DEVELOPMENT OF A MATERIAL REQUIREMENTS PLANNING (MRP) SOFTWARE FOR JOBSHOPS

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DEDICATION

This project is dedicated to the glory of the Lord Jesus Christ

CERTIFICATION

This is to certify that this research work was carried out by **Akintunlaji, Olusola Akinbolaji** of the **Department of Mechanical Engineering** and is accepted as meeting the requirements in partial fufilment of the award of Master of Engineering (M.Eng.) degree in Mechanical Engineering (Production Engineering option)

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ABSTRACT

The development of a Material Requirements Planning (MRP) software for jobshops is presented in this write-up.

The software aims to help in managing materials requirements in job shops by providing weekly reports of orders to work centers and suppliers in order to meet the scheduled due dates for customers' orders.

Studies on material requirements planning were conducted to determine the necessary data required for developing a material requirements planning software for jobshops.

The software was developed in window based Visual Basic 6.0 programming language, by creating a user-friendly interface to facilitate easy input of data. Then a database was created to integrate the various input data and by taking into consideration all the operational factors involved in material requirements planning, appropriate outputs are generated, which will enhance planning in jobshops.

The output report of the application was tested for accuracy by comparing the material plans generated for a machine fabrication jobshop over a period of time with the result obtained from manual material requirements planning computation. The reports of the software were found to be accurate. The software is easy to use and will find great application in industries in developing countries.

CHAPTER ONE

1.0 INTRODUCTION

In a developing country like Nigeria where technology is just evolving, most small-scale industries tend to avoid specializing in the production of a single product. This is because of the desire to have the flexibility to accommodate the production of a variety of products so that when the demand for a particular product is low, they can easily engage in the production of other products so as to avoid idleness and to optimize the capacity utilization of their resources.

The type of production activity, which accommodates variety of products, is referred to as job shop production. Job shop production is commonly used to meet specific customer orders, some of which are assembly work consisting of component parts (Adam and Ebert, 1992).

In most jobshop productions, materials form the largest single expenditure item. Therefore, any significant contribution made through material management in reducing material cost will go a long way in improving profitability and the rate of return on investment (Gopalakrishnan and Sudaresan, 1989). However, managing job shops, particularly in respect of material management is a Herculean task. Therefore, the two major goals of most job shops are:

(i) Keeping inventory cost low.

(ii) Meeting due dates promised to customers so as to encourage their patronage while there is the problem of sourcing and making materials available on time to meet the production schedule

Material planning problems are prevalent in job shops because of the following reasons:

(i) Production of a product made of multiple components requires significant coordination to ensure that component parts are available when they are required for production

(ii) Inability to stock materials because of variability of orders, unpredictability of demand, and holding cost,

(iii) Limited operational capital to procure and stock materials required for production,

(iv) Limited capacity, in terms of manpower, machines, suppliers etc., to source for the required materials,

(v) Managers tend to forget to place order for the required materials for production at the appropriate time when handling many orders simultaneously, particularly in assemble-to-order environments,

(vi) It is difficult to determine the most economical quantities of materials to order for at a given time.

Many inventory models, some of which are classified under deterministic models and probabilistic models, have been developed. Some of these are ABC inventory models, Economic Order Quantity models, deterministic lot-size inventory model (Shah and Shah, 1992) etc. All these models are designed to minimize total cost of production by balancing cost of order, holding cost of inventory and shortage cost, while trying to generate confidence in the stock of meeting any anticipated demand by providing for no shortage by incorporating very high penalties on cases of shortage. However, these models are not suitable for jobshops because they do not provide for the dynamic nature of material cost, production requirement, uncertainties of job demands and dates of execution.

One approach to solving the variability nature in demand in job shops is to use a minimum stock level and reorder point to order and schedule materials. With reorder point planning a reorder level is established for each item, usually based on usage, the lead-time it takes to get the material in, and some safety stock to cover unexpected increase in demand (Plossl, 1986).

However, the biggest problem with reorder point planning is that it typically does not get maintained at regular enough intervals and can lead to higher stocking levels when it is not really necessary. The situation becomes very serious when dealing with assembly products. Whenever a finished good, subassembly, or component gets delayed, many supporting schedules must also be delayed. If a job is delayed because one component does not turn up on time, all of the other components needed for the same job are not needed until the rescheduled date, and so are the other subassemblies needed. The problem becomes more serious with a multi-level bill-of-material.

In production environment with the above mentioned problems, material requirements planning has been found to be the most suitable technique to employ to efficiently manage both inventory and production to satisfy customer's needs by improving company's overall capabilities and completion times (Orlicky, 1975, Plossl, 1986). MRP is a system that controls inventory levels, plans production, helps supply management with important information, and helps with the manufacturing control system with respect to the production of assembled parts.

It is materials management approach that applies to large job shop in which many parts are manufactured in periodic lots in several processing steps (Bedworth and Bailey, 1987)

A survey of MRP users conducted by Schroeder et.al (1991) shows that the major benefits that have been derived from MRP implementation are lower inventory holding costs, shorter production lead-time and higher customer service level.

The concept of Material Requirements Planning is relatively straight forward, but what complicates the application of the technique is the sheer magnitude of the data to be processed. In large job shops where there are many customized and assembled products, the number of parts can easily be in thousands. Therefore, Material

Requirements Planning can only be accomplished with the aid of a digital computer (Groover, 1987).

Today, industry has adopted the use of computer systems to perform much of the manual planning and clerical work that was previously accomplished by human beings. This has led to the concept of computer-integrated manufacturing.

Manufacturing has undergone this revolution in most developed countries, where advanced manufacturing systems such as Computer integrated Manufacturing Systems (CIM), Just-In-Time Systems (JIT) etc are employed to improve productivity and many MRP softwares have been developed as one the components of the manufacturing-planning phase of CIM.

However, a survey carried out by Ogedengbe et.al (2002) revealed that the adoption of CIM is still very low in Nigeria. The reasons attributed to this are the lack of sufficient capital to integrate manufacturing network at once and the capital wastage that might result if the expected result is not generated from the computer integrated system after installation. Ogedengbe et.al (2002) suggested the use of sequential re-investment for computer integrated manufacturing systems (SEQCIM). The concept of SEQCIM will prevent heavy loss in case of failure of CIM and assist the achievement of CIM in a sequential manner without having large capital investment.

Thus, the development of a made-in-Nigeria material requirements planning (MRP) software, which will not be as expensive as the foreign softwares we have around is considered as one of the first steps that should be taken in the adoption of SEQCIM by companies in Nigeria because of the significance of materials in any organization.

