MANUFACTURING CAPACITY PLANNING AND CONTROL

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'THE UNIVERSITY OF ASTON IN BIRMINGHAM'

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SUMMARY

Using a textile machinery plant as the case study, this Teaching Company project looks into the causes for some typical problems in capacity management and its related areas, stressing the importance of having a formal and systematic capacity planning and control routine in the Company.

Various factors affecting the manufacturing performance in each work-centre have to be examined in order to obtain an accurate capacity figure. The theme is the development of a computerized system based on the existing manufacturing set-up and product varieties within the Company. It allows the capacity requirement patterns to be assessed in details against different specified product-mix combinations. An optional sub-system, the rough-cut method also plays a significant role in preliminary capacity analysis, particularly when the availability of time and information dictates.

Though, this work lends itself to solving the problems for the sponsoring Company, sufficient flexibility has been built in to enable the system to be implemented in other firms with limited modifications.

KEY WORDS: CAPACITY LOADING PRODUCT-MIX SCHEDULING

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DECLARATION

No part of the work described in this thesis has been submitted in support of an application for another degree or other qualification of this or any other Institution.

The industrial project work was done by the author himself or under his supervision.

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CHAPTER 1

INTRODUCTION

A manufacturing organisation possesses a number of production facilities, such as lathes, milling machine, on which work can be carried out by human operators. Both machines and operators can simply be referred to as 'Manufacturing Resources'.

The availability of such resources over a period of time can be referred to as 'Manufacturing Capacity'. In the majority of cases, capacity is expressed in units of time such as hours or days, although in some industries, it may be expressed by weight or volume.

In processing an order, calls are made upon the available manufacturing capacity and it is a problem facing management that the capacity required and the capacity available should balance. Perfect balance is extremely rare, but if achievable, management problems can be greatly eased.

There are three levels of planning at which management make use of capacity measures of varying degrees of detail (3)(11).

(i) Long-term planning, 1-3 years,

(ii) Medium-term planning, 6-18 months, and

(iii) Short-term planning, up to 6 months.

Accurate knowledge of capacity is essential for (iii) which is intended for immediate scheduling/capacity allocations. Depending upon the degree of centralised control, the capacity quoted may be for

- a group of machines or work-centres, or

- an individual machine.

For (i) and (ii), capacity is usually expressed in general terms and the figures quoted are usually blanket figures applying to an entire workshop or a group of machines. The plans formulated in this project are medium to long term and the accuracy required is not as critical as that for the detailed analysis (iii).

The research work undertaken and reported in the following pages was an endeavour to provide for an industrial organisation a method of assessing the capacity required to achieve a number of feasible product-mixes which can be evaluated in further detail in order to determine the most suitable Master Production Schedule over a period of 1 to 2 years ahead.

To carry out this analysis effectively, an accurate method which can give an answer quickly with minimum manual effort is essential.

In group technology (12)(16) the concept of a 'composite component' has been developed. Such a component has all the characteristics of the various components being considered as a family and can be processed in a chosen manufacturing cell.

It was considered possible that such an approach could be applied to capacity planning at the required 'rough-cut' level. In this case, the composite component would require machine processing which would represent the manufacturing contents for every component in a total machine build.

A statistical sampling technique was used to sample the individual machine build stages and the approach had been formulated into a computer system.

The terms of reference for the project were therefore

- to gather and analyse data in order to establish a procedure suitable for Rough-Cut and Detailed Capacity Planning, and having done so to prepare the required computer softwares to enable the procedure to be effectiviely performed by management during the preparation of initial production programmes.

The work was carried out at William Cotton Ltd., Loughborough, and was done under the SERC Teaching Company Scheme (10).

CHAPTER 2

BACKGROUNDS OF THE RESEARCH

This research project was a part of the Teaching Company Programme established between Bentley Textile Machinery (Loughborough) Limited and the Department of Production Technology and Production Management of the University of Aston in Birmingham.

2.1 Teaching Company Scheme (TCS)

It is strongly believed that new scientific and technological developments can only be fruitful if they can be put into practice. The same principal applies to the advance in academic knowledge and its applications in manufacturing industry. In order to strengthen the collaborations between these two aspects, a working committee was appointed in 1974 by the Science (and Engineering) Research Council (SERC) and the Department of Industry (DOI) to look into the feasibility of establishing an active partnership between universities and manufacturing companies. The recommendations from this study led to the foundation of the Teaching Company Scheme (TCS).

2.1.1 The Objectives of TCS

(a) To raise manufacturing efficiency by using the available academic knowledge and facilities.

(b) To improve manufacturing methods by the effective implementation of advanced technology.

(c) To train able graduates for careers in manufacturing industry.

(d) To develop and retrain existing company and academic staff through active involvements in the programmes.

(e) To give academic staff broad and direct associations with industry for research and as background for teaching.

2.1.2 How the TCS Works

The scheme operates through Teaching Company Programmes in which a university or polytechnic participates in a company programme to improve the overall manufacturing performance. Each programme consists of one or more research projects which are carried out by graduates (Teaching Company Associates) appointed by the university on a two-year contract. The associates are based almost full-time at the company, working in collaboration with company and academic staff on their research areas. At the same time, associates are also encouraged to attend regular courses and seminars with a view to broadening their scope of knowledge and experience.

2.2 <u>The Company</u>

Bentley Textile Machinery (Loughborough) Ltd., (which has been renamed 'William Cotton Ltd.,' since its re-organisation in December 1981) was the leading supplier of fully-fashioned knitting machines, dominating more than eighty percent of the world market. However, in the mid-1970's, the company was severely hit by the world economic recession which resulted in a great reduction of the workforce from 2,000 to just over 200. The manufacturing programme was reduced to a jobbing level, relying on a high level of stock. As a result, no proper manufacturing nor stock control system were necessary.

It was not until the late 1970's that the order situations began to improve, and the workforce increased gradually to around 500. The company realised that they should make use of this opportunity to diversify its product range in order to lessen the effects of market fluctuation on the company. As a result, weaving and V-bed knitting machinery were introduced into the company.

New design concepts were acquired through the purchase of Singer Alemannia Company in Germany, the patent of a partly developed Italian weaving machine and the rights of a series of knitting machines from F.N.Company in Belgium.

With the formation of V-bed knitting machines and weaving machine divisions, further developments and updating were carried out on various models under government fundings.

Under the impacts of these transformations, some manufacturing problems began to show, such as

(a) the stock levels for commonly used components were rapidly reduced, resulting in increasing shortages,

(b) the work-loads and backlogs increased in both machine shop and assembly areas,

(c) the traditional production control practices became inadequate to cope with the increasing output demands,

(d) the existing management patterns were unsuitable for a multi-product company of this size.

In view of these existing problems, the company expressed the enthusiasm in carrying out a series of research and development projects with help from the government.

After a series of discussions, it was agreed that an investigation should be conducted to assess the feasibility and implications of setting up a Teaching Company Programme between the company and the University of Aston. The proramme eventually materialised in early 1980.

2.3 Contents of the (Aston/Bentley) Teaching Company Programme

From the report of the investigation (March 1979) the following project areas were identified:

(i) Design integration and component coding

(ii) Capacity Planning for new products

(iii) Stock and Inventory Control

(iv) Material Requirements Planning (MRP)

(v) Cam Design and Manufacture

(vi) Standard Costing

(vii) Assembly Planning for New Products

(viii) Manufacturing Control (WIP)

(ix) Company NC Policy

The projects were to be carried out in three phases spread over a period of four years. Nine research associates were to be appointed each on a two year contract. A senior fellow was also appointed to organise the smooth running and integrations of the various projects.

Being one of the projects in Phase I of the Programme, this research was carried out over the period from May 1980 to February 1982.

CHAPTER 3

MANUFACTURING CAPACITY

3.1 Definition

In simple terms, Manufacturing Capacity of a company can be defined as the maximum capability of outputs by its available facilities and manpower.

3.2 General Concepts

3.2.1 Relationship between capacity and workload

This relationship can be represented pictorially as shown in Figure 3.1 in which a funnel is used to simulate a particular manufacturing plant. Sales orders and finished products as the input and output parameters respectively. The workload in the plant can be simulated as the volume of liquid inside the funnel at any particular moment. The rate at which the liquid can pass through the funnel mainly depends on the cross-sectional area A which represents the manufacturing capacity. In other words, manufacturing capacity actually governs the amount of orders that can go through the plant at any particular time.

To assess the overall manufacturing capacity of a company, the capacity expressed in the production plan can be based on the total capacity of the individual work-centres.

To explore the available capacity in each work-centre, the rate of output of each individual machine or equipment has to be worked out.

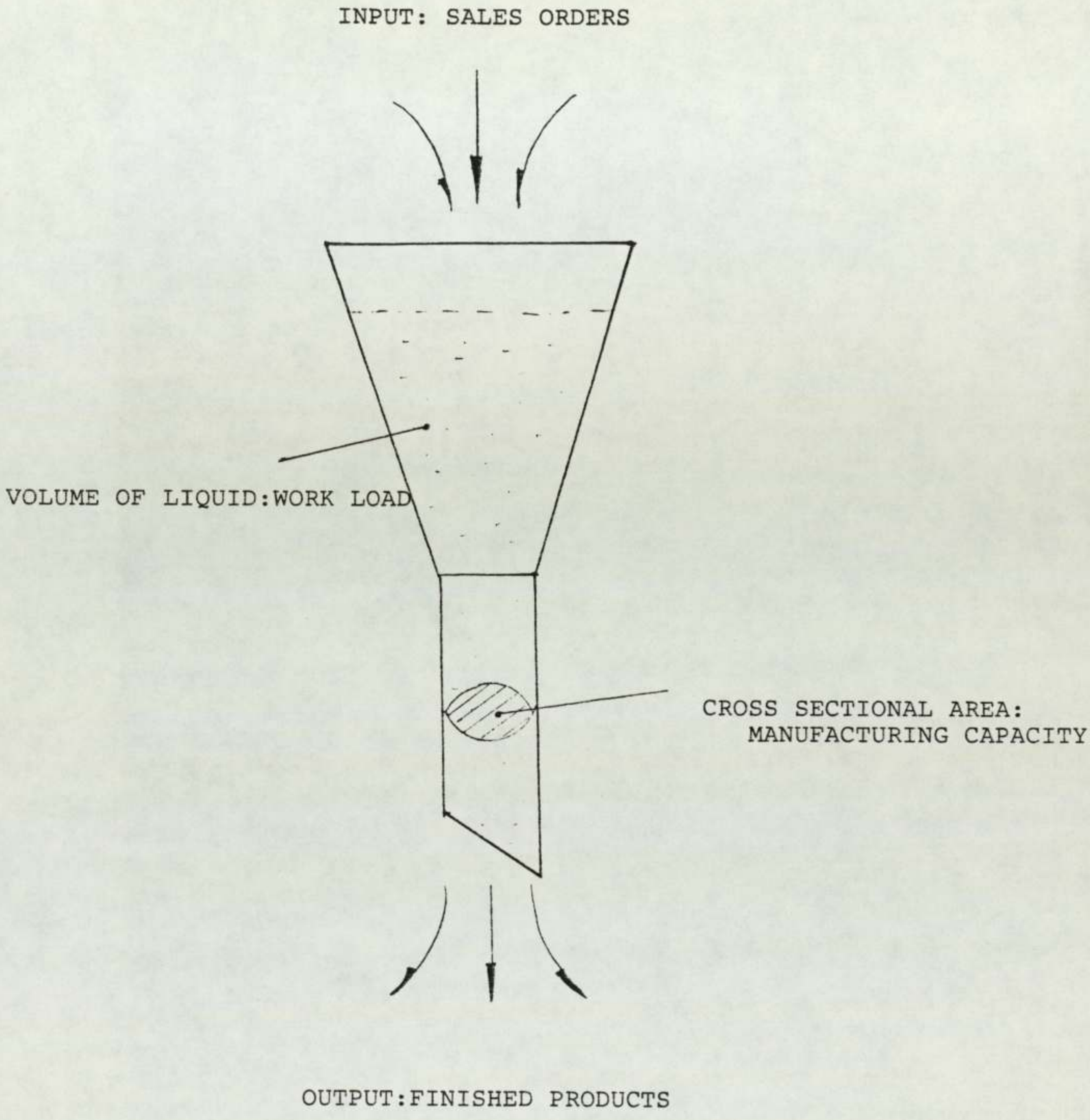


Figure 3.1: Simulation of work-load Vs capacity

3.2.2 Capacity Measurement and Determination

For the sake of consistency, the unit of measure selected when planning capacity should be one that is common to the mix of products encountered, i.e., pieces, tons, feet or standard work hours etc., per time period. When dealing with manufacturing capacity, estimates based on hours or other time units seem to be more relevant than the other units.

The essential point that one has to bear in mind in choosing the unit of capacity measure is that all the products using the capacity of some facility must be measueable in a common denominator based on some output per unit of time.

There are two basic ways of determining capacity. The more direct approach is to measure the average standard hours actually produced in a certain number of weeks or months. This measurement approach is relatively straight forward, but it is more suitiable when the capacity utilisation in each individual work centre is reasonably steady and at a high level.

In most cases it is found more practical to rate and calculate the available capacity in each work centre. To do that various factors affecting the manufacturing performance have to be taken into account, as mentioned in the following section.

3.3 Factors affecting Manufacturing Capacity

There are a large number of factors that can affect manufacturing capacity. Some of these factors that have more direct effects can be briefly divided into two categories, namely Planned Factors and Monitored Factors.

3.3.1 Planned Factors

These are factors that can be planned by management. Some common ones can be given as follows:

(a) Availability of facilities - it refers to the number of machines or equipment in the company. It is considered to be the main governing factor because the maximum output of each individual work centre is directly proporotional to the amount of facilities it possesses.

(b) Availability of manpower - it has a more direct effect on the output of a work centre in which the processes are more labour-intensive such as assembly, fitting, wiring or testing operations.

(c) Functional features of the facilities - machines and equipment in a manufacturing set-up are usually divided into individual work centre (e.g. turning, milling, grinding, drilling etc.), simply because they are functionally different. In certain areas in order to assess the available capacity more precisely, the analysis has to be extended to distinguishing the different varieties of machines or facilities in the same work centre. For instance, a cylindrical grinder can never be replaced by a surface grinder.

(d) Dimensional constraints - every piece of equipment has its maximum job holding features which quite often governs its areas of applications. For example, a centre lathe can only take work-pieces within a certain range of sizes and weights.

(e) Operating conditions - the number of working hours per week can only give an indication of the maximum capacity available in each work centre. In order to find out what percentage of this maximum figure can actually be productive, other factors such as frequency of breakdown, accuracy achievable, general conditions of the equipment etc., have to be taken into account.

(f) Other sources of manufacturing capacity - increasses in capacity are available through overtime, adding shifts or subcontracting etc., but these should only be treated as temporary measures because excessive overtime can result in deteriorations both in the workers' health and product quality. Whereas the extra expenditure involved may result in high manufacturing cost which affects the company's competitive power.

3.3.2 Monitored Factors

Monitored factors refer to those which are subject to less direct control and have to be monitored carefully in order to obtain more accuracte capacity estimations.

Some common monitored factors can be given as follows:

(a) Absenteeism

(b) Unplanned operations - they can be due to changes in materials, tooling, production routings etc.

(c) Urgent orders for repairs or re-works.

(d) Operator performance - it varies from person to person as well as from work-centre to work-centre. Therefore, detailed records are required to establish the corresponding performance figures.

(e) Machine breakdowns.

(f) Material shortages.

(g) Unusual tool problems etc.

3.4 Ways of expanding manufacturing capacity

When a company undergoes a period of rapid expansion it is not uncommon that there is a gradual growth in unfilled orders and overtime, shifts are added, and any slack or hidden capacity comes into use. Thus management has several alternatives to increase capacity. (7)

3.4.1 Temporary Expansion

If increase in demand is believed to be short-lived it is better to increase the capacity temporarily rather than being caught with new capacity which is being idle. Typical ways of temporary expansions can be outlined as follows:

(a) Overtime - it is usually chosen first, though it is expensive simply because its effects are not as irreversible.

(b) Sub-contracting part of the production work-load to other firms and effectively buying rather than manufacturing some of the required components and sub-assemblies.

(c) Increasing inventories - it is possible to use inventories as a demand buffer to insulate to a certain extent the steady operations of production facilities from fluctuations in market demand. Negative inventories or back orders are useful means of meeting what appears to be temporary increases in capacity demand.

The general management decision problem of what mix of inventory, overtime and sub-contracting to use in any situation is a difficult one to bring under careful analysis. Yet all are used, largely because their reversibility outweighs their expense, as means of damping out the changes in plant capacity in the face of varying demand.

3.4.2 Permanent Expansion

The usual ways of expanding the plant capacity in a long-term basis can be:

1. increasing the work force
2. adding new facilities and technology etc.

However, before any permanent action can be taken to increase the manufacturing capacity of a company, the management has to make a long-term (over three years) forecast to assess the trend of market demands. It is essential not only because the cost of adding new plant, new technology or new employees is high, but also the ill will generated by having to 'lay people off' in the future if output demand drops.

Bearing in mind the uncertainty of any forecast if an increase in capacity demand is believed to be permanent, then it may be economically preferable to increase capacity, rather than the more costly alternatives of overtime or inventories which are often chosen in the face of demand uncertainty.

The timing in which new plant facilities are brought in is also an important aspect in permanent capacity expansion. It is because a capital asset tends to yield its lowest cost per unit when fully utilised. This permits spreading the fixed costs over the maximum number of units of production. Thus on the one hand there are advantages of postponing the addition of new facilities until demand has risen to the point that it can be fully utilised. Opposed to these are advantages arising from early additions to capacity in order to avoid the more costly alternatives of overtime, work force expansion, or negative inventories. Of course, earlier introduction of new capacity also prepares the company for unforeseen increases in market demand, while postponing it allows the accumulation of more information on which to base predictions of future demand.

CHAPTER 4

GENERAL CAPACITY MANAGEMENT

4.1 Basic areas of consideration

To organise capacity planning and control in a company there are three common questions that have to be answered:

(i) What capacity do we have?

(ii) What capacity do we need? and

(iii) When are those capacities required?

The answers to these questions are very essential for answering the following questions posed by management.(2)

- Do we have the capacity to produce this year's sales forecast?
- Do we have the capacity to produce next year's sales forecast?
- What is our manufacturing capacity?

4.1.1 Capacity Availability

Depending on its size, a company may consist of different divisions or subsidiary plants. The capacity of the company is often expressed as the total of the individual plants. Each of the divisions is normally made up of a number of manufacturing units, namely work centres which differ in their areas of application according to their functional and operating features.

To assess the capacity availability in a manufacturing firm, the basic step is to identify the amount of facilities and manpower resources in each work-centre. The maximum capacity can easily be found by simple calculations. Unfortunately this figure does not necessarily give the true picture. As it has been mentioned earlier in Chapter 3 there are numerous factors, such as overtime, absenteeism, percentage machine breakdowns, unusual tool problems etc., that can affect the actual manufacturing performance. All of these factors have to be taken into account in order to arrive at more realistic figures. Details of how these factors can be examined in a company will be given in Appendix I, II and III.

4.1.2 Capacity Requirements

Knowing what capacity is available one also needs to find out what capacity is required before any comparison can be made. The capacity demands can take the form of customer orders, spares parts requisitions, forecast demands etc (4). To study the impacts of these capacity demands on various work-centres, detailed product structures for the orders concerned are required so that a bill of materials (BOM) can be established for each individual product. The available parts should then be checked against the BOM so that a shortage list can be drawn up.

The production routing of each of the manufctured items on the shortage list has to be called up in order to allow the capacity requirement in each work-centre to be worked out.

As a result, a bill of capacity for the manufactured items concerned can be obtained.

This approach involves very detailed analyses which are in fact more applicable to mature products whose structure and routing information are available. However, to estimate the capacity requirements for any new products an alternative approach, which uses sampling techniques to calculate the capacity requirements (product profiles), has to be adopted.

4.1.3 Requirement Timing

After the available capacity in each work centre (supply) and the capacity requirements (demand) against a given output target have been worked out, the next thing to do is to compare and balance the capacity supply and demand against a time scale. With reference to the details of timing, a capacity requirement pattern can be established and superimposed onto the existing load pattern in each work centre. The resulting pattern will then show the actual fluctuations of capacity demands and highlight any forthcoming problem areas. If it is necessary, re-scheduling has to be carried out to achieve a more steady distribution of work-load over a given period of time (1)(2)(3).

4.2 Linkages between capacity planning and other aspects of manufacturing management

It is important to realise that capacity planning is by no means a discrete function. In fact, it is closely related to other managerial functions such as forecasting, inventory management, material requirements planning (MRP), control of manufacture and master production scheduling etc.

4.2.1 Forecasting

Forecasting is a critical input into establishment of the production plan and the master production schedule (MPS). Similarly the forecast can be converted via a data base into the corresponding capacity requirements to help set long-range capacity plans. To obtain a reliable forecast the market trend has to be observed and predicted well ahead in order to work out the volume of production and a suitable product-mix which will enable the facilities in a company to be effectively utilised.

4.2.2 Master Production Scheduling

Master Production Scheduling mainly encompasses the variety of activities involved in the preparation and maintenance of the Master Production Schedule (MPR), which is an anticipated build schedule for the company's products. Typically this might be the quantity to be produced in the next six months, twelve months or longer. The MPS can be stated in different terms, such as end product items, actual customer orders etc. The MPS represents a production statement which disaggregates the production plan into individual product items. Each of these product items can then be exploded to give a bill of materials which consists of assemblies, sub-assemblies and components as far as raw materials required to build the product concerned. Detailed analyses can then be carried out to study the effects of the MPS upon various work centres in the company at different horizons of capacity management.

4.2.3 Materials Requirements Planning (MRP)

Materials Requirements Planning (4) is the explosion logic that launches all orders. It is also the system that accomplishes this process with reduced inventory levels, the system that changes capacity requirement timings and produces a time phased set of expected capacity requirements. It can also feed back anticipated execution problems to the master production schedule for any appropriate re-planning.

4.2.4 Inventory Management

Inventory Management can significantly affect production plan and capacity utilisation because any net change to overall inventory or backlog levels will have a direct influence on the resources required. At a more detailed level, lot sizes, safety stock and lead time offsetting all affect the timing and the amounts of individual work orders. Manufacturing capacity has to be carefully planned with the objective of meeting the resultant requirements.

4.2.5 Control of Manufacture

The objective of controlling manufacture is to produce goods in the quantities specified and by the date specified on the shop orders, subject to meeting quality and cost standard.

In order to meet the completion date the load in any work-centre should not exceed its capacity for any length of time (5). If capacity planning has been carried out effectively the work-load should not be irretrievably out of line with available capacity. It is the responsibility of the management to foresee any impending overload or underload situations so that corrective actions can be taken soon enough to maintain a reasonable utilisation of labour and plant. Apart from that, every effort should also be made to minimise material shortages, last minute design modifications and machine failures.

4.3 Basic Steps in Capacity Planning and Control

There are five basic procedures in capacity analysis.

4.3.1 Preparation of Sales Forecast

A sales forecast is critical to capacity planning. Since the goal of most manufacturers is to produce what marketing can sell, i.e. manufacturing must plan to produce the forecast sales level. A good sales forecast should be able to help:

- define units of production, not only monetary totals
- consider changes in product-mix
- project capacity requirements periodically
- include the requirements for new products.

4.3.2 Forecast Explosion

The forecast of finished product requirements has to be exploded to give gross part requirements in the form of a bill of materials. This can be done more easily by means of a computer. The gross part requirements are then extended into standard machining or assembly hours to obtain a summary of the projected standard hours in each work-centre. However, this projection of standard hours is not sufficient for defining the actual capacity requirements because other factors, such as percentage breakdown and operator performance also need to be taken into account.

4.3.3 Identification of Efficiency Factors

Experience indicates that machine standards are not always up to date nor are operators 100% efficient. An average gross efficiency factor for each work-centre can be established by means of activity sampling as well as the actual time records. Eventually projected capacity requirements can be established.

4.3.4 Capacity Scheduling and Loading

The projected requirement pattern can then be compared with the existing load pattern so that any unbalance can be highlighted and dealt with accordingly either by re-scheduling the work load or expanding the capacity.

4.3.5 Capacity Expansion

Capacity expansion can be accomplished by various means:

(i) add equipment - the most obvious but often the most costly way

(ii) increase manpower - by adding shifts or overtime

(iii) balance machine workload by changing routings

(iv) improve production efficiency by methods improvements

(v) improve operator's performance through incentive plans, or tighter scheduling of work

(vi) re-sequence shop orders to reduce set-up and downtime thus improving the machine's efficiency and increasing its ability to produce work, i.e. increasing its capacity.

4.4 Data Required

(i) Up to date capacity load records are essential for showing the existing work-load distribution and providing a more reliable foundation for subsequent capacity scheduling and loading.

(ii) A detailed structure is required for every product to enable the bill of materials to be produced. As a result both purchased and manufactured items can be dealt with promptly.

(iii) Relevant production routings and time estimation are also required to enable accurate work-load calculations and sequencing.

4.5 Basic Tools

Capacity Planning and Control is a very time consuming and labour intensive topic simply because it involves detailed data collections and analyses from various related areas. However, a large proportion of the operations are in fact repetitive, therefore the use of a computer seems most appropriate. The type of computer required normally depends on the product types and the number of different components employed in the company.

The computer chosen must have sufficient core memory to handle the large number of manipulations and reasonable memory backup for the various data files such as current work-load records, product structure records and the production planning details etc.

In addition to the computer, suitable input and output consoles are also important to facilitate the system applications.

4.6 Standard Reports

Among the reports available from a typical capacity planning and control system, some significant ones can be given as follows (6)(7).

(i) Work Centre Master Listing - it details the availability of machines, manpower and facilities in each individual work-centre.

(ii) Master Production Routing Records - in the process of setting up a capacity planning and control system, the routings for all the manufactured items have to be stored in the computer memory. As a result the routing details for any manufactured item can be readily retrieved by the computer and used for various purposes of production planning and control.

(iii) Work-Centre Load Analysis - it is normally in the form of a print-out sometimes accompanied by a histogram showing the up to date distribution of work-load over a selected period of time.

(iv) Job Sequence List - when the product-mix policy is defined, the system should be able to initiate a relevant list showing the work orders required to meet the output target by referring to the relevant product structures. As a result a work-to list either in part number or launch date sequence can be produced for production and work-in-progress control purposes.

CHAPTER 5

CURRENT MANAGEMENT PRACTICES IN THE COMPANY

5.1 Production and Inventory Control

The present production and inventory control procedures in the company are entirely manual. Although a computer programme has been used for the purpose of shortage allocations, there is no interface between this particular routine and other production control functions.

On receipt of a new customer order, the production control department is responsible for interpreting the specifications from the order into the relevant product type plus any required standard or special options. As a result the corresponding parts lists are put together to form a bill of materials. The whole process may take as much as six weeeks to complete, depending on the complexity of the product concerned. The bill of materials will then be passed over to store for kitting up and shortage identifications. As a result a shortage list can be drawn up and fed back to the production control department where shop orders and purchase requisitions will be released. Any necessary batching and order quantity adjustments will also be carried out at this stage. At the same time the shortage records are stored on a computer file in order to assist subsequent allocations as the outstanding items arrive.

The purchasing department then places the orders for any outstanding bought-out items, while the production control department releases the shop orders for the manufactured items required.

During the late seventies the machine manufacturing was performed almost entirely from stocked items which had been there before the recession in the early seventies. No proper stock records were kept. However, the stocked items gradually ran out and the work-load in the machine shop increased significantly, resulting in an obvious increase in individual order through-put time and hence delay in delivery.

5.2 Manufacturing

The production department is made up of two major divisions, i.e. the machine shop and fitting shop.

The machine shop can be further broken down into individual work centres according to the functional and dimensional features of the machines. Apart from the conventional machine tools, such as millers, lathes, grinders etc., some special-purpose machines, such as multi-station trick-cutting machines, verge-rolling machines etc., are also required for this particular industry.

In recent years, numerical controlled lathes and machining centre have been introduced into the company, forming a separate NC work-centre. These machines have been proved to be effective in reducing the machine setting-up and operation time.

All the shop orders are released from the production control department to the machine or fitting shop through the scheduling office. Individual work orders are then allocated to the relevant work-centres in a correct operational sequence as indicated on the production planning sheets, although in certain cases a limited amount of flexibility can be allowed for alternative routings with a view to lessening the effect of any capacity unbalance. The foreman or chargehand in each work-centre is responsible for the actual loading of the facilities according to the job priorities which are getting complicated to sort out as the amount of spares and unforeseen orders increases.

The fitting shop is product-oriented, being sub-divided into fully-fashioned, V-bed and weaving sections. They are basically self-contained assembly bays for individual product groups.

5.3 Capacity Planning and Control

At present the company has no formal system for capacity planning and control. However, the total amount of assembly man-hours is estimated for budgetary control purposes. The assembly man-hour content of the products is budgeted against the sales forecast to arrive at a figure of total assembly hours during the year.

Unfortunately a similar approach is inapplicable in the machine shop simply because there is no way the forecast can be translated into capacity demands on various work-centres. Shop load is measured as it occurs and day-to-day management judgement applied to increase or decrease the sub-contract volume as required.

At present plant capacity is difficult to allocate to meet the increasing demands for the new product models becaue unlike the conventional fully-fashioned knitting machines, the supervisors have insufficient experience on the new products to give a reasonable estimation on assembly hours.

As far as the fitting shop is concerned, assembly of knitting mchines is a highly skilled process requiring profound experience. The job is further complicated by the lack of proper assembly instructions and detailed assembly drawings. As a result individual fitters have to develop their own philosophy of tackling the job. This may result in two machines of the same type being assembled in different ways. This practice does create inconvenience and confusion in future repairs and services.

5.4 General Management

As the company is currently undergoing a period of rapid product development and diversification, some fundamental problems which have been latent in the company for quite some time become more critical. Typical problems can be noticed in the following areas:

(a) Production Control Department - as the production control practice is basically manual, an increasing level of manufacturing activities with the introduction of new products simply causes chaos in certain areas.

(b) Machine/Fitting Shop - the reduction of useful stocks and the increasing capacity demands cause a significant amount of backlog in both the machining and assembly areas.

(c) Design Department - the present design practices rely very much on the product knowledge of a small group of key personnel. Few formalised procedures are available to systematise the job knowledge which may be forgotten with the passage of time.

(d) Capacity Control - the existing plant capacity is undefined as to a very large extent is future capacity requirements. Therefore it remains uncertain how far the existing capacity can cope with the future output demands.

(e) Stock Control - since there is no formal stock control system in the company the stock records can hardly be up to date. Owing to insufficient stores staff, perpetual stock check is done only once a year with the assistance of staff from other departments. Major items are ordered against sales contracts while commonly used low-cost items are re-ordered at some convenient level.

Apparently the existing management control systems are inefficient and lack of co-ordination. The problems are further intensified by the introduction of new products. The company has come to a stage that unless some inter-related control systems can be set up immediately with the aid of a computer, the troubles will multiply rapidly.

In view of the existing problems in the company, the following areas have to be dealt with urgently:

(a) Setting up a master file holding all the basic information for every component used in the company. It is essential for effective material management.

(b) Setting up a unique structure file for every product so that an up to date bill of materials can be obtained for production and inventory control functions.

(c) Identifying the existing manufacturing capacity in the company.

(d) Establishing the purchasing, processing and assembly leadtimes for every item or sub-assembly.

(e) Establishing proper routine for effective shop scheduling and loading.

(f) Setting up a work-in-progress control routine to monitor the manufacturing programme.

CHAPTER 6

EXISTING PLANT CAPACITY

6.1 Basic Divisions

The complete manufacturing set-up of the company can be fundamentally divided into two areas, the machine shop and the fitting shop.

6.1.1 Machine Shop

The machine shop is reasonably well equipped, possessing a good balance of conventional machines such as lathes, millers, grinders etc. In addition there is also a fair amount of special-purpose equipment, such as trick-cutting machines, verge rolling machines and cam millers, etc., which are unique for the manufacturing of textile machineries. The machine shop resources have been further enhanced following the additions of NC lathes and machining centre in recent years.

According to the functional and dimensional features of the machine tools, the machine shop can be divided into different groups as shown in Figure 6.5.1. Details of the machine distributions in various work-centres can be found in Appendix I - The Plant Register.

6.1.2 Fitting Shop

The fitting/assembly shop is made up of fourteen assembly groups as detailed in Figure 6.5.2. Most of the mechanical assembly areas are product-oriented and specialised in certain types of product models, such as fully-fashioned machines, V-bed machines or Orbit weaving machine.

Whereas the electrical assembly area caters for the wiring and electrical installation for every product.

6.2 General Conditions of the Equipment

6.2.1 Mechanical Conditions

With the exception of some newly acquired NC machines for the V-bed knitting section, most of the machines have been in the company well over twenty years. However, the accuracy and reliability on most of the machines are still acceptable for normal applications.

All the same, in order to improve the production efficiency, some recently developed cutting tools, which can be used for much heavier duties, have been used. As a result the power output demands from the machine tools increase accordingly sometimes to an extent that the machines are practically overloaded. It has an adverse effect of rapidly deteriorating the machine life. Therefore a considerable proportion of the existing machine tools will be due for replacement in the next few years' time.

6.2.2 Capacity Utilisations

(a) Machine Utilisation - At the beginning of this project, an activity sampling study was undertaken to study the utilisation situations in individual machine groups. From analysis of the study less frequently used equipment can be identified and dealt with separately.

To begin with, a pilot study was conducted to work out the suitable sample size required in each machine group in order to achieve a specified confidence level of accuracy (9).

The results show that in the more commonly used machine groups, such as turning, milling, grinding etc., the percentage utilisation lie between 55 to 65, while the utilisations in some special-purpose machine groups only range from 30% to 40%. Detailed results from the activity sampling exercise can be found in Appendix II (A).

(b) Man-Power Utilisations - To collect the necessary information, from each work-centre a weekly record, showing the time spent on direct productive work and other indirect activities (e.g. repairs, jig and tool preparations etc.), was taken. As a result, the manpower utilisation figures were worked out accordingly as shown in Appendix II (B).

6.3 Operator Performance

Normally, every work order that goes through the machine or assembly shop is accompanied by the related paper work, such as drawings or planning sheets. Estimated times can be found against each operation in the routing. However, the actual time taken to do a job varies from one operator to another and these discrepencies have to be taken into account for accurate capacity scheduling and loading.

The relationship between the planned time and actual time taken for a particular job can be assessed in terms of performance factors. To establish the average operator performance in each work-centre, time records from the costing department were taken and compared to the estimated time on the related planning sheets.

Details and results of the analysis on each individual work-centre can be found in Appendix II.

6.4 Effects of Overtime and Absenteeism on Manufacturing Capacity

Overtime is always an effective way of expanding the capacity of a company at least on a temporary basis. However, the amount of overtime should be carefully controlled because excessive overtime work over a long period of time will not only lower the working efficiency but also increase the rate of scrappages and accidents.

Absenteeism simply means losses of productive hours which can hardly be positively predicted. Therefore previous records have to be analysed in order to assess its effects on manufacturing capacity.

Detailed analyses of these two important factors can be found in Appendix III.

6.5 Present Manufacturing Capacity in the Company

6.5.1 Machine Shop Capacity

The maximum machine shop capacity is a function of the facilities within various work-centres and can be easily worked out. However in order to obtain a more realitic figure, various relating factors such as machine utilisation, operator performance, percentage overtime and absenteeism etc., established in previous sections have to be taken into account.

Detailed calcultions of the effective machine shop capacity are shown in Figure 6.5.1.

Machine Group	Number of Machines (a)	% Utilisation (b)	Operator Performance (c)	% Overtime (d)	% Absenteeism (e)	Weekly Capacity 40(a)(b)(c) [1+d-e] (hrs/wk)
Heavy	23	55.2%	118.8%	8.94%	7.1%	614.4
Turning	13	65.5%	119.6%	6.5%	5.3%	412.25
Grinding	7	67.1%	118.3%	6.23%	6.1%	222.6
Orbit Milling	11	57.8%	116.5%	7.21%	5.31%	301.9
General Millings	27	56%	118.7%	7.21%	5.31%	731.5
Inside Milling	7	61.2%	117.5%	7.21%	5.31%	205.2
Drilling	13	57.5%	121.3%	5.94%	14.3%	333.5
Cam	12	42.4%	110.5%	3.68%	15%	200
Mortice Milling	10	66%	109.6%	7.21%	5.31%	294.8
Sinker	22	38%	120.5%	4.56%	3.86%	406.2
Trick Cutting	18	41.3%	119.7%	11.8%	5.1%	380
V-Bed Trick Cut	16	64.2%	115.4%	7/2%	6.9%	475.6

Figure 6.5.1: Existing Weekly Machine Shop Capacity

6.5.2 Assembly/Fitting Capacity

Since the assembly and fitting operations in this particular trade are highly labour-intensive, the manufacturing capcities in those areas are directly proportional to the number of direct operatives they have. Once again the effects of all the related factors have to be considered. The relevant calculations can be found in Figure 6.5.2.

Assembly Area	Number of Operatives (a)	% Utilisation (b)	Operator Performance (c)	% Overtime (d)	% Absenteeism (e)	Weekly Capacity 40(a)(b)(c) [1+d-e] (hrs/wk)
Paint Shop	3	60%	106%	10.5%	13.6%	74
S/Assy	5	83.9%	113%	7.4%	7.1%	190
Panel	3	76.6%	114%	5.3%	4.6%	105
Pliering	3	60%	112.5%	2.9%	2.43%	81
Stripping	3	32.3%	117.6%	5.95%	5.6%	46
Carcase	5	75.5%	109.4%	5.7%	6.2%	164
Splicing	6	94.6%	115.6%	6.7%	5.9%	265
Rib/Welt	4	45.4%	108.6%	6.4%	4.32%	81
Finish	10	88.3%	106.9%	7.7%	5.75%	385
F/Attach	5	82%	109.7%	6.9%	5.45%	183
V-Bed Assy	17	85.7%	113.6%	7.1%	6.9%	664
Str	5	89.5%	115.1%	5.2%	4.96%	207
Elect.Assy	5	86.1%	117.2%	8.5%	6.95%	205
General	14	79.7%	114.7%	8.32%	5.75%	525

Figure 6.5.2: Existing Weekly Assembly Capacity

CHAPTER 7

DETAILED APPROACH TO CAPACITY PLANNING AND CONTROL - DETAILED METHOD

7.1 General Description

This approach offers a detailed analysis of the manufacturing resources and demands with respect to the production programme in the company. It forms the skeleton of the system proposed by the project.

7.1.1 Aim

This method was developed to provide the company with a means of planning and controlling its manufacturing capacity effectively in order to achieve its yearly output target.

In the longer term, it can help plan the future plant expansions and investments in order to match the future capacity demands.

7.1.2 Areas of Application

The benefits to be gained by individual departments in the company by the application of capacity planning include;

(a) Finance Department - different product-mix policies can be tried out for budgeting purposes just by varying the input parameters.

(b) Sales Department - with the up-to-date capacity information provided by the system, more effective order intake control can be achieved. Therefore, more realistic delivery times can be quoted.

(c) Production Department - the master production schedule can be planned in such a way that the available manufacturing resources can be used efficiently by referring to the work-load distribution patterns in various work-centres. Thus, work orders can be released to the right areas at the right time. As a result, work-in-progress can be reduced significantly.

(d) Purchasing Department - with more reliable requirement timings, the buying orders can be placed promptly to suit the production programme. Therefore, both material shortages and stock holding costs can be brought under control.

7.1.3 Brief Outline of the Detailed Method

The system softwares were prepared in MICROSOFT-80 BASIC Programming Language. They were designed to be run on a CPM or MPM Operating System. However, only slight modification would be needed to tailor the system for used on other machines.

The running of the system can be roughly divided into three stages:

Stage I - specifying the input parameters

Stage II - capacity analysis, scheduling and loading

Stage III - output of results.

In stage I all the relevant input conditions, such as the year concerned, production target, batch quantity, etc, have to be specified by entering the required data into the system through a VDU.

In stage II, the computer will copy the lastest capacity-load records onto a work-file which will be updated as the analysis proceeds. The structure file for the specified product will then be gone through one by one. The planning details for every manufactured item will be obtained from the production routing file in order to calculate the corresponding capacity requirements. Scheduling and loading will take place against the time scale set by the input conditions. If finite loading option has been chosen any overloads will be re-scheduled.

The same routine will be repeated for each of the production cycles as specified at the beginning of the analysis.

In the end, a new capacity-load pattern will be available for each work-centre. These patterns can be presented in stage III in any of the following ways:

(a) on a VDU

(b) in the form of tabulated computer print-out

(c) in the form of a histogram

The resulting capacity distribution corresponding to the input product-mix policy can then be examined. If the new loading situations are acceptable, the current capacity records on the work file can be transferred onto the permanent capacity-load record file. Otherwise, the new records will be ignored as the programme is terminated. The system characteristics enable different product-mix policies to be experimented with and the resulting effect on capacity requirements studied.

7.2 Data Preparation and Maintenance

7.2.1 Capacity-Load Records

This is the first record file that has to be set up because the most important feature of this system is to maintain up-to-date capacity records for every work-centre in the company.

The basic weekly capacity can be derived from the average weekly working hours and the availability of machine/operators in each individual work-centre.

However, in order to obtain the effective capacity figures, the following factors have to be taken into account.

(a) Machine utilisation

(b) Operator performance

(c) Percentage overtime

(d) Percentage absenteeism

The "rated" weekly capacity in every work centre can then be obtained by adjusting the normal figure with reference to the above factors. The resulting records will then be held in a random data file as a data base which will be subsequently updated as soon as loading in any work-centre changes.

7.2.2 Production Routing Records

The production routing record of each particular item contains details of operation sequence, the setting-up and machining time allowed for various operations etc. These records have to be kept up-to-date to enable capacity requirements to be calculated accurately.

Since an item can be used on different products in the company, the production routing file is in fact set up at the plant level rather than product level. The operation planning sheet used in most companies should contain the necessary information for establishing the required routing file. The most important thing to do in this stage is to check whether the available setting-up and machining times are reasonably realistic. The BASIC programme, "RNFILE" was written for creating, updating and displaying production routings. Details of this programme can be found in Appendix VII.

7.2.3 Stage Chart

In capacity planning, being able to tell what capacity is required is only half the story because the time factor is equally important. A Material Requirements Planning (MRP) system can work backward from the delivery due date to work out when exactly a certain operation in a given component or assembly has to be done in a specified work-centre. It is a very detailed process for working out the capacity timing. There is no MRP system in the company at the moment, therefore an alternative procedure using a stage chart to indicate timing had to be used.

A stage chart (3) shows against a time scale the sequence of activities by which finished products are made. The major activities that have to be considered in a manufacturing set-up can be identified as purchasing, machining and assembly. The duration for each of these activities represents the time required to complete it from the completion of the preceding one. It is often referred to as the lead time.

To prepare the stage chart for a given product, firstly the complete manufacturing cycle has to be divided into a suitable number of stages according to the sequence of major assemblies. The various lead-times for each stage have to be obtained from the related departments.

The machining/processing lead time is by far the most complicated one to establish because in addition to the actual processing time, the time required for queueing, transportation between work-centres and other unplanned operations has to be taken into consideration.

After the lead times for all the items in a particular stage have been established, the longest purchasing, machining and assembly lead times are then used to denote the durations for these three major activities in the stage concerned. They will then be plotted against a time scale in similar form to a Gantt chart. The same procedures have to be repeated for every stage in the production cycle. In the end, a complete stage chart results as shown in Figure IV.1 .

From a stage chart, one can tell when exactly the purchasing, machining and assembly processes in any stage are due for starting and finishing with reference to the overall production schedule. Another important application of stage charts is to help identify which activities have to be initiated before receipt of customer's orders, owing to exceptionally long lead times, a requirement which causes some work orders to be released against a forecast.

7.2.4 Structure Records

As mentioned in 7.2.3, to construct a stage chart of a certain product, the manufacturing processes have to be stratified into different stages of major assemblies. To extend this idea a step further, since the components and sub-assemblies required to build up each major assembly bear close relationships to one another, a product structure tree can thus be drawn up to relate various items to the end product.

The structure record of a particular item should contain the following details:

PN - the part number of the item.

STNO - the stage number in which the item is used for the first time in the production cycle. This can ensure that the total requirements of the item are manufactured in a single batch at its first occurence in each production cycle.

QTYPER - total quantity of the item required per end product.

LT - the lead time required for the item concerned.

CM - the cycle message indicates how often a work order for the item needs to be released.
ie CM = 1,2 or 3 means that work order is released every one, two or three production cycles respectively. This device enables some simple and less expensive items to be produced in

a larger quantity sufficient to cover their total requirements over a certain number of production cycles, especially when the setting-up time outweighs the machining.

The structure records for two of the items used on 'ACE' knitting machine can be shown as follows:-

PN	STNO	CM	QTYPER	LT
101025	2	1	1	4
242030	4	2	4	2

The BASIC programme "STR" can be used to create, update and display any structure record. Details of this programme can be found in Appendix VII.

7.3 Basic Features of the System

7.3.1 Input Parameters

To enable the detailed method to carry out its designed functions, a series of input parameters have to be specified as follows:-

YEAR	- That is the calendar year concerned. The system was designed to handle data up to a maximum of five years.
STARTING WEEK	- It defines the week in which the production programme is planned to commence.
PRODUCTION TARGET	- It represents the annual output target for the product concerned.
CHOICE OF APPROACH	- Detailed or rough-cut method (the latter will be dealt with in Chapter 8)

LOADING OPTIONS - Choices of infinite or finite loading are available. In the former case, the capacity demand is loaded against the week number worked out by the computer, disregarding any overloading while in the latter case, any capacity overload will be re-scheduled automatically.

BATCH QUANTITY - the number of machines of the given type to be made in each production cycle.

TIME INTERVAL - the duration (in weeks) between the beginnings of two successive production cycles.

After getting sufficient information from the input parameters, the computer will start working out the optimum number of production cycles required to meet the output target. Adjustments to the batch sizes in individual cycles can be made at this stage.

7.3.2 Calculations of Capacity Requirements

After the number of production cycles and the corresponding batch quantities have been finalized, the computer will call up the product structure file (7.2.4) and go through the records one by one in stage number order. The relevant routing record will then be called up from the production routing file (7.2.2) against each structure record. The capacity requirement for every operation on the routing record will be worked out with reference to the setting-up time, machining time and various input parameters.

The same procedures will be repeated for every manufactured item in each production cycle.

7.3.3 Capacity Scheduling and Loading

After the capacity requirements for each manufactured item have been calculated, they will be allocated to the appropriate work-centre against the week number derived from the stage chart (7.2.3) in either of the following two ways.

(a) Infinite loading

(b) Finite loading

With infinite loading, the capacity demands will be loaded onto different work-centres against the required week number disregarding the resulting work load (4) (6) (11) whereas, with finite loading, the required capacity will be checked against the free capacity in the work centre before loading. If the required capacity exceeds the free capacity in certain weeks, the balance will be re-scheduled backward to the nearest week(s) in which the outstanding work-load can be absorbed.

Infinite loading can be used to highlight when and by how much a particular work-centre will be overloaded, and as a result remedy actions, such as increasing overtime or sub-contracting, can be planned in advance. With the finite loading option any necessary re-scheduling in order to give a smooth and steady load distribution is done by the computer during the programme run.

7.3.4 Work-load Analysis Reports

The work-load distribution in any work centre can be shown in three different ways:

(a) VDU - the capacity-load situations in any week-work centre combination can be shown on the screen.

(b) Detailed Report - the capacity-load information can also be printed on computer hard copies, showing the weekly capacity allocation for any work centre over a given period of time.

(c) Graphical Output - the capacity distribution pattern for a certain work-centre can be plotted in the form of a histogram together with the corresponding analysis figures alongside the week numbers over a specified period of time as shown in Figure 7.3.4 (a) and 7.3.4 (b).

7.3.5 Capacity - Load File Handling

At the start of the programme, the initial capacity (work-load) records for every work-centre are copied from the permanent data file onto a work file which is subsequently updated as the new capacity allocations proceed. In the end of the programme, the work file will contain the most recent capacity-load records of the company. According to various applications, the user can choose to have these records transferred into the permanent data file which will be used as the capacity data base for subsequent analysis. Otherwise, the records in the work-file will vanish as soon as the programme is terminated leaving the initial capacity records in the data-base.

GRAPHICAL OUTPUT OF THE WORK-CENTRE LOAD ANALYSIS

YEAR = 1982 WORK CENTRE = C4 NORMAL WEEKLY CAPACITY = 200 HOURS

WK NO	LOAD HRS	% LOAD	FREE CAP HRS
1	0	0 %	200
2	13	7 %	186
3	127	63 %	73
4	320	160 %	-121
5	263	131 %	-63
6	238	119 %	-38
7	54	27 %	146
8	13	7 %	186
9	109	55 %	90
10	73	36 %	127
11	52	26 %	147
12	9	4 %	191
13	2	1 %	198
14	13	7 %	186
15	127	63 %	73
16	320	160 %	-121
17	263	131 %	-63
18	238	119 %	-38
19	54	27 %	146
20	0	0 %	200
21	0	0 %	200
22	18	9 %	181
23	194	97 %	6
24	497	249 %	-298
25	409	204 %	-209
26	369	185 %	-170
27	88	44 %	111
28	0	0 %	200
29	18	9 %	181
30	167	83 %	33
31	113	57 %	86
32	78	39 %	121
33	13	6 %	187
34	3	2 %	197
35	0	0 %	200
36	18	9 %	181
37	194	97 %	6
38	497	249 %	-298
39	409	204 %	-209
40	369	185 %	-170
41	88	44 %	111
42	0	0 %	200
43	0	0 %	200
44	0	0 %	200
45	16	8 %	184
46	160	80 %	39
47	409	204 %	-209
48	336	168 %	-136
49	303	152 %	-104
50	71	36 %	128
51	0	0 %	200
52	0	0 %	200

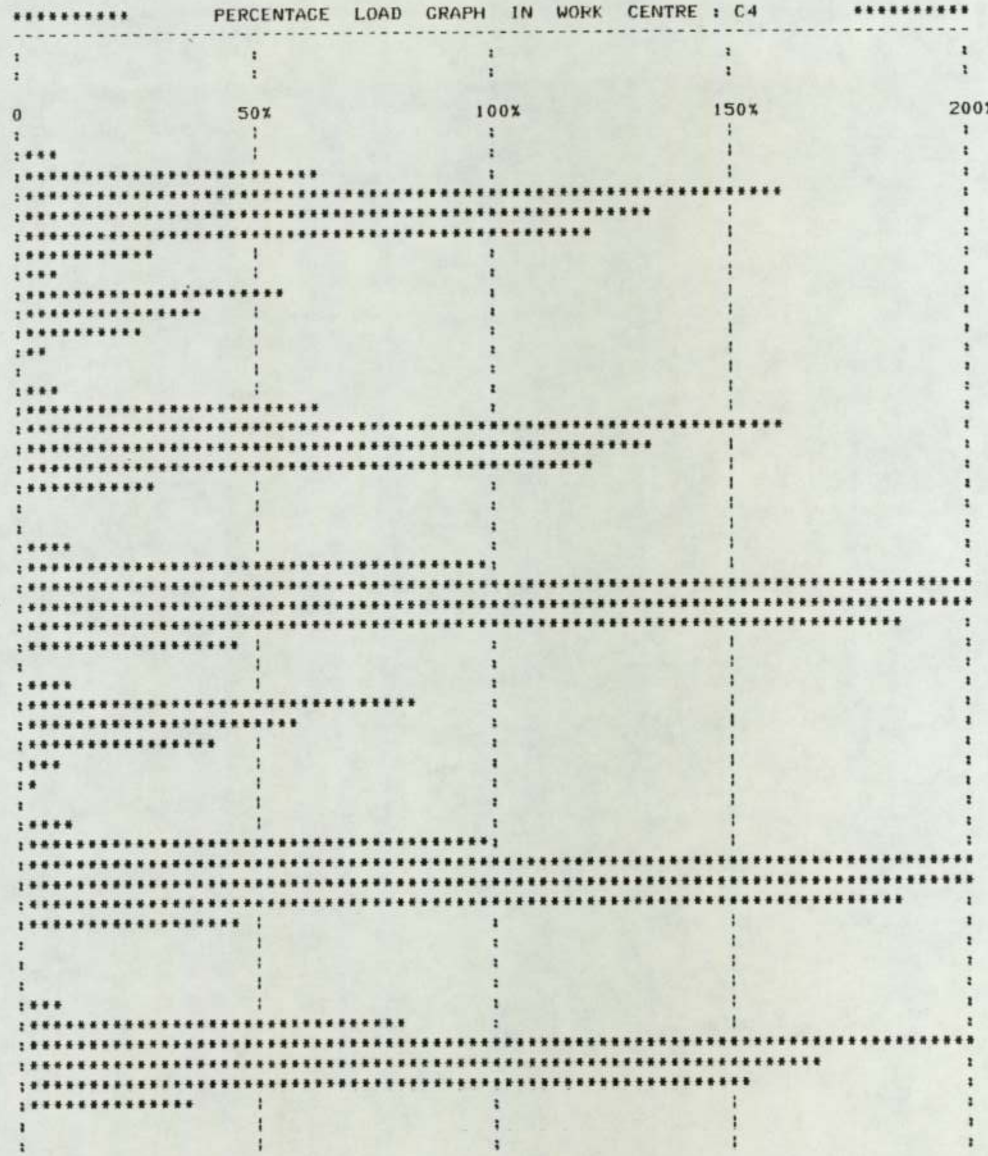


Figure 7.3.4(a): Sample Graphical Output using Infinite Loading Option

GRAPHICAL OUTPUT OF THE WORK-CENTRE LOAD ANALYSIS

YEAR = 1982   WORK CENTRE = C4   NORMAL WEEKLY CAPACITY = 200 HOURS

WK NO	LOAD HRS	% LOAD	FREE CAP HRS
1	0	0 %	200
2	160	80 %	39
3	200	100 %	0
4	200	100 %	0
5	200	100 %	0
6	200	100 %	0
7	54	27 %	146
8	13	7 %	186
9	109	55 %	90
10	73	36 %	127
11	52	26 %	147
12	9	4 %	191
13	2	1 %	198
14	160	80 %	39
15	200	100 %	0
16	200	100 %	0
17	200	100 %	0
18	200	100 %	0
19	141	71 %	58
20	200	100 %	0
21	200	100 %	0
22	200	100 %	0
23	200	100 %	0
24	200	100 %	0
25	200	100 %	0
26	200	100 %	0
27	88	44 %	111
28	0	0 %	200
29	18	9 %	181
30	167	83 %	33
31	113	57 %	86
32	78	39 %	121
33	103	52 %	96
34	200	100 %	0
35	200	100 %	0
36	200	100 %	0
37	200	100 %	0
38	200	100 %	0
39	200	100 %	0
40	200	100 %	0
41	88	44 %	111
42	0	0 %	200
43	24	12 %	176
44	200	100 %	0
45	200	100 %	0
46	200	100 %	0
47	200	100 %	0
48	200	100 %	0
49	200	100 %	0
50	71	36 %	128
51	0	0 %	200
52	0	0 %	200

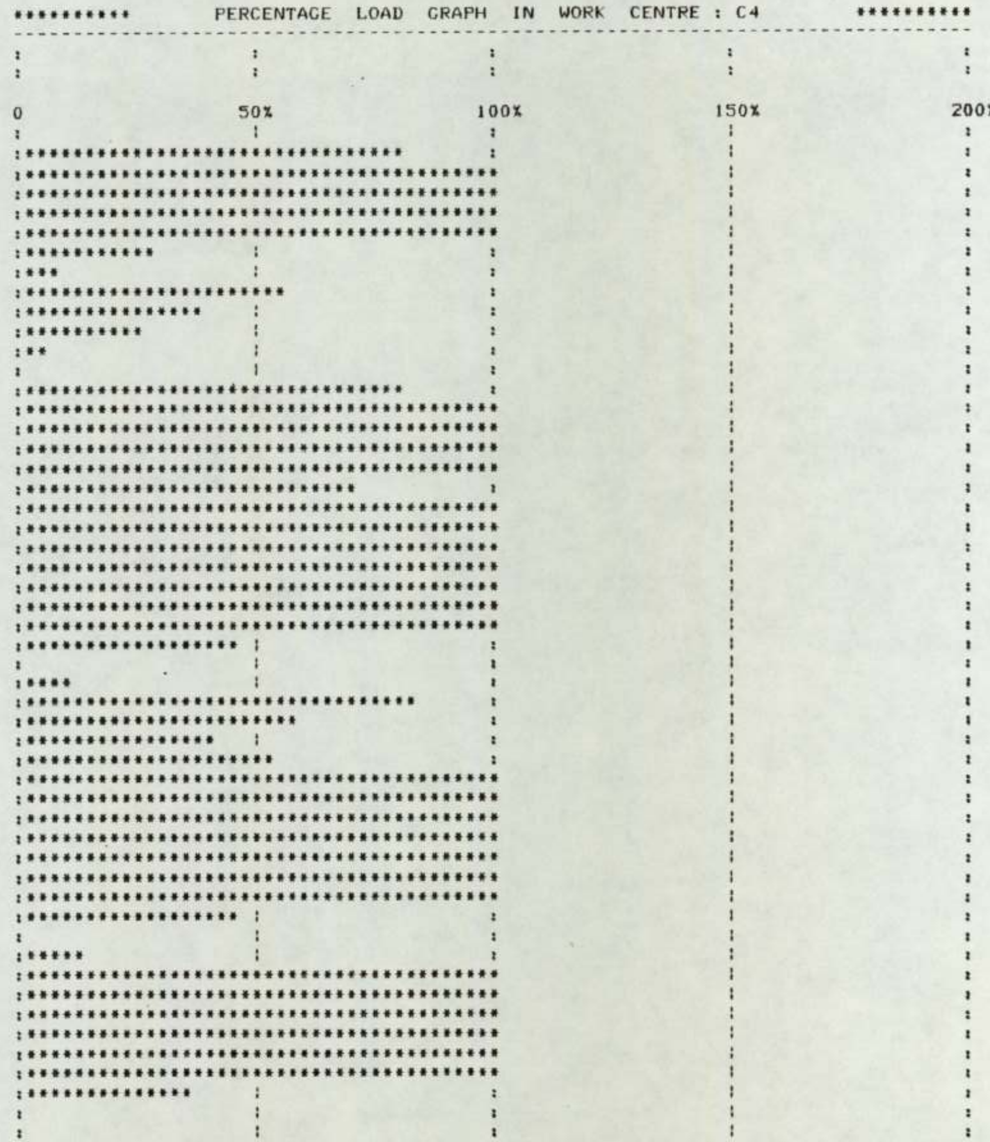


Figure 7.3.4(b): Sample Graphical Output using Finite Loading Option

These options provide the flexibility for experimenting with different product-mix policies without having to make any permanent changes on the records until a suitable combination is found.

7.4 Pros and Cons of the Detailed Method

7.4.1 Advantages

(a) It gives the company an effective means of planning and controlling its manufacturing capacity.

(b) The effects of different product-mix policies can be assessed before the company's annual budget is drawn up.

(c) The impacts of any sales/customer orders on the manufacturing sector (work-centres) of the company can be predicted well in advance so that any necessary actions can be taken in good time.

(d) It provides an accurate way of estimating capacity requirements because every single item is analysed in detail.

(e) When infinite loading is used, any overloading can be highlighted so that corrective actions can be taken.

(f) When the finite loading option is chosen, the re-scheduling property can ensure a smooth and steady shop-load.

(g) Flexible output formats are available to suit different applications and analyses.

7.4.2 Limitations of this Approach

(a) It is more suitable for mature products - the establishment of various system files for production routings, product structures and lead time records, etc require very detailed information which may not be available with new products or prototypes.

(b) Extensive Data Preparation Process - with this detailed approach, records have to be established for every single manufactured item. The amount of work involved is intensive and very time consuming. This problem becomes more significant when products of high complexity like fully-fashioned knitting machines are dealt with.

(c) Slow System Feedback - the detailed method allows the capacity requirements for every item to be worked out and loaded accordingly. However, the total manipulations involved in each production cycle may be too massive for a micro-computer of limited core memories. As a result, it takes so long to work its way through that it may limit its applications on some occasions, such as preliminary planning or decision making meetings.

CHAPTER 8

ALTERNATIVE APPROACH - ROUGH-CUT METHOD

8.1 General Descriptions

8.1.1 Introduction

As it was mentioned in section 7.4.2 there are certain areas in which the application of the detailed method may be limited by the availability of of time and data. An alternative system approach called the rough-cut method was thus introduced to take care of some areas which have not been fully covered by the detailed approach with a view to improving the flexibility of the system proposed.

8.1.2 Characteristics

The basic logic of the rough-cut metod is identical to that of the detailed approach. In fact, some of the system programmes are shared by both approaches.

The essential features of this approach lie in the ways in which the structure and production routing records are established. A hypothetical item (12) (16) has to be created in each stage to account for all the manufactured items in the stage concerned. Each hypothetical item can be fully described by two records:

- a dummy structure
- a dummy routing

Therefore, instead of preparing a large number of detailed data, only a few dummy records need to be established according to the stages of major assemblies. Moreover, the system response rate can be significantly improved because of the reductions in data handling and system manipulation time.

8.2 Data Preparation

8.2.1 Dummy Structure

A dummy structure record having the same format as a detailed structure record prepared for the detailed approach (Chapter 7), consists of:

PN - the part number assigned to the hypothetical item, eg, 999991 and 999992 represent the hypothetical items in stage 1 and 2 respectively in the production cycle.

STNO - represents the stage number.

CM - cycle message - it indicates how frequently a work order for the item concerned has to be issued.

QTYPER - It is a variable which gives the total number of manufactured items in the stage concerned.

LT - represents the average manufacturing lead time in weeks for the hypothetical item.

For example, the dummy structure records for the first two stages of the 'ACE' knitting machine can be expressed as follows:-

PN	STNO	CM	QTYPER	LT
999991	1	1	64	3
999992	2	1	95	4

Dummy structure records can be created, updated and displayed by running the BASIC programme "STR" which will be explained in detail in Appendix VII.

8.2.2 Dummy Routing

A dummy routing is used in the rough-cut method to simulate the production operations required for manufacturing each of the hypothetical items.

It is in the same format as a detailed routing record with the exception that equivalent setting up and machining times are used in every operation.

Those equivalent figures were statistically established using the 'stratified sampling technique' (13).

Manufactured items of the chosen product are stratified into different sample groups according to the sequence of major assemblies as in the construction of stage chart (7.2.4). A random sample of a suitable size (8.4) is taken from each stage. The operations for the manufacturing of all the items in the random sample are further stratified into work-centre groups to which they belong.

For each work-centre group, the setting-up time and processing time for every operation are recorded from the relevant production planning sheets for further statistical analyses as shown in the following paragraphs.

As an example of how the equivalent setting up time and equivalent processing time can be worked out, the HM2 work-centre in stage 1 is chosen for illustration.

QTYPER = the total number of manufactured items in stage 1.

N = the size of the random sample.

N_1 = the total number of HM2 operations from the sample.

tsi = the setting up time for the i^{th} HM2 operation.

tmi = the machining time for the i^{th} HM2 operation.

ni = the quantity of *the i^{th} HM2 item required per end product.

Ts = the equivalent setting up time per item in stage 1.

Tm = the equivalent machining time per item in stage 1.

*Note: the i^{th} HM2 item refers to the item that calls up the i^{th} operation.

(a) The mean setting up time per HM2 operation

$$= \left(\sum_{i=1}^{N_1} tsi \right) / N_1 \text{ ---(i)}$$

(b) The rated mean machining time per HM2 operation

$$= \left(\sum_{i=1}^{N_1} tmi \cdot ni \right) / \sum_{i=1}^{N_1} ni \text{ ---------------------------------(ii)}$$

(c) The average number of HM2 operations per sample item

$$= N_1 / N \text{ ---(iii)}$$

(d) The average manufacturing quantity per sample item

$$= \left(\sum_{i=1}^{N_1} ni \right) / N_1 \text{ ------------------------------------ (iv)}$$

(e) The equivalent setting up time per item in stage 1 can be given by (i) x (iii)

$$\text{ie} \quad Ts = \left(\sum_{i=1}^{N_1} tsi \right) / N_1 \cdot N_1/N$$

$$Ts = \left(\sum_{i=1}^{N_1} tsi \right) / N \text{ ------------------------------ (v)}$$

(f) The equivalent machining time per item in stage 1 can be given by (ii) x (iii) x (iv)

$$\text{ie} \quad Tm = \left(\sum_{i=1}^{N_1} tmi \times ni \right) \Big/ \left(\sum_{i=1}^{N_1} ni \right) \cdot (N_1/N) \cdot \left(\sum_{i=1}^{N_1} ni \right) / N_1$$

$$Tm = \left(\sum_{i=1}^{N_1} tmi \cdot ni \right) / N \text{ ---------------------------- (vi)}$$

By repeating the same procedures with every work-centre group, the dummy routing for the hypothetical item in stage 1 has been worked out as shown:-

PN	STNO	Work Centre	Ts	Tm
999991	1	C4	10.5	0.75
		C6	15.6	0.96
		CL1	13.7	1.02
		NC	20.3	0.65
		HM2	25.5	2.15
		HM3	30.2	2.4
		VM2	23.1	1.75
		VM3	22.4	1.90
		G2	12.5	3.00
		G3	13.7	2.65

The above data can then be input into a dummy routing file by running the BASIC programme "RPLAN" which will be explained in detail in Appendix VII.

8.3 Basic Functions of the Rough-Cut Method

8.3.1 Input Parameters

The input parameters required for this method are very similar to those used for the detailed method as mentioned in section 7.3.1.

When they have been specified, the computer will work out the optimum number of production cycles required to satisfy the output target.

Adjustments on batch quantity in each individual production cycle can be done at this stage.

8.3.2 Calculations of Capacity Requirements

To work out the total capacity requirement in every work centre, the computer needs to go through the stages in the correct sequence, the dummy structure and dummy routing for each stage being called up as required.

Example: For a production cycle quantity of Q, the total HM2 capacity requirement for stage 1 can be worked out as shown.

(a) Total HM2 setting up time for stage 1

= **0.5 (QTYPER·equivalent setting up time)

$$= 0.5 \cdot \text{QTYPER}\left(\sum_{i=1}^{N_1} tsi\right) / N \text{ ---------------------------- (vii)}$$

** Assuming a work order is released every alternate cycle, therefore a corrective factor of 0.5 is used.

(b) Total HM2 machining time for stage 1

= cycle quantity x QTYPER x equivalent machining time

$$= Q \,.\, \text{QTYPER} \,.\left(\sum_{i=1}^{N_1} tmi \cdot ni\right) / \; N \text{ -------------------- (viii)}$$

In the end, the total capacity required in work centre HM2 can be obtained by superimposing the results from individual stages.

8.3.3 Scheduling and Loading

As soon as the capacity requirement on each work centre has been worked out, the system will go ahead with scheduling and loading. Since only ne hypothetical item is used in each stage for capacity calculation, it is more reliable to use the finite loading option, otherwise excessive overloading in certain areas will seriously distort the true picture.

8.3.4 Work-load Reports

The resulting work-load in a certain work centre can be expressed in the following ways.

(a) On a VDU - the work-load information in every work centre for a given week-year combination can be listed on a VDU. Instead of going through a complete list, an option is available to concentrate on the capacity situation of a specified work centre alone.

(b) Outputs from a line-printer

The capacity pattern in any work centre over a given period can be printed on hard copies. The output details are in two sections. An analytical report showing the load hours, the percentage load and the free capacity can be printed on the left hand half of the page. Whereas a histogram showing the graphical load-pattern on the right. This is a very handy document which not only gives the capacity figures but also presents a physical picture of the distribution pattern for easy reference as shown in Figure 7.3.4 (a) and 7.3.4 (b).

8.3.5 Capacity Record Update

After examining the resulting work-load information which is temporarily held in a work file, the user then has to decide whether to make the present capacity records permanent or just ignore them. In the former case, the computer will transfer the new capacity records into the permanent capacity load file which will be taken as the initial conditions for any subsequent loading. Whereas, in the latter case, the existing records will be erased, leaving the initial capacity records unaltered. This option allows different product-mix policies and input parameters to be experimented.

8.4 Determination of Sample Sizes

As mentioned in section 8.2.2 a random sample containing a certain percentage of the manufactured items used in a given product has to be taken in every stage for establishing the production routing. The sample should be of the right size that:-

(a) it gives a reasonable estimation on the distribution of operating times;

(b) the amount of data preparation and processing time can be kept to a minimum.

An easy way of testing the sampling accuracy is to compare the results from the rough-cut approach to those from the detailed one for a number of stages of manufacture. If the estimation errors lie within a specified limit, say +/- 15%, the sample might be considered to be acceptable. If the error was too great to be acceptable a larger sample would be required and the accuracy should be re-assessed.

However, this way of testing the accuracy may not be practicable when the product is getting too complex or when the detailed data is unavailable for comparison purposes. A method for checking the accuracy statistically is based upon the concept of "Sequential Probability Ratio Test" (14).

Using this technique, the sample size is variable to begin with but will be determined in an experimental routine by criteria which depend on the observations as they occur. The routing will be terminated as soon as the the error of estimation falls within the specified confidence interval. As a result, a suitable sample size can be determined for each individual stage for establishing the corresponding dummy routing.

8.5 Advantages of the Rough-Cut Approach

In addition to some of the benefits provided by the detailed method (8.4.1), this rough-cut approach offers the following merits.

(a) It is applicable to both mature and newly developed products provided an estimation can be made of the manufacturing operation mix for the hypothetical component.

(b) The data preparation time can be greatly reduced (see Chapter 9 - Case Study).

(c) Almost instantaneous system feedback can be expected because only a few dummy structure and routing records need to be dealt with.

(d) Reasonable accuracy can be achieved.

(e) A smaller computer may be used because the amount of data requires very much less memory spaces than those for the detailed method.

(f) It can be readily linked to other production control packages with minimum modifications.

8.6 Limitations of the rough-cut approach

The approach does suffer from some drawbacks.

(a) Simplicity is obtained at the expense of accuracy.

(b) The resulting capacity-load distribution tends to be slightly distorted from the actual pattern because the requirement timing in each work centre is dictated by just a limited number of hypothetical items.

(c) Any changes in product design or manufacturing methods will mean a complete re-establishment of the dummy structure and routing records in the stages concerned. Whereas, with the detailed approach, only the items involved need updating which is a relatively simpler process.

CHAPTER 9

CASE STUDY - 'ACE' V-BED KNITTING MACHINE

9.1 The Product

9.1.1 Origin

Alemannia Maschinengabrik was a German knitting machine company originally owned by the Singer Corporation. It was then purchased by the Bentley Engineering Group in 1977. Since then a high level of development has been maintained both in Germany and Loughborough. And, this has resulted in the 'ACE' electronic machine.

9.1.2 Special Features

Being a newly developed machine, ACE has acquired the latest microprocessor control technology. It also possess the following distinctive features.

Versatility	- it is capable of transferring in the leading and trailing systems and within the same traverse knitting on the two knitting systems.
Simplicity	- the small number of moving cams within the cambox gives a considerable reduction in maintenance cost.
Rapid Pattern Change	- using magnetic tape and high speed tape reader

9.1.3 Reasons for using 'ACE' in this case study

(a) New Product - one of the major objectives of this project is to develop a system for planning and controlling the manufacture of new models.

(b) Increase market demand - with it being a new design with revolutionary features, its market demand will go up significantly in the coming few years.

(c) Product details - among the new models, ACE is relatively more mature, therefore more complete construction and planning information can be obtained.

(d) Time-scale - owing to the tight schedule of this project, ACE is just the right sort of example with reasonable complexity to illustrate operational functions of the proposed system.

9.2 Data Availability

9.2.1 Parts Lists

According to the sequence of major assemblies, the construction of the machine can be divided into thirteen stages.

ie Stage 1 - Needle-bed shogging assembly

Stage 2 - Carcuss and take-down assembly

Stage 3 - Racking unit assembly

Stage 4 - Cambox and rail assembly

Stage 5 - Drive mechanism assembly

Stage 6 - QC mechanism assembly

Stage 7 - Electrical assembly

Stage 8 - Carrier assembly

Stage 9 - Element assembly

Stage 10 - Mechanical test

Stage 11 - Electrical test

Stage 12 - Knit test

Stage 13 - Assembly of spares, guards and labels

All the purchased and manufacured items required in each stage were shown on the corresponding parts lists. However, the data available was not ready for immediate analysis because the components in each stage were not arranged in any particular order. Besides, the same component could appear time after time on the parts lists depending on its frequency of use. Hence, this made the calculation of batch quantity complicated.

9.2.2 Production Planning Information

The routing and time estimation details for any manufactured items used on ACE can be obtained from the relevant production planning sheets which might come from three different sources.

Since ACE was initially designed and manufactured in Germany, a majority of the planning details were prepared at Alemannia Maschinenfabrik based on their production set-up. When the production activities of ACE was moved over to Loughborough, the planning information was translated into

English. As time went by, modifications and improvements were made to the design and the methods of manufacture. Therefore, new planning details were added at the Loughborough plant. On the other hand, some of the machining operations on certain components used to be subcontracted to Bookham which was a part of the Bentley Engineering Group. Therefore, a certain proportion of the production routings were prepared by the planners at Bookham.

At the moment, the planning details from these three separate sources are still being used for the manufacturing of ACE.

To suit the data requirements for the proposed system, some necessary modifications were carried out.

9.3 Production Routing File

9.3.1 Preparation of Detailed Routing Records

Since the production planning details came from different sources, they had significant differences in the following areas.

(a) The way in which a given component is to be produced is often dictated by the experience of the planners as well as the equipment and machine tools available in the Company.

(b) Time standard - the time taken to set up and process a given job depends on various factors, such as the method used, the conditions of the equipment and other human aspects which may differ from one company to another.

It was thus necessary to modify the available production routing records to ensure that they are compatible to the manufacturing environments here in Loughborough.

With the assistance of the work study engineers in the company, all production planning records for ACE knitting machine were brought up-to-date. As a result, more relevant production routings were made available and stored in a random file forming a data-base for detailed capacity analysis and many other applications.

9.3.2 Preparation of Dummy Routing Records

As mentioned in section (8.2.2), dummy routing records have to be created when the 'rough-cut' approach is employed.

First of all, the equivalent setting-up and equivalent machining time for ACE in every work-centre were established against each of the thirteen stages as indicated on the Parts Lists.

For every stage, a random sample covering around twenty-five per cent of the manufactured items was taken. The corresponding operations for producing those items in each sample were further stratified into different work-centre groups. For each of these groups, the equivalent setting-up time and equivalent machining time were worked out statistically in the way as shown in (8.2.2).

The same procedures were repeated for each work-centre, and in the end a dummy production routing was created for every stage.

The resulting dummy routings for various stages in ACE can be found in Appendix (V).

9.4 Stage Chart

As explained in section (7.2.3), the normal activities in each stage can be fundamentally divided into three sections, ie the purchasing, machining and assembly periods. The duration of each period is determined by the item which required the longest leadtime in the stage concerned.

9.4.1 Leadtime Establishment

The leadtime for every stage of manufacture of a given product have to be worked out before the corresponding stage chart can be constructed.

For the purchasing leadtime, data could be obtained from the production control department. It was concluded from the data that castings normally require a longer leadtime than others. The average purchasing leadtime was about five weeks with the exception of some imported items, such as needle-bed and cambox castings, which had to be ordered more well in advance.

In order to accurately establish the manufacturing leadtime for each item, in addition to the actual time required for processing, extra time has to be allowed for transportation, queuing, sub-contracting and any other unplanned operation. Under normal circumstances, the machining leadtime for a majority of the components used on ACE should not exceed four weeks with the exception of the needle-bed and needle-bed support which require almost twice as long simply because of the extensive amount of trick-cutting and sub-contract operations involved.

Assembly leadtimes can be relatively easily worked out provided there is no delay on components and sub-assemblies. They were found ranging from one to five days depending on the complexity of the assembly process concerned.

9.4.2 Stage Chart Construction

According to the sequence of major assemblies, the complete building of an ACE V-bed knitting machine can be divided into thirteen stages. The longest purchasing, machining and assembly leadtimes in each stage were then taken and plotted against a chosen time-scale accordingly as shown in Figure (IV.1). Special care had been taken to ensure that the assembly operations were arranged in the correct sequence, although the electrical assembly stage 7 can be carried out any time after stage 4 assembly has been completed. The mechanical test in stage 10 and the electrical test in stage 11 can in fact be done in parallel. With reference to the complete stage chart, the total manufacturing through-put time for machining and assembling a batch of twelve ACE knitting machines is found to be around sixteen weeks.

In fact, as long as the plant capacity can cope, a batch of twelve ACE machines can be released every 4 weeks. The individual capacity requirements can be superimposed onto one another, forming the total capacity-load pattern.

9.5 Comparisons of the Two Approaches

Experiments were carried out on both the detailed and rough-cut methods with the same set of input parameters. Special emphasis was put on comparing following areas.

9.5.1 Data Preparation Time

To establish the detailed production routings and product structures for ACE, nearly five months were taken. Whereas, only 4 weeks were spent on establishing the dummy records for the rough-cut approach.

In another word, about 80% of the data preparation time had been saved with the rough-cut method.

9.5.2 Programme Running Time

With the detailed method, the computer has to go through every structure record and call up the relevant routing so that the corresponding capacity requirements in various work-centres can be calculated. Then capacity scheduling and loading follows. For this medium-size knitting machine, about ninety minutes was taken by the computer to tackle each production cycle.

When the rough-cut method was chosen, only a few dummy structure and routing records had to be considered. As a result, the corresponding scheduling and loading time was found significantly reduced to just over ten minutes per cycle.

9.5.3 Accuracy of the Rough-Cut Approach

It has been outlined in Chapter 8 that the rough-cut capacity requirement for any particular stage, say stage i of a production cycle can be expressed as the sum of the corresponding total setting-up time and total machining time in each particular work centre. Whereas,

Total setting up time = 0.5 (QTYPER) (eq. set-up time)---(1)

Total machining time = Q(QTYPER) (eq. machining time)---(2)

The values of individual variables for stage i can be found from the relevant dummy structures and dummy routings.

Example 1: For a batch quantitiy (Q) of ten, the rough-cut capacity requirements for work-centre HM2 can be calculated as shown:

For Q=10,

Stage Number	EQ Set-Up (Mins)	EQ Machining Time (Mins)	QTYPER	Total Set-Up (Hrs)	Total Machining (Hrs)	Sum (Hrs)
1	237.27	49.95	45	88.98	374.63	463.31
2	34.74	1.67	75	21.71	20.88	42.59
3	122.73	8.51	87	88.98	123.40	212.38
4.	120	3.5	14	14.00	8.17	22.17
5.	53.18	5	85	37.67	70.83	108.5
6	60	4.44	35	17.5	25.9	43.4

Total: 892.35 hrs

By repeating the same procedures with different batch quantities, Q, the following results were found

For Q=5, required capacity = 580.75 hrs,

For Q=15, required capacity = 1203.34 hrs,

For Q=20, required capacity = 1514.84 hrs.

Example 2: Similar calculations were carried out for work centre D4.

For Q=10,

Stage Number	EQ Set-Up Time (Mins)	EQ Machining Time (Mins)	QTYPER	Total Set-Up (Hrs)	Total Machining (Hrs)	Sum
1	38.18	2.25	45	14.32	16.88	31.2
2	24.47	1.94	75	15.29	24.25	39.54
3	30	2.07	87	21.75	30.02	51.77
4	60	9.58	14	7.0	22.35	29.35
5	23.86	2.04	85	16.9	28.9	45.8
6-8	16.67	2.72	35	4.86	15.87	20.73

Total : 218.39 hrs

Repeat the same procedure for different Qs,

For Q=5, required capacity = 149.26 hrs

For Q=15, required capacity = 287.53 hrs

For Q=20, required capacity = 356.66 hrs.

In order to assess the accuracy achievable using the rough-cut method, the same input parameters were used on the detailed method. The results from the different approaches can be compared as follows:

Work Centre	Batch Quantity	Capacity Required Per Cycle		(R)/(D) x 100%	Percentage Error
		Detailed (D) (hours)	Rough-Cut (R) (hours)		
HM2	5	625.13	580.75	92.9%	-7%
	10	858.32	892.35	104%	+5%
	15	1084.09	1203.34	111%	+11%
	20	1317.25	1514.84	115%	+15%
D4	5	158.79	149.26	94%	-6%
	10	213.27	218.39	102.4%	+2.4%
	15	267.97	287.53	107.3%	+7.3%
	20	324.24	356.66	110%	+10%

Similar comparisons for evey work centre can be found in Appendix VI.

The above analysis indicated that errors do exist with the use of rough-cut method which appeared to under-estimate the work-load at small batch quantities. However, as the batch quantity, Q, increased to around 10 to

15 the errors approached zero, but they tended to diverge again as Q increased any further.

The causes of inaccuracies could be due to a combination of various factors, such as

- equivalent setting up time being too low
- equivalent machining time being too high
- the sample size was not large enough
- the sample taken was not representative etc.

To investigate the problem further, the capacity requirements were compared stage by stage rather than as a complete production cycle. The results show that with a chosen combination of work centres and batch quantity, the errors were larger in some stages than the others, ranging between plus and minus 30%.

The results from this stage by stage investigation suggested that the actual errors in individual stages were larger than that of a complete production cycle in which the errors leveled themselves out. The errors might in fact be normally distributed with their mean approaching zero. It meant that the rough-cut approach suffers from an obvious limitation which could well be overcome by taking a larger sample, say 60%-70%, however this may defeat the objective of having the rough-cut alternative.

9.6 Conclusions

(a) The system was proved to be able to carry out the required analyses with any specified set of input parameters using either the detailed or rough-cut approach.

(b) The flexibility in selecting input and output options was found to be very useful.

(c) The accuracy from the detailed approach was proved to be reasonable.

(d) Eighty per cent reduction of data preparation time could be achieved with the rough-cut method.

(e) The average system running time was found to be reduced from ninety minutes per cycle to just over ten minutes when the rough-cut method was used.

(f) The discrepancies resulted from rough-cut method were due to a combined effect of various factors. However, in normal circumstances the accuracy available should be acceptable for preliminary capacity assessment.

(g) An effective way of improving the rough-cut accuracy is to increase the sample size. But, this solution may not be feasible for new products with limited data.

CHAPTER 10

GENERAL DISCUSSION ON THE PROJECT AND TEACHING COMPANY SCHEME

10.1 Capacity Planning and Control - a team effort

As it was mentioned earlier, the objective of introducing a capacity planning and control system into a company is to ensure the right resources can be available when they are needed. Apparently, it seems to be a sole concern of the production department. However, as the topic is considered in depth, it can be realised as a problem that requires active involvements, participations and co-operations from various departments in the Company.

10.1.1 Research and Development

A highly motivated and forward-looking Research and Development Team has a very important role to play in keeping the company in a competitive position. This can be achieved through active product development to meet the future market demands. On the other hand, they are also responsible for advising the company on the technology and manufacturing resources required for those new designs. Therefore, any plant expansions and investments can be planned in advance accordingly.

10.1.2 Sales Forecast

The major function of the Sales Department is to sell the goods by various means of introducing the products to the customers. At the same time, they are also responsible for exploring the potential markets and forecasting the future market demands on their products. A reliable sales forecast is essential because it will enable the forward production plan to be drawn up so that any impending capacity problems can be identified and tackled as soon as possible.

10.1.3 Marketing Strategy

Manufacturing firms are very often confronted with two contradicting questions.

(a) Shall we make what we can sell? and

(b) Shall we sell what we can make?

In fact, we can never go to either extreme, for there should always be one or more feasible solutions somewhere between the two. To find that out, the capacity requirements for different product-mix policies have to be worked out and balanced against the available resources over a given period of time.

The work supporting this research was to investigate the effects of various factors on manufacturing capacity and to develop a systematic approach for determining the suitable product-mix capacity required combinations.

10.2 The Project Work

In handling the problems in capacity planning and control, there are a few basic areas which need to be evaluated in depth.

(a) What manufacturing resources the company has.

(b) What capacity is required to satisfy the output target.

(c) When the capacity is needed against the production programme.

(d) How these inter-relating aspects can be integrated systematically.

The project work can be stratified into six major stages which were spread over a period of twenty working months.

(A) Stage I (2 months) - Problem Shooting

At the beginning of this research, a considerable amount of time was spent on discussions with people from various departments in order to identify the actual problems in capacity management within the company. As a result, the appropriate terms of reference could be fixed for the project.

(B) Stage II (6 months) - Information and Data Collecting

The first background exercise that had to be carried out was to revise the Plant Register in order to set up-to-date records of all the equipment and machines in each work-centre. These records formed the capacity-load data-base.

Exercises were also done to investigate the various factors affecting manufacturing capacity, such as

- operating conditions and areas of application of the facilities,
- machine utilisation,
- operator performance,
- percentage overtime and absenteeism, etc.

Activity sampling and various work study techniques were employed.

(C) Stage III (4 months) - System Development

After the basic information had been collected, the next step in the project was to design a systematic approach for capacity planning and control mainly on a medium-term (1 to 3 years) basis, although the system can also be tailored for other short-term applications, such as work-in-progress control.

The basic logic of the system can be outlined as follows.

(i) Define the input parameters.

(ii) Calculate the corresponding capacity requirements in various work-centres.

(iii) Capacity scheduling and loading (re-scheduling wherever necessary).

(iv) Output the results of analysis in the chosen formats.

(v) Update the permanent capacity load data-base as required.

(D) Stage IV (3 months) - Computer Programming

Most of the products in the company are reasonably complex, consisting of thousands of different components and sub-assemblies. Therefore, going through the procedures manually would be impossible. Using a computer seemed to be the only alternative.

To do this, the system logic was transformed into BASIC computer programmmes which could be run on CP/M or MP/M Operating System. Getting familiar to the computer, the operating system and the file handling techniques also formed a significant part of the programming stage.

System debugging and modifications were done in the end.

(E) Stage V (3 months) - Data Files Establishment

Owing to the tight project time-scale, it did not allow the data files for all the products in the company to be set up. Therefore, the new "ACE" V-bed knitting machine was chosen as a case study to illustrate the characteristics of the system.

The following data files are required to run the system.

(i) Capacity-load records file.

(ii) Product structure file - it outlines the material requirements for each assembly stage.

(iii) Production Routing File - it consists of all the operational details for each manufactured item.

(iv) Stage chart and lead time - information file which governs the capacity requirement timings.

Setting up data files is always a time-consuming process.

(F) Stage VI (2 months) - Experiments and Demonstrations

At the final stage of the research, a series of experiments and demonstrations were carried out with a view of:-

(i) testing the general functions of the system,

(ii) assessing the system responses to different input parameters and loading policies,

(iii) comparing the results from the detailed and rough-cut approach so as to assess the accuracy of the latter,

(iv) enabling the personnel from relevant departments to get familiar with and confident in the system proposed.

10.3 Some Observations and Comments

10.3.1 The Research Topic

At this stage, it is worth clarifying that the individual ideas and techniques used in this project are by no means new. However, the ways in which they were put together so as to tackle the problems do suggest some effective applications in the area of capacity planning and control.

Though the system was developed specially for the products in Bentley, sufficient options had been included in order to enable the system to be applied in other manufacturing companies with minimum modifications and customisation.

The system was basically for medium-term (1-3 years) applications, however it can also be tailored to carry out work-in-progress control and short-term shop loading functions.

The possibility of integrating the system with other teaching company projects had been borne in mind during the system development stage.

10.3.2 The University

Since this research is a part of the Aston/Bentley Teaching Company Programme, the majority of the research work was done within the company. However, academic staff from the university also played an important role in guiding the approaches to the problems and supervising the progress of the project. Continuous supports from the university in the form of regular meetings and research equipment, such as computer facilities and appropriate technical advice enabled the project to advance with minimum interruptions.

Lectures, seminars and course-works arranged regularly by the university also served to broaden the associates' general knowledge and awareness towards modern manufacturing technology. And, they can in turn benefit the immediate research and future careers of the associates.

10.3.3 The Company

Owing to the increase in market demands in recent years, the company has gone through some rapid changes in product designs and manufacturing re-organisation. It had been realised that some sort of advice and assistance from the government would be essential to facilitate the company's rapid development. That resulted in the setting up of this Teacing Company Programme.

The recent diversifications of product range in the company obviously justified the urgent needs for a more effective approach in capacity management. In other words, the timing of this project tied in nicely with the overall development plan of the company.

Throughout the project period, the supports from the company had been reasonable in the form of advice and co-operations from people in different areas. Special tributes have to be paid to the production managers, production control staff and work study engineers whose contributions to this project was extremely valuable.

10.3.4 The Teaching Company Scheme

The idea of teaching company schemes is revoluntionary because it breaks through the barriers between the industrial and the academic organisations by setting up active partnerships between the two through a number of teaching company programmes. The scheme allows:-

- the associates have the opportunities to build up their practical experience through working together with the people from the industry as well as the university;

- the company to benefit from the development (project) work carried out by the associates with the influence of advanced technology and new ideas;

- the university to maintain close contacts with the practical world through industrial consultancies and post-graduate research activities offered by the scheme.

Moreover, the TCS plays a far more important role in bringing together a team of young graduates who work on different programmes all over the country. By sharing their experience and achievements, they represent a central driving force towards the future of the British Industry.

With the encouragement and sponsorship from the SERC and DOI, both formal and informal national communication networks have already been established through seminars, associate club news-letters, meetings as well as regional events organised for both current and ex-associates.

CHAPTER 11

CONCLUSIONS

The major objective of capacity planning and control is to ensure that the required manufacturing resources are available at the right time.

The work presented here demonstrates how certain commonly used production control and work study techniques can be put together to give some new and effective applications in the area of capacity management with the help of a micro-computer.

11.1 General Principles

11.1.1

Capacity planning and control is by no means a discrete function. It requires team efforts and involvements from various departments in the company.

11.1.2

The research and development department has the responsibility of advising the company on future requirements of technology and equipment for manufacturing the impending new models.

11.1.3

Being an important input to capacity planning and control, reliable sales forecasts are indispensable for future plant expansion and investment planning so as to bring the manufacturing capacity in line with the future market demands.

11.2 General Conclusions on Capacity Planning System Developed

11.2.1

The system is designed mainly for handling the capacity planning and control problems in the textile machinery industry.

11.2.2

A reasonable amount of options are available in the input and output fields to provide sufficient system flexibilities for tackling the capacity problems in other manufacturing industries.

11.2.3

Up-to-date capacity records for all work centres are required to form the capacity-load data-base.

11.2.4

Apart from the availability of machines and manpower, there also exist other factors that can effect manufacturing capacity. The planned factors are under more direct control, while some other factors have to be monitored carefully in order to control the manufacturing performance.

11.2.5

Up-to-date product structure and production routing records are absolutely essential because the system can only be as good as what goes into it.

11.2.6

Realistic manufacturing lead times are essential for the construction of production stage charts which indicate the capacity requirement timings for various products in the company.

11.2.7

With the detailed approach, every manufactured item has to be considered to give the capacity-load pattern with high accuracy.

11.2.8

The effectiveness of the rough-cut approach relies on the accuracy of the dummy structures and routings which may be difficult to achieve with small sample size. Therefore, this method may not be applicable to new products with limited data.

11.2.9

Infinite and finite loading options are available. The former can highlight when exactly capacity overload occurs, while the latter can perform re-scheduling to give a more evenly distributed load pattern.

11.2.10

The results of analysis can be shown on a VDU, in the form of a detailed print or a histogram.

11.2.11

If necessary, the resulting capacity-load details can be transferred from the work-file onto the permanent data-base, otherwise the original records will remain unchanged. This option enables the effects of different product-mixes to be conveniently assessed.

11.2.12

The benefits of a successful capacity planning and control system can be noticed in the following areas:

- more effective production control
- more accurate budgeting input
- reduced inventory level
- more confident customer order acceptance
- better delivery performance
- promoting company goodwills

11.3 General Conclusions on the Project Work

11.3.1

A firm with efficient capacity management practice should be able to balance its available resources against the capacity requirements according to a specified output schedule.

11.3.2

As the product varieties increase,the needs for a systematic approach to capacity management become more urgent.

11.3.3

Up-to-date work-centre capacity information, relevant product structure and production routing records are the prerequisites for accurate capacity analysis.

11.3.4

It is essential to ensure that people in various departments as well as the shop floor are aware of the purpose of the project work because their first hand experiences and suggestions can always help identify the areas where the problems lie.

11.3.5

Positive attitudes amongst senior managment have a significant effect on the introduction of changes and new approaches.

11.3.6

Effective communications among the company, the research associates and the university are critical towards the success of a teaching company programme.

CHAPTER 12

FUTURE WORK

The work presented in the previous chapters illustrates the design, development and implementation aspects of a practical system for effective capacity planning and control.

The logic and computer softwares for the proposed system have been fully established and experimented.

The system has been implemented on one of the selected products, "ACE" V-bed knitting machine because the tight project time-scale simply did not allow a full-scale analysis. Moreover, the resources made available up to the current time have not enabled all the product groups to be covered.

To improve the effectiveness of the proposed system, further work can be done in the following areas:

12.1 Extension of the system to cover work-in-progress control

The system explained here lends itself to performing capacity planning and control practices mainly on a medium to long term basis, (ie from one year onwards). However, the logic and the functions of the system can be tailored reasonably easily to carry out daily work-in-progress control.

The work will involve the developments of more system softwares for handling the daily transactions of job status and progress so that shop scheduling and loading information can be kept up-to-date. Ideally, an on-line system should be used to give the best effects. All the same, a batch processing approach by adopting an overnight updating practice has been proved reasonably successful in many manufacturing firms where computer facilities dictate.

12.2 More Accurate Rough-cut Data

Other methods of calculating the mean times used for the hypothetical component should be evaluated to improve the accuracy of the rough cut method.

12.3 Incorporating the proposed system with other projects in the programme

Since capacity management can never be an independent function, it is important that the system can be linked up to other activities in the company. Furthermore, with this research being a part of a four-year teaching company programme, work should be done in some later stage of the programme to integrate the various research projects to form a complete management information system (MIS).

Some potential areas that are worth looking into can be given as follows.

12.3.1 Access to Component Coding Information

Running in parallel to this project, the component coding research was also one of the Phase I projects in this teaching company programme. It mainly dealt with the establishment of a system for identifying components based on their material and geometric characteristics. Its major area of application is in design retrievals, however it can also assist process planning and machine tool selection. A means of accessing and analysing the component coding information will be useful for operation re-routing, especially when overloads occur in one or more work-centres.

12.3.2 More Accurate Capacity Requirements Timing Inputs Using MRP

In this project, a stage chart is used to reckon the requirement timings for items in different stages of the manufacture cycle. For more precise analysis, instead of being divided into stages according to the sequence of major assemblies, the items can be structurally stratified into different levels of manufacture as used in most material requirement planning (MRP) systems. The building of a given product can be represented in the form of a family tree with the finished product at the top, ie level zero.

An MRP system enables the capacity requirement timings for different components and assemblies to be determined more accurately with explicit definitions of part to part relationships. Thus, material shortages or delays can be reduced to a minimum.

12.4

Finally, these additional features will make the system more sophisticated. However, the gateway to success still relies on how soon and how well the people in the company can depart from their present informal practices and accept changes towards a more systematic approach.

APPENDIX I

Plant Register

In order to assess the manufacturing capacity available in the company, an exercise was carried out at an early stage of this research to find out the quantity and applications of each type of equipment or machine in every work centre.

The results of this investigation can be shown as follows.

HEAVY SECTION

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
1	P1	Planning (Tandem)	Large	Standard	532
1	P2	Planing	Medium		1110
1	VHM	Plano Miller			917
1	HB1	Borer			496
1	HB2	Jig Borer	3B		600
1	HB2A	Jig Borer	3H-48		547
1	VM3	Vertical Mill		Hydrotel	4
1	D25	Drill	Radial	Standard	924
2	SD1	Drill	Spar	Rails	526
					771
1	SR	SAW		Rails	824

HEAVY SECTION

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
1	G2	Lumsden Grinder			871
1	BMH1	Broach			548
		"			
1	CL2	Centre Lathe			1355
1	CL3	Centre Lathe	Large		188
1	BMV1	Vertical Broach			1137
1	D2	Radial Drill		Round Table	1148
1	VTB60	Web 9 Vert Borer			1024
1	D2	Radial Drill			109
1	D4	4 Spindle Drill		General	1085
1	HMS	Horizontal Mill	Large		1092

HEAVY SECTION

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
1	HB1	Horizontal Borer			1127
1	HB1	Horizontal Borer			1130

TURNING SECTION

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
1	C4	Capstan Lathe	up to and incl 11/2 dia		696
1	AC4	Capsten Robot Lathe	up to and incl 11/2 dia		844
1	C6	Capsten Lathe	9" chuck No 4		701
1	C7	Turret Lathe	No 7 chucking 12" chuck		896
1	C8	Turret Lathe	No 7 Bar 21/2 dia		711
1	CA1	Automatic Lathe	up to and incl 5/8 dia	Sawcut Attach	18
1	CL25	Centre Lathe	9"-3 and 4 Jaw	Screw Cutting	23
			18" Face Plate		
	1	CL2C	Centre Lathe	Copy Attachment	976
1	OG1	Oil Grooving			19

TURNING SECTION

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
1	OG1	Oil Grooving			19
	TM1	Thread Miller			1097
2	C4	Herbert No 4 Capsten			1047
					1048
1	C4	Capsten Lathe			1307

GRINDING SECTION

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
1	G4	Cylindrical Grinder			434
2	G3	Surface Grinder			529
1	G3	Surface Grinder			739
1	G5	Internal Grinder			756
1	G6	Centerless Grinder			603
1	G45	Cylindrical Grinder			1095
1	G4	Cylindrical Grind			1096

MILLING (ORBIT SECTION

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
3	VM2	Vertical Mill		General	479
	VM2	Vertical Mill			1187
	VM2	Vertical Mill			1318
2	HM3	Horizontal Mill		Universal	1196
	HM3	Horizontal Mill			698
4	HM2	Horizontal Mill		General	225
	HM2	Horizontal Mill			1308
	HM2	Horizontal Mill			1126
	HM2	Horizontal Mill			1336

MILLING (ORBIT SECTION)

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
1	D6	6 Spindle Drill			573
1	C4	Capsten Lathe			1359

MILLING (GENERAL SHOP)

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
7	VM2	Vertical Mill		General	1315
					1339
	VM2	Vertical Mill			1197
	"	"			1186
	"	"			1232
	"	"			936
	"	"			77
1	VM3	Vertical Mill	Large	General	428
16	HM2	Horizontal Mill		General	1189
	"	"			1192
	"	"			1337
	"	"			1338

MILLING (GENERAL SHOP)

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
	HM2	Horizontal Mill			1312
	"	"			1158
	"	"			1310
	"	"			441
	"	"			471
	"	"			42
	"	"			443
	"	"			461
	"	"			1309
	"	"			76
	"	"			424

MILLING (GENERAL SHOP)

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
	HM2	Horizontal Mill			568
2	HM3	Horizontal Mill	Large	Universal	669
	HM3	Horizontal Mill	Large		477
1	UPM1	Tracemaster			837

MILLING (INSIDES)

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
2	VM2A	Vertical Mill		Insides	524
					1093
4	HM3A	Horizontal Mill		Insides	440
					444
					445
					1156
1	HM3A	Horizontal Mill	Large	Insides	1050

DRILLING SECTION

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
3	D2	Radial Drill			150
	"	"			628
	"	"			1328
1	D3	Tapping			433
3	D4	4 Spindle Drill			945
	"	"			1341
	"	"			
2	D6	6 Spindle Drill			522
	D6	"			589
1	MD1A	Special Multi-Spindle	36-Spindle	Insides	1019

DRILLING SECTION

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
1	DT6	Drill Multi-Head Turret		General	856
1	D3	Tapping	Flash Tapper m/c	General	857
1	D1	Newark NC	Drill		881

CAM SECTION

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
2	HM2	Horizontal Mill		1 Attachment	70
					705
1	HB3	Borematic			61
1	CM1	Horiz Prof Cam Mill		Archdale	510
2	CM2	Horiz Prof Cam Mill		Hey	67
					1193
1	CM3	Horiz Prof Cam Mill		Relieving	65
1	D4	Drilling		4 Spindle	64
1	BS1	Bandsaw			501
1	PM1	Vert Prof Mill			72
1	VM2	Vertical Mill			500
1	HM2	Horizontal Mill			933

TRUCK ARMS AND MORTICE MILL SECTION SHOP (18)

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
1	D2	Drilling	Radial		615
3	MM1	Mortice Mill	Large		604
					507
					192
2	MMD	Mortice Mill	Small		1305
1	HB3	Borematic			633
1	VM2	Vertical Mill			1314
1	VM3	Vertical Mill	Large		940
1	HM2	Horizontal Mill			41

SINKER SHOP

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
2	APM 1	Auto Profile Mill M/C		Single Spindle	114
	"	"		"	116
2	G3C	Surface Grinder		With crushing attachment	578
	"	"		"	579
4	G3	Surface Grinder			431
	"	"			462
	"	"			657
	"	"			956
1	GU	Guillotine	1/32" Mat 20" Blade	Foot Operated	95
1	FP1	Fly Press Small	1 Ton		137
4	FP3	Fly Press	3 Ton		128

SINKER SHOP

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
	FP3	Fly Press	3 Ton		133
	"	"	"		109
	"	"	"		660
2	PP2	Power Press	2 Ton	Meco	119
	"	"	"	"	465
1	PP10	Power Press	10 Ton		970
1	PP12	Power Press	12 Ton	Bliss	458
1	PP20F	Power Press	20 Ton	Bliss with coil feed	92
1	PP25	Power Press	25 Ton	Ferracute	94
2	PP35	Power Press	35 Ton	Bliss (2) Edwards	877
	"	"	"	"	90

SINKER SHOP

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
3	RVA	Rivetter Air Operated		Air Operated	748
	"	"		"	749
	"	"		"	751
1	RVPP	Rivetter Power Press			107
1	PPP	Planishing Power PR		Humphries and Bliss	468
1	D1	Single Spindle Drill		Herbert and PP Cera (3) J&S	111
1	L1	Linisher		Bandpacer	6612PMS

THICK CUTTING SECTION (GENERAL)

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
3	TCH	Hand Trick Cutting m/c	36" long 6" stroke	With drilling	244
	"	"	"	"	245
	"	"	"	"	246
2	TCA2	Auto Trick Cutting m/c			1001
	"	"			1027
6	TCD1	Auto Trick Cutting m/c	36" long 3" stroke		227
	"	"	"		648
	"	"	"		649
	"	"	"		769
	"	"	"		770

THICK CUTTING SECTION (GENERAL)

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
	TCD1	Auto Trick Cutting m/c	36" long 3" stroke		822
4	EX-TCD1	Auto Trick Cutting m/c			646
	"	"			768
	"	"			226
	"	"			819
1	TCD2	Auto Trick Cutting m/c			229
2	EN	Engraving Machine			613
	"	"			252

ALLEMANIA TRICK SECTION

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
1		Hand Trick/ Cut Machine	36" long 6" stroke	With Drilling	247
2		Moes Trick/ Cut m/c	8 Head		1058
					1060
1		Moes Trick/ Cut m/c	10 Head		1344
1		Mauser Trick/ Cut m/c			1079
1		Surface Grinder	Large	Needle Bed Grinder	1080
1		Verge Rolling	Large	Mills/Burnishes Verges N/Beds	1138
1		Verge Rolling	Large		1081
1		Bench Grinder			1089

ALLEMANIA TRICK SECTION

QUANTITY	CODE	MACHINE TYPE	CAPACITY	REMARKS	PLANT NUMBER
1		Drill (Horizontal)	Large Bed	Used for long repetitive drilling	1112
1		Surface Polisher	Large		1088
1		2 Spindle Drill			1104
1		Cutter Grinder			1105
1		Verge Rolling	Large		1085
1		Suging m/c			1082
1		Grind/Polisher	Large		1114

APPENDIX II: Machine Utilisation and Operator Performance

Exercises were carried out at an early stage of this research to establish the machine utilisation and operator performance figures which are essential for assessing the actual manufacturing capacity in various work centres.

II(A) Machine Utilisation

Activity sampling technique was used to find out the operating conditions in each work centre. First of all, a pilot study was conducted to establish the frequency of occurrence of the activity in question. In the end the number of observations required in each work centre could be determined based on a 90 per cent confidence level.

To simplify the process only two major categories (ie machine running and machine idling) were taken into consideration in this exercise. A given machine was counted as running when it was either being set up or actually machining. Otherwise the machine was considered to be idling no matter the stoppages were due to breakdowns, awaiting materials or information etc.

Samples were taken at random intervals in order to avoid any discrepancies in observations which might happen to be time-dependent. The foremen and shop stewards in various work centres had been approached beforehand so that the psychological effects could be significantly reduced. All the same the first hundred readings in each work centre were also discarded to this end.

The resulting machine utilisation figures can be found in Figure II(a).

II(B) Man-Power Utilisation

A detailed weekly record as shown in Figure II(b) representing how the man-power resources (hours) were allocated in various productive and non-productive activities was used to establish the man-power utilisation in different work centres.

The average figures for the machine shop and assembly areas resulted from a three month study can be found in Figure II(c) and Figure II(d) respectively.

II(C) Operator Performance

As was mentioned in section (7.3) although a planned time is normally given against every operation on the production planning sheet, the actual time taken does inevitably vary. It depends on the accurancy of the estimations.

Figure II(e) explained how operator performance figures can be worked out.

The average figures for the machining and assembly areas obtained from random samples of 2,000 items can be found in Figure II(f) and Figure II(g) respectively.

MACHINE GROUP	TOTAL NO. OF OBSERVATIONS	FREQUENCY OF RUNNING	FREQUENCY OF IDLING	PERCENTAGE MACHINE UTILISATION
Heavy(127)	3000	1656	1344	55.2%
Turning (121)	3500	2293	1207	65.5%
Grinding (125)	2000	1342	658	67.1%
General Milling (123)	3500	1960	1540	56%
Orbit Milling (123)	1000	578	422	57.8%
Inside Milling (123)	1500	918	582	61.2%
Mortice Milling (123)	800	528	272	66%
Drilling (124)	800	460	340	57.5
Cam Milling (133)	1000	424	576	42.4%
Sinker Shop (126)	800	304	496	38%
Trick-cutting (132)	1000	413	587	41.3%
V-Bed Trick-cutting (133)	800	514	486	64.2%

Figure II(a):
Machine utilisation figures obtained by activity sampling method.

	10 Heavy	11 T+G	12 Mill	13 Drill	14 Cams	17 Bench	30 Sink	75 Saws	81 Trick	80 Hard	82 Paint	Total actual hours
Sales	41.92	154.00	183.25	18.83	43.75	48.84	147.58	0.50	27.75	10.00	3.50	679.91
V-bed	1.50	16.50	66.58	1.00		4.92	6.50	0.50	5.33	7.50	13.00	123.33
F, Ft Intarsia		1.00	3.25	2.42	25.00	0.92		1.75				34.34
AEF/ETF	242.67	131.75	727.50	113.75	98.42	139.42	130.67	25.00	62.83	11.00	116.50	1799.51
CRP	124.33	46.83	157.25	67.67	28.83	46.00	13.75	1.25	23.75	3.00	23.50	536.16
Sub-cont.	7.00									3.00		10.00
Alemannia	179.25	59.16	77.25	4.00		7.33	0.75	0.50	0.42	14.00	1.00	343.66
Setting	4.75	50.50	59.25	51.00	46.00		53.50	20.00	39.50			324.50
Treatment	22.50					39.50	57.00				93.00	212.00
SUBTOTAL	623.92	459.74	1274.33	258.67	242.00	286.92	409.75	49.50	159.58	48.50	250.50	4063.41
434 Rectif'n	3.16		5.00	0.50								8.66
423 Waiting	2.58		4.25									6.83
Projects	12.16	22.00	48.25	2.08		2.33		0.50	2.50			89.82
TOTAL	641.82	481.74	1331.83	261.25	242.00	289.25	409.75	50.00	162.08	48.50	250.50	4168.72
438 Experiment		5.00										5.00
435 Personnel	0.50	4.16	14.50		4.50		3.67					27.33
452 Maintenance	13.00	10.75									4.50	28.25
433 M/C clean	9.25	6.00	17.50	2.50	2.50	4.00	4.50	0.50	1.50			48.25
442 Jigs/Fix		2.00	4.25	2.00								8.25
453 Security	4.16		27.58									31.74
441 Loose tools	1.50	2.33	6.50				14.67					26.00
444 Int Trans					2.00							2.00
446						39.50						39.50
451	6.00											6.00
424	79.00		11.00			7.50						97.50
493.02		11.50	7.00									18.50
TOTAL	114.41	41.74	88.33	4.50	9.00	51.00	22.84	0.50	1.50		4.50	338.32
Directs	17	12	32	6	6	8	10	1	4	1	6	103
Clock hrs	755	505	1377	266	251	340	447	50	164	48	255	4438
Util %	82.6	91.0	92.5	97.2	96.4	84.4	91.7	99.0	97.3	101.0	98.2	91.1

Number of excluded operators 7

Figure II(b)
Weekly man-power utilisation record

MACHINE GROUP	OPERATOR UTILISATION
Heavy	88.2%
Turning	89.1%
Grinding	93.7%
General Milling	91.3%
Inside Milling	93.6%
Drilling	85.7%
Cam Milling	95.5%
Mortice Milling	92.5%
Sinker	87.1%
Trick Cutting	93.7%
V-Bed Trick-Cutting	95.4%

Figure II(c):
Average Machine Shop Operator Utilisation Figures

ASSEMBLY AREA	OPERATOR UTILISATION
Paint Shop	60%
Sub-Assembly	83.9%
Panel Wiring	76.6%
Pliering	60%
Stripping	32.3%
Carcase	75.5%
Splicing	94.6%
Rib and Welt	45.4%
Finish Assy	88.3%
Finishing Attachment	82%
Vee-Bed Assy	85.7%
Straightening	89.5%
Electrical Assy	86.1%
General Assy	79.7%

Figure II(d):
Average Fitting Shop Operator Utilisation Figures

Batch Qty Q	Estimated Time		Actual time taken, Ta(hr)	Operator Performance $\frac{Ts + Q\ Tm}{60 \cdot Ta} \times 100\%$
	Set-up, Ts(min)	Processing, Tm(min)		
20	90	8	3.75	111%
20	60	7.84	3.67	98.5%
20	30	1.5	0.83	120%
20	45	2.5	1.25	126.7%
49	30	4.5	3.38	123.5%
49	45	2	2.00	119%
49	20	1.0	1.00	115%
10	30	2	0.67	124%
10	-	63	1.17	104%
19	20	0.75	0.5	114%
19	15	0.5	0.33	123.7%
10	20	1.0	0.58	86%
40	135	7.5	6.50	112%
10	30	3.92	1.2	96%
10	20	4.50	1.25	86%
10	45	2.5	1.08	108%
10	20	3.5	1.33	69%
20	30	2.0	1.00	116%
10	45	4.61	1.42	107%

Figure II(e):
Typical examples of operator performance calculations

MACHINE GROUP	AVERAGE OPERATOR PERFORMANCE
Heavy	118.8%
Turning	119.6%
Grinding	118.3%
General Milling	118.7%
Orbit Milling	116.5%
Inside Milling	117.5%
Mortice Milling	109.6%
Drilling	121.3%
Cam Milling	110.5%
Sinker Shop	120.5%
General Trick-Cutting	119.7%
V-Bed Trick-Cutting	115.4%

Figure II(f):
Average machine shop operator performance figures obtained from a random sample of 2,000 operations.

ASSEMBLY AREA	AVERAGE OPERATOR PERFORMANCE
Paint Shop (152)	106%
Sub-Assy (161)	113%
Panel Wiring (162)	114%
Pliering (164)	112.5%
Stripping (165)	117.6%
Carcase (171)	109.4%
Splicing (172)	115.6%
Rib and Welt (173)	108.6%
Finish Assy (174)	106.9%
Finishing-Attachment (175)	109.7%
Vee-Beds Assy (176)	113.6%
Straightening (177)	115.1%
Electrical Assy (178)	117.2%
General Assy (166)	114.7%

Figure II(g):
Average fitting shop operator performance figures.

APPENDIX III: Direct labour input analysis

To calculate the actual available capacity in each work centre, various factors and contingencies have to be taken into account. Among them, the average normal working hours, the overtime hours and the absenteeism hours are the most influential elements. In order to establish all these figures, a Direct Labour Input Analysis was carried out over a 12 month period on a weekly basis.

To do this the normal working hours, the overtime hours and absenteeism hours in each work centre were recorded every week. The data indicates that actual working hours follow a seasonal trend which shows an obvious decrease in certain months mainly due to holidays and general reduction in the amount of overtime worked in the summer months. To bring the available capacity in line with this trend, average figures were calculated on a monthly basis as shown in Figure III(a).

The summary of the analysis can be shown in Figure III(b), III(c) and III(d). As a result, the available capacity of a certain work centre over a given month can be calculated:

Available capacity = Normal capacity [1 + (% overtime - % absenteeism)]

Cost Centre	Shop No.	Work-Centre	NORMAL HOURS w/e 5/12	12/12	19/12	26/12	Total	OVERTIME HOURS 5/12	12/12	19/12	26/12	Total	% O/T	ABSENTEEISM HOURS 5/12	12/12	19/12	26/12	Total	% A
121	11	Turning and Grinding	800	800	800	720	3120	35	38.5	39	34.5	147	4.7	26	35	20	35.75	116.75	3.
123	12	Milling	2000	2000	2000	2000	8000	20	97.5	119	80	226.5	2.8	46	106	122	145.	419	5.
124	13	Drilling	480	480	440	400	1800	11.5	12.5	21	21	66	3.7	56	40	74	102	272	15.
126	30	Sinker Shop	760	740	720	760	2980	-	195	12	8.5	40	1.3	-	40	28	97.5	165.5	5.
127	10	Heavy Section	680	600	640	640	2560	54	42	40	22.5	158.5	6.2	8.0	-	-	61	69	2.
128	75	Saws	100	120	120	120	460	-	6.5	7.5	11.0	25	5.4	-	32	8.0	5.5	45.5	9.
129	17	Bench Hands	320	320	280	320	1240	8.5	19	26	13.0	16.5	5.3	8	16.0	24.0	40.5	88.5	7.
132	81	Trick Shop	280	240	280	280	1080	15.5	27	18	18	78.5	7.3	-	22.0	-	67.5	89.5	8.
133	14	Cam Section	200	200	240	240	880	-	1.8	17.5	11.8	31.1	3.5	-	18	22	19	59	6.
152	82	Painting	240	240	240	200	920	11.5	31.75	25.5	28	96.75	10.5	4.5	11.5	19	7.0	42	4.
154	18	Welding	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
155	80	Heat Treatment	80	80	60	80	300	-	27.42	4.0	-	31.4	10.4	8.00	8.0	8.0	13.5	37.5	12.

Figure III(a): Monthly direct labour input analysis for December 1980

Cost Centre	Shop No.	Work Centre	MONTHLY NORMAL CAPACITY											
		Month /Yr	7/80	8/80	9/80	10/80	11/80	12/80	1/81	2/81	3/81	4/81	5/81	6/81
121	11	Turning and Grinding	2440	3080	3080	3120	3120	3120	3120	3080	3080	3080	3040	3040
123	12	Milling	6080	7200	7600	7600	8000	8000	8000	8000	8000	8000	7600	7600
124	13	Drilling	1320	1600	1600	1680	1760	1800	1800	1760	1760	1720	1720	1720
126	30	Sinker Shop	2200	2800	2840	2940	2940	2980	2940	2980	2980	2840	2900	2840
127	10	Heavy Section	1800	2400	2480	2520	2560	2560	2520	2520	2560	2560	2560	2560
128	75	Saws	340	420	380	480	480	460	460	460	480	480	420	420
129	17	Bench Hands	960	1180	1040	1140	1200	1240	1280	1200	1240	1200	1140	1220
132	81	Trick Shop	800	1000	1040	1080	1080	1080	1080	1000	1000	1020	960	960
133	14	Cam Section	640	680	800	880	880	880	880	840	800	720	720	760
152	82	Painting	680	860	860	820	860	920	920	880	880	800	860	860
154	18	Welding	80	160	120	120	100	-	160	160	120	120	100	80
155	80	Heat Treatment	200	280	280	320	300	300	320	300	280	240	280	260

Figure III(b): Summary of monthly normal capacity

Cost Centre	Shop No.	Work-Centre	MONTHLY PERCENTAGE OVERTIME											
		Month /Yr	7/80	8/80	9/80	10/80	11/80	12/80	1/81	2/81	3/81	4/81	5/81	6/81
121	11	Turning and Grinding	3.2	2.7	3.12	3.7	4.5	4.7	4.3	4.2	4.3	3.5	3.7	3.9
123	12	Milling	1.5	2.2	1.9	1.85	2.4	2.8	2.9	3.1	2.8	2.75	2.7	2.6
124	13	Drilling	2.3	2.5	2.25	3.2	3.5	3.7	3.8	3.2	3.25	2.9	2.75	2.6
126	30	Sinker Shop	0.75	1.2	1.6	2.2	2.1	1.3	1.8	1.7	1.75	1.60	1.50	1.15
127	10	Heavy Section	4.5	5.2	4.2	4.75	5.1	6.2	6.35	5.75	4.75	5.25	6.15	5.3
128	75	Saws	4.7	4.9	5.1	4.8	4.9	5.4	5.6	5.3	5.45	6.12	7.13	6.15
129	17	Bench Hands	5.17	6.14	7.56	6.34	5.3	5.3	5.4	5.13	4.8	4.6	5.7	4.9
132	81	Trick Shop	7.5	6.95	6.74	5.25	4.38	7.3	5.34	6.7	7.3	5.6	6.7	7.3
133	14	Cam Section	2.9	2.75	3.5	3.2	3.4	3.5	3.3	3.57	3.75	3.2	4.6	3.2
152	82	Painting	6.9	7.3	6.45	7.2	8.6	10.5	9.3	9.4	8.7	6.3	8.75	7.5
154	18	Welding	-	-	-	-	-	-	-	-	-	-	-	-
155	80	Heat Treatment	7.7	7.9	8.3	8.25	8.4	10.4	10.9	13.4	10.2	9.4	8.5	9.7

Figure III(c): Summary of monthly percentage overtime

			MONTHLY PERCENTAGE ABSENTEEISM											
Cost Centre	Shop No.	Work Centre	Month /Yr 7/80	8/80	9/80	10/80	11/80	12/80	1/81	2/81	3/81	4/81	5/81	6/81
121	11	Turning and Grinding	3.5	2.9	3.3	3.7	3.5	3.7	3.8	3.95	3.2	3.3	3.6	3.7
123	12	Milling	6.3	6.7	5.2	6.3	5.5	5.2	7.2	6.5	6.2	7.1	6.7	6.4
124	13	Drilling	14.5	15.7	19.2	13.4	7.5	15.1	11.3	12.5	16.3	15.3	14.3	11.2
126	30	Sinker Shop	6.7	7.3	4.5	4.9	5.7	5.6	6.9	7.3	10.1	13.4	5.2	6.3
127	10	Heavy Section	6.4	5.6	9.5	10.5	4.5	2.7	3.8	4.5	3.2	9.5	10.7	5.3
128	75	Saws	10.3	5.9	6.4	5.3	4.7	9.9	7.5	8.4	6.4	7.6	7.9	6.9
129	17	Bench Hands	4.5	6.9	4.3	5.6	7.7	7.1	6.8	7.3	6.6	7.4	7.9	6.3
132	81	Trick Shop	7.5	7.3	6.9	7.2	9.4	8.3	9.3	6.4	6.7	7.5	6.3	7.7
133	14	Cam Section	7.9	6.3	6.7	7.7	8.4	6.7	7.3	4.5	5.6	7.8	4.9	6.3
152	82	Painting	7.6	6.3	7.4	6.8	8.5	4.6	3.4	6.5	7.3	3.9	4.5	6.2
154	18	Welding	9.5	10.3	3.7	-	6.9	-	-	-	4.3	6.8	8.9	9.2
155	80	Heat Treatment	14.5	6.3	9.1	8.4	7.6	12.5	13.1	12.1	6.5	7.8	8.4	6.7

Figure III(d): Summary of monthly percentage absenteeism

APPENDIX IV: Construction and applications of stage charts

In this research, Stage Charts played a very significant role in representing the manufacturing sequence and timing of complete products, such as knitting machines and fully-fashioned machines.

A stage chart, often referred to as a Production Stage Chart, is a simplified version of networks employed in Critical Path Analysis. It shows against a time scale the sequence of activities by which finished products are made. The time for each activity is the time required to complete it from the completion of the preceeding one. (3) It takes time for setting up, machining or assembling the job. In addition, the time for transportation and queueing also need to be considered. As a result, the sum of the processing times can give a realistic leadtime for the entire series of activities.

In a manufacturing cycle, the activities mainly consist of functions, such as design, purchasing, store kitting-up, machining, assembly and inspection etc.

To illustrate the details of its construction, let us look at the production stage chart for a batch of 12-off 'ACE' V-bed knitting machines.

First of all the manufacturing cycle of the machine is stratified into a certain number of stages according to the sequence of major assemblies.

In 'ACE' there are basically thirteen manufacturing stages, namely

Stage 1: Needle-bed assembly

Stage 2: Carcuss and Take-down assembly

Stage 3: Racking unit assembly

Stage 4: Cambox and rails assembly

Stage 5: Drive mechanism assembly

Stage 6: Q.C. mechanism assembly

Stage 7: Electrical assembly

Stage 8: Carrier assembly

Stage 9: Element assembly

Stage 10: Mechanical test

Stage 11: Electrical test

Stage 12: Knit test

Stage 13: Assembly of spares

The components called up in each individual stage, say Stage 1 can then be put together forming a stage parts list.

The next step is to establish the leadtimes for the three major manufacturing functions, purchasing (or materials procurement), machining and assembly for every item in the given stage. The longest lead time is chosen from each of the three functions and used to represent the corresponding time span for stage 1 on the chart.

The same procedures have to be repeated for all other stages and in the end a complete Stage Chart can be constructed as shown in Figure IV(a) with all the relevant lead times plotted against a common time scale.

(B) Applications of Stage Chart

Some typical applications can be outlined as follows:

(1) With reference to its production stage chart, the total manufacturing through-put time for a given batch quantity of a certain product can be readily worked out. Sometimes this through-put time may be significantly longer than the delivery period expected by customers. In order to cope with these demands, stage charts can be used to identify the assemblies and sub-assemblies which need to be built for stock well before the receipts of firm orders. This certainly has direct effects on the stock holding policies of a manufacturing firm.

(2) Stage Chart is also a useful tool for scheduling the start and finish dates of each activity in a manufacturing cycle. This property has been clearly illustrated in this project because it enables the capacity requirement timings to be assessed without relying on other complicated analyses, such as Material Requirement Planning(MRP). (4)

(3) A Stage Chart can also be treated as a simplified version of product structure because by looking at the Stage Chart of a given product, one can visualise how various assemblies and sub-assemblies in different stages are related to one another.

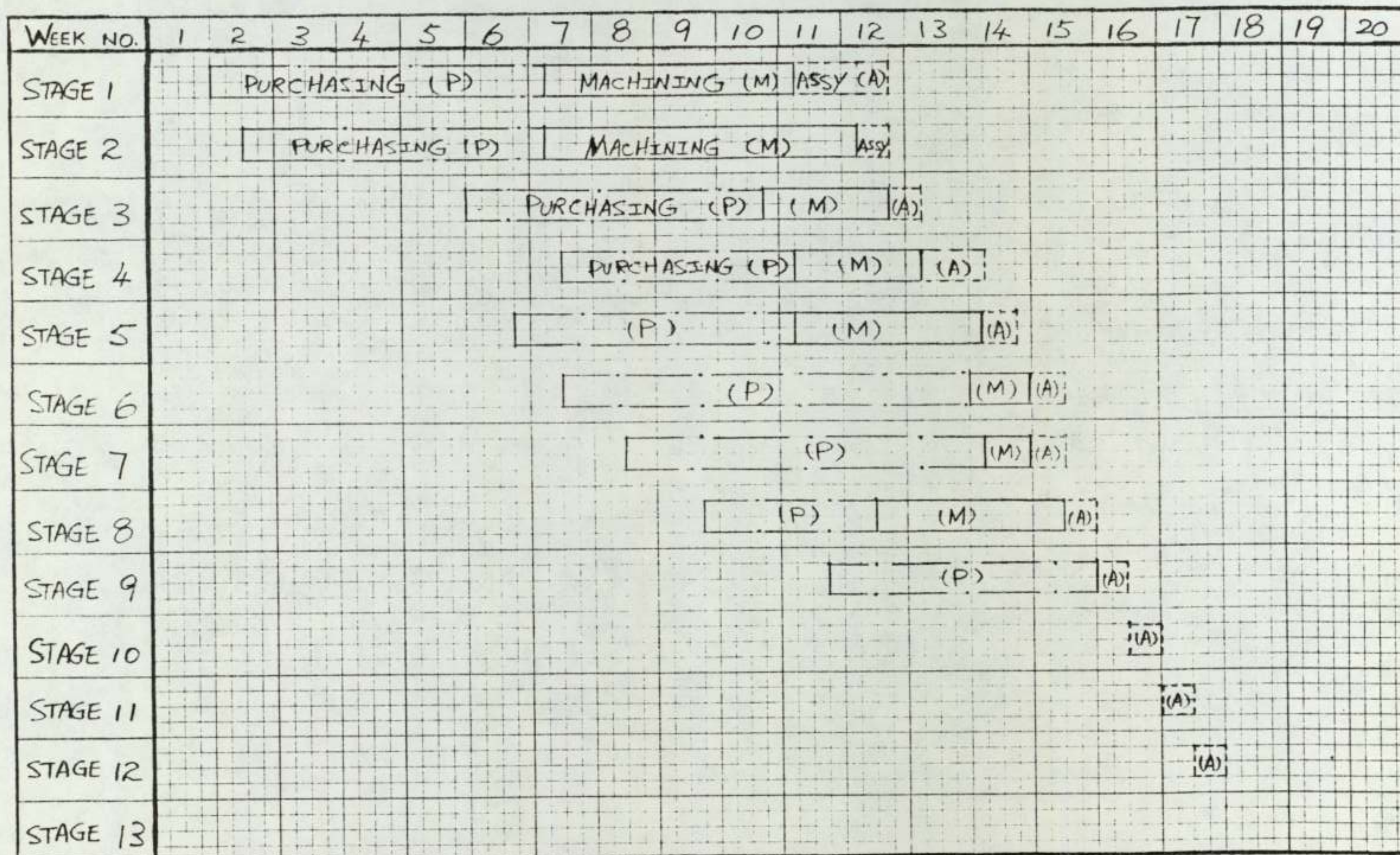


FIGURE IV·1: PRODUCTION STAGE CHART FOR 'ACE' KNITTING MACHINES (12 OFF)

APPENDIX V

Dummy Routings for 'ACE' V-Bed Knitting Machine

STAGE NUMBER: 1	PART NUMBER: 999991	
Work Centre	Set-up (mins)	Machining (mins)
C4	46.36	3.08
C6	32.73	3.08
CL1	-	-
NC	-	-
HM2	237.27	49.95
HM3	-	-
VM2	152.73	40.34
VM3	32.73	18.44
G2	13.64	2.4
G3	9.55	.91
G4	10.9	2.05
G5	4.1	1.36
G6	5.45	.182
D1-3	35.45	30.34
D4	38.18	2.25
D6	-	-
WDKN	-	-

Figure (V.1): Stage 1

Dummy Routing for 'ACE' Kniting Machine

STAGE NUMBER: 2	PART NUMBER: 999992	
Work Centre	Set-up (mins)	Machining (mins)
C4	51.32	4.22
C6	9.47	1.21
CL1	-	-
NC	12.63	.69
HM2	34.74	1.67
HM3	-	-
VM2	82.11	24.66
VM3	66.32	12.34
G2	-	-
G3	2.37	.42
G4	-	-
G5	-	-
G6	2.37	.32
D1-3	23.68	2.28
D4	24.47	1.94
D6	6.32	1.84
WDKN	8.28	2.46

Figure (V.2): Stage 2

Dummy Routing for 'ACE' Knitting Machine

STAGE NUMBER: 3	PART NUMBER: 999993	
Work Centre	Set-up (mins)	Machining (mins)
C4	21.82	1.74
C6	32.73	6.85
CL1	5.45	.41
NC	-	-
HM2	122.73	8.51
HM3	20.45	2.14
VM2	43.64	3.18
VM3	17.73	1.81
G2	2.73	0.17
G3	2.73	.18
G4	2.73	.64
G5	2.05	.205
G6	-	-
D1-3	21.82	1.42
D4	30	2.07
D6	-	-
WDKN	7.73	.967

Figure (V.3): Stage 3

Dummy Routing for 'ACE' Knitting Machine

STAGE NUMBER: 4	PART NUMBER: 999994	
Work Centre	Set-up (mins)	Machining (mins)
C4	20	1.16
C6	-	-
CL1	-	-
NC	-	-
HM2	120	3.5
HM3	-	-
VM2	150	22.67
VM3	-	-
G2	-	-
G3	-	-
G4	-	-
G5	-	-
G6	20	.33
D1-3	-	-
D4	60	9.58
D6	-	-
WDKN	-	-

Figure (V.4): Stage 4

Dummy Routing for 'ACE' Knitting Machine

STAGE NUMBER: 5	Part Number: 999995	
Work Centre	Set-up (mins)	Machining (mins)
C4	39.55	2.36
C6	17.73	3.47
CL1	-	-
NC	10.91	.86
HM2	53.18	5
HM3	20.45	1.52
VM2	79.77	9.61
VM3	-	-
G2	2.27	.41
G3	6.82	.72
G4	-	-
G5	2.04	.23
G6	1.36	.09
D1-3	6.82	.64
D4	23.86	2.04
D6	-	-
WDKN	-	-

Figure (V.5): Stage 5

Dummy Routing for 'ACE' Knitting Machine

STAGE NUMBER: 6-8	PART NUMBER: 999996	
Work Centre	Set-up (mins)	Machining (mins)
C4	46.67	23.31
C6	-	-
CL1	-	-
NC	-	-
HM2	60	4.44
HM3	-	-
VM2	130	30.33
VM3	-	-
G2	3.33	0.67
G3	3.33	0.028
G4	-	-
G5	-	-
G6	-	-
D1-3	3.33	.17
D4	16.67	2.72
D6	-	-
WDKN	-	-

Figure (V.6):

Dummy Routing for Stage 6 Onwards

APPENDIX VI

Summary Of Results From Case Study
(Chapter 10)

Work Centre	Batch Quantity Q	Capacity Required Per Cycle Detailed (D) (Hours)	Rough-Cut (R) (Hours	R/D x 100%	Percent Error
C4	5	238.23	245.85	96.9%	-3.1%
	10	393.54	382.45	102.9%	+2.9%
	15	550.2	519.06	106%	+6%
	20	727.13	655.66	110.9%	+10.9%
C6	5	140.92	149.46	106%	6%
	10	199.34	245.07	122%	22%
	15	257.76	340.68	132.2%	32.2%
	20	316.2	436.29	138%	38%
CL1	5	6.09	6.925	87.9%	-12%
	10	9.5	9.895	96%	-4%
	15	14.06	12.875	109.2%	+9.2%
	20	17.0	15.85	107.3%	+7.3%

Figure VI (a) Comparison Of Results From Detailed And Rough-Cut Approach

		Capacity Required Per Cycle			
Work Centre	Batch Quantity Q	Detailed (D) (Hours)	Rough-Cut (R) (Hours)	R/D x 100%	Percent Error
NC	5	21.8	27.98	128%	+28%
	10	28.62	39.07	136%	+36%
	15	35.4	50.16	141%	+41%
	20	42.23	61.25	145%	+45%
HM2	5	625.13	580.75	92.9%	-7%
	10	858.32	892.65	104%	+5%
	15	1084.09	1203.34	111%	+11%
	20	1317.25	1514.84	115%	+15%
HM3	5	48.93	55.6	88%	-12%
	10	84.34	81.88	103%	+3%
	15	122.22	108.16	113%	+13%
	20	108.42	134.44	124%	+24%

Figure VI (b) Comparison Of Results From Detailed And Rough-Cut Approach

Work Centre	Batch Quantity Q	Capacity Required Per Cycle Detailed (D) (Hours)	Rough-Cut (R) (Hours)	R/D x 100%	Percent Error
VM2	5	720.07	763.59	94.3%	-5.7%
	10	1308.18	1275.03	102.6%	+2.6%
	15	1952.6	1786.47	109.3%	+9.3%
	20	3261.8	2802.21	116.4%	+16.4%
G2	5	22.19	24.77	89.6%	-10.4%
	10	39.78	39.86	99.8%	-.2%
	15	60.99	54.95	111%	+11%
	20	83.35	70.045	119%	+19%
VM3	5	232.75	225.97	103%	+3%
	10	414.27	385.365	107.5%	+7.5%
	15	622.67	544.76	114.3%	+14.3%
	20	842.18	704.16	119.6%	+19.6%

Figure VI (c) Comparison Of Results From Detailed And Rough-Cut Approach

		Capacity Required Per Cycle			
Work Centre	Batch Quantity Q	Detailed (D) (Hours)	Rough-Cut (R) (Hours)	R/D x 100%	Percent Error
G3	5	23.75	25.295	93.9%	-6.1%
	10	39.79	37.748	105.4%	+5.4%
	15	56.83	50.205	113.2%	+13.2%
	20	72.99	62.66	116.5%	+16.5%
G4	5	13.39	15.061	88.9%	-11.1%
	10	22.66	24.053	94.2%	-5.8%
	15	31.82	33.046	96.3%	-3.7%
	20	43.38	42.038	103.2%	+3.2%
G5	5	11.09	12.686	87.4%	-12.6%
	10	19.77	20.901	94.6%	-5.4%
	15	30.63	29.116	105.2%	+5.2%
	20	40.8	37.331	109.3%	+9.3%

Figure VI (d) Comparison Of Results From Detailed And Rough-Cut Approach

		Capacity Required Per Cycle			
Work Centre	Batch Quantity Q	Detailed (D) (Hours)	Rough-Cut (R) (Hours)	R/D x 100%	Percent Error
G6	5	9.08	10.518	115.8%	+15.8%
	10	11.08	14.223	128.3%	+28.3%
	15	15.75	17.928	113.8%	+13.8%
	20	19.08	21.633	113.4%	+13.4%
D1-3	5	198.1	192.561	97.2%	-2.8%
	10	301.1	336.412	111.73%	+11.7%
	15	400	479.763	119.9%	+19.9%
	20	498.94	623.114	124.9%	+24.9%
D4	5	158.79	149.26	94%	-6%
	10	213.27	218.39	102.4%	+2.4%
	15	267.97	287.53	107.3%	+7.3%
	20	324.24	356.66	110%	+10%

Figure VI (e) Comparison Of Results From Detailed And Rough-Cut Approach

Work Centre	Batch Quantity Q	Capacity Required Per Cycle Detailed (D) (Hours)	Rough-Cut (R) (Hours)	R/D x 100%	Percent Error
D6	5	14.15	15.45	91.6%	-8.4%
	10	27.76	26.95	103%	+3%
	15	41.72	38.45	108.5%	+8.5%
	20	55.69	49.95	111.5%	+11.5%
	5				
	10				
	15				
	20				
	5				
	10				
	15				
	20				

Figure VI (f) Comparison Of Results From Detailed And Rough-Cut Approach

APPENDIX VII: System Manual

Contents:

Preface:

Definitions

System - The computer-aided system designed in this research for Manufacturing Capacity Planning and Control.

Work-Centre - a collection of similar machines or resources, that can be considered as a single manufacturing unit or facilities. A work-centre may consist of one or more machine/equipment.

Stage Chart - A version of bar chart which shows against a time scale the sequence of activities by which finish products are made.

Operation - A specification of the work to be performed on one or more materials or components at a single machine during the building of a product.

Routing - A series of operations required to be performed to manufacture a component or assembly. It may be considered as an "Operation-String".

Structure - It is a collection of items required to build up the assemblies and sub-assemblies in each stage against a production stage chart of a given product.

HOW TO USE THIS MANUAL:

This manual is divided into four parts. Part I is an introduction which defines the problem areas in capacity Planning and Control. It also outlines the areas of applications of the system.

Part II describes how various data files used in this system can be set up and maintained. It also explains the significance of each of the files and how they are interfaced to one another.

Part III is a user guide which gives a step by-step operating instruction to users who may not have previous experience in computer systems.

The final part consists of a collection of flow diagrams for the programmes and subroutines used in the system.

Part I: INTRODUCTION

In capacity management there are some fundamental problems confronted by a majority of manufacturing firms, such as

- Have we got enough manufacturing capacity for this year's output?
- What are the production targets for next year and how they can be best dealt with?

To solve these problems one has to consider three major areas:

(1) What capacity have we got in each work centre?

(2) What capacity do we need to fulfil the various production targets?

(3) When are these capacities required in different work centres?

The ways in which these problems can be tackled depend very much on the accuracy on:

(a) Sales forecast

(b) Capacity and utilisation figures in every work centre

(c) Product structure for every model

(d) Production routings and leadtimes information.

Starting with the sales forecast which calls up the various product structures, production routings and leadtimes, the corresponding capacity demands in terms of man-hours or machine-hours in various work centres can be calculated. By matching these demands against the capacities available over a specified period of time, one will be able to predict whether the forecast targets can be satisfied.

This system was primarily developed for a multi-product textile machinery company. Using one of their newly introduced microprocessor-controlled knitting machines as a case study, the system is designed to perform the following functions:

(1) To derive the capacity requirement pattern for each model in every work centre.

(2) To provide a procedure for medium-term capacity scheduling and loading.

(3) To help determine a suitable production programme by comparing the effects of different product-mixes.

(4) To help assess future capacity and plant investments.

Part II: DATA FILES ESTABLISHMENT AND MAINTENANCE

To enable the system to perform its function there are three basic data files that have to be set up:

- Capacity-Load Record File
- Stage Structure File
- Production Routing File

(A) Capacity-Load Record File - It holds the up-to-date capacity allocation information in various manufacturing centres over a period of five years to enable the system to handle medium to long term analysis.

To establish this record file, all the machines and equipment in the company have to be grouped into a number of sections according to their functional and dimensional features, such as milling, turning etc. The mchines in each section, say milling, can be further stratified into smaller sub-groups, namely HM2, HM3, VM2 and VM3, which are normally referred to as work-centres.

In each work-centre the maximum weekly capacity can be worked out by simple multiplications and expressed in terms of hours. To obtain a more realistic figure other relating factors such as % overtime, % sub-contracting, % absenteeism, operator performance and % machine utilisation etc., have to be considered. As a result the actual weekly capacity can be given as:

Actual weekly capacity = max.weekly capacity [1+(%O/T-%Abs)]

x op. performance x % utilisation

A BASIC programme "CAPRECOR" has been prepared for setting up and maintaining this data file.

(B) Stage Structure File - The term product structure is commonly used in a Material Requirements Planning System, taking the form of a family tree which shows how parts are related to one another in various levels of manufacture. To develop a capacity planning system for a company where MRP is unavailable, the items are grouped according to the various stages of build, forming a stage structure. A complete product structure file can be established by combining the various stage structures.

Since this system was designed to perform both detailed and rough-cut capacity planning, separate product structure files have to be set up. In the detailed structure file, items are represented by its own part number, whereas a hypothetical part number is used to represent each stage of production. For example, the part number 999991 and 999992 have been used to represent the hypothetical items in stage 1 and stage 2 of 'ACE' V-bed knitting machine in the Case Study (Chapter 9). A BASIC programme "STR" has been prepared for setting up and maintaining product structure files.

(C) Production Routing File - The structure file specifies the materials required to build a given product. In order to translate these material requirements into the corresponding capacity requirements in various work-centres, the planning details of each manufactured item have to be called up from the Production Routing File. The routing record of each given item shows the work-centre, launch week, setting up time and machining time of each operation required.

For detailed capacity planning, the actual setting up time and machining time for each operation can be used. On the other hand, for the Rough-Cut approach, dummy routings with equivalent setting up and machining times have to be used. The derivation of dummy routings has been illustrated in Chapter 9.

When a routing record is created, it is more convenient to have the details input in the reverse order of operations so that the last operation can be loaded first during capacity allocations. This can ensure the capacities required for all the operations following the one being considered to have been satisfied before loading the current work-centre in order to take into account any changes in requirement date due to re-scheduling.

The BASIC proramme "RNFILE" has been prepared for setting up, maintaining and displaying the production routing information which is being kept in a separate random file, "ROUTING".

Part III: GUIDE TO USERS

It was the intention of the system designer to keep the operating procedures as simple as possible so that no previous computing knowledge is required to apply the system. Once the programme is started by typing in the command "RUN" the user will be directed to answer a series of dialogue-type questions on the VDU in order to specify the input parameters.

After that the computer will copy the most up-to-date capacity-load records onto a workfile for further capacity loading. The user will be informed as the programme proceeds.

To calculate the capacity requirements for a given batch quantity in various work-centres, the relevant product structure and production routing records have to be called up.

The users also have to specify whether finite or infinite loading method will be required. With infinite loading, the capacity requirement in each work-centre will be loaded according to the week number derived from the structure disregarding whether the capacity is available. This option will highlight any capacity unbalance so that actions can be taken earlier to tackle the problems. Whereas, with finite loading option, re-scheduling will be automatically carried out whenever there is an overload, resulting in a more evenly distributed capacity-load pattern.

The time required to run the programme depends on the following factors:

(1) The complexity of the product

(2) The number of production cycles involved

(3) The amount of re-scheduling required

(4) Most of all, whether Detailed or Rough-Cut approach is chosen. It is because in the latter case only a few dummy records need to be considered and that will result in tremendous reductions in time.

When the analysis is completed the resulting capacity-load situations can be presented in different forms.

(1) VDU - The results can be quickly shown on the screen

(2) Detailed Report - The capacity-load figures for any particular work-centre in the year concerned can be printed in week number order on hard copies.

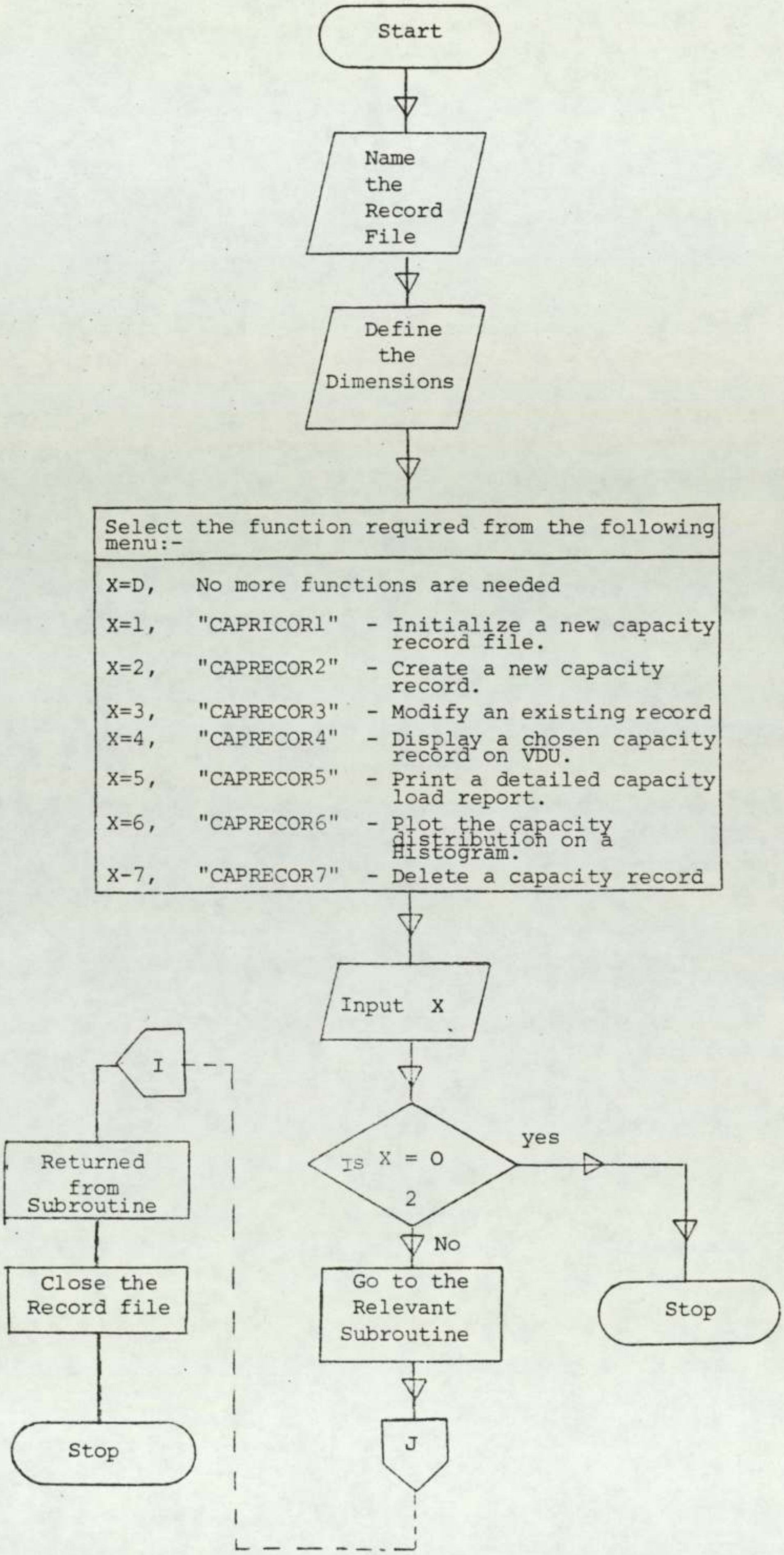
(3) Graphical Output - the resulting capacity distribution of any chosen work-centre can be presented in the form of a histogram showing the overall pattern.

Having assessed the results of the analysis corresponding to the parameters specified, the user has to decide whether to accept or neglect the capacity records. In the former case, the resulting capacity records will be copied from the work-file onto the capacity-load data-base for subsequent analyses. Otherwise the present records will be erased as the programme ends without affecting the original figures.

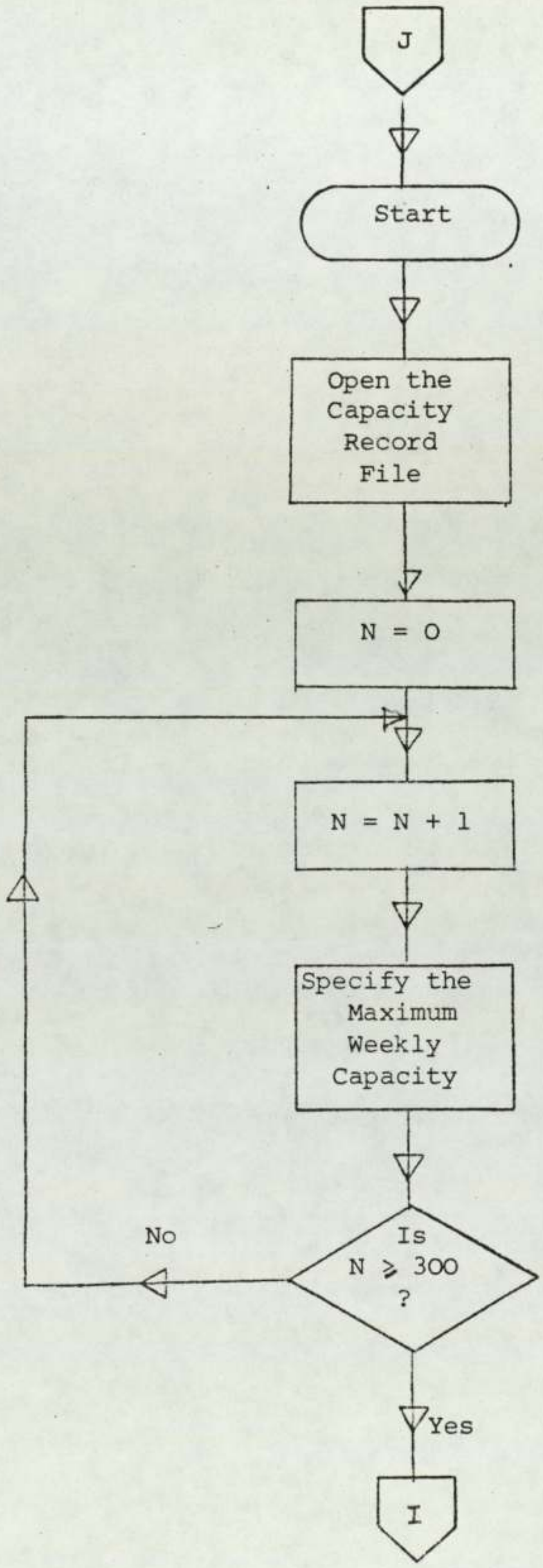
If no further outputs or displays are required, the programme can be terminated.

PART IV Flow Diagrams For The System Programmes

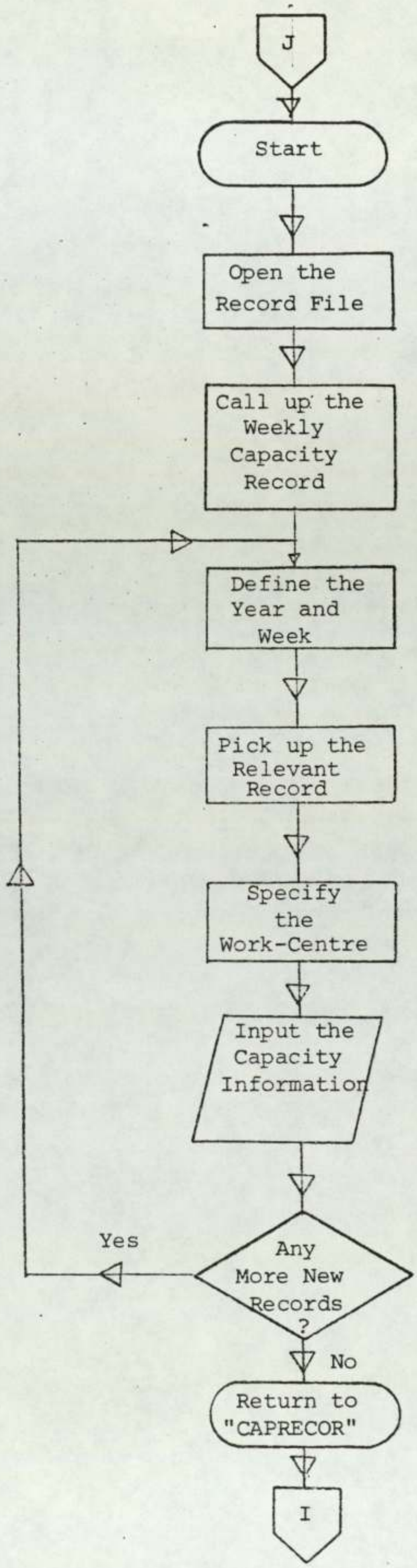
Prog IV.1 Programme "CAPRECOR"



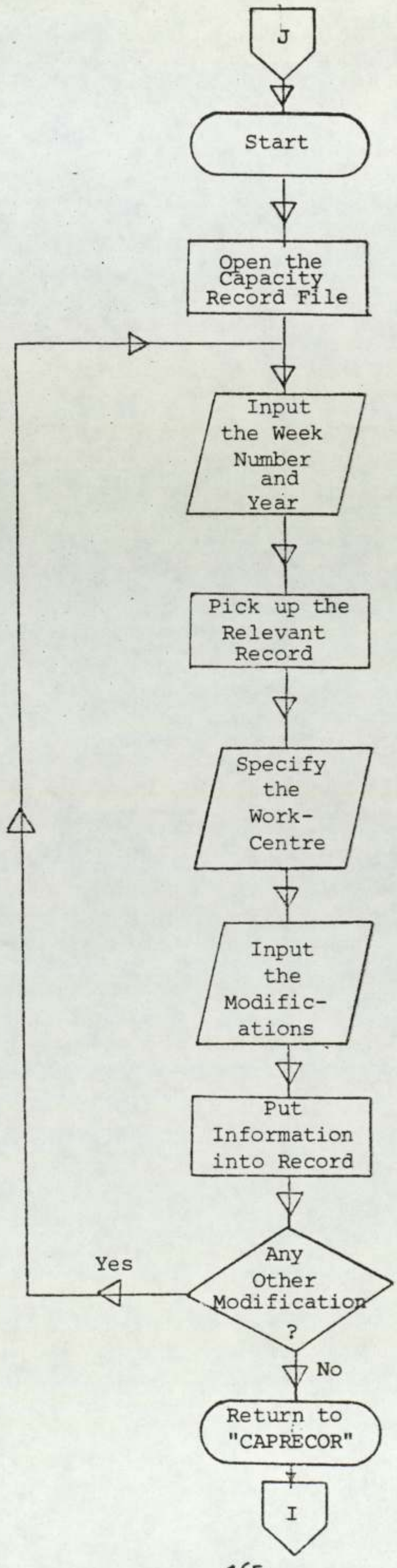
Prog IV.1.1 Subroutine "CAPRECOR 1" - to initialize a new capacity Record File



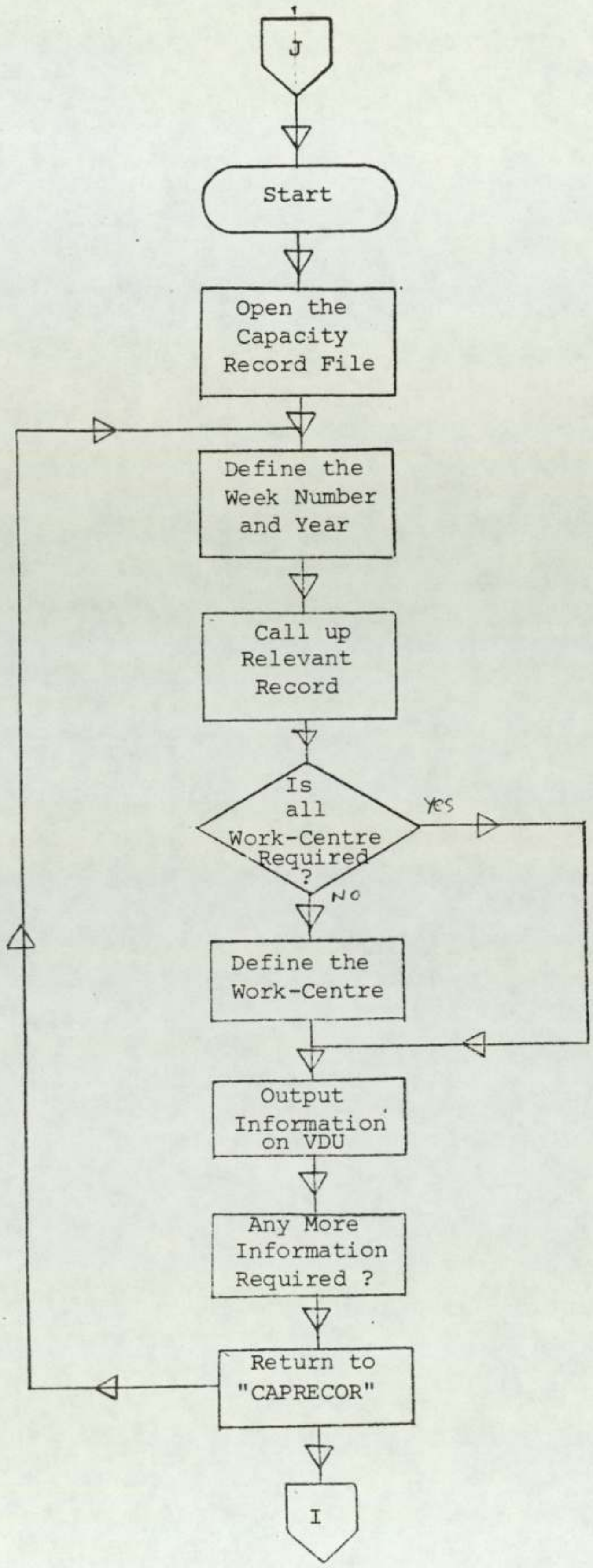
Prog IV.1.2 Subroutine "CAPRECOR 2" - To create New Capacity Reocrds



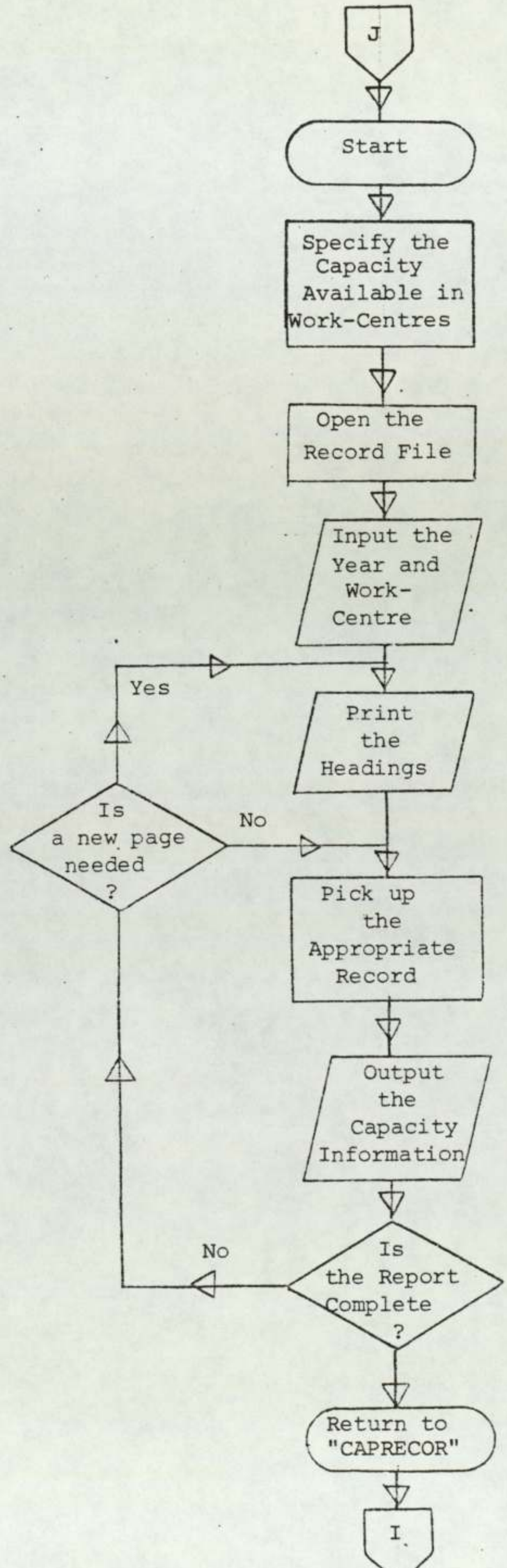
Prog IV.1.3 Subroutine "CAPRECOR 3" - To modify existing Capacity Records



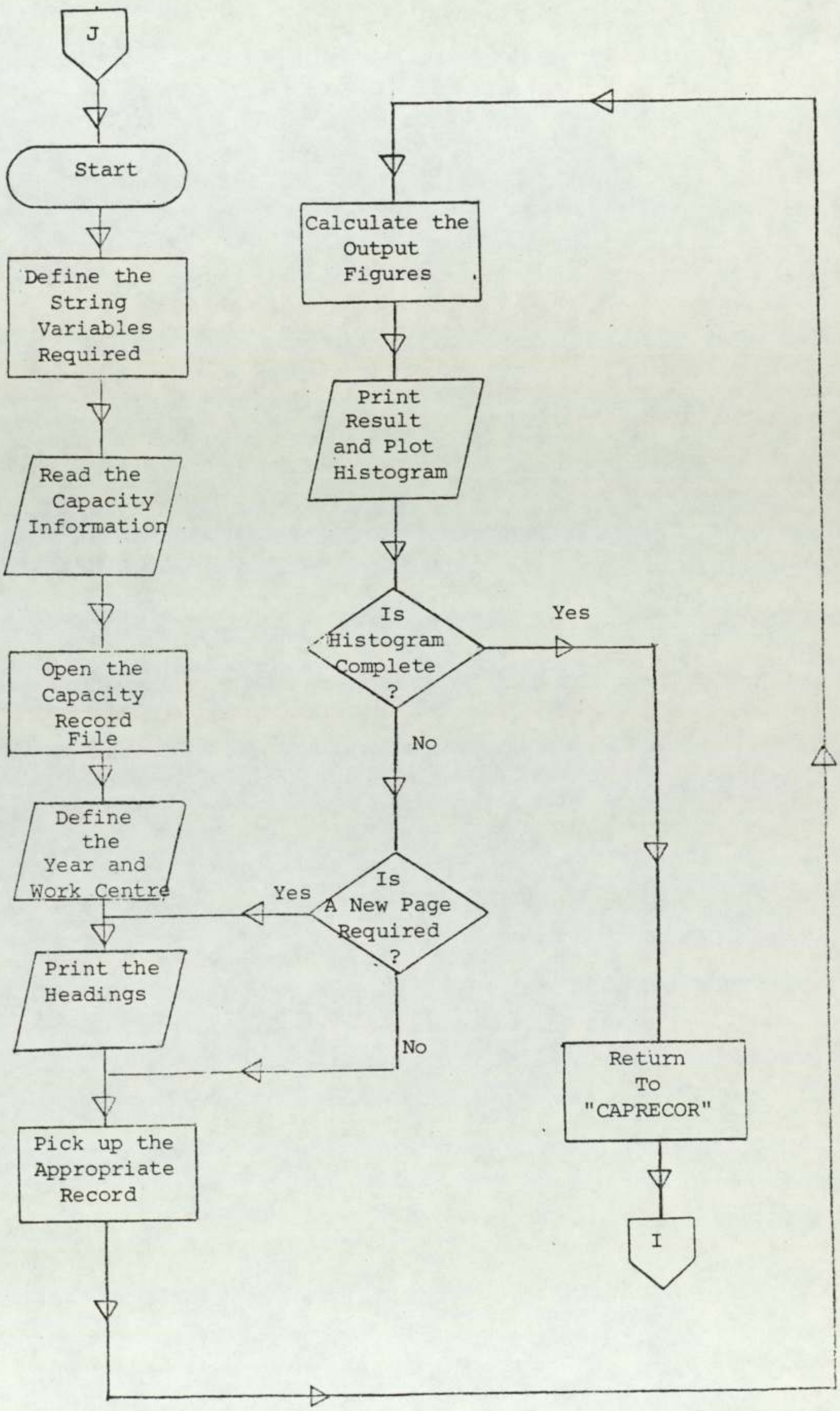
Prog IV.1.4 Subroutine "CAPRECOR 4" - To display the capacity information on the VDU



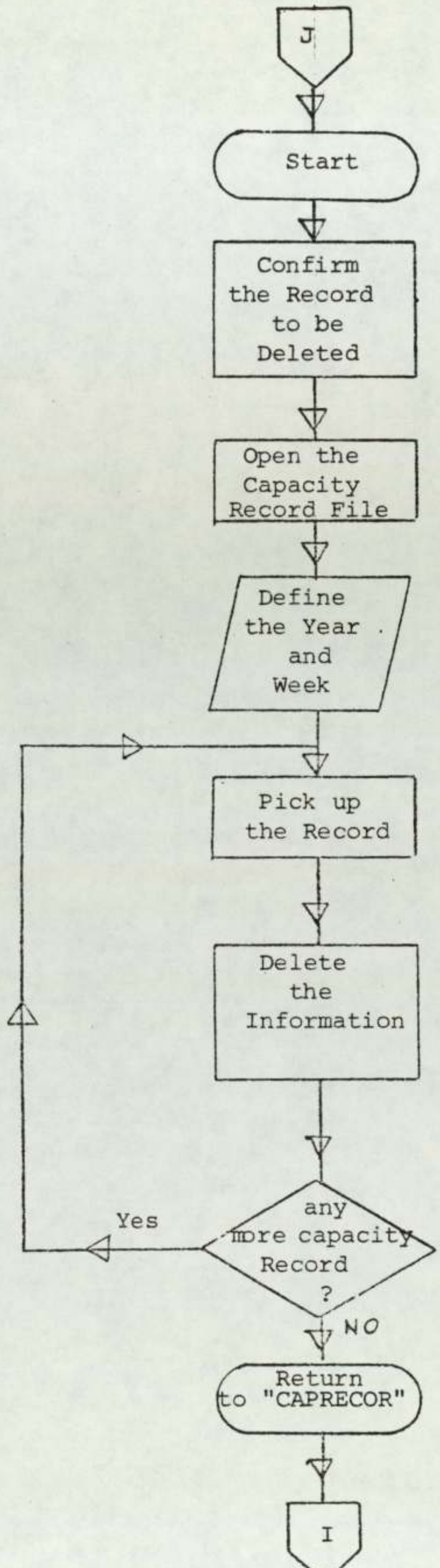
Prog IV.1.5 Subroutine "CAPRECOR 5" - To print an annual capacity-load report



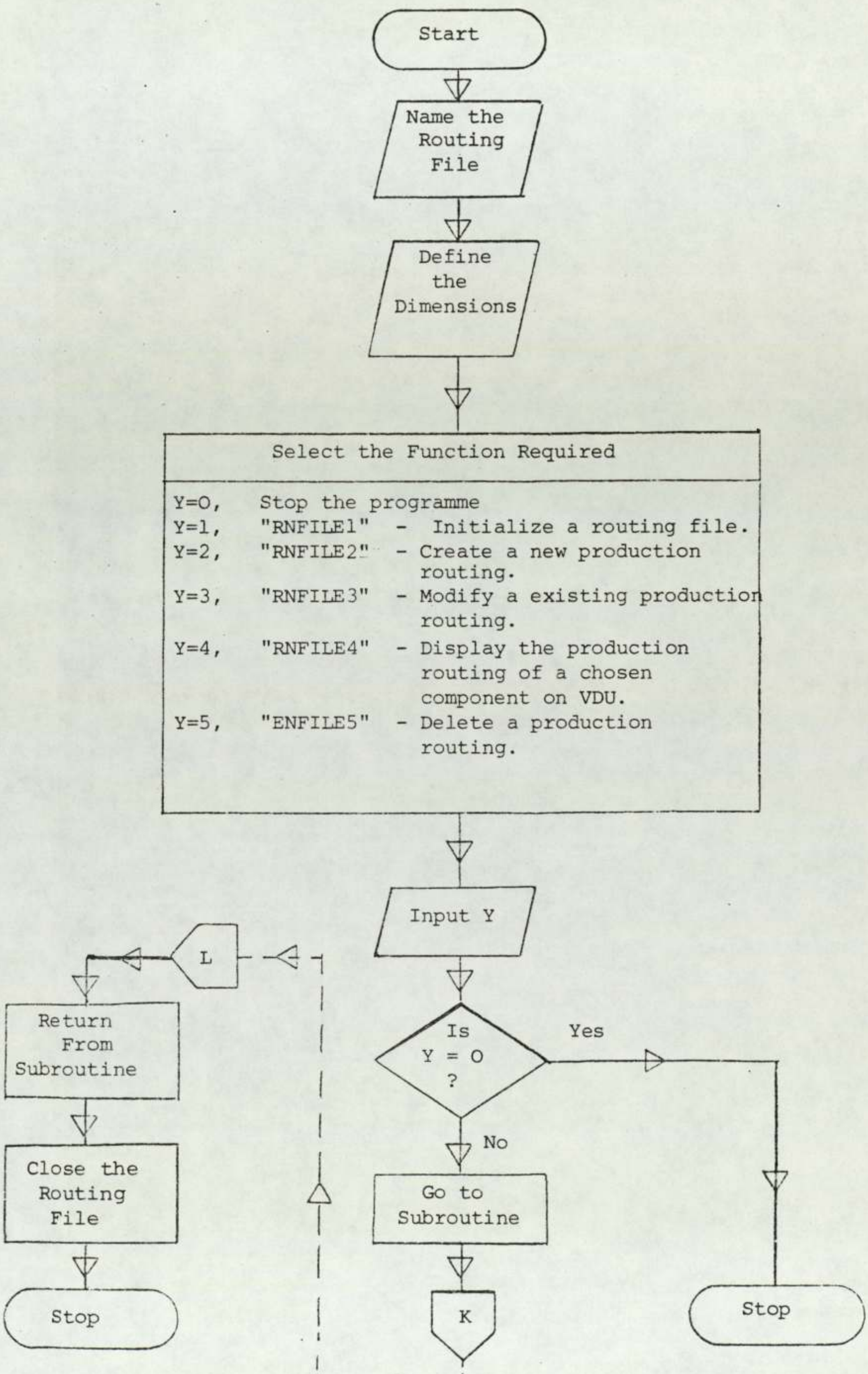
Prog IV.1.6 Subroutine "CAPRECOR 6" - To plot the annual Capacity-Load Distribution Pattern



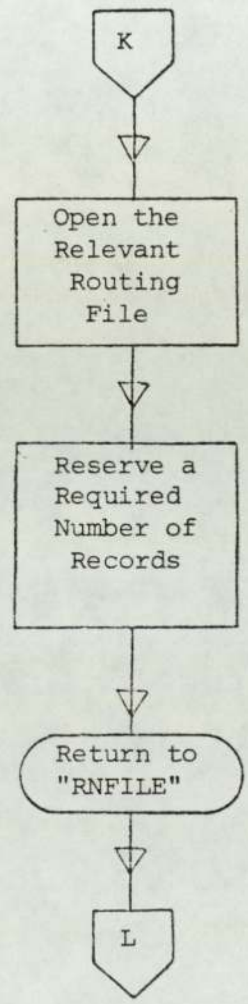
Prog IV.1.7 Subroutine "CAPRECOR 7" - To delete Capacity Records



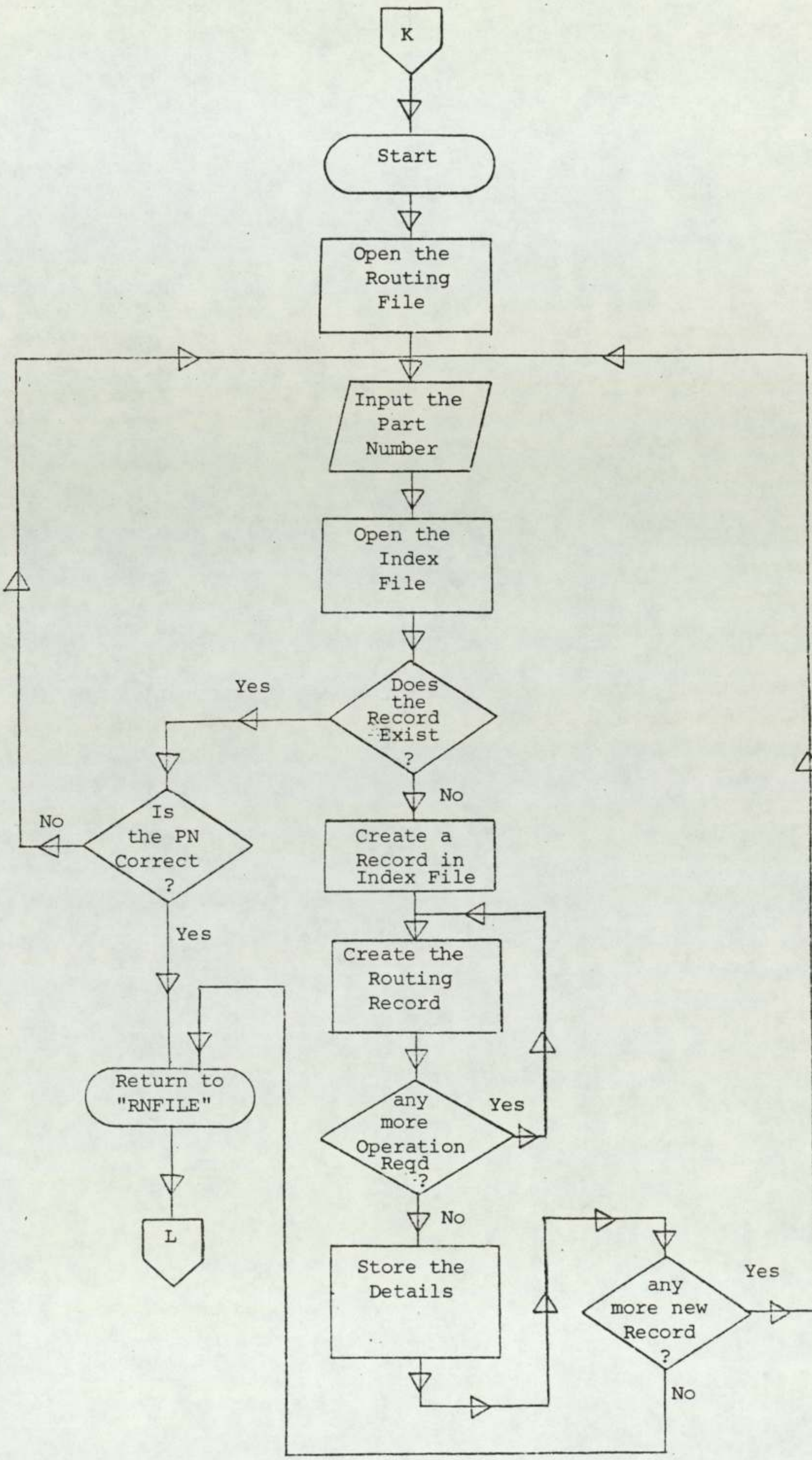
Prog IV.2 Programme "RNFILE"



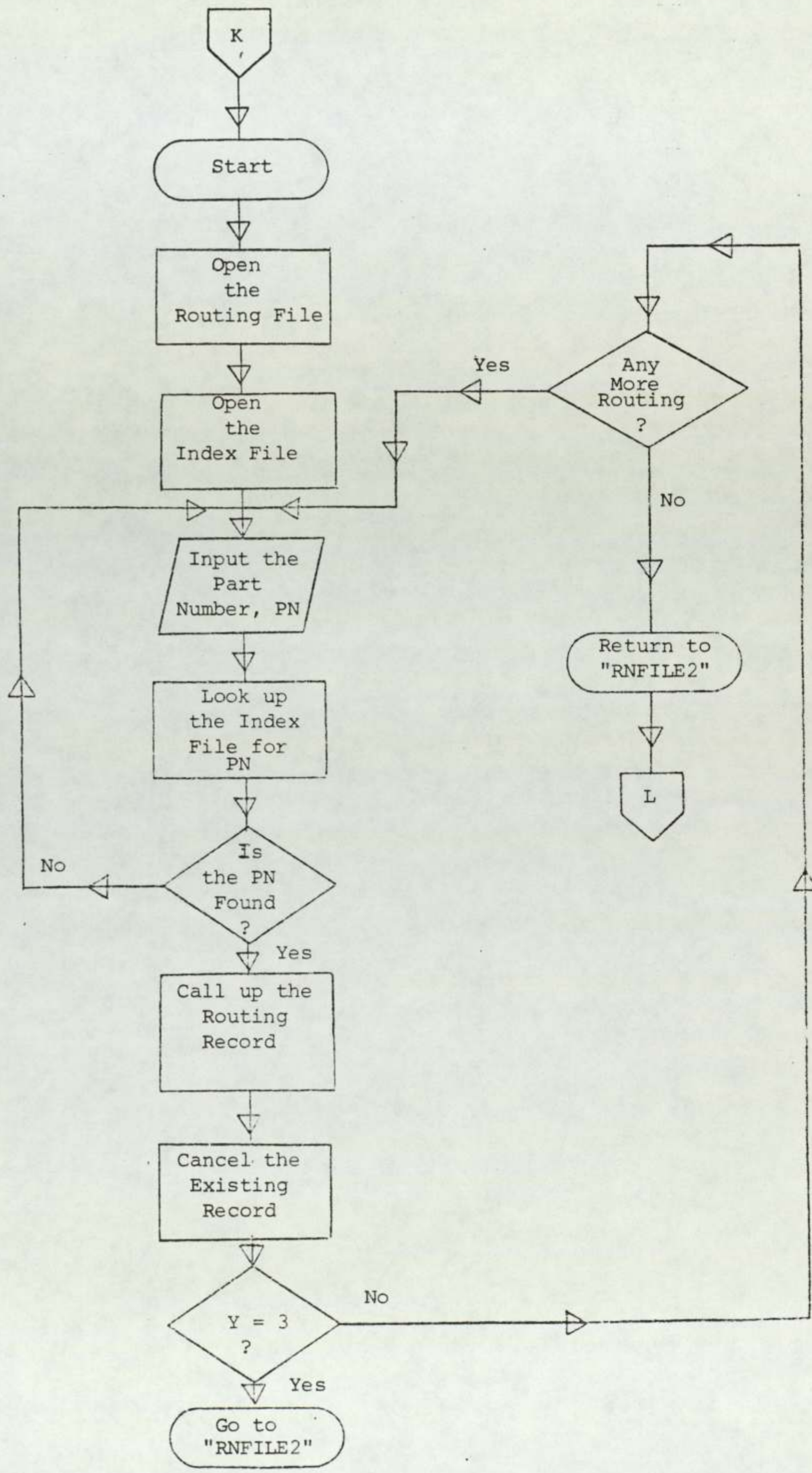
Prog IV.2.1 Subroutine "RNFILE1" - To initialize a Production Routing File



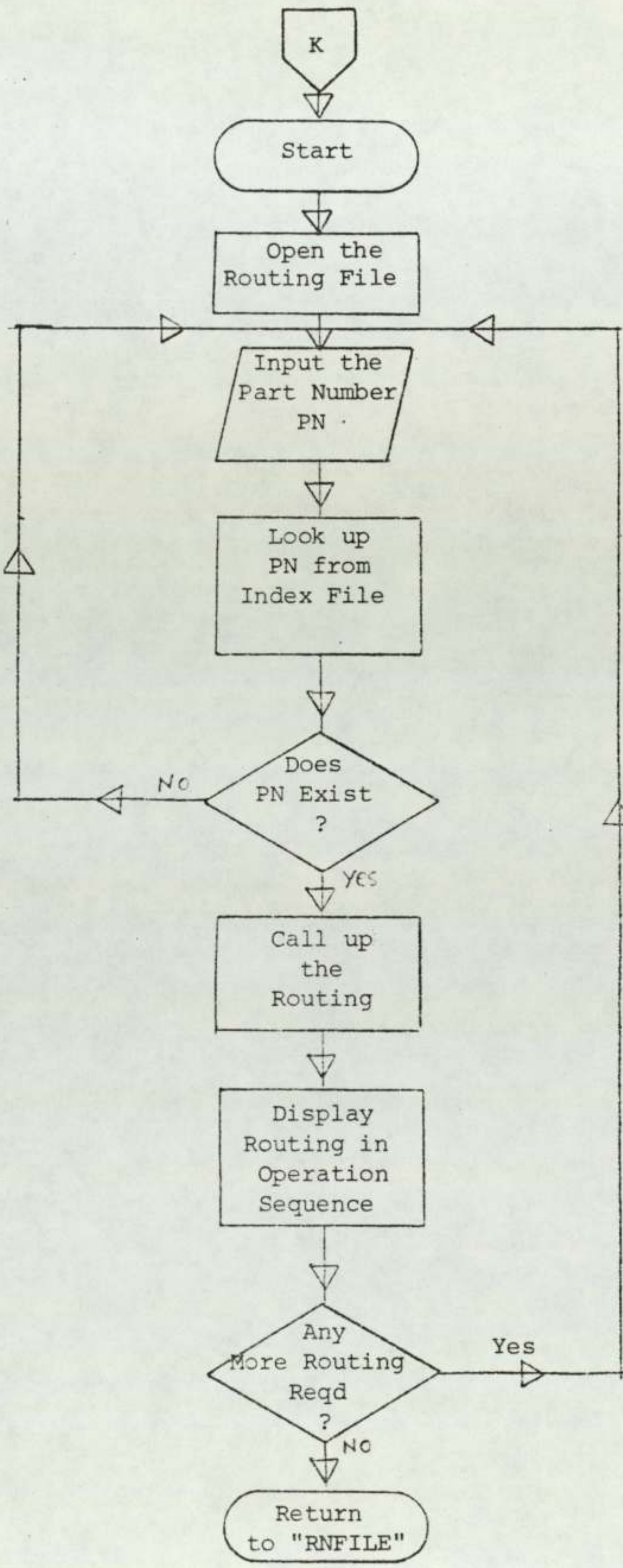
Prog IV.2.2 Subroutine "RNFILE2" - to create new Production Routing Records



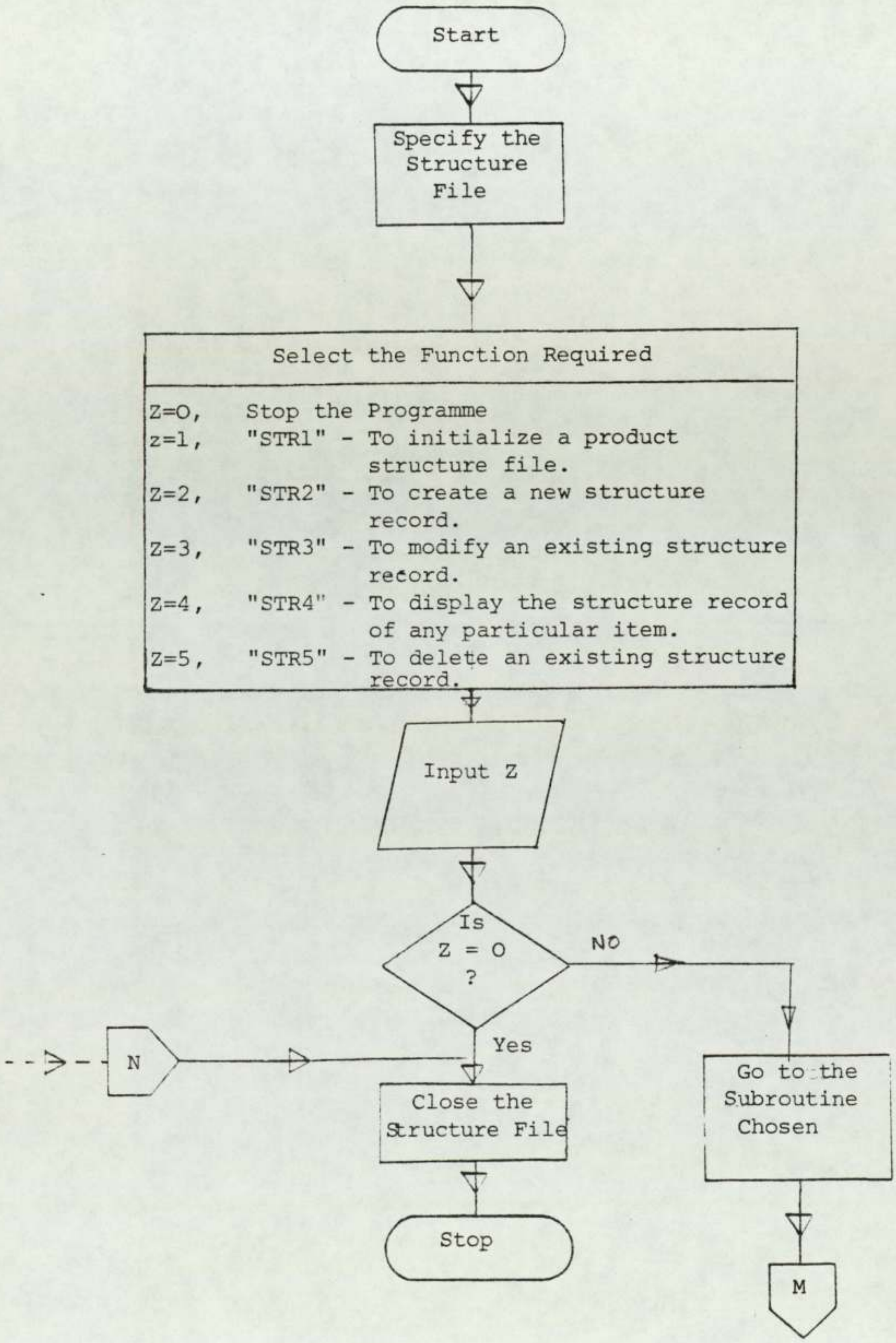
Prog IV.2.3 Subroutine "RNFILE3" and "RNFILE5" - to Modify or Delete a Production Routing Record



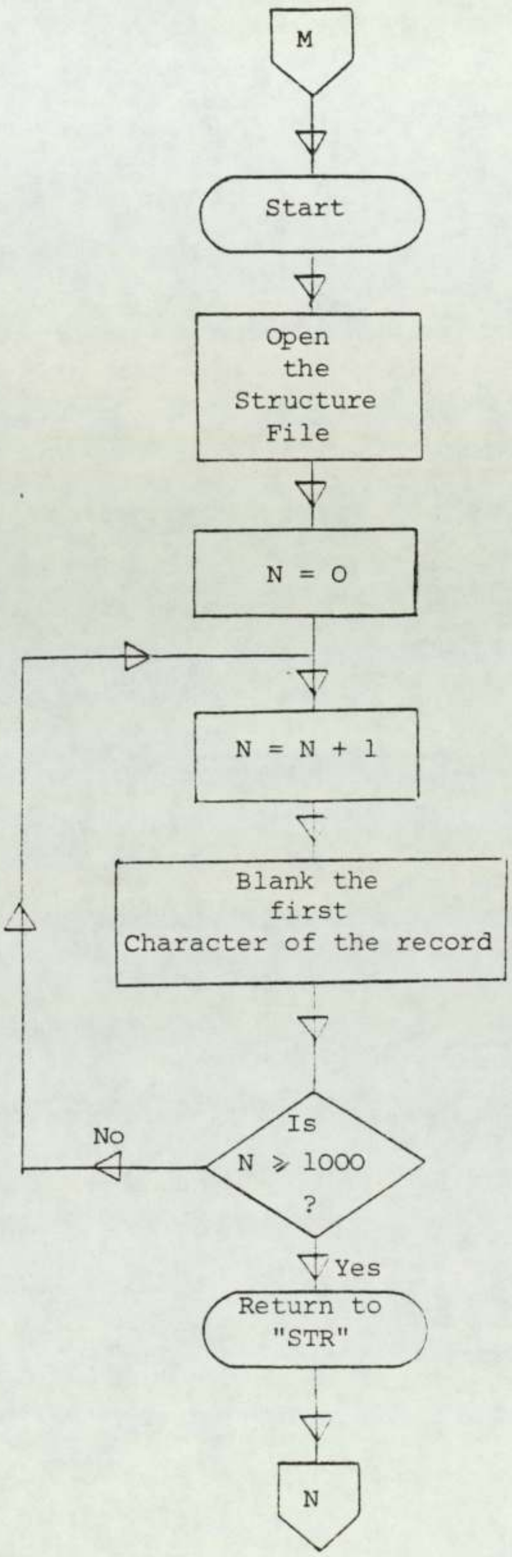
Prog IV.2.4 Subroutine "RNFILE4" - TO Display a Production Routing on VDU



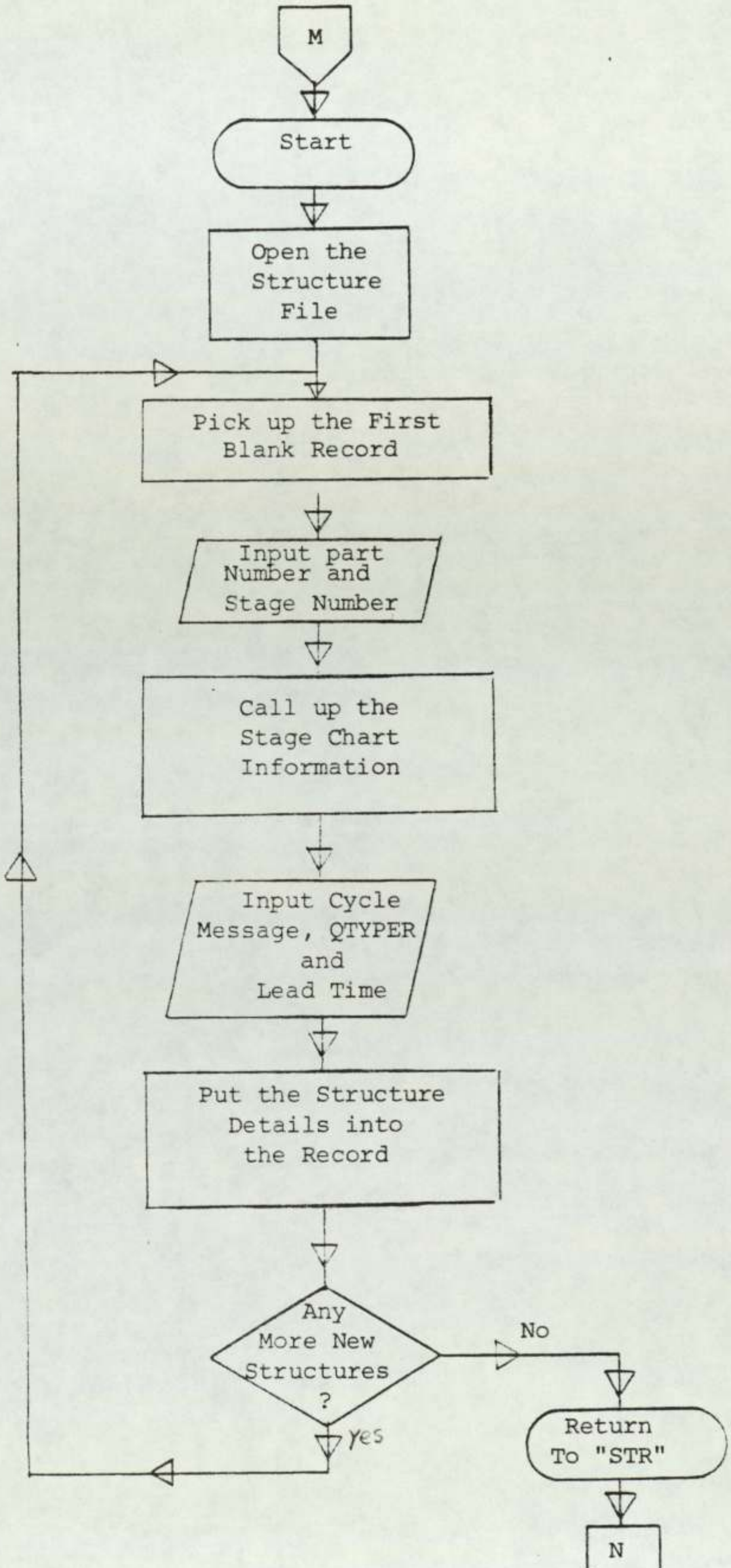
Prog IV.3 Programme "STR" - to set up and maintain Product Structure File



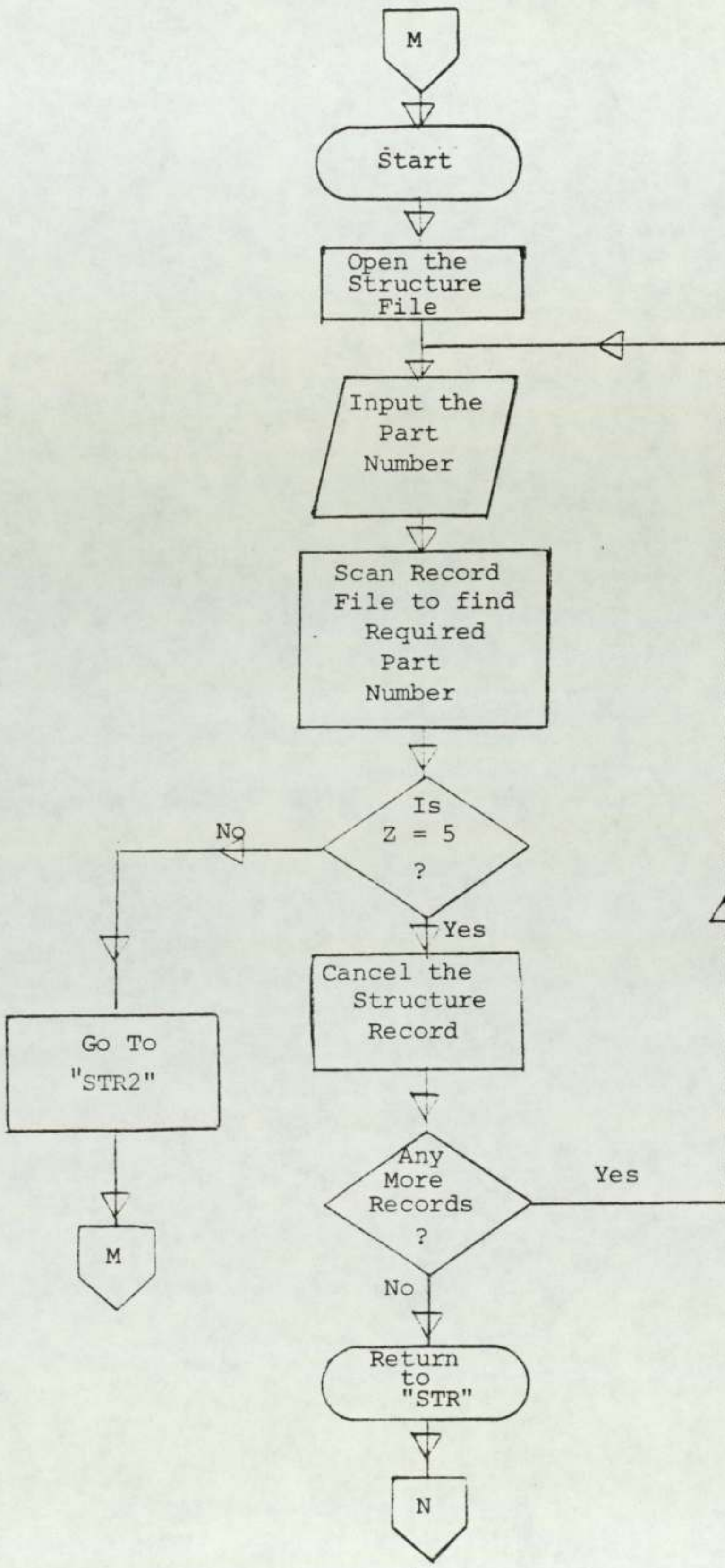
Prog IV.3.1 Subroutine "STR1" - to initialize a new Structure File



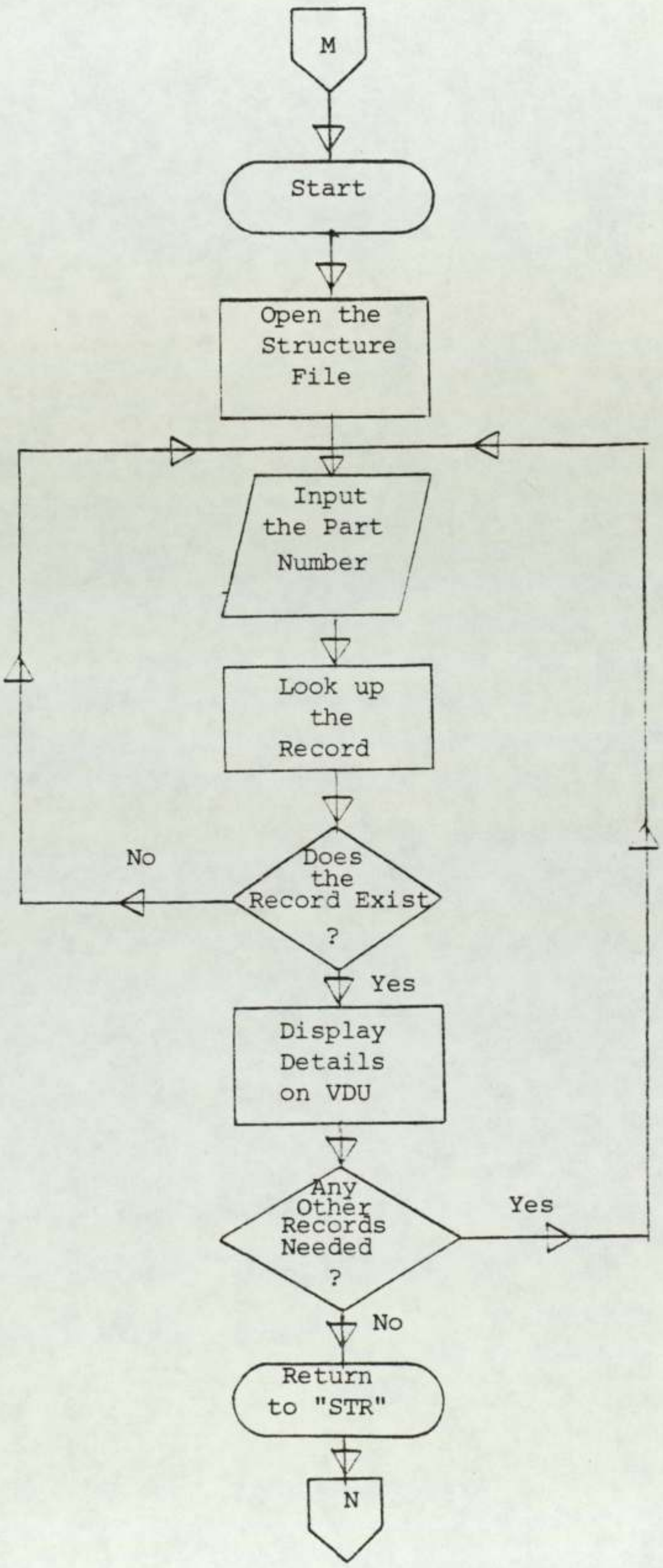
Prog IV.3.2 Subroutine "STR2" - to create a new Structure Record

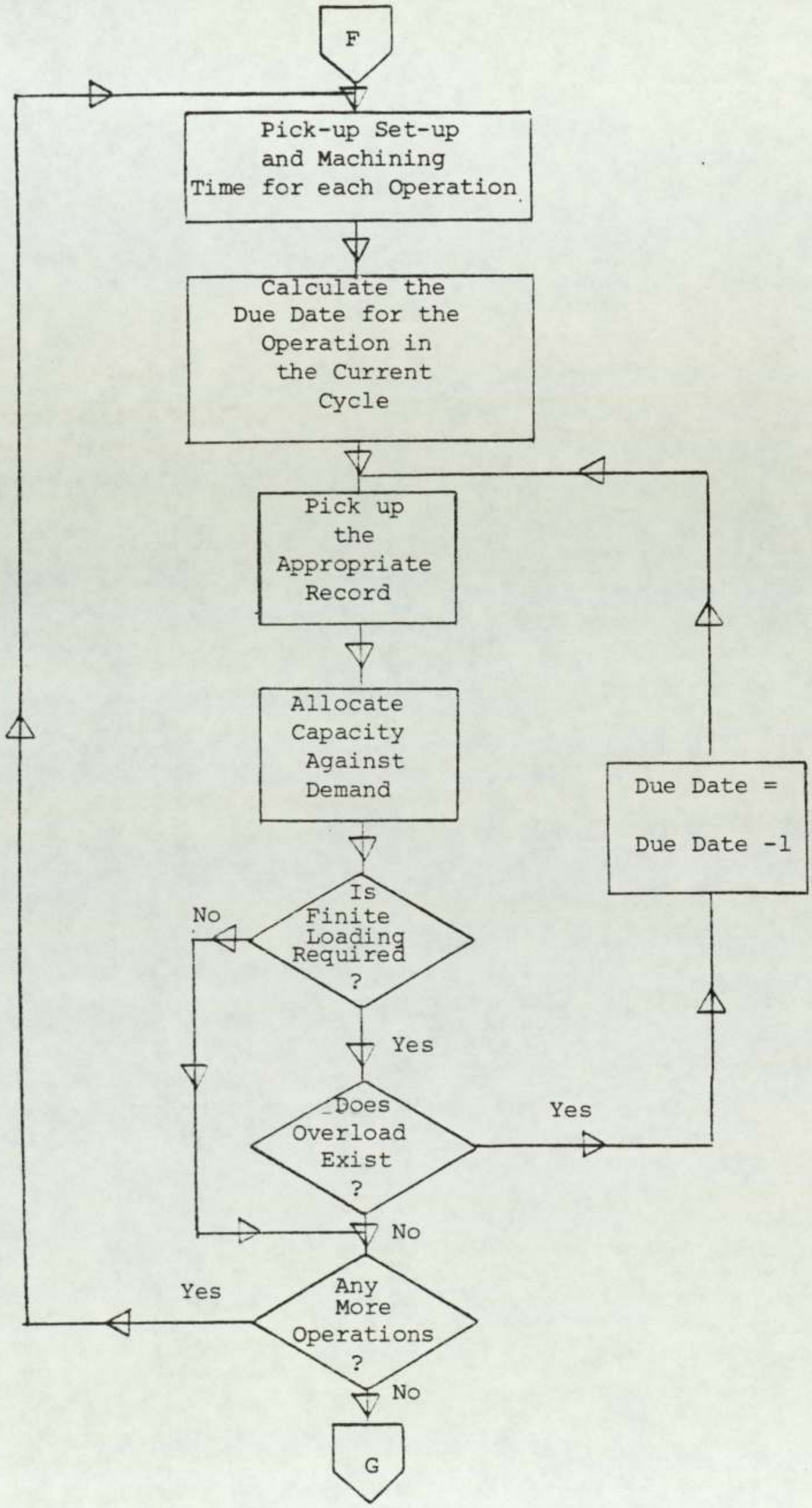


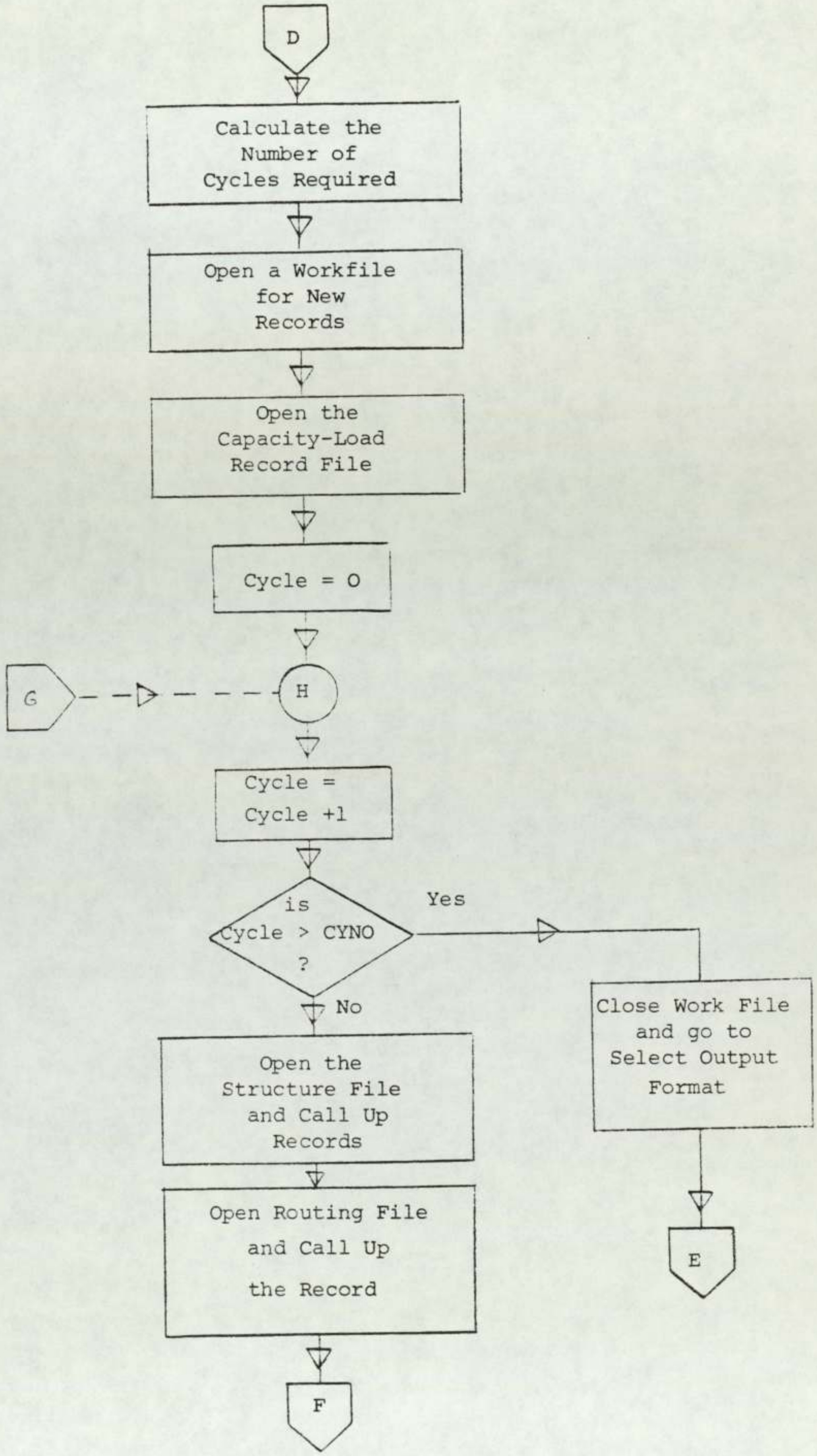
Prog IV.3.3 Subroutines "STR3" and "STR5" - to Modify or Delete an existing Structure Record

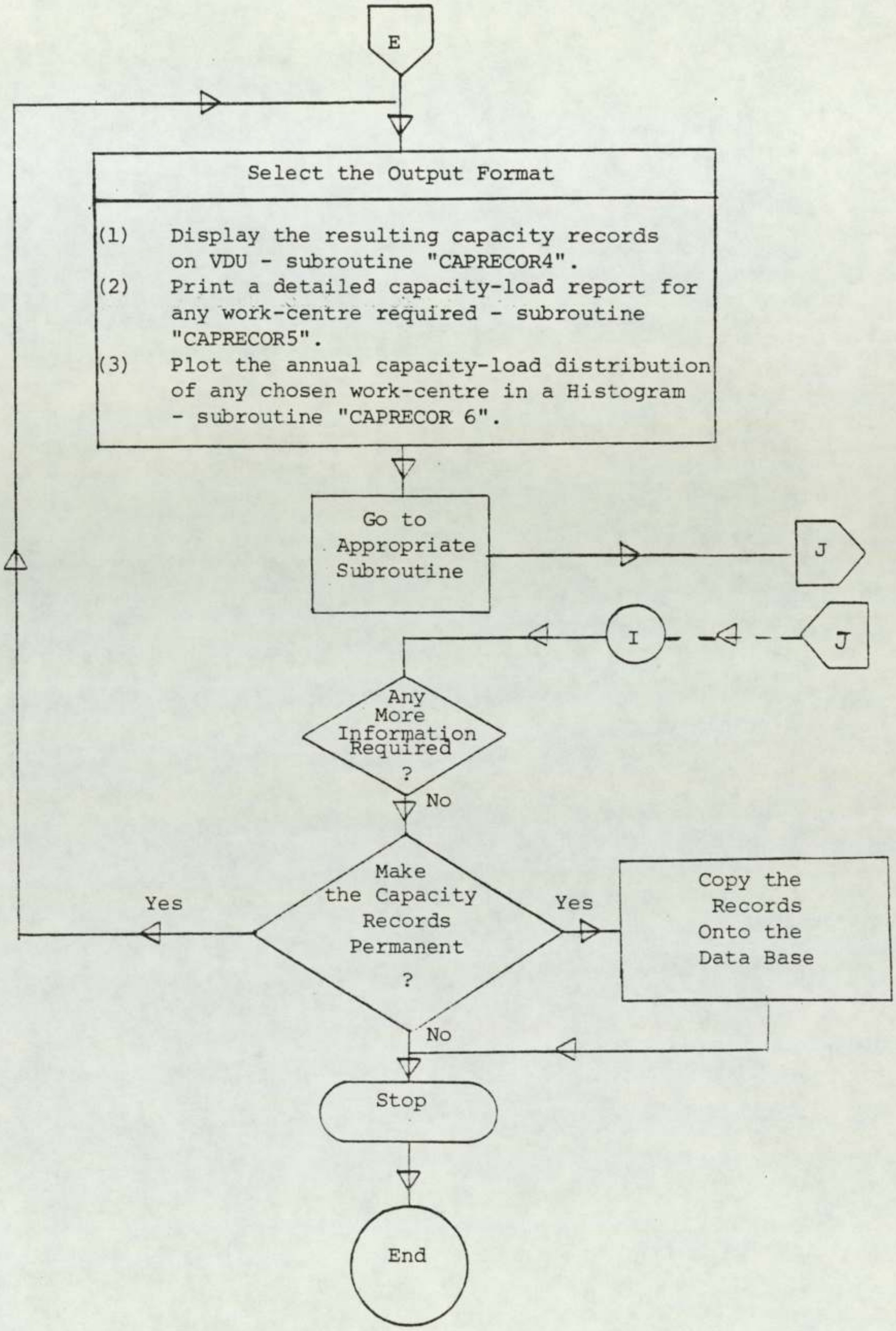


Prog IV.3.4 Subroutine "STR4" - To Display a Structure Record

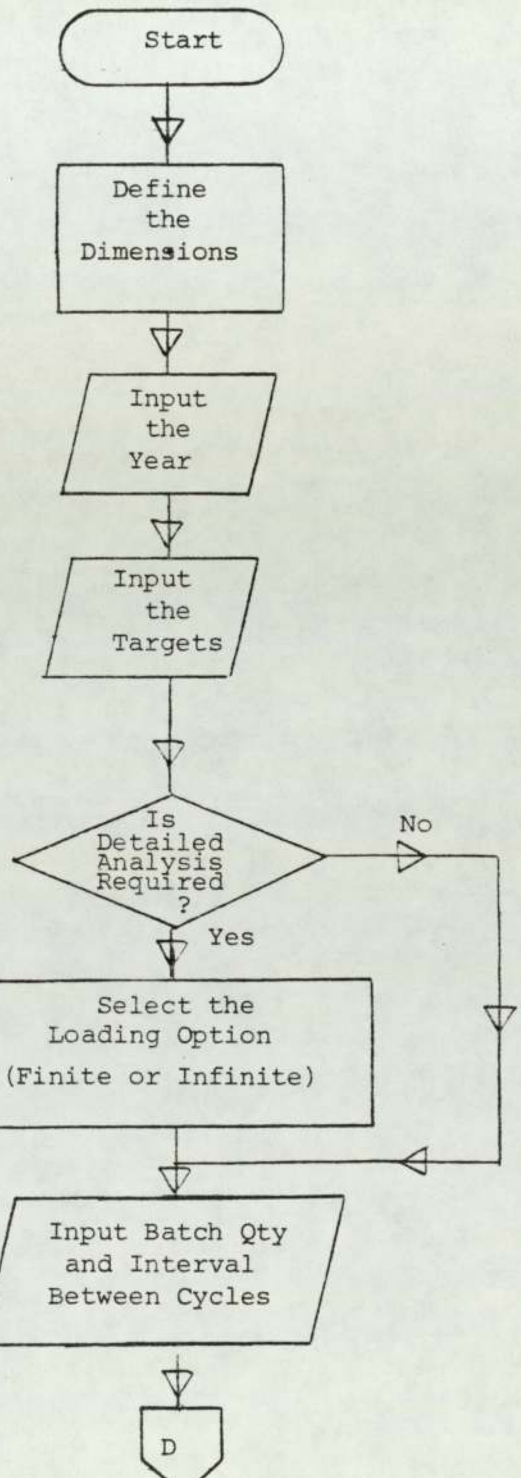



F
Pick-up Set-up and Machining Time for each Operation
Calculate the Due Date for the Operation in the Current Cycle
Pick up the Appropriate Record
Allocate Capacity Against Demand
Is Finite Loading Required ?
No
Yes
Does Overload Exist ?
Yes
No
Due Date = Due Date -1
Any More Operations ?
Yes
No
G


D
Calculate the Number of Cycles Required
Open a Workfile for New Records
Open the Capacity-Load Record File
Cycle = O
G
H
Cycle = Cycle +1
is Cycle > CYNO ?
Yes
No
Close Work File and go to Select Output Format
E
Open the Structure File and Call Up Records
Open Routing File and Call Up the Record
F


E
Select the Output Format
(1) Display the resulting capacity records on VDU - subroutine "CAPRECOR4".
(2) Print a detailed capacity-load report for any work-centre required - subroutine "CAPRECOR5".
(3) Plot the annual capacity-load distribution of any chosen work-centre in a Histogram - subroutine "CAPRECOR 6".
Go to Appropriate Subroutine
J
I
J
Any More Information Required ?
No
Yes
Make the Capacity Records Permanent ?
Yes
Copy the Records Onto the Data Base
No
Stop
End

Prog IV.4 Programme "NEWCPC" - The Production Capacity Planning and Control System



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