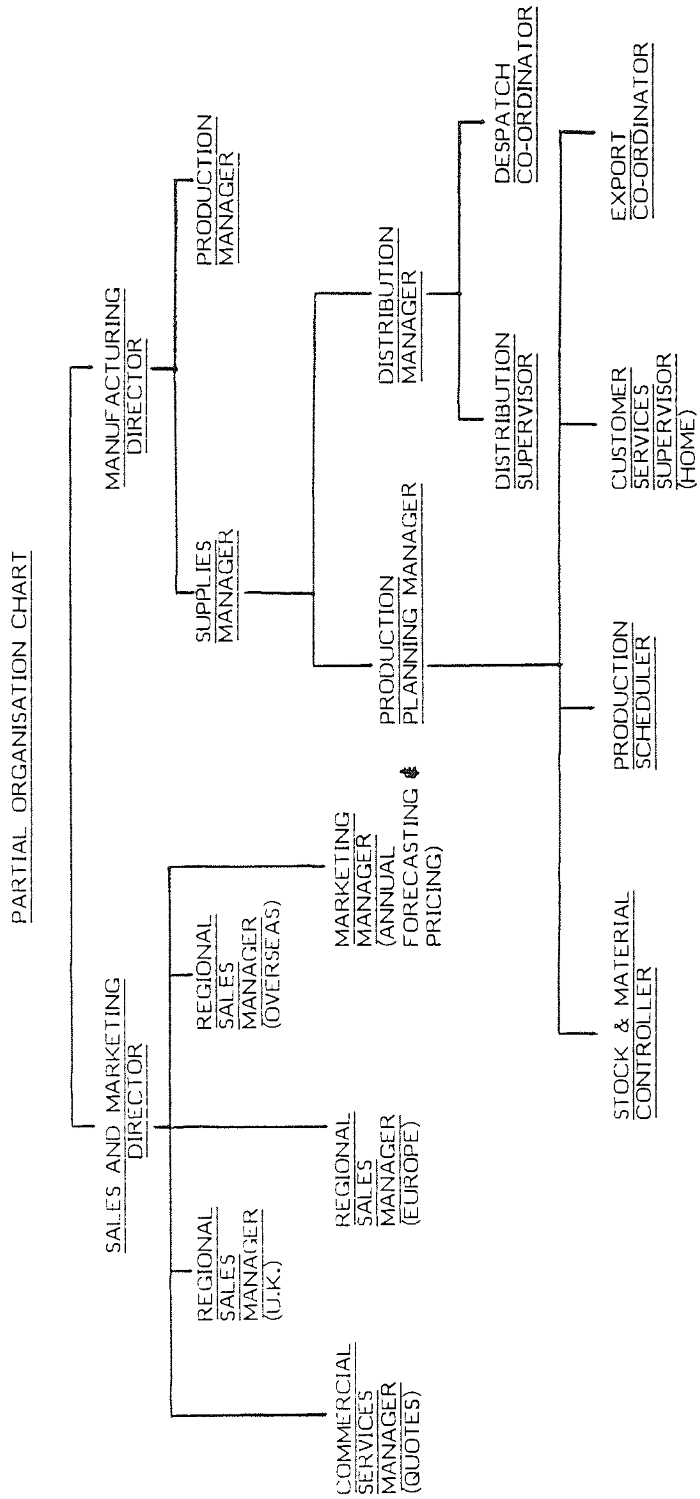


Figure 3. - Partial Organisation Chart.

PRODUCT MIX 84

PRODUCT	GROUP	VOLUME KCAH	% OF TOTAL	NUMBER OF CELLS	% OF TOTAL	AVERAGE CELL SIZE AH
EP	1	4559	11.72	198224	36.15	23.00
LP	2	8268	21.26	46284	8.44	178.64
LS	3	350	0.90	392	0.07	892.86
RAILWAY	4	262	0.67	9180	1.67	28.54
LOW MAIN	5	8	0.02	912	0.17	8.77
OBSOLETE	6	8	0.02	400	0.07	20.00
TOT. GEN PURPOSE		13455	34.60	255392	46.58	52.68
UHP	10	4022	10.34	60152	10.97	66.86
UHS	11	289	0.74	2000	0.36	144.50
HP	12	978	2.51	11080	2.02	88.27
HS	13	419	1.08	3113	0.57	134.60
DLP	14	458	1.18	5010	0.91	91.42
DLS	15	1090	2.80	8408	1.53	129.64
ES/LR	16	95	0.24	416	0.08	228.37
LCV/HL	17	2006	5.16	16370	2.99	122.54
TOT. HIGH PERF'NCE		9357	24.06	106549	19.43	87.82
MP	20	7865	20.22	76161	13.89	103.27
MS	21	2865	7.37	11863	2.16	241.51
RAILWAY	22	73	0.19	2355	0.43	31.00
TOT. MED PERF'NCE		10803	27.78	90379	16.48	119.53
VP	30	671	1.73	4074	0.74	164.70
RV/VF	31	2080	5.35	17276	3.15	120.40
RVP/VE	32	2440	6.27	74351	13.56	32.82
GV/MV	33	85	0.22	265	0.05	320.75
TOT. CYCLING		5276	13.57	95966	17.50	54.98
TOTAL CELLS		38891	100.00	548286	100.00	70.93
PLATES		4100				
TOT. CELLS & PLATES		42991		548286		

Figure 4.

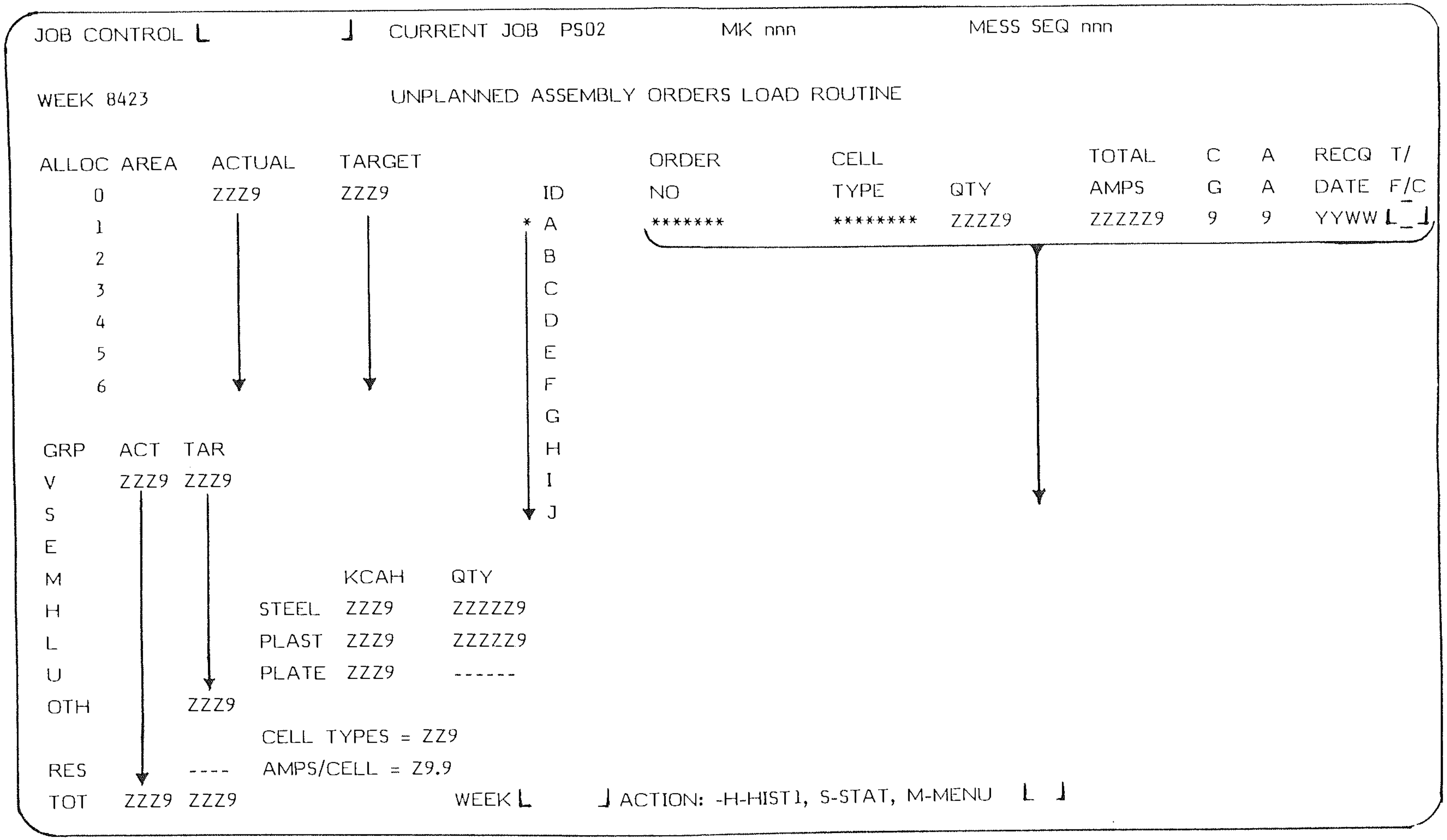
```
ALCAD LTD              OVERDUE ORDER REPORT           DATE 31/01/84       WEEK NO. 84/05

ORDER GROUP AA

PART NUMBER  DESCRIPTION              ORDER    -------QUANTITY--------   START  DUE    CON  ORDER    CUSTOMER     WKS
                                      NO.      ORDERED    OUTSTANDING    DATE   DATE   FIR  STATUS   NAME         LATE


44000        LR40 CELL                88795     19             19        84/04  84/04       CELL 23  B. RAIL      1
02650S       NP25 CELL SCREW VENT     11037     92             92        84/05  84/05       CELL 26  STANDBY      0
00770S       UHP35 SCREW VENT CELL    1103801   200            200       84/05  84/05       CELL 30  STANDBY      0
   |            |                       |        |              |          |      |            |        |         |
   |            |                       |        |              |          |      |            |        |         |
74970        LP135 CELL               88380     90             90        84/03  84/04       OINS 25  CSSL         2
77450        EP0.5 CELL               88716     80             80        84/04  84/04       OINS 30  CERTINA      1
75570        RE16 CELL                88960     4              4         84/04  84/04       OINS 25  B. RAIL      1
   |            |                       |        |              |          |      |            |        |         |
   |            |                       |        |              |          |      |            |        |         |
74990        LP200 CELL               1108402   40             40        84/03  84/03       QUEU 18  C. HOLLAND   2
03470        UHP14 CELL               88332     90             90        84/03  84/03       QUEU 30  CSSL         2
01920        HS400 CELL               00002     1              1         84/04  84/04       QUEU 30  PATERSON     1
77480        EP2.5 CELL               1100003   200            200       84/04  84/04       QUEU 25  HUTCHISON    1
77480        EP2.5 CELL               11041     75             75        84/05  84/05       QUEU 27  C.N. ZEALAN  0
74990        LP200 CELL               1105504   92             92        84/05  84/05       QUEU 30  FIAMM        0
02620        MP18 CELL                1108403   20             20        84/05  84/05       QUEU 25  C. HOLLAND   0
```

Figure 5.



```
JOB CONTROL L          ┘ CURRENT JOB  PS02        MK nnn              MESS SEQ nnn

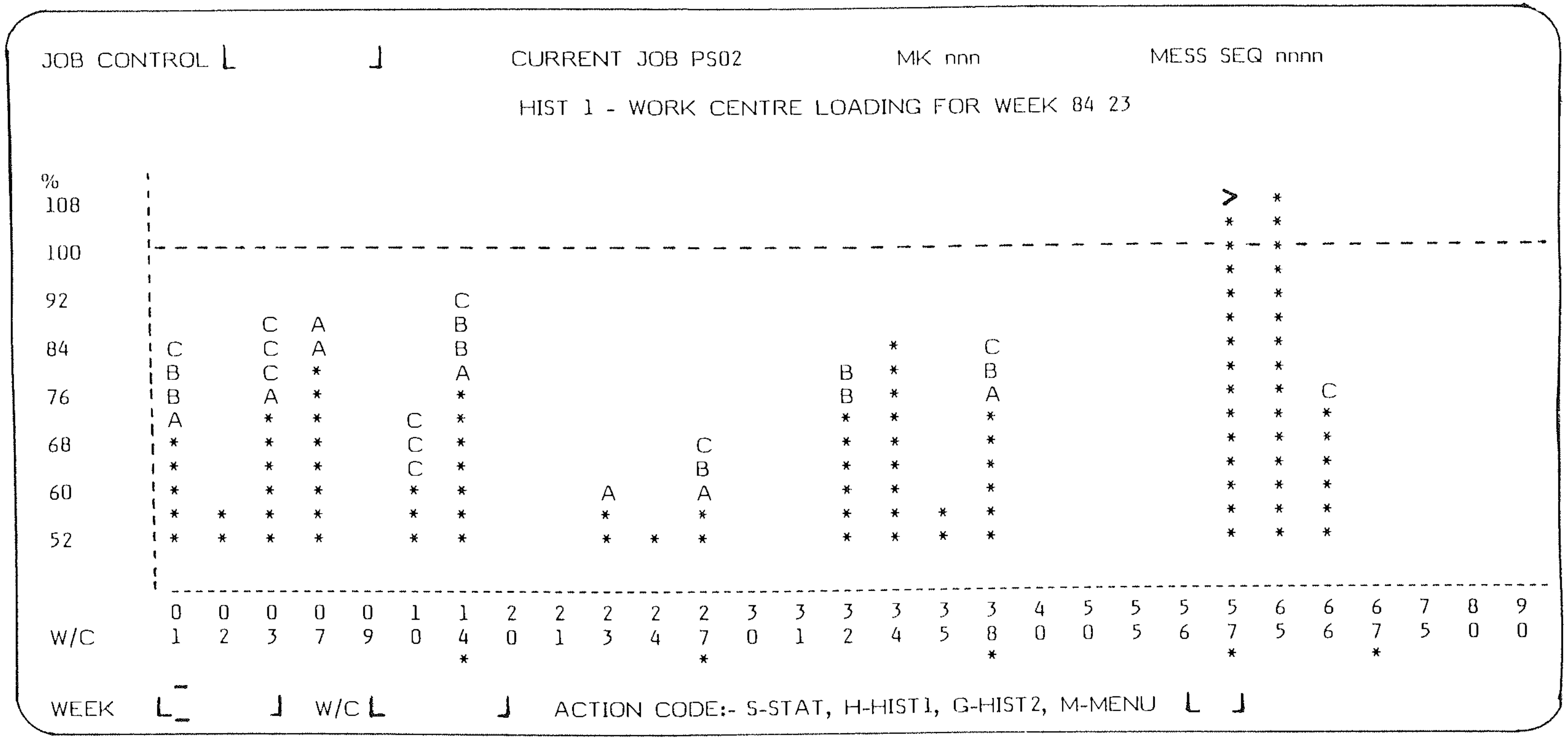
WEEK 8423                UNPLANNED ASSEMBLY ORDERS LOAD ROUTINE

ALLOC AREA   ACTUAL   TARGET                ORDER      CELL             TOTAL    C   A   RECQ  T/
     0        ZZZ9     ZZZ9           ID    NO         TYPE      QTY    AMPS     G   A   DATE  F/C
     1                              * A     *******    ********  ZZZZ9  ZZZZZ9   9   9   YYWW L_┘
     2                                B
     3                                C
     4                                D
     5                                E
     6                                F
                                      G
GRP   ACT   TAR                       H
V     ZZZ9  ZZZ9                      I
S                                     J
E
M                     KCAH    QTY
H             STEEL   ZZZ9    ZZZZZ9
L             PLAST   ZZZ9    ZZZZZ9
U             PLATE   ZZZ9    ------
OTH         ZZZ9
              CELL TYPES = ZZ9
RES         ----      AMPS/CELL = Z9.9
TOT   ZZZ9  ZZZ9                WEEK L      ┘ ACTION: -H-HIST1, S-STAT, M-MENU  L  ┘
```

PS02

SCREEN 2

Figure 6.



JOB CONTROL └ ┘ CURRENT JOB PS02 MK nnn MESS SEQ nnnn

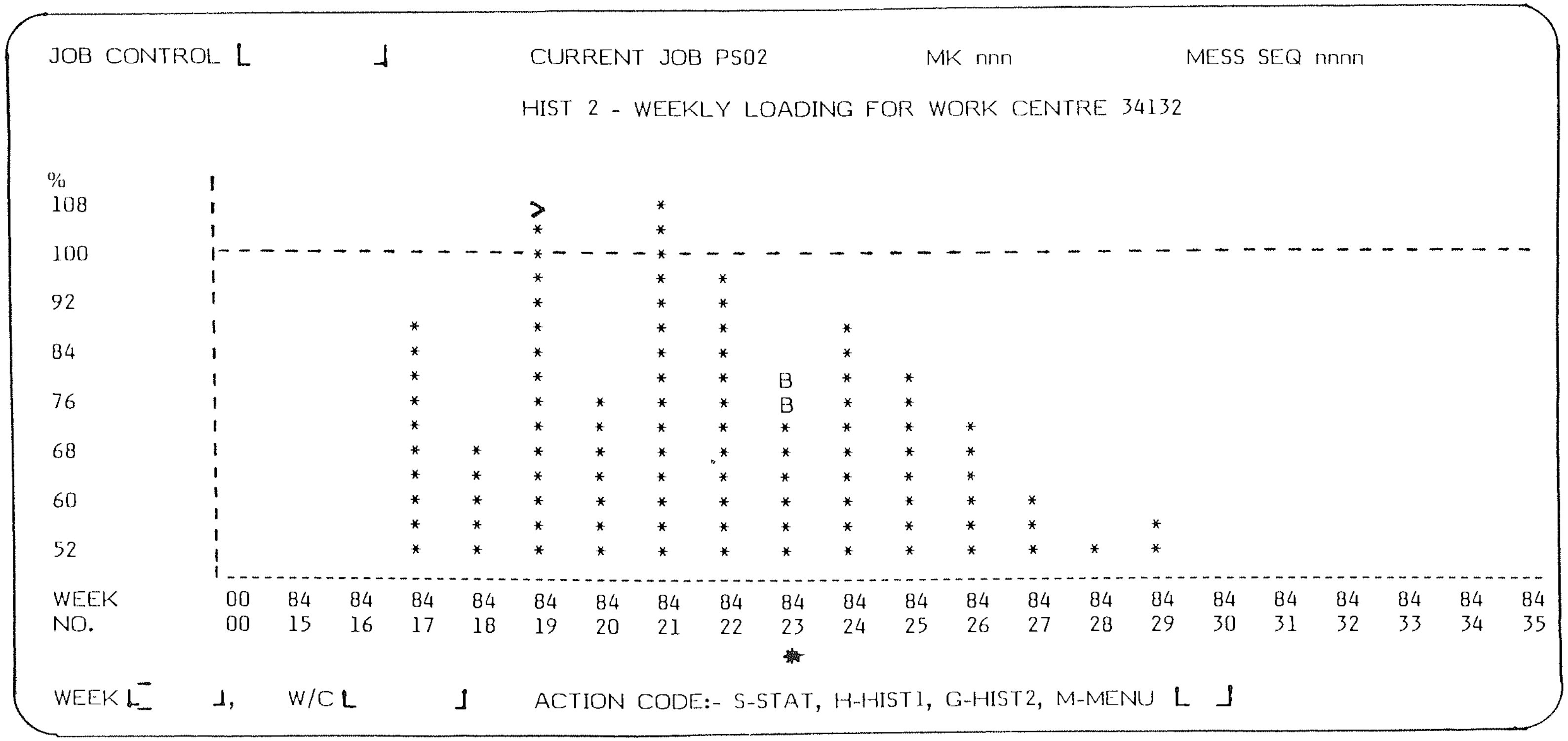
HIST 1 - WORK CENTRE LOADING FOR WEEK 84 23

WEEK └ ┘ W/C └ ┘ ACTION CODE:- S-STAT, H-HIST1, G-HIST2, M-MENU └ ┘

PS02

SCREEN 3

Figure 7.



```
JOB CONTROL └        ┘          CURRENT JOB PS02        MK nnn          MESS SEQ nnnn
                              HIST 2 - WEEKLY LOADING FOR WORK CENTRE 34132
%
108    |                      >       *
       |                      *       *
100    |----------------------*-------*---------------------------------------------------------
       |                      *       *   *
92     |                      *       *   *
       |              *       *       *   *       *
84     |              *       *       *   *       *
       |              *       *       *   *   B   *   *
76     |              *       *   *   *   *   B   *   *
       |              *       *   *   *   *   *   *   *   *
68     |              *   *   *   *   *   *   *   *   *   *
       |              *   *   *   *   *   *   *   *   *   *
60     |              *   *   *   *   *   *   *   *   *   *   *
       |              *   *   *   *   *   *   *   *   *   *   *       *
52     |              *   *   *   *   *   *   *   *   *   *   *   *   *
       +----------------------------------------------------------------------------------------
WEEK     00  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84
NO.      00  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35
                                              *

WEEK └  ┘,  W/C └       ┘   ACTION CODE:- S-STAT, H-HIST1, G-HIST2, M-MENU └ ┘
```

PS02

SCREEN 4

Figure 8.

MARATHON ALCAD LTD.

PS51
DATE 30/4/84
PAGE 2

WEEKLY PROGRAMME FOR CELLS TO STORES WEEK 84/23

	QTY	AMPS	AMPS/CELL
STEEL	2,135	554,750	260
PLASTIC	6,270	420,378	67
PLATES		46,270	
TOTAL	8,405	1,021,398	116

CELLS			PLATES	
TYPE	QTY	AMPS	TYPE	AMPS
V	550	213,700	V	9,600
S	720	94,150	S	6,670
E	3,000	64,800	E	30,000
M	1,578	95,978	M	0
H	870	62,695	H	0
L	772	235,155	L	0
U	915	288,650	U	0
P	0	0	P	0
OTHER	0	0	OTHER	0

	8419	8420	8421	8422	WORK CENTRE	PERMANENT CAP. AVAIL	EFF %	NET CAP.	CAP. USED
E/L NEG (BRIQ)					32401	156	80	125	137.15
E/L POS (BRIQ)					32402	156	95	148	91.32
V NEG (BRIQ)					32403	156	90	140	155.92
S/H/U/V POS (L/P)					32407	468	80	374	284.96
S/H/U/M NEG (L/P)					32409	468	70	327	213.23
M/E/L/ POS (THIN L/P)					32410	234	80	187	44.17
TOTAL S/F LABOUR					32414	897	92	780	926.97
PLATE SPOTWELDING					32520	897	95	852	771.22
PLATE PRE-ASSEMBLY					32521	468	95	445	133.68
WIDE PLATE PRESSING					32523	312	90	280	245.85
NARROW PLATE PRESSING					32524	312	90	280	115.07
TOTAL PLATEMAKING LABOUR					32527	1,365	80	1092	1,265.99
GROUP WELDING					34130	195	95	185	47.84
GROUP BOLTING					34131	312	95	296	223.83
CRANK PLATES (AIR PRESS)					34132	39	95	37	72.93
PIN + EDGE CELL ASSEMBLY					34134	390	95	370	174.00
SHEET SEP.CELL ASSEMBLY					34135	390	95	370	320.13
TOTAL CELL ASSEMBLY LABOUR					34138	780	85	663	839.00
FORMATION					34340	215	63	135	206.87
POLYSTYRENE CELLS					34250	702	95	222	94.74
POLYPROPYLENE CELLS					34255	312	75	234	143.05
HAND HEAT SEALING					34256	78	85	66	84.96
TOTAL PLASTICS LABOUR					34257	566	85	481	372.62
CAN ASSEMBLY WELDING					33365	250	80	200	239.24
TOP WELDING					33366	250	80	200	241.90
TOTAL WELDING LABOUR					33367	480	80	384	481.14
SHOTBLASTING					33375	78	70	55	88.45
CELL PAINTING					34780	117	70	82	27.23
CHARGESHOP					34690	331	88	291	332.45

NET KEY WORK CENTRE HOURS AVAILABLE:3400

PLANNED: 3886 114%

Figure 9.

MARATHON ALCAD LTD.

PS55
DATE 30/04/84
PAGE 1

FORWARD PRODUCTION PROGRAMME

	8423	8424	8425	8426	8427	8428	8429	8432	8433	8434	8435	8436	8437	8439	TOTAL	%
V TYPE KCAH	223	66	183	190	81			29			21				793	19.92
S TYPE KCAH	101		24		68			78				67		15	354	8.87
E TYPE KCAH	95	85	171	118	80	4				4			4		560	14.07
M TYPE KCAH	96	24			4	6	37		64		26	52	158	19	485	12.18
H TYPE KCAH	63					17		18							98	2.45
L TYPE KCAH	235	254	176		8					14				18	704	17.68
U TYPE KCAH	209	189	214	181	183	13									987	24.79
P TYPE KCAH																
OTHER KCAH																
TOTAL KCAH	1021	617	767	489	424	39	37	125	64	18	47	119	162	53	3982	
STEEL QTY	2155	1880	1889	2010	629	130		780	100			200		38	9841	26.98
PLASTIC QTY	6270	2065	5996	1600	4967	720	476	545	200	500	996	632	1385	271	26623	73.01
STEEL KCAH	555	293	421	370	128	6		53	24			48		15	1912	48.01
PLASTIC KCAH	420	254	276	49	227	34	37	72	40	18	47	71	162	38	1744	43.78
PLATE KCAH	46	70	70	70	70										326	8.19
NO OF CELL TYPES	37	11	23	8	26	4	3	4	2	2	3	3	2	3		
AVG AMPS/CELL	116	138	88	116	63	43	77	94	213	35	46	143	116	170	100	

Figure 10.

Appendix 3.

Riker Laboratories Case Study.

[May 1984]

RIKER LABORATORIES, LOUGHBOROUGH, LEICS. [1984]

THE COMPANY, PRODUCTS AND MARKETS

Riker Laboratories, part of the international 3M group of companies, manufactures and markets pharmaceuticals in the form of packaged tablets, capsules, sachets and aerosols. It also manufactures and sells fine chemicals and carries out contract manufacturing, particularly aerosol filling, for other pharmaceutical companies.

The company started manufacture in the U.K. some 30 years ago and now produces approximately 9 million finished packs per year with a sales value of £29 million and exports to over 75 countries throughout the world, many of the markets requiring different packaging due to individual language and legal constraints.

Riker employs approximately 600 persons of whom 350 work in its manufacturing division which is based at two sites in Loughborough.

Approximately 50% of products are for the Home Market, being made to stock with a target service level of 99% of the value of orders being available for allocation on the same day. The products for the Export Market are made to customer order with a target of 95% of the value of orders despatched within 6 weeks of receiving an order. Approximately 15% of total sales is accounted for by contract work which is manufactured and packed in accordance with the terms of each particular contract. The Home Market consists of several hundred different customers with approximately 20% of them accounting for 80% of the sales value. Riker do not operate branch warehouses or distribution centres and therefore deliveries are made direct to home customers. The Export Market consists of agents and 3M subsidiary companies representing an order book of about 2 months. The company typically holds a 1 month stock of finished products for home sales and receives about 15,000 home orders and 1,500 export orders per year.

THE PRODUCTION PROCESS

One of the plants in Loughborough manufactures fine chemicals, some of which are used in its own products, and "intermediates", the total output of which in 1983 was approximately 342 million tablets, 48 million capsules, 4 million sachets, 6 million aerosols and various aerosol components and liquids.

The other plant carries out the packaging of the 500 different finished product specifications which amounted to 9 million packs in 1983.

Typical lead times for tablet production are shown in figure 1. Across all products, internal cumulative lead times range from 2 to 5 months and composite lead times, including raw material purchasing and testing range between 4 and 9 months. Approximately 8 weeks worth of raw material, 3 weeks worth of intermediates and 8 weeks worth of packaging materials are held in stock.

The number of works orders processed each year are approximately 2,600 in the Manufacturing Plant and 1,500 in the Packaging Plant. From the previous description it follows that manufacturing is organised on a batch production basis. The sequence of batches have to be carefully planned to minimise the amount of cleaning down of equipment and process plant between products.

COMPUTER SYSTEMS

In 1973 the company decided to adopt the IBM R.P.S. package using their existing IBM 370/115 computer. Eleven years later, a much modified version of this original package is running on an IBM 4341 model 2.

At present, all updating of mainframe data files is carried out in batch mode although the order book input is on-line to a transaction file which is then batch up-dated over night. It is planned to introduce on-line stock recording next year.

The R.P.S. system does not include a routing file, but, to allow capacity planning to be undertaken, routing information has been stored on an "Easitrieve" file (a personal file) and routines are used to extract information from the R.P.S. system which can then be combined with the Easitrieve data. The number of parts and bill of material structure links are illustrated in figure 2. There is a relatively low rate of changes to the B.O.M. of the order of about five new part numbers each week, the majority of these being changes in packaging design.

THE MASTER PRODUCTION SCHEDULE - OVERVIEW

When MRP was first introduced at Riker, sales requirements were fed in and the resulting net requirements for manufacturing were expected to be achieved by the production departments. In practice, back-logs of work developed in many areas, masking real priorities. This was because the requirements did not take account of the effective capacities of the manufacturing departments.

In 1976 the Master Production Scheduling technique was introduced and now involves Master Scheduling all finished products and at all levels down through the product structures.

The Master Schedule at the finished product stage (packaging) has a planning horizon of approximately 13 weeks and consists of forecast replenishment orders for Home Sales together with actual and forecast orders for Export Sales.

The Master Scheduling at different levels down through the Product Structures is completed over three weekly MRP runs.

A "new" Master Schedule is created every 2 months looking 3 months ahead, with the first two of these months agreed in terms of capacity requirements with the various Production Managers.

Master Scheduling is carried out by a team of 4 people including and led by the Planning Manager. He reports to the Materials Control Manager who also has responsibility for Packaging Design and Control, Export Customer Services and Purchasing (see figure 3).

The Master Scheduling task is split on a Product Group basis with two planners dealing with liquids, aerosols and fine chemicals and the other two people dealing with tablets and capsules. Since some of these products share the packaging facilities, the overall packaging schedule is co-ordinated by the Planning Manager.

The constraints on Master Scheduling are in terms of meeting targets which have been set in several areas which, in order of priority are; Customer Service, Manufacturing Efficiency and Inventory levels. The details of these targets and the measures used are described in later sections, as are the details of the Master Scheduling procedures.

PLANNING AND CONTROL SYSTEM INTERACTIONS

Using the model of the MPS and its relationship with other planning and control activities as shown in figure 4.1, this section describes how these relationships operate at Riker Laboratories.

Demand Management

This function incorporates the activities of forecasting, order entry, order promising and physical distribution, not all of which are the responsibility of the Materials Control Manager at Riker.

Forecasting is regarded as the key to the success of the whole system in the company. Much effort and resources have been applied to the problem of obtaining better forecasts over the years in terms of the development of systems and of managers spending time visiting overseas customers. A forecast file is held for every finished product (Home and Export) which looks forward about 15 months and is up-dated every three months (with exceptions input every month). The current approach is to provide information on the last 12 months' history of orders, the current forecasted orders for the next 12 months and 3 blank boxes in which new forecasted orders are to be added. (See figure 4). In the case of Home Sales, these new forecasted orders are put in by the Planners and in the case of Export Sales they are entered by the overseas customers or agents.

A new approach to aid forecasting, which is in the process of implementation, uses local sales histories as opposed to a history of shipments from Riker, together with one of a choice of forecasting models (Average, Trend or Manual) to provide a computer generated local sales forecast. (See figure 5). This approach automatically takes account of the problem of 4 and 5 week months and then, working from the current stock position and the required stock cover, it forecasts the shipments required from Riker. This monthly Local Sales/ Shipment Forecast will be sent out every three months with a request for a Changed Local Forecast to be added if required, (i.e. if the local market knowledge suggests a different forecast from that given by the statistical model).

Materials Management Staff visit the local Market Manager in each overseas market at least once a year in an effort to explain the importance of the forecasts, feedback forecast inaccuracies and thus improve forecasting performance.

The Production Planners can use a "hunch country" on their forecast file to put in a positive or negative forecast quantity for any product if they do not believe that the sales forecast being suggested is realistic. They have chosen to do this rather than altering the individual forecasts so that eventually forecast inaccuracies can still be fed back to those providing them. This "dummy" forecast does, however, allow more realistic Master Scheduling.

Export Sales orders are received by the Export Customer Services section which is part of the responsibility of the Materials Control Manager (see figure 3). The orders are matched on line against the forecast file and a shipment date is calculated.

Home Sales from stock are entered directly every day by the Accounts Department.

The stores and physical distribution activities of the company are not within the responsibility of the Materials Control Department.

Production Planning and Resource Planning

Production Planning at Riker is in the form of an Annual Production Forecast which is usually produced every April or May for the forthcoming financial year which runs from November to October. The units of measure used for this plan are mixed; for example, total number of tablets or capsules for Intermediate production and total manufacturing hours for chemical production.

This Annual Production Forecast uses information from the Forecast file for Home and Export sales and forms the basis for resource planning in terms of manpower planning, plant capacity planning and overhead recovery. Production planning and Resource planning are currently carried out manually on paper.

Final Assembly Scheduling

The Packing schedule is analogous to a Final Assembly Schedule at Riker. This is not a separate schedule but forms part of the overall Master Scheduling process. For Export Sales, the Packaging Schedule includes only firm orders whereas Intermediate Manufacturing Schedules and Purchase Requirements are mostly generated from forecasts.

Rough Cut Capacity Planning

During the Master Scheduling Process, loads are roughly checked against capacities for each work centre. At this stage, both loads and capacities are expressed in terms of units of product per week e.g. number of tablets/bottles/ sachets per week.

The requirements produced as a result of Master Scheduling decisions are shown on Requirements Summary Reports (RP 49) (see figure 6), which show details of requirements and their starting weeks for the next 13 weeks and the remaining requirements up to the ninth month ahead. These reports also show a total of the last twelve months' actual demand as a comparison.

These requirements have to be visualised as being spread over the available weeks to give an average weekly load and this has to be mentally checked against the expected available capacity.

Material Requirements Planning

At Riker, MRPI is run once a week on a Monday and produces, amongst other reports, Works Orders, Purchase Requirements and Laboratory Work lists. At present, the MRP system only deals with 13 weekly periods although there are plans in the pipeline to alter this to 26 weekly periods.

Items such as solvents and gases are not planned and ordered using the MRP system, but are dealt with using a Reorder Level approach.

Capacity Planning

Capacity Planning in terms of Productive Standard Hours (PSHs) is carried out each week for each Work Centre. As mentioned earlier, the Routing file is not one of the R.P.S. mainframe files but is held on a personal Easitrieve file. Each week, after the MRP run, a program is used which goes into the R.P.S. files, retrieves the weekly requirements and multiplies these by their respective PSH contents held on the Easitrieve file to give the predicted weekly load in PSH's by Work Centre for the next 13 weeks.

Each week the Work Study Department issues Control Reports in terms of the PSHs actually produced by each Work Centre.

MASTER PRODUCTION SCHEDULE PREPARATION

This section outlines in more detail the sequence of events and methods used in Master Production Scheduling at Riker Laboratories.

There are basically two types of updating to the Master Schedule used at the company. The first is the creation of a "new" Master Schedule every two months which looks ahead three months and the first two months of which are regarded as relatively fixed. This is then followed over the next few weeks by the Master Scheduling down through the product structures. The second type is the weekly revision of the "current" Master Schedule with minor alterations.

The creation of the "new" Master Schedule follows through several stages, namely:

Stage 1 : Forecasted requirements from the forecast file and actual orders from the order file for the next three months are obtained. These requirements are then allocated to weeks on the Packaging Master Schedule and a Rough Cut Capacity Plan developed which attempts to smooth out the work load. At this stage each Departmental Production Manager is contacted and a tentative agreement reached as to the capacity required over the first two months of the schedule. A formal meeting then takes place between the Materials Control Manager, the Planning Manager and the Production Director at which the proposed MPS is checked against the Annual Production Forecast and eventually agreed.

Stage 2 : The individual planners now schedule each of the eight packaging facilities in detail on bar charts showing packaging runs and clean down times, attempting to fill them to the agreed capacity for at least the next two months.

Stage 3 : The schedules for all the packaging facilities are combined on one bar chart (see figure 7) and the resulting load is checked by the Planning Manager against the "contracted" capacity. The measures used here are quantities of products packed and productive standard hours using cumulative totals and weekly averages since the schedules only specify start dates for the packaging runs.

Stage 4 : Once the detailed Packaging Master Schedule has been finalised, it is put in to a weekly MRP run and the requirements "to plan" at the next level down in the product structure (e.g.

tablet production) are produced as output and used as the basis for Master Scheduling at that level. This process of scheduling continues down through Intermediate manufacture and chemical manufacture (which might include up to 5 scheduled stages) eventually producing raw material requirements. Thus each week, for about three weeks, a "new" Master Schedule is input to MRP at descending levels through the product structures, each schedule having been derived to meet the calculated requirements and fill up capacity to the agreed level.

Stage 5 : At this stage a Production Weekly Requirements Report (see figure 8) is produced showing historical actual achievement and forecasted requirements per week for the next two months for each of the Packaging and Manufacturing areas.

The weekly monitoring of actuals against the schedules and the making of minor changes to the schedules is a continuous process which follows a regular pattern, namely:

Monday: MRP run is made and output produced including a Master Schedule Summary Report, RP51 (see figure 9) which is used by the Planning Manager to check the validity of the Master Schedules in each Production area. This is done by monitoring the "to schedule" quantities on this report which shows how far ahead the Planners have scheduled and which quantities have been "missed" or are still left to schedule as a result of the previous MPS input.

Wednesday: Planners visit the Packaging Factory Production Managers to review the current schedules in terms of feeding back what has actually been achieved and highlighting any material or capacity problems.

Thursday: Similar visits are made to the Production Managers in the other Factory, this time also taking account of any schedule changes which have been suggested by the Packaging Factory.

Friday: Using an up-to-date Work in Progress report which has been produced over night, the Planners review every part number by reference to a Forecast Review/R.P.S. Report (see figure 10) which shows M.R.P.'s suggestions of what is left "to plan". Taking this information into account and the suggestions made by the Production Managers, the Planners decide on amendments to the current Master Schedules and punched cards are produced ready for the MRP run on the following Monday.

This feeding back of information from the Production areas to produce Master Schedule amendments is regarded as the "closing of the loop' in their MRP system.

PLANNING AND CONTROL SYSTEM EVALUATION

In this section the performance measures which are used to evaluate the planning and control systems at Riker Laboratories are described.

As mentioned previously, targets are set which are used to measure the performance of the Materials Management function and the Master Production Scheduling process in particular. Where there is any conflict in meeting these targets, the order of priority is Customer Service, followed by Manufacturing Efficiency then Inventory Levels. Customer Service is measured by the percentage of the value of orders despatched on time. For U.K. sales, "on time" means that the stock should be available for allocation on the same day as receiving the order. For Export sales, it means goods despatched within six weeks of receiving the order or by the promised due date if it is outside the normal six weeks.

Riker's performance against these Customer Service Measures is shown below in Table 1.

Year	1976	1982	1983	1984 Target	1984 Y.T.D.
U.K.	96%	99%	99%	99%	98%
Export	40%	91%	95%	95%	91%

Table 1. Customer Service Measures.

Manufacturing Efficiency or the Service given by Materials Management to Production is measured in terms of the percentage of Works Orders available to be worked on (i.e. all materials available) in the week specified by the Master Schedule. The performance against this measure is shown in Table 2.

Year	1981	1982	1983	1984 Target	1984 Y.T.D.
Avail	78%	87%	88%	95%	90%

Table 2. Service to Production Measures.

Inventory Levels are measured in several different ways at Riker. Firstly, the value of the total inventory, including Raw Materials through to Finished Goods is monitored. Secondly, the Net Manufacturing Inventory valued at the cost of sales is measured and this is also expressed as a number of months' cover which takes account of changing output levels. These measures are shown in Table .3.

Year	1974 (PreMRP)	1983	1984 Target	1984 Y.T.D.
Value(£k)	2200	3606	3575	3731
Net Mf Inv	420	912	970	971
Mths' Cover	7.2	3.7	3.75	3.94 (Average)

Table 3. Inventory level measures.

The inventory of Direct Materials is also analysed in terms of the actual cover for the months ahead as shown in Table 4.

	Feb. 1984	%	% 1983 Avg.	% 1982 Avg
Current Value(£k) of Direct Materials	2800	100	100	100
Value for Next 3 Mths	2300	82	85	80
" " " 4-6 Mths	200	7	8	9
" " 7 Mths & Over	300	11	7	11

Table 4. Forward cover of direct materials.

The forecasting system at Riker is also monitored in terms of a Forecast vs. Orders Comparison for each Product line and in each country (for Export Sales). An example of a report is given in Figure 11 which shows the performance over the last 12 months and the financial year to date. This report is particularly useful when Materials Management staff visit overseas customers to discuss forecast performance.

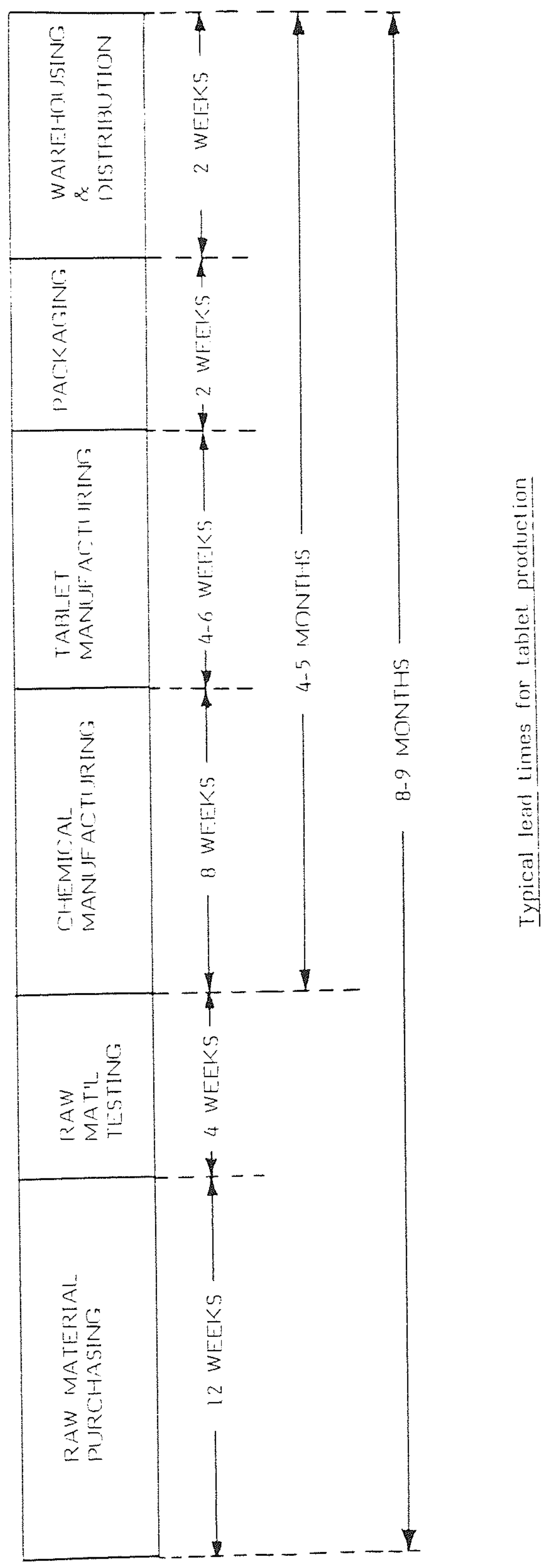


Figure 1. - Typical Leadtimes for Tablet Production

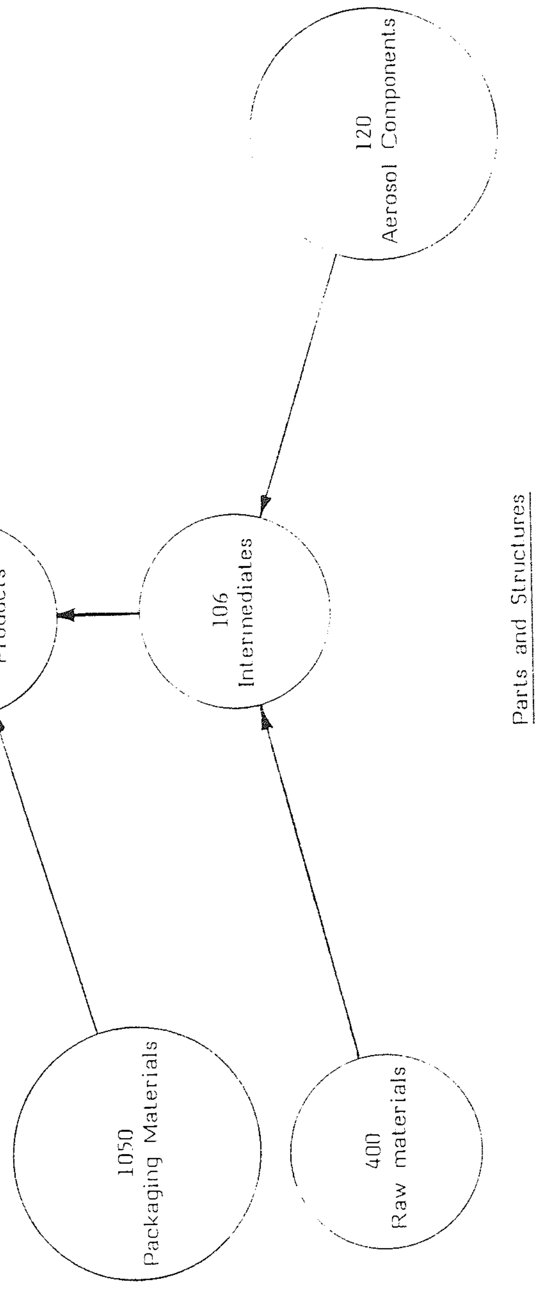


Figure 2. - Parts and Structures

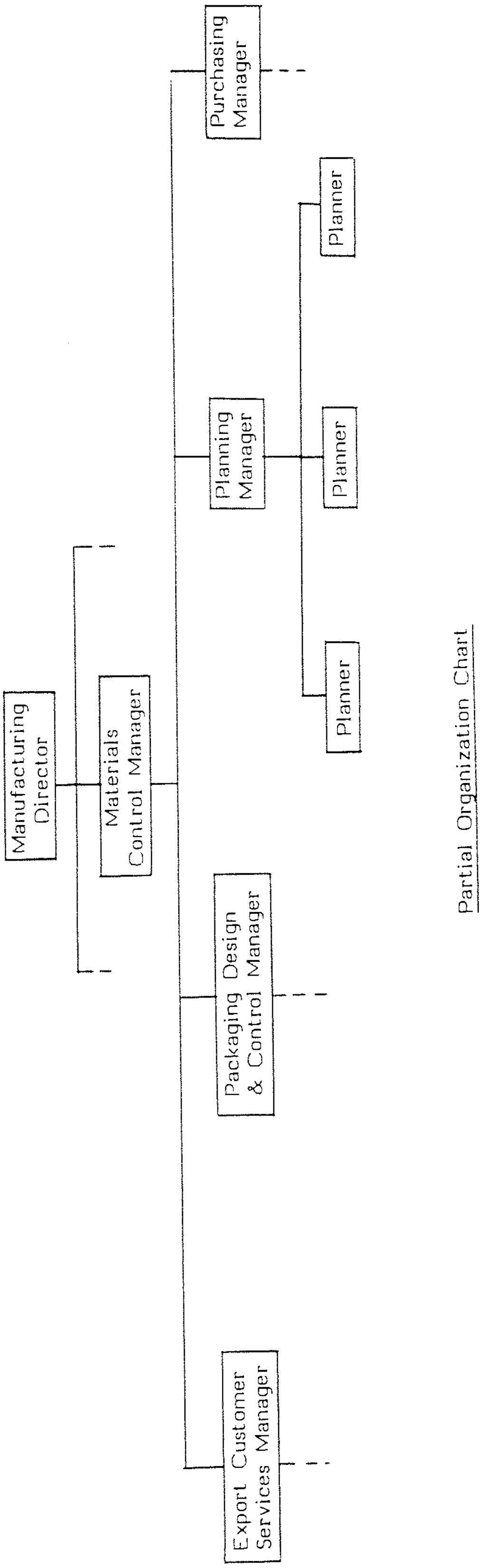
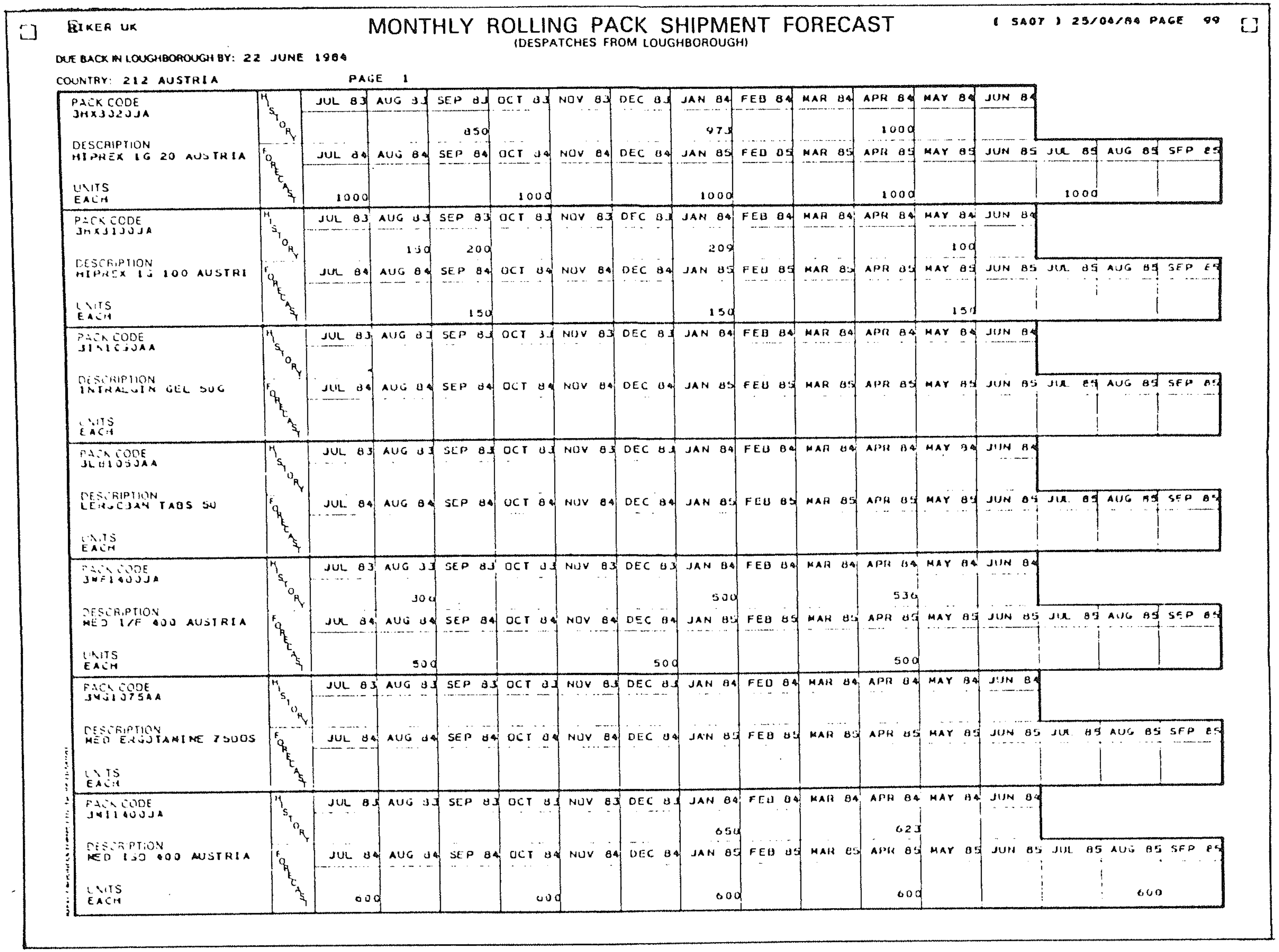


Figure 3. - Partial Organisation Chart



RIKER UK

MONTHLY ROLLING PACK SHIPMENT FORECAST

(DESPATCHES FROM LOUGHBOROUGH)

(SA07) 25/04/84 PAGE 99

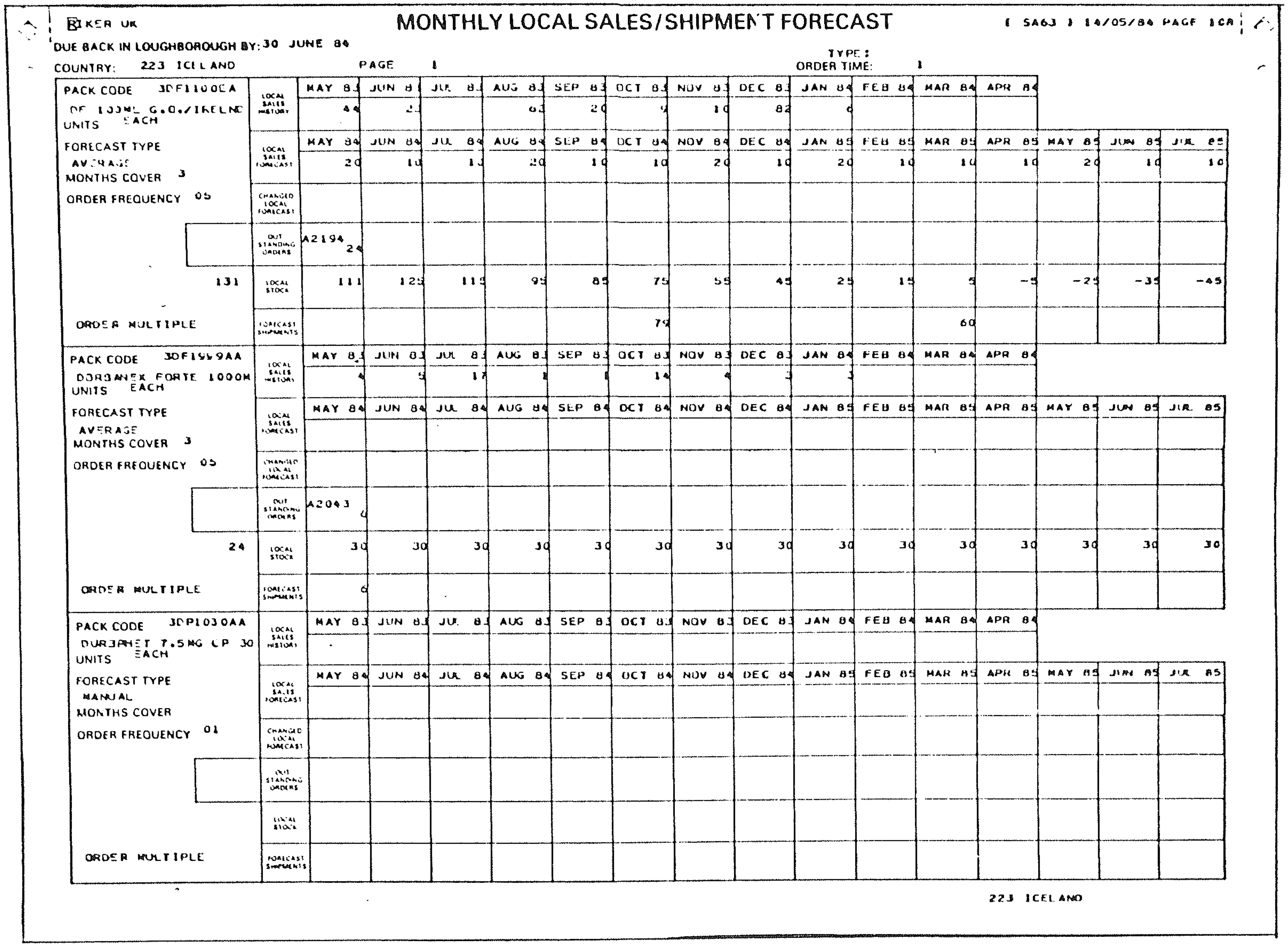
DUE BACK IN LOUGHBOROUGH BY: 22 JUNE 1984

COUNTRY: 212 AUSTRIA

PAGE 1

PACK CODE 3HX33200JA	HISTORY	JUL 83	AUG 83	SEP 83	OCT 83	NOV 83	DEC 83	JAN 84	FEB 84	MAR 84	APR 84	MAY 84	JUN 84			
				850				973			1000					
DESCRIPTION HIPREX 1G 20 AUSTRIA	FORECAST	JUL 84	AUG 84	SEP 84	OCT 84	NOV 84	DEC 84	JAN 85	FEB 85	MAR 85	APR 85	MAY 85	JUN 85	JUL 85	AUG 85	SEP 85
UNITS EACH		1000			1000			1000			1000			1000		
PACK CODE 3HX31000JA	HISTORY	JUL 83	AUG 83	SEP 83	OCT 83	NOV 83	DEC 83	JAN 84	FEB 84	MAR 84	APR 84	MAY 84	JUN 84			
			150	200				209				100				
DESCRIPTION HIPREX 1G 100 AUSTRI	FORECAST	JUL 84	AUG 84	SEP 84	OCT 84	NOV 84	DEC 84	JAN 85	FEB 85	MAR 85	APR 85	MAY 85	JUN 85	JUL 85	AUG 85	SEP 85
UNITS EACH				150				150				150				
PACK CODE 3INIC00AA	HISTORY	JUL 83	AUG 83	SEP 83	OCT 83	NOV 83	DEC 83	JAN 84	FEB 84	MAR 84	APR 84	MAY 84	JUN 84			
DESCRIPTION INTRALGIN GEL 50G	FORECAST	JUL 84	AUG 84	SEP 84	OCT 84	NOV 84	DEC 84	JAN 85	FEB 85	MAR 85	APR 85	MAY 85	JUN 85	JUL 85	AUG 85	SEP 85
UNITS EACH																
PACK CODE 3LB1050AA	HISTORY	JUL 83	AUG 83	SEP 83	OCT 83	NOV 83	DEC 83	JAN 84	FEB 84	MAR 84	APR 84	MAY 84	JUN 84			
DESCRIPTION LERGOBAN TABS 50	FORECAST	JUL 84	AUG 84	SEP 84	OCT 84	NOV 84	DEC 84	JAN 85	FEB 85	MAR 85	APR 85	MAY 85	JUN 85	JUL 85	AUG 85	SEP 85
UNITS EACH																
PACK CODE 3MF1400JA	HISTORY	JUL 83	AUG 83	SEP 83	OCT 83	NOV 83	DEC 83	JAN 84	FEB 84	MAR 84	APR 84	MAY 84	JUN 84			
			300					500			536					
DESCRIPTION MED I/F 400 AUSTRIA	FORECAST	JUL 84	AUG 84	SEP 84	OCT 84	NOV 84	DEC 84	JAN 85	FEB 85	MAR 85	APR 85	MAY 85	JUN 85	JUL 85	AUG 85	SEP 85
UNITS EACH			500				500				500					
PACK CODE 3MG1075AA	HISTORY	JUL 83	AUG 83	SEP 83	OCT 83	NOV 83	DEC 83	JAN 84	FEB 84	MAR 84	APR 84	MAY 84	JUN 84			
DESCRIPTION MED ERGOTAMINE 7500S	FORECAST	JUL 84	AUG 84	SEP 84	OCT 84	NOV 84	DEC 84	JAN 85	FEB 85	MAR 85	APR 85	MAY 85	JUN 85	JUL 85	AUG 85	SEP 85
UNITS EACH																
PACK CODE 3MI1400JA	HISTORY	JUL 83	AUG 83	SEP 83	OCT 83	NOV 83	DEC 83	JAN 84	FEB 84	MAR 84	APR 84	MAY 84	JUN 84			
								650			623					
DESCRIPTION MED ISO 400 AUSTRIA	FORECAST	JUL 84	AUG 84	SEP 84	OCT 84	NOV 84	DEC 84	JAN 85	FEB 85	MAR 85	APR 85	MAY 85	JUN 85	JUL 85	AUG 85	SEP 85
UNITS EACH		600			600			600			600				600	

Figure 4. Monthly Rolling Pack Shipment Forecast



RIKER UK

MONTHLY LOCAL SALES/SHIPMENT FORECAST

(SA63) 14/05/84 PAGE 1CR

DUE BACK IN LOUGHBOROUGH BY: 30 JUNE 84

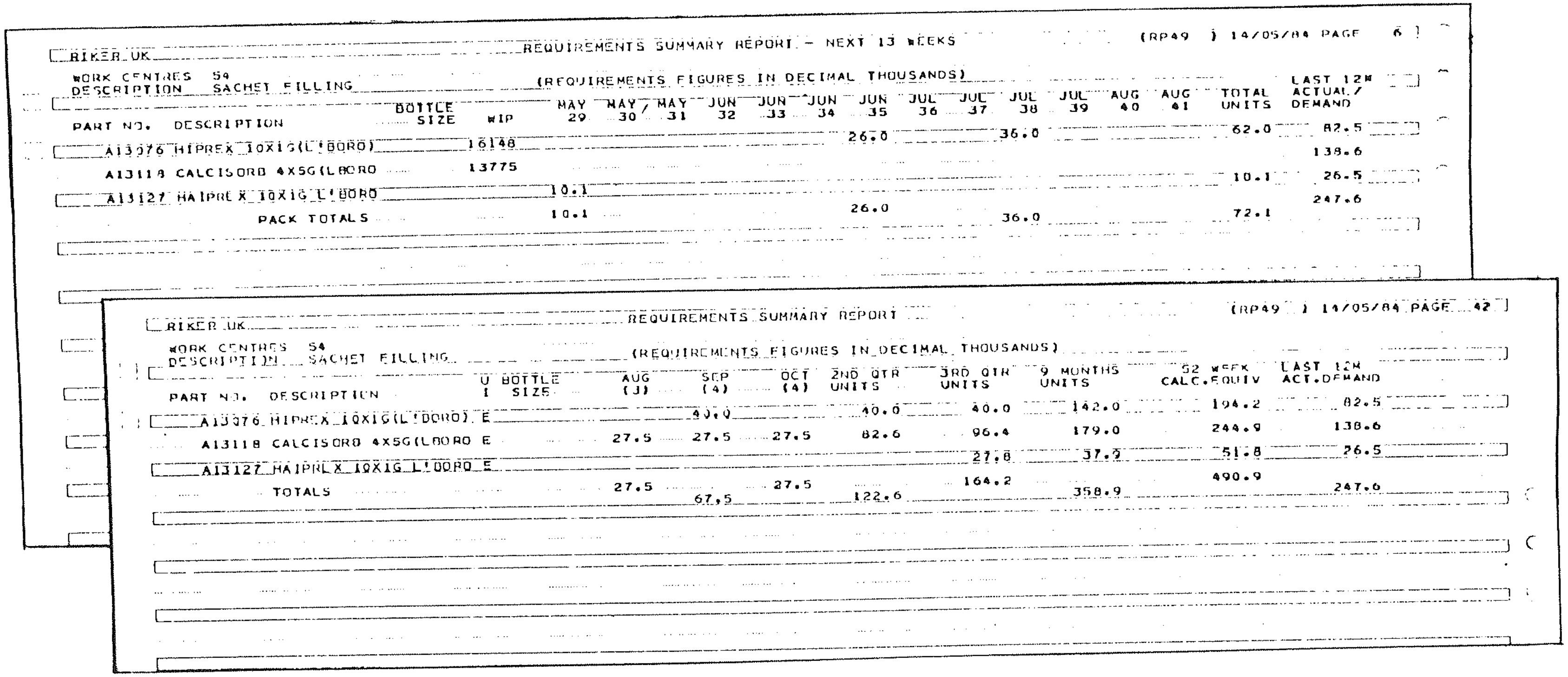
TYPE :

COUNTRY: 223 ICELAND PAGE 1 ORDER TIME: 1

PACK CODE 3DF1100CA DF 100ML G.O./IKELND UNITS EACH	LOCAL SALES HISTORY	MAY 83	JUN 83	JUL 83	AUG 83	SEP 83	OCT 83	NOV 83	DEC 83	JAN 84	FEB 84	MAR 84	APR 84			
		44	21		63	20	9	10	82	6						
FORECAST TYPE AVERAGE MONTHS COVER 3	LOCAL SALES FORECAST	MAY 84	JUN 84	JUL 84	AUG 84	SEP 84	OCT 84	NOV 84	DEC 84	JAN 85	FEB 85	MAR 85	APR 85	MAY 85	JUN 85	JUL 85
		20	10	13	20	10	10	20	10	20	10	10	10	20	10	10
ORDER FREQUENCY 05	CHANGED LOCAL FORECAST															
	OUT STANDING ORDERS	A2194 24														
131	LOCAL STOCK	111	125	115	95	85	75	55	45	25	15	5	-5	-25	-35	-45
ORDER MULTIPLE	FORECAST SHIPMENTS						79					60				
PACK CODE 3DF1969AA DORBANEX FORTE 1000M UNITS EACH	LOCAL SALES HISTORY	MAY 83	JUN 83	JUL 83	AUG 83	SEP 83	OCT 83	NOV 83	DEC 83	JAN 84	FEB 84	MAR 84	APR 84			
		4	5	17	1	1	14	4	3	3						
FORECAST TYPE AVERAGE MONTHS COVER 3	LOCAL SALES FORECAST	MAY 84	JUN 84	JUL 84	AUG 84	SEP 84	OCT 84	NOV 84	DEC 84	JAN 85	FEB 85	MAR 85	APR 85	MAY 85	JUN 85	JUL 85
ORDER FREQUENCY 05	CHANGED LOCAL FORECAST															
	OUT STANDING ORDERS	A2043 6														
24	LOCAL STOCK	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
ORDER MULTIPLE	FORECAST SHIPMENTS	6														
PACK CODE 3DP1030AA DUROPHET 7.5MG CP 30 UNITS EACH	LOCAL SALES HISTORY	MAY 83	JUN 83	JUL 83	AUG 83	SEP 83	OCT 83	NOV 83	DEC 83	JAN 84	FEB 84	MAR 84	APR 84			
FORECAST TYPE MANUAL MONTHS COVER	LOCAL SALES FORECAST	MAY 84	JUN 84	JUL 84	AUG 84	SEP 84	OCT 84	NOV 84	DEC 84	JAN 85	FEB 85	MAR 85	APR 85	MAY 85	JUN 85	JUL 85
ORDER FREQUENCY 01	CHANGED LOCAL FORECAST															
	OUT STANDING ORDERS															
	LOCAL STOCK															
ORDER MULTIPLE	FORECAST SHIPMENTS															

223 ICELAND

Figure 5. - Monthly Local Forecast



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RIKER UK                              REQUIREMENTS SUMMARY REPORT - NEXT 13 WEEKS                      (RP49  ) 14/05/84 PAGE   6

WORK CENTRES   54
DESCRIPTION    SACHET FILLING         (REQUIREMENTS FIGURES IN DECIMAL THOUSANDS)                                LAST 12M
                               BOTTLE           MAY  MAY  MAY  JUN  JUN  JUN  JUN  JUL  JUL  JUL  JUL  AUG  AUG  TOTAL  ACTUAL/
PART NO.  DESCRIPTION            SIZE    WIP     29   30   31   32   33   34   35   36   37   38   39   40   41  UNITS  DEMAND

  A13076 HIPREX 10X1G(L'BORO)          16148                           26.0           36.0                      62.0    82.5
  A13118 CALCISORB 4X5G(L BORO         13775                                                                            138.6
  A13127 HAIPREX 10X1G L'BORO                   10.1                                                            10.1    26.5
                                                                                                                        247.6
             PACK TOTALS                        10.1                   26.0           36.0                      72.1
```

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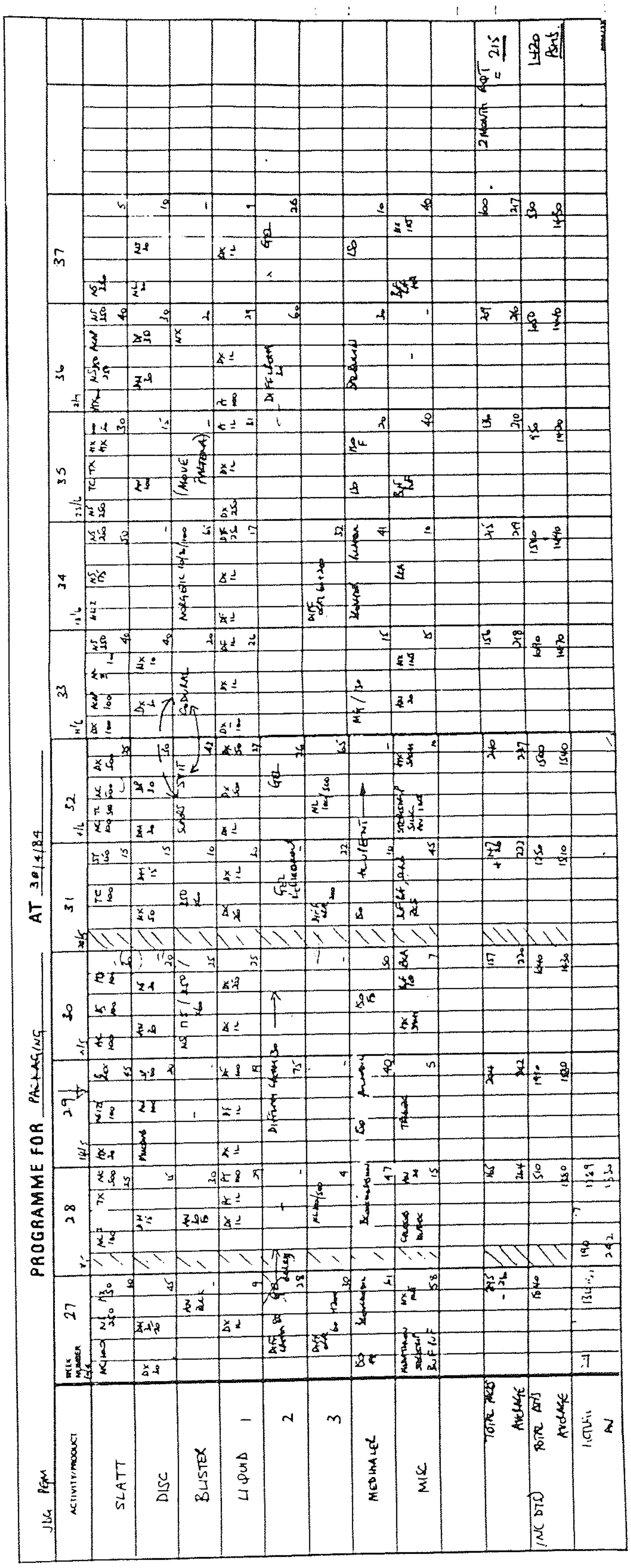
RIKER UK                                REQUIREMENTS SUMMARY REPORT                       (RP49  ) 14/05/84 PAGE  42

WORK CENTRES   54
DESCRIPTION    SACHET FILLING           (REQUIREMENTS FIGURES IN DECIMAL THOUSANDS)
                              U BOTTLE     AUG     SEP     OCT  2ND QTR   3RD QTR   9 MONTHS      52 WEEK  LAST 12M
PART NO.  DESCRIPTION         I  SIZE      (3)     (4)     (4)  UNITS     UNITS     UNITS      CALC.EQUIV  ACT.DEMAND

  A13076 HIPREX 10X1G(L'BORO). E                  40.0            40.0      40.0     142.0        194.2      82.5
  A13118 CALCISORB 4X5G(LBORO E            27.5   27.5    27.5    82.6      96.4     179.0        244.9     138.6
  A13127 HAIPREX 10X1G L'BORO E                                             27.8      37.9         51.8      26.5
                                                                           164.2                  490.9
            TOTALS                         27.5           27.5                                               247.6
                                                  67.5           122.6               358.9
```

Figure 6. - Requirements Summary Report



JDG PGM

PROGRAMME FOR PACKAGING AT 30/4/84

ACTIVITY/PRODUCT

WEEK NUMBER

27 28 29 30 31 32 33 34 35 36 37

SLATT

DISC

BLISTER

LIQUID 1

2

3

MEDIHALER

MISC

TOTAL PACKS

AVERAGE

(INC DTS) TOTAL ACTS

AVERAGE

ACTUAL

AV

2 MONTH AOT = 215

1420 PSHS

Figure 7. - Packaging Programme

To: S. J. Baum
B. E. Cuthbert
P.R.J. Clay
P. Durban
S. H. Ellis
B. A. Fryer

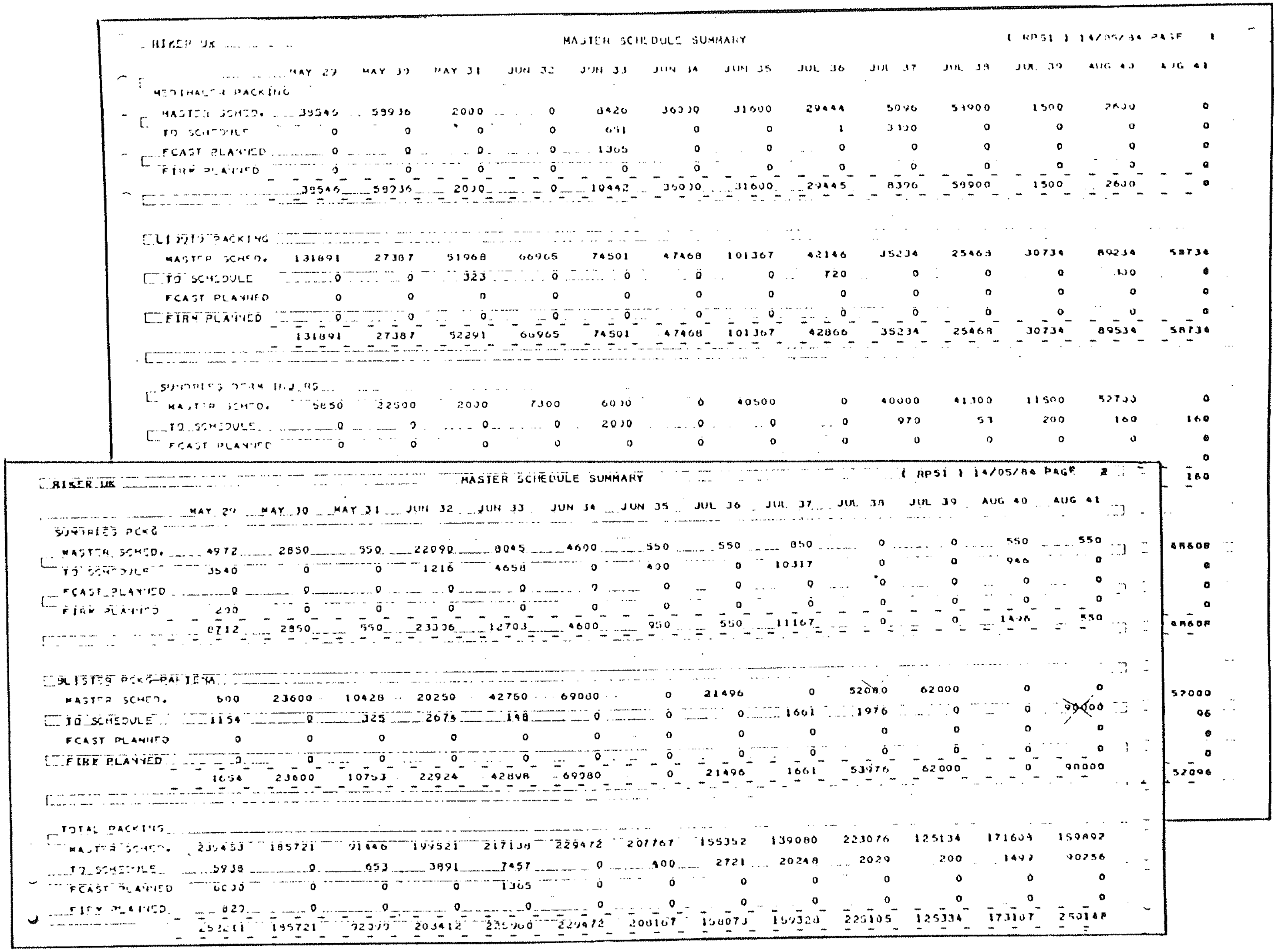
M. A. Horrill
M. J. Piggins
J. A. Vaughan
W. R. Webb
I. P. Tansey

PRODUCTION WEEKLY REQUIREMENTS

DEPARTMENT	BASE	QUANTITY FOR FORECAST FOR O/H RECOVERY	QUANTITY FOR UPDATED PRODN FORECAST	NOV/DEC RQT	NOV/DEC ACTUAL AV	JAN/FEB RQT	JAN/FEB AV	MARCH/APRIL RQT	M/A AV	MAY/JUN RQT
PACKAGING	Finished Packs	188,000	200,000	250,000	238,000	250,000	232,000	210,000	205000	215000
	Bulk Packs	11,000	11,000	-	-	42,000	38,000	44,000	N/A	4000
	DTS Tapes	115,000	132,000	155,000	112,000	180,000	185,000	135,000	110	100
	Total PSH's	-	-	-	-	-	1,510	1,440	1436	1440
TABLET	Millions	7.6	7.4	9.4	8.1	8.4	8.1	7.3	6.9	8·0
CAPSULE	Millions	1.1	1.1	1.2	1.0	1.2	1.1	1.4	1.2	1·4
SACHETS	Thousands	82	55	55	30	60	41	60	22	60
AEROSOLS	PSH's.	-	-	840	770	900	885	710	850	600
	Cold Fill	144,000	176,000	200,000	185,000	204,000	195,000	150,000	175000	190000
	Pressure Fill	8,400	8,400	9,600	12,800	12,000	13,900	13,200	15000	12500
	Sterile	11,600	15,000	14,000	18,300	15,000	12,750	13,200	14700	Nil
VALVES	Valves	408,000	410,000	450,000	440,000	460,000	560,000	450	533000	500000
LIQUIDS	Litres	16,600	17,300	18,600	16,750	17,500	17,250	15,800	15400	20500
CHEMICALS	REC O/H Hours Man Hours	320 -	330 -	330 -	N/A -	320 -	N/A	340 520	N/A -	390 550

Note: Last period actual achievement and new requirements 8 May 1984 SJA:ef

Figure 8. - Production Weekly Requirements



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RIKER UK                                MASTER SCHEDULE SUMMARY                              ( RPS1 ) 14/05/84 PAGE  1

                  MAY 29   MAY 30   MAY 31   JUN 32   JUN 33   JUN 34   JUN 35   JUL 36   JUL 37   JUL 38   JUL 39   AUG 40   AUG 41
MEDIHALER PACKING
  MASTER SCHED.    39546    59936     2000        0     8426    36030    31600    29444     5096    53900     1500     2600        0
  TO SCHEDULE          0        0        0        0      651        0        0        1     3300        0        0        0        0
  FCAST PLANNED        0        0        0        0     1365        0        0        0        0        0        0        0        0
  FIRM PLANNED         0        0        0        0        0        0        0        0        0        0        0        0        0
                   39546    59936     2030        0    10442    36030    31600    29445     8396    59900     1500     2600        0

LIQUIDS PACKING
  MASTER SCHED.   131891    27387    51968    66965    74501    47468   101367    42146    35234    25463    30734    89234    58734
  TO SCHEDULE          0        0      323        0        0        0        0      720        0        0        0      300        0
  FCAST PLANNED        0        0        0        0        0        0        0        0        0        0        0        0        0
  FIRM PLANNED         0        0        0        0        0        0        0        0        0        0        0        0        0
                  131891    27387    52291    66965    74501    47468   101367    42866    35234    25468    30734    89534    58734

SUNDRIES OTHR INJ.RS
  MASTER SCHED.     5850    22500     2030     7300     6030        0    40500        0    40000    41300    11500    52700        0
  TO SCHEDULE          0        0        0        0     2030        0        0        0      970       53      200      160      160
  FCAST PLANNED        0        0        0        0        0        0        0        0        0        0        0        0        0
                                                                                                                                    0
                                                                                                                                  160

                                                                                                                                48608
                                                                                                                                    0
                                                                                                                                    0
                                                                                                                                    0
                                                                                                                                48608

                                                                                                                                57000
                                                                                                                                   96
                                                                                                                                    0
                                                                                                                                    0
                                                                                                                                52096
```

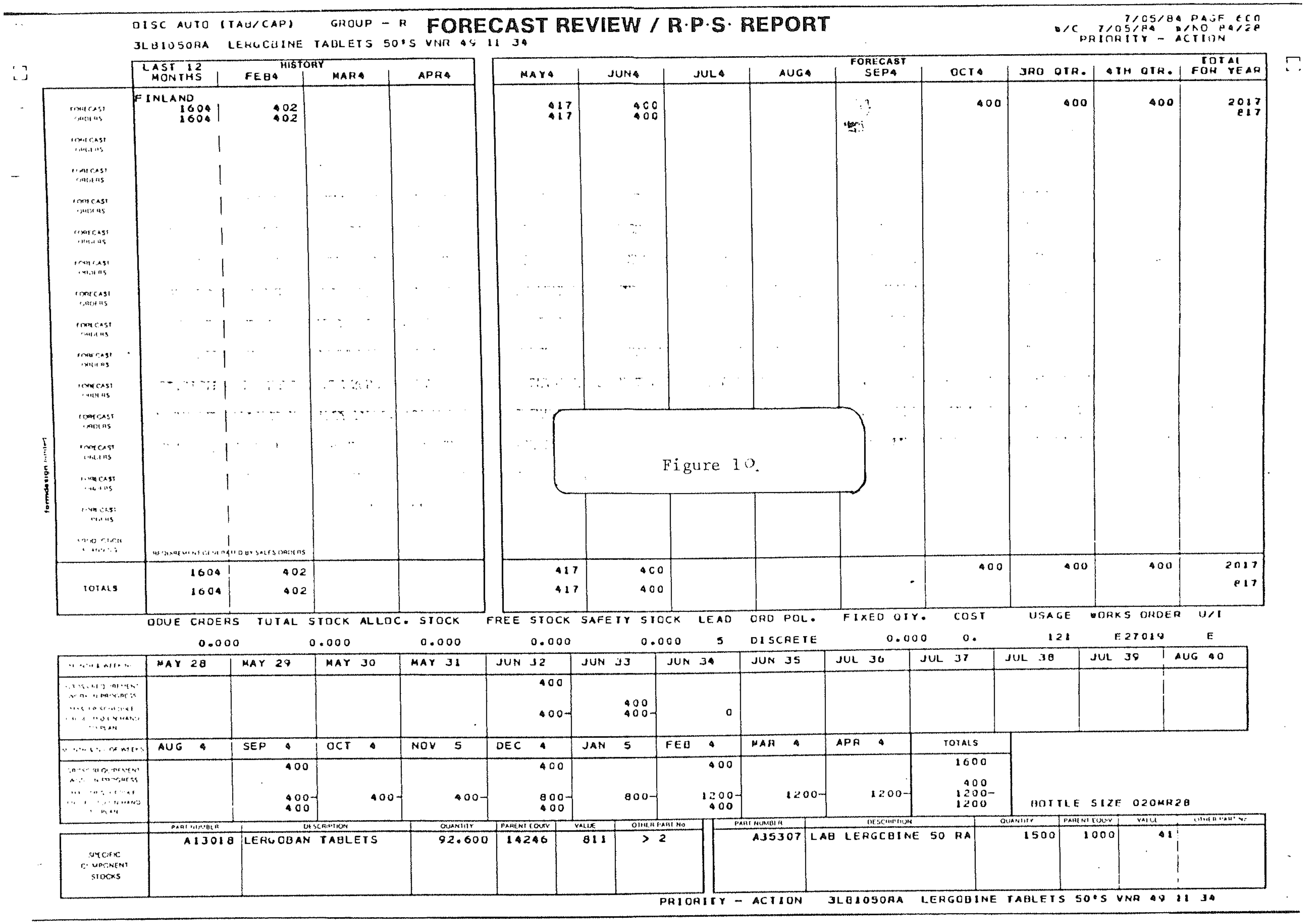
```
RIKER UK                                MASTER SCHEDULE SUMMARY                              ( RPS1 ) 14/05/84 PAGE  2

                  MAY 29   MAY 30   MAY 31   JUN 32   JUN 33   JUN 34   JUN 35   JUL 36   JUL 37   JUL 38   JUL 39   AUG 40   AUG 41
SUNDRIES PCKG
  MASTER SCHED.     4972     2850      550    22090     8045     4600      550      550      850        0        0      550      550
  TO SCHEDULE       3540        0        0     1216     4658        0      400        0    10317        0        0      946        0
  FCAST PLANNED        0        0        0        0        0        0        0        0        0        0        0        0        0
  FIRM PLANNED       200        0        0        0        0        0        0        0        0        0        0        0        0
                    8712     2850      550    23306    12703     4600      950      550    11167        0        0     1496      550

BLISTER PCKG-PATTERN
  MASTER SCHED.      600    23600    10428    20250    42750    69000        0    21496        0    52080    62000        0        0
  TO SCHEDULE       1154        0      325     2674      148        0        0        0     1661     1976        0        0    90000
  FCAST PLANNED        0        0        0        0        0        0        0        0        0        0        0        0        0
  FIRM PLANNED         0        0        0        0        0        0        0        0        0        0        0        0        0
                    1654    23600    10753    22924    42898    69980        0    21496     1661    53976    62000        0    90000

TOTAL PACKING
  MASTER SCHED.   235453   185721    91446   199521   217138   229472   207767   155352   139080   223076   125134   171603   159802
  TO SCHEDULE       5938        0      653     3891     7457        0      400     2721    20248     2029      200     1493    90256
  FCAST PLANNED     6030        0        0        0     1365        0        0        0        0        0        0        0        0
  FIRM PLANNED       820        0        0        0        0        0        0        0        0        0        0        0        0
                  252211   185721    92099   203412   235960   229472   208167   158073   159328   225105   125334   173107   250148
```

Figure 9. - Master Schedule Summary



DISC AUTO (TAB/CAP) GROUP - R **FORECAST REVIEW / R·P·S· REPORT** 7/05/84 PAGE 600

W/C 7/05/84 W/NO 84/28

3LB1050RA LERGCBINE TABLETS 50'S VNR 49 11 34 PRIORITY - ACTION

	LAST 12 MONTHS	HISTORY FEB4	MAR4	APR4	MAY4	JUN4	JUL4	AUG4	FORECAST SEP4	OCT4	3RD QTR.	4TH QTR.	TOTAL FOR YEAR
FORECAST ORDERS	FINLAND 1604 1604	402 402			417 417	400 400				400	400	400	2017 817
FORECAST ORDERS													
FORECAST ORDERS													
FORECAST ORDERS													
FORECAST ORDERS													
FORECAST ORDERS													
FORECAST ORDERS													
FORECAST ORDERS													
FORECAST ORDERS													
FORECAST ORDERS													
FORECAST ORDERS													
FORECAST ORDERS													
FORECAST ORDERS													
FORECAST ORDERS													
[illegible]	REQUIREMENT GENERATED BY SALES ORDERS												
TOTALS	1604 1604	402 402			417 417	400 400				400	400	400	2017 817

DUE ORDERS	TOTAL STOCK	ALLOC. STOCK	FREE STOCK	SAFETY STOCK	LEAD	ORD POL.	FIXED QTY.	COST	USAGE	WORKS ORDER	U/I
0.000	0.000	0.000	0.000	0.000	5	DISCRETE	0.000	0.	121	E27019	E

[illegible]	MAY 28	MAY 29	MAY 30	MAY 31	JUN 32	JUN 33	JUN 34	JUN 35	JUL 36	JUL 37	JUL 38	JUL 39	AUG 40
[illegible]					400 400-	400 400-	0						

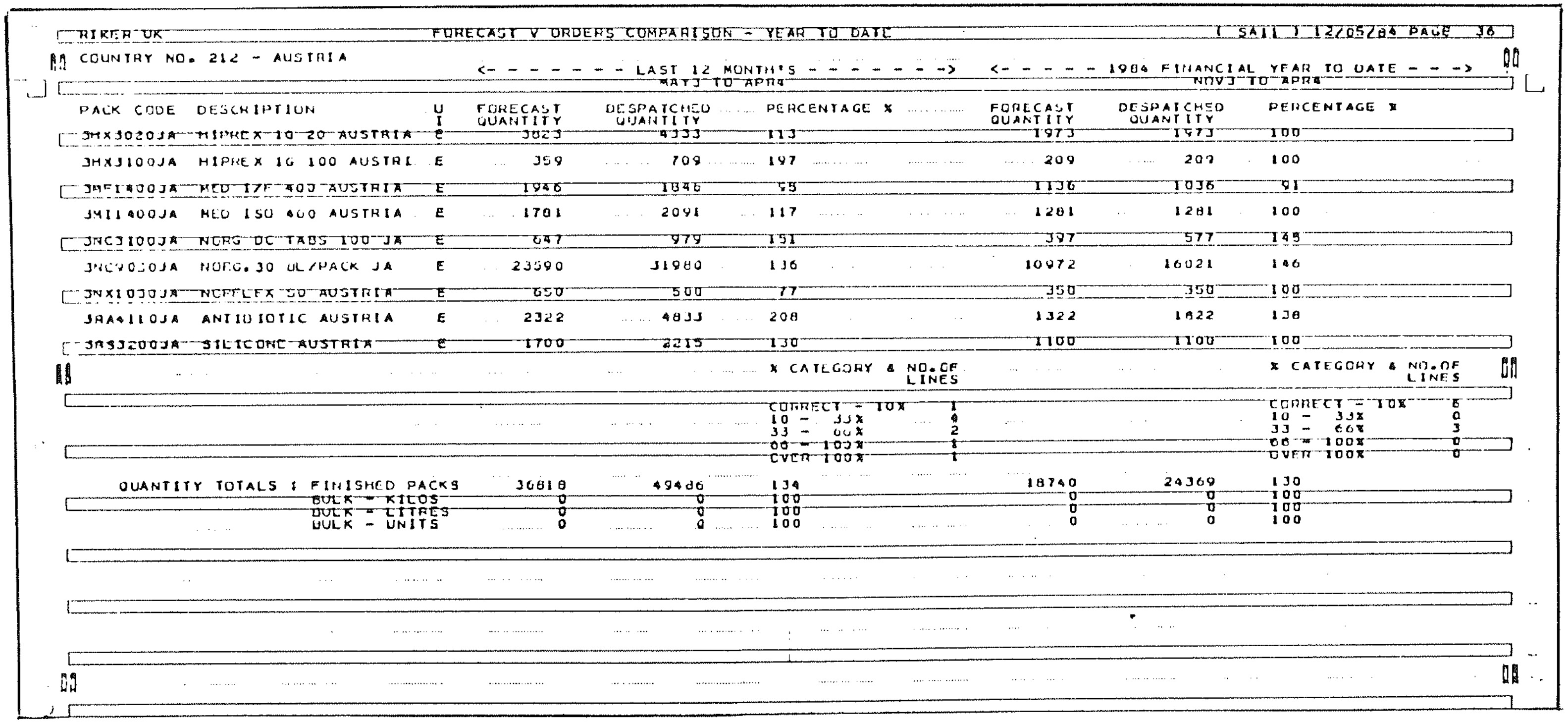
[illegible]	AUG 4	SEP 4	OCT 4	NOV 5	DEC 4	JAN 5	FEB 4	MAR 4	APR 4	TOTALS
[illegible]		400 400- 400	400-	400-	400 800- 400	800-	400 1200- 400	1200-	1200-	1600 400 1200- 1200

BOTTLE SIZE 020MR28

	PART NUMBER	DESCRIPTION	QUANTITY	PARENT EQUIV	VALUE	OTHER PART No	PART NUMBER	DESCRIPTION	QUANTITY	PARENT EQUIV	VALUE	OTHER PART No
SPECIFIC COMPONENT STOCKS	A13018	LERGOBAN TABLETS	92.600	14246	811	> 2	A35307	LAB LERGCBINE 50 RA	1500	1000	41	

PRIORITY - ACTION 3LB1050RA LERGOBINE TABLETS 50'S VNR 49 11 34

Figure 10.- Forecast Review R.P.S. Report



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RIKER UK                    FORECAST V ORDERS COMPARISON - YEAR TO DATE                         ( SAI1 ) 12/05/84 PAGE  36

COUNTRY NO. 212 - AUSTRIA
                                  <- - - - - - - LAST 12 MONTH'S - - - - - - ->   <- - - - - 1984 FINANCIAL YEAR TO DATE - - ->
                                                 MAY3 TO APR4                                   NOV3 TO APR4
PACK CODE  DESCRIPTION            U   FORECAST     DESPATCHED    PERCENTAGE %          FORECAST    DESPATCHED    PERCENTAGE %
                                  I   QUANTITY     QUANTITY                            QUANTITY    QUANTITY
3HX3020JA  HIPREX 10 20 AUSTRIA   E       3823         4333      113                       1973        1973      100
3HX3100JA  HIPREX 1G 100 AUSTRI   E        359          709      197                        209         209      100
3MF1400JA  MED 17F 400 AUSTRIA    E       1946         1846       95                       1136        1036       91
3MI1400JA  MED ISO 400 AUSTRIA    E       1781         2091      117                       1281        1281      100
3NC3100JA  NORG DC TABS 100 JA    E        647          979      151                        397         577      145
3NC9030JA  NORG.30 UL/PACK JA     E      23590        31980      136                      10972       16021      146
3NX1030JA  NOFFLEX 50 AUSTRIA     E        650          500       77                        350         350      100
3RA4110JA  ANTIBIOTIC AUSTRIA     E       2322         4833      208                       1322        1822      138
3RS3200JA  SILICONE AUSTRIA       E       1700         2215      130                       1100        1100      100

                                                    % CATEGORY & NO.OF                           % CATEGORY & NO.OF
                                                                 LINES                                        LINES

                                                    CORRECT - 10%      1                         CORRECT - 10%     6
                                                    10 -   33%         4                         10 -   33%        0
                                                    33 -   66%         2                         33 -   66%        3
                                                    66 -  100%         1                         66 -  100%        0
                                                    OVER  100%         1                         OVER  100%        0

    QUANTITY TOTALS : FINISHED PACKS     36818        49486      134                      18740       24369      130
                      BULK - KILOS           0            0      100                          0           0      100
                      BULK - LITRES          0            0      100                          0           0      100
                      BULK - UNITS           0            0      100                          0           0      100
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Figure 11. - Forecast v. Orders Comparison

Appendix 4.

Kalamazoo Plc. Case Study.

[August 1984]

KALAMAZOO PLC, NORTHFIELD, BIRMINGHAM. [1984]

THE COMPANY, PRODUCTS AND MARKETS.

The Kalamazoo Group of companies consists of a British parent company, Kalamazoo PLC and several wholly and partly owned subsidiaries in the U.K. and overseas. The group's activities, with only minor exceptions, consist entirely of the design, manufacture and marketing of computerised and manual business systems and services.

From modest beginnings as a small Birmingham printing firm in 1896, Kalamazoo quickly established its reputation with a range of quality loose-leaf binders. Today, with approximately 2,000 employees on the Northfield site, Kalamazoo continues to expand in the business systems field, with new developments in both manual and computer systems. The computer bureau service, set up in 1967, is now one of the largest in Europe. Building on the experience and success of this bureau operation, Kalamazoo are now applying modern computer technology in the form of in-house mini and micro computers to the accounting and recording problems of businesses. Kalamazoo is active in three main markets, namely; Small business systems, the Motor trade and Overseas.

It is the Master Scheduling of micro-computer production within the Small Business Systems Division which is the subject of this investigation.

In the U.K. alone, over 125,000 organisations of all kinds use Kalamazoo products ranging from stationery through to computers. The U.K. sales network consists of over 40 regional sales branches, selling direct to the customers.

In 1979 Kalamazoo extended its computer related activities into the General Commercial market with the design and manufacture of its own range of small business micro-computers known as the K-range.

Both hardware and software for the K-range are designed, manufactured and supported exclusively by Kalamazoo from its head office in Northfield and sold through the company's Small Business Systems Division. It is not company policy to market business equipment and paperwork as products in their own right; instead, each business system is sold as a package (or "outfit") containing all necessary equipment and paperwork to perform a function tailored to the customer where necessary. Prices range from £3,000 to over £7,000 per outfit.

The K-range of micro-computers includes two floppy disk based micros known as the K1lOO and K1200, plus a hard disk, multiprocessor micro-computer known as the K2150. (See Figures 1 and 2)

Software packages available on the K-range include; Pay-roll with absence recording for Statutory Sick Pay, Sales Accounting, Stock Control, Invoicing, Purchase Accounting, General Ledger and Word Processing. In addition, trade-specific software packages for the Construction Industry, Insurance Brokers, Hotels, Clubs and Associations, Holiday Site Operators, Independent Schools, Dairies, Bakers and Wholesale Markets are also available.

The micro-computer modules are produced for stock with a target of approximately four weeks' supply of finished modules in stock. Currently there is approximately two weeks' supply of work in process and four weeks' supply of components and raw material inventory.

There is an "Installation Period" of about 6 weeks given by the Client Support (Sales) department which represents the time from initial order receipt to final installation and allows the preparation of customised stationery and letter heads as well as giving the Production Planning Manager forward notice of the requirements of micro-computer modules from stock.

Orders are usually for single systems for each customer and about 25 customer orders are received each month, virtually 100% of which are for the U.K. domestic market.

THE PRODUCTION PROCESS

The manufacturing division at the Northfield site comprises two sections of roughly equal size, namely; the Printing Factory and the Equipment Factory. The micro-computer manufacturing facility forms part of the Equipment Factory.

The Equipment Factory is situated in several buildings and the manufacturing function comprises the following activities:- General stationery equipment assembly, Micro-computer assembly, Components production, General raw materials stores, Microcomputer material stores and Finished goods stores.

The General Assembly shop employs approximately eighty persons and consists of four main sections, namely, Equipment Assembly, Index Manufacture, Binding and Box Making. None of the products of the General Assembly shop are used in Micro-computer production.

Micro-computer Assembly is carried out on a batch production basis. Batch sizes are small, usually ten to twenty machines. All components are picked from stock and issued as a kit. There are approximately twenty people employed in this area; fifteen involved in component and sub-assembly manufacturing and inspection, three on final assembly and two on final inspection and test. Typical manufacturing lead times are shown in Figure 3. This shows that from a stock of basic components, a batch of micro-computers can be produced in about three weeks. There are, however, some basic components, for example Integrated Circuits, with purchase lead times of up to twelve months and other components are manufactured in the Components Production Department.

There are approximately seven hundred components and subassemblies to each micro-computer but the rate of turnover of stock is relatively slow due to the low levels of production.

The Components Production department comprises four major functional areas, namely; i) Injection moulding, ii) Polyurethane foam moulding and vacuum forming, iii) Light engineering and Press work and iv) Paint shop and component finishing. The department employs about twenty-five people. Approximately sixty five different metal components and thirty five different mouldings are supplied to the Micro-Computer assembly department.

The General Raw Material Stores is the central stockholding facility for all raw material, components and sub-assemblies used in the Equipment Factory except for Micro-computer material. In addition, the department carries out all goods inwards administration and inspection procedures for equipment and microcomputer manufacture.

The Micro-computer Material Stores holds approximately 1500 different items on file. It represents the highest value of stockholding within the company and therefore needs close control. Items are picked from stock and issued in kit form for assembly. Each finished micro-computer comprises a number of sub-assemblies which are assembled and returned to stock before being issued for final assembly.

The Finished Goods Stores stock all finished products, finished paperwork, spare parts and goods bought in for resale, for example printers for micro-computer business systems. At this point, all the separate products that go to make up an outfit are picked from stock and despatched.

COMPUTER SYSTEMS

The present computer based production control system, installed in 1977 replaced a manual system that had been in operation for well over thirty years. This system is a Burroughs P.C.S.II running on a Burroughs B3500 mainframe. It consists of four interacting modules for Engineering Data Control, Material Requirements Planning, Work in Progress and Inventory. The system is batch processed; the Engineering Data Control, Inventory and W.I.P. modules being run daily, five nights per week and the MRPI module being run on a weekly basis at the end of each working week.

The P.C.S.II system covers the Equipment Factory but not the Printing Factory. Of all the part numbers dealt with by the system, those concerned with micro-computers account for about 1100 purchased parts, 300 sub-assemblies and 100 manufactured components. The finished micro-computer modules have bills of material with about 4 levels of breakdown and a relatively low rate of engineering changes of the order of three per week (excluding new model introductions). There is a high degree of commonality of parts between the different micro-computer models.

THE MASTER PRODUCTION SCHEDULE - OVERVIEW

The Master Production Schedule (MPS) which is fed in to MRP is stated in micro-computer modules, for example, keyboards, terminals and Central Processing Units. At present there are thirteen different modules on the MPS, however this includes the phasing in and out of modules during a change-over situation.

The MPS is planned for six to eight months ahead in weekly time periods and is updated once a month. This first month is "fine-tuned" and is then regarded as being relatively firm.

The Master Scheduling of Microcomputer manufacture is carried out by one person with the title of Production Planning Manager who also has the responsibility for the Master Scheduling of the rest of the Equipment Factory, the detailed scheduling of the Moulding and Components Shops and the control of the 'A' Class stock in the Printing Factory. He reports to a Production Control Manager. (See Figure 4).

The Production Planning Manager Master Schedules within the constraints of Testing capacity, Manufacturing capacity and the availability of certain purchased items. Although the microcomputer modules are made for stock, information on the actual orders due for installation is used to adjust the first month of the Master Schedule. The details of the Master Production Scheduling process will be described in later sections.

PLANNING AND CONTROL SYSTEM INTERACTIONS

Using the basic model of MPS and its relationship with other planning and control activities as shown in Figure 4.1 , this section describes how these relationships operate at Kalamazoo.

Demand Management

This incorporates the activities of forecasting, order entry, order promising and physical distribution, none of which come under the responsibility of the Production Control function at Kalamazoo. All of these activities form part of the job of the Client Support (Sales) department.

Forecasting is undertaken by this department using trends and Market Intelligence and the results are relayed in the form of a Business Plan for the next 12 months showing monthly expected sales for each Finished product range. This plan is usually produced every three months, however, if sales trends are changing rapidly, it is updated more frequently.

Order entry and order promising are part of the job of the salesman who sells a business system "outfit" to a customer. The normal situation is to quote a six-week installation period to allow the customising of stationery and software to the client. This also allows a Delivery Schedule for the next month (See Figure 5) to be sent to the Production Planning Manager who can then monitor sales against the forecast and adjust the Master Schedule accordingly. This is necessary since although forecasting is the responsibility of Client Support and historically has been rather inaccurate, the level of finished stocks and delivery performance are the responsibility of Production Control.

The finished Business System "outfits" are kitted from the Finished Goods Stores, delivered and installed at the Customers' premises by the Client Support staff.

Production Planning

There is no separate high-level Production Plan at Kalamazoo, but the Business Plan (Sales Schedule) produced by Client Support is regarded as the long term plan although it does not take account of finished goods stock levels or manufacturing capacity constraints. Occasionally questions are asked by the Client Support Department as to whether changes in sales mix in future months could be coped with. This is usually dealt with by the Production Planning Manager suggesting different Master Schedules which either build stock early or use up stock and talking these over with the Production Manager.

Resource Planning

The longer term planning of manufacturing resources in terms of plant, equipment and labour is currently carried out without the aid of a computer at Kalamazoo.

Final Assembly Scheduling

The Final Product Assembly at Kalamazoo is the Business System "outfit" and, as mentioned previously, this is kitted from the Finished Goods Stores in line with the Delivery/Installation Schedule.

Rough Cut Capacity Planning

During the Master Scheduling process the Production Planning Manager is taking account of the capacity that is available in the Micro-computer Manufacturing Department. Since there was no work measurement data available on the work in this section, the manager set up a manual system of the booking out of materials and the booking in of completed work from Production and then the booking in after inspection and test. This has continued over an 18 month period and has produced average actual times for the various manufacturing stages which are now used for Rough Capacity calculations. It should be noted however, that some stages, particularly final testing and fault repairs, have very variable work contents. Fortunately, the labour in the Microcomputer Manufacturing department is very flexible, particularly those in the component and sub-assembly section, and this allows imbalances in work load to be tolerated.

Material Requirements Planning

At Kalamazoo, MRP is run once a week on a Friday night. The PCS II system can deal with planning horizons of up to 2 years depending upon the setting of a calendar. At present the MPS file calendar is set about 18 months ahead and the MRP cut-off date is set about 12 months ahead. This is adjusted every three months.

The majority of production material is on the Bill of Material. The main exceptions are new product developments and printers which are bought as required for each customer order. As mentioned earlier, some components have purchase lead times of up to 12 months and these items have to be ordered separately. This is because the MPS file usually only has quantities in it up to 8 months ahead and therefore would not generate orders in sufficient time. For these few exception items the Production Planning Manager and the buyer concerned , meet every month and manually estimate their requirements and place orders accordingly, sometimes committing deliveries as far as 18 months into the future.

Capacity Planning

There is no detailed Capacity Planning undertaken for Microcomputer production at Kalamazoo. Firstly there is no Work Measurement data available and secondly Capacity Planning is not a module offered on the PCS II system.

MASTER PRODUCTION SCHEDULE PREPARATION

This section outlines in more detail the preparation of the Master Production Schedule for Micro computer production at Kalamazoo PLC.

As mentioned previously, the MPS is planned for six to eight months ahead in weekly time periods and is updated once a month. The MPS is set out on paper in chart form, an example of which is shown in Figure 6.

The first month of the MPS is "fine -tuned", but any major changes are spread forward over the following 5-7 months. Since about 80% of the components are common to the different micro computer models, changes to product mix in the future months do not cause too many problems as long as the total volume across all product ranges remains about the same.

The information used in the MPS process is as follows: i) Physical stock counts, ii) Work In Progress Reports, iii) Shortage reports and iv) Delivery Schedules (see Figure 5).

The Delivery Schedules are manually broken down into the requirements for computer modules, checked against current finished stock and Work in Progress for these modules, and then decisions are made regarding changes to the MPS.

It is rare for the MPS to be altered because of shortages of manufactured components or sub-assemblies since the lead times for these items on the MRP system provide a certain amount of Safety Time. There have been a few instances, however, where hold-ups in the delivery of purchased components have meant changes in the MPS, but not in the first month.

Normally only the first six months of the MPS are used, but occasionally months seven and eight contain product quantities which have been pushed out into the future because of sales reductions in the current months.

Decisions regarding the MPS are the sole responsibility of the Production Planning Manager and no formal meetings are held to discuss the MPS for Microcomputer Production. There is, however, continuous informal communication with the Production foremen and stores staff.

As discussed earlier, the Production Planning Manager does a Rough Cut Capacity Plan "in his head" whilst preparing the MPS. He uses historical actual times which give him guide-lines, such as; with current labour, 35 monitors can be assembled and 45 P.C.B.'s can be populated per week.

Having said that Capacity Planning is not undertaken in Micro computer assembly, some detailed capacity planning and scheduling is undertaken by the Planning Manager on a few key work centres in the Component Shop.

PLANNING AND CONTROL SYSTEM EVALUATION

In this section the performance measures which are used to evaluate the planning and control systems at Kalamazoo are described.

The two measures used relate to Stock Levels and Delivery Performance. Target stock levels are set for Purchased Parts, Work in Progress, Assemblies and Finished Stock and actual levels are reviewed every month.

Whilst delivery performance (i.e. off the shelf availability) is held to be a measure, it is claimed that a customer has never yet been held up because of a shortage of micro-computer hardware.

Figure 1. - K-Range of Micro-Computers

Kalamazoo's Range of Micro-Computers

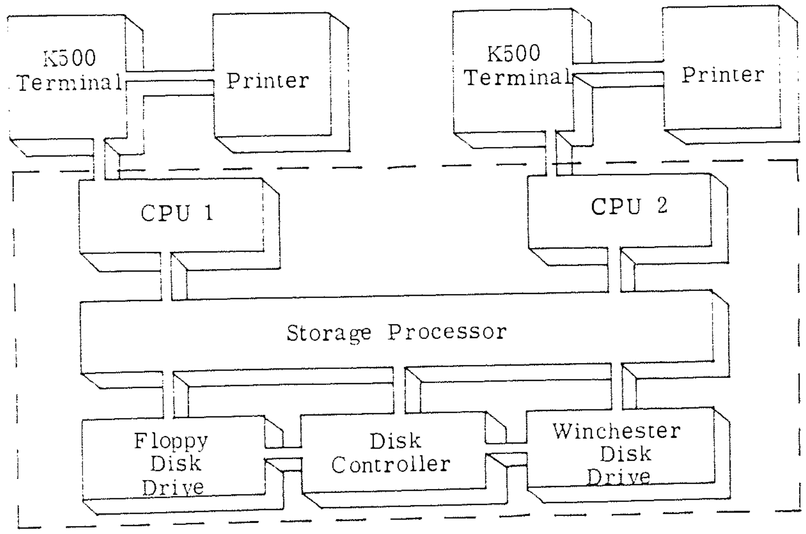
TECHNICAL SPECIFICATION

Kalamazoo's range of micro-computers consist of two product lines - floppy disk based machines known as the K1100 and K1200, and Winchester hard-disk machine known as the K2150 series.

The K1100 and K1200 are 'stand alone' systems, with the only difference between them being the disk storage capacity, while the K2150 is a multi-terminal system that can support up to two intelligent K500 terminals with a central database on Winchester disk. Three different types of printer are offered with all K-range machines.

- WINCHESTER DISK MACHINES - K2150 Series.

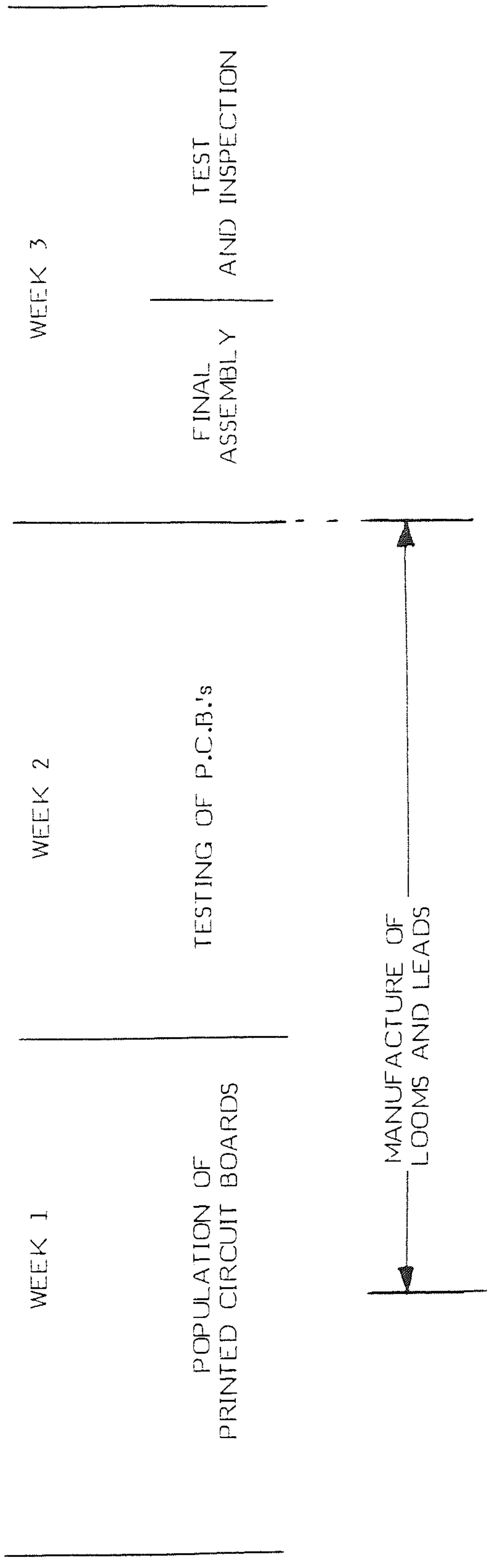
  The K2150 series consists of a processor box linked to one or two K500 terminals, each with an optional printer. A block diagram of the K2150 is shown below:



- FLOPPY DISK MACHINES - K1100 & K1200

  The two floppy disk machines consist of a CPU containing floppy disk storage and a separate monitor housing, comprising screen display, keyboard and processor board which is identical to the K500 terminal.

Figure 2. - Micro-Computer Specifications



Typical Manufacturing Lead Times for a batch of 10 Micro-computers

Figure 3. - Manufacturing Processes and Leadtimes

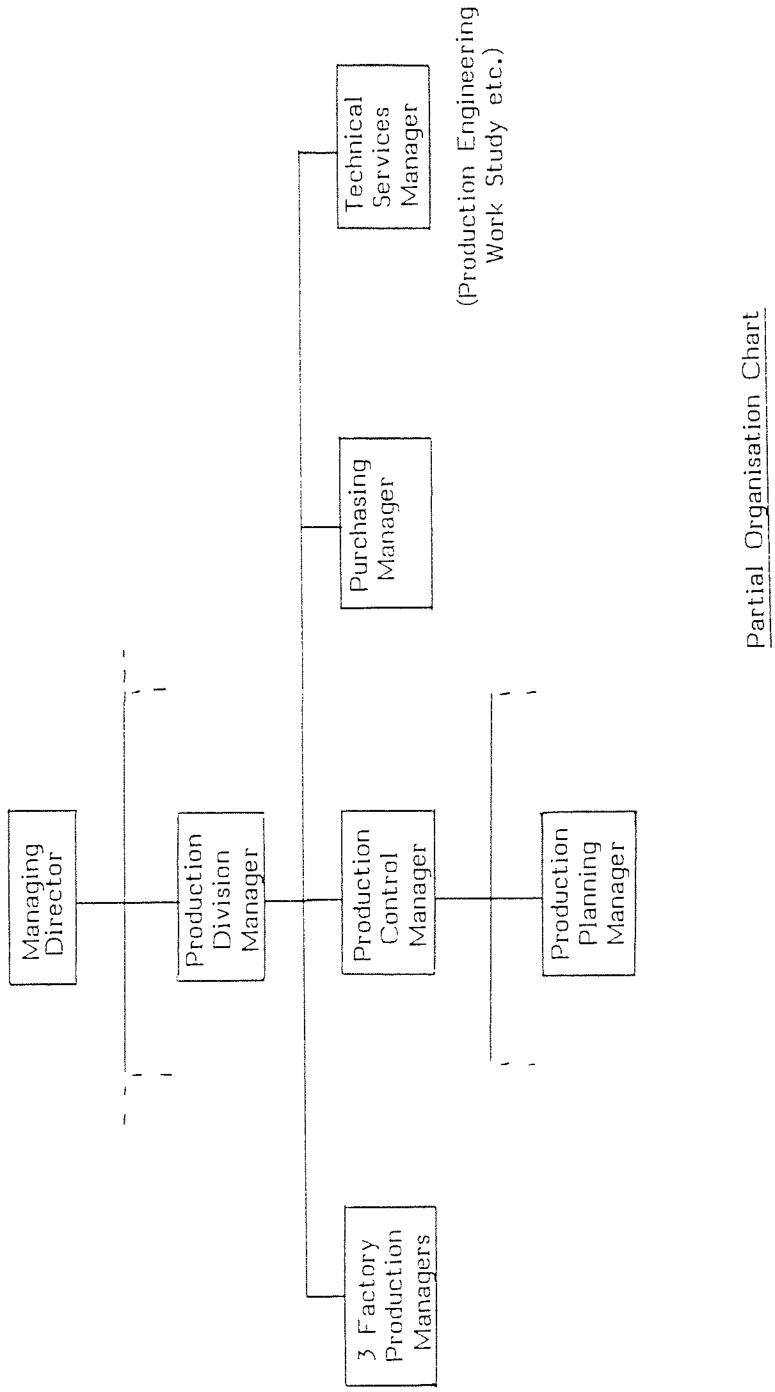


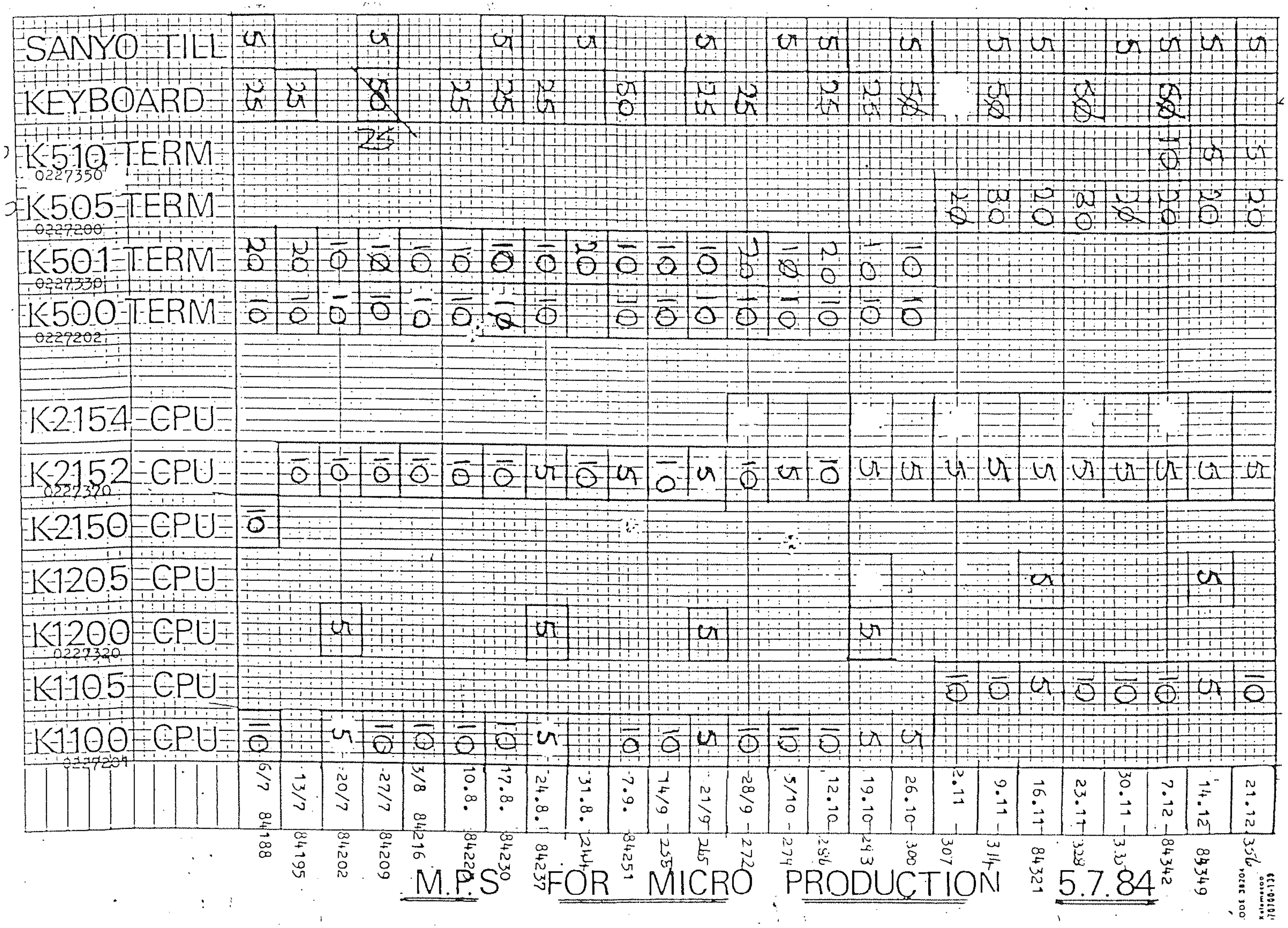
Figure 4. - Partial Organisation Chart

Delivery Schedule. 20/7/84.

Customer	Installation Week	Model	Printer, Software etc.
XYZ Dairies	27/7	1-K2150 + 2-K500 Terms	1 - GP300L Printer 1 - 9500A Printer Payroll Absence Recording package. Customised Stationery
|	|	|	|
|	|	|	|
|	|	|	|

Delivery Schedule Example

Figure 5. - Example of Delivery Schedule



M.P.S FOR MICRO PRODUCTION 5.7.84

	6/7 84188	13/7 84195	20/7 84202	27/7 84209	3/8 84216	10.8. 84223	17.8. 84230	24.8. 84237	31.8. 244	7.9. 84251	14/9 258	21/9 265	28/9 272	5/10 274	12.10 286	19.10 293	26.10 300	2.11 307	9.11 314	16.11 84321	23.11 328	30.11 335	7.12 84342	14.12 84349	21.12 356
SANYO TILL	5			5			5		5			5		5	5		5		5	5		5	5	5	5
KEYBOARD	25	25		~~50~~ 25		25	25	25		50		25	25		25	25	50		50		30		50		
K510 TERM 0227350																							10	5	5
K505 TERM 0227200																		20	30	20	30	20	20	20	20
K501 TERM 0227330	20	20	10	10	10	10	10	10	20	10	10	10	20	10	20	10	10								
K500 TERM 0227202	10	10	10	10	10	10	10	10		10	10	10	10	10	10	10	10								
K2154 CPU																									
K2152 CPU 0227370		10	10	10	10	10	10	5	10	5	10	5	10	5	10	5	5	5	5	5	5	5	5	5	5
K2150 CPU	10																								
K1205 CPU																				5				5	
K1200 CPU 0227320			5					5				5				5									
K1105 CPU																		10	10	5	10	10	10	5	10
K1100 CPU 0227201	10		5	10	10	10	10	5		10	10	5	10	10	10	5	5								

Figure 6. - Example of MPS

Appendix 5.

Rolls-Royce Ltd. Case Study.

[September 1984]

ROLLS-ROYCE LTD., DERBY AND GLASGOW [1984]

THE COMPANY, PRODUCTS AND MARKETS

The Rolls-Royce Derby and Glasgow manufacturing units supply products to Rolls-Royce's Civil Engine Group (see Figure 1.) who produce jet aircraft engines at other plants in the U.K.. They also produce spare parts and modification kits for the airline industry and for their own Repair and Overhaul business. Annual output of these plants is approximately £300 million at factory cost.

The Derby and Glasgow plants employ about 10,000 people in the Manufacturing and Materiel departments producing a range of machined components such as wheels, discs, shafts, turbine blades and compressor blades as well as various sub-assemblies.

Approximately 40% of output is for the spares business which is mostly made for stock, the remainder being to support the building of engines which is strictly made to order. Typical inventory levels are about 10 weeks finished parts (for engine build) 30 weeks finished stock (for spares), 20 weeks work-in-progress and 4 weeks raw material.

The company deals with several hundred customers, primarily airlines across the world for spares requirements and the major aircraft manufacturers, such as Boeing, for complete new engines. Approximately 60% of sales are for export, with the delivery dates being specified by the customer. For engines, the notice given might be as short as 13 months with an average of 18 months and some orders are as far out as 3 years. For spares, two types of service are offered; 60 % are given a guarantee of 90% delivery within 90 days, the rest, known as "lead time " orders are quoted based on the actual lead time required to produce and ship them. Parts for new engines are shipped direct to other Rolls-Royce plants and spares are shipped to customers, usually through major spares stores in Derby and East Kilbride or satellite stores located in the U.S.A., Brazil and Canada.

THE PRODUCTION PROCESS

It is difficult to describe a typical manufacturing sequence, since so many different items are produced from varying raw materials. Twenty years ago, an exercise was carried out to classify parts by size, for example, smaller or larger than a ten inch cube, and they were then given a "rationalised code" accordingly. Manufacturing facilities were then arranged to deal with particular family sizes. Machining is usually all carried out in one shop, at various sites, organised on a traditional functional, cell or semi-flow basis depending on the volumes of product involved. Manufacturing processes might involve casting, forging, traditional machining, such as turning, boring, broaching, drilling, milling and grinding as well as high technology activities such as electro-deposit machining, electro-chemical finishing, electro-jet drilling and electron beam welding. The control of machines ranges from manual through Numerical Control (NC), Computer Numerical Control (CNC), Direct Numerical Control (DNC) and Flexible Manufacturing Systems (FMS). Apart from metal machining and fabrication, there is also an increasing use of composite materials.

Manufacturing lead times can vary from 2 months up to 18 months with an overall total cumulative production lead time (including engine build) of as much as two and a half years.

Ninety percent of the manufacturing system is batch production with the remainder being continuous flow. In the aircraft industry, batch traceability is an important issue and the design of all the materials and production planning systems reflect this.

COMPUTER SYSTEMS

As far as the Derby and Glasgow plants are concerned, the company uses several main-frame computers. The first is an IBM 3033 with IMS and KICS as an Information Centre machine which allows users to copy various files across from the company databases via terminals and then program themselves locally using the data. An IBM 3081 deals with communications using an Online Time Sharing Option (OTSO). An Amdahl and various other computers are used in the Engineering and Design departments. The plants' MRP system referred to as Commitment and Netting (C&N) is a bespoke system and is run on an IBM 3032.

Rolls-Royce have been using in-house developed MRP systems for the past 18 years. The latest version is regenerative and is batch run every four weeks. The stock recording system runs nightly and there is an on-line purchasing system. The on-line spares materiel system is not integrated with the MRP system, which causes interface problems particularly with the allocating of stock to spares orders.

The current systems are dealing with a total of 140,000 part numbers of which approximately 35,000 are live current parts. Of the 35,000 live parts, 10% account for 90% of the usage value, 1,600 are raw materials and 10,000 are bought-out items. If engine build is included, there can be up to 12 levels of breakdown in the bills of material. About 5,000 new top level part numbers are introduced each year which, when exploded, can give up to 15,000 new part numbers. There is a very low degree of part commonality between products.

THE MASTER PRODUCTION SCHEDULE - OVERVIEW

Rolls-Royce do not Master Schedule in the classical sense, in that Engine Programmes and changes go straight into the MRP process and it is only the spares requirements which are dealt with by Master Schedulers who manipulate schedules to what can actually be done in line with what is required. The Commitment and Acceptance procedure for engines is carried out at the policy level in the company. The Master Schedule is therefore stated in engines and top level spares part numbers, in four weekly accounting periods over a maximum horizon of 52 periods or four years. However, it is common for only the first two and a half years of the horizon to be used, since this prevents buying and issuing ahead as the requirements are not shown on the horizon. Orders for engines are firm customer orders, whereas spares orders are a mixture of customer orders ("lead time" spares) and forecast (90 day spares).

Master Scheduling is carried out by a group of three people with the title of Master Scheduler, reporting to a Materiel Operations Manager in the Civil Engine Materiel Group (see figure 2). Within Rolls-Royce, the organisation has been set up such that a Materiel Group for each major product/market plans the requirements and an overall Supply Group manufactures and purchases to support these requirements. (See figure 1.)

The constraints on Master Scheduling are in terms of meeting customer delivery dates for engines, achieving the promised customer service for 90 day spares and holding to acceptable delivery promises for other spares. This has to be done within the framework of 5 year, annual and quarterly plans and budgets. The details of the MPS process will be described in detail in later sections.

PLANNING AND CONTROL SYSTEM INTERACTIONS

Using the basic model of MPS and its relationship with other planning and control activities, as shown in figure 4.1 , this section describes how these interactions operate at Rolls-Royce.

Demand Management

This incorporates the activities of forecasting, order entry and order promising which come under various responsibilities within Rolls-Royce.

For complete engines, negotiations take place with customers at a high level in the company and the engine programme is decided at a three monthly top level Management Review which includes the chairman and Executive Board members. Orders for engines are input via an Engine Schedule Input Programme (ESIP) which together with the Production Engine Specification Tape (PEST) produce Consolidated Schedules for Engines (CSE). Any risks, concerning how tentative the engine orders might be, are therefore taken at the highest level.

Spares requirements, apart from the split between "90 day" spares and "lead time" spares, are also split into three categories by usage value and dealt with accordingly. The highest usage value parts, 600 in total, are referred to as Volume Supply Monitor parts (VSM's). Forecasts for these are supplied by the airlines and every six months the relevant Materiel Planning Groups, part of the Materiel organisation (figure 2.), attend a Provisioning Conference with the airlines, where they review usage, production rates and stocking policies. An overall business forecast in terms of an increase or decrease in flying hours or repair and maintenance visits is used to calculate a trend which is applied to the average VSM spares item usage. This forecast is then passed on to the Master Schedulers who each cover about 200 VSM parts.

The intermediate usage value parts are known as Planning Parts. These are dealt with in a similar way to the V.S.M. parts but without the Provisioning Conference, because the airlines cannot cope with forecasting the usage of any more parts at the moment. Therefore, these parts are forecasted manually by the relevant Materiel Planning groups within Rolls-Royce and these forecasts passed on to the Master Schedulers.

The rest of the parts, the low usage value ones, are controlled on a Reorder Point basis known as the Assets Checker system and are therefore referred to as Asset Checker Parts. The Assets Checker system entails forecasting (using the Exponentially Weighted Moving Average method with a smoothing constant of 0.2), automatic stock target setting, stock level checking and scheduling (or time-phased ordering). This system operates on three sites and is closely integrated with complementary manual processes via a transaction processing (T/P) network. It controls around 100,000 parts and £100 million per year of spares sales. It is currently being redesigned under the acronym "S5" (Single Stock, Single Scheduling System) to cope with the additional requirements arising from New Engine Build. It already handles a mixture of "speculative" and "non-speculative" spares requirements, against which it writes both executive and recommended schedules for input into the MRP system. (See Figure 3).

There are also Satellite Stores Replenishment systems which supply parts "off the shelf" to repair and overhaul lines (mainly Rolls-Royce), reorder periodically and receive replenishments from the Main Store within 1-3 months. Five of these systems handle about £20m - £30m per year of spares.

Production Planning and Resource Planning

In Rolls-Royce the long term plan is called the 5 Year Plan. This is prepared and revamped once a year in the Autumn and provides detailed figures for the following two years, by quarter and annual totals for the remaining three years. This process is coordinated by a Production Planning Manager. Since this planning process is taken down to each Budget Centre which , in manufacturing, is a Product Centre (rationalised code or group of codes within a geographical location), the relevant managers at each site have to put forward their information for the plan. This plan is very detailed and is split down into the following sections: Basis of Domestic Capacity, Staff and Indirect Personnel, Method Improvements, Standard Hour Input Plan, Purchase Plan - Raw Material, Purchase Plan - Policy Permanent Sub Contract, Purchase Plan - BOF, Output Plan, Inventory Plan and Excess and Surplus Plan. Examples of draft Resource Plan charts for these plans are shown in figures 4 to 14. The same type of planning takes place at non-manufacturing Budget Centres such as Headquarters and Services. This is obviously an iterative process, with aggregate long term forecasts being provided and resource plans to meet these demands being eventually agreed. As can be seen from the charts, the units of measure used are £'s and Standard Hours, with a move towards Machine Hours where there is a lot of automated machinery. The overall comment made concerning this process, is that it is relatively easy to put in the capacity side of the plan but much more difficult to put in the load (output) side.

Rough Cut Capacity Planning

Rough Cut Capacity Planning at Rolls-Royce is, in fact, very detailed, being a continuation of the long term planning process, but reviewing the first two to two and a half years of the plan (the MPS period) every quarter. Load profiles are calculated locally by accessing the company databases for Engine Programmes via the Information Centre computer and then using the standard hour content for an "average engine". The results are then displayed graphically, being handwritten at present. (see figures 15 & 16).

Material Requirements Planning

The MRP system, Commitment and Netting (C&N), is an open-loop, regenerative system which performs the usual cascading, netting and time-phasing processes every four weeks. The planning periods which are used are Accounting Periods (4 weeks). The C & N system does not have all the features of packaged MRP systems; for example, it does not deal with Firm Planned Orders or provide reschedule suggestions. Since no scrap factors are applied to Engine Build, any actual scrap creates a new front-end increase, that is, immediate arrears, as soon as the MRP system is run.

Capacity Requirements Planning

Two types of detailed Capacity Requirements Planning by Product Centre using the output of the MRP system have been attempted. The first was an infinite capacity schedule evaluation referred to as WIPPET (Work In Progress Production Evaluation Tape). The second involved the use of finite capacity shop simulation models which predicted batch movements and shopfloor bottlenecks. These have been used with varying degrees of success.

Purchasing

There are two main purchasing systems: the Purchase Decision Model (PDM) and The Low Cost Parts Purchasing system (LOCUST). The PDM takes its inputs from the MRP system and creates a recommended order schedule for outside suppliers by trading-off order stability, inventory and price/quantity breaks. It handles around £250m per year of orders, all at recommendation status. It is a periodic-review batch-run system which complements manual activity via a transaction processing network. LOCUST is an alternative route to PDM for low usage cost parts. It currently handles about £10m per year of the purchase business. It explicitly builds stock in anticipation of fluctuations in requirements, some of which cannot be passed on to suppliers.

Shopfloor Scheduling

A system known as GILT (Generated Ideal Loading Technique) schedules batches on the shopfloor. With an input of MRP requirements and feedback of achievements it shows queues, sequences batches and evaluates work in progress in terms of items, £'s and standard hours for the following ten weeks. It is reviewed every week and generates new sequence instructions daily.

MASTER PRODUCTION SCHEDULE PREPARATION

This section outlines the activities entailed in Master Scheduling.

As mentioned in an earlier section, the Master Schedulers do not control the Engine Schedule requirements nor deal manually with the Asset Checker parts, other than implementing the suggested schedules. Consequently, the bulk of their efforts are put into the planning and controlling of the Volume Supply Monitor (VSM) parts and Planning parts.

The Master Schedulers use Materiel Planning Worksheets, which are supplied from the Materiel Planning Groups to plan the schedules of parts. (See figure 17). These include information on customer usage, customer stock and customer orders due. Since the MRP system does not deal with Firm Planned Orders, the only way that the Master Schedulers can override the requirements which have cascaded down, is to put in a "break-line schedule". This is a manual schedule which has to be put in for the whole horizon and manually updated for every change required. These are used for very few items, for example turbine blades for the purpose of load smoothing.

Working for the Master Schedulers are Component Controllers who deal with individual component parts, and they have regular monthly meetings with the managers at the Product Centres to agree schedules and suggest revisions. The average amount of stock planned into the schedules is one month's worth.

As described earlier, forecasting and order entry is not the responsibility of the Master Schedulers, although they do informally challenge the Materiel Planners' forecasts. Whilst they cannot control orders, they can control the sequence of orders and their priority. Master Schedulers will sometimes push for order amendments.

Master Schedules are updated every four weeks, but the spares content can be changed on-line and "break-line schedules" are input weekly.

Time fences are not used, although, informally, every effort is made not to change schedules within twelve weeks of despatch.

What-If simulations are not used in Master Scheduling and are only sometimes used for major changes in Engine Programmes. They involve a non-executive MRP (C&N) run which is very cumbersome.

PLANNING AND CONTROL SYSTEM EVALUATION

In this section the performance measures which are used to evaluate planning and control systems at Rolls-Royce are briefly described and some system improvements which are being planned are mentioned.

Measures

Apart from the detailed budgetary control system outlined in the five year planning process, the basic measure of scheduling performance is whether the schedule is in line with the forecast. The other is the provisioning performance for 90 day spares. It has been calculated from simulation that to give 90% service within 90 days, on the day that the customer places an order, the assets (stock plus WIP) must cover orders to the tune of 97%.

The ultimate measure is whether engines get built on time.

Improvements

The main system improvement which is planned is the S5 (Single Stock, Single Scheduling System). As the title suggests, this will integrate the spares stock system with the production stocks and the MRP system.

True Master Scheduling within the whole of Rolls-Royce is undertaken for only 50 or 60 items, including, for example, turbine blades, fan casings and fuel flow regulators. It is the ultimate aim that the 60 should become 2,000.

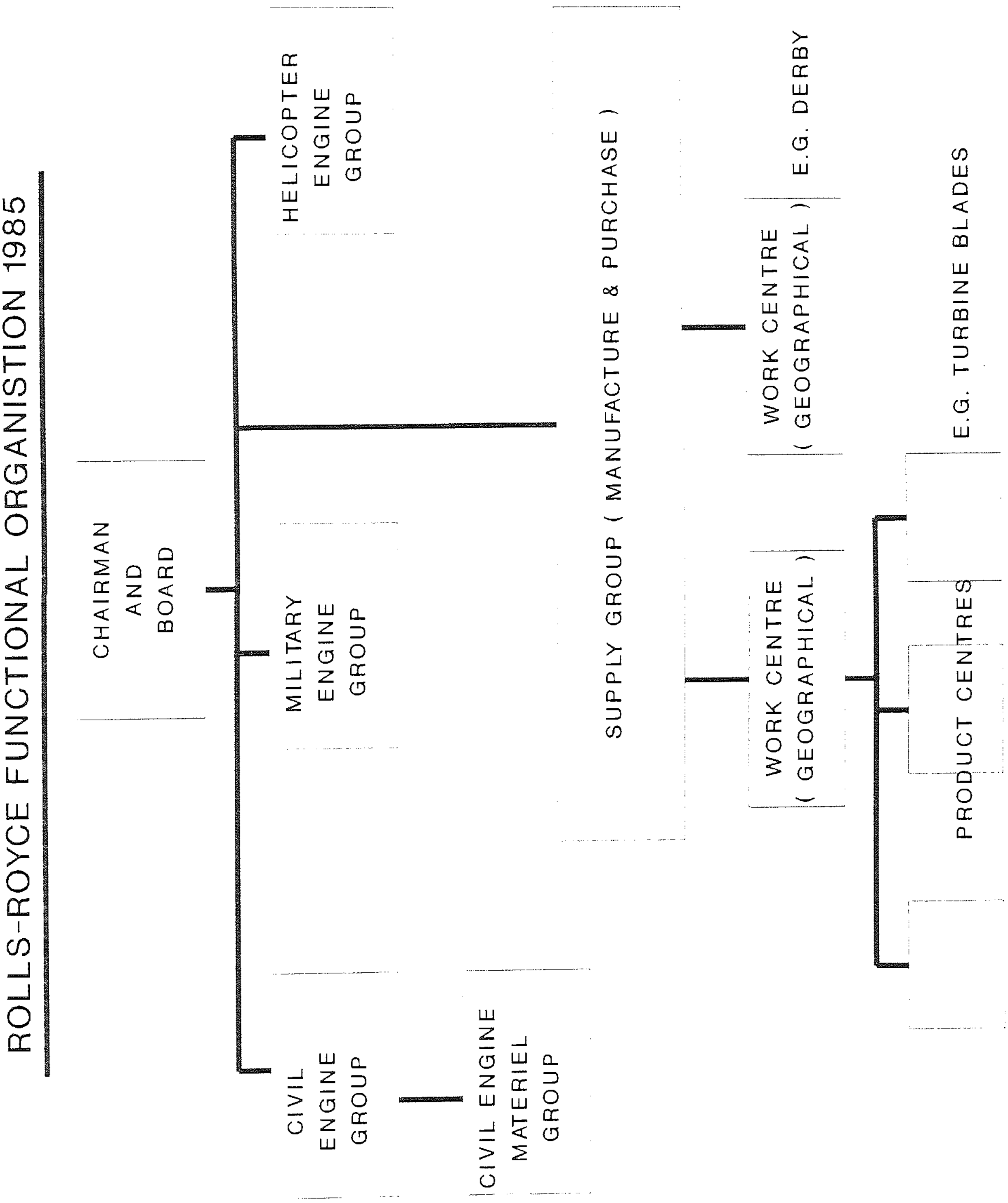


Figure 1. Rolls-Royce Functional Organisation - 1985

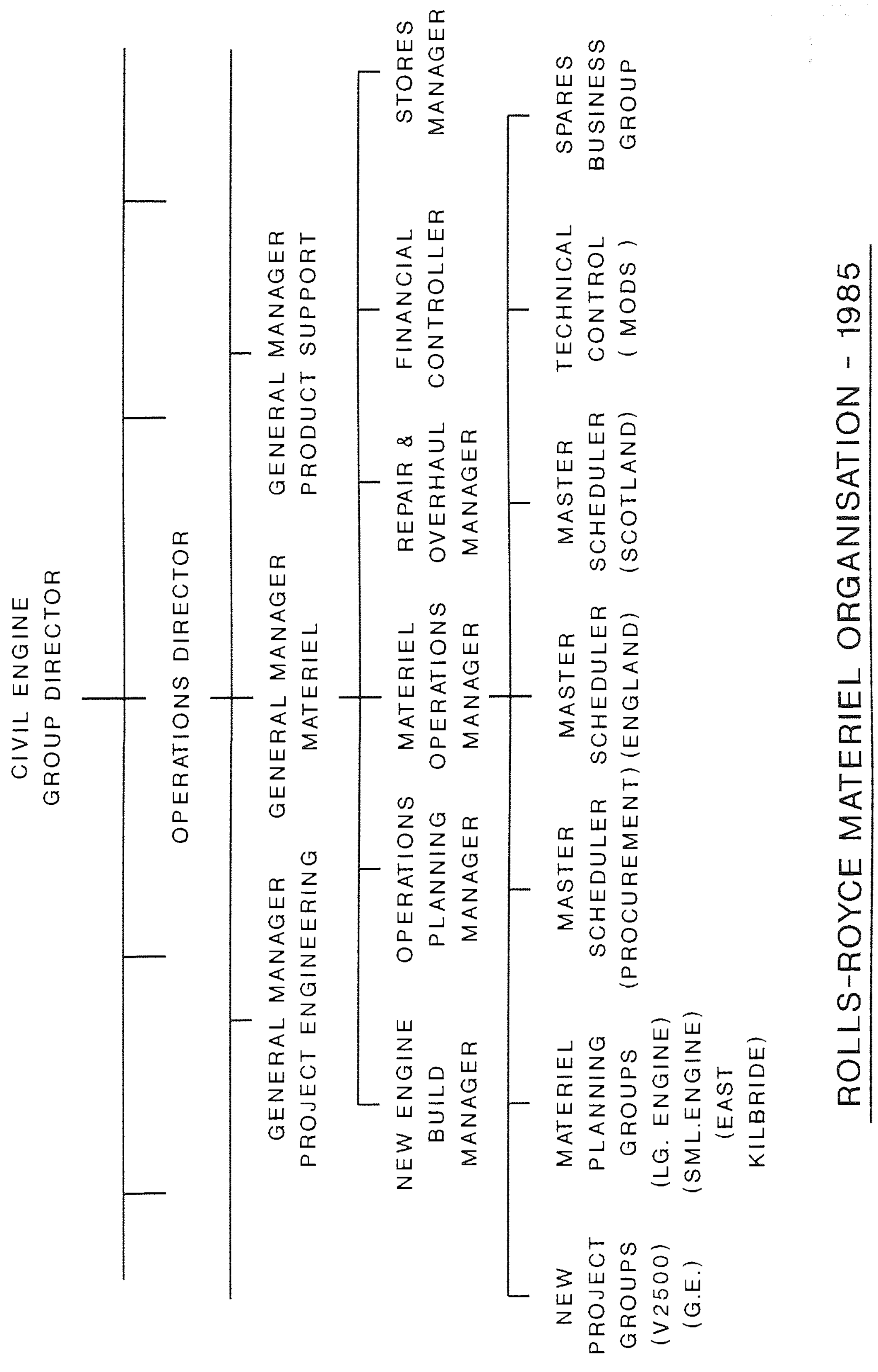
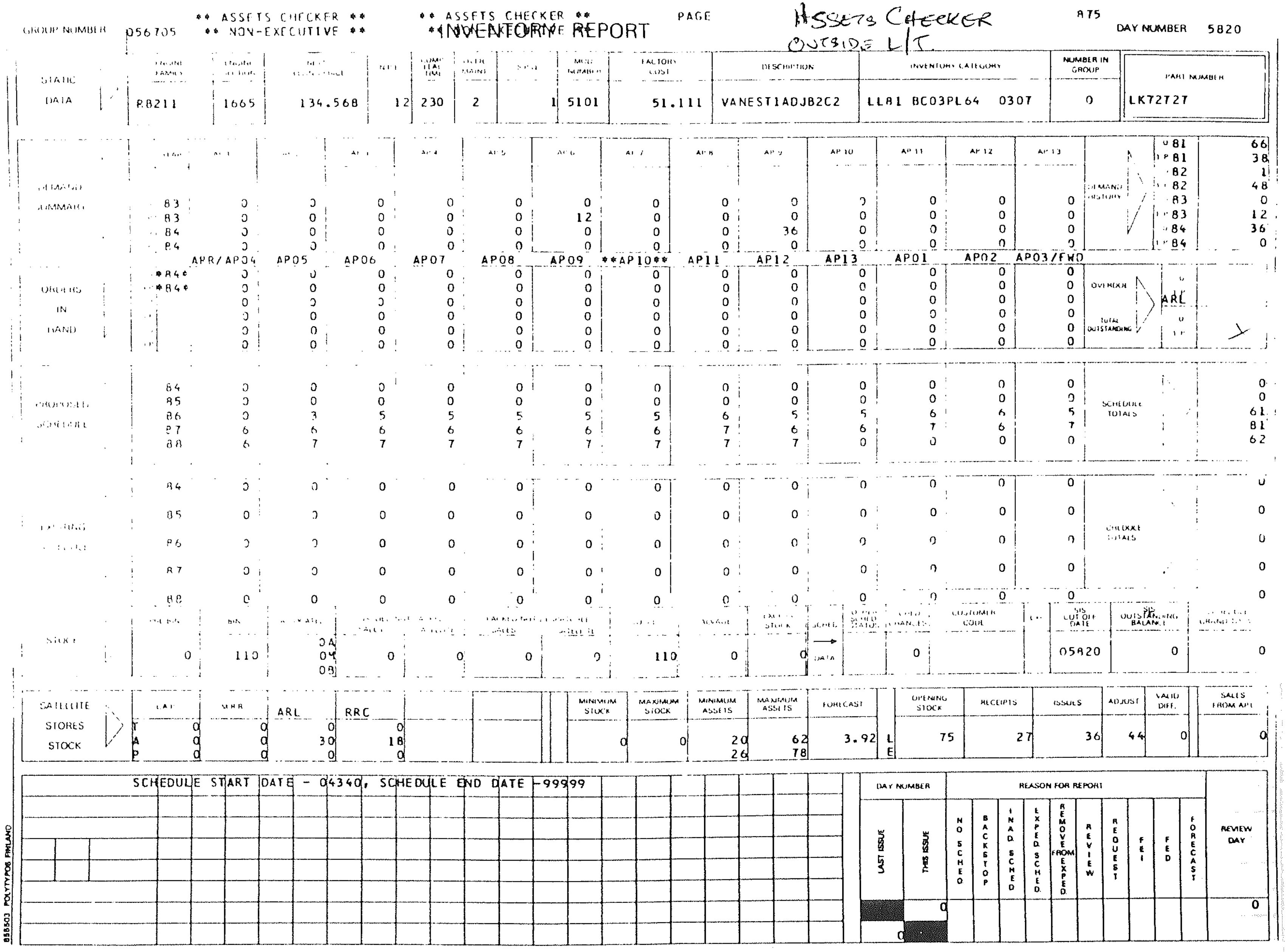


Figure 2. Rolls-Royce Materiel Organisation - 1985



GROUP NUMBER 056705 ** ASSETS CHECKER ** ** NON-EXECUTIVE ** ** ASSETS CHECKER ** INVENTORY REPORT PAGE 875 DAY NUMBER 5820

Assets Checker
Outside L/T.

STATIC DATA								MOD NUMBER	FACTORY COST	DESCRIPTION	INVENTORY CATEGORY	NUMBER IN GROUP	PART NUMBER
	RB211	1665	134.568	12	230	2	1	5101	51.111	VANEST1ADJB2C2	LLB1 BC03PL64 0307	0	LK72727

DEMAND SUMMARY

				AP 4	AP 5	AP 6	AP 7	AP 8	AP 9	AP 10	AP 11	AP 12	AP 13
83	0	0	0	0	0	0	0	0	0	0	0	0	0
83	0	0	0	0	0	12	0	0	0	0	0	0	0
84	0	0	0	0	0	0	0	0	36	0	0	0	0
84	0	0	0	0	0	0	0	0	0	0	0	0	0

DEMAND HISTORY

U 81	66
P 81	38
82	1
82	48
83	0
83	12
84	36
84	0

ORDERS IN HAND

	APR/AP04	AP05	AP06	AP07	AP08	AP09	**AP10**	AP11	AP12	AP13	AP01	AP02	AP03/FWD
R4	0	0	0	0	0	0	0	0	0	0	0	0	0
R4	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0

OVERDUE
TOTAL OUTSTANDING
ARL

PROPOSED SCHEDULE

														SCHEDULE TOTALS
84	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0	0	0	0	0	0
86	0	3	5	5	5	5	5	6	5	5	6	6	5	61
87	6	6	6	6	6	6	6	7	6	6	7	6	7	81
88	6	7	7	7	7	7	7	7	7	0	0	0	0	62

CHECKED SCHEDULE

														CHECKED TOTALS
84	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0	0	0	0	0	0
86	0	0	0	0	0	0	0	0	0	0	0	0	0	0
87	0	0	0	0	0	0	0	0	0	0	0	0	0	0
88	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STOCK

	BIN								EXCESS STOCK	SCHED. DATA			CUSTOMER CODE		S/S CUT OFF DATE	S/S OUTSTANDING BALANCE	
0	110	0A 04 08	0	0	0	0	110	0	0	→		0			05820	0	0

SATELLITE STORES STOCK

			ARL	RRC
T	0	0	0	0
A	0	0	30	18
P	0	0	0	0

MINIMUM STOCK	MAXIMUM STOCK	MINIMUM ASSETS	MAXIMUM ASSETS	FORECAST		OPENING STOCK	RECEIPTS	ISSUES	ADJUST	VALID DIFF.	SALES FROM API
0	0	20 26	62 78	3.92	L E	75	27	36	44	0	0

SCHEDULE START DATE - 04340, SCHEDULE END DATE -99999

DAY NUMBER		REASON FOR REPORT										REVIEW DAY
LAST ISSUE	THIS ISSUE	NO SCHED	BACKSTOP	INAD. SCHED	EXPED. SCHED.	REMOVE FROM EXPED	REVIEW	REQUEST	FEI	FED	FORECAST	
0	0											0

855503 POLYTYPOS FINLAND

Figure 3. - Assets Checker Report

PROGRAMME P8230 Pc/Wc

2

BASIS OF DOMESTIC CAPACITY STH x 000

			1982			1983					1984	1985	1986
			ACT 1-9	10-13	TOTAL	Q1	Q2	Q3	Q4	TOTAL	TOTAL	TOTAL	TOTAL
1.	AVERAGE DIRECT OPERATORS	ON 1/2 SHIFT											
2.		ON 3 SHIFT											
3.	POSSIBLE ATT HOURS/OPERATOR	ON 1/2 SHIFT											
4.		ON 3 SHIFT											
5.	TOTAL POSSIBLE ATT HOURS												
6.	ABSENTEEISM	PERCENT											
7.		HOURS											
8.	OVERTIME	PERCENT											
9		HOURS											
10.	CLOCK TO BOOKED ERROR												
11.	TOTAL HOURS BOOKED												
12.	DIVERSIONS	PERCENT											
13		HOURS											
14	MISC PROD HOURS												
15	REPAIR HOURS												
16.	UNRESOLVED HOURS												
17.	TOTAL ATT HOURS ON PROD												
18	MEASURED WORK	PERCENT											
19		HOURS											
20		O.P											
21.		STH											
22.	NON-MEASURED WORK	HOURS											
23.		O.P											
24.		STH											
25.	COMBINED O.P.												
26.	COMBINED D.P												
27.	TOTAL PRODUCTION STH												
28.	SCRAP DOMESTIC	PERCENT											
29.		STH											
30.	SCRAP SUPPLIERS (RDM)	PERCENT											
31.		STH											
32.	END QTR/YR OPERATORS												

Figure 4. Resource Plan Chart - Basis of Domestic Capacity

PROGRAMME P8230 PC/WC

STAFF AND INDIRECT PERSONNEL

3

				1982			1983					1984	1985	1986
				ACT 1-9	10-13	TOTAL	Q1	Q2	Q3	Q4	TOTAL	TOTAL	TOTAL	TOTAL
1.	AVER INDIRECT PERSONNEL	PROD	ON 1/2 SHIFT											
2.			ON 3 SHIFT											
3		NON-PROD	ON 1/2 SHIFT											
4.			ON 3 SHIFT											
5.		N.M.C OPER	ON 1/2 SHIFT											
6.			ON 3 SHIFT											
7		TOTAL	ON 1/2 SHIFT											
8.			ON 3 SHIFT											
9.		TOTAL												
10.	POSSIBLE ATT HOURS / PERSON		ON 1/2 SHIFT											
11.			ON 3 SHIFT											
12.	TOTAL POSSIBLE ATT HOURS													
13.	ABSENTEEISM		PERCENT											
14.			HOURS											
15.	OVERTIME		PERCENT											
16			HOURS											
17.	TOTAL ATT HOURS													
18	END QTR / YEAR INDIRECTS		PROD											
19.			NON PROD											
20.			N.M.C. OPER											
21.			TOTAL											
22.	STAFF	AVER PERSONNEL												
23.		OVERTIME %(CASH)												
24.		ABSENTEEISM												
25.		END QTR/YEAR												

Figure 5. Resource Plan Chart - Staff & Indirect Personnel

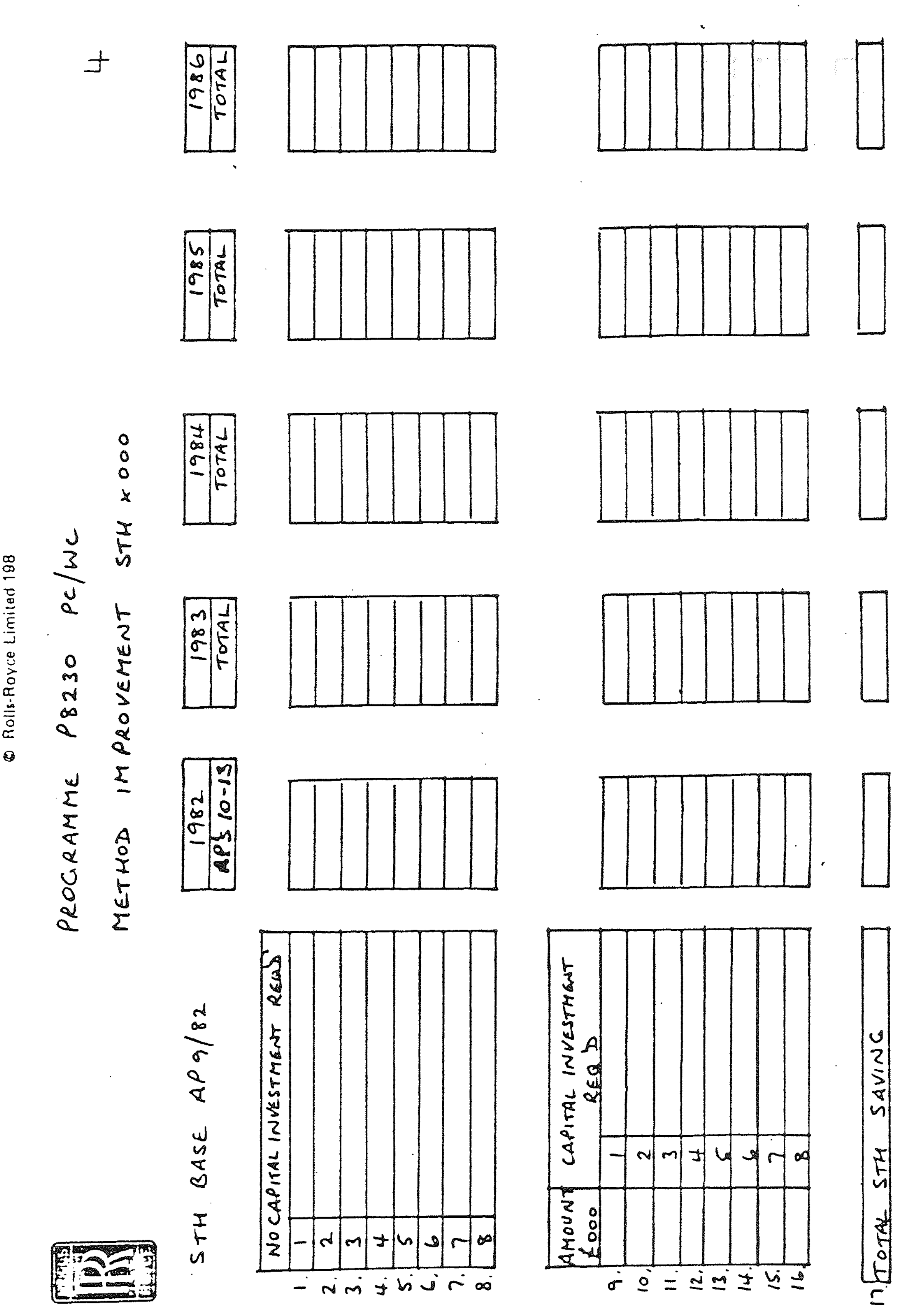
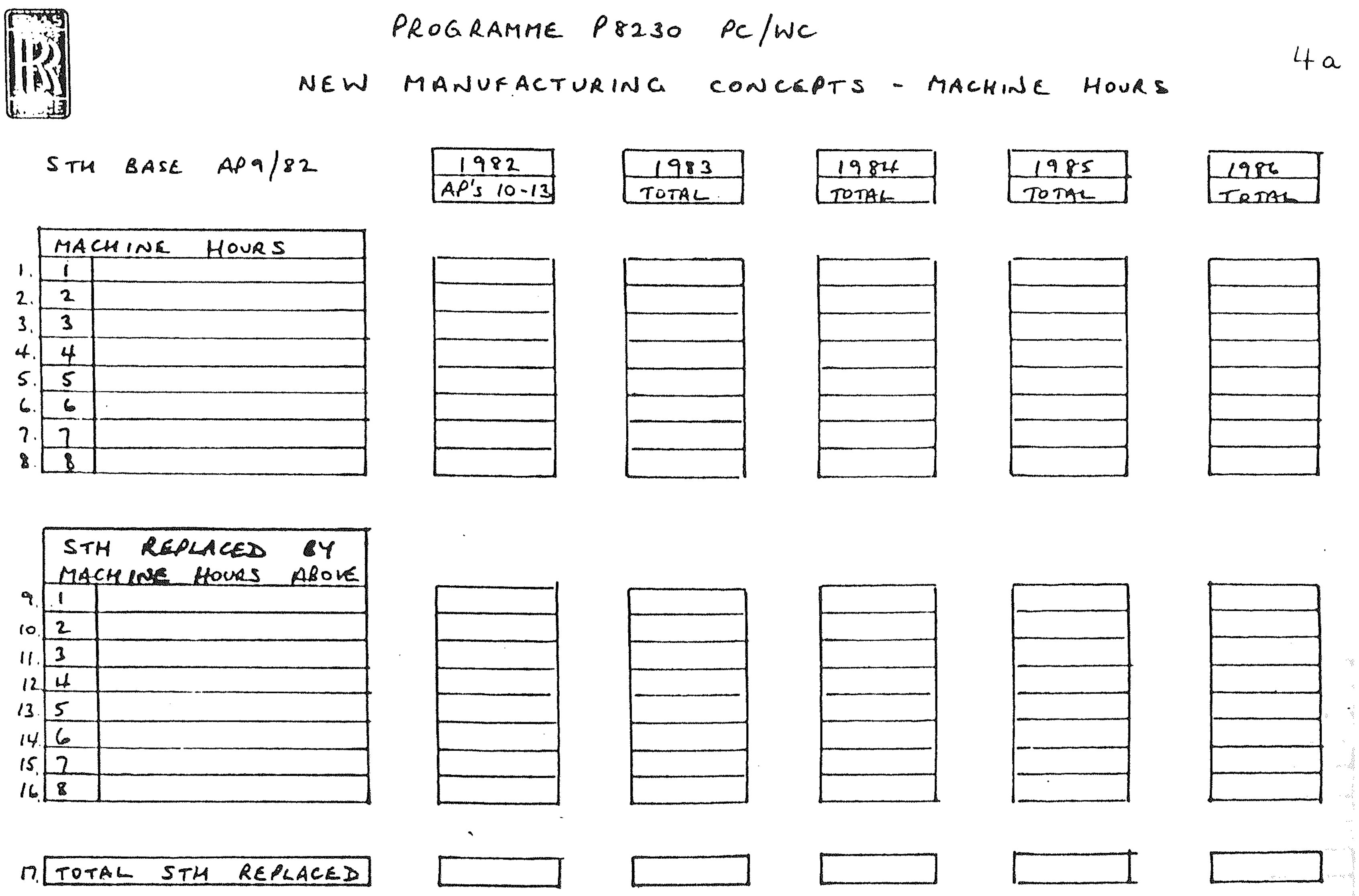


Figure 6. Resource Plan Chart - Method Improvement



PROGRAMME P8230 PC/WC

NEW MANUFACTURING CONCEPTS - MACHINE HOURS

4a

STH BASE AP9/82

		1982 AP's 10-13	1983 TOTAL	1984 TOTAL	1985 TOTAL	1986 TOTAL
	MACHINE HOURS					
1.	1					
2.	2					
3.	3					
4.	4					
5.	5					
6.	6					
7.	7					
8.	8					
	STH REPLACED BY MACHINE HOURS ABOVE					
9.	1					
10.	2					
11.	3					
12.	4					
13.	5					
14.	6					
15.	7					
16.	8					
17.	TOTAL STH REPLACED					

Figure 7. Resource Plan Chart - New Manufacturing Concepts

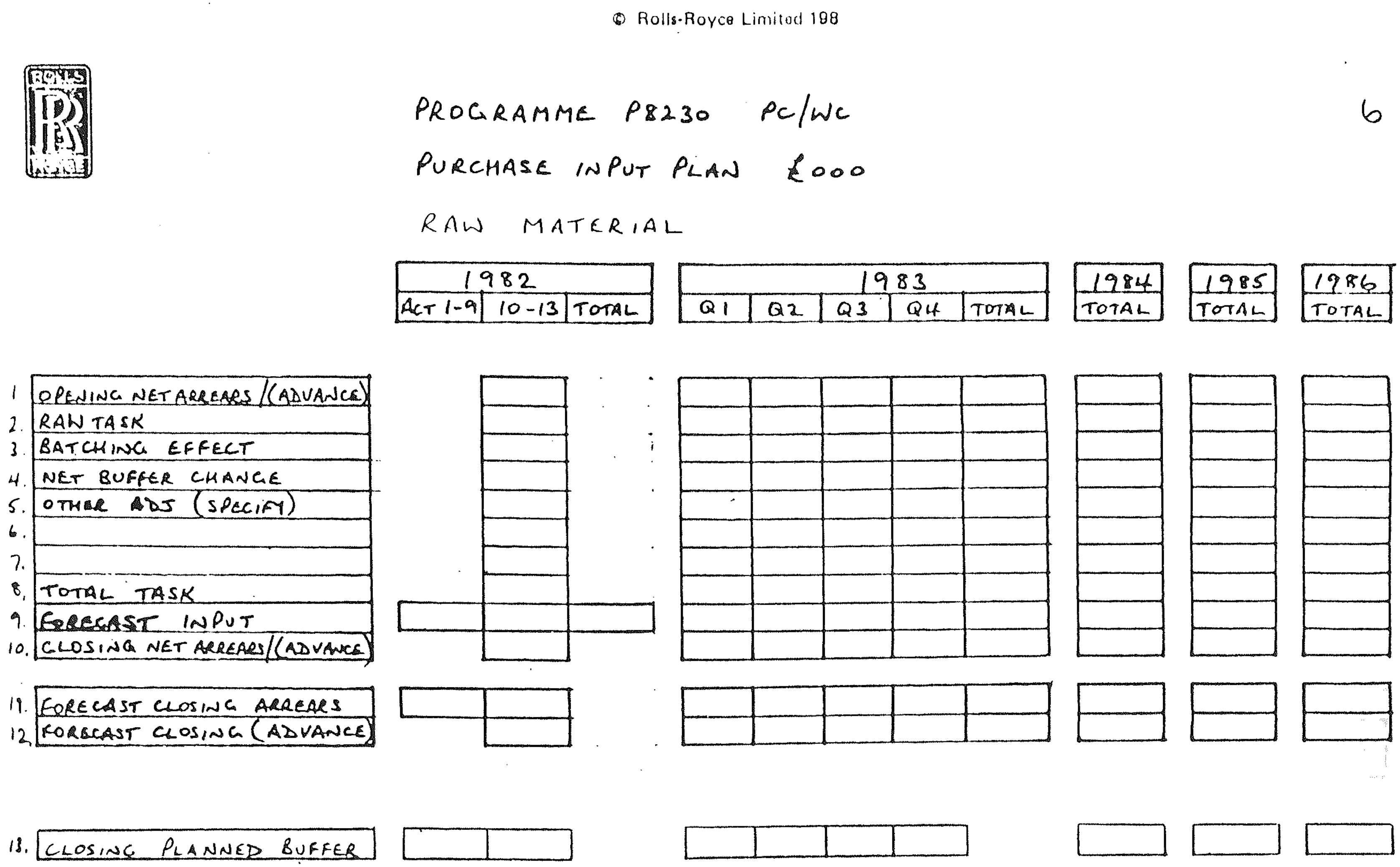
PROGRAMME P8230 PC/WC

STANDARD HOUR INPUT PLAN STH x 000

5

		1982			1983					1984	1985	1986
	AT WIP	ACT 1-9	10-13	TOTAL	Q1	Q2	Q3	Q4	TOTAL	TOTAL	TOTAL	TOTAL
	DOMESTIC											
1	OPENING NET ARREARS/(ADVANCE)											
2	RAW TASK											
3	(METHOD IMPROVEMENTS) BASE AP9/82											
4	(STH REPLACED BY MACHINE HOURS)											
5	OTHER ADJS (SPECIFY)											
6												
7												
8	NET ADJUSTED TASK											
9	FORECAST INPUT											
10	MISMATCH											
11	INLOAD/(OFFLOAD) B.O.F											
12	INLOAD/(OFFLOAD) S.CON											
13	INLOAD/(OFFLOAD) OTHER PC/WC											
14	CLOSING NET ARREARS/(ADVANCE)											
15	FORECAST ARREARS											
16	FORECAST (ADVANCE)											
	AT FPS											
	SUB CONTRACT (INC EXP ASSIST)											
17	OPENING NET ARREARS/(ADVANCE)											
18	EXISTING ALLOCN RAW TASK											
19	(REDUCTION FOR P.P.S.C.)											
20	TO/(FROM) SUB CONTRACT											
21	TOTAL TASK											
22	FORECAST INPUT											
23	EXP ASSIST CONTENT OF INPUT											
24	CLOSING NET ARREARS/(ADVANCE)											
25	FORECAST ARREARS											
26	FORECAST (ADVANCE)											

Figure 8. Resource Plan Chart - Standard Hour Input Plan



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PROGRAMME P8230 PC/WC

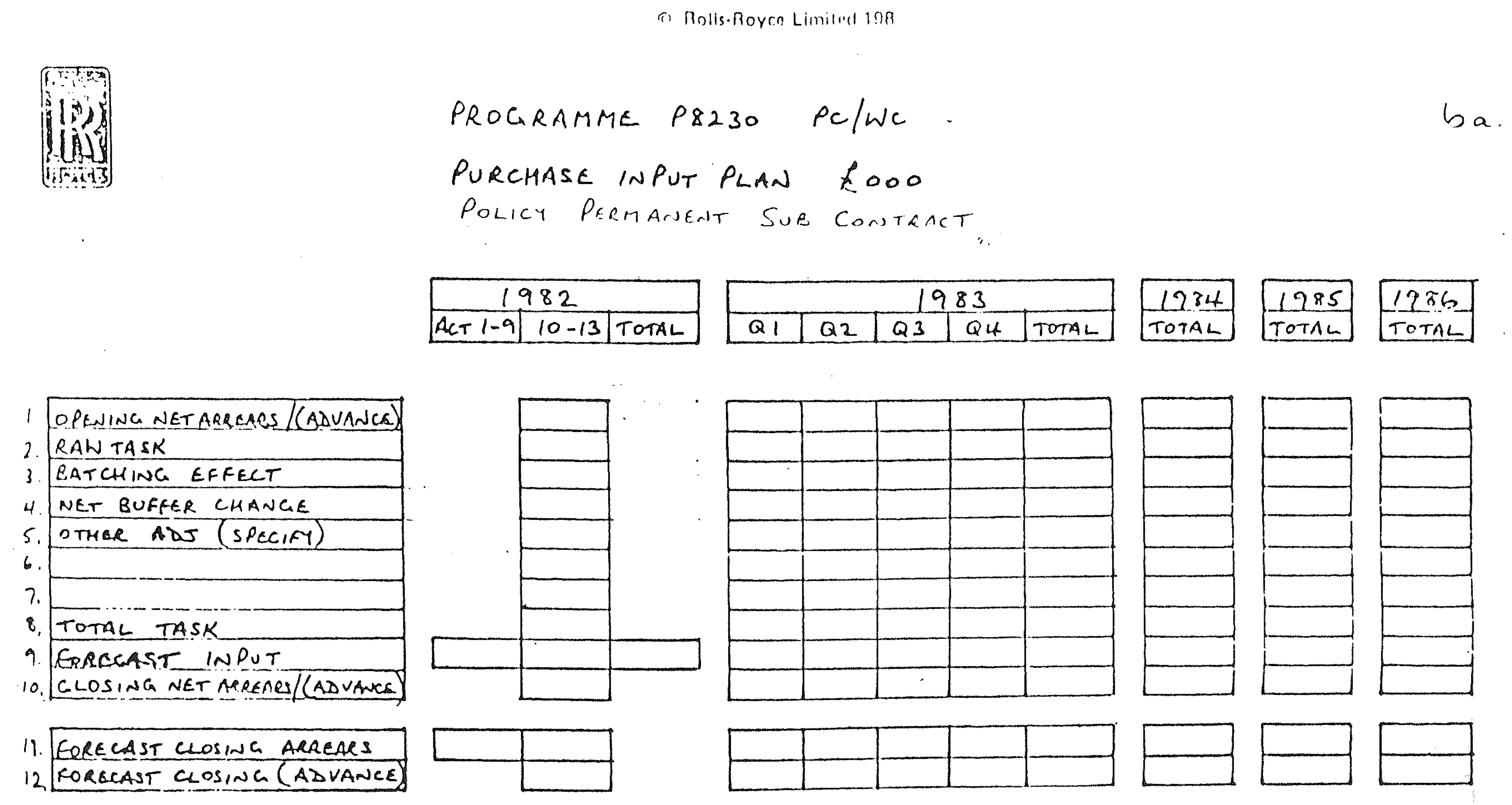
6

PURCHASE INPUT PLAN £000

RAW MATERIAL

	1982			1983					1984	1985	1986
	ACT 1-9	10-13	TOTAL	Q1	Q2	Q3	Q4	TOTAL	TOTAL	TOTAL	TOTAL
1 OPENING NET ARREARS/(ADVANCE)											
2. RAW TASK											
3. BATCHING EFFECT											
4. NET BUFFER CHANGE											
5. OTHER ADJS (SPECIFY)											
6.											
7.											
8. TOTAL TASK											
9. FORECAST INPUT											
10. CLOSING NET ARREARS/(ADVANCE)											
11. FORECAST CLOSING ARREARS											
12. FORECAST CLOSING (ADVANCE)											
13. CLOSING PLANNED BUFFER											

Figure 9. Resource Plan Chart - Purchase Input Plan: Raw Material



PROGRAMME P8230 PC/WC

PURCHASE INPUT PLAN £000

POLICY PERMANENT SUB CONTRACT

6a.

		1982			1983					1984	1985	1986
		ACT 1-9	10-13	TOTAL	Q1	Q2	Q3	Q4	TOTAL	TOTAL	TOTAL	TOTAL
1	OPENING NET ARREARS/(ADVANCE)											
2.	RAW TASK											
3.	BATCHING EFFECT											
4.	NET BUFFER CHANGE											
5.	OTHER ADJ (SPECIFY)											
6.												
7.												
8.	TOTAL TASK											
9.	FORECAST INPUT											
10.	CLOSING NET ARREARS/(ADVANCE)											
11.	FORECAST CLOSING ARREARS											
12.	FORECAST CLOSING (ADVANCE)											

Figure 10. Resource Plan Chart - Purchase Plan: Sub-Contract

PROGRAMME P8230 PC/WC

6b.

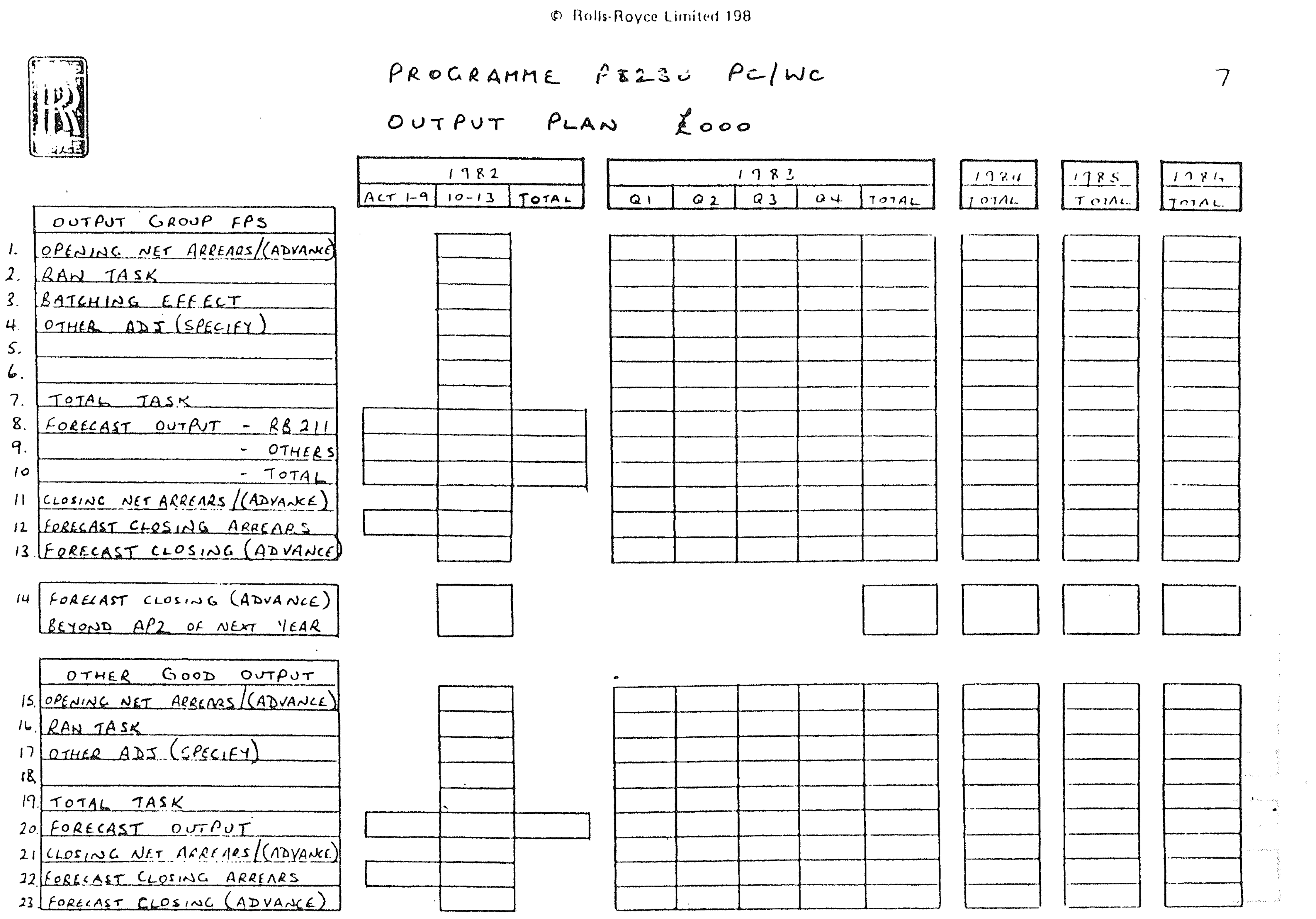
PURCHASE INPUT PLAN £000

BOUGHT OUT FINISHED

~~RAW MATERIAL~~

		1982			1983					1984	1985	1986
		ACT 1-9	10-13	TOTAL	Q1	Q2	Q3	Q4	TOTAL	TOTAL	TOTAL	TOTAL
1.	OPENING NET ARREARS/(ADVANCE)											
2.	RAW TASK											
3.	BATCHING EFFECT											
4.	NET BUFFER CHANGE											
5.	OTHER ADJ (SPECIFY)											
6.												
7.												
8.	TOTAL TASK											
9.	FORECAST INPUT											
10.	CLOSING NET ARREARS/(ADVANCE)											
11.	FORECAST CLOSING ARREARS											
12.	FORECAST CLOSING (ADVANCE)											

Figure 11. Resource Plan Chart - Purchase Plan: Bought Out Finished



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PROGRAMME F823U PC/WC 7

OUTPUT PLAN £000

		1982			1983					1984	1985	1986
		ACT 1-9	10-13	TOTAL	Q1	Q2	Q3	Q4	TOTAL	TOTAL	TOTAL	TOTAL
	OUTPUT GROUP FPS											
1.	OPENING NET ARREARS/(ADVANCE)											
2.	RAW TASK											
3.	BATCHING EFFECT											
4.	OTHER ADJ (SPECIFY)											
5.												
6.												
7.	TOTAL TASK											
8.	FORECAST OUTPUT - RB 211											
9.	- OTHERS											
10	- TOTAL											
11	CLOSING NET ARREARS/(ADVANCE)											
12	FORECAST CLOSING ARREARS											
13.	FORECAST CLOSING (ADVANCE)											
14	FORECAST CLOSING (ADVANCE) BEYOND AP2 OF NEXT YEAR											
	OTHER GOOD OUTPUT											
15.	OPENING NET ARREARS/(ADVANCE)											
16.	RAW TASK											
17	OTHER ADJ (SPECIFY)											
18												
19.	TOTAL TASK											
20.	FORECAST OUTPUT											
21	CLOSING NET ARREARS/(ADVANCE)											
22	FORECAST CLOSING ARREARS											
23	FORECAST CLOSING (ADVANCE)											

Figure 12. Resource Plan Chart - Output Plan

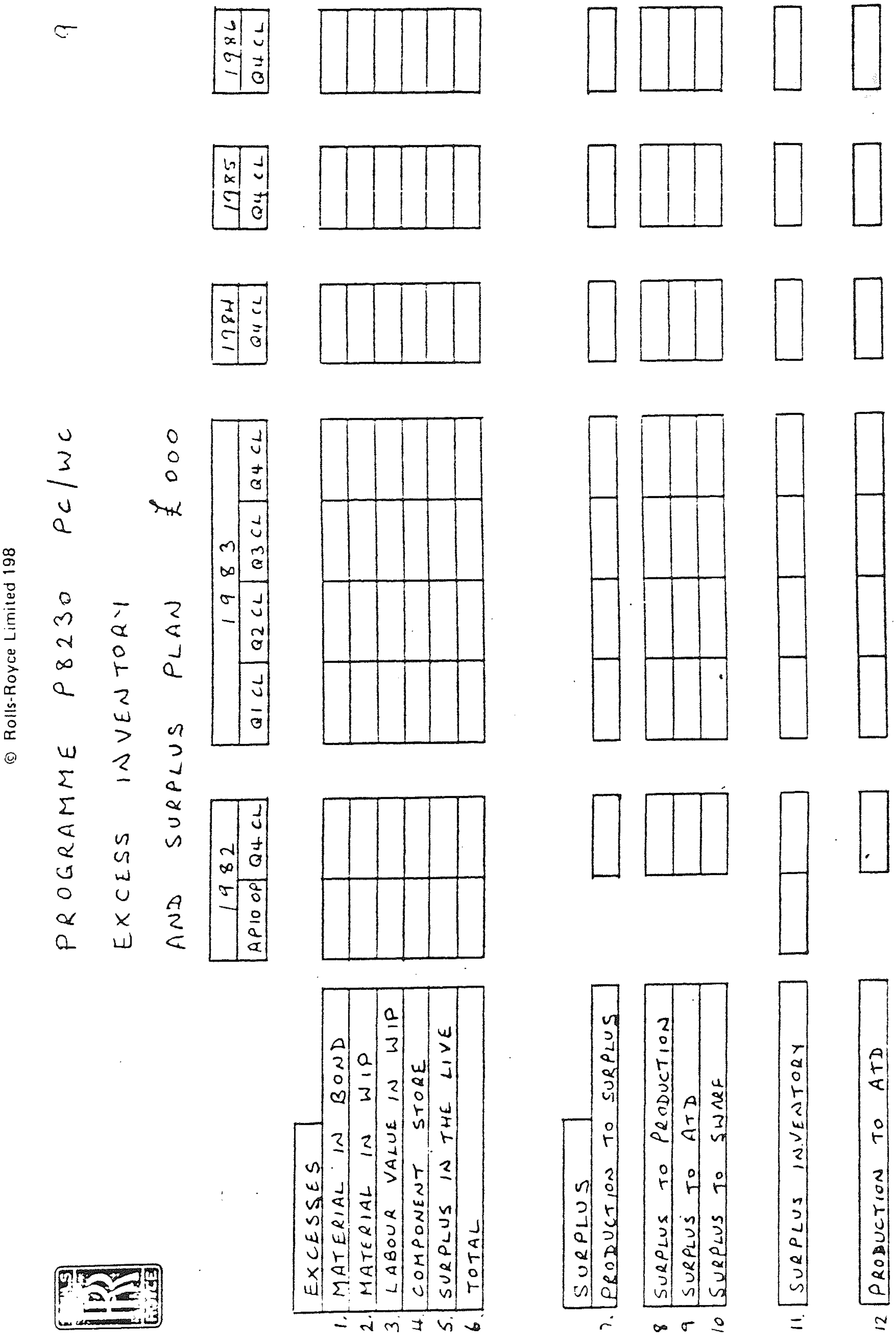
PROGRAMME P8230 PC/WC

8

INVENTORY PLAN £000

		1982	1983					1984	1985	1986
		AP10-13	Q1	Q2	Q3	Q4	TOTAL	TOTAL	TOTAL	TOTAL
1.	OPENING INVENTORY									
	INPUT									
2	RAW MATERIAL									
3	PURCHASES - P.P.S.C									
4.	- B.O.F									
5	STH VALUE - DOMESTIC									
6.	- EXTERNAL									
7.	- ASSIST FROM OTHER P.C's									
8	METHOD IMPROVEMENTS - CON^V									
9	- NMC									
10	INPUT FROM OTHER PC's									
11.	MISC									
12	TOTAL									
	OUTPUT									
13	TO FPS									
14.	TO OTHER P.C's									
15	STH ASSIST TO OTHER PC's									
16.	SCRAP									
17.	SALES									
18.	MISC									
19	TOTAL									
20	CLOSING INVENTORY									
21	NUMBER OF WEEKS WORTH OF TOTAL OUTPUT IN OPENING INV									

Figure 13. Resource Plan Chart - Inventory Plan



9

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PROGRAMME P8230 PC/WC

EXCESS INVENTORY

AND SURPLUS PLAN £000

		1982 AP10 OP	1982 Q4 CL	1983 Q1 CL	1983 Q2 CL	1983 Q3 CL	1983 Q4 CL	1984 Q4 CL	1985 Q4 CL	1986 Q4 CL
	EXCESSES									
1.	MATERIAL IN BOND									
2.	MATERIAL IN WIP									
3.	LABOUR VALUE IN WIP									
4.	COMPONENT STORE									
5.	SURPLUS IN THE LIVE									
6.	TOTAL									
	SURPLUS									
7.	PRODUCTION TO SURPLUS									
8	SURPLUS TO PRODUCTION									
9	SURPLUS TO ATD									
10	SURPLUS TO SWARF									
11.	SURPLUS INVENTORY									
12	PRODUCTION TO ATD									

Figure 14. Resource Plan Chart - Excess Inventory & Surplus

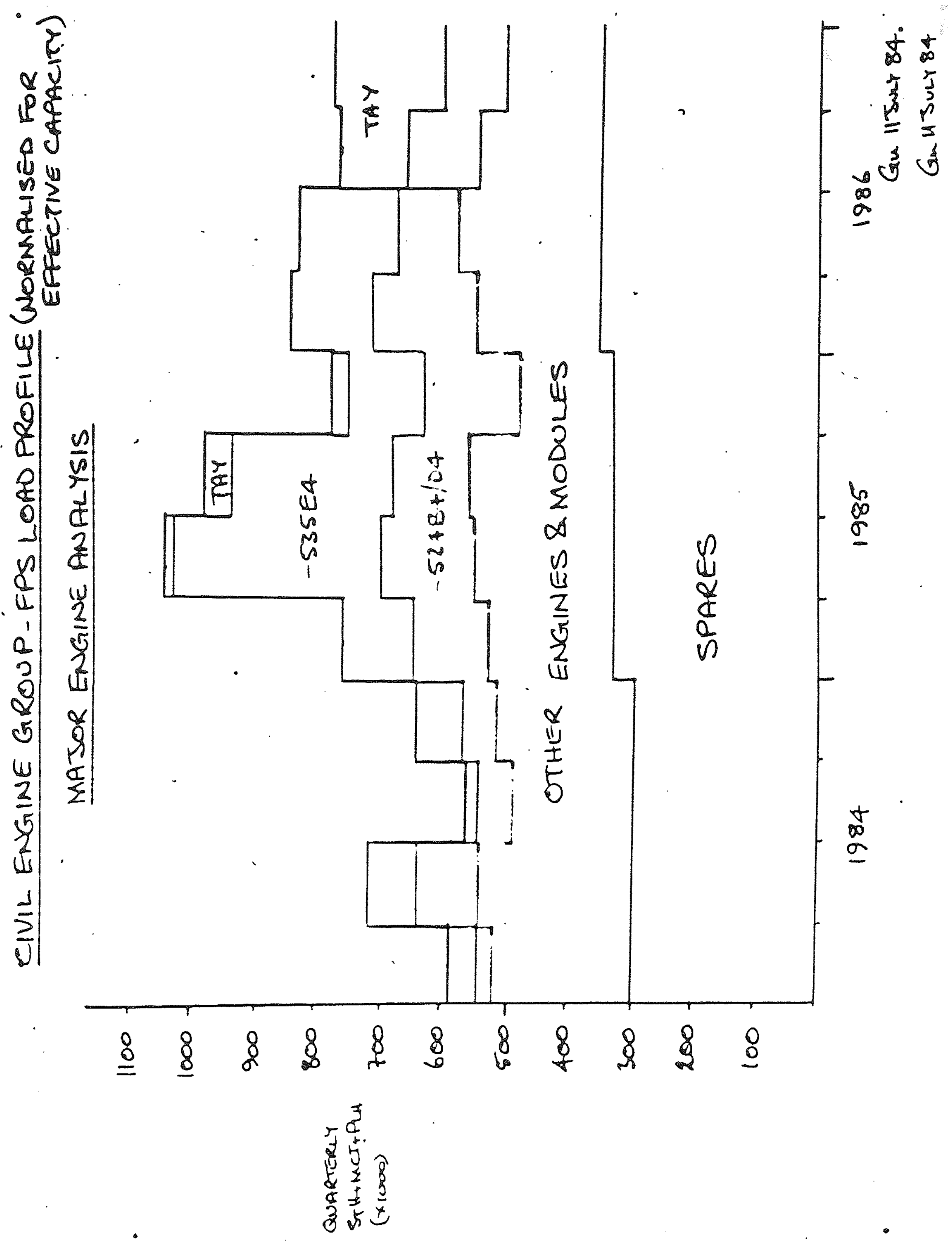
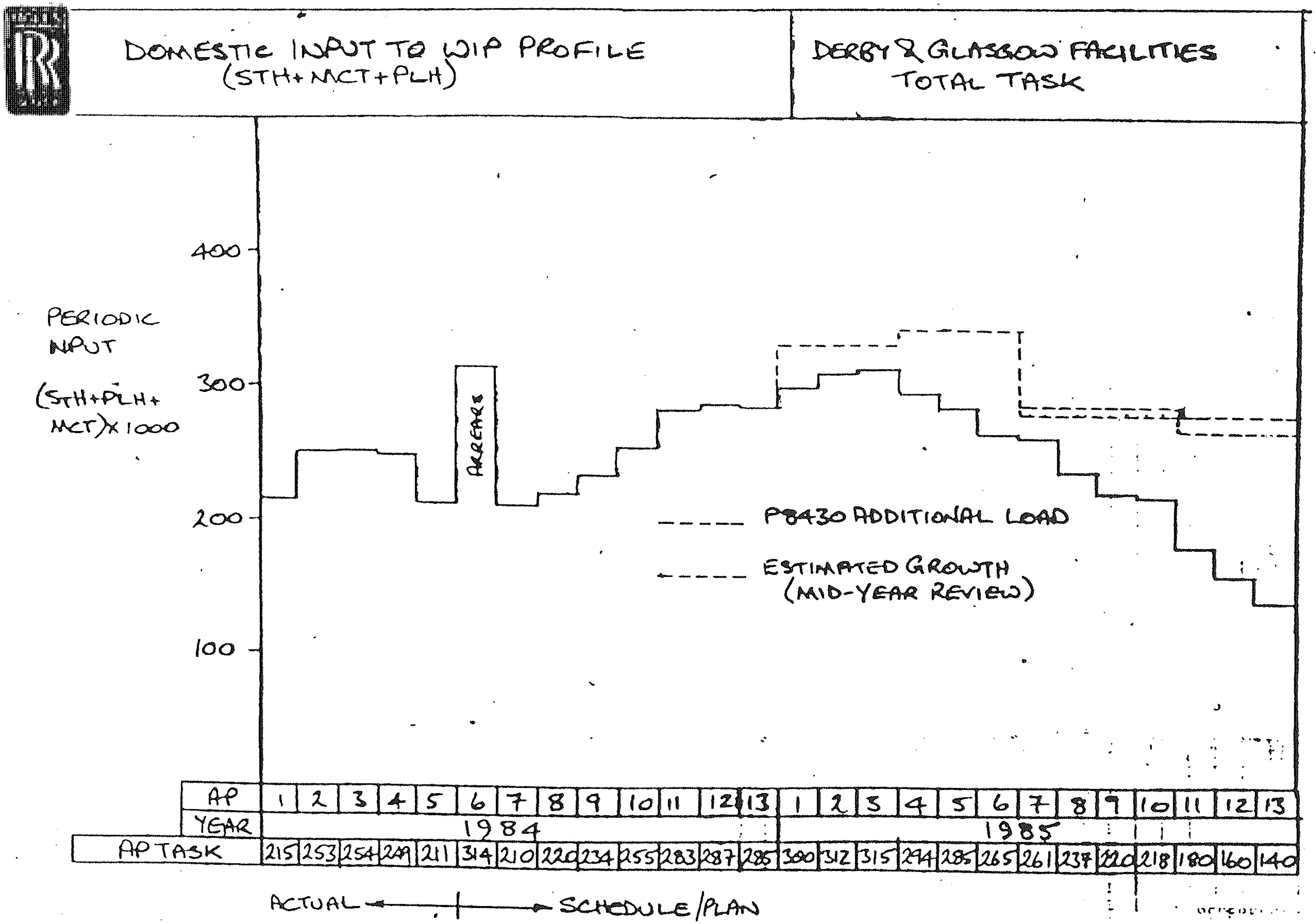


Figure 15. Load Profile: Major Engines



AP	1	2	3	4	5	6	7	8	9	10	11	12	13	1	2	3	4	5	6	7	8	9	10	11	12	13
YEAR	1984													1985												
AP TASK	215	253	254	249	211	314	210	220	234	255	283	287	285	300	312	315	294	285	265	261	237	220	218	180	160	140

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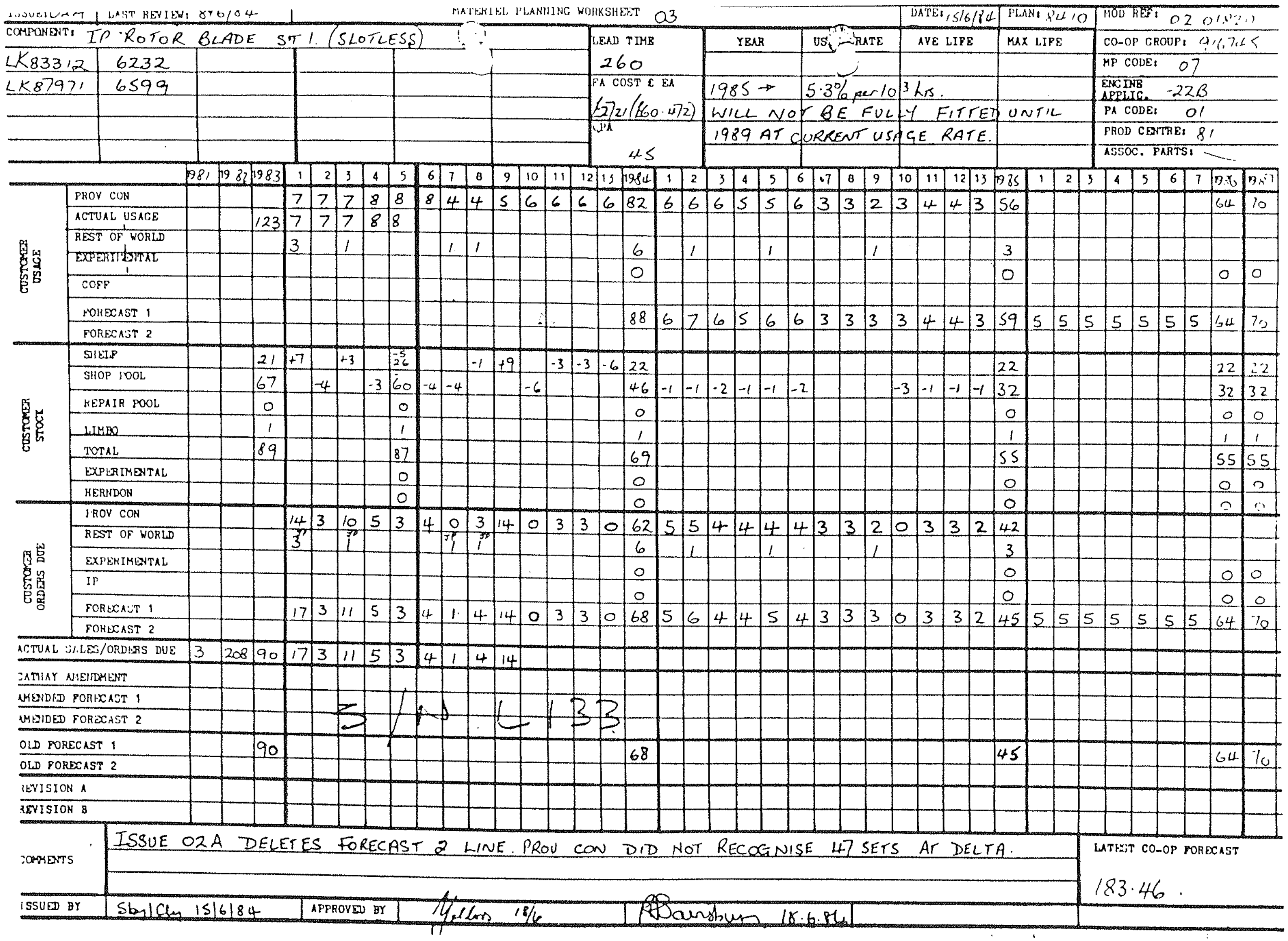
GM 10JULY84

GM-DPR 10JULY84

Figure 16. Load Profile : Work in Progress



ISSUE: 02A | LAST REVIEW: 8/6/84 | MATERIEL PLANNING WORKSHEET 03 | DATE: 15/6/84 | PLAN: 8410 | MOD REF: 02 01870

COMPONENT: IP ROTOR BLADE ST 1. (SLOTLESS)

LK83312 6232

LK87971 6599

LEAD TIME: 260

FA COST £ EA: £721 (£60.472)

QPA: 45

YEAR	USAGE RATE	AVE LIFE	MAX LIFE
1985 →	5.3% per 10³ hrs.		

WILL NOT BE FULLY FITTED UNTIL 1989 AT CURRENT USAGE RATE.

CO-OP GROUP: 96745

MP CODE: 07

ENGINE APPLIC.: -22B

PA CODE: 01

PROD CENTRE: 81

ASSOC. PARTS: —

		1981	1982	1983	1	2	3	4	5	6	7	8	9	10	11	12	13	1984	1	2	3	4	5	6	7	8	9	10	11	12	13	1985	1	2	3	4	5	6	7	1986	1987
CUSTOMER USAGE	PROV CON				7	7	7	8	8	8	4	4	5	6	6	6	6	82	6	6	6	5	5	6	3	3	2	3	4	4	3	56								64	70
	ACTUAL USAGE			123	7	7	7	8	8																																
	REST OF WORLD				3		1				1	1						6		1			1				1					3									
	EXPERIMENTAL																	0														0								0	0
	COFF																																								
	FORECAST 1																	88	6	7	6	5	6	6	3	3	3	3	4	4	3	59	5	5	5	5	5	5	5	64	70
	FORECAST 2																																								
CUSTOMER STOCK	SHELF			21	+7		+3		-5 26			-1	+9		-3	-3	-6	22														22								22	22
	SHOP POOL			67		-4		-3	60	-4	-4			-6				46	-1	-1	-2	-1	-1	-2				-3	-1	-1	-1	32								32	32
	REPAIR POOL			0					0									0														0								0	0
	LIMBO			1					1									1														1								1	1
	TOTAL			89					87									69														55								55	55
	EXPERIMENTAL								0									0														0								0	0
	HERNDON								0									0														0								0	0
CUSTOMER ORDERS DUE	PROV CON				14	3	10	5	3	4	0	3	14	0	3	3	0	62	5	5	4	4	4	4	3	3	2	0	3	3	2	42									
	REST OF WORLD				3		1				1	1						6		1			1				1					3									
	EXPERIMENTAL																	0														0								0	0
	IP																	0														0								0	0
	FORECAST 1				17	3	11	5	3	4	1	4	14	0	3	3	0	68	5	6	4	4	5	4	3	3	3	0	3	3	2	45	5	5	5	5	5	5	5	64	70
	FORECAST 2																																								
ACTUAL SALES/ORDERS DUE		3	208	90	17	3	11	5	3	4	1	4	14																												
CATHAY AMENDMENT																																									
AMENDED FORECAST 1																																									
AMENDED FORECAST 2																																									
OLD FORECAST 1				90														68														45								64	70
OLD FORECAST 2																																									
REVISION A																																									
REVISION B																																									

3/N. L133

COMMENTS: ISSUE 02A DELETES FORECAST 2 LINE. PROV CON DID NOT RECOGNISE 47 SETS AT DELTA.

LATEST CO-OP FORECAST: 183.46.

ISSUED BY: Sby/Cly 15/6/84 | APPROVED BY: Mellors 18/6 | Bainbury 18.6.84

Figure 17. Materiel Planning Worksheet

Appendix 6.

Cincinnati Milacron Case Study.

[February 1985]

CINCINNATI MILACRON, BIRMINGHAM [1985]

THE COMPANY, PRODUCTS AND MARKETS

Cincinnati Milacron Ltd., Birmingham, part of the multi-national Cincinnati Milacron Corporation, has its parent organisation in the U.S.A. and other U.K. plants in Biggleswade, Bedfordshire and Tamworth, Staffordshire. It produces 13 major product families of machine tools with annual sales of approximately £50 million.

The Birmingham factory employs 462 people of which 212 are direct operators. 55 per cent of these work in assembling the products and the remaining 45 per cent in the machining of components. The product range includes machining centres, turning centres, traditional milling machines, grinding machines, tool grinders and cutter grinders. These products are also sold as part of Flexible Manufacturing Systems (FMS). (See figure 1.).

Virtually all machine tools are made to customer order including a wide variety of options which are often tailored to customer needs at the last moment. Not including options, the company customises about 20% of products , although half of this may be accounted for by software customisation. The company deals with a large number of customers in this country and abroad, the sales being dealt with through a separate U.K. sales company, although the U.S. sales company is dealt with for some products. The customers are all industrial, ranging from aerospace through computer to automobile manufacturers.

Products are shipped direct to customers and the current length of the firm order book averages at about 26 weeks, although some products are sold on delivery lead times as short as 5 weeks.

THE PRODUCTION PROCESS

A simplified manufacturing sequence for a typical machine tool is shown in figure 2. It can therefore be seen that the total average lead time is 35 weeks, with considerable variation due to the complexity of the actual product concerned.

The manufacturing system is essentially a small batch and jobbing organisation.

COMPUTER SYSTEMS

The company currently uses an IBM 4341 mainframe computer with a MRP system developed in-house by the parent company in the U.S. and piloted in a small division of the U.K. company in 1979. There have been two versions of the requirements planning module. The first called HARP (Heald Automated Requirements Planning), was a fully regenerative approach. This has been recently superseded by a single-level Net Change system, MULETRANE (MUlti-LEvel TRAnsfer NEtwork) which runs every night and which allows inventory planners to adjust batch sizes and dates, level by level, but can take three to four days to get down to the bottom level. This system then regenerates requirements each weekend in a 20 hour run for any necessary realignment of requirements and orders.

There is an on-line system for machine order entry and for the cancellation and deletion of requirements. These transactions are simply highlighted on the system and then processed overnight in the net-change MRP run.

Personal computers are currently used to produce Master Schedule reports and capacity plans.

The current systems are dealing with a total of 105,000 part numbers of which 45-50,000 are live at any one time, and 50% of these being purchased parts. Bills of material for finished products have about 4 levels and, because of the late tailoring to customer needs, about 20 changes per day are being input across about 400 live works orders. There is very little commonality of parts between products.

THE MASTER PRODUCTION SCHEDULE - OVERVIEW

The Master Production Schedule (MPS) which is input to MRP is stated in actual finished products, as firm planned works orders in weekly time periods translated into days since the MRP system works on a 1,000 day calendar by day.

Inventory Planning Orders are put in approximately 20 weeks prior to the start of final assembly (Start Build) and orders are "firmed up" 8 weeks prior to Start Build. (See figure 2.) The company currently have a 70% success rate in keeping the 8 weeks schedule prior to Start Build frozen; the 30% changes are usually for external reasons, that is, from the customer or sales organisation. It is thought, however, that these changes account for 50% of the problems in the machine shop and in shortages which cause final assembly reschedules. The Inventory Planning orders or "Fill-In" machines are average or most popular machines within a product family. They are, therefore, actual machines that could be built and not Planning Bills Of Material or hypothetical machines.

The Master Scheduling is carried out by one person with the title of Master Scheduler (and MRP Co-ordinator). He reports to the Materials Manager. (See figure 3.).

The constraints on Master Scheduling are in terms of Production Capacity, particularly Final Assembly capacity, meeting customer delivery dates and planning in line with five year and one year plans and Quarterly Financial Estimates. The details of Master Production Scheduling will be dealt with in later sections.

PLANNING AND CONTROL SYSTEM INTERACTIONS.

Using the basic model of Master Production Scheduling and its relationship with other planning and control activities as shown in figure

4.1 , this section describes how these relationships operate at Cincinnati Milacron.

Demand Management

This incorporates the activities of forecasting, order entry and order promising which come under the responsibility of the Materials Manager with considerable liaison with the sales companies in the U.K. and U.S.A. (See figure 3.)

Forecasting for the longer term 5 year and annual plans is carried out by the sales company and this information is used to help in the forecasting for Master Scheduling. The forecast, which is used to determine the "fill-in" machines is done at a meeting between the Materials Manager, Master Scheduler and Inventory Control Manager once every Accounting Period (4 weeks). Usually a 13 period (one year) history of sales is available together with a six month moving average for each product family. An example of this can be seen at the top of the Master Schedule sheet which has been produced using Multiplan, a P.C. spreadsheet package, shown in figure 4. Direct contact with the sales companies, to which all products are sold, also helps in this forecasting process.

The specification of the "fill-in" machines is determined by the popularity of the options with which the machine is sold. For example, the T10 product is a horizontal machining centre which forms the basis of an FMS and which includes a tool changer with 30, 45 or 90 tools. Since the 45 tool changer is the most popular, this is the option specified for the average machine. To cater for the fact that a 30 or 90 tool changer might actually be ordered, the parts which are different between a 30 or 90 and a 45 tool changer are specified as phantom assemblies and Safety Stocks for those assemblies are set up on the MRP system. It should be noted that on many of the product types there are hundreds of options which have to be dealt with in this fashion.

Sales Order entry is usually the process of trying to match actual orders with the "fill-in" machines as closely as possible. This is done in close liaison with the sales companies. Promised dates are then acknowledged to customers and shown on the Master Schedule sheets as an "A" or "D" if it coincides with the finish build date or "N" if it coincides with the MRP firm planned order date. (See figure 4).

Spare parts are not scheduled separately, but are catered for by setting up appropriate fixed quantity safety stocks within the MRP system, which keeps separate records for production and spares requirements. Wherever possible, the production of non-current spares is off-loaded to outside contractors.

Production Planning

There are two types of longer term plan at Cincinnati Milacron, the five year and the one year plan. These are then split down into Quarterly Financial Expenditure Plans and 4 week period plans. The Five year Plan is updated every year and the one year plan is updated every quarter. These plans provide a broad framework in terms of the introduction of new products and the phasing out of the old and how many of each family type of product is likely to be manufactured and sold. The units of measure are firstly the number of product types and then secondly translated into financial objectives.

Resource Planning

The translation of the longer term plans into manufacturing resources in terms of plant, equipment and labour is currently carried out manually.

Final Assembly Scheduling

The Final Assembly Schedule is part of the normal Master Scheduling function as can be seen in figure 4., shown as the Build part of the schedule, denoted by the symbols: ---- B, followed by the Test and Ship stages, denoted by the symbols: ....S. This Build and Test phase is also broken down into a detailed finite capacity schedule as shown in Figure 5. This plan schedules the orders on to the individual build and test operators on a weekly time bucket basis. At present, this schedule is being produced on a Multiplan spreadsheet on a P.C., but there are plans to move this onto the main system.

Rough Cut Capacity Planning

As can be seen above, the Master Schedule is checked out for capacity in terms of the Final assembly and Test stages. The reason for planning the capacity only at this level is that it is easy to sub-contract the machining of components but impossible to subcontract final assembly. It could be argued that this is the Rough Cut check since the times that are used are estimates and the time buckets are weeks. Currently Work Study times cannot be used since they have not been updated for years and many parts do not have any standard times at all. A new incentive plan which is being introduced in the near future will mean that more reliable standard times should be available for all parts for capacity planning. The Master Scheduler believes that a RCCP with simplified manpower requirements would be a good idea, giving requirements for operators by skill type and allowing managers to judge the effect of learning curves.

Material Requirements Planning

As described previously, the current MRP system, known as MULETRANE, is a single-level net change system run every night and run in regenerative mode over each weekend. Figure 6. shows an internal document describing their Manufacturing Control system. The outputs of the system include Inventory Reports (figure 7.), Multi-level Expediting Lists (figure 8.) and Route Sheets (figure 9.) as part of the shop packet. To verify the accuracy of stock records, the works orders for final assembly are "laid-up" (kitted) 4 weeks prior to Start-Build (see figure 2.). Not all parts are expected to be available at this stage and since orders have been firmed-up 4 weeks earlier, there is not too much re-allocation of materials within the kits.

Capacity Requirements Planning

The only detailed capacity planning that is undertaken at present is in Final Assembly and Test as described previously, and even there, standard times are not used. Cincinnati do not have any CRP software at present and believe that it will be difficult to obtain any that will give sufficient detail in their working environment. For example, they would like to be able to take into account the learning curve effect for new employees or for the introduction of new products. They would also like to use efficiency ratings for each operator on each different machine that he might work on. The Master Scheduler was quoted as saying " I think we need CRP, but it will be a hell of a job to get it off the ground! " Currently the Assembly and Manufacturing Managers are checking the load and capacity themselves as will be described in the next section.

MASTER SCHEDULE PREPARATION

This section outlines the detailed preparation of the MPS at Cincinnati Milacron.

The current format of the MPS document has been developed by the Master Scheduler over the past 12 months and has been produced using a Multiplan Spreadsheet package on a P.C. (See figure 4). The previous

Master Schedule document was produced manually and lacked sufficient detail. (see figure 10.) For example, works orders were not shown and machines were scheduled in batches, also, only "Finish Build" was shown on the chart. The current situation of using a P.C. is only temporary because of a long queue for programming work on the mainframe system. The P.C. MPS document has, however, allowed a test-bed for ideas and document layout. In general, the view is that the use of P.C.'s in Production Control is not a good idea, since everyone should be working from the same database. The new mainframe document will include totals of period values of shipments per product and grand totals.

As previously outlined in the demand management section, Inventory Planning orders and firm customer orders are input to the Master Schedule, the new machines being input between MRP runs and then their position swapped for old "in-fill" machines ready for the MRP run.

Prior to a 4 weekly MPS meeting, the Master Scheduler has a meeting with the Manufacturing and Assembly Managers during which they go through every line checking the capacity consequences of the schedule. The Master Scheduler then updates the MPS on the P.C. This version of the MPS is then taken to the MPS meeting which is held on the first Wednesday of each period and which involves a minimum of three directors, usually the Managing Director, Sales Director and Materiel Director. It is this meeting which authorises the MPS and any changes to it.

Once the MPS is authorised, the Master Scheduler has to update his P.C. MPS document and then has to manually change the Works Orders on the mainframe system since the two are not integrated. Copies of the P.C. MPS document (figure 4) are then produced and circulated to Production and the Sales companies. The Build/Test capacity plan (figure 5) is also produced and circulated to Production.

The Master Scheduler also holds a Front End Tracking Meeting every week with representatives from Sales Ordering, Engineering and Special Projects (new proposals). (see figure 6). At this meeting they try to agree release dates for engineering specifications for new machines and determine any knock-on effects that particular customer requirements may have on the MPS.

There is also feedback to the MPS from Purchasing, for example if a buyer discovers that a vendor cannot deliver on time. It should be noted, however, that the Master Scheduler does not always change the MPS and puts pressure on the vendor to deliver. Also some attachment materials can allow the product to be short-shipped and retro-fitted later , thus keeping the MPS more stable.

A limited "What-If" simulation can be undertaken using a system called "SUPERMAN" (Special Unit Print Out for Retrieval Manually) which is run on an overnight basis. This allows the Master Scheduler to put in tentative machines and see the effect in terms of shortages.

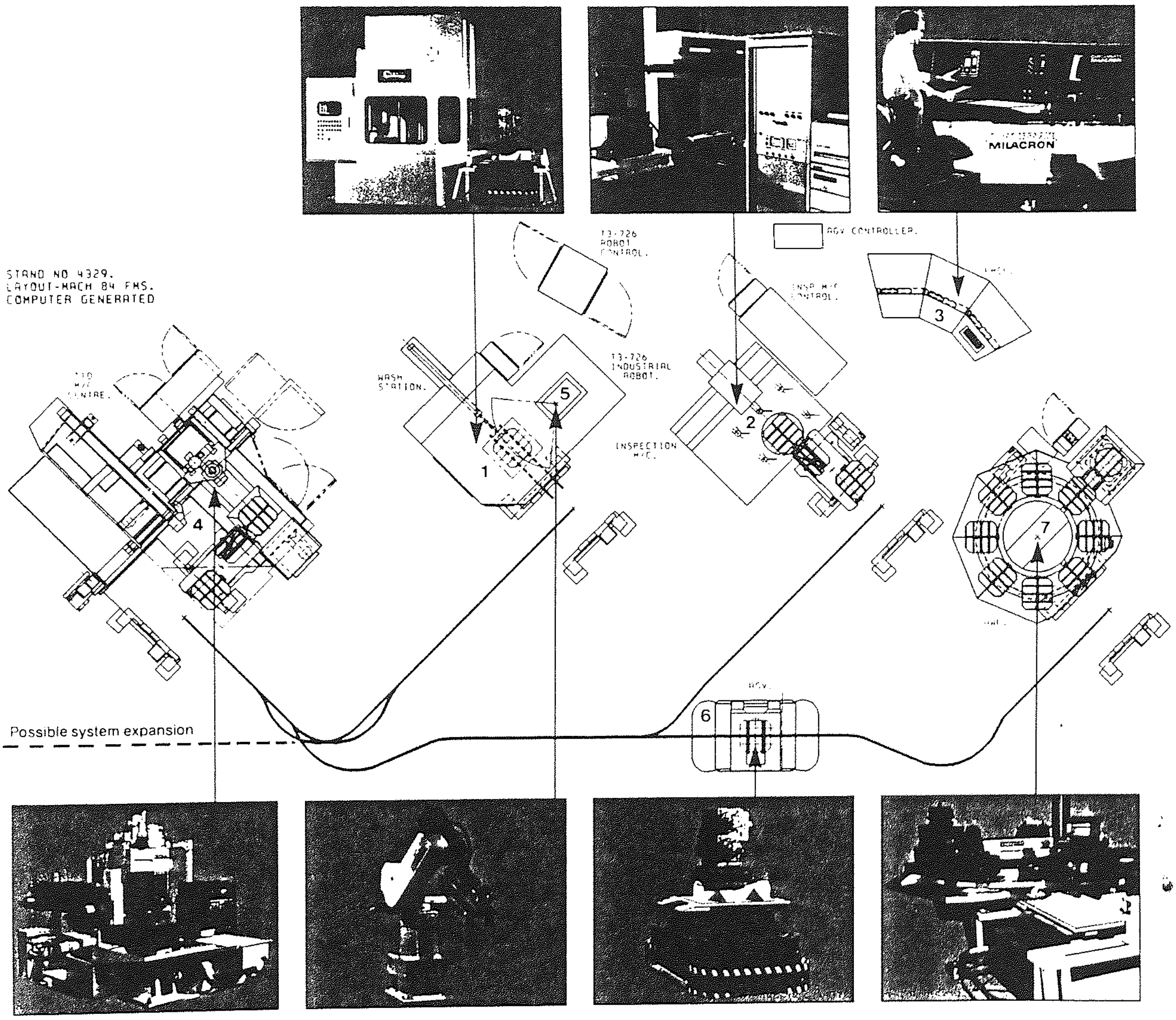
PLANNING AND CONTROL SYSTEM EVALUATION

In this section the performance measures which are used to evaluate the planning and control systems at Cincinnati Milacron are briefly described.

Measures

The key measures of effectiveness of the MPS process are the meeting of acknowledged dates to customers, inventory levels and the profit margins on individual machines. Lateness to customer reports are produced each period, as is an inventory level report which is sent to the Managing Director. A bad profit margin on a machine could mean that the Master Schedule started off with a "wrong" average machine and a lot of conversion work had to be done to produce the customer order.

The overall achievements are compared to the Quarterly Financial Estimates, the annual plan and the five year plan.



1 Automatic parts washing station (CERA) incorporating Milacron T^3-726 programmable industrial robot.

2 Horizontal automatic co-ordinate measuring machine (LK Metre Four) measures all surfaces machined within the system.

3 ACRAMATIC computer based Flexible Manufacturing Cell Controller (FMCC) controls any combination of up to six work stations, all linked by an automatic workpiece handling system.

4 Milacron T-10 horizontal CNC machining centre with dual-pallet shuttle, automatic tool change with 90 tool storage and ACRAMATIC 900 CNC with advanced features for unmanned operation – probe, adaptive control, torque controlled machining and tool monitoring.

5 Milacron T^3-726 six-axis programmable robot equipped with microprocessor controlled washing and drying jet, incorporated into washing station.

6 Automatic wire guided vehicle (ACS), highly flexible means of automatic transfer of work pallets between load/unload station and machines.

7 Milacron 8-pallet rotary work changer (AWC) load/unload unit and docking station.

Figure 1. - Cincinnati Milacron Products in an FMS

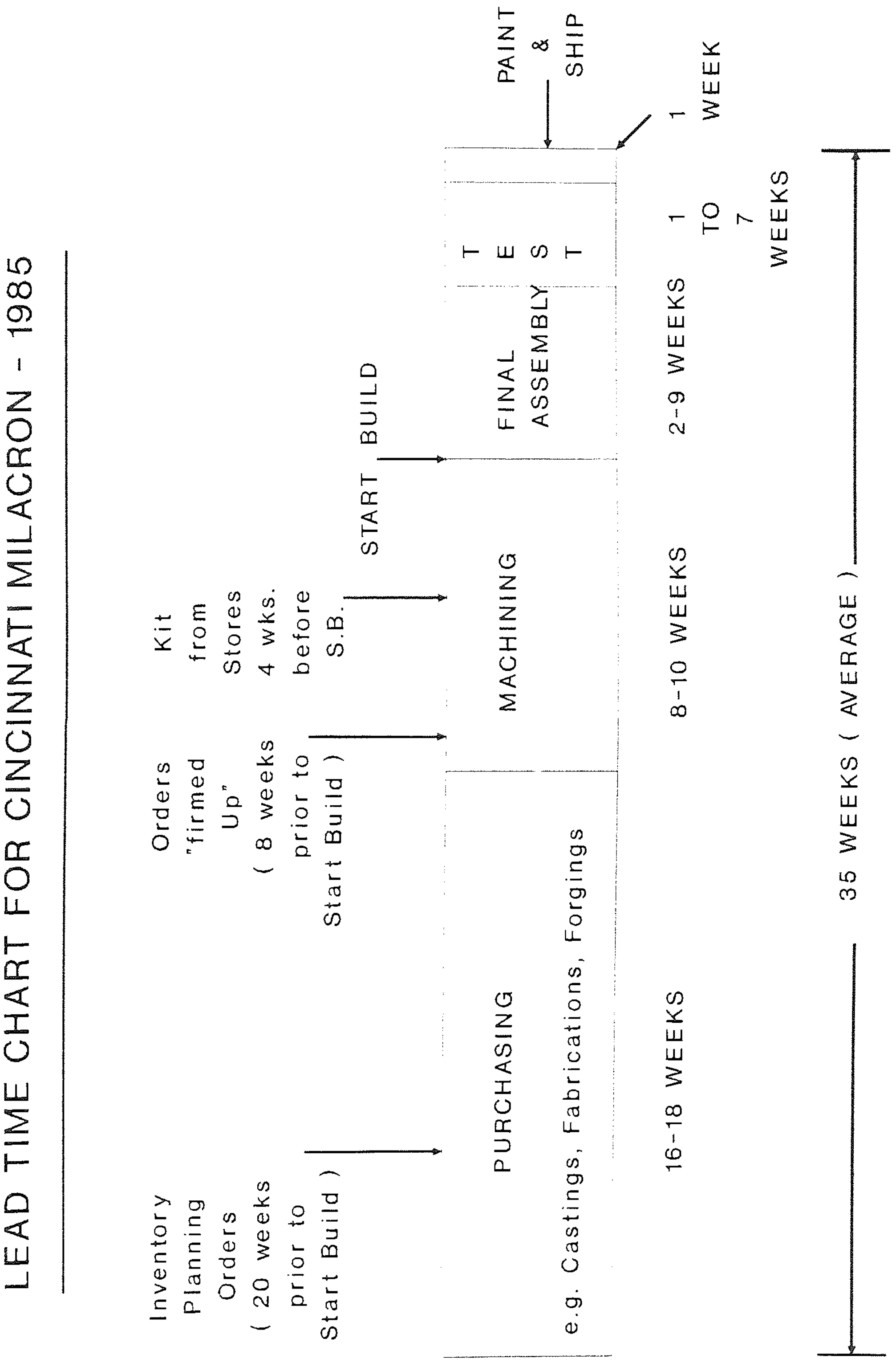


Figure 2. - Lead Time Chart

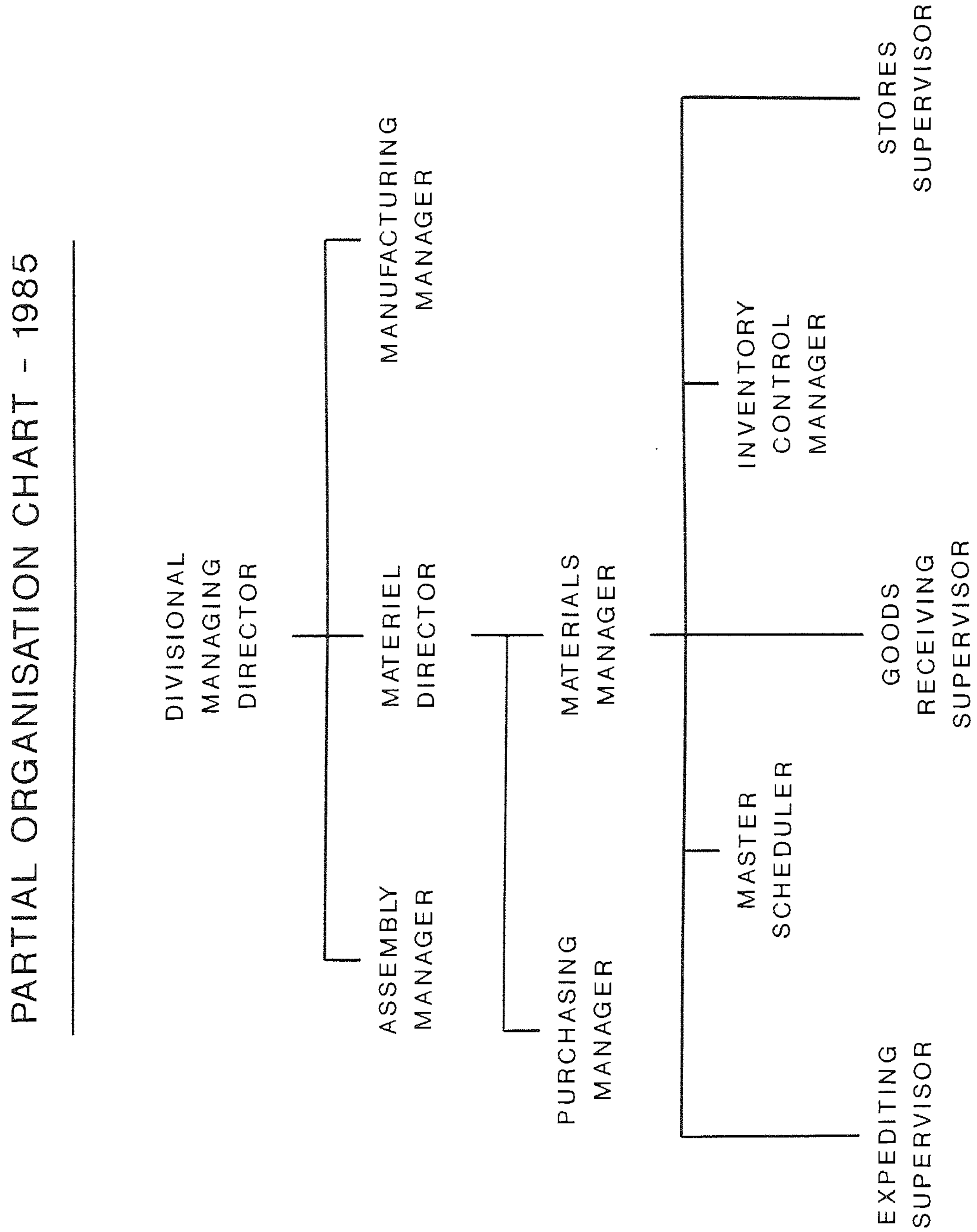
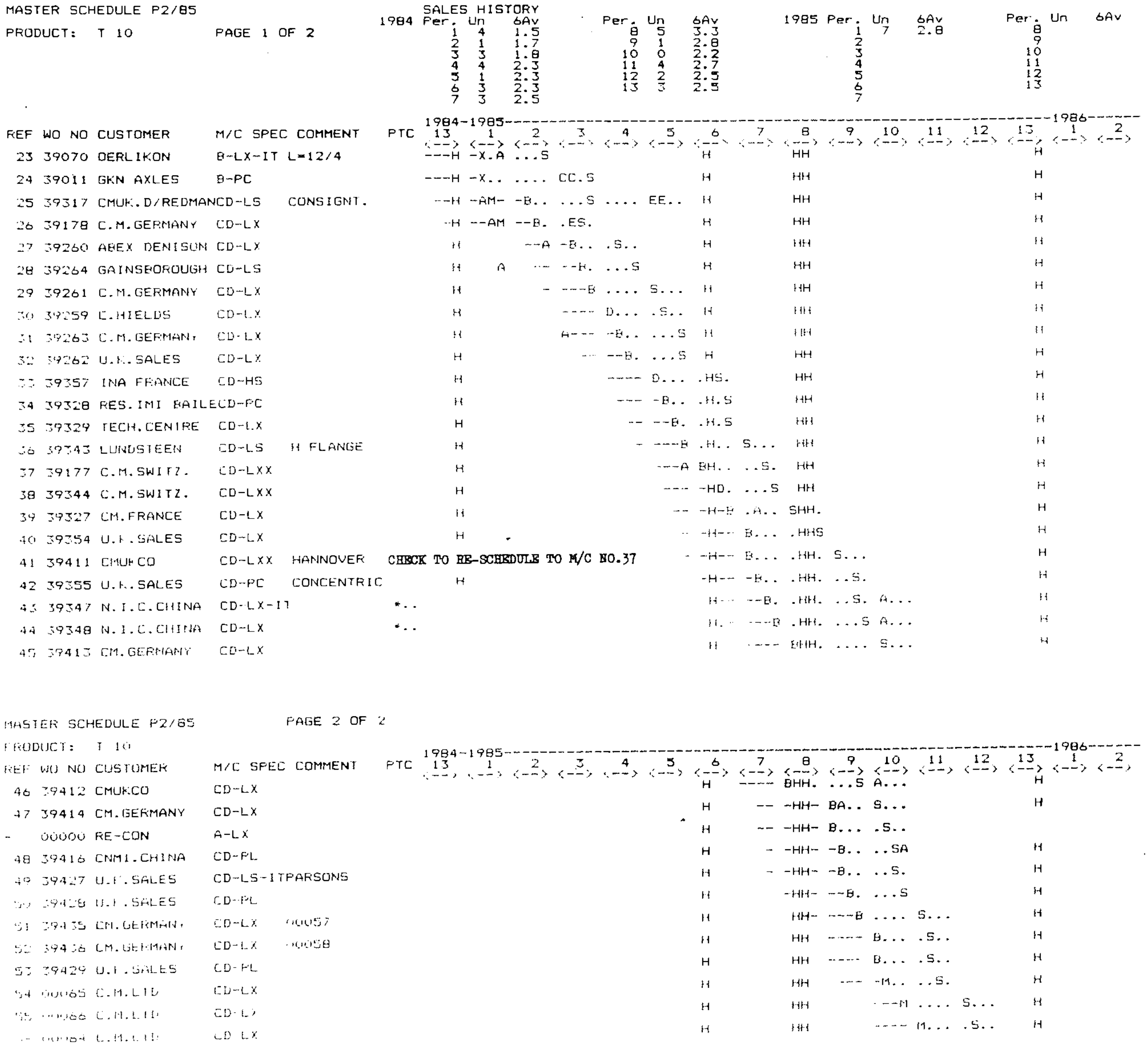


Figure 3. - Partial Organisation Chart



```
MASTER SCHEDULE P2/85                         SALES HISTORY
                                         1984 Per. Un   6Av       Per. Un   6Av       1985 Per. Un   6Av      Per. Un   6Av
PRODUCT:  T 10         PAGE 1 OF 2               1  4   1.5          8  5   3.3               1  7   2.8         8
                                                 2  1   1.7          9  1   2.8               2                  9
                                                 3  3   1.8         10  0   2.2               3                 10
                                                 4  4   2.3         11  4   2.7               4                 11
                                                 5  1   2.3         12  2   2.5               5                 12
                                                 6  3   2.3         13  3   2.5               6                 13
                                                 7  3   2.5                                   7

                                              1984-1985------------------------------------------------------------1986------
REF WO NO CUSTOMER     M/C SPEC COMMENT   PTC  13    1    2    3    4    5    6    7    8    9   10   11   12   13    1    2
                                              <--> <--> <--> <--> <--> <--> <--> <--> <--> <--> <--> <--> <--> <--> <--> <-->
 23 39070 OERLIKON     B-LX-IT L=12/4         ---H -X.A ...S                 H         HH                        H
 24 39011 GKN AXLES    B-PC                   ---H -X.. .... CC.S            H         HH                        H
 25 39317 CMUK.D/REDMANCD-LS    CONSIGNT.      --H -AM- -B.. ...S .... EE..  H         HH                        H
 26 39178 C.M.GERMANY  CD-LX                    -H --AM --B. .ES.            H         HH                        H
 27 39260 ABEX DENISON CD-LX                     H       --A -B.. .S..       H         HH                        H
 28 39264 GAINSBOROUGH CD-LS                     H    A   -- --H. ...S       H         HH                        H
 29 39261 C.M.GERMANY  CD-LX                     H         - ---B .... S...  H         HH                        H
 30 39259 C.HIELDS     CD-LX                     H           ---- D... .S..  H         HH                        H
 31 39263 C.M.GERMANY  CD-LX                     H           A--- -B.. ...S  H         HH                        H
 32 39262 U.K.SALES    CD-LX                     H             -- --B. ...S  H         HH                        H
 33 39357 INA FRANCE   CD-HS                     H                ---- D... .HS.       HH                        H
 34 39328 RES.IMI BAILECD-PC                     H                 --- -B.. .H.S       HH                        H
 35 39329 TECH.CENTRE  CD-LX                     H                  -- --B. .H.S       HH                        H
 36 39343 LUNDSTEEN    CD-LS    H FLANGE         H                   - ---B .H.. S...  HH                        H
 37 39177 C.M.SWITZ.   CD-LXX                    H                     ---A BH.. ..S.  HH                        H
 38 39344 C.M.SWITZ.   CD-LXX                    H                      --- -HD. ...S  HH                        H
 39 39327 CM.FRANCE    CD-LX                     H                       -- -H-B .A.. SHH.                       H
 40 39354 U.K.SALES    CD-LX                     H                        - -H-- B... .HHS                       H
 41 39411 CMUKCO       CD-LXX   HANNOVER  CHECK TO RE-SCHEDULE TO M/C NO.37 - -H-- B... .HH. S...                H
 42 39355 U.K.SALES    CD-PC    CONCENTRIC       H                          -H-- -B.. .HH. ..S.                  H
 43 39347 N.I.C.CHINA  CD-LX-IT           *..                                H-- --B. .HH. ..S. A...             H
 44 39348 N.I.C.CHINA  CD-LX              *..                                H.- ---B .HH. ...S A...             H
 45 39413 CM.GERMANY   CD-LX                                                 H   ---- BHH. .... S...             H

MASTER SCHEDULE P2/85          PAGE 2 OF 2
PRODUCT:  T 10
                                              1984-1985------------------------------------------------------------1986------
REF WO NO CUSTOMER     M/C SPEC COMMENT   PTC  13    1    2    3    4    5    6    7    8    9   10   11   12   13    1    2
                                              <--> <--> <--> <--> <--> <--> <--> <--> <--> <--> <--> <--> <--> <--> <--> <-->
 46 39412 CMUKCO       CD-LX                                                 H   ---- BHH. ...S A...             H
 47 39414 CM.GERMANY   CD-LX                                                 H     -- -HH- BA.. S...             H
  - 00000 RE-CON       A-LX                                                  H     -- -HH- B... .S..
 48 39416 CNMI.CHINA   CD-PL                                                 H      - -HH- -B.. ..SA             H
 49 39427 U.K.SALES    CD-LS-ITPARSONS                                       H      - -HH- -B.. ..S.             H
 50 39428 U.K.SALES    CD-PL                                                 H        -HH- --B. ...S             H
 51 39435 CM.GERMANY   CD-LX    00057                                        H         HH- ---B .... S...        H
 52 39436 CM.GERMANY   CD-LX    00058                                        H         HH  ---- B... .S..        H
 53 39429 U.K.SALES    CD-PL                                                 H         HH  ---- B... .S..        H
 54 00065 C.M.LTD      CD-LX                                                 H         HH   --- -M.. ..S.        H
 55 00066 C.M.LTD      CD-LX                                                 H         HH       ---M .... S...   H
  - 00064 C.M.LTD      CD-LX                                                 H         HH       ---- M... .S..   H
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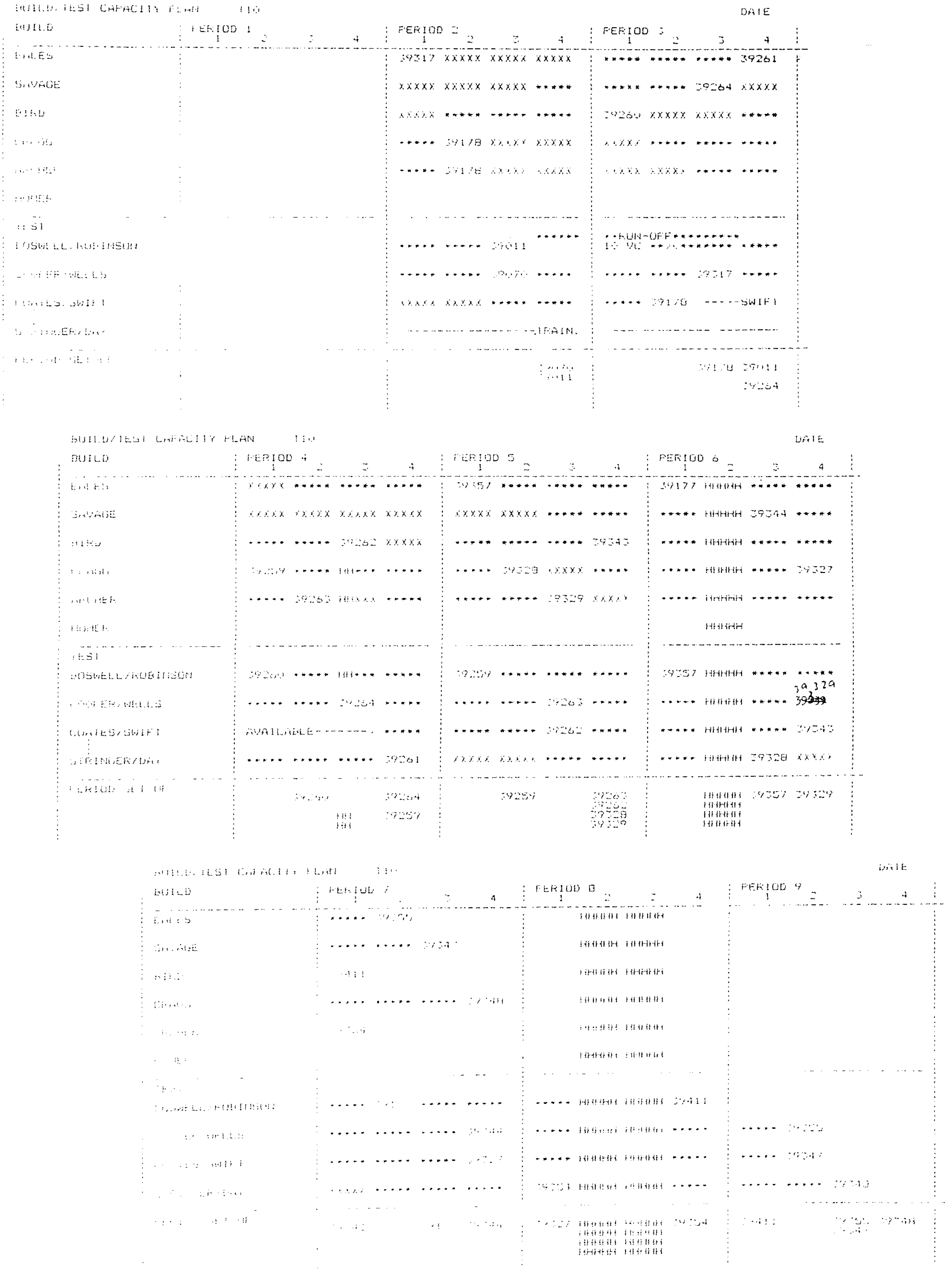
Figure 4. - Example of Current MPS Document



```
BUILD/TEST CAPACITY PLAN      110                                                      DATE
BUILD                  : PERIOD 1                : PERIOD 2                : PERIOD 3                :
                       :    1     2     3     4  :    1     2     3     4  :    1     2     3     4  :
-----------------------------------------------------------------------------------------------------
EALES                  :                         : 39317 XXXXX XXXXX XXXXX : ***** ***** ***** 39261 :
SAVAGE                 :                         : XXXXX XXXXX XXXXX ***** : ***** ***** 39264 XXXXX :
BIRD                   :                         : XXXXX ***** ***** ***** : 39260 XXXXX XXXXX ***** :
CROSS                  :                         : ***** 39178 XXXXX XXXXX : XXXXX ***** ***** ***** :
ARCHER                 :                         : ***** 39178 XXXXX XXXXX : XXXXX XXXXX ***** ***** :
HOMER                  :                         :                         :                         :
-----------------------------------------------------------------------------------------------------
TEST                   :                         :                  ****** : **RUN-OFF*********      :
ROSWELL.ROBINSON       :                         : ***** ***** 39011       : 10 VC ********** ***** :
FOSTER/WELLS           :                         : ***** ***** 39070 ***** : ***** ***** 39317 ***** :
COATES.SWIFT           :                         : XXXXX XXXXX ***** ***** : ***** 39178  -----SWIFT :
STRINGER/DAY           :                         : ----------------TRAIN.  : ----------------------- :
-----------------------------------------------------------------------------------------------------
PERIOD SET UP          :                         :                   39070 :       39178 39011       :
                       :                         :                   39011 :             39264       :
```

```
BUILD/TEST CAPACITY PLAN      110                                                      DATE
BUILD                  : PERIOD 4                : PERIOD 5                : PERIOD 6                :
                       :    1     2     3     4  :    1     2     3     4  :    1     2     3     4  :
-----------------------------------------------------------------------------------------------------
EALES                  : XXXXX ***** ***** ***** : 39357 ***** ***** ***** : 39177 HHHHH ***** ***** :
SAVAGE                 : XXXXX XXXXX XXXXX XXXXX : XXXXX XXXXX ***** ***** : ***** HHHHH 39344 ***** :
BIRD                   : ***** ***** 39262 XXXXX : ***** ***** ***** 39343 : ***** HHHHH ***** ***** :
CROSS                  : 39259 ***** HH*** ***** : ***** 39328 XXXXX ***** : ***** HHHHH ***** 39327 :
ARCHER                 : ***** 39263 HHXXX ***** : ***** ***** 39329 XXXXX : ***** HHHHH ***** ***** :
HOMER                  :                         :                         :       HHHHH             :
-----------------------------------------------------------------------------------------------------
TEST                   :                         :                         :                         :
ROSWELL/ROBINSON       : 39260 ***** HH*** ***** : 39259 ***** ***** ***** : 39357 HHHHH ***** ***** :
                       :                         :                         :                   39329 :
FOSTER/WELLS           : ***** ***** 39264 ***** : ***** ***** 39263 ***** : ***** HHHHH ***** ~~39349~~ :
COATES/SWIFT           : AVAILABLE--------- ***** : ***** ***** 39262 ***** : ***** HHHHH ***** 39343 :
STRINGER/DAY           : ***** ***** ***** 39261 : XXXXX XXXXX ***** ***** : ***** HHHHH 39328 XXXXX :
-----------------------------------------------------------------------------------------------------
PERIOD SET UP          :       39260       39264 :       39259       39263 :       HHHHHH 39357 39329 :
                       :             HH    39257 :                   39262 :       HHHHHH             :
                       :             HH          :                   39328 :       HHHHHH             :
                       :                         :                   39329 :       HHHHHH             :
```

```
BUILD/TEST CAPACITY PLAN      110                                                      DATE
BUILD                  : PERIOD 7                : PERIOD 8                : PERIOD 9                :
                       :    1     2     3     4  :    1     2     3     4  :    1     2     3     4  :
-----------------------------------------------------------------------------------------------------
EALES                  : ***** 39355             :       HHHHHH HHHHHH     :                         :
SAVAGE                 : ***** ***** 39341       :       HHHHHH HHHHHH     :                         :
BIRD                   : 39411                   :       HHHHHH HHHHHH     :                         :
CROSS                  : ***** ***** ***** 39348 :       HHHHHH HHHHHH     :                         :
ARCHER                 : [illegible]             :       HHHHHH HHHHHH     :                         :
HOMER                  :                         :       HHHHHH HHHHHH     :                         :
-----------------------------------------------------------------------------------------------------
TEST                   :                         :                         :                         :
ROSWELL/ROBINSON       : ***** [illegible] ***** ***** : ***** HHHHHH HHHHHH 39411 :                   :
FOSTER/WELLS           : ***** ***** ***** 39348 : ***** HHHHHH HHHHHH ***** : ***** 39355       :
COATES/SWIFT           : ***** ***** ***** [illegible] : ***** HHHHHH HHHHHH ***** : ***** 39347  :
STRINGER/DAY           : XXXXX ***** ***** ***** : 39353 HHHHHH HHHHHH ***** : ***** ***** 39343 :
-----------------------------------------------------------------------------------------------------
PERIOD SET UP          : [illegible]             : 39327 HHHHHH HHHHHH 39354 : 39411     39355 39348 :
                       :                         :       HHHHHH HHHHHH     :           39347         :
                       :                         :       HHHHHH HHHHHH     :                         :
                       :                         :       HHHHHH HHHHHH     :                         :
```

Figure 5. - Example of Build/Test Capacity Plan.

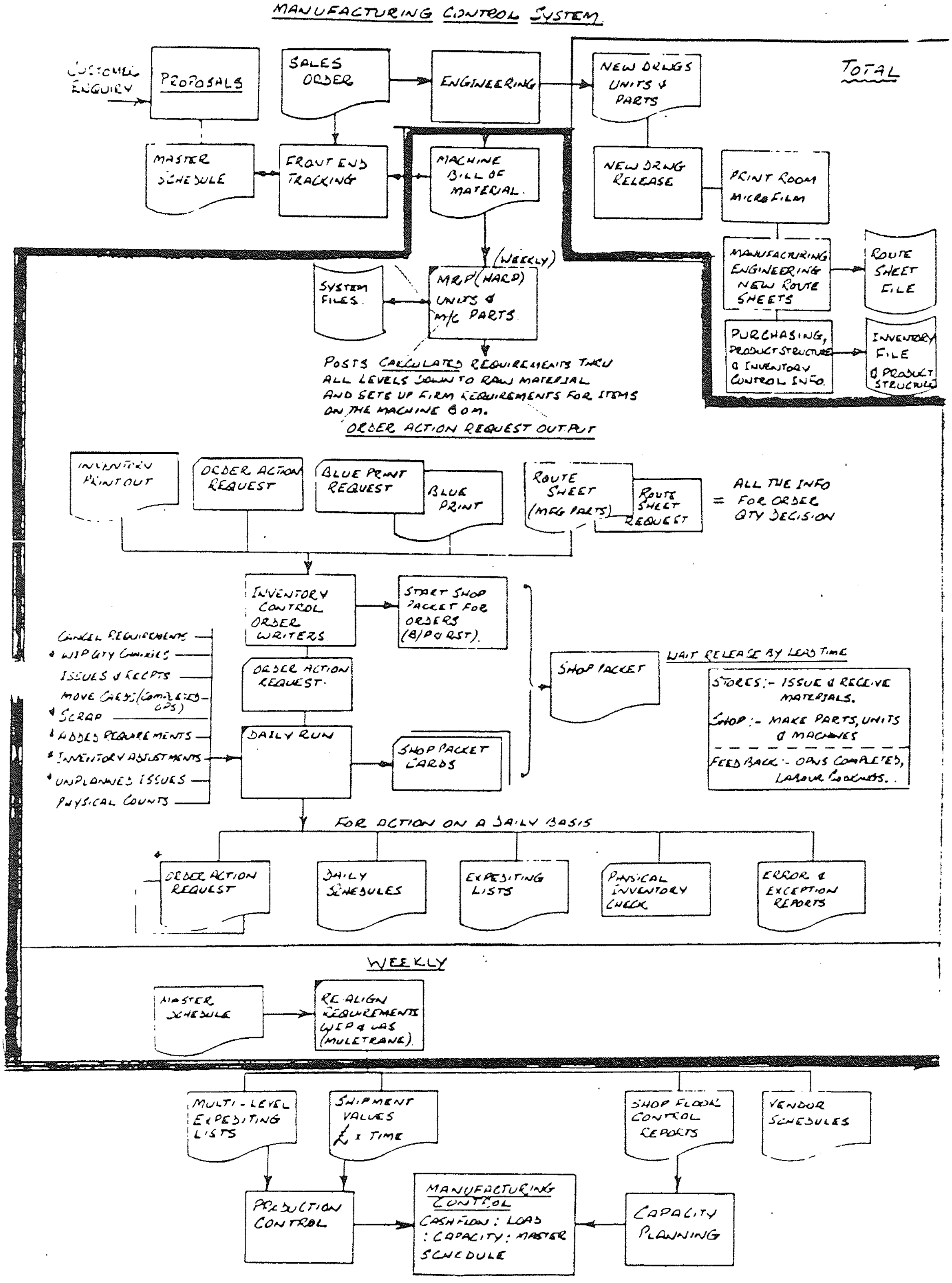
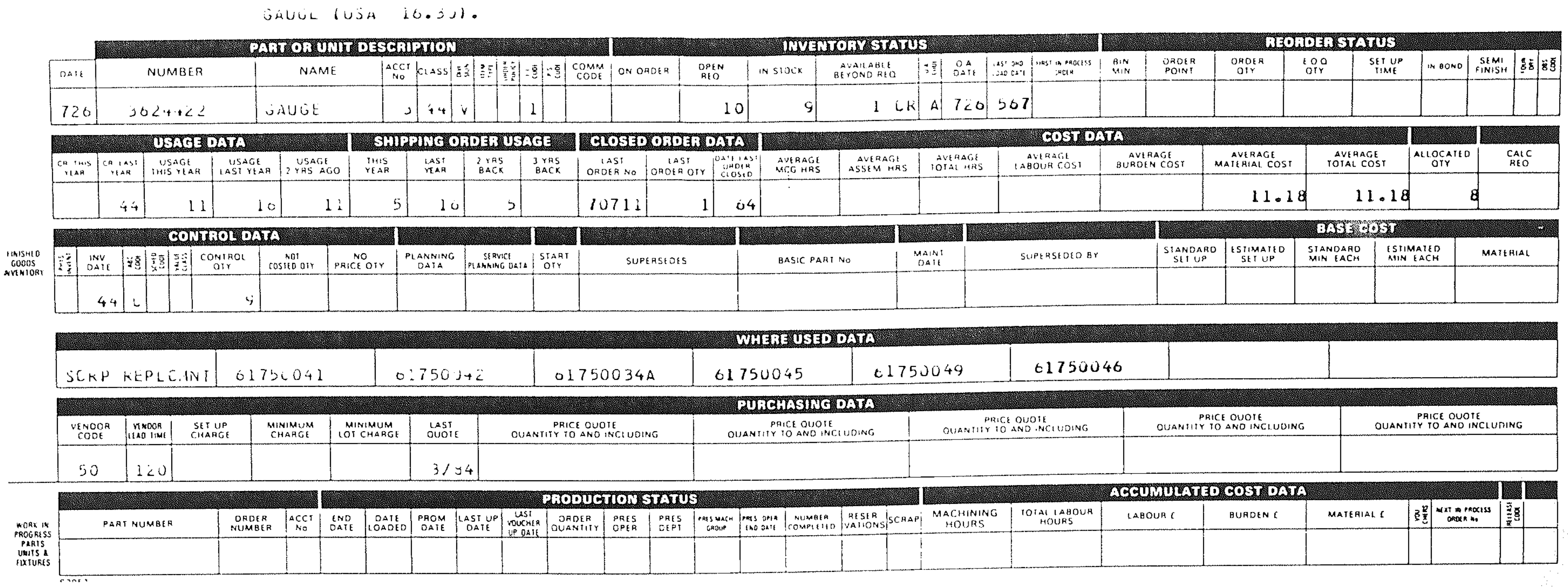


Figure 6. - Manufacturing Control System Diagram



GAUGE (USA 16.35).

PART OR UNIT DESCRIPTION

DATE	NUMBER	NAME	ACCT No	CLASS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	COMM CODE
726	3624422	GAUGE	3	44	V			1		

INVENTORY STATUS

ON ORDER	OPEN REQ	IN STOCK	AVAILABLE BEYOND REQ	[illegible]	O A DATE	LAST ORD LOAD DATE	FIRST IN PROCESS ORDER
	10	9	1 CR	A	726	567	

REORDER STATUS

BIN MIN	ORDER POINT	ORDER QTY	E O Q QTY	SET UP TIME	IN BOND	SEMI FINISH	[illegible]	[illegible]

USAGE DATA

CR THIS YEAR	CR LAST YEAR	USAGE THIS YEAR	USAGE LAST YEAR	USAGE 2 YRS AGO
	44	11	10	11

SHIPPING ORDER USAGE

THIS YEAR	LAST YEAR	2 YRS BACK	3 YRS BACK
5	10	5	

CLOSED ORDER DATA

LAST ORDER No	LAST ORDER QTY	DATE LAST ORDER CLOSED
70711	1	64

COST DATA

AVERAGE MCG HRS	AVERAGE ASSEM HRS	AVERAGE TOTAL HRS	AVERAGE LABOUR COST	AVERAGE BURDEN COST	AVERAGE MATERIAL COST	AVERAGE TOTAL COST	ALLOCATED QTY	CALC REQ
					11.18	11.18	8	

FINISHED GOODS INVENTORY

CONTROL DATA

[illegible]	INV DATE	[illegible]	[illegible]	[illegible]	CONTROL QTY	NOT COSTED QTY	NO PRICE QTY	PLANNING DATA	SERVICE PLANNING DATA	START QTY	SUPERSEDES	BASIC PART No	MAINT DATE	SUPERSEDED BY
	44	L			9									

BASE COST

STANDARD SET UP	ESTIMATED SET UP	STANDARD MIN EACH	ESTIMATED MIN EACH	MATERIAL

WHERE USED DATA

SCRP REPLC.MNT	61750041	61750042	61750034A	61750045	61750049	61750046	

PURCHASING DATA

VENDOR CODE	VENDOR LEAD TIME	SET UP CHARGE	MINIMUM CHARGE	MINIMUM LOT CHARGE	LAST QUOTE	PRICE QUOTE QUANTITY TO AND INCLUDING	PRICE QUOTE QUANTITY TO AND INCLUDING	PRICE QUOTE QUANTITY TO AND INCLUDING	PRICE QUOTE QUANTITY TO AND INCLUDING	PRICE QUOTE QUANTITY TO AND INCLUDING
50	120				3/54					

WORK IN PROGRESS PARTS UNITS & FIXTURES

PRODUCTION STATUS

PART NUMBER	ORDER NUMBER	ACCT No	END DATE	DATE LOADED	PROM DATE	LAST UP DATE	LAST VOUCHER UP DATE	ORDER QUANTITY	PRES OPER	PRES DEPT	PRES MACH GROUP	PRES OPER END DATE	NUMBER COMPLETED	RESER VATIONS	SCRAP

ACCUMULATED COST DATA

MACHINING HOURS	TOTAL LABOUR HOURS	LABOUR £	BURDEN £	MATERIAL £	[illegible]	NEXT IN PROCESS ORDER No	RELEASE CODE	

Figure 7. - Inventory Report

```
                        CINCINNATI  - DIVISION MULTI-LEVEL EXPEDITING LIST

CINCOC                  SERIAL NO. 39283 CHIC CAT'PILLAR        START BUILD IN 2 WEEKS         OCT. 15,1984                  PAGE NO. 26

ORDER NUMBER      PART NUMBER  PT. NAME   QTY  CHASE  ORD-QTY   ACCT CD  CONTROL NO.   DPT-MG  DPT-MG  DPT-MG  DPT-MG +DA ORD DTE

 . 39283          61242065     FILTER C    1  17438       6     100 5 4EDV000 39283   34-931  62-099                   2 608 616

 . 39283          61242066     CYL CL  A   1  16868       9     100 5 4EDV000 39283   34-931  62-099                   2 608 612

 . 39283          61242067     BRAKE AS    1  16889      10     100 5 4EDV000 39283   34-931  62-099                   2 608 621

 .. 16889           183468     BRAKE LL    2  61495      13       4 4  61242067       81-223  62-099                   2 613 650

 . 39283          61242069     CLUTCH A    1   5445       6     100 5 4EDV000 39283   62-087  62-055  62-057  62-077  10 608 658

 ..   5445           73057     PLATE C/   48  ALLOC               4 4  61242069                                          658

 ..   5445          148817     BEARING    12  ALLOC               4 4  61242069                                          658

 ..   5445          191973     KEY-DOVE   18  ALLOC               4 4  61242069                                          658

 ..   5445          194372     GEAR-RAP    6  ALLOC               4 4  61242069                                          658

 ..   5445          194374     PISTON-R    6  ALLOC               4 4  61242069                                          658

 ..   5445          194418     SPACER-C    6  ALLOC               4 4  61242069                                          658

 ..   5445          801366     CYLINDER    6   5358      15       4 4  61242069       14-211  14-252  31-010  62-099   5 658 653

 . 39283          61242070     PAWL ASS    1  17772      10     100 5 4EDV000 39283   34-931  62-099                   2 608 612

 . 39283          61242071     CTRL ASS    1  17440       9     100 5 4EDV000 39283   34-931  62-099                   2 608 612

 . 39283          61242073  10 KNEE P/A    1   5044       1      95 5 4EDV000 39283   62-055  62-057  62-077  33-907   9 603 654

 ..   5044          175801     BUSHING-    1  ALLOC               4 4  61242073  10                                      653

 ..   5044          175806     BUSHING-    1  ALLOC               4 4  61242073  10                                      653

 ..   5044          192098     PLATE-MO    1  15815       3       4 4  61242073  10   32-439  29-000  33-907  33-902   9 653 629

 ..   5044          194391     COVER R     1  ALLOC               4 4  61242073  10                                      653

 ..   5044          196072     BUSHING-    1  ALLOC               4 4  61242073  10                                      653

 ..   5044          301860     GUIDE-KN    1  ALLOC               4 4  61242073  10                                      653

 ..   5044          801861     GUIDE-KN    1  ALLOC               4 4  61242073  10                                      653

 . 39283          61242074   2 PLUG ASS    1   2378       6     100 5 4EDV000 39283   34-931  62-099                   2 608 621

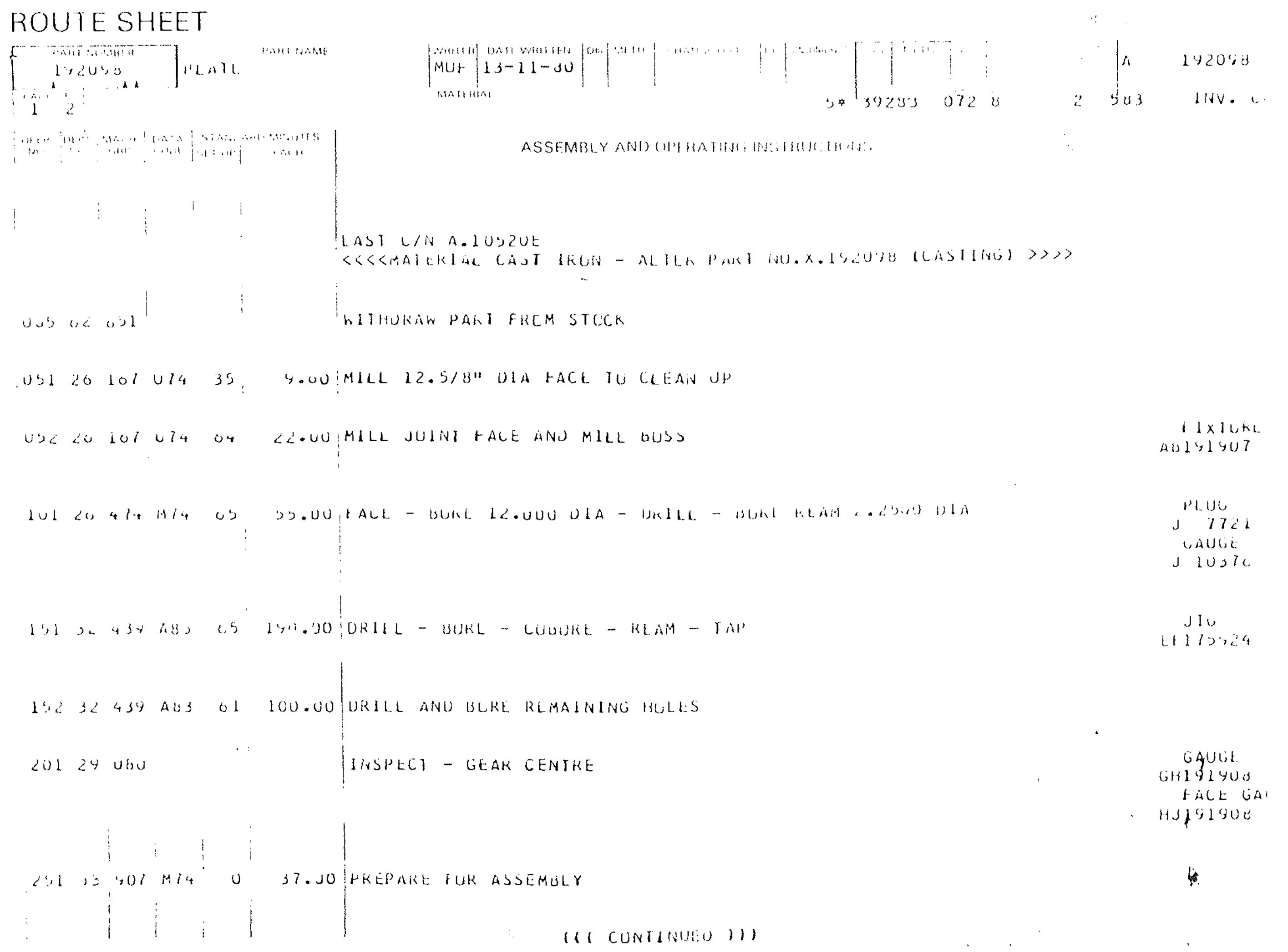
 ..   2378          173846     SHAFT-VE    1   5300      15       4 4  61242074   2   16-836  18-810  18-804  18-830  16 613 597

 . 39283          61242075   1 FEED CHG    1  17441       5     100 5 4EDV000 39283   62-077  62-099                   2 608 621

 .. 17441         61242108     ASS LEVE    3   2541       9       4 4  61242075   1   34-931  62-099                   2 613 600

 . 39283          61242076     M/RHASSY    1   5040       6     100 5 4EDV000 39283   62-055  62-057  62-077  35-917   5 608 638
```

Figure 8. - Multi-level Expediting List



ROUTE SHEET

PART NUMBER 192098 | PART NAME PLATE | WRITER MUF | DATE WRITTEN 13-11-80 | A 192098

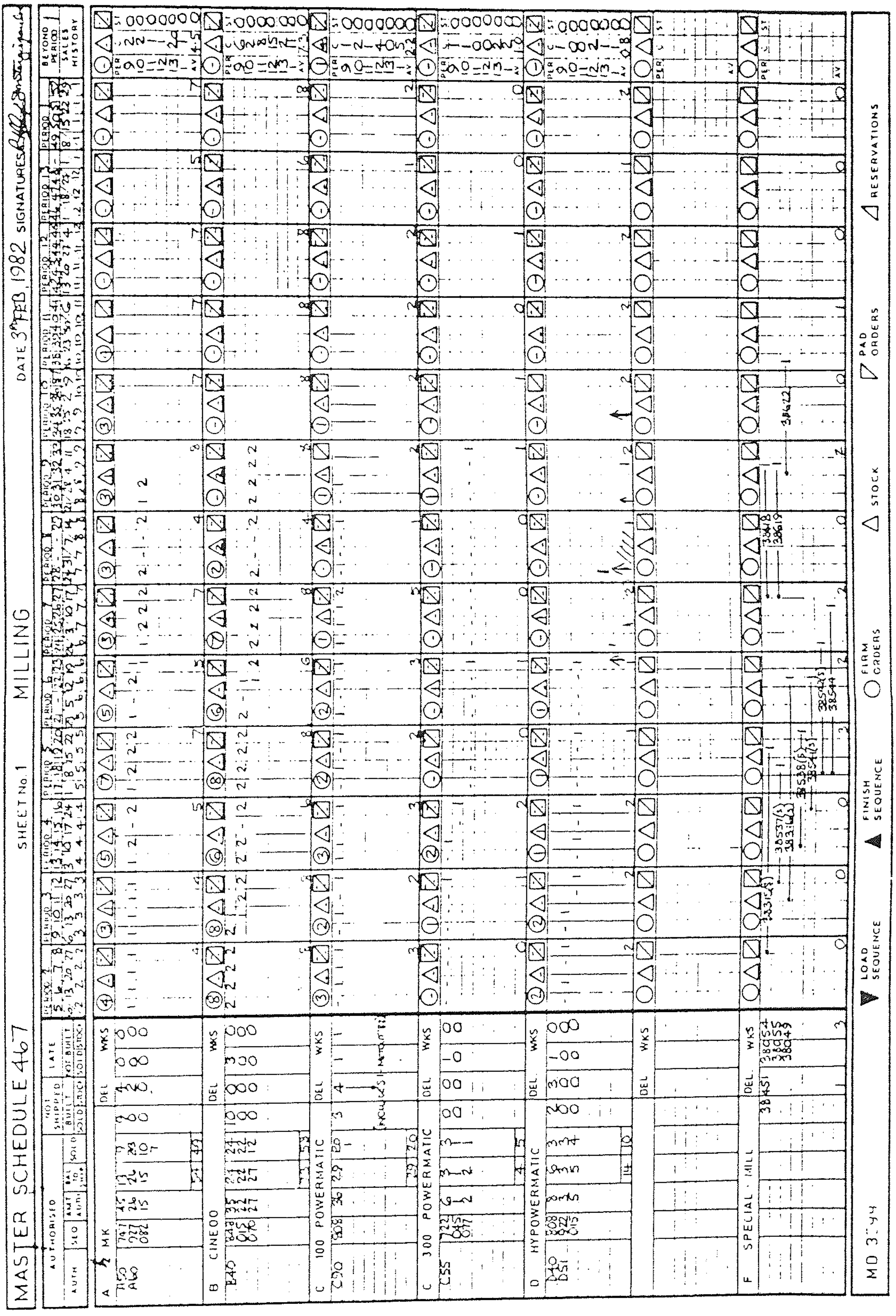
PAGE 1 2

MATERIAL 5* 39283 072 8 2 583 INV.

OPER NO.	DEPT	MACH GRP	DATA CODE	STAND. AND MINUTES SET UP	EACH	ASSEMBLY AND OPERATING INSTRUCTIONS	
						LAST C/N A.10520E <<<<MATERIAL CAST IRON - ALTER PART NO.X.192078 (CASTING) >>>>	
005	02	051				WITHDRAW PART FROM STOCK	
051	26	167	074	35	9.00	MILL 12.5/8" DIA FACE TO CLEAN UP	
052	26	167	074	64	22.00	MILL JOINT FACE AND MILL BOSS	FIXTURE AB191907
101	26	474	M74	65	55.00	FACE - BORE 12.000 DIA - DRILL - BORE REAM 2.2500 DIA	PLUG J 7721 GAUGE J 10376
151	32	439	A83	65	190.00	DRILL - BORE - COBORE - REAM - TAP	JIG EF175524
152	32	439	A83	61	100.00	DRILL AND BORE REMAINING HOLES	
201	29	060				INSPECT - GEAR CENTRE	GAUGE GH191908 FACE GA HJ191908
251	33	907	M74	0	37.00	PREPARE FOR ASSEMBLY	

(((CONTINUED)))

Figure 9. - Route Sheet.



MASTER SCHEDULE 467

SHEET No. 1

CINCINNATI DIVISION

MILLING

DATE 3rd FEB 1982 SIGNATURES

A MK

B CINEOO

C 100 POWERMATIC

C 300 POWERMATIC

D HYPOWERMATIC

F SPECIAL MILL

MD 3744

▼ LOAD SEQUENCE

▲ FINISH SEQUENCE

○ FIRM ORDERS

△ STOCK

◸ PAD ORDERS

◿ RESERVATIONS

Figure 10. - Previous MPS Document.

Appendix 7.

Midland Electric Manufacturing Co. Ltd. Case Study.

[September 1985]

MIDLAND ELECTRIC MANUFACTURING COMPANY LTD. (MEM), BIRMINGHAM [1985]

THE COMPANY, PRODUCTS AND MARKETS

MEM is part of the Industrial and Commercial subdivision of the Accessories and Switchgear Division of the multi-national Delta Group plc. It manufactures a range of industrial and commercial switchgear, fusegear, distribution boards and accessories with an annual sales value of approximately £26 million.

The Birmingham factory employs a total of about 850 people including the sales organisation, producing a range of over 1200 different products, of which about 150 account for 90% of sales. An example of one of the ranges of distribution boards is shown in figure 1. MEM is one of three companies in the Accessories and Switchgear division in the Birmingham area which share the same Production and Material Control software system.

Virtually all products are final assembled to customer order, although within the last year an increase in finished stock levels has been allowed in order to reduce the delivery lead time to customers from 4 weeks to one to two weeks. Typical inventory levels are 4 weeks finished stock, 10 weeks work in progress, (including bought-out finished items) and 5 weeks of raw materials. The company sells virtually all of its output to electrical wholesalers in this country and abroad plus a small proportion to group companies at home and abroad. It deals with about 850 home customers which account for 60% of sales and 40-50 export customers which account for the remaining 40%. The typical home customer delivery lead time requested is still 4 weeks although this is trying to be reduced. Some export sales are scheduled orders, and for some others the customer specifies delivery dates based on the availability of letters of credit. Between 10 and 15% of sales are for parts and accessories. The current unallocated order book is down to several days, compared to up to 10 weeks a year ago. Very few orders are changed between receipt and shipment and very little customisation is carried out.

THE PRODUCTION PROCESS

A simplified manufacturing sequence is shown in figure 2. It can be seen that a typical manufacturing lead time is about 4 weeks with the final assembly element taking only one or two days. The purchase lead time for materials such as copper can be up to 16 weeks.

The manufacturing system is a small and large batch production organisation. The plant was relaid out about three years ago to give a better flow. There is a very small workshop for the production of specials which mainly consist of adding accessories, joining products together and repainting.

COMPUTER SYSTEMS

The company currently uses two Hewlett Packard mini computers,(one as standby), with Hewlett Packard's MM3000 software package, servicing the three Birmingham based companies. This includes the usual manufacturing database, MRP, inventory management and purchase order processing modules. The bespoke Sales Order Processing (SOP) system is completely stand-alone, apart from a link with the main system to check part numbers. There is an overnight batch run of all orders invoiced on the SOP system which down-dates the stock levels on the main system. All stock entries and order entries are carried out on-line.

A bespoke MPS and Assembly Scheduling system has been developed on a P.C. and the overall Production plan is produced and displayed using a Multiplan spreadsheet on a P.C.. Some proprietary software has been purchased to produce customised reports from the MM3000 database.

The current systems are dealing with 25,000 part numbers , bills of material having about 7 levels of breakdown and a low rate of engineering/design changes (about 6 per week). There is a medium degree of part commonality.

THE MASTER PRODUCTION SCHEDULE - OVERVIEW

The Master Production Schedule (MPS) is stated in finished products, in weekly time periods. There is usually a 7 to 9 month horizon to give plenty of visibility to the buyers. Sales orders for the first five weeks of the MPS have stock automatically allocated to them if there is free finished stock available.

Beyond the five week section, the MPS contains any firm home or export orders that have been taken and forecast orders for individual products or, for many of the product families, Planning Bills of Material representing all the products in a family. There are about 20 product families.

Master Scheduling is carried out by two people; the Production Control Manager and the Programme Controller. The organisation structure of the company is shown in figures 3 and 4.

The constraints on Master Scheduling are in terms of keeping the MPS compatible with the longer term plan (the "Budget"), achieving the desired home customer service level, meeting the promised export delivery dates and meeting the overall inventory level targets.

The details of Master Scheduling will be covered in later sections.

PLANNING AND CONTROL SYSTEM INTERACTIONS.

Using the basic model of the MPS and its relationship with other planning and control activities as shown in figure 4.1 , this section describes how these relationships operate at MEM.

Demand Management

This incorporates the activities of forecasting, order entry and order promising, which come under various responsibilities at MEM.

Forecasting is carried out by the Marketing department using a combination of historical averages, monthly reports from the area sales managers and trade statistics from the various trade associations. These forecasts are for product families for home and export and are used in producing the Production Plan (Budget) and MPS (the Plan). The units of measure used are Standard £'s, defined as the equivalent average Home invoiced sales price for the product family. These forecasts are issued monthly for the next 6 months, on a document called "Key Trends" which also monitors forecast error and variance against the budget. (See figure 5.) Marketing also produce historical sales statistics showing, for each individual product, for the past 12 months, the monthly sales and 12 month, 6 month and 3 month moving averages in units and Standard £'s value. (See figure 6.- £'s value not shown on this copy).

Order entry for home orders is a continuous process and uses the stand-alone SOP system described previously, with orders being offset from receipt date by the standard 4 weeks at present and automatically allocated from free stock if available. For export orders, some of which tend to be large, the Master Schedulers usually get involved in order promising.

Production Planning

There are two types of top level plan at MEM. One is the annual "Budget" covering a financial year and the other is a rolling seven to nine month plan by month at the product family level, referred to as the "Programme Pack". (See figure 7.). This Programme Pack is updated monthly and authorised at a meeting attended by the Home and Export Sales Managers, Marketing Manager, Site Director, Production Control Manager and Materials Manager. It shows the monthly Production Plan quantities and values at Standard £'s and Production Rate per day (a measure more easily understood by shop floor supervision). It is produced by the Materials Manager using a Multiplan spreadsheet package on a P.C..

Resource and Rough Cut Capacity Planning.

The comment made concerning Resource and Rough Cut Capacity Planning was that "they were woefully lacking". At present the Programme Pack is looked at by the Site Director ,Works Manager, Area Managers and Supervisors in terms of the Production Rates per day and Standard £'s per month per Product family and comparisons made to what has been achieved historically.

In the Press and Fabrication shops there are many options open to Management to overcome capacity problems in terms of overtime and the use of alternative machines and routes. In the assembly areas, which mostly involve benchwork, the movement of labour can often solve capacity imbalances.

In one critical area, porcelain production, a capacity check has been carried out using a Multiplan spreadsheet model on a P.C..

There are already Standard Times and Routes available and being used for Standard Costing, but it is thought that these are not reliable enough for use in Capacity Planning.

Final Assembly Scheduling

The Final Assembly Schedule is the first part of the MPS and will be dealt with under that heading.

Material Requirements Planning

At MEM, MRP (part of MM3000) is run in full regenerative mode usually once every two weeks or as necessary. All previous MPS firm planned orders are wiped out and a new set entered from the stand-alone P.C. based MPS and Final Assembly Scheduling system. The use of works orders was phased out a year ago, since there were too many transactions and everything is now planned and controlled on a production rate and cumulative achievement basis. MRP has been in operation for about two and a half years.

Capacity Requirements Planning

Detailed Capacity Requirements Planning is not carried out at MEM. It is thought that despite the fact the Rough Cut Capacity Planning procedures might be in need of improvement, the check at the Programme Pack (family) stage is probably good enough, bearing in mind the fact that day to day capacity problems are highlighted and sorted out at the Daily Production Meetings.

MASTER PRODUCTION SCHEDULE PREPARATION

This section outlines the procedures used to break down the Programme Pack plan into a weekly MPS for individual products.

The MPS module on MM3000 has never been used since it would have been too cumbersome, was finite order based and could not cope with production rates or cumulative production quantities.

A P.C. based system entitled ASDA (Assembly Schedule Demand Analysis) has been developed internally which is essentially a Final Assembly Scheduling and Master Scheduling system. (see figure 8.). This is linked to the main Production Control system only in terms of checking the validity of part numbers.

This system is continually updated with finished product despatches (which are then passed on to MM3000) and new home orders which are currently automatically offset four weeks into the future on ASDA .

"What-if" trials are often carried out to see the effect of promising delivery dates for large export orders. The Master Schedulers also receive a demand schedule for "badge engineered" products which are supplied to other companies in the group (i.e. a copy of their ASDA report).

An "edit run" is carried out every Friday morning and an ASDA report produced. This is then amended where necessary and rolled forward a week. The new Home and Export forecasts for individual products for a new month are developed by taking the Programme Pack monthly family quantities and pro-rating them down using the historical average figures from the Sales Statistics. (figure 6.) . This is done with the help of a P.C. based system. For many products, a single Planning Bill item is Master Scheduled for each family, again using percentages derived from the Sales Statistics. An "updated run" of ASDA is carried out on a Monday morning and copies of the ASDA reports circulated to Production Control, Materials and Production Management.

ASDA plans in weeks for the first 9 weeks and then months thereafter. Every order to the left of the "&" is automatically allocated stock from Free Stock.(week 40 in figure 8.) The ASDA report shows the home and export demand lines, the Plan (MPS) and the Projected Available Balance and Available to Promise quantities. It also shows the Planned and Free Stock situations. Every two weeks a piece of specially written software is used to translate the Plan line on ASDA into a string of Firm Planned Orders for direct input to MM3000 for the MRP run.

The feedback of arrears and capacity problems comes from the supervisors on the shop floor and whilst most of these problems are solved by adjusting capacity or alternative routes, there are occasions when the MPS has to be amended.

Purchase and supply problems can be investigated using the Pegged Requirements facility in MM3000 MRP and on rare occasions feedback to the Master Schedulers will result in a reschedule.

PLANNING AND CONTROL SYSTEM EVALUATION

In this section the performance measures which are used to evaluate planning and control systems at MEM are briefly described and some of the improvements that are planned are discussed.

Measures

Delivery performance is measured in terms of home service level (weeks from receipt), overdues and any changes in export delivery dates.

Raw material, work in progress and finished product inventory levels are also monitored.

The main measure is how compatible the MPS and actual production are to the Programme Pack plan, since this is the plan that has been authorised by Management.

Improvements

It is planned to make further use of the P.C. to main system link, particularly in the area of Rough Cut Capacity Planning. There is also a project in place to introduce measurement in terms of Standard Works Cost for many of the plans instead of the Standard Invoiced £'s used at present.

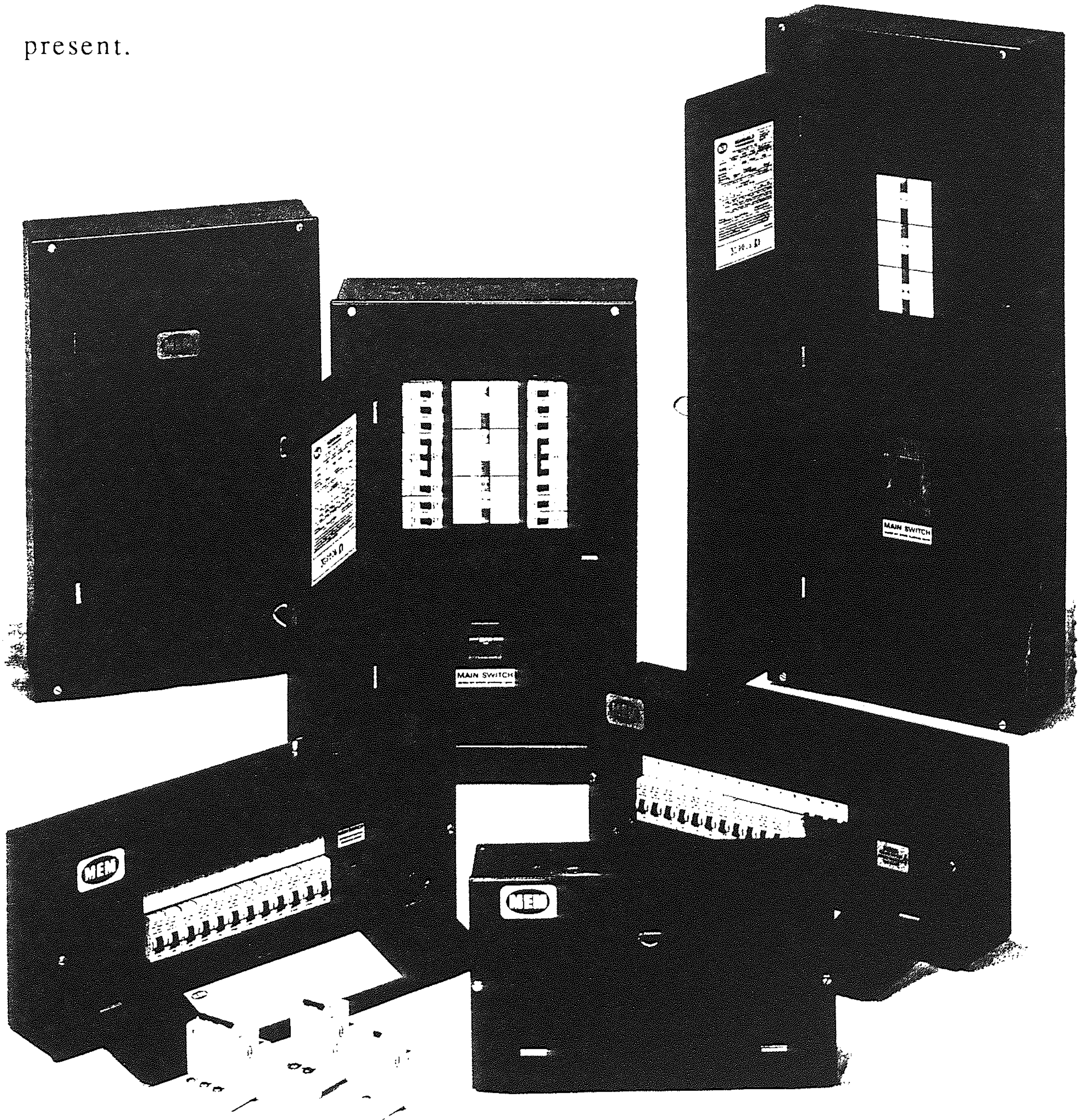


Figure 1. - Example of Distribution Board Products

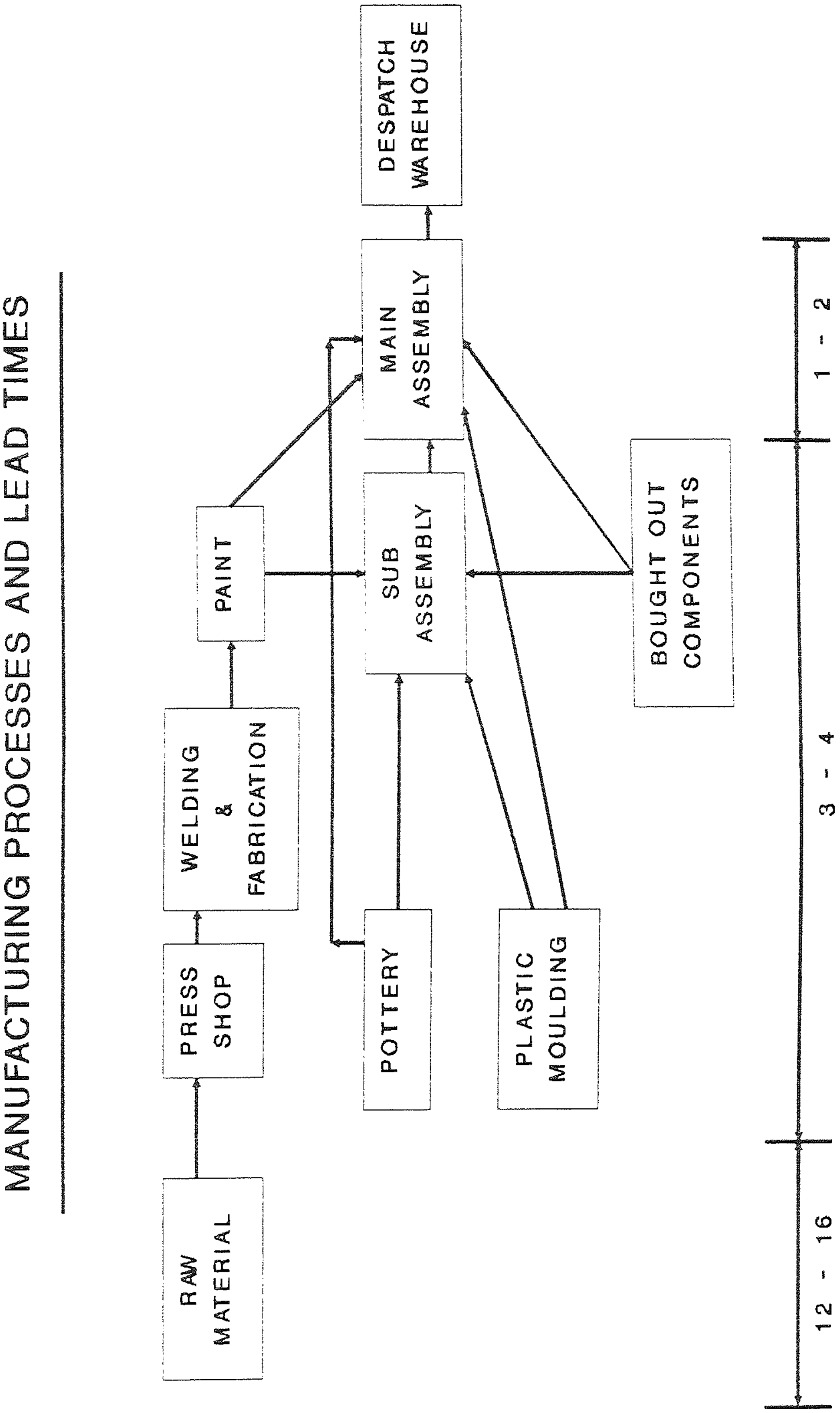


Figure 2. - Manufacturing Processes and Lead Times

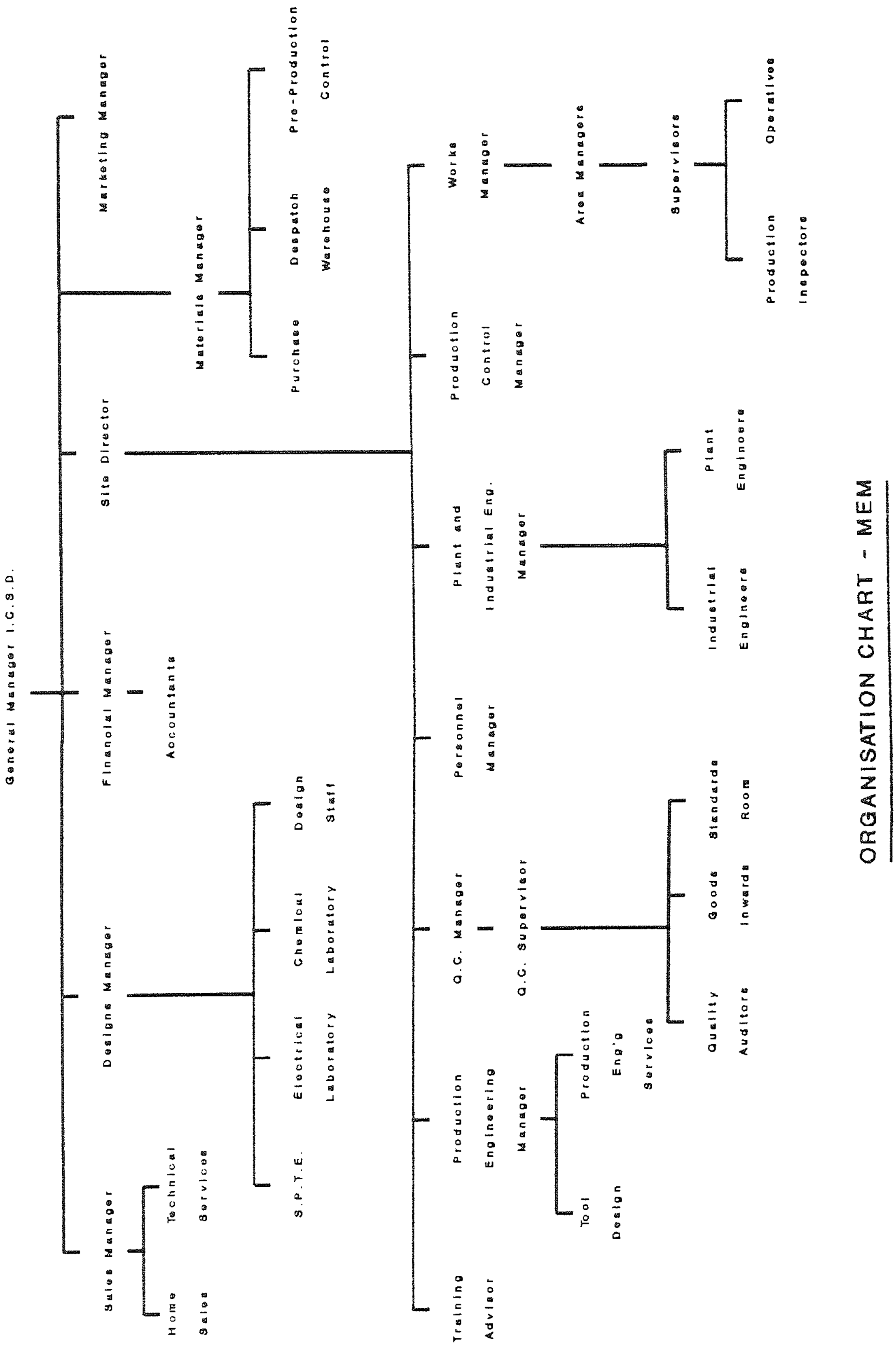


Figure 3. - Organisation Chart

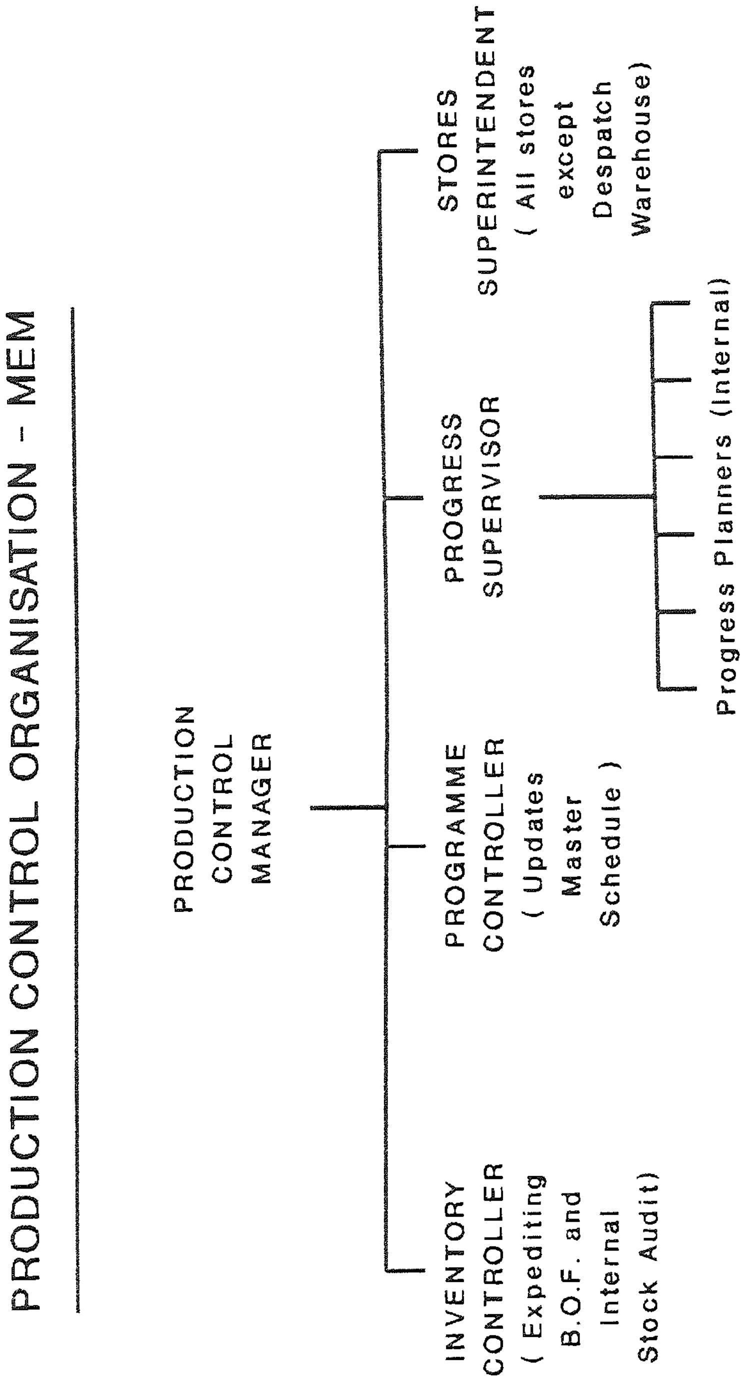
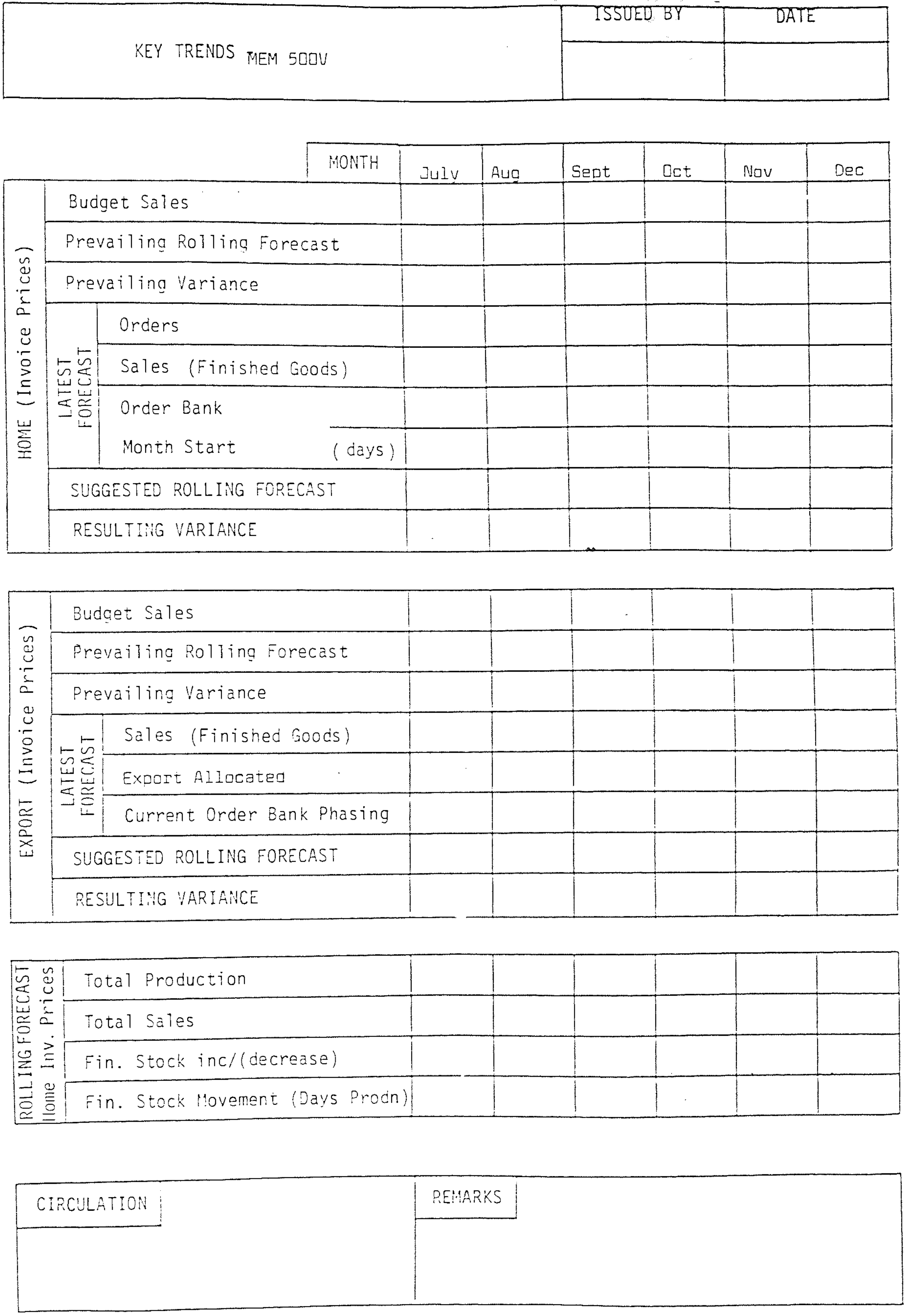


Figure 4. - Production Control Organisation



KEY TRENDS MEM 500V	ISSUED BY	DATE

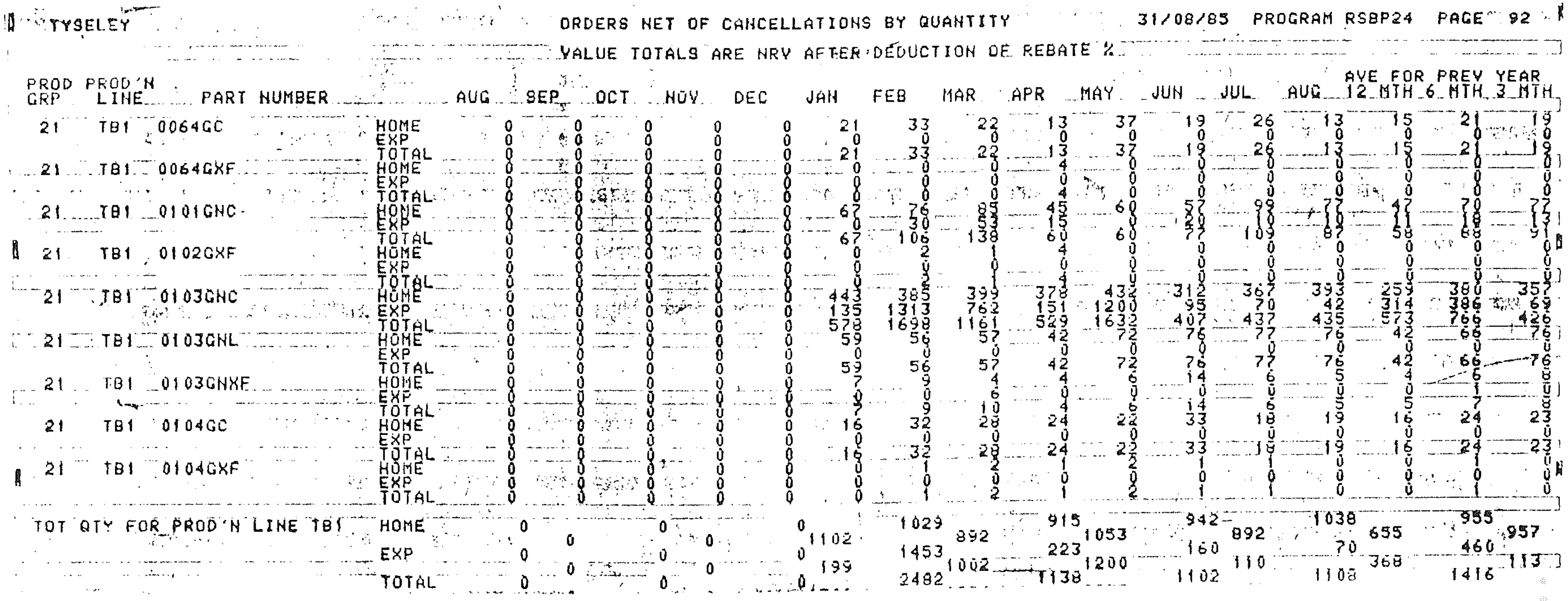
		MONTH	July	Aug	Sept	Oct	Nov	Dec
HOME (Invoice Prices)		Budget Sales						
		Prevailing Rolling Forecast						
		Prevailing Variance						
	LATEST FORECAST	Orders						
		Sales (Finished Goods)						
		Order Bank Month Start (days)						
		SUGGESTED ROLLING FORECAST						
		RESULTING VARIANCE						

EXPORT (Invoice Prices)		Budget Sales						
		Prevailing Rolling Forecast						
		Prevailing Variance						
	LATEST FORECAST	Sales (Finished Goods)						
		Export Allocated						
		Current Order Bank Phasing						
		SUGGESTED ROLLING FORECAST						
		RESULTING VARIANCE						

ROLLING FORECAST Home Inv. Prices	Total Production						
	Total Sales						
	Fin. Stock inc/(decrease)						
	Fin. Stock Movement (Days Prodn)						

CIRCULATION	REMARKS

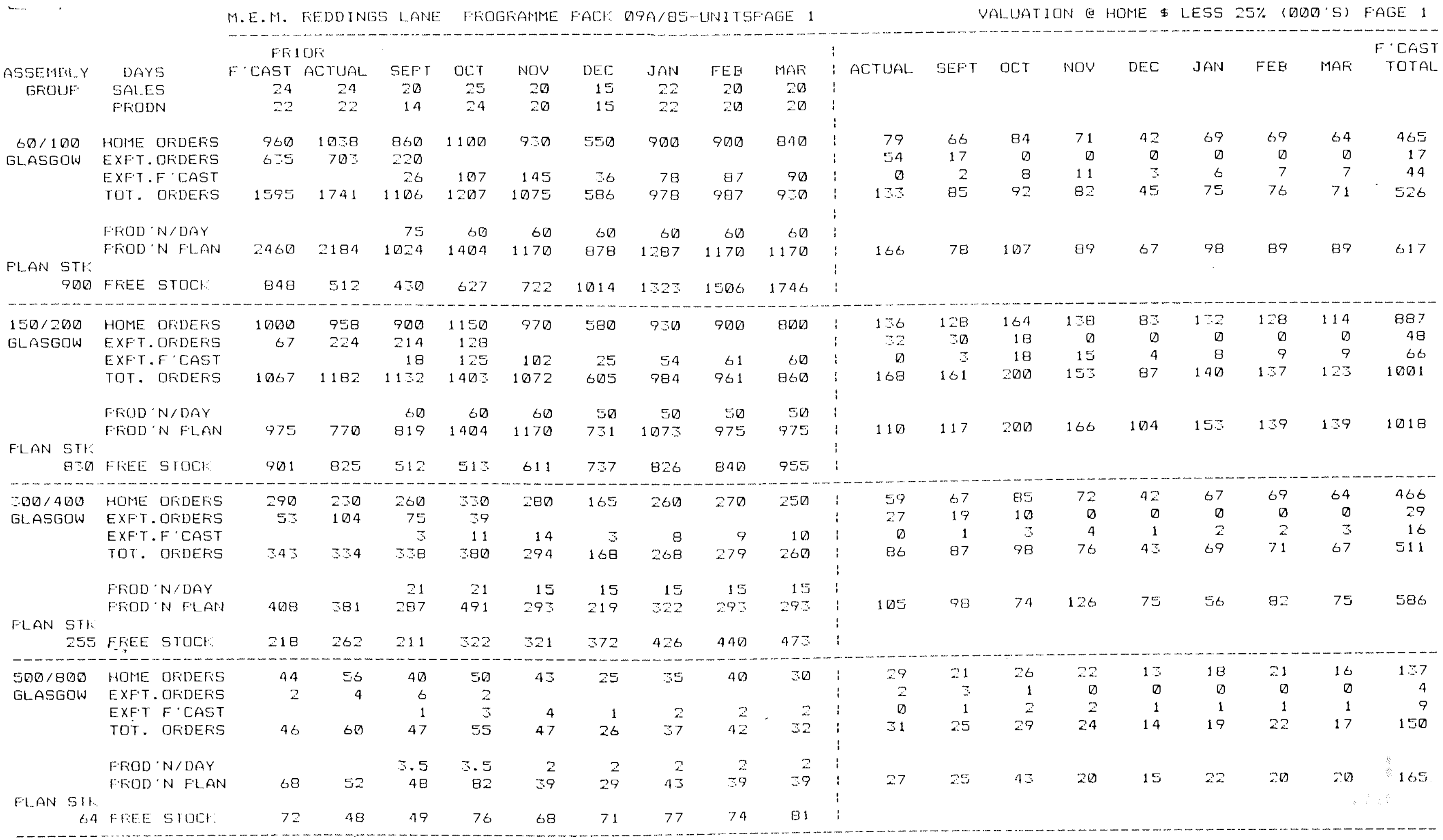
Figure 5. "Key Trends" Document



```
  TYSELEY                        ORDERS NET OF CANCELLATIONS BY QUANTITY         31/08/85  PROGRAM RSBP24  PAGE  92
                                 VALUE TOTALS ARE NRV AFTER DEDUCTION OF REBATE %
                                                                                                      AVE FOR PREV YEAR
PROD PROD'N
GRP  LINE   PART NUMBER            AUG  SEP  OCT  NOV  DEC   JAN   FEB   MAR   APR   MAY   JUN   JUL   AUG  12 MTH 6 MTH 3 MTH
 21   TB1   0064GC        HOME      0    0    0    0    0    21    33    22    13    37    19    26    13    15    21    19
                          EXP       0    0    0    0    0     0     0     0     0     0     0     0     0     0     0     0
                          TOTAL     0    0    0    0    0    21    33    22    13    37    19    26    13    15    21    19
 21   TB1   0064GXF       HOME      0    0    0    0    0     0     0     0     4     0     0     0     0     0     0     0
                          EXP       0    0    0    0    0     0     0     0     0     0     0     0     0     0     0     0
                          TOTAL     0    0    0    0    0     0     0     0     4     0     0     0     0     0     0     0
 21   TB1   0101GNC       HOME      0    0    0    0    0    67    76    85    45    60    57    99    77    47    70    77
                          EXP       0    0    0    0    0     0    30    53    15     0    20    10    10    11    18    13
                          TOTAL     0    0    0    0    0    67   106   138    60    60    77   109    87    58    88    91
 21   TB1   0102GXF       HOME      0    0    0    0    0     0     2     1     4     0     0     0     0     0     0     0
                          EXP       0    0    0    0    0     0     0     0     0     0     0     0     0     0     0     0
                          TOTAL     0    0    0    0    0     0     2     1     4     0     0     0     0     0     0     0
 21   TB1   0103GNC       HOME      0    0    0    0    0   443   385   399   378   432   312   367   393   259   380   357
                          EXP       0    0    0    0    0   135  1313   762   151  1200    95    70    42   314   386    69
                          TOTAL     0    0    0    0    0   578  1698  1161   529  1632   407   437   435   573   766   426
 21   TB1   0103GNL       HOME      0    0    0    0    0    59    56    57    42    72    76    77    76    42    66    76
                          EXP       0    0    0    0    0     0     0     0     0     0     0     0     0     0     0     0
                          TOTAL     0    0    0    0    0    59    56    57    42    72    76    77    76    42    66    76
 21   TB1   0103GNXF      HOME      0    0    0    0    0     7     9     4     4     6    14     6     5     4     6     8
                          EXP       0    0    0    0    0     0     0     6     0     0     0     0     0     0     1     0
                          TOTAL     0    0    0    0    0     7     9    10     4     6    14     6     5     5     7     8
 21   TB1   0104GC        HOME      0    0    0    0    0    16    32    28    24    22    33    18    19    16    24    23
                          EXP       0    0    0    0    0     0     0     0     0     0     0     0     0     0     0     0
                          TOTAL     0    0    0    0    0    16    32    28    24    22    33    18    19    16    24    23
 21   TB1   0104GXF       HOME      0    0    0    0    0     0     1     2     1     2     1     1     0     0     1     0
                          EXP       0    0    0    0    0     0     0     0     0     0     0     0     0     0     0     0
                          TOTAL     0    0    0    0    0     0     1     2     1     2     1     1     0     0     1     0

 TOT QTY FOR PROD'N LINE TB1  HOME   0         0         0          1029        915         942        1038          955
                                          0         0         1102        892        1053        892         655         957
                              EXP    0         0         0          1453        223         160          70          460
                                          0         0          199        1002        1200        110         368         113
                              TOTAL  0         0         0          2482        1138        1102        1108         1416
```

Figure 6. - Example of Sales Statistics Report



```
                          M.E.M. REDDINGS LANE  PROGRAMME PACK 09A/85-UNITSPAGE 1              VALUATION @ HOME $ LESS 25% (000'S) PAGE 1
                          ----------------------------------------------------------------------------------------------------------------
                              PRIOR                                                  :                                                 F'CAST
ASSEMBLY   DAYS           F'CAST ACTUAL  SEPT   OCT   NOV   DEC   JAN   FEB   MAR  : ACTUAL  SEPT   OCT   NOV   DEC   JAN   FEB   MAR   TOTAL
  GROUP    SALES             24     24     20    25    20    15    22    20    20  :
           PRODN             22     22     14    24    20    15    22    20    20  :
                                                                                   :
 60/100   HOME ORDERS       960   1038    860  1100   930   550   900   900   840  :   79     66    84    71    42    69    69    64    465
GLASGOW   EXPT.ORDERS       635    703    220                                      :   54     17     0     0     0     0     0     0     17
          EXPT.F'CAST                      26   107   145    36    78    87    90  :    0      2     8    11     3     6     7     7     44
          TOT. ORDERS      1595   1741   1106  1207  1075   586   978   987   930  :  133     85    92    82    45    75    76    71    526
                                                                                   :
          PROD'N/DAY                       75    60    60    60    60    60    60  :
          PROD'N PLAN      2460   2184   1024  1404  1170   878  1287  1170  1170  :  166     78   107    89    67    98    89    89    617
PLAN STK                                                                           :
     900 FREE STOCK         848    512    430   627   722  1014  1323  1506  1746  :
--------------------------------------------------------------------------------------------------------------------------------------------
150/200   HOME ORDERS      1000    958    900  1150   970   580   930   900   800  :  136    128   164   138    83   132   128   114    887
GLASGOW   EXPT.ORDERS        67    224    214   128                                :   32     30    18     0     0     0     0     0     48
          EXPT.F'CAST                      18   125   102    25    54    61    60  :    0      3    18    15     4     8     9     9     66
          TOT. ORDERS      1067   1182   1132  1403  1072   605   984   961   860  :  168    161   200   153    87   140   137   123   1001
                                                                                   :
          PROD'N/DAY                       60    60    60    50    50    50    50  :
          PROD'N PLAN       975    770    819  1404  1170   731  1073   975   975  :  110    117   200   166   104   153   139   139   1018
PLAN STK                                                                           :
     830 FREE STOCK         901    825    512   513   611   737   826   840   955  :
--------------------------------------------------------------------------------------------------------------------------------------------
300/400   HOME ORDERS       290    230    260   330   280   165   260   270   250  :   59     67    85    72    42    67    69    64    466
GLASGOW   EXPT.ORDERS        53    104     75    39                                :   27     19    10     0     0     0     0     0     29
          EXPT.F'CAST                       3    11    14     3     8     9    10  :    0      1     3     4     1     2     2     3     16
          TOT. ORDERS       343    334    338   380   294   168   268   279   260  :   86     87    98    76    43    69    71    67    511
                                                                                   :
          PROD'N/DAY                       21    21    15    15    15    15    15  :
          PROD'N PLAN       408    381    287   491   293   219   322   293   293  :  105     98    74   126    75    56    82    75    586
PLAN STK                                                                           :
     255 FREE STOCK         218    262    211   322   321   372   426   440   473  :
--------------------------------------------------------------------------------------------------------------------------------------------
500/800   HOME ORDERS        44     56     40    50    43    25    35    40    30  :   29     21    26    22    13    18    21    16    137
GLASGOW   EXPT.ORDERS         2      4      6     2                                :    2      3     1     0     0     0     0     0      4
          EXPT F'CAST                       1     3     4     1     2     2     2  :    0      1     2     2     1     1     1     1      9
          TOT. ORDERS        46     60     47    55    47    26    37    42    32  :   31     25    29    24    14    19    22    17    150
                                                                                   :
          PROD'N/DAY                      3.5   3.5     2     2     2     2     2  :
          PROD'N PLAN        68     52     48    82    39    29    43    39    39  :   27     25    43    20    15    22    20    20    165
PLAN STK                                                                           :
      64 FREE STOCK          72     48     49    76    68    71    77    74    81  :
--------------------------------------------------------------------------------------------------------------------------------------------
```

Figure 7. Programme Pack

```
**********************************************************************************************************************
*
* RUN ON MON, SEP  2, 1985,   1:00 AM             A.S.D.A. FOR M.E.M.                      MP6005P/1/1        PAGE 309
*
**********************************************************************************************************************

                                                         PRODUCTION LINE  TB1
Part Number                       PRIOR     *36    WK37    WK38    WK39    WK40    WK41    WK42    WK43    WK44     NOV     DEC   FUTUR

  0064GC
Average              19 HOME         0*       0       0       0      0*      0&       0       0       0      0*       0       0       0
Monthly               0 EXPT         0*       0       0       0      0*      0&       0       0       0      0*       0       0       0
Demand               19 TOT          0*       0       0       0      0*      0&       0       0       0      0*       0       0       0

ABC Class     A        PLAN          0*      30       0       0      0*     40&       0       0       0      0*      40      30     120

Planned stock        30 PAB         27*      57      57      57     57*     97&      97      97      97     97*     137     167
Free stock           27 ATP         27*      30       0       0      0*     40&       0       0       0      0*.     40      30
----------------------------------------------------------------------------------------------------------------------------------
  0064GMF
Average               0 HOME         0*       0       0       0      0*      0&       0       0       0      0*       0       0       0
Monthly               0 EXPT         0*       0       0       0      0*      0&       0       0       0      0*       0       0       0
Demand                0 TOT          0*       0       0       0      0*      0&       0       0       0      0*       0       0       0

ABC Class     C        PLAN          0*       0       0       0      0*      0&       0       0       0      0*       5       0       0

Planned stock         5 PAB         10*      10      10      10     10*     10&      10      10      10     10*      15      15
Free stock           10 ATP         10*       0       0       0      0*      0&       0       0       0      0*       5       0
----------------------------------------------------------------------------------------------------------------------------------
  0101GHC
Average              77 HOME         0*       0       0       8     32*      0&       0       0       0      0*       0       0       0
Monthly              13 EXPT         0*       0       0       0      0*      0&       0      15       0      0*       0       0       0
Demand               90 TOT          0*       0       0       8     32*      0&       0      15       0      0*       0       0       0

ABC Class     A        PLAN          0*     112       0      60      0*     90&       0       0       0      0*      90      80     240

Planned stock        60 PAB          0*     112     112     164    132*    222&     222     207     207    207*     297     377
Free stock            0 ATP          0*     112       0      20      0*     75&       0       0       0      0*      90      80
----------------------------------------------------------------------------------------------------------------------------------
  0102GMF
Average               0 HOME         0*       0       0       0      0*      0&       0       0       0      0*       0       0       0
Monthly               0 EXPT         0*       0       0       0      0*      0&       0       0       0      0*       0       0       0
Demand                0 TOT          0*       0       0       0      0*      0&       0       0       0      0*       0       0       0

ABC Class     C        PLAN          0*       0       0       0      0*      5&       0       0       0      0*       0       0       5

Planned stock         5 PAB          6*       6       6       6      6*     11&      11      11      11     11*      11      11
Free stock            6 ATP          6*       0       0       0      0*      5&       0       0       0      0*       0       0
----------------------------------------------------------------------------------------------------------------------------------
  0103GHC
Average             357 HOME         0*       0       0       0      0*      0&       0       0       0      0*       0       0       0
Monthly              69 EXPT         0*       0       0       0      0*      0&       0     150       0      0*       0       0       0
Demand              426 TOT          0*       0       0       0      0*      0&       0     150       0      0*       0       0       0

ABC Class     A        PLAN          0*       0      29     205      0*      0&       0     170     170    300*     455     300    2230

Planned stock       300 PAB        273*     273     302     507    507*    507&     507     527     697    997*    1452    1752
Free stock          273 ATP        273*       0      29     205      0*      0&       0      20     170    300*     455     300
----------------------------------------------------------------------------------------------------------------------------------
```

Figure 8. - Example of an ASDA Report

Appendix 8.

Quinton Hazell Transmission Division Case Study.

[January 1986]

QUINTON HAZELL, TRANSMISSION DIVISION, REDDITCH, WORCS. [1986]

THE COMPANY, PRODUCTS AND MARKETS.

Quinton Hazell Transmission Division, part of the Quinton Hazell group of companies, produces a wide range of motor vehicle clutches and other components, mainly for the aftermarket, with an annual sales value of approximately £6 million.

The Redditch factory occupies some 160,000 square feet and employs 220 personnel. Annual production exceeds 450,000 clutch covers, 650,000 clutch plates, 300,000 release bearings together with clutch carbons, exhaust brackets, drive couplings and other components.

All products are supplied directly to the main company warehouse in Nuneaton, who are responsible for onward distribution to customers and the company's own retail outlets. 95% of output is for the aftermarket, a lot of which is for other retail companies' own brands, such as Don International, General Motors (AC Delco), Mintex and Brown Brothers. This involves labelling and packaging what are essentially the same manufactured products for different customers. The remaining 5% of output is sold to Original Equipment Manufacturers such as Land Rover, Ford Tractor and Ford Competition. As far as the Redditch Factory is concerned there is only one customer; the Nuneaton warehouse.

All products are made to a warehouse order, with typical inventory levels of £180,000 in raw materials, £120,000 in bought out parts and £200,000 in work in progress. There are no finished stocks in the factory since everything transferred from work in progress becomes the responsibility of the warehouse.

The Stock Planning function at the warehouse give two to three months' notice of firm orders. The split between export and domestic sales is approximately 40/60.

THE PRODUCTION PROCESS

A simplified manufacturing sequence and approximate lead times are shown in figure 1. The longest purchase lead times are for steel and friction materials, ranging from 6 to 8 weeks. With a manufacturing lead time of 2 weeks, made up of 3 days for pressing, 5 days for casting machining and the remainder for heat treatment, phosphating, sub-assembly and final assembly, the total lead time is about 8-10 weeks. Some products require as many as 10 operations.

The manufacturing system is essentially a batch manufacturing organisation. Of the 1,000 different products that are sold, only about 500 different manufactured assemblies have to be produced, because of the own-brand packaging requirements. No products require special design or customising work.

COMPUTER SYSTEMS.

The company installed a Cincom MRPS MRPII system three and a half years ago on a DEC VAX 11/750 computer. There is also a link to the corporate systems on ICL equipment. The package has all the facilities of an MRPII system, though, since the Vendor and Purchasing module was not available at the time of implementation, a bespoke package has been written to translate the MRP output into supplier schedules. Currently, not all modules are being used as will be discussed in later sections. A P.C. is used for the Master Scheduling function.

The current systems are dealing with about 10,000 part numbers, bills of material having up to 5 levels of breakdown and a relatively low level of engineering/design changes (4 per week). There is about 30% commonality of material between products and 65% of parts (by value) are purchased.

MASTER PRODUCTION SCHEDULE- OVERVIEW.

The Master Production Schedule (MPS) which is input to MRP is stated in a mixture of phantom assemblies and actual finished product orders over a 6 month horizon. Whilst the planning is done in monthly time periods, the input to MRP is on a day/date basis.

The first 2 or 3 months are regarded as frozen and the MPS is updated once a month.

Master Scheduling is carried out by the Production Manager in conjunction with the Assembly and Manufacturing Planners, Production Superintendent and Shop Foremen. (see figure 2.)

The constraints on Master Scheduling are in terms of production capacity, the Annual Budget, manufacturing stock levels and, most of all, the service level in terms of stock availability percentages. The details of Master Scheduling will be dealt with in later sections.

PLANNING AND CONTROL SYSTEM INTERACTIONS.

Using the basic model of MPS and its relationship with other planning and control activities as shown in figure 4.1 , this section describes how these relationships operate at Quinton Hazell.

Demand Management

This incorporates the activities of forecasting, order entry, order promising and physical distribution, all of which come under the responsibility of the Nuneaton warehouse and corporate headquarters.

An annual sales forecast is produced and issued every August for the following calendar year by the Sales and Marketing division. It is stated in £'s sales value by product family and is mainly used for the financial budgeting of the organisation and any longer term capital equipment and manning decisions.

The rolling six month MPS includes a mixture of firm orders and forecasts which have been derived from historical averages and trends together with an analysis of the current order book. These are provided by the Stock Planning section of the warehouse and as far as the factory is concerned, there is little difference between orders and forecast on the schedule. Over the years the forecast appears to have been reasonably accurate.

Sales Order entry, Export delivery date promising and physical distribution are all dealt with at the Nuneaton warehouse.

Production Planning

Apart from a 5 year plan which is at a very aggregate level and is used by the Board of Directors, the only other long term plan is the annual forecast/budget mentioned above. This is stated in Sales £'s per product family and provides only a rough guide for Master Scheduling.

Resource and Rough Cut Capacity Planning

Longer term Resource Planning is carried out manually, attempts having been made to translate Sales £'s into products and Standard Hours using ratios but without much success.

The Rough Cut Capacity Planning module is available on the Cincom MRPS MRPII system but is not being used. Times are used for a piece-work payment scheme but it is not thought that they would be sufficiently accurate for capacity planning.

Over the years, local knowledge has been built up as to what is achievable in terms of daily production rates of the three main commodity groups i.e. clutch covers, clutch drive plates and release bearings. This experience is used in determining a "Rough Cut" MPS check of sorts. Currently production rates are set at 2,000 covers per day, 3,000 drive plates per day and 2,500 bearings per day.

Capacity is reasonably flexible in terms of being able to increase it by means of overtime or extra shifts. It is not quite so easy to reduce capacity.

Final Assembly Scheduling

The Final Assembly schedule , which includes final packaging is all part of the MPS process and will be dealt with in that section.

Material Requirements Planning

At Quinton Hazell, MRP is run once a week in regenerative mode. As mentioned previously, the system uses daily periods, but the MPS is input on a weekly basis (i.e. no more than one firm planned order per product per week). Minimum batch sizes are set to prevent too many small batches being generated and firm planned orders are used in the frozen portion of the MPS at several levels in the Bill of Material to keep stable production schedules and take account of required sequences of changeovers of multi-part tooling.

Virtually all material is controlled through MRP with the exception of a few low usage value items, such as labels, which are dealt with on a Reorder Point basis.

Capacity Requirements Planning

Detailed Capacity Requirements Planning is not undertaken despite the fact that the software module is available. The comment was made that CRP was not worth the effort, particularly in a relatively fast moving, short lead time environment,(up to 5 operations per day on some product batches).

MASTER PRODUCTION SCHEDULE PREPARATION

This section outlines the detailed procedures used to develop and update the Master Production Schedule at Quinton Hazell.

Each month an initial rolled forward version of the "Production Plan" (MPS) is produced by the Stock Planning function at Nuneaton using the most up to date order and forecast position. This is produced on a P.C. spreadsheet package and a hard and soft copy sent to the Production Manager at Redditch.(see figure 3.) The constraints put on Stock Planning by the factory are that the quantity of any one individual product should not be more than 30% of that product range in a month and also certain minimum batch quantities should be adhered to.

Products are graded according to their usage value in terms of a Pareto distribution and grades 1 to 6, representing the first 60% of usage value, are given a 2 month lead time to the warehouse. In other words the first two months of the MPS is frozen and they can only make alterations to the third month. For grades 7 to 10, there is a 3 month lead time i.e. only changes to the fourth month are allowed. Most of the time these rules are adhered to, but there will always be some occasions where changes will be required across the horizon.

A first "Rough Cut" check is made by the Production Manager and products requiring shared tooling or sequential changeovers are scheduled together. A meeting is then held with the Production Superintendent, Assembly and Manufacturing Planners and Shop Foremen to modify and eventually agree the MPS. This is then sent back to Stock Planning in Nuneaton for final agreement. Once agreed, the monthly plan is then translated into weekly batches for input on a day/date basis to MRP on the weekly run.

The items which are Master Scheduled are a mixture of actual finished products and phantom assemblies which represent the common manufactured assembly. For example, in figure 3., part number Q10016ASS is a phantom assembly for all the Q10016 family and is only scheduled in months 2 to 6. In month 1, the requirements for individual finished products are scheduled e.g. 200 of Q10016B (Brown Brothers own brand). The Bill of Material for Q10016B would simply call up

Q10016ASS plus the packaging, labels and instructions for the Brown Brothers product. This method of Master Scheduling considerably reduces the effort required.

On a daily basis, the Production Manager also receives a copy of the warehouse stock balances via a terminal link to the Nuneaton corporate system. (see figure 4.) This allows him to keep one step ahead in terms of spotting abnormally high demands or stock levels which are dangerously low and give higher priority to batches for those products which are already in production.

The ultimate objective is to provide a high level of availability from the warehouse for those products produced at the Redditch plant.

PLANNING AND CONTROL SYSTEM EVALUATION

In this section, the performance measures which are used to evaluate the planning and control systems at Quinton Hazell are briefly described together with some of the improvements which are planned.

Measures

The main measure which is used, as mentioned previously, is Stock Availability. A report is produced weekly which shows stock availability per grade per product family as a percentage. These are totalled by major product group and factory. (See figure 5.) It can be seen that in the example shown that Redditch achieved a 99% availability for grades 1-6 and a 98% availability for the total of grades 1-9.

Other measures are concerned with manufacturing stock levels where a target stock turn of 15 per year (including raw materials) has been set and a rate of about 12 is currently being achieved. Performance against the annual budget in financial terms is also measured.

Production Achievement Reports are also produced on a monthly basis.

Improvements

It is intended to add consumable tools, consumable materials and general tooling to the Bills of Material to aid better planning and control.

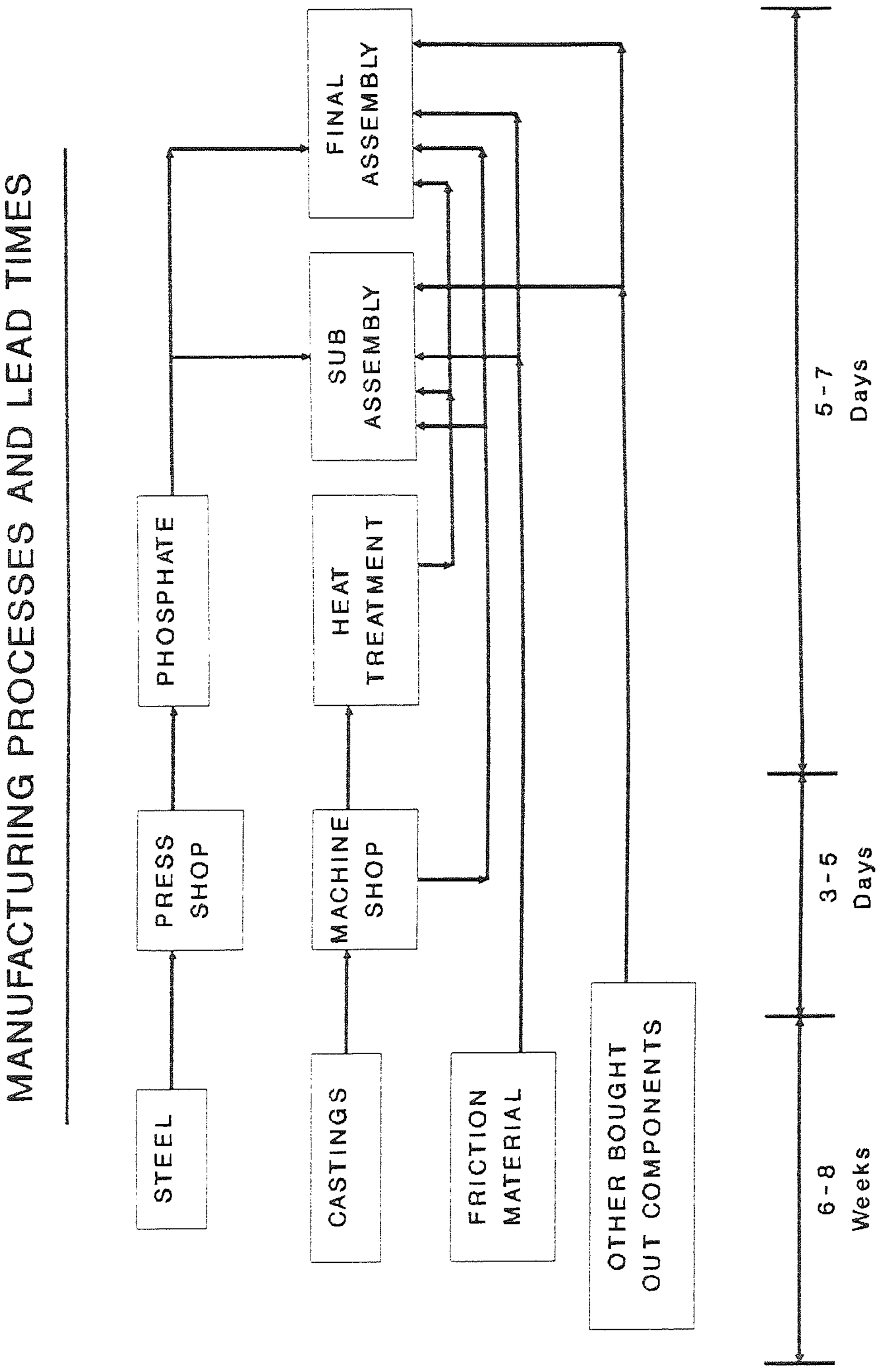


Figure 1. - Manufacturing Processes and Lead Times

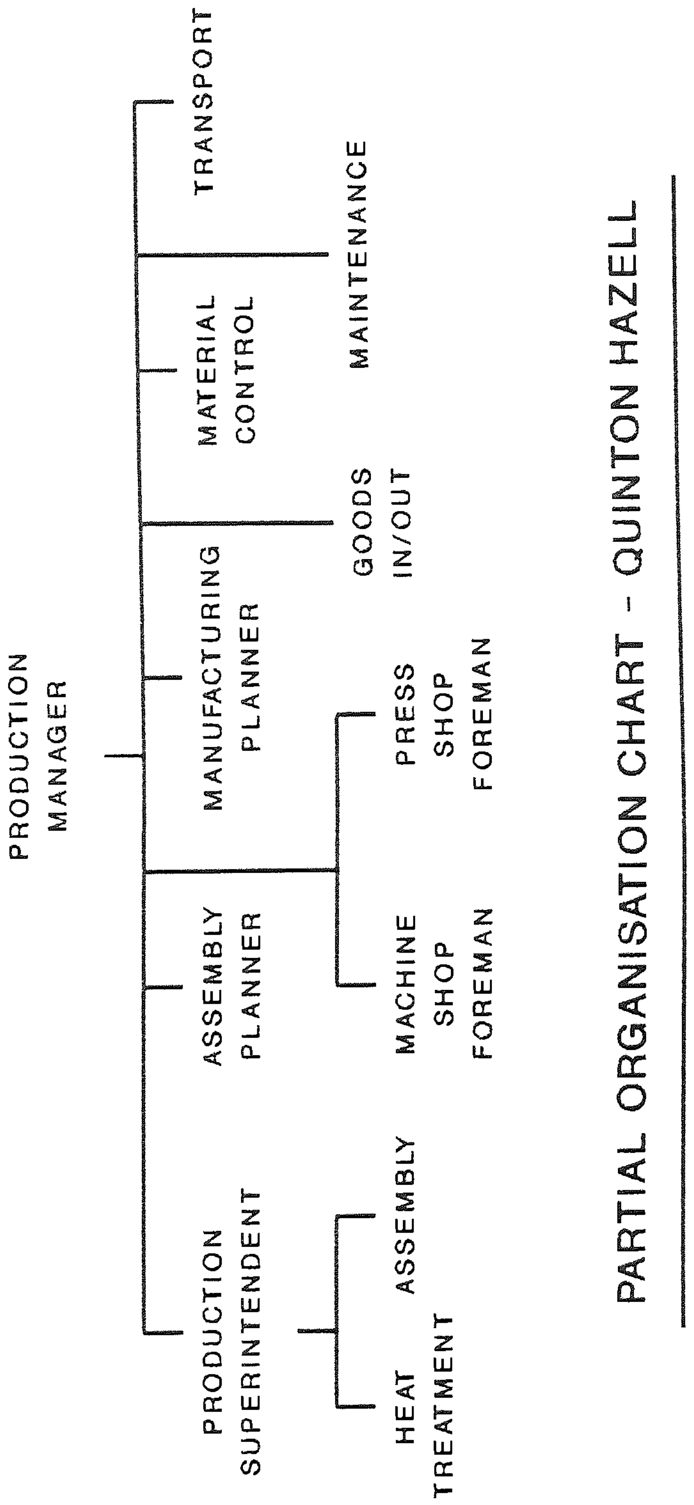


Figure 2. - Partial Organisation Chart

```
DATE 08/01/86                          PRODUCTION PLAN DETAIL - PRODUCT GROUP 10     DIVISION T                        PS50    PAGE    9

      PART NUMBER        DEV    GRD    S.M.D.  AVL STK  FROZEN    ARREARS    MTH 01    MTH 02    MTH 03    MTH 04    MTH 05    MTH 06

      Q10016              I      2      829      735      6          0        1300        0         0         0         0         0
      Q10016ASS             PART NOT PRESENT ON HE-FPS FILE          0           0      4900      2000      2200      1800      1900
      Q10016B             I      6      205      425      0          0         200        0         0         0         0         0
      Q10016DN            I      8       88      113      0          0         100        0         0         0         0         0
      Q10016GM            I              68       85      0          0           0        0         0         0         0         0
      Q10016M             I      8       82      200      0          0           0        0         0         0         0         0
      Q10018              I      9       27      442      0          0           0        0         0         0         0         0
      Q10018ASS             PART NOT PRESENT ON HE-FPS FILE          0           0        0         0         0         0         0
      Q10018DN            I               5        1      0          0           0        0         0         0         0         0
      Q10018M             I               6      -42      0          0           0        0         0         0         0         0
      Q10019              I      3      439      725     10          0         150        0         0         0         0         0
      Q10019ASS             PART NOT PRESENT ON HE-FPS FILE          0           0      1400       800       900       700       700
      Q10019B             I      6      104      -63      0          0         300        0         0         0         0         0
      Q10019DN            I      7       70       16      0          0         100        0         0         0         0         0
      Q10019GM            I              10       49      0          0           0        0         0         0         0         0
      Q10019M             I      7       81     -268      0          0         150        0         0         0         0         0
      Q10019W             I              19       30    150          0           0        0         0         0         0         0
```

Figure 3. - "Production Plan" (MPS) Document

```
05/02/86     06/41/27        STOCK BALANCES - UNCOSTED(NWC)  T DIVISION        REF. HE60.2/T  **              PAGE   158

  PART          DIV D S PART FX STK IN    CDV    C-P-L    TOTAL    FREE   EXP    EXP     HOME MTH H BUFF   EXP     HOME TOTAL OR
 NUMBER         STR S F S/CC RT TRANSIT STOCK   STOCK    STOCK    STOCK  STOCK  UNAPP   STOCK DEM. WKS    B/O     B/O COV B/O

C    731LF      T/X I 2    1A  M      0       0       0        0        0      0      0       0     0 0      0       0        0
C    731M       T/X I 2    1A  M      0       8       0        8        8      0      0       0     5 0      0       0 (      8)
C    731S       T/X I 1 9  1A  M      0     512       0      512      512      0      0       0    26 0      0       0 (    512)
C    731SB      T/X I 1    1A  M      0      29       0       29       29      0      0       0     5 0      0       0 (     29)
C    736DN      T/X I 2    1A  M      0      28       0       28       29      0      0       0    20 0      0       0 (     28)
C    736LF      T/X I 2    1A  M      0      50       0       50       50      0      0       0     0 0      0       0 (     50)
C    736M       T/X I 2 9  1A  M      0      58       0       58       58      0      0       0    26 0      0       0 (     58)
C    736S       T/X I 1 4  1A  M    220     653       0      873      828     45      0       0    54 0     15       0 (    813)
C    736SB      T/X I 2    1A  M      0      20       0       20       20      0      0       0     6 0      0       0 (     20)
C    741DN      T/X J 2    1A  M      0      44       0       44       44      0      0       0    15 0      0       0 (     44)
C    741GM      T/X J 1    1A  M      0      30       0       30       30      0      0       0     5 0      0       0 (     30)
C    741M       T/X J 2    1A  M      0      20       0       20       20      0      0       0    24 0      0       0 (     20)
C    741S       T/X J 1 6  1A  M      0      48       0       49       48      0      0       0   160 0      0       0 (     48)
C    741SB      T/X J 2 9  1A  M      0      21       0       21       21      0      0       0    26 0      0       0 (     21)
C    745DN      T/Y I 2 9  1A  M      0     211       0      211      211      0      0       0    52 0      0       0 (    211)
C    745GM      T/X I 1    1A  M      0      35       0       35       35      0      0       0    40 0      0       0 (     35)
C    745LF      T/X I 2    1A  M      0      50       0       50       50      0      0       0     0 0      0       0 (     50)
C    745M       T/X I 2 9  1A  M      0      62       0       62       62      0      0       0    52 0      0       0 (     62)
C    745S       T/X I 1 3  1A  M      0    3151       0     3151     2899    272      0       0   462 0    700       0 (   2189)
C    745SB      T/X I 1 8  1A  M      0     166       0      166      166      0      0       0   111 0      0       0 (    166)
C    745SW      T/X E 2    1A  M      0     250       0      250      250      0      0       0     0 0    250       0        0
C    746DN      T/X I 1    1A  M      0       0       0        0        0      0      0       0    20 0      0       8        8
C    746LF      T/X I 2    1A  M      0      10       0       10       10      0      0       0     0 0      0       0 (     10)
C    746M       T/X I 2    1A  M      0      21       0       21       21      0      0       0    22 0      0       0 (     21)
C    746S       T/X I 1 7  1A  M      0    1031       0     1031      979     52      0       0   130 0     67       0 (    912)
C    746SB      T/X I 1    1A  M      0      20       0       20       20      0      0       0    18 0      0       0 (     20)
C    747LF      T/X I 2    1A  M      0      25       0       25       25      0      0       0     0 0      0       0 (     25)
C    747S       T/X I 1    1A  M      0     532       0      532      482     50      0       0     5 0      0       0 (    482)
C    749S       T/X J 1 9  1A  M      0     312       0      312      312      0      0       0     5 0      0       0 (    312)
C    752DN      T/X I 2 5  1A  M      0     401       0      401      401      0      0       0   360 0      0       0 (    401)
C    752GM      T/X I 1 9  1A  M      0     255       0      255      255      0      0       0    77 0      0       0 (    255)
C    752LF      T/X I 2    1A  M      0       0       0        0        0      0      0       0     0 0      0       0        0
C    752M       T/X I 2 6  1A  M      0       0       0        0        0      0      0       0   305 0      0       0        0
C    752S       T/X I 1 1  1A  M    400   24708       0    25108    24341    767      0       0  3907 0    650       0 (  23691)
C    752SB      T/X I 1 3  1A  M      0    2004       0     2004     2004      0      0       0   916 0      0       0 (   2004)
C    752SW      T/X I 2    1A  M      0     540       0      540      540      0      0       0     0 0      0       0 (    540)
C    753DN      T/X I 2    1A  M      0      60       0       60       60      0      0       0    31 0      0       0 (     60)
C    753GM      T/X I 1    1A  M      0      45       0       45       45      0      0       0    12 0      0       0 (     45)
C    753LF      T/X I 2    1A  M      0       0       0        0        0      0      0       0     0 0      0       0        0
C    753M       T/X I 2    1A  M      0       0       0        0        0      0      0       0    29 0      0       0        0
C    753S       T/X I 1 5  1A  M      0    2453       0     2463     2454      9      0       0   228 0      5       0 (   2449)
C    753SB      T/X I 1 9  1A  M      0      57       0       57       57      0      0       0    53 0      0       0 (     57)
C    759LF      T/X I 2    1A  M      0       0       0        0        0      0      0       0     0 0      0       0        0
C    759S       T/X I 1 9  1A  M      0     625       0      625      603     17      0       0     5 0      0       0 (    608)
```

Figure 4. - Warehouse Stock Balance Report

STOCK AVAILABILITY		GRADE											
1/25/1986		1	2	3	4	5	6	7	8	9	TOTAL	1-6	1-9
Water pumps	QCP	4	3	9	5	9	18 (5)	20 (2)	29 (3)	37 (1)	134 (11)	90%	92%
Pump kits	QW								5 (2)	7 (1)	12 (3)		75%
COOLING TOTAL		4	3	9	5	9	18 (5)	20 (2)	34 (5)	44 (2)	146 (14)	90%	90%
Ball joints	QSJ	1	3	3	7 (1)	12 (3)	8 (2)	14 (2)	13 (5)	38 (11)	99 (24)	82%	76%
Drag link assy	QDL				1 (1)			2	5	10 (2)	18 (3)		83%
Drag link ends	QD					1				3	4		100%
Track rod ends	QR	1	1	3 (2)	2 (1)	6 (1)	7 (3)	15 (5)	15 (2)	40 (5)	90 (19)	65%	79%
Idler arms	QRS									3 (1)	3 (1)		67%
STEERING TOTAL		2	4	6 (2)	10 (3)	19 (4)	15 (5)	31 (7)	33 (7)	94 (19)	214 (47)	75%	78%
King pin sets	QP			2 (1)	1	3 (2)	4 (2)	7 (3)	12 (3)	21 (11)	50 (22)	50%	56%
King pin kits	QSK		2	1	3	1	4	3	2	13 (3)	29 (3)	100%	90%
Shackle pins	SS								3 (1)	8 (2)	11 (3)		73%
Susp comps	Y								1	8	9		100%
SUSPENSION TOTAL			2	3 (1)	4	4 (2)	8 (2)	10 (3)	18 (4)	50 (16)	99 (28)	76%	72%
Banelli clamps	EC												
Carbon brgs	CC					1		3	2	3	9		100%
Clutch covers	Q	3	3	2	6	7	7	20 (1)	15	14 (1)	77 (2)	100%	97%
Clutch plates	C	1	3	5	6	12	14	16	22	22	101	100%	100%
Thrust brgs	CCT			2	5	2	4	5	8	24	50	100%	100%
Clutch kits	QKT		2 (1)	2	2	2	5	5	2 (1)	5	25 (2)		92%
Drive couplings											0		0%
TRANSMISSION TOTAL		4	8 (1)	11	19	24	30	49 (1)	49 (1)	68 (1)	262 (4)	99%	98%
Alternators	FRA		1	2	1	1	1	2 (1)	3	2 (2)	13 (3)	100%	77%
Dynamos	FRD						1				1		100%
Starters	FRS			2	1	2		5 (1)	6 (2)		16 (3)		81%
MIDAR TOTAL				4	2	3	2	7 (2)	9 (2)	2 (2)	29 (6)	100%	79%
Fan belts	QBA				2 (2)	1 (1)	3	6 (3)	8 (4)	20 (2)	40 (12)	50%	70%
Filler caps	FC		1		1	2	1	2	8	5	20	100%	100%
Heater hose	HP				1	1			1 (1)		3 (1)		67%
Hose clips	TC					3	5	3 (1)	2	3	16 (1)	100%	94%
Quinflex	TR			2	1		2	1	2 (1)		8 (1)	100%	88%
Radiator hoses	RH			1	3	1	3 (2)	11 (6)	15 (6)	49 (20)	83 (34)	75%	59%
Thermostats	QTH	3 (1)			1 (1)	7 (2)	6 (2)	9 (4)	11 (4)	12 (8)	49 (22)	65%	55%
Therm gaskets	QTG								1		1		100%
Timing belts	QTB		2	1	2	7 (1)	5 (1)	5 (1)	7 (1)	7 (1)	36 (5)	88%	86%
FACT COOLING TOTAL		3 (1)	3	4	11 (3)	22 (4)	25 (5)	37 (15)	55 (17)	96 (31)	256 (76)	81%	70%
Univ joints	QL	1	3 (1)	4	4	2	4	3	5 (2)	11	37 (3)	94%	92%
Engine mounts	EM				6 (3)	5	10 (5)	8 (1)	20 (2)	36 (4)	85 (15)	62%	82%
Clutch cables	QCC			1	1	6	4 (1)	8	19 (2)	22 (4)	61 (7)	92%	89%
Wheel brg kts	QWB	1	6	14 (2)	9 (2)	13	29 (4)	25 (3)	38 (3)	51 (3)	186 (17)	89%	91%
Exhaust mtgs	QEF												
Cen sup brgs	QCS				2			1	2	1 (1)	6 (1)		83%
Brake pads	BP						1	3	4 (1)	23 (8)	31 (9)		71%
Brake shoes	BS							3	9 (3)	16 (3)	28 (6)		79%
Brake cables	BC		2		5	5	9 (1)	15 (1)	25 (1)	33 (4)	94 (7)	95%	93%
Strg gaiters	QG		1					3	2	3	9		100%
FACT TRANS TOTAL		2	12 (1)	19 (2)	27 (5)	31	57 (11)	69 (5)	124 (14)	196 (27)	537 (65)	87%	88%
Wheel cylds	BWC			1	1	2	4	6 (1)	8 (2)	19	41 (3)	100%	93%
Wheel cyld kts	BWR							1	3	3	7		100%
Master cylds	BMC						3 (1)	2	1	20 (2)	26 (3)	67%	88%
Mast cyld kts	BMR									7 (2)	7 (2)		71%
Flexible hoses	BFH							1	3	9 (1)	13 (1)		92%
Brake discs	BDC					1		5	6	16	28		100%
HYDRAULICS TOTAL				1	1	3	7 (1)	15 (1)	21 (2)	74 (5)	122 (9)	92%	93%
COLWYN BAY TOTAL		6	9	18 (3)	19 (3)	32 (6)	41 (12)	61 (12)	85 (16)	188 (37)	459 (89)	81%	81%
REDDITCH TOTAL		4	8 (1)	11	19	24	30	49 (1)	49 (1)	68 (1)	262 (4)	99%	98%
FACTORED TOTAL		5 (1)	15 (1)	24 (2)	39 (8)	56 (4)	89 (17)	121 (21)	200 (33)	366 (63)	915 (150)	86%	84%
MIDAR TOTAL				4	2	3	2	7 (2)	9 (2)	2 (2)	29 (6)	100%	79%

Figure 5. - Stock Availability Report.

Appendix 9.

Pye Telecom Ltd. Case Study.

[December 1985]

PYE TELECOM LTD. CAMBRIDGE [1985]

THE COMPANY, PRODUCTS AND MARKETS

Pye Telecom, a member of the Philips Group of Companies and part of the Professional Mobile Radio Group, produces Radio Telephones, Paging Systems and Portable Two-way Radios. These are produced for such customers as the police, fire brigades and defence as well as many other public utilities and industrial and commercial organisations in this country and abroad.

The Cambridge factory is one of two manufacturing sites in the U.K., the other being at Haverhill, 20 miles from Cambridge. At Haverhill, most of the mobile radios and the lower cost base stations (e.g. for taxis) are produced and at Cambridge there are four sections dealing with different products, namely; complex base stations, portable radios, special production units (customisation) and paging units. An example of one of the portable radios can be seen in figure 1.

The value of orders can be from as little £25 for some accessories to as large as a complete system for the whole of the public services of Kuwait. One of the latest portable radios, the PFX, sells for about £1000. The company offers about 100 major products, but within these it could sell approximately one billion different variations! Many of these variations occur because of the nature of the technology in the products in terms of non-programmability and the legal requirements from country to country and within countries in terms of frequencies, band spacing and power outputs. However, in practice, over the last four years, only 8,000 actual variants have been sold.

Virtually all products are made to customer order with a typical lead time of 12 weeks although the company does offer a "fast delivery" for some of the simpler products.

THE PRODUCTION PROCESS

The production processes at Pye Telecom are mainly assembly and test, which include chip placement, use of thick and thin film, P.C.B. production, final assembly and automated testing. Much of the layout is currently traditional batch manufacturing, but for the production of portables, three new flow lines are in the late stages of planning. They are currently producing about 600 of these portables per week in batches and experiencing considerable difficulties with work in progress and queueing. The new flow lines should enable lead times to be reduced from about 10 weeks to 3 weeks and output to be increased to 1,000 per week.

It is planned that much of the common inexpensive materials will be stored line-side and topped-up using some form of Kanban control. The more expensive and unique materials will be kitted from stores and will travel down the assembly lines in a kit container, to be used at the appropriate work stations. Bar-Code readers will be used for shop floor tracking.

COMPUTER SYSTEMS

The company currently uses an Amdahl V8 and an IBM 4300 computer with IBM's COPICS system which has been running for about three years. This incorporates all the usual modules together with a Commercial Order Servicing (COS) module developed by the Professional Systems Department of Philips ISA-UK and based on the IBM COPICS Customer Order Servicing module. Much of COS is on-line (see figure 2.) and is linked with COPICS Master Scheduling which is on-line and COPICS MRP which is batch run in regenerative mode every two weeks. Various P.C.'s are used in different departments and will be mentioned in the sections which follow.

The current systems are coping with approximately 100,000 part numbers of which 23,000 are viewed as live and current and 16,000 are classed as dynamic. There is about 50% commonality of parts within a major product range but very little commonality of parts between major products.

THE MASTER PRODUCTION SCHEDULE - OVERVIEW

Master Scheduling at Pye Telecom takes place on two levels. First of all the major basic products are scheduled, these having Bills of Material which contain historical percentages of the various variants which have been derived from data in the Commercial Order Servicing system. This generates an initial MPS for combinations of variant material which are grouped together into super bills of material. This initial MPS for super bills can then be modified by the Master Scheduler if the demand for option materials derived from actual customer orders appears to be significantly different from the MPS derived by using the historical percentages.

Currently the Master Schedule uses weeks as the planning period with an horizon of about 30 to 40 weeks, with the first 12 weeks being regarded as "frozen".

There are four Master Schedulers, each one responsible for one of the following product manufacturing areas: 1) Special Production Unit and Pagers, 2) Complex Mobiles, 3) Portables, 4) Haverhill (simple mobiles and base stations). The Master Schedulers report to a Production Planning Manager, who, in turn, reports to a Logistics Manager. (see figure 3.).

The constraints on Master Scheduling are in terms of Production Capacity, which is very difficult to alter within three months, meeting quoted delivery dates, reaching financial targets and containing manufacturing stock levels. The details of Master Scheduling will be dealt with in later sections.

PLANNING AND CONTROL SYSTEM INTERACTIONS

Using the basic model of MPS and its relationship with other planning and control activities as shown in figure 4.1 , this section describes how these relationships operate at Pye Telecom.

Demand Management

This incorporates the activities of forecasting, order entry and order promising and is dealt with mainly as part of the Commercial Order Servicing (COS) module.

Forecasting is carried out by the Marketing Department every three months, looking forward two years. Various pieces of information are brought together as depicted in figure 4. Trends are picked up by monitoring 3 month and 12 month averages for basic products (see figure 5.).

A forecast of variation codes (option mix) is also required for the two level Master Scheduling process and this is done by monitoring the historical monthly, moving annual total and moving quarterly totals and percentages. (see figure 6).

The sequence of events involved in order entry is shown in the functional flow diagram for the COS module (figure 7.). Orders arrive , usually by post, to the Order Schedulers who work in teams of two. The first carries out a technical check to validate the 17 digit sales order code (see figure 8.) using a PC database to ensure that the product is buildable and will meet the legal requirements of the market area in question. He will also check the price quoted using a PC based price monitoring system. If these checks are satisfactory, the order is passed on to the other scheduler who will enter and check customer details such as account number and salesman and enter order date, requested shipment date, sequential COS number and various other text messages. The order, including the full 17 digit code is then loaded onto the Sales Order File, the system carrying out an on-line check to see whether this code has ever been made before and if not, requesting confirmation of validation and suggesting the need to update the PC database. The order is then held pending a credit check of the customer and a check on crystal supply (a critical component) before being passed back to the Order Scheduler for final loading, acceptance and acknowledgement of delivery date. This final order loading is carried out using Projected Available To Promise (PATP) enquiries for the major equipment and all the super bill requirements of the order (i.e. at the option level). So for each relevant combination of variation code, a superbill has already been master scheduled and the check is then being made as to the earliest date that all material will be available. In figure 9, an example is shown for an order of 50 PF85 mobile radios, the basic equipment being available on 11/04/86 and all the option material being available by 27/03/86 (the latest ATP date). In this example the option material showing NO ATP has not been Master Scheduled and is being covered by a buffer stock. Since material from different manufacturing areas may be required, the ATP information has to be called up on different screens, so the Order Scheduler has a four screen gas plasma terminal plus another terminal for final entry of the order.

Production Planning

There is no clear-cut division between the Production Plan and the Master Production Schedule, the MPS being managed for the first 40 weeks or so of the 2 year plan.(i.e. the Planning Time Fence is set at 40 weeks.) The derivation of this plan will therefore be covered in the section on Master Scheduling.

Resource Planning and Rough Cut Capacity Planning

Again, since the Production Plan and MPS are one and the same, Resource and Rough Cut planning can be treated as one. A report is produced using a Multiplan Spreadsheet on a PC detailing the Labour Requirements and Labour Capacity for the three main manufacturing sections for each product. This is shown for fixed weekly run rates per product per quarter for the next year and accounts for lost time percentages under several headings. (see figure 10.) This plan is formally reviewed every quarter with the Technical Centre (Production) Managers concerned.

Material Requirements Planning

As mentioned previously, the standard COPICS MRP module is run in regenerative mode every two weeks. The MPS input is firm planned orders at the option (super bill) level. COPICS MRP has been in use for the last three years. A typical output in terms of a Time Phased Material Plan is shown in figure 11.

Capacity Requirements Planning

Detailed CRP is not carried out at Pye Telecom.

MASTER PRODUCTION SCHEDULE PREPARATION

This section outlines the detailed procedures for Master Scheduling which were started two years ago and implementation of which was completed one year ago.

Master Scheduling is seen to have several functions. It involves setting the Master Schedule and parameters down to the option level; it has the responsibility for the "health" of a factory; it is the main contact between Sales, Marketing, Engineering and Production and it has the responsibility for manufacturing stock levels.

There is actually another level above Master Scheduling referred to as Master Planning, which is involved in the setting of production strategies and the provision of logistics systems in and between factories.

The production of the MPS ("The Plan") entails the massaging of many pieces of information and then checking the outcome in terms of labour requirements as described previously. This process is best described in diagrammatic form as shown in figure 12. The forecasts of equipment orders and option mix are received from Marketing together with information on New Product Introductions and Product Cessations. The Master Scheduler takes account of orders already overdue and tries to reduce these to zero. He then looks at products currently being given extended delivery lead times and tries to bring these back to the minimum manufacturing lead time. Taking account of material buffers at the first and second levels of the bill of material and any Production Strategy for the build-up or reduction of commercial stocks, he then produces the MPS, first of all for the major equipment. (see figure 13.) This is then exploded to give an initial Option MPS Report (Figure 14.).

As described previously, these options are represented as super bills for the combinations of parts of the sales code. For example, the combination of Frame Size "B" and Band Receive "UP" for the PF85 mobile radio produces a super bill SBPF85/72 (see figure 9).There are approximately 400 super bills under each major product which have to be Master Scheduled. As described earlier, the initial super bill MPS may have to be altered if it is noticed that the historical percentage take up is not reflecting the actual option material requirement from customer orders scheduled. This is shown in the Actual Demand (ADEM), and reflected in the Projected Available balance (PAV) and Available to Promise (PATP & CATP) rows.

The first 12 weeks of the MPS are regarded as "frozen" and if an order is requested to be cancelled in this zone, another order with a very similar specification has to be found to replace it, otherwise the product will still be made and put into a "Frustrated Equipment Store" with the hope that it might eventually be sold.

Meetings are held with the Technical (Production) Managers every month to ascertain how any problems concerning overdues might be overcome within the quarter and there is a formal review of the plan every quarter.

PRODUCTION PLANNING AND CONTROL SYSTEM EVALUATION

In this section the performance measures which are used to evaluate the planning and control systems at Pye Telecom are briefly described and some of the improvements to the current methods of operating which are being planned are mentioned.

Measures

Delivery performance is measured in terms of the amount of overdue orders and the length of delivery lead times promised.

Manufacturing and commercial stock levels are also measured in financial and coverage terms.

Forecast Error is also measured by product and option.

Improvements

Most of the effort currently is being put into methods of simplifying the bill of material structures, particularly at the variant (super bill) level. Here the objective is to separate out common materials and then identify those few commonly made variants and deal with these on a different basis to the majority of less used variants. There is also a need to structure the bills of material to assist in the allocation of materials to the work stations on the new flow lines which are being planned.

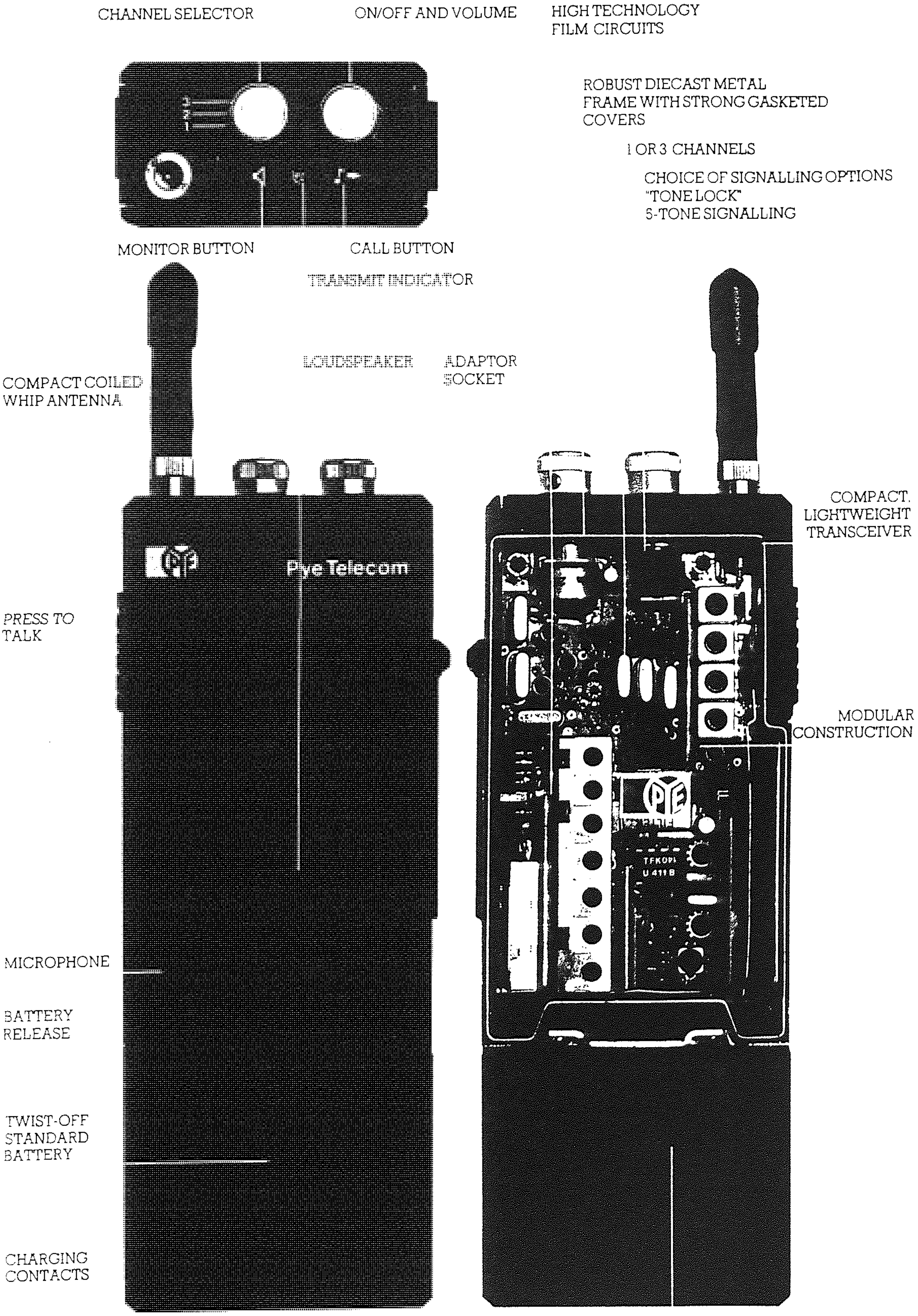


Figure 1. - Example of a PF85 Portable Radio

CONCEPTS

COMMERCIAL ORDER SERVICING

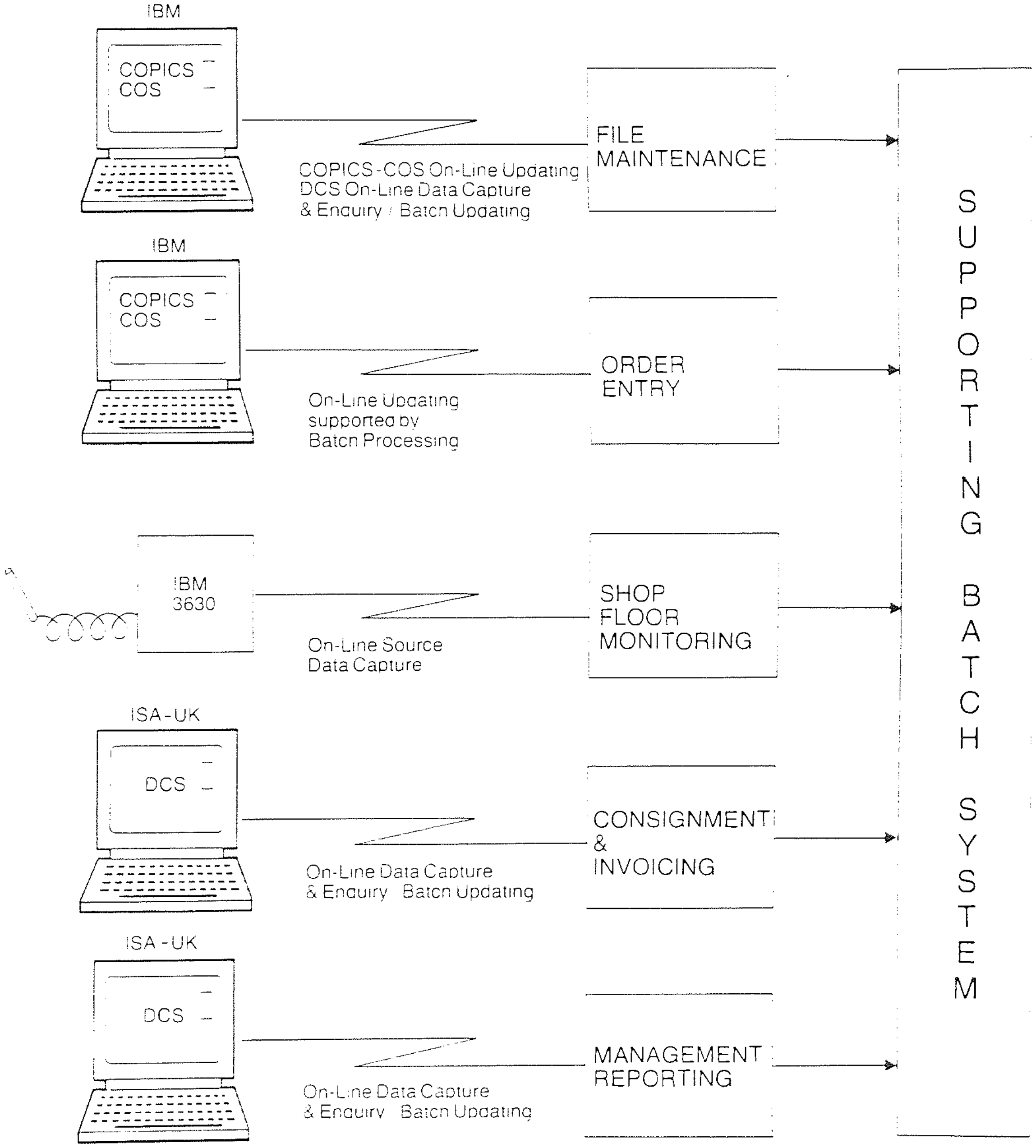


Figure 2. - Commercial Order Servicing System (COS)

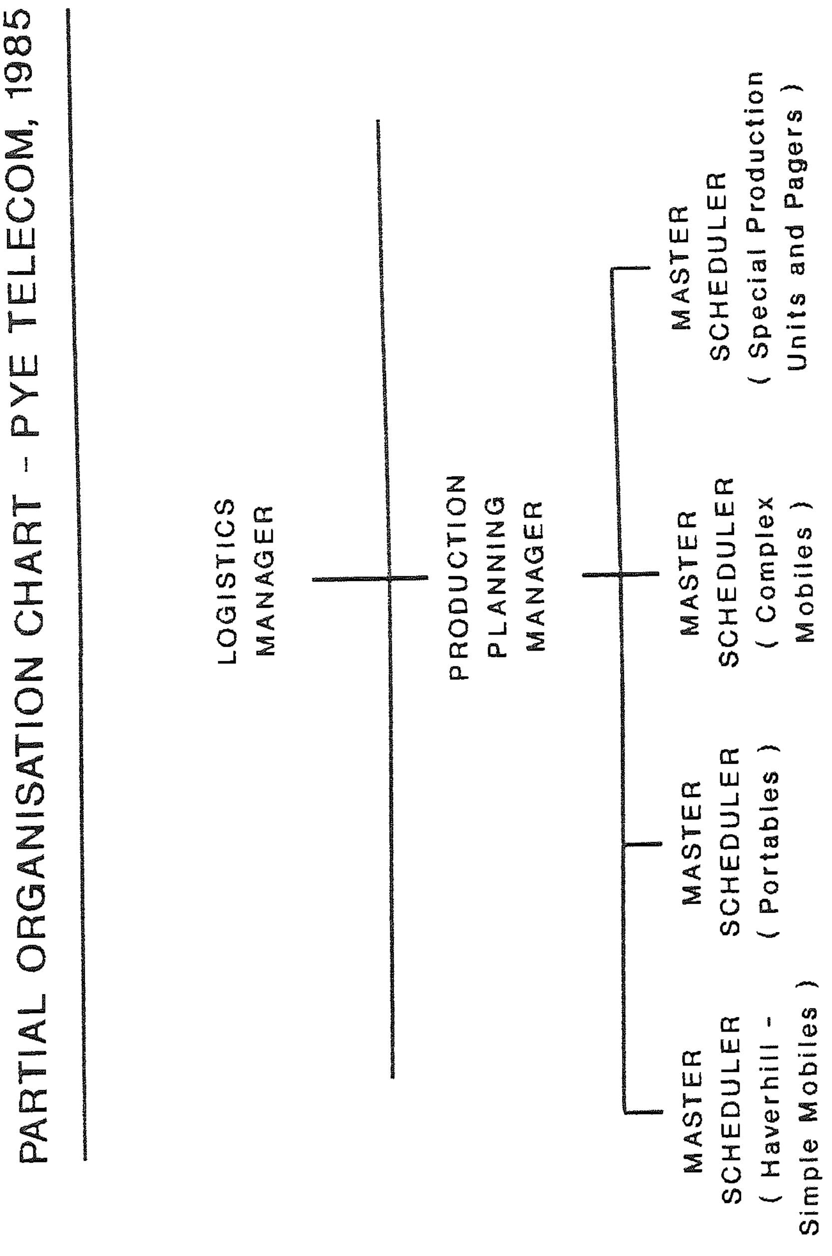


Figure 3. - Partial Organisation Chart

FORECASTING PROCEDURE

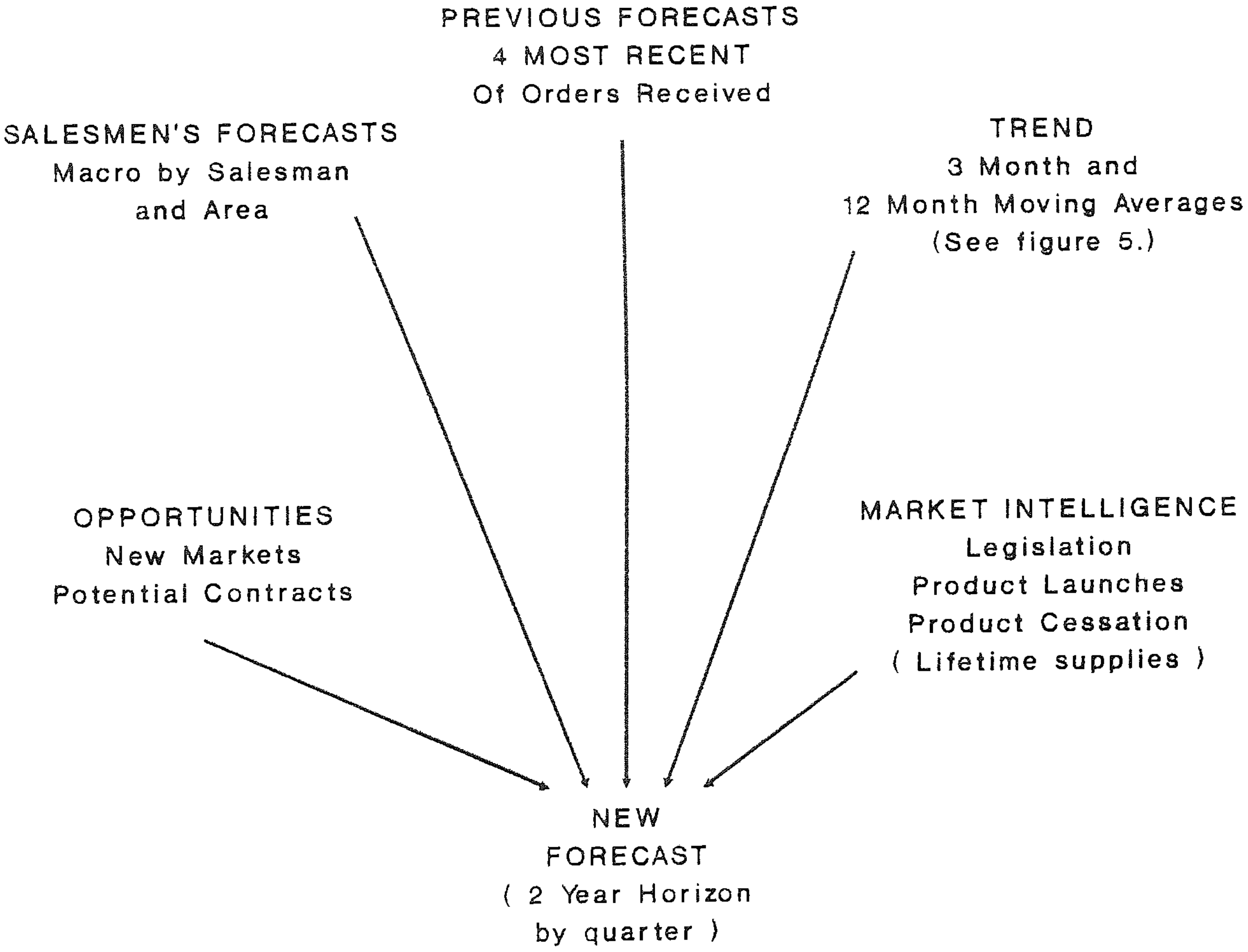
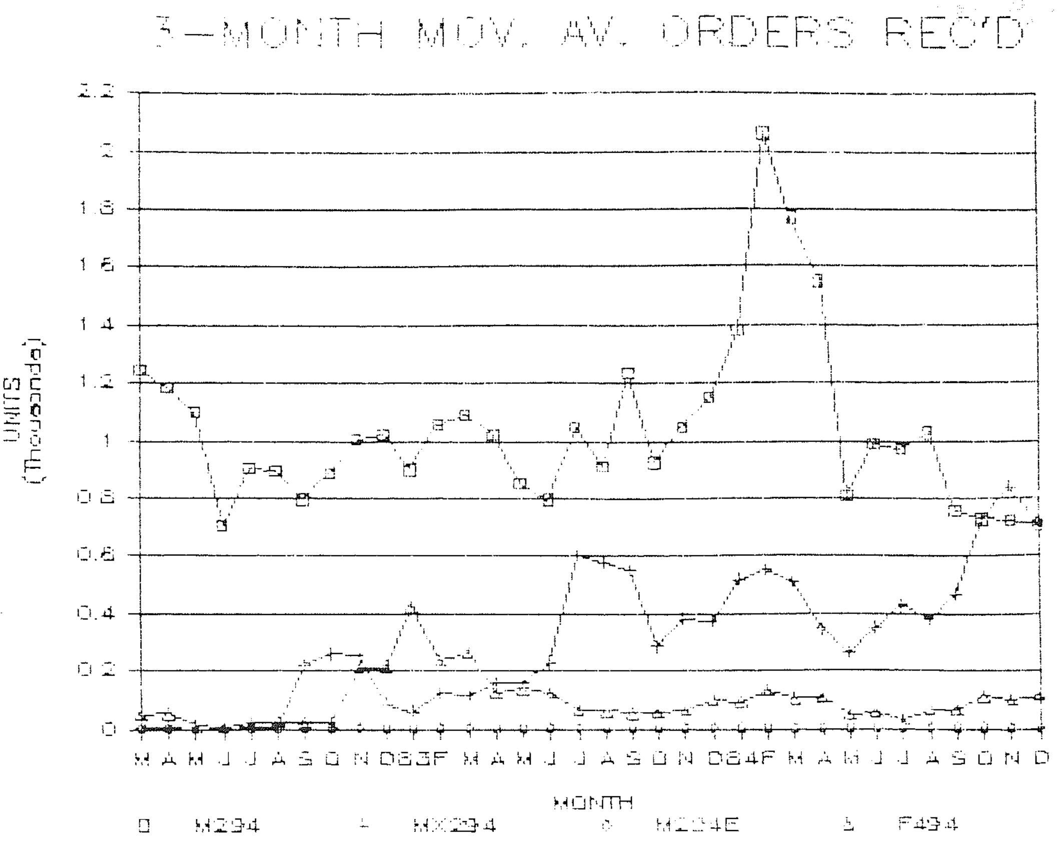


Figure 4. - Forecasting Procedure at Pye Telecom



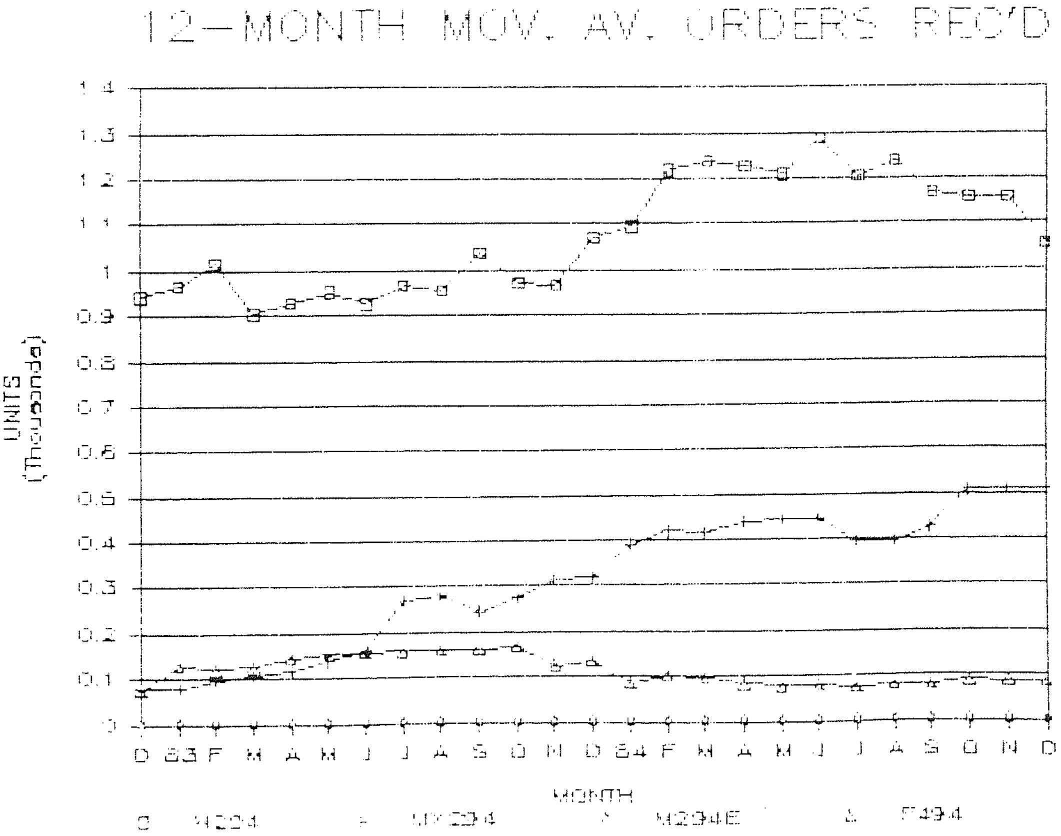


Figure 5. - Graphical Display of Orders Received

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                                                    PYE TELECOMMUNICATIONS LTD
25/11/85                                        VARIATION ANALYSIS AND PERCENTAGES                                              PAGE    20
RESPONSIBILITY: 01                              NOV84 DEC84 JAN85 FEB85 MAR85 APR85 MAY85 JUN85 JUL85 AUG85 SEP85 OCT85         OCT84
----------------------------------------------------------------------------------------------------------------------------------------
EQUIPMENT           ---VARIATION CODES---
                    MK SALES STNDRD PO SO
----------------------------------------------------------------------------------------------------------------------------------------

           .    .S--UP-.   .   MTH    75     3    15    70     1    18     1    26   107    14     0    13           15
                                PC     6     1     2     8     1     2     1     2     6     4     0     2
                               MAT   162   165   180   254   251   258   230   253   360   374   345   343           87
                                PC     2     2     2     3     3     3     2     2     3     3     3     3
                               MQT   119    93    93    88    86    89    20    45   134   147   121    27           44
                                PC     4     3     4     4     3     3     1     2     3     4     4     2

           .    .S--WP-.   .   MTH     0     0     0     0     0     0     0     0     0     0     0     0            0
                                PC     0     0     0     0     0     0     0     0     0     0     0     0
                               MAT     0     0     0     0     0     0     0     0     0     0     0     0            0
                                PC     0     0     0     0     0     0     0     0     0     0     0     0
                               MQT     0     0     0     0     0     0     0     0     0     0     0     0            0
                                PC     0     0     0     0     0     0     0     0     0     0     0     0

           .    .V-----.   .   MTH   623   440   629   508   882  1102   491   838   561   213   406   508          577
                                PC    49    80    65    54    47    72    40    59    30    52    47    59
                               MAT  4499  4875  5279  5266  5955  6808  7065  7263  7727  7304  7270  7201         4274
                                PC    51    53    54    53    53    56    56    56    53    52    51    52
                               MQT  1640  1640  1692  1577  2019  2492  2475  2431  1890  1612  1180  1127         1648
                                PC    50    52    60    64    54    58    54    58    42    44    38    53

           .    .V--A1-.   .   MTH    85    40   224     0    62    63    49   112    86     1    60     0           72
                                PC     7     8    23     0     4     5     4     8     5     1     7     0
                               MAT   410   414   607   578   685   692   722   733   857   810   854   782          625
                                PC     5     5     7     6     6     6     6     6     6     6     6     6
                               MQT   173   197   349   264   286   125   174   224   247   199   147    61          136
                                PC     6     7    13    11     8     3     4     6     6     6     5     3

           .    .V--A2-.   .   MTH    76    78   210     6    20   192    59   312   153     9    42    30          129
                                PC     6    15    22     1     2    13     5    22     9     3     5     4
                               MAT   586   654   839   820   776   879   915  1197  1330  1257  1286  1187          514
                                PC     7     8     9     9     7     8     8    10    10     9     9     9
                               MQT   218   283   364   294   236   218   271   563   524   474   204    81          224
                                PC     7     9    13    12     7     5     6    14    12    13     7     4

           .    .V--B1-.   .   MTH     0     0     0     0     1     0    20     0     0     0     0     1            0
                                PC     0     0     0     0     1     0     2     0     0     0     0     1
                               MAT     0     0     0     0     1     1    21    21    21    21    21    22            0
                                PC     0     0     0     0     1     1     1     1     1     1     1     1
                               MQT     0     0     0     0     1     1    21    20    20     0     0     1            0
                                PC     0     0     0     0     1     1     1     1     1     0     0     1

           .    .V--B2-.   .   MTH     0     0     0     0     0   132    20     1     0     0     0     0            0
                                PC     0     0     0     0     0     9     2     1     0     0     0     0
                               MAT     0     0     0     0     0   132   152   153   153   153   153   153            0
                                PC     0     0     0     0     0     2     2     2     2     2     2     2
                               MQT     0     0     0     0     0   132   152   153    21     1     0     0            0
                                PC     0     0     0     0     0     4     4     4     1     1     0     0
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Figure 6. - Variation Analysis and Percentages

FUNCTIONAL FLOW

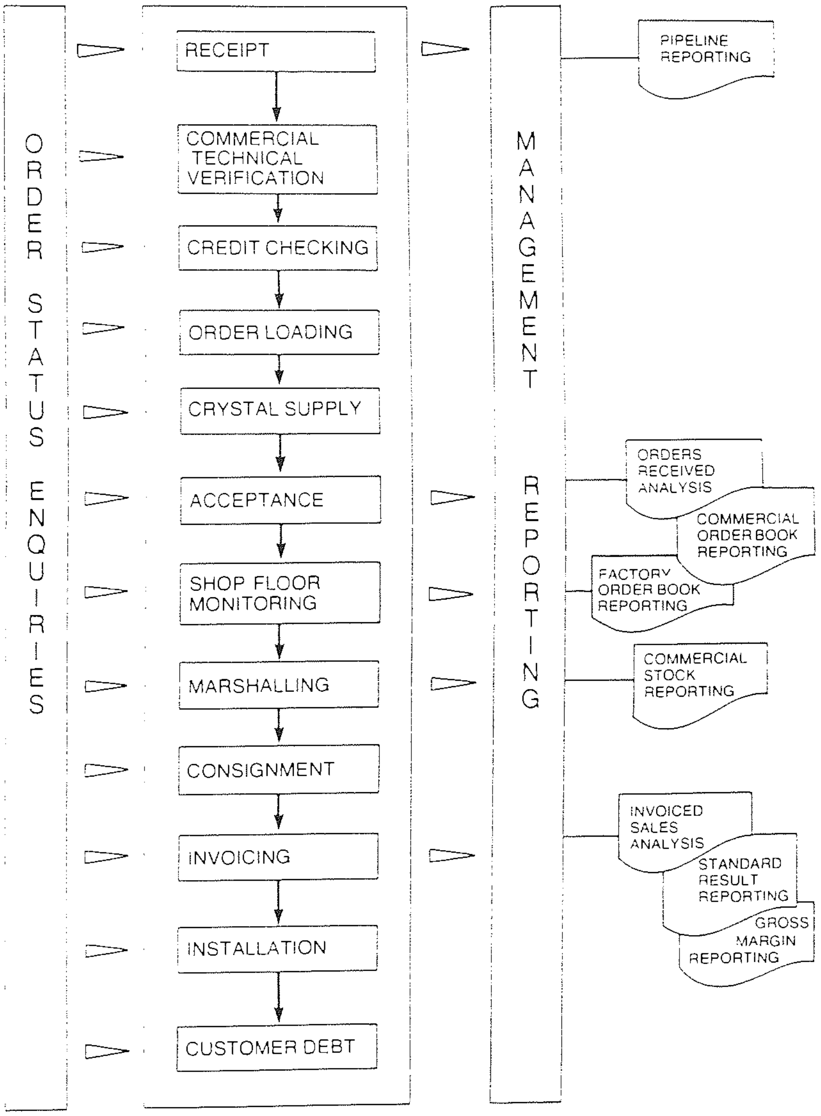


Figure 7. - Commercial Order Servicing - Functional Flow

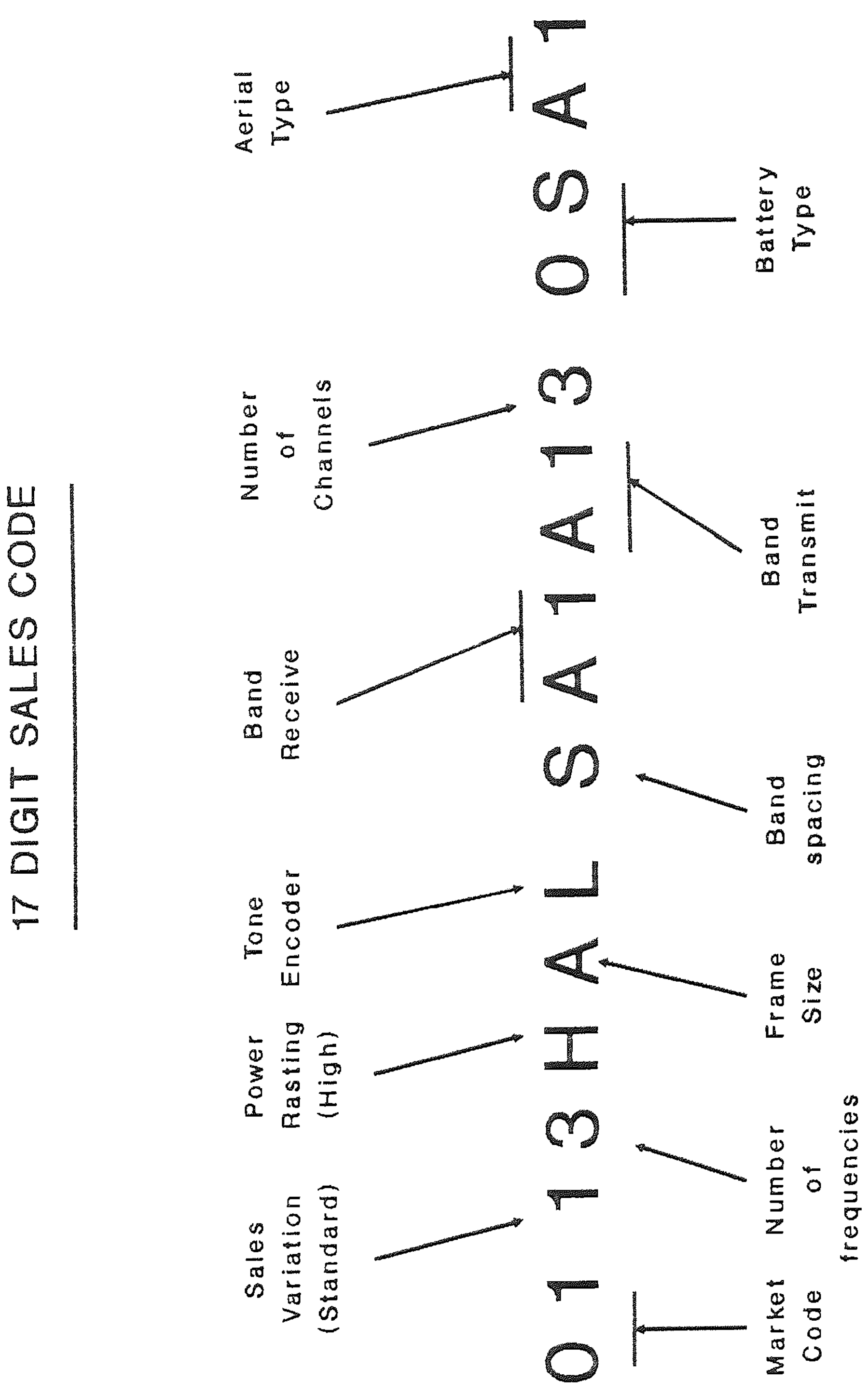
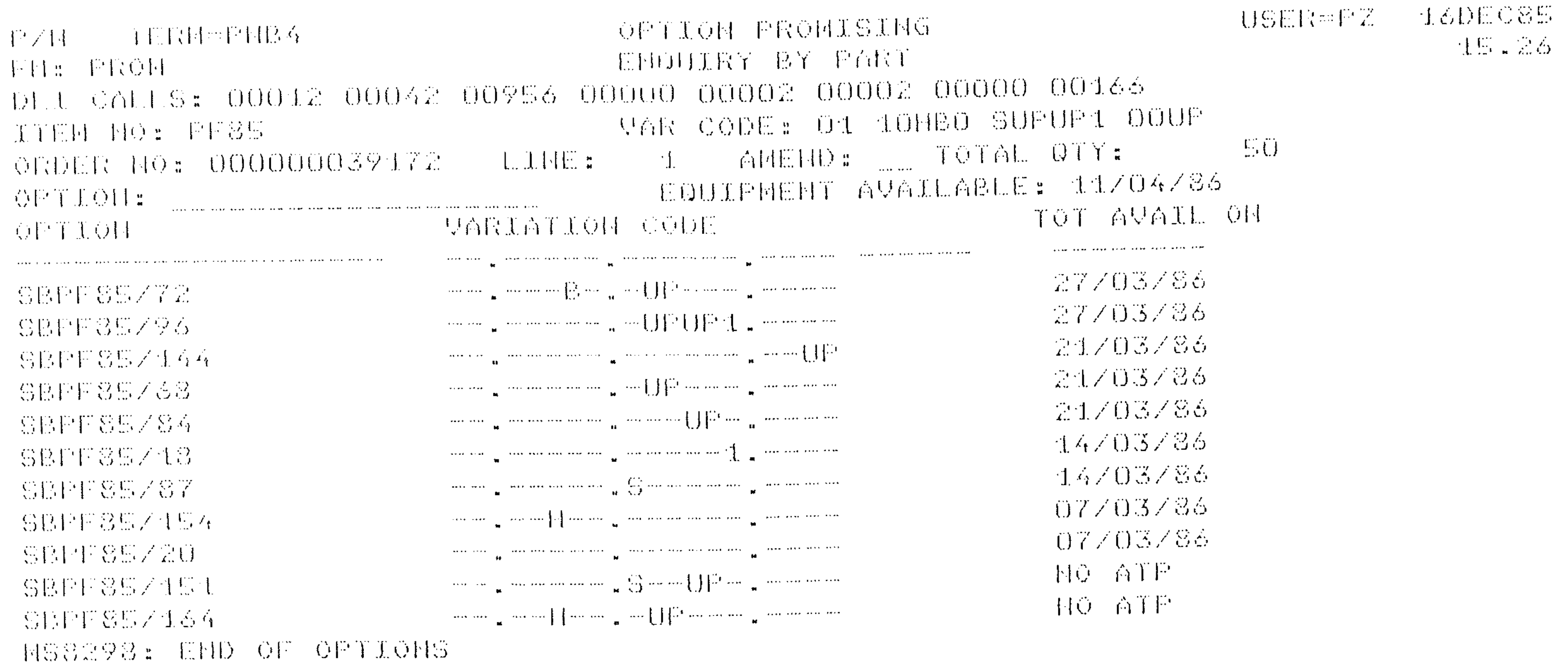
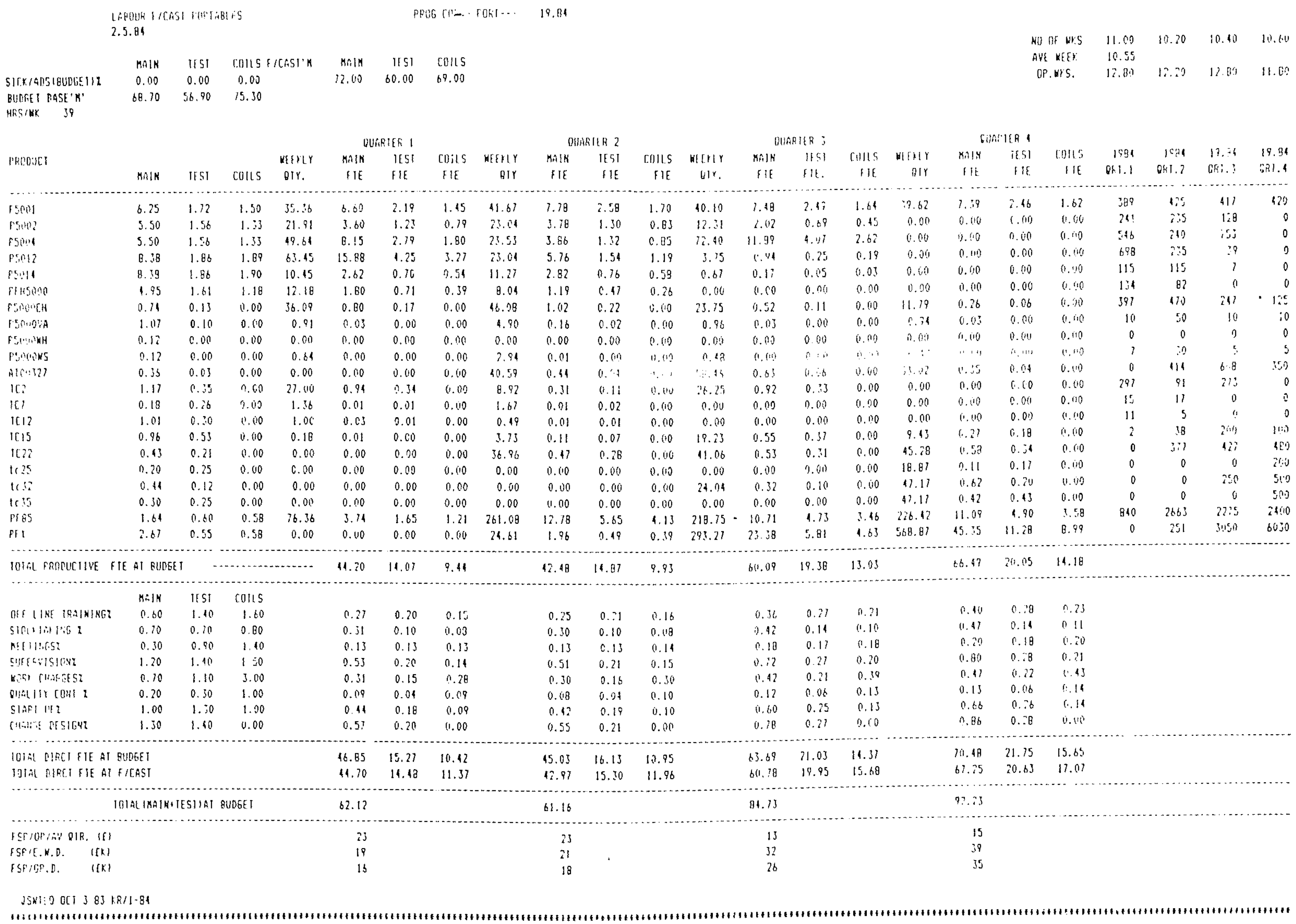


Figure 8. - 17 Digit Sales Code



```
P/N    TERM=PHB4                  OPTION PROMISING            USER=PZ  16DEC85
FN: PROM                          ENQUIRY BY PART                        15.26
DLI CALLS: 00012 00042 00956 00000 00002 00002 00000 00166
ITEM NO: PF85                     VAR CODE: 01 10HBO SUPUP1 OOUP
ORDER NO: 000000039172   LINE:   1   AMEND: __ TOTAL QTY:      50
OPTION: ____________________       EQUIPMENT AVAILABLE: 11/04/86
OPTION                VARIATION CODE                  TOT AVAIL ON
--------------------  --.-----.------.----  -----     --------
SBPF85/72             --.---B-.-UP---.----            27/03/86
SBPF85/96             --.-----.-UPUP1.----            27/03/86
SBPF85/144            --.-----.------.--UP            21/03/86
SBPF85/68             --.-----.-UP---.----            21/03/86
SBPF85/84             --.-----.---UP-.----            21/03/86
SBPF85/18             --.-----.-----1.----            14/03/86
SBPF85/87             --.-----.S-----.----            14/03/86
SBPF85/154            --.--H--.------.----            07/03/86
SBPF85/20             --.-----.------.----            07/03/86
SBPF85/151            --.-----.S--UP-.----            NO ATP
SBPF85/164            --.--H--.-UP---.----            NO ATP
HS8298: END OF OPTIONS
```

Figure 9. - Example of Option Promising

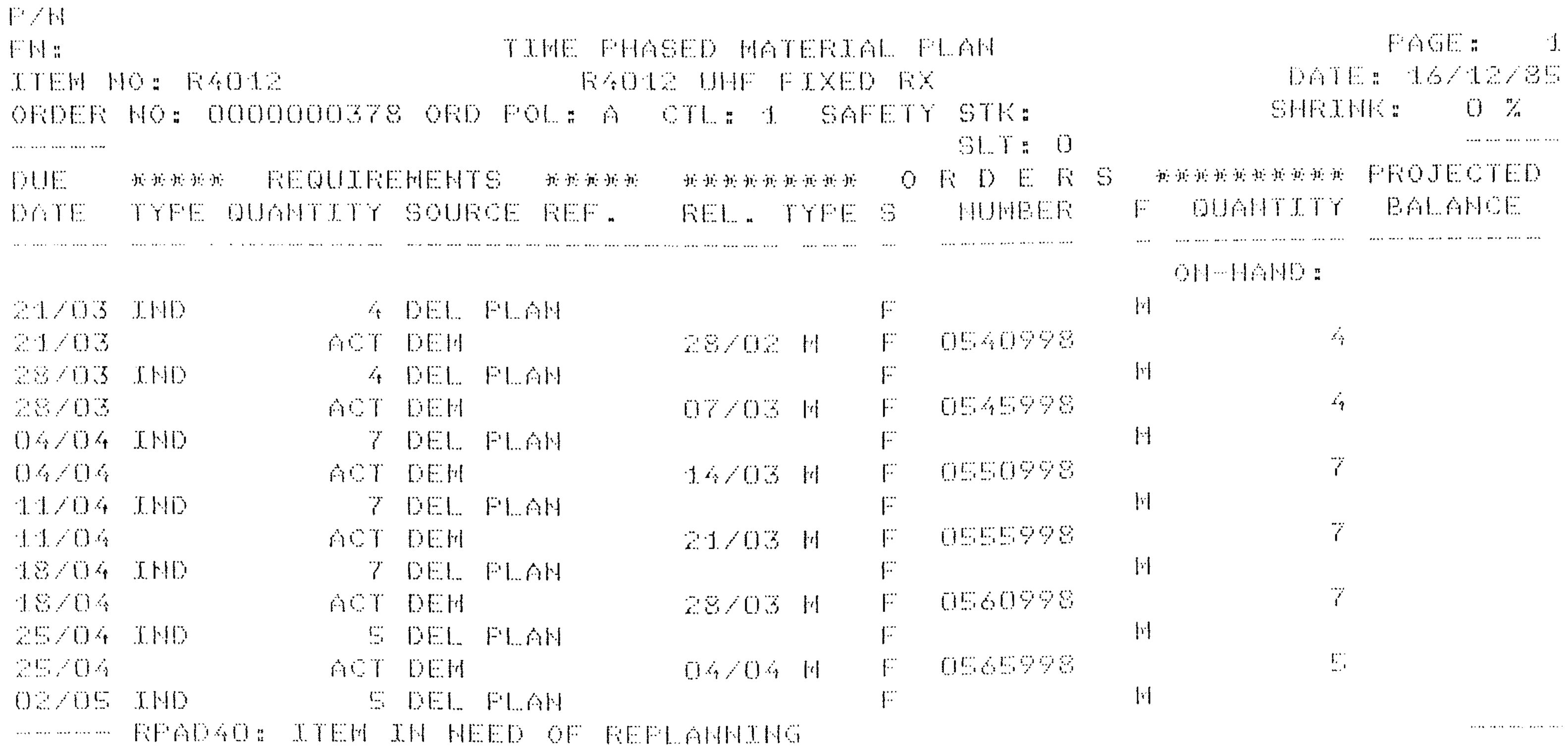


```
                LABOUR F/CAST PORTABLES                             PROG CO-- FORT---   19.84
                2.5.84                                                                                                                     NO OF WKS   11.09   10.20   10.40   10.60
                                                                                                                                           AVE WEEK    10.55
                   MAIN    TEST    COILS F/CAST'N   MAIN    TEST    COILS                                                                  OP.WKS.     12.80   12.20   12.80   11.00
SICK/ADS(BUDGET)%  0.00    0.00    0.00             72.00   60.00   69.00
BUDGET BASE'N'    68.70   56.90   75.30
HRS/WK    39

                                                      QUARTER 1                          QUARTER 2                          QUARTER 3                          QUARTER 4
PRODUCT                                  WEEKLY   MAIN    TEST    COILS   WEEKLY   MAIN    TEST    COILS   WEEKLY   MAIN    TEST    COILS   WEEKLY   MAIN    TEST    COILS   1984    1984    19.84   19.84
                   MAIN    TEST   COILS  QTY.     FTE     FTE     FTE        QTY   FTE     FTE     FTE     QTY.     FTE     FTE.    FTE        QTY   FTE     FTE     FTE     QRT.1   QRT.2   QRT.3   QRT.4
---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
F5001              6.25    1.72   1.50   35.36    6.60    2.19    1.45     41.67   7.78    2.58    1.70     40.10    7.48    2.47    1.64     39.62   7.39    2.46    1.62     389     475     417     420
P5002              5.50    1.56   1.33   21.91    3.60    1.23    0.79     23.04   3.78    1.30    0.83     12.31    2.02    0.69    0.45      0.00   0.00    0.00    0.00     241     235     128       0
P5004              5.50    1.56   1.33   49.64    8.15    2.79    1.80     23.53   3.86    1.32    0.85     72.40   11.99    4.07    2.62      0.00   0.00    0.00    0.00     546     240     753       0
P5012              8.38    1.86   1.89   63.45   15.88    4.25    3.27     23.04   5.76    1.54    1.19      3.75    0.94    0.25    0.19      0.00   0.00    0.00    0.00     698     235      39       0
P5014              8.39    1.86   1.90   10.45    2.62    0.70    0.54     11.27   2.82    0.76    0.58      0.67    0.17    0.05    0.03      0.00   0.00    0.00    0.00     115     115       7       0
FEH5000            4.95    1.61   1.18   12.18    1.80    0.71    0.39      8.04   1.19    0.47    0.26      0.00    0.00    0.00    0.00      0.00   0.00    0.00    0.00     134      82       0       0
P5000EH            0.74    0.13   0.00   36.09    0.80    0.17    0.00     46.08   1.02    0.22    0.00     23.75    0.52    0.11    0.00     11.79   0.26    0.06    0.00     397     470     247  •  125
F5000VA            1.07    0.10   0.00    0.91    0.03    0.00    0.00      4.90   0.16    0.02    0.00      0.96    0.03    0.00    0.00      0.34   0.03    0.00    0.00      10      50      10      10
P5000WH            0.12    0.00   0.00    0.00    0.00    0.00    0.00      0.00   0.00    0.00    0.00      0.00    0.00    0.00    0.00      0.00   0.00    0.00    0.00       0       0       0       0
P5000WS            0.12    0.00   0.00    0.64    0.00    0.00    0.00      2.94   0.01    0.00    0.00      0.48    0.00    0.00    0.00  [illegible]  0.00    0.00    0.00       7      30       5       5
AIC0327            0.35    0.03   0.00    0.00    0.00    0.00    0.00     40.59   0.44 [illegible] [illegible] [illegible] 0.63 0.56  0.00     33.02   0.35    0.04    0.00       0     414     648     350
TC2                1.17    0.35   0.60   27.00    0.94    0.34    0.00      8.92   0.31    0.11    0.00     26.25    0.92    0.33    0.00      0.00   0.00    0.00    0.00     297      91     273       0
TC7                0.18    0.26   0.00    1.36    0.01    0.01    0.00      1.67   0.01    0.02    0.00      0.00    0.00    0.00    0.00      0.00   0.00    0.00    0.00      15      17       0       0
TC12               1.01    0.30   0.00    1.00    0.03    0.01    0.00      0.49   0.01    0.01    0.00      0.00    0.00    0.00    0.00      0.00   0.00    0.00    0.00      11       5       0       0
TC15               0.96    0.53   0.00    0.18    0.01    0.00    0.00      3.73   0.11    0.07    0.00     19.23    0.55    0.37    0.00      9.43   0.27    0.18    0.00       2      38     200     100
TC22               0.43    0.21   0.00    0.00    0.00    0.00    0.00     36.96   0.47    0.28    0.00     41.06    0.53    0.31    0.00     45.28   0.58    0.34    0.00       0     377     427     480
tc25               0.20    0.25   0.00    0.00    0.00    0.00    0.00      0.00   0.00    0.00    0.00      0.00    0.00    0.00    0.00     18.87   0.11    0.17    0.00       0       0       0     200
tc32               0.44    0.12   0.00    0.00    0.00    0.00    0.00      0.00   0.00    0.00    0.00     24.04    0.32    0.10    0.00     47.17   0.62    0.20    0.00       0       0     250     500
tc35               0.30    0.25   0.00    0.00    0.00    0.00    0.00      0.00   0.00    0.00    0.00      0.00    0.00    0.00    0.00     47.17   0.42    0.43    0.00       0       0       0     500
PF85               1.64    0.60   0.58   76.36    3.74    1.65    1.21    261.08  12.78    5.65    4.13    218.75 - 10.71    4.73    3.46    226.42  11.09    4.90    3.58     840    2663    2275    2400
PF1                2.67    0.55   0.58    0.00    0.00    0.00    0.00     24.61   1.96    0.49    0.39    293.27   23.38    5.81    4.63    568.87  45.35   11.28    8.99       0     251    3050    6030
---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
TOTAL PRODUCTIVE  FTE AT BUDGET   -----------------   44.20   14.07    9.44             42.48   14.87    9.93             60.09   19.38   13.03             66.47   20.05   14.18
---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
                   MAIN    TEST   COILS
OFF LINE TRAINING%  0.60   1.40   1.60             0.27    0.20    0.15              0.25    0.21    0.16              0.36    0.27    0.21              0.40    0.28    0.23
STOLLAGING %        0.70   0.70   0.80             0.31    0.10    0.03              0.30    0.10    0.08              0.42    0.14    0.10              0.47    0.14    0.11
MEETINGS%           0.30   0.90   1.40             0.13    0.13    0.13              0.13    0.13    0.14              0.18    0.17    0.18              0.20    0.18    0.20
SUPERVISION%        1.20   1.40   1.50             0.53    0.20    0.14              0.51    0.21    0.15              0.72    0.27    0.20              0.80    0.28    0.21
WORK CHARGES%       0.70   1.10   3.00             0.31    0.15    0.28              0.30    0.16    0.30              0.42    0.21    0.39              0.47    0.22    0.43
QUALITY CONT %      0.20   0.30   1.00             0.09    0.04    0.09              0.08    0.04    0.10              0.12    0.06    0.13              0.13    0.06    0.14
START UP%           1.00   1.30   1.00             0.44    0.18    0.09              0.42    0.19    0.10              0.60    0.25    0.13              0.66    0.26    0.14
CHANGE DESIGN%      1.30   1.40   0.00             0.57    0.20    0.00              0.55    0.21    0.00              0.78    0.27    0.00              0.86    0.28    0.00
---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
TOTAL DIRCT FTE AT BUDGET                         46.85   15.27   10.42             45.03   16.13   10.95             63.69   21.03   14.37             70.48   21.75   15.65
TOTAL DIRCT FTE AT F/CAST                         44.70   14.48   11.37             42.97   15.30   11.96             60.78   19.95   15.68             67.75   20.63   17.07
---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
                 TOTAL(MAIN+TEST)AT BUDGET        62.12                             61.16                             84.73                             92.23
---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
FSP/OP/AV DIR. (E)                                  23                                23                                13                                15
FSP/E.W.D.     (EK)                                 19                                21                                32                                39
FSP/OP.D.      (EK)                                 16                                18                                26                                35

 JSWIED OCT 3 83 KR/1-84
#############################################################################################################################################################################################
```

Figure 10. - Labour Forecast - Portables



```
P/N
FN:                      TIME PHASED MATERIAL PLAN                   PAGE:    1
ITEM NO: R4012               R4012 UHF FIXED RX                 DATE: 16/12/85
ORDER NO: 0000000378 ORD POL: A  CTL: 1  SAFETY STK:           SHRINK:    0 %
----                                            SLT: 0                   -----
DUE   *****  REQUIREMENTS  *****  ********** O R D E R S  ********** PROJECTED
DATE  TYPE QUANTITY SOURCE REF.   REL. TYPE S   NUMBER   F  QUANTITY  BALANCE
----  ---- -------- ------------------------ ---- -   -------   -  -------- --------
                                                           ON-HAND:
21/03 IND         4 DEL PLAN                F            M
21/03           ACT DEM           28/02 M   F  0540998             4
28/03 IND         4 DEL PLAN                F            M
28/03           ACT DEM           07/03 M   F  0545998             4
04/04 IND         7 DEL PLAN                F            M
04/04           ACT DEM           14/03 M   F  0550998             7
11/04 IND         7 DEL PLAN                F            M
11/04           ACT DEM           21/03 M   F  0555998             7
18/04 IND         7 DEL PLAN                F            M
18/04           ACT DEM           28/03 M   F  0560998             7
25/04 IND         5 DEL PLAN                F            M
25/04           ACT DEM           04/04 M   F  0565998             5
02/05 IND         5 DEL PLAN                F            M
----- RPAD40: ITEM IN NEED OF REPLANNING                                 -----
```

Figure 11. - Example of a Time Phased Material Plan

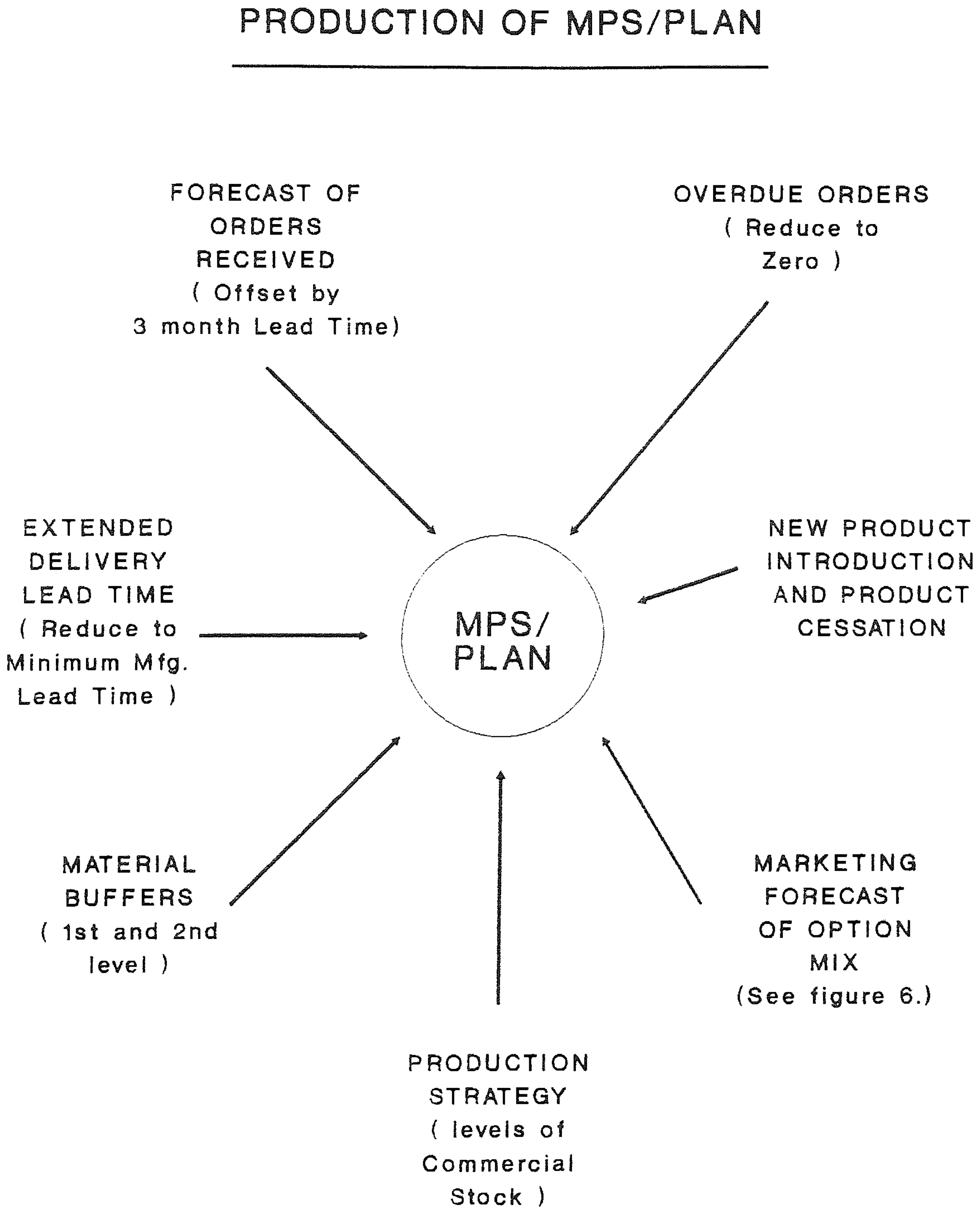
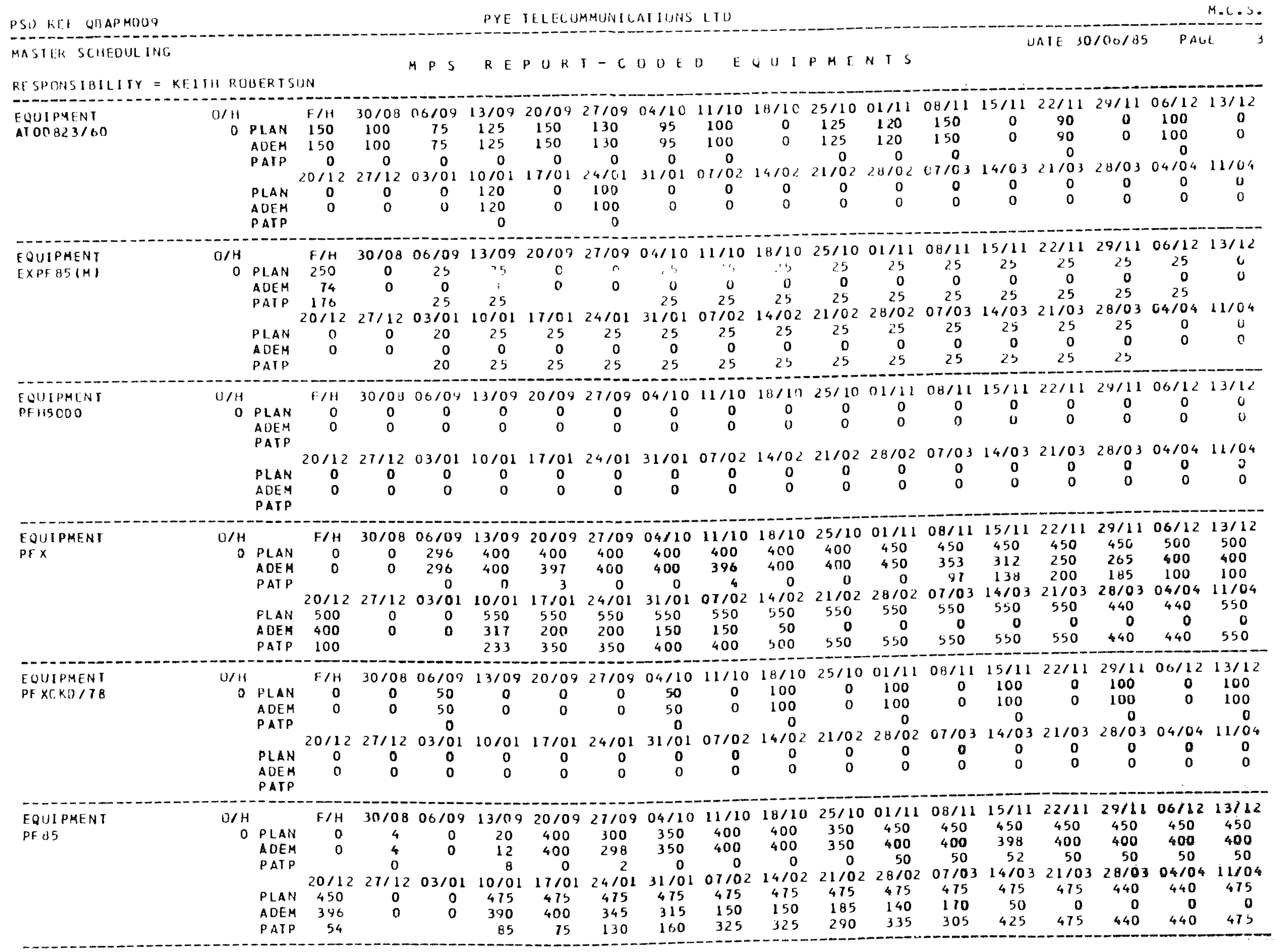
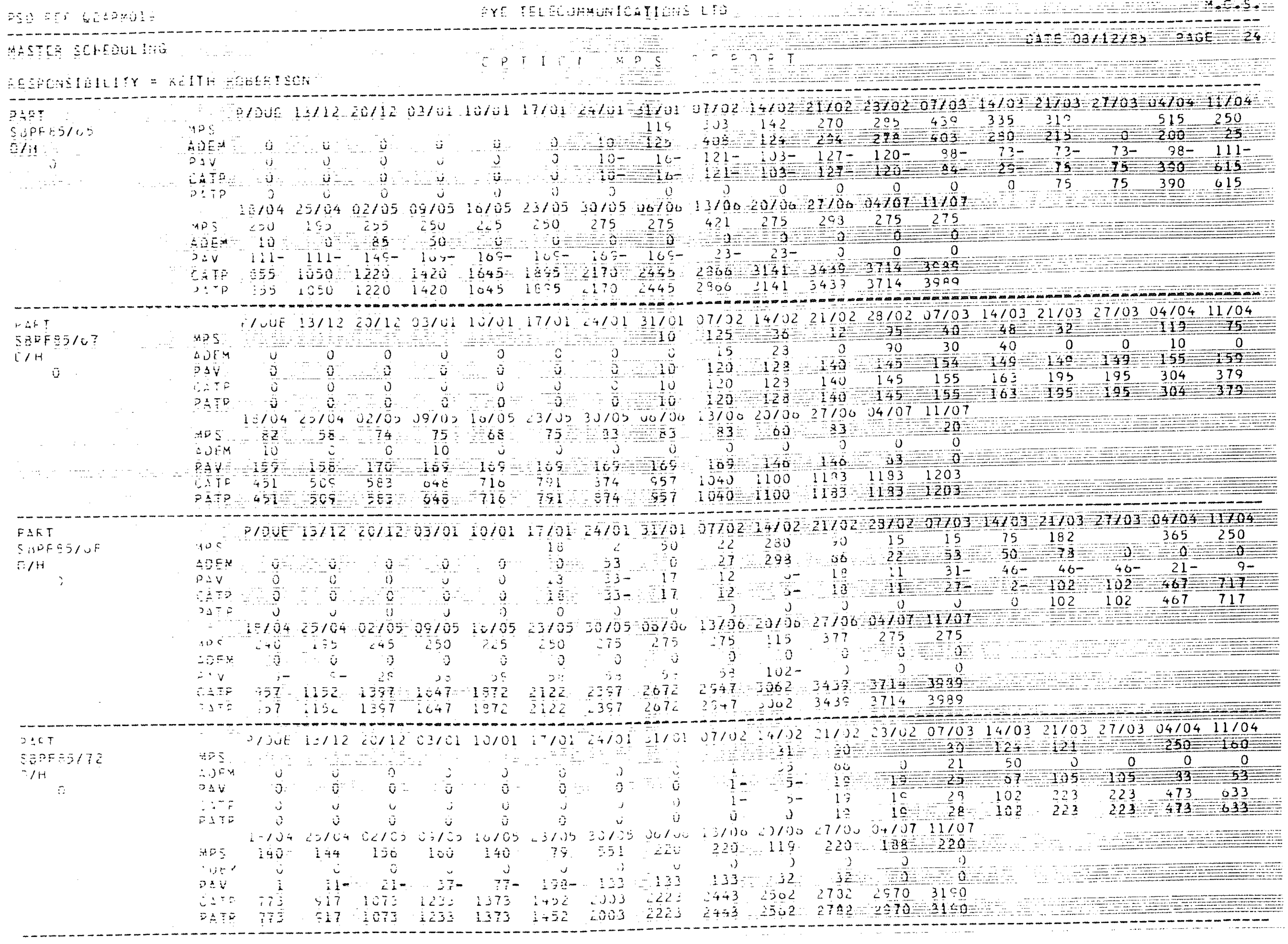


Figure 12. - Production of the MPS/Plan



```
PSD REF QBAPM009                        PYE TELECOMMUNICATIONS LTD                                              M.C.S.
                                                                                                   DATE 30/06/85   PAGE   3
MASTER SCHEDULING
                                  M P S   R E P O R T - C O D E D   E Q U I P M E N T S
RESPONSIBILITY = KEITH ROBERTSON
--------------------------------------------------------------------------------------------------------------------------------------------
EQUIPMENT         O/H         F/H  30/08  06/09  13/09  20/09  27/09  04/10  11/10  18/10  25/10  01/11  08/11  15/11  22/11  29/11  06/12  13/12
AT00823/60          0 PLAN    150    100     75    125    150    130     95    100      0    125    120    150      0     90      0    100      0
                      ADEM    150    100     75    125    150    130     95    100      0    125    120    150      0     90      0    100      0
                      PATP      0      0      0      0      0      0      0      0             0      0      0             0             0
                            20/12  27/12  03/01  10/01  17/01  24/01  31/01  07/02  14/02  21/02  28/02  07/03  14/03  21/03  28/03  04/04  11/04
                      PLAN      0      0      0    120      0    100      0      0      0      0      0      0      0      0      0      0      0
                      ADEM      0      0      0    120      0    100      0      0      0      0      0      0      0      0      0      0      0
                      PATP                             0             0
--------------------------------------------------------------------------------------------------------------------------------------------
EQUIPMENT         O/H         F/H  30/08  06/09  13/09  20/09  27/09  04/10  11/10  18/10  25/10  01/11  08/11  15/11  22/11  29/11  06/12  13/12
EXPF85(H)           0 PLAN    250      0     25     25      0      0     25     25     25     25     25     25     25     25     25     25      0
                      ADEM     74      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0
                      PATP    176            25     25                   25     25     25     25     25     25     25     25     25     25
                            20/12  27/12  03/01  10/01  17/01  24/01  31/01  07/02  14/02  21/02  28/02  07/03  14/03  21/03  28/03  04/04  11/04
                      PLAN      0      0     20     25     25     25     25     25     25     25     25     25     25     25     25      0      0
                      ADEM      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0
                      PATP                   20     25     25     25     25     25     25     25     25     25     25     25     25
--------------------------------------------------------------------------------------------------------------------------------------------
EQUIPMENT         O/H         F/H  30/08  06/09  13/09  20/09  27/09  04/10  11/10  18/10  25/10  01/11  08/11  15/11  22/11  29/11  06/12  13/12
PFH5000             0 PLAN      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0
                      ADEM      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0
                      PATP
                            20/12  27/12  03/01  10/01  17/01  24/01  31/01  07/02  14/02  21/02  28/02  07/03  14/03  21/03  28/03  04/04  11/04
                      PLAN      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0
                      ADEM      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0
                      PATP
--------------------------------------------------------------------------------------------------------------------------------------------
EQUIPMENT         O/H         F/H  30/08  06/09  13/09  20/09  27/09  04/10  11/10  18/10  25/10  01/11  08/11  15/11  22/11  29/11  06/12  13/12
PFX                 0 PLAN      0      0    296    400    400    400    400    400    400    400    450    450    450    450    450    500    500
                      ADEM      0      0    296    400    397    400    400    396    400    400    450    353    312    250    265    400    400
                      PATP                    0      0      3      0      0      4      0      0      0     97    138    200    185    100    100
                            20/12  27/12  03/01  10/01  17/01  24/01  31/01  07/02  14/02  21/02  28/02  07/03  14/03  21/03  28/03  04/04  11/04
                      PLAN    500      0      0    550    550    550    550    550    550    550    550    550    550    550    440    440    550
                      ADEM    400      0      0    317    200    200    150    150     50      0      0      0      0      0      0      0      0
                      PATP    100                  233    350    350    400    400    500    550    550    550    550    550    440    440    550
--------------------------------------------------------------------------------------------------------------------------------------------
EQUIPMENT         O/H         F/H  30/08  06/09  13/09  20/09  27/09  04/10  11/10  18/10  25/10  01/11  08/11  15/11  22/11  29/11  06/12  13/12
PFXCKD/78           0 PLAN      0      0     50      0      0      0     50      0    100      0    100      0    100      0    100      0    100
                      ADEM      0      0     50      0      0      0     50      0    100      0    100      0    100      0    100      0    100
                      PATP                    0                           0             0             0             0             0             0
                            20/12  27/12  03/01  10/01  17/01  24/01  31/01  07/02  14/02  21/02  28/02  07/03  14/03  21/03  28/03  04/04  11/04
                      PLAN      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0
                      ADEM      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0
                      PATP
--------------------------------------------------------------------------------------------------------------------------------------------
EQUIPMENT         O/H         F/H  30/08  06/09  13/09  20/09  27/09  04/10  11/10  18/10  25/10  01/11  08/11  15/11  22/11  29/11  06/12  13/12
PF85                0 PLAN      0      4      0     20    400    300    350    400    400    350    450    450    450    450    450    450    450
                      ADEM      0      4      0     12    400    298    350    400    400    350    400    400    398    400    400    400    400
                      PATP             0             8      0      2      0      0      0      0     50     50     52     50     50     50     50
                            20/12  27/12  03/01  10/01  17/01  24/01  31/01  07/02  14/02  21/02  28/02  07/03  14/03  21/03  28/03  04/04  11/04
                      PLAN    450      0      0    475    475    475    475    475    475    475    475    475    475    475    440    440    475
                      ADEM    396      0      0    390    400    345    315    150    150    185    140    170     50      0      0      0      0
                      PATP     54                   85     75    130    160    325    325    290    335    305    425    475    440    440    475
--------------------------------------------------------------------------------------------------------------------------------------------
```

Figure 13. - MPS Report - Coded Equipments



```
PSD REF Q2APM01                          PYE TELECOMMUNICATIONS LTD                                                M.C.S.
--------------------------------------------------------------------------------------------------------------------------
MASTER SCHEDULING                                                                          DATE 03/12/85   PAGE   24
                                          O P T I O N   M P S   R E P O R T
RESPONSIBILITY = KEITH ROBERTSON
--------------------------------------------------------------------------------------------------------------------------
PART                P/DUE 13/12 20/12 03/01 10/01 17/01 24/01 31/01 07/02 14/02 21/02 23/02 07/03 14/03 21/03 27/03 04/04 11/04
SBPF85/65     MPS                                                119   303   142   270   295   439   335   319         515   250
O/H           ADEM      0     0     0     0     0     0    10   125   405   124   294   278   403   280   215     0   200    25
     0        PAV       0     0     0     0     0     0   10-   16-  121-  103-  127-  120-   98-   73-   73-   73-   98-  111-
              CATP      0     0     0     0     0     0   10-   16-  121-  103-  127-  120-   84-   29-    75    75   390   615
              PATP      0     0     0     0     0     0     0     0     0     0     0     0     0     0    75    75   390   615
                    18/04 25/04 02/05 09/05 16/05 23/05 30/05 06/06 13/06 20/06 27/06 04/07 11/07
              MPS     250   195   255   250   225   250   275   275   421   275   293   275   275
              ADEM     10     0    85    50     0     0     0     0     0     0     0     0     0
              PAV    111-  111-  149-  169-  169-  169-  169-  169-   23-   23-     0     0     0
              CATP    855  1050  1220  1420  1645  1895  2170  2445  2866  3141  3439  3714  3989
              PATP    855  1050  1220  1420  1645  1895  2170  2445  2866  3141  3439  3714  3989
--------------------------------------------------------------------------------------------------------------------------
PART                P/DUE 13/12 20/12 03/01 10/01 17/01 24/01 31/01 07/02 14/02 21/02 28/02 07/03 14/03 21/03 27/03 04/04 11/04
SBPF85/67     MPS                                                 10   125    36    12    35    40    48    32         113    75
O/H           ADEM      0     0     0     0     0     0     0     0    15    23     0    90    30    40     0     0    10     0
     0        PAV       0     0     0     0     0     0     0    10   120   128   140   145   154   149   149   139   155   159
              CATP      0     0     0     0     0     0     0    10   120   128   140   145   155   163   195   195   304   379
              PATP      0     0     0     0     0     0     0    10   120   128   140   145   155   163   195   195   304   379
                    18/04 25/04 02/05 09/05 16/05 23/05 30/05 06/06 13/06 20/06 27/06 04/07 11/07
              MPS      82    58    74    75    68    75    83    83    83    60    83          20
              ADEM     10     0     0    10     0     0     0     0     0     0     0     0     0
              PAV     159   158   170   169   169   169   169   169   169   146   146    83     0
              CATP    451   509   583   648   716   791   874   957  1040  1100  1183  1183  1203
              PATP    451   509   583   648   716   791   874   957  1040  1100  1183  1183  1203
--------------------------------------------------------------------------------------------------------------------------
PART                P/DUE 13/12 20/12 03/01 10/01 17/01 24/01 31/01 07/02 14/02 21/02 28/02 07/03 14/03 21/03 27/03 04/04 11/04
SBPF85/68     MPS                                          18     2    50    22   280    90    15    15    75   182         365   250
O/H           ADEM      0     0     0     0     0     0    53     0    27   298    66    22    53    50    73     0     0     0
     0        PAV       0     0     0     0     0    18   33-    17    12    5-    18    11   31-   46-   46-   46-   21-    9-
              CATP      0     0     0     0     0    18   33-    17    12    5-    18    11   27-    2-   102   102   467   717
              PATP      0     0     0     0     0     0     0     0     0     0     0     0     0     0   102   102   467   717
                    18/04 25/04 02/05 09/05 16/05 23/05 30/05 06/06 13/06 20/06 27/06 04/07 11/07
              MPS     240   195   245   250   225   250   275   275   275   115   377   275   275
              ADEM      0     0     0     0     0     0     0     0     0     0     0     0     0
              PAV      5-    9-    29    55    59    58    58    57    53  102-     0     0     0
              CATP    957  1152  1397  1647  1972  2122  2397  2672  2947  3062  3439  3714  3989
              PATP    957  1152  1397  1647  1972  2122  2397  2672  2947  3062  3439  3714  3989
--------------------------------------------------------------------------------------------------------------------------
PART                P/DUE 13/12 20/12 03/01 10/01 17/01 24/01 31/01 07/02 14/02 21/02 23/02 07/03 14/03 21/03 27/03 04/04 11/04
SBPF85/72     MPS                                                             31    30          30   124   121         250   160
O/H           ADEM      0     0     0     0     0     0     0     0     1    35    66     0    21    50     0     0     0     0
     0        PAV       0     0     0     0     0     0     0     0    1-    5-    19    19    25    67   105   105    33    53
              CATP      0     0     0     0     0     0     0     0    1-    5-    19    19    28   102   223   223   473   633
              PATP      0     0     0     0     0     0     0     0     0     0    19    19    28   102   223   223   473   633
                    18/04 25/04 02/05 09/05 16/05 23/05 30/05 06/06 13/06 20/06 27/06 04/07 11/07
              MPS     140   144   156   160   140    79   551   220   220   119   220   188   220
              ADEM      0     0     0     0     0     0     0     0     0     0     0     0     0
              PAV       1   11-   21-   37-   77-  198-   133   133   133    32    32     0     0
              CATP    773   917  1073  1233  1373  1452  2003  2223  2443  2562  2732  2970  3190
              PATP    773   917  1073  1233  1373  1452  2003  2223  2443  2562  2782  2970  3190
--------------------------------------------------------------------------------------------------------------------------
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Figure 14. - Option MPS Report

Appendix 10.

User Survey Questionnaire.

ASTON BUSINESS SCHOOL

☐☐☐☐

USER SURVEY OF CAPACITY REQUIREMENTS PLANNING IN MANUFACTURING PLANNING AND CONTROL SYSTEMS

Would you like a summary of the findings of this survey ? YES / NO

SECTION A. - GENERAL

1.Respondent Name : ______________________ Position: ______________________

Company Name : ____

2.Company Address : ____
____
____

3. Approximate number of Employees : ☐☐☐☐

4. Approximate Annual Turnover (£m) : ☐☐☐☐

5. Industry : (Please tick one box)

- Food, drink & tobacco ☐
- Metal goods & machinery ☐
- Vehicle manufacture ☐
- Brick, pottery, glass, cement, etc. ☐
- Textiles, leather, footwear & clothing ☐
- Timber & furniture ☐
- Paper, printing & packaging ☐
- Mechanical engineering ☐
- Electrical & electronic engineering ☐
- Shipbuilding & marine engineering ☐
- Aerospace engineering ☐
- Construction & civil engineering ☐
- Other (Please specify) ☐

6. Type of Operation :
(Please tick as many boxes as you wish)

Manufacturing ☐	Assembly ☐	Process ☐
Make to stock ☐	Make to order ☐	Repetitive ☐
Large Batch ☐	Small/medium Batch ☐	One-offs ☐

SECTION B. - COMPUTER HARDWARE AND SOFTWARE

Answers in this section are concerned with Manufacturing Planning and Control systems (only include other systems if part of an integrated approach).

7. Type of Hardware: (Tick as many boxes as you wish)

Main Frame ☐	Mini ☐
P.C.'s (networked) ☐	P.C. (s) (Stand-alone) ☐

8. Type of Software:

(Please tick as many boxes as you wish)

Standard Package	(Package Name(s))	Customised Package	(Package Name(s))
☐	____________	☐	____________
	____________		____________
	____________		____________

Internally developed software ☐

9. Software modules used:

Please refer to figure 1. for a diagram of typical module information flows.

Module	Packaged Module purchased (Please tick)	Module developed internally (Please tick)	Is this module being used routinely?	How long since purchased /developed (months)	If planned to purchase or develop, when? (months)
Sales Order Processing	☐	☐	☐	☐☐	☐☐
Sales Forecasting	☐	☐	☐	☐☐	☐☐
Resource Requirements Planning	☐	☐	☐	☐☐	☐☐
Master Production Scheduling	☐	☐	☐	☐☐	☐☐
Rough Cut Capacity Planning	☐	☐	☐	☐☐	☐☐
Inventory Management	☐	☐	☐	☐☐	☐☐
Bills of Material	☐	☐	☐	☐☐	☐☐
Routing File	☐	☐	☐	☐☐	☐☐
Work Centre File	☐	☐	☐	☐☐	☐☐
Material Requirements Planning	☐	☐	☐	☐☐	☐☐
Capacity Requirements Planning	☐	☐	☐	☐☐	☐☐
Shopfloor Scheduling	☐	☐	☐	☐☐	☐☐
Works Order Control	☐	☐	☐	☐☐	☐☐
Purchase Order Control	☐	☐	☐	☐☐	☐☐
Shop Floor Data Collection	☐	☐	☐	☐☐	☐☐
JIT software (please specify)	☐	☐	☐	☐☐	☐☐
Synchronised manufacturing software... OPT or Other (please specify)	☐	☐	☐	☐☐	☐☐
Any other Production Management software (please specify)	☐	☐	☐	☐☐	☐☐

SECTION C. - USE OF CAPACITY OR RESOURCE PLANNING

10. **Resource Requirements Planning (RRP)** or Resource Planning refers to the translation of a long term Production (or Business) Plan into resource terms. Please refer to figure 1.

If RRP is not being carried out, please move to 10 j).

a). Is Resource Requirements Planning carried out....

(Please tick as many boxes as you wish)

Manually	Using a P.C. spreadsheet	Using a software module
☐	☐	☐

b). For RRP, what horizon do you plan against?

(months) ☐☐☐

c). For RRP what planning periods (buckets) are used?

(Please tick as many boxes as you wish)

Years	Qtrs.	Months	Acctg. Period	weeks	days
☐	☐	☐	☐	☐	☐

Resource Requirements Planning (Cont'd)

d). How often do you calculate the RRP?
(Tick as many boxes as you wish)

Annually	Qtrly.	Mthly.	4wkly.	weekly	daily
☐	☐	☐	☐	☐	☐

e). For RRP, what type of product groupings do you use? (Tick as many boxes as you wish)

Families	Ranges	Individual products	Other	Please specify
☐	☐	☐	☐	

f). Approximately how many groups are planned? ☐☐☐☐

g).For RRP, what units of measure do you use for workload and resource availability ?
(Tick as many boxes as you wish)

Products	£	tonnes	litres	standard hrs	actual hours
☐	☐	☐	☐	☐	☐

Other ☐ Please specify

h). For RRP, to what level of detail do you plan against resources?
(please tick as many boxes as you wish)

Total Plant	Department	Work Centre	Critical W/C's
☐	☐	☐	☐

Other ☐ Please specify

i). For RRP, what type of resources do you check against? (Please tick as many boxes as you wish)

Labour	Machines/Processes
☐	☐

Other ☐ Please specify

j). In your view, is Resource Requirements Planning operating successfully in your plant ?

YES	NO
☐	☐

k) If not, please briefly explain why not.

11. **Rough Cut Capacity Planning (RCCP)**, refers to the translation of a medium term Master Production Schedule into Capacity terms. Please refer to Fig. 1.

If Rough Cut Capacity Planning is not carried out, please move on to Question 11 j).

a). Is Rough Cut Capacity Planning carried out....
(Please tick as many boxes as you wish)

Manually	Using a P.C. spreadsheet	Using a software module
☐	☐	☐

b). For RCCP, what horizon do you plan against?
(weeks) ☐☐☐

c). For RCCP, what planning periods (buckets) are used? (Please tick as many boxes as you wish)

Yrs.	Qtrs.	Mths.	Acctg. periods	Weeks	Days
☐	☐	☐	☐	☐	☐

d). How often do you calculate the RCCP?
(Please tick as many boxes as you wish)

Annually	Qtrly.	Mthly.	4wkly	Weekly	Daily
☐	☐	☐	☐	☐	☐

e). What type of Master Schedule items do you use?

End Product	Planning B.O.M.	Pseudo Product	Other	Please specify
☐	☐	☐	☐	

f). Approximately how many items are Master Scheduled? ☐☐☐☐

g). For RCCP, what units of measure do you use for workload and capacity availability ?
(Please tick as many boxes as you wish)

Products	£	tonnes	litres	standard hrs	actual hrs
☐	☐	☐	☐	☐	☐

Other ☐ Please specify

Rough Cut Capacity Planning (Continued)

h). To what level of detail do you plan against capacity at the RCCP stage?
(please tick as many boxes as you wish)

Total plant	Department	Work centre	Critical w/c's
☐	☐	☐	☐

Other ☐ Please specify

i). For RCCP which type of resources do you check against ? (Please tick as many boxes as you wish)

Labour	Machines	Other (Please specify)
☐	☐	☐

j). In your view, is Rough Cut Capacity Planning operating successfully in your plant ?

YES	NO
☐	☐

k). If not, please briefly explain why not ?

12. **Capacity Requirements Planning (CRP):**

Capacity Requirements Planning (CRP) refers to the translation of current work-in-progress (usually works orders) and future planned orders (often the output of Material Requirements Planning) into capacity terms. See Fig. 1.

If CRP is not carried out in your plant, please move on to Question 12 m).

a). How is Capacity Requirements Planning carried out? (Please tick as many boxes as you wish)

Manually	Using a P.C. spreadsheet	Using a software module
☐	☐	☐

b). For CRP, what horizon do you plan against?

(weeks) ☐☐☐

c). For CRP, what planning periods (buckets) are used?
(Please tick as many boxes as you wish)

Years	Qtrs.	Mths	4Wks	Weeks	Days
☐	☐	☐	☐	☐	☐

d). How often do you calculate the CRP?
(Please tick as many boxes as you wish)

Annually	Qtrly.	Mthly.	4wkly.	Weekly	Daily
☐	☐	☐	☐	☐	☐

e). Approximately how many live and planned orders are included in the CRP ?

☐☐☐☐☐

f).For CRP, what units of measure do you use for workload and capacity availability ?
(Please tick as many boxes as you wish)

Products	£	Tonnes	Litres	Std. hrs	Actual hrs
☐	☐	☐	☐	☐	☐

Other ☐ Please specify

g). For CRP, to what level of detail do you plan against capacity? (please tick as many boxes as you wish)

Total plant	Department	Work Centre	Critical w/c's
☐	☐	☐	☐

Other ☐ Please specify

h). For CRP, which type of resources do you check against? (please tick as many boxes as you wish)

Labour	Machines	Other (Pleasespecify)
☐	☐	☐

i). Is Capacity Requirements Planning information fed back to the Master Schedule for rescheduling ?

YES	NO
☐	☐

j). If not, please briefly explain why not?

Capacity Requirements Planning (Cont'd)

k). Is CRP information used to do the detailed schedule on the shop floor ?

YES ☐ NO ☐

l). If not, please briefly explain why not?

m). In your view, is Capacity Requirements Planning operating successfully in your plant?

YES ☐ NO ☐

n). If not, please briefly explain why not ?

SECTION D. -AVAILABILITY OF INFORMATION FOR CAPACITY AND RESOURCE PLANNING.

13. Approximately what proportion of your current workload has standard times or time estimates on it?

☐☐☐ %.

14. Do you have an Industrial Engineering (or Work Study / Management Services / Process Planning) department which provides times for operations ?

YES ☐ NO ☐

15. If the answer to Qu.14 is Yes:

a) How many staff carry out this function ?

☐☐

b) Do they provide:

(Please tick) Standard Times ☐ Estimates ☐

c) Which techniques are used to provide this information ?
(Please tick as many boxes as you wish)

- i) Stop-watch Time Study ☐
- ii) Rated Activity Sampling ☐
- iii) Synthetic times
  - -Based on company studies ☐
  - - Proprietary system (e.g. MTM) ☐
- iv) Comparative Estimating (e.g. Categorised Work Values) ☐
- v) Rate Fixing ☐
- vi) Other (Please specify) ☐

16. Do you regularly collect the following information for use in Capacity / Resource planning ?
(Please tick as many boxes as you wish)

- a) Labour Utilisation ☐
- b) Labour Efficiency ☐
- c) Work Centre Utilisation ☐
- d) Work Centre Efficiency ☐

17. If any answer to Qu. 16 is Yes:

How is this information collected?
(please tick as many boxes as you wish)

- a) as part of a Wage Payment or Bonus Scheme? ☐
- b) from a "paperwork" data collection system ? ☐
- c) from a computerised Shop Floor Data Collection System? ☐

18. Please include below or overleaf any comments you wish to make regarding your use or lack of use of Resource and Capacity Planning, including the benefits, costs, problems and knock-on effects encountered.

Thank you for spending the time to complete this questionnaire.

Please return the completed document, in the enclosed envelope to:

Mr. Peter G Burcher
ASTON BUSINESS SCHOOL
AstonTriangle, BIRMINGHAM B4 7ET.

MANUFACTURING PLANNING AND CONTROL SOFTWARE MODULES

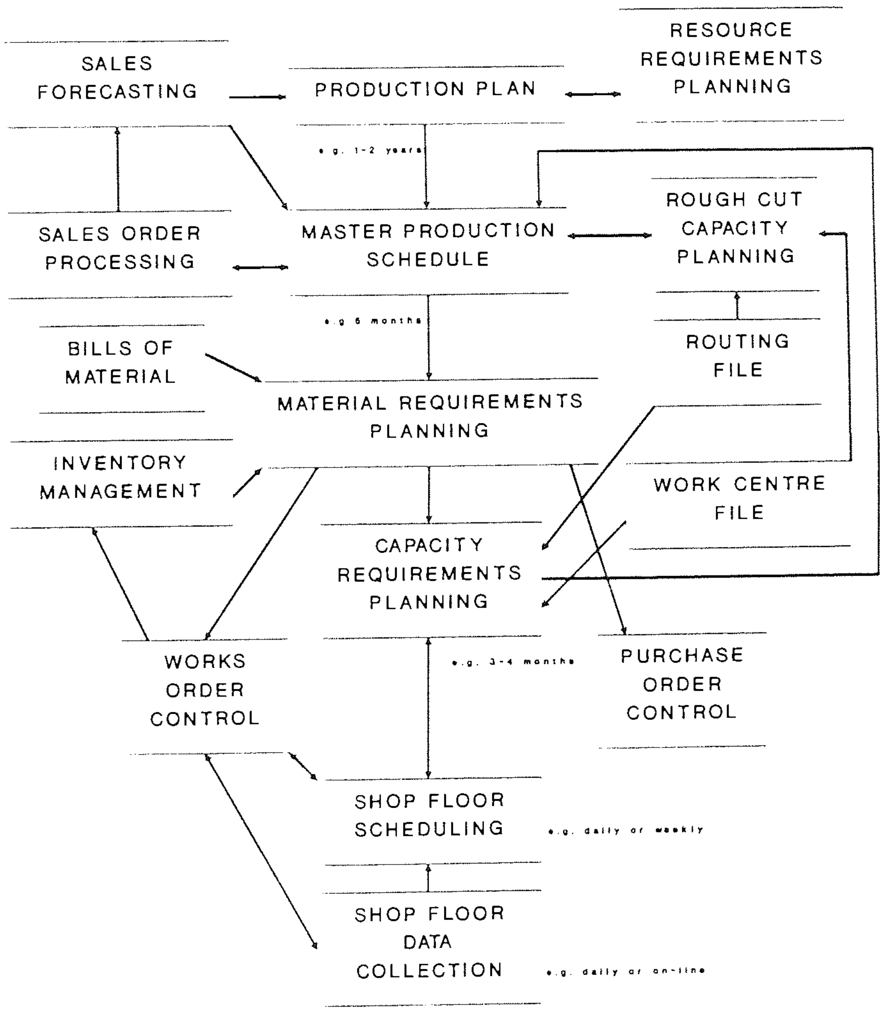

Figure 1.

Appendix 11.

Supplier Survey Questionnaire.

ASTON BUSINESS SCHOOL

☐☐☐

SUPPLIER SURVEY OF THE USE OF CAPACITY PLANNING WITHIN MANUFACTURING PLANNING & CONTROL SYSTEMS.

Would you like a summary of the findings of this survey ? Yes/No

Would you like a summary of the findings of a more detailed User Survey ? Yes/No

SECTION A. - GENERAL

Respondent Name:______________________________ Position:__________________

Company Name: ____

Company Address:____

____

____

SECTION B. - USE AND BARRIERS TO USE OF CAPACITY PLANNING

For ease of future analysis, the terms Resource Requirements Planning, Rough Cut Capacity Planning and Capacity Requirements Planning are defined as follows and are shown in diagrammatic form in Figure 1.

Resource Requirements Planning (RRP) refers to the translation of a long term Production (or Business) Plan into Resource terms.

Rough Cut Capacity Planning (RCCP) refers to the translation of a medium term Master Production Schedule into Capacity terms.

Capacity Requirements Planning (CRP) refers to the translation of current work-in-progress (usually works orders) and future planned orders (often the output of Material Requirements Planning) into Capacity terms.

1. For your Production Management Systems, approximately what proportion of your total system sales include the following modules ?

Resource Requirements Planning ☐☐☐ %

Rough Cut Capacity Planning ☐☐☐ %

Capacity Requirements Planning ☐☐☐ %

2. In your view what are the main barriers to the successful use of RRP, RCCP and CRP in user companies ?

(Please tick as many boxes as you wish)

a) A lack of standard or estimated times. ☐

b) A lack of regularly collected reliable information on:

Labour Utilisation ☐

Labour Efficiency ☐

Work Centre Utilisation ☐

Work Centre Efficiency ☐

c) A lack of routing information ☐

d) Other reasons ☐

Please specify:

SECTION C. - PACKAGE DETAILS

In this section would you please answer questions related to each major Production Management package that you sell on a separate data sheet. (Please copy any extras needed)

PACKAGE NAME : ____________________________

1. To which type of production operations is the package best suited ?

(Please tick as many boxes as you wish)

Manufacturing ☐ Assembly ☐ Repetitive ☐

Large Batch ☐ Small/Medium Batch ☐ One -Offs ☐

2. Which type of hardware is the package designed to run on ?

Mainframe ☐ Mini ☐ Networked P.C.'s ☐ Stand-alone P.C. ☐

3. Which of the following modules are offered as part of the package ?
(Please tick as many boxes as you wish)

Sales Order Processing ☐ Sales Forecasting ☐

Resource Requirements Planning ☐ Master Scheduling ☐

Rough Cut Capacity Planning ☐ Inventory Management ☐

Bills of Material ☐ Routing File ☐

Material Requirements Planning ☐ Work Centre File ☐

Capacity Requirements Planning ☐ Shopfloor Scheduling ☐

Works Order Control ☐ Purchase Order Control ☐

Shop Floor Data Collection ☐ JIT modules (Please specify) ☐

Synchronised Manufacturing Modules (Pleasespecify) ☐

Other Production Management Modules (Please specify) ☐

4. Does this package offer the facility of downloading of data into P.C. spreadsheets.?

Yes ☐ No ☐

Resource Requirements Planning:

5. For Resource Requirements Planning, what is the longest planning horizon that is allowed ?

(weeks) ☐☐☐☐

6. For RRP, what planning periods (buckets) are offered ? (Please tick as many boxes as you wish)

Years ☐ Quarters ☐ Months ☐ Acctg periods ☐ Weeks ☐ Days ☐

User Specified ☐

7. For RRP, what type of product groupings can be accommodated ?

Families ☐ Ranges ☐ Products ☐ Other (Please specify) ☐

8. What is the maximum number of product groupings that can be accommodated for RRP ?

☐☐☐☐

9. For RRP, what units of measure for workload and capacity does the package support ?

Products ☐ £ ☐ Tonnes ☐ Litres ☐ Std. Hrs. ☐ Actual Hrs. ☐

Any user specified unit ☐

10. What is the lowest level of detail that RRP can be taken to?

Plant ☐ Dept. ☐ Work Centre ☐ Other (please specify) ☐

11. Which type of resources can be included in the RRP ?

Labour ☐ Machines ☐ Any User specified resource ☐

Other (Please specify) ☐

Rough Cut Capacity Planning:

12. For Rough Cut Capacity Planning, what is the longest planning horizon that is allowed ?

(weeks) ☐☐☐☐

13. For RCCP, what planning periods (buckets) are offered ?
(Please tick as many boxes as you wish)

Years	Qtrs	Months	Acctg periods	Weeks	Days
☐	☐	☐	☐	☐	☐

User Specified ☐

14. For RCCP, what type of Master Schedule items can be accommodated ?

End Product	Planning B.O.M.	Modular B.O.M.	Other (Please specify)
☐	☐	☐	☐

15. What is the maximum number of Master Schedule Items that can be accommodated for RCCP ?

☐☐☐☐

16. For RCCP what units of measure for workload and capacity does the package support ?

Products	£	Tonnes	Litres	Std. Hrs.	Actual Hrs.
☐	☐	☐	☐	☐	☐

Any user specified unit ☐

17. What is the lowest level of detail that RCCP can be taken to?

Plant	Dept.	Work Centre	Other (please specify)
☐	☐	☐	☐

18. Which types of resources can be included in the RCCP?

Labour	Machines	Any User specified resource
☐	☐	☐

☐ Other (Please specify)

Capacity Requirements Planning:

19. For Capacity Requirements Planning, what is the longest planning horizon that is allowed ?

(weeks) ☐☐☐☐

20. For CRP, what planning periods (buckets) are offered ? (Please tick as many boxes as you wish)

Years	Qtrs	Months	Acctg periods	Weeks	Days
☐	☐	☐	☐	☐	☐

User Specified ☐

21. What is the maximum number of live and planned orders that can be accommodated for CRP ?

☐☐☐☐☐

22. For CRP what units of measure for workload and capacity does the package support ?

Products	£	Tonnes	Litres	Std. Hrs.	Actual Hrs.
☐	☐	☐	☐	☐	☐

Any user specified unit ☐

23. What is the lowest level of detail that CRP can be taken to?

Plant	Dept.	Work Centre	Other (please specify)
☐	☐	☐	☐

24. Which types of resources can be included in the CRP ?

Labour	Machines	Any User specified resource
☐	☐	☐

Other (Please specify)

☐

25. Please include below any other features of your product which concern Capacity Planning and which have not been covered above.

Thank you for spending the time to complete this questionnaire.

Please return the completed documents, in the enclosed envelope to:

Mr. Peter G Burcher

ASTON BUSINESS SCHOOL

Aston Triangle, BIRMINGHAM B4 7ET

MANUFACTURING PLANNING AND CONTROL SOFTWARE MODULES

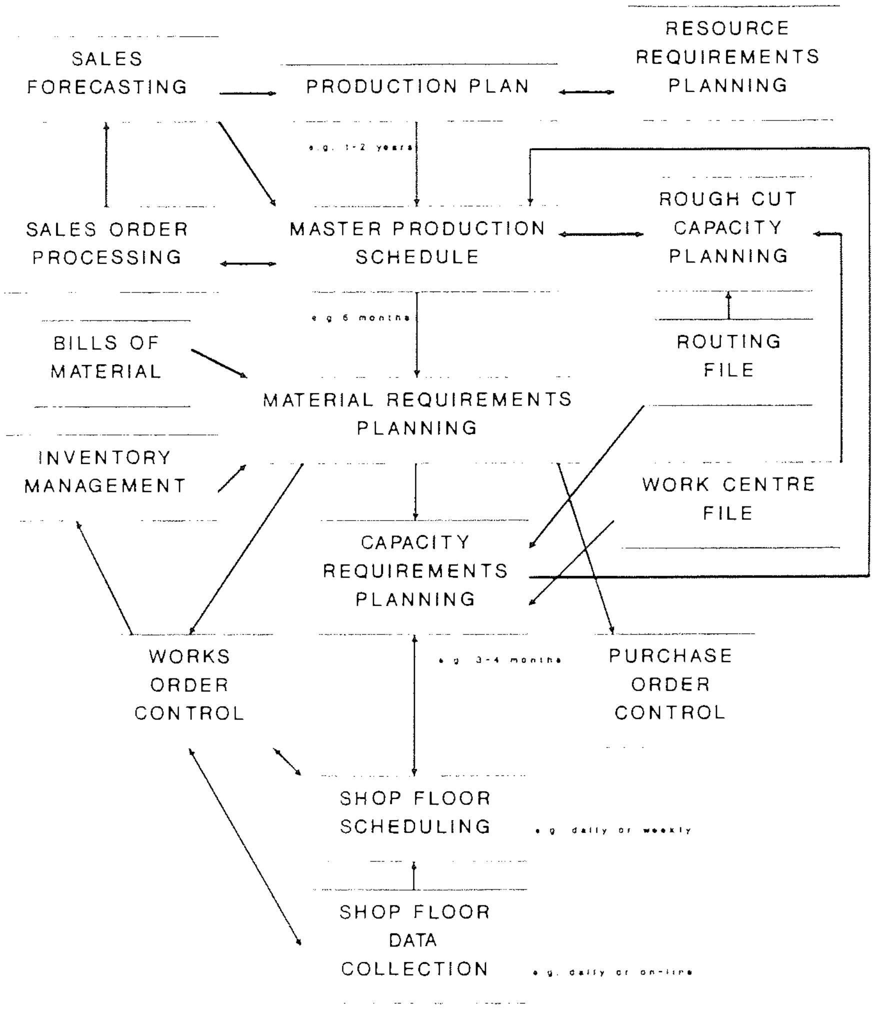

Figure 1.