1.1 Aim of the Project

The aim of this project is to develop a 'home grown', user-friendly software application that will help in managing the materials requirements in job shops by providing weekly reports of orders to be released to work centers and suppliers in order to meet the scheduled due dates for customers' orders.

1.2 Objectives

The objectives are to:

(i) Create a user-friendly interface

(ii) Create a database that will integrate the Master Production Schedule, Inventory, and Bill-of-materials subsystems to generate material requirement plans that will satisfy jobshop production schedules

(iii) Validate the MRP software output by comparing its output with a manually computed material requirements plan.

1.3 Methodology

This application software was developed using Visual Basic 6.0. The application is designed in the familiar Microsoft Windows environment to be user-friendly. Interface consisting of controls such as textboxes, command buttons, appropriate message boxes etc. are used to interact with the user. In addition, a Help menu is provided to easily guide user through the use of the package.

The Material Requirements Planning (MRP) application tightly integrates the Customer Orders, Inventory, and Bill-of-materials modules using Microsoft Relational database management system. Using a lot-for-lot sizing technique, the existing on-hand position of an item, open purchase orders, open manufacturing orders and open customer orders are analyzed to produce an overall material requirements plan for the job.

The system would blow through the Bill-Of-Materials (BOM), taking into account lead-times, to schedule purchases of raw materials, or to schedule manufacturing orders for sub-assemblies and the action is then displayed on the screen, in weekly time buckets. The MRP software provides the user with the latest requirements and a manufacturing calendar is provided for user to define the weekly time periods according to the calendar of the manufacturing year.

The application also responds rapidly to changes in design (engineering changes), lead-times and rescheduling of open orders by generating a complete MRP report. Furthermore, provision is made to solve a potential part capacity requirement problem by identifying the end item source of the part's requirement. Knowing the source, the planner is able to decide the best action.

The output report of the application was tested for accuracy by comparing the result of material requirements planning generated for a machine fabrication job shop by the software with the result obtained from manual material requirements planning process.

CHAPTER TWO

2.0 LITERATURE REVIEW

Material planning is the scientific way of determining the requirements of raw materials, components, spaces, and other items that go into meeting production needs with the economic investment policies (Gopalakrishnan and Sudaresan, 1989).

This is the first activity in materials management. Material planning and budgeting function is given prominence in the integrated materials management set because it serves as a control device and also ensures that the organization satisfies the customer by meeting due dates.

2.1 Materials Planning in Job Shop Production

A job shop can be defined as a high variety, low volume production system in which products are not mass-produced as on assembly line, but made to order (Heizer and Render, 1988). Products are usually manufactured to customer's specifications and orders may not be repeated (Haslehurst, 1988). Equipments used in jobshops must be flexible and general purposed while the skill level of the workers must be high so that they can perform a wide range of different works and assignments (Groover, 1987). A characteristic of job shops is the generally high percentage of unplanned urgent work that is undertaken, particularly in connection with the maintenance and servicing of plant and equipment.

Jobshop orders usually differ considerably in terms of materials used, order of processing, processing requirements, and time of processing and set up requirements. And because of this, the scheduling task in the job shop can be complex. Thus, the management in the job shop attempts to run the shop in a balanced and efficient manner.

To do this, the management needs a production planning and control system. According to Heizer and Render (1988), the planning control system should:

(i) Schedule incoming orders without violating capacity constraint of the work centers and supply sources.

(ii) Establish likely due dates for incoming orders

(iii) Provide information on the dates of releasing planned order to work centers and suppliers.

(iv) Establish new material plans where there are sudden changes in production schedule.

(v) Provide information on the inventory status

One aspect of the production planning and control in the job shop that should be given serious attention is the material planning function. This is because materials form the largest single expenditure item. Therefore, any significant contribution made through material management in reducing material cost will go a long way in improving profitability and the rate of return on investment (Gopalakrishnan and Sudaresan, 1989). However, managing job shops have been found to be very difficult, particularly in respect of material requirements and planning. The reasons for this are:

(i) Inability to stock materials because of variability of orders, unpredictability of demand, and holding cost,

(ii) Limited operational capital to procure and stock materials required for production,

(iii) Limited capacity, in terms of manpower, machines, suppliers etc., to source for the required materials,

(iv) Producing a product made of multiple components requires significant coordination to ensure that component parts are available when they are required for production

(v) Managers tend to forget to place order for the required materials for production at the appropriate time when handling many orders simultaneously, particularly in assemble-to-order environments,

(vi) It is difficult to determine the most economical quantities of materials to order for at a given time.

Many inventory models have been developed for jobshops. These models aim at keeping inventory cost low and also maintain a reasonably high service level.

2.2 Inventory Control Techniques

Inventory control attempts to strike a proper balance between the dangers of too little inventory (with possible stock-outs of materials) and the expense of having too much inventory (holding cost). In inventory control, two questions are pertinent. The first question is how much should be ordered each time a replenishment order is placed. This is answered by the Economic Order Quantity (EOQ) concept. The EOQ concept balances the cost of ordering (set up cost) against the cost of carrying inventory (holding cost) to give minimum total cost.

The second question is that of when replenishment order should be placed and this question is answered by various reordering techniques. These can take many forms but are usually related to one of the following:

(i) Order point (Fixed-order quantity-variable-cycle system) in which replenishment order (usually EOQ) is placed when withdrawals bring inventory of an item to a predetermined level, called order point.

(ii) Periodic review (Fixed-cycle ---variable order quantity system) which involves reviewing inventory records periodically and ordering sufficient materials to restore total on hand plus on order to a predetermined maximum level.

The EOQ concept and the reordering techniques are limited in application because of their fundamental problems. According to Buffa (1983), when demand is not equal from period to period, one of the assumptions underlying the EOQ formula is violated. Adhering to fixed lot sizes results in carrying of excess inventory.

Also, the EOQ concept and reordering techniques are only applicable to independent demand, that is products that are inventory stock but difficult to apply in environments where demand tend to be intermittent and for products which have component tree structure, in which component requirements are dependent on requirements at higher level of assembly (Plossl, 1985).

Reorder point planning is also not maintained at regular enough intervals and this can lead to higher stocking levels and delay in supporting schedules in an assemble-to-order environment. Another problem with reorder point planning is that it only works for very short term planning with simple bill-of-materials. Most companies, even job shops, have to plan months ahead for many orders, at which point reorder point planning is less than optimal (Plossl, 1986). Furthermore, some materials have low annual usage such that the general reordering methods fail to control their inventories efficiently.

Many uncertainty models have been developed to handle demand uncertainty problems of inventory control. Most of these models employed probability distributions such as normal and exponential distribution (Taha, 1992). Realistic approaches that incorporate standard forecasting techniques such as moving averages and exponential smoothing procedure were also suggested to improve demand forecasting. But uncertainty models can only be applied to the end items when products being considered are assemblies with component tree structure (Buffa, 1983)

Orlicky suggested independent/dependent demand rule, which provides a good guide to select ordering techniques (Plossl, 1986). According to Orlicky (1975), demand for an item in a manufacturing environment can be classified as either being independent or dependent. Independent demand describes any demand for finished products or components unrelated to demand for other items in a company's inventory while dependent demand describes any demand for items directly determined by schedules to a parent (in a bill-of-materials) or other associated item.

One procedure to plan material requirements in a manner that provides an optimal inventory level and allows for real time changes to demands, particularly when demand is dependent and intermittent would be through a material requirements planning (MRP) program (Plossl, 1995).

The complexities of producing numerous different products, as the case is in large jobshops, can cause confusion, inefficiencies and inferior customer service, but material requirements planning can serve as the information system required to integrate the production activities under this kind of environment (Adam and Ebert, 1992).

2.3 Material Requirements Planning

Material requirements planning is a computational technique that converts the master schedule for an end item into a detailed schedule for the raw materials and components used in the end product (Groover, 1987). It is an approach to materials management that applies to large job shop production, complex products, assemble-to-order environments, and discrete and dependent demand items (Bedworth and Bailey, 1987)

Material requirements planning system controls inventory levels, plans production, helps supply management with important information, and helps the manufacturing system with respect to assembled parts. (Plossl, 1995)

The goal of MRP is to reduce inventory cost while simultaneously ensuring that dependent demand relationships are met. MRP in its purest form is very simple.

Demand for materials is created by existing sales orders, work orders, and by entering forecasts. The MRP program compares the demand for materials with available inventory and suggests purchase orders and production orders. These new orders are offset by the lead times needed to purchase or manufacture the items.

Apart from being a potent inventory control technique, MRP serves as a production planning and scheduling system. According to Adam and Ebert (1992), MRP is a system of planning and scheduling time-phased material requirements for production operations. It plays a central role in translating the aggregate plan of a firm into a production and ordering schedule.

The major benefits of MRP implementation are lower inventory holding costs, shorter production lead-time and higher customer service level (Schroeder et.al , 1991).

2.4 Material Requirements Planning Inputs

The basic inputs into MRP computation, as shown in figure 2.1, are:

(i) Master production schedule file

(ii) Bill-of-materials file

(iii) Inventory balance file

(iv) Open purchase/manufacturing orders (Scheduled receipt) file

(v) Lead-times file

2.4.1 Master Production Schedule File

The master production schedule file specifies which end items or finished products the company is to produce, how many are needed, and when they are needed. The numbers that are on the MPS represent production, not demand. It may be a combination of customer orders and demand forecast.

The MPS must be in accordance with production or business plans. It is the vehicle, which communicates the business plan to the MRP subsystem. The Master Schedule in effect drives the Material Requirements Plan. The time periods used mostly in MPS is weekly. Monthly time buckets are also used, but daily time buckets are impractical, though it may be more precise and accurate (Plossl, 1985).

MPS must be viewed as a continuous "scroll" being steadily moved to drop past periods off on one end and reveal future periods on the other (Orlicky, 1975). As customer orders are booked, these can be viewed as consuming the MPS if they are converted into end items in MPS. The MPS must not include past-due data indicating that end items planned in some previous time have not been produced as this overloads the schedule.

2.4.2 Bill of Materials File

A bill-of-materials (BOM) file lists the quantities of components, ingredients and materials required to make a product. A bill of materials summarizes an engineer's designs and provides the interface to all departments involved in the manufacturing process. A drawing exists for an entire product, and drawings are also created for each of its subassemblies and components until every item in a product are specified. The drawings do not only describe the physical dimensions, but also any special processing as well as the raw materials from which each part is made. Item above any level are called parents; items below any level are called components or children.

BOM also provides the product structure. The product structure is a way structuring the BOM such that it supplies the information for the order in which the product is to be assembled. The product structure can be exploded to reveal the requirement for each component. This could be useful for costing and serving as a list of items to be issued to production or assembly personnel. When bills-of-materials are used this way, they are called pick list (Heizer and Render, 1988)

The MRP accesses the product structure file to determine which component items need to be scheduled. The BOM forms the framework of MRP systems. A material requirements planning system requires one common BOM, which must be highly accurate and properly structured (Plossl, 1985).

The BOM can be presented in the form of single level BOM, indented BOM and modular BOM. In indented form, the BOM is shown with the components (children) going into the making of a subassembly (parent) indented to the right to show parent-children relationships.

Another thing in BOM is the assignment of low-level codes. Low-level codes indicate the lowest level at which an item appears in the BOM in which it is used. Low-level coding of an item is necessary when identical items exist at various levels in the BOM.

One of the major problems encountered while manufacturing is engineering changes. Engineering changes occur due to a number of reasons. Some of these are incomplete design, incomplete drawing and specification, errors in design and specifications etc. Therefore, the BOM file of an MRP system should be able to facilitate smooth introduction of engineering changes to assemblies in production. A way of effecting engineering change is for a new item to replace an old one in every application in the BOM. Information on the old item such as lead-time must be substituted with those of the new ones (Plossl, 1985).

2.4.3 Inventory Balance File

Accurate inventory balances (on-hand) are essential to an effective material requirement planning system. When inventory items are received, an inventory credit transaction is generated; and when an item is taken out of inventory and placed on manufacturing line, an inventory debit transaction is generated. The inventory subsystem will calculate the inventory balances to determine the quantity on-hand for each inventory item at the beginning of the planning period.

Another important thing in keeping a reliable inventory record is part numbering. Every item must have one and only one part number (Plossl, 1985).

2.4.4 Scheduled Receipt File

Scheduled receipt file is also important for MRP to work. It is the information on orders already released. Whether purchased or manufactured, the information on the order must include quantity ordered and delivery dates.

2.4.5 Lead-Times File

Groover (1987) defined lead-time for a job as the time that must be allowed to complete a job from start to finish. There are two types of lead-times in MRP: ordering lead-times and manufacturing lead-times. Ordering lead-time for an item is the time required from initiation of purchase requisition to receipt of the item from the vendor; and manufacturing lead-time is the time required to process the work part or product through the plant.

For every product, some raw materials or components be purchased or converted through sequence of manufacturing process into finished item. The longest planned time span to do this, which is equal to the sum of the lead-times on the critical path, is called the cumulative lead-time or stacked lead-time (Plossl, 1986).

MRP operates best in deterministic and predictable manufacturing environment (Dilworth, 1996). Critical path method is applicable when lead-time is deterministic, but this is not obtainable in most manufacturing environment due to uncertainties in the production system. Therefore, it is recommended that production planners should use preset buffer (or safety) lead-times (Ho et.al., 1995).

Determining the cumulative lead-time of a product using critical path scheduling meth involves:

(i) Setting up the chart of activities involved in the processing of a product,

(ii) Showing the necessary sequences and interrelationships, and

(iii) Determining the longest sequence of events that can really determine the time production can be completed.

2.5 Material Requirements Planning Computational Processes

For each part required to satisfy firm's MPS during a planning horizon, MRP computation is carried out in each time unit called a "bucket". In each time bucket, the on-hand inventory and the scheduled receipt are subtracted from the gross requirement to determine the net requirement and planned order receipt at that time. From this, the planned order release is determined.

2.5.1 Gross Requirements

Gross Requirements is the overall quantity of an item needed during a time period to meet planned output levels. Planned outputs for end items are obtained from the MPS while planned outputs for low level items are obtained from the MRP processing. Explosion of requirements in the MRP module flows down through component levels following the linkage specified in the product structure.

The planned order release of a parent item multiplied by the quantity of child item that goes into the making of one parent item becomes the gross requirement of the component required at the next level.

In reality, there is demand for many products over time. A component may appear in several branches of the product structure of a parent product and also in the product structure of other products. Scheduled production of each product contributes to the master schedule of the component. This necessitates aggregation of the several schedules contributing to the gross requirements schedule and ultimately to the net requirements plan for the component.

2.5.2 Net Requirements

Net Requirements is net quantity of an item that must be acquired to meet the scheduled output for the period. Net requirement is calculated as gross requirement minus the sum of scheduled receipts for the period and the available inventory from past period.

$(NR)_t = (GR)_t - [(SR)_t + (OH)_t]$ ....(2.1)

where:

$(NR)_t$ = Net requirement in period t

$(GR)_t$ = Gross requirement in period t

$(SR)_t$ = Scheduled receipt in period t

$(OH)_t$ = On-hand inventory in period t

2.5.3 Planned Order Receipt

Planned Order Receipt is the quantity of items that has to be received or produced at the end of a particular period.

$(POR)_t = (NR)_t$, for $(NR)_t > 0$……………………………(2.2a)

$(POR)_t = 0$, for $(NR)_t <= 0$, ……………………………(2.2b)

where:

$(POR)_t$ = Planned order receipt in period t

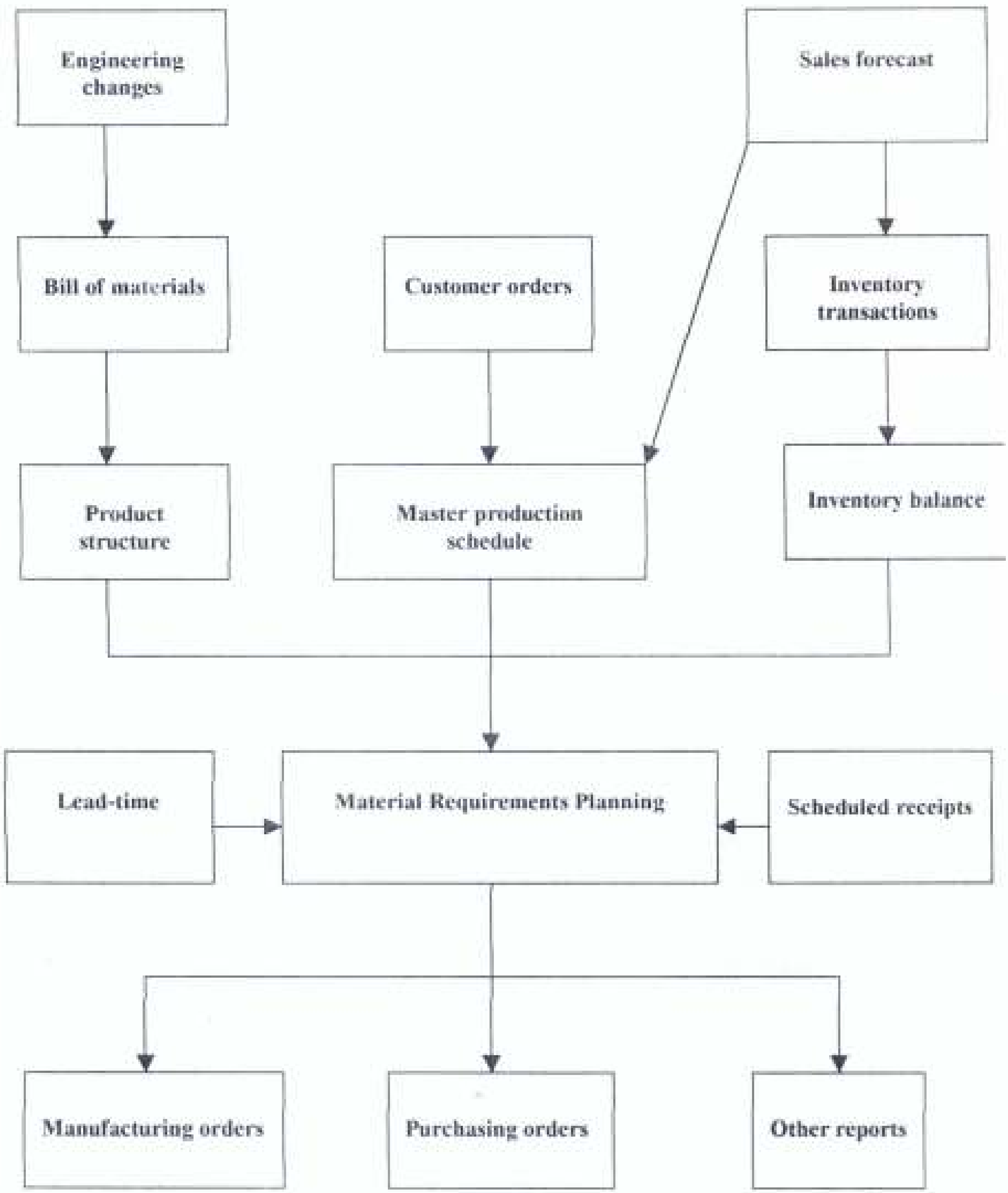


Figure 2.1: Structure of a Material Requirements Planning System

2.5.4 Planned Order Release

Planned Order Release tells the quantity, and when purchase requisition has to be released to the vendor or production order must commence. The planned order release takes into consideration the lead-time. Planned order release is the planned order receipt offset lead-time.

$$(PREL)_t = (POR)_{t+L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.3)$$

where:

$(PREL)_t$ = Planned order release in period t

$(POR)_{t+L}$ = Planned order receipt in period t+L

2.6 Capacity Planning in MRP

Groover. (1987) defined capacity as the maximum rate of output that a plant (or other production facility) is able to produce under a given set of assumed operating conditions. Capacity for a production unit can be measured in terms of the type of output produced by the plant.

In its basic form, MRP logic does not consider the availability of resources, that is, MRP uses infinite capacity whereas in reality there is limit to capacity. Consequently, MRP computation is often capacity infeasible. Rough-cut capacity planning can be used with MRP to make it feasible.

Rough-cut capacity planning is the process of testing the feasibility of master production schedules in terms of capacity before MPS is finally settled. This step ensures that the proposed MPS does not inadvertently overload any key department, work center or machine.

According to Plossl (1986), rough-cut capacity requirement planning, based on forecast of customer orders, is used in make-to-order products, while assembly schedules are based on customers' orders

Work rescheduling can be used to cope with violated capacity limit at a work center (Heizer and Render, 1988). Many attempts have been made to write software that will do automatic load leveling (Cybor Communications Limited, 1997). In a sense, this is what finite scheduling attempts to do. But the problem is that there are too many exceptions, too many ways to respond with capacity changes and too many judgments to be made for planners to depend on a computer program to do all the thinking. Scheduling can hardly be fully automated. All that can be attempted is to provide is a tool that assists with scheduling process. Cybor Communications Limited (1997) suggested that a way to schedule is to project when production will be completed via the schedule and add a predetermined buffer to quote realistic due dates.

Another way of handling overbooked work centers is by adding more capacity (Adam and Ebert, 1993). If work centers are overbooked by infinite scheduling, more capacity must be added through overtime, hiring, adding machines, moving people among work centers, etc. or negotiating with customers to move due dates out

To use scheduling and capacity planning, work centers must be set up and all bills of materials must have estimated production times for each operation, together with load limits on the plant machine (Heizer and Render, 1988). However, when doing this, work centers still have to be reviewed every now and then to optimise the schedule.

When functions such as capacity planning are incorporated with an MRP system, we have a closed looped MRP. A closed-loop MRP system provides feedback to the capacity plan, master production schedule and ultimately to the production plan. Close-looped MRP systems allow production planners to move work between time periods to smooth the load or at least bring it within capacity. The MRP system can then reschedule all items in the net requirements plan.

Tactics for smoothing the load and minimizing the impact of the changed lead-time include th following:

(i) **Overlapping,** which reduces the lead-time. It entails sending pieces to the second operation before the entire lot is completed on the first operation.

(ii) **Operation splitting,** which involves sending the lot to two different machines for the same operation. This requires additional set up, but results in shorter throughput times, since only part of the lot is processed on each machine,

(iii) **Lot splitting,** which involves breaking up the order and running part of it ahead of the schedule.

2.7 MRP II or Enterprise Resource Planning (ERP)

The inventory data of MRP can be augmented by labour hours, by material cost (rather than material quantity), or by capital cost or virtually any resource variable and when MRP is used this way, it is referred to as MRP II, material resource planning or Enterprise resource planning (ERP).

2.8 Regeneration of MRP Schedules

MRP is not a static technique. Changes sometimes occur in MRP schedules because of change in bill of material as a result of change in design and processes, change in MPS, change in lead-time, machine breakdown, delayed material supply etc. All these variations bring about regeneration MRP requirements and schedules.

As much as the timely and accurate regenerative ability of the MRP system is its central strength, frequent changes generate what is called 'system nervousness'. Calson et.al (1979) define system nervousness as the shifting of scheduled set up.

Many research works are going on in this area. However, three approaches are generally used to reduce the nervousness created by MRP changes (Heizer and Render, 1988). These are

(i) Evaluating the need and impact of changes prior to disseminating requests to other departments.

(ii) Establishment of 'time fences'. Time fences allow a segment of the master schedule to be designated as "not to be rescheduled." This segment of the master schedule is thus not changed during the periodic regeneration of schedules.

(iii) Pegging, which refers to the tracing upward in the BOM from the component to the parent item. This enables the production planners to determine the cause for the requirement and make judgment about the necessity for a change in the schedule.

2.9 Lot Sizing Techniques in MRP

The fundamental concept of MRP uses lot-for-lot determination of production units. Th objective of MRP system is to produce units only as needed, with no safety stock and no anticipatio of further orders. However, there could be cases where set up cost are significant or wher management find it difficult to implement the JIT philosophy. Then, there may be the need to fin other methods of determining lot sizes in MRP system. The lot sizing methods in MRP may b classified as Static and Dynamic lot sizing rules.

2.9.1 Static Lot-sizing Rules

In the static lot-sizing rule, the same quantity is ordered each time an order is placed. The fixed order may be an order to or produce a fixed quantity, or a multiple of that fixed quantity or to produce the economic order quantity (EOQ), plus any additional item needed to replenish safety stock if it has fallen below its desired level.

The EOQ formula averages demand obtained from the MRP over an extended time horizon. With this average demand, the annual usage for raw material or component can be established and used in the EOQ formula to calculate a constant order quantity. The EOQ formula is given as

$$Q = [(2 \times D \times S) / H]^{1/2} \qquad (2.4)$$

where:

Q = Economic Order Quantity

D = Annual usage

S = Set up cost

H = Holding cost on annual basis per unit

Although the EOQ formula yields minimum total setup or ordering plus holding costs, but it tends to generate higher average on-hand inventory because inventory remnants are created (Buffa, 1983). Safety stock is created as well.

2.9.2 Dynamic Lot-Sizing Rule

This rule changes the order quantity with each order so that each order is large enough to prevent shortages over a specified period of time. The dynamic lot-sizing rule may be broadly classified as lot-for-lot and periodic order quantity.

2.9.2.1 Lot-for-Lot

In lot-for-lot technique, order is placed to produce or purchase exactly the quantity required in each period to satisfy gross requirements and to maintain safety stock at its required level. Lot-for-lot is simple to use, and agrees with Just-In-Time philosophy of ordering/producing only when required. Lot-for-lot is used in the basic MRP computation.

Lot size can be modified easily for purchase discounts or restrictions, scrap allowances, process constraints, etc. It minimizes on-hand inventory, but maximizes number of orders placed (so can be expensive if setup/ordering costs are significant).

2.9.2.2 Periodic Order Quantity

This involves ordering or producing a quantity equal to the gross requirements for P periods minus any items in on-hand inventory plus any additional items needed to replenish safety stock if it has fallen below its desired level. Periodic Order Quantity restores safety stock and covers exactly P periods of gross requirements. It reduces on-hand inventory by attempting to match the quantity ordered to the quantity required.

There are other lot-sizing techniques under the periodic order quantity technique. These include the part period cost balancing, least total cost rule, the Wagner-Whitin algorithm etc.

One technique, among these, that performs well is part period cost balancing (Bedworth and Bailey, 1987). In Part period cost balancing, lot sizes are changed to reflect requirements of the next lot size in the future. PPB means one part carried in inventory for one period. It uses the information provided by the requirement schedule and attempts to minimize total cost by comparing the cost of placing order and carrying cost over a period of time. PPB performs well because of its flexibility in considering replenishments involving both variable reorder quantity and variable reorder frequency. It considers several different possible horizons and selects the one in which order and inventory costs are approximately equal. Part period cost balancing is also an effective lot-sizing rule to reduce system nervousness (Ho et al, 1995).

Although some of the dynamic lot sizing technique provide optimal lot size, but dynamic lot-sizing rule tends to cause instability by tying lot-size to gross requirement. However, the lot-for-lot approach is the most desirable in production management and should be used whenever economical. Then it can be modified as necessary for scrap allowances and process constraints (Heizer and Render, 1988).

2.10 Computer Integrated Manufacturing

The aim of most manufacturing organization is to make profit. Therefore, there is the need for production control, which will help to effectively utilize the limited resources in the production of good and services to satisfy customer demands and create profit for investors.

There are certain basic functions that must be carried out to convert raw materials into finished product. For a firm engaged in making discrete products, the functions are processing, assembly, material handling and storage, inspection and test, and control.

However, many companies make hundreds of different products, each product consisting of individual components perhaps numbering in the thousands. Therefore manufacturing firms must organize themselves to accomplish the five functions effectively.

The task of coordinating all of the individual activities required to make the parts, assemble them, and deliver the product to the customer is complex indeed. It is a problem in information processing (Bedworth and Bailey, 1987).

The on-line use of computer to control and link together all the functions in a manufacturing plant is called Computer Integrated Manufacturing (CIM). Application of computer systems to manufacturing ranges from product design to manufacturing planning, manufacturing control and include the business functions of the company as well (Groover, 1987).

The business functions are the beginning and the end of the information-processing cycle because they are principal means of communicating with the customer. Included within this category are sales and marketing, sales forecasting, order entry, cost accounting, customer billing, and others. Production usually begins with order entry and an order may take the form of manufacturing an item to the customer's specifications, a customer order to buy one or more of the manufacturer's proprietary products, or an order based on a forecast of future demand for a proprietary product.

Product design follows order entry. If the product is to be manufactured to customer's specifications, the customer will have provided the design. The manufacturer's product design department will not be involved. If the product is proprietary, the manufacturing firm is responsible for its development and design. The cycle of events that initiates a new product often originates in the sales and marketing department. The product design is documented by means of component drawing, specifications, and a bill of materials that defines how many of each component go into the product.

The information and documentation that constitute the design of the product flow into the manufacturing planning function. The information- processing activities in manufacturing include process planning, master scheduling, requirement planning, and capacity planning. Process planning consists of determining the sequence of the individual processing and assembly operations needed to produce the part.

The authorization to produce the product must be translated into the master production schedule. The master schedule is the listing of the products to be made, when they are to be delivered, and in what quantities. Units of months are generally used to specify deliveries on the master schedule.

Based on this schedule, the individual components and subassemblies that make up each product must be planned. This is called material requirements planning. In addition, master schedule must not list more quantities of product than the factory is capable of producing with its given number of machines and worker each month. The production quantity that the factory is capable of producing is referred to as the plant capacity. Capacity planning is concerned with planning the manpower and machine resources of the firm.

Manufacturing control is concerned with managing and controlling the physical operations in the factory to implement the manufacturing plans. The flow of information is from planning to control. Information also flows back and forth between manufacturing control and the factory operations. Included with the control functions are shop floor control, inventory control, and various other control activities. Shop floor control is concerned with the problem of monitoring the progress of the product as it is being processed, assembled, moved, and inspected in the factory. The activities of production planning and control department include scheduling, dispatching and expediting. Production scheduling is concerned with assigning start dates and due dates to the various parts (and products) that are to be made in the factory. Based on the production schedule, dispatching involves issuing the individual work orders to the machine operators to accomplish the processing of the parts. Even with the best plans and schedules, things sometimes go wrong (e.g. machine breakdowns, improper tooling, parts delayed at the vendor). The expediter compares the actual progress of a production order against the schedule to take the necessary corrective action to complete the order on time.

Inventory control attempts to strike a proper balance between the danger of too little inventory (with possible stock-outs of materials) and the expense of having too much inventory, while the mission of quality control is to assure that the quality of the product and its components meet the standards specified by the product designer.

Computer Integrated Manufacturing can be achieved only by connecting the various computer systems in a firm's information processing cycle by means of computer networks. This allows the respective users of the computer systems to communicate with each other and share a common database.

Ogedengbe et.al, (2002) observed that the adoption of CIM generally is still very low in Nigeria and recommended sequential acquisition and implementation of CIM by using reinvestment method.

2.11 Review of MRP Softwares

Many MRP softwares have been developed, particularly in developed countries, but Vormittag Associates, Inc (2002), while commenting on System 2000 MRP, a material requirements planning software they developed, said MRP is a common term but no two MRP systems look and plan in the same ways. The differences may include the underlying logic, the user interface, and the phrases used etc.

Many of the existing MRP softwares still use the traditional MRP logic, but the most common practice is to develop the MRP software and develop other software applications as complementary softwares to help in using MRP software as an enterprise resource planner for their users (Deloitte Consulting, 1998).

Development of MRP software applications depends on the level of technology and size of the company where it is intended to be used or the improvement that is demanded by existing users to meet needs (Teltumbe, 2000).

2.12 Visual Basic as a Programming Language

Visual Basic is an object oriented programming language developed to run on any version of Microsoft Window operating system. Microsoft Window is an example of graphical user interface in which instead of the cryptic commands that DOS (disc operating system) users are familiar with, what is seen is a desktop that is filled with icons and a program that uses mice and menus (Cornel, 1997).

Before the advent of Visual Basic, writing program in window environment was much harder than writing program in DOS because programmer had too much to worry about and window applications are expected to have the feels and looks of window. Visual Basic allows programmer to add menus, textboxes, command buttons, option buttons, checkboxes, listboxes, scroll bars etc to blank widows. With the introduction of Visual Basic, programming in widow has become more efficient and simpler.

Visual Basic is described as an object oriented programming language because it allows the programmer to view a concept as one consisting of varieties of objects that are related to each other. Objects are forms and various other Visual Basic controls. These objects can be treated as variables such as strings and numeric variables. Thus the object variables can also be manipulated as any other Visual Basic variables and event procedures are written for these objects.

In Visual Basic programming language, software design process may be broken into seven steps (Cornel, 1997).

These steps are:

(i) Definition of the problem to be solved.

(ii) Determination of the inputs available to solve the problem and the required output.

(iii) Determination of how the user will enter, retrieve and inspect information.

(iv) Design of user interface using forms and controls.

(v) Review of the interface to determine how much it is user-friendly.

(vi) Writing of procedures and modules for the design.

(vii) Testing of the design to see if it is acceptable.

One of the most important features of Visual Basic is that it provides tools for creating and using structured databases in the management of application's data. Database is an organized store where data are kept in a more efficient manner, which enhances the efficiency, effectiveness and speed with which data are added, updated and retrieved from the database.

One of the most popular types of database model is the relational database model. The relational database allows the manipulation of two or more set of records called table at the same time.

Terms used in relational database are

(i) Table, which is a logical structure used to group sets of related information

(ii) Record, which is the grouping of a set of attributes describing each person, place or item in a database.

(iii) Field, which is an attribute of a record.

(iv) Queries, which are questions, asked of a database.

The advantages of Visual Basic are numerous, but some of the most important ones are:

(i) Relative ease of designing user interface

(ii) Less coding

(iii) Ability to relate with other widow applications

(iv) Possibility of unlimited number of users to access the same database.

(v) It is a nice choice for writing business packages.

CHAPTER THREE

3.0 SOFTWARE DESIGN AND IMPLEMENTATION

Software design process may be viewed to consist three parts:

(i) Analysis

(ii) Algorithm design

(iii) Coding

3.1 System Analysis

System Analysis is the logical process that determines exactly what must be done to solve a problem. To computerize Material Requirements Planning (MRP) for job shops, theory of Material Requirements Planning was properly studied and adapted to job shops where many heterogeneous products are being manufactured.

Material Requirements Planning allows for demand-driven production plans to be made. It determines what to produce, when to produce, and how much to produce.

The planning and control functions of MRP can be accomplished by:

(i) Establishing likely due dates for incoming orders

(ii) Providing most current information on the inventory status

(iii) Providing information on the dates of releasing planned order to work centers and suppliers.

(iv) Scheduling incoming orders without violating capacity constraint of the work centers and supply sources.

(v) Establishing new material plans where there are sudden changes in production schedules.

These goals would be accomplished by creating various subsystems (or modules) for the MRP software.

The Material Requirement Planning system implemented in this project considers the process that begins when an order is created for a job. The computer system is modeled to be one that can be networked among the various departments in a typical job shop. The departments are business department, production planning department, material management department, and the shop floor.

The MRP system is divided into several modules or subsystems that are integrated with each other. These subsystems are:

(i) BOM (or Process Planning) subsystem

(ii) MPS subsystem

(iii) Inventory subsystem

(iv) MRP subsystem

3.1.1 BOM and Lead-time (or Process Planning) Subsystem

The BOM and Lead-time subsystem is a planning tool in the hands of the product design and production planning departments. The BOM subsystem provides the interface to all departments involved in the manufacturing process. That is, it is a document relied on by Purchasing, Production, Inventory Control, and virtually every function concerned with manufacturing operations.

The functions of the BOM subsystem are the following:

(i) Description of parts that will be used in each manufactured product.

(ii) Description of product structures for all manufactured items

(iii) Definition of assembling paths (or sequence of operations) and work centers for the manufacturing of the products

(iv) Determination of the total time it will take to assemble specified products

In the BOM subsystem, the bill-of-materials document is obtained from the product design, which may be proprietary or specified by the customer. BOM subsystem establishes the parent-child relationships among the various parts required for the production of an assembly (or end item). The bill-of-material statement for a product is developed into the product structure of the product. The product structure then defines the assembling route or sequence of operations. Using the bill of material, the engineer must determine the most efficient set of operations to manufacture a product and from this, the BOM defines work centers for these operations.

Based on the planned lead-time specified by the production planner for each assembling route (or work center), the BOM subsystem calculates the Cumulative Manufacturing Lead-time (CMLT) for the product using critical path method (Plossl, 1986). Buffer (or safety) lead-time are recommended to be added to the production and purchasing lead-time to be used for the MRP computation (Ho et.al, 1995).

Total lead-time for each operation sequence (or assembling) paths can be expressed as

$$TT_r = \sum_{i=1}^{n} TO_i \qquad (3.1)$$

TT_r = Total lead-time for assembling path r

TO_i = Lead-time for an operation i along assembling path r

n = number of operations along assembling path r

After calculating the total lead-times for each of the assembling paths, then the BOM subsystem compares the lead-times of the assembling paths to determine the longest lead-time.

The longest lead-time is the total time (critical manufacturing lead-time) it will take to assemble the components of product to its final assembly.

Capacity planning function is also included in the BOM module. Rough-cut capacities for work centers are used in the BOM subsystem for the development of workable schedules and overall shop floor efficiency. Work centers and all bills of materials must have estimated production times for each operation, together with load limits on the plant machines or work centers. Load limits in this system are expressed in terms of the maximum output produced by the specified work center (Groover, 1987).

The Bill of Material subsystem also facilitates the smooth introduction of engineering changes to assemblies in production. It makes it easy to develop a bill of material statement for a new product and provides flexible methods to implement changes to old bills. As part requirements change due to engineering changes made to the old bill of material, the Bill of Material subsystem keeps other subsystems involved in manufacturing operations up-to-date. All changes made to a product's components are automatically reflected in the MRP subsystem's schedules, and order pick-lists.

BOM subsystem inputs include:

(i) Products (or assemblies) records

(ii) Components records

(iii) Parent-child relationship among assembly components

(iv) Lead-time for assembly components

(v) Method of procuring assembly parts: produce or purchase

Reports from the BOM subsystem are:

(i) Bill of material record tables

(ii) A summarized list of all components

(iii) Product Structure for specified assemblies (products)

(iv) Lead-time record tables for production and purchases of parts

(v) Cumulative lead-time for specified assemblies (products)

3.1.2 MPS Subsystem

MPS subsystem communicates the company production plans to the MRP subsystem. Two goals of the production planning and control functions are accomplished in the MPS subsystem and these are:

(i) Establishing likely due dates for incoming orders

(ii) Establishing master production schedules (or production time table) for the firm

A company's master schedule clearly defines the sales and production objectives management intends to achieve. Based on customer orders, a master production schedule (MPS) is established which shows the quantities of the different products ordered by customers and when they are due to be delivered to the customers.

The major input file required in the MPS subsystem is the job-card (or order) file, which contains the customer orders' data. The job-card file specifies which end items or finished products the company is to produce, how many are needed, and when they are needed (due date).

MPS may be a combination of customer orders and demand forecast. The MPS subsystem aggregates the quantities of end items or products (assemblies or manufactured items) scheduled for delivery period by period. The aggregated quantities in period t can be expressed as

$$PS_t = \sum_{x=1}^{y} Q_{tx} \quad (3.2)$$

where

PS_t = Sum of quantities of product from different orders due for delivery in week t

Q_{tx} = Quantity of product in order x scheduled for delivery in week t

y = number of orders for product

The output MPS subsystem is the MPS report, which could be viewed as a continuous "scroll" being steadily moved to drop to drop past periods off on one end and reveal future periods on the other (Orlicky, 1975). This is a common practice in real-world systems (Vollman et.al., 1998)

Every product in the master production schedule should be described by a bill-of-materials with lead-time record for all its component items. Thus the cumulative lead-times for specified assemblies (products) are calculated in the BOM subsystem.

Therefore, on the choosing an appropriate commencement period, a realistic due date can be calculated for the completion of an order. Feasible Due Date for period is given by:

Feasible Due Date = Commencement period + Cumulative Lead-time

3.1.3 Inventory Subsystem

The primary concern of the inventory subsystem is the maintenance of accurate inventory records of parts on-hand.

The inventory subsystem records vendor receipts and production completions and provides for quick check of the current status of any part. It also records information on quantities and delivery dates for orders (purchased or manufactured) already released. The subsystem records date and time of transaction, part number, change in on-hand, and as well as identification of persons concerned with material flow and its documentation. It also makes available the most current value of on-hand inventory for material planning computation.

3.1.4 Material Requirements Planning Subsystem.

The MRP subsystem coordinates activities of all subsystems to meet production goals. It translates management, marketing, and productions planning goals into detailed and coordinated schedules for purchasing and production. Material Requirements Planning subsystem, in conjunction with its companion subsystems, delivers the orderly, integrated control needed for effective production planning.

The MRP module quickly converts organization's MPS to net assembly, component and raw material requirements. The module uses the MRP processing logic to explode the MPS (created from the sales order file) using the database product link and allowing for lead times to determine the time-phased gross requirements for all the components, the net requirements and the planned order releases in each week to meet the master production schedule. MRP module also compares the planned order release of each item with the capacity available at its work center.

The output is a set of periodic recommendations for manufacturing orders, purchase orders, and indication if production capacity is exceeded suggesting the need for rescheduling and cancellation actions. These recommendations are displayed on the screen in weekly time buckets. The MRP subsystem also establishes new material plans where there are sudden changes in production plans.

MRP subsystem starts with end product due dates and uses planned lead-times to compute the component release dates.

Net Requirements is given by

$NR_t = GR_t - (SR_t + OH_t)$ .... (3.3)

where:

NR_t = Net requirement in period t

GR_t = Gross requirement in period t

SR_t = Scheduled receipt in period t

OH_t = On-hand inventory in period t

For end-items (or products) in MPS,

$GR_t = PS_t$

For lower-level items,

$$GR_t = \sum_{p=1}^{q} PREL_{pt} * N_p \quad (3.4)$$

where:

GR_t = Gross Requirements lower level item in period (or week) t

$PREL_{pt}$ = Planned order releases of child item's parent source p in week t

N_p = Number of units of item that goes into the production of 1unit of parent source p

q = Number of parent sources of the lower level item from the various product structure branches

Planned On-hand inventory in week t, OH_t can be expressed as:

$OH_t = EI_{t-1}$, for $EI_{t-1} > 0$. .... (3.5)

$OH_t = 0$, for $EI_{t-1} <= 0$

EI_{t-1} = End inventory in period t-1

End inventory in a period t can be expressed as:

$EI_t = (SR_t + OH_t) - GR_t$ .... (3.6)

Hence,

$EI_{t-1} = (SR_{t-1} + OH_{t-1}) - GR_{t-1}$

Planned Order Receipt is given by:

$POR_t = NR_t$, for $NR_t > 0$ .... (3.7)

$POR_t = 0$, for $NR_t <= 0$,

where:

POR_t = Planned order receipt in period t

Planned Order Release is given by:

$PREL_t = POR_{t+L}$ .... (3.8)

where:

$PREL_t$ = Planned order release in period t

POR_{t+L} = Planned order receipt in period t+L

To identify potentially critical capacity problems - the MRP subsystem provides capacity planning checks. Planned order releases are compared with the rough-cut capacity limit or load limit at each work center to report if the work schedule is feasible.

For $PREL_{t+L} > R$, Report = "Above Capacity"

For $PREL_{t+L} <= R$, Report = "Within Capacity"

R = Rough-cut capacity per specified lead-time at part's work center

To solve a potential part requirement problem highlighted by the MRP run, the MRP system generates pegging which identifies the parent source of the part's requirement. Knowing the source, the planner is able to readily decide the best action.

3.2 Algorithm Design

The steps of the MRP algorithm are discussed in this section and the flowchart is also shown in figures 3.1a to 3.1g

After entry to the program (Computerised MRP System), the following steps are taken:

Step 10: User checks if product ordered is old (familiar) or new (unfamiliar) to the firm. If product is old, go to step 22

Step 20: For a new product, user will enter data for product and specify all the components needed to assemble the product. Data required are component (part) name, part number, part description (or specification), and work center capacity (maximum quantity that can be produced at its work center).

Step 21: User will specify (or write) the BOM document.

The data required are specification of parent/ child relationship in the product assembly, quantities of component required for each parent part, method of procurement: make or buy, lead-time for procurement operation and code level

Step 22: User will verify the BOM by commanding the system to display the product structure.

Step 23: If product structure is satisfactory, go to step 25

Step 24: User will command the system to display the BOM document, write or edit BOM document and then go to step 22

Step 25: User will open lead-time record. If lead-times for components are satisfactory, go to 27

Step 26: User will edit lead-time record.

Step 27: Calculate the total lead-time, TT_r for each assemblying path in product's product structure (from r =1 to S)

$$TT_r = \sum_{i=1}^{n} TO_i$$

S = number of possible assemblying routes (or paths)

Step 28: Determine the highest TT_k. (from k=1 to L)

Step 29: Determine the critical path lead-time for the product. Critical path lead-time, CMLT, is the highest TT_k.

Step 30: User will open job card for product ordered. User will enter the quantity ordered and the expected production start date.

Step 31: Calculate the feasible due date (or order completion time)

Due Date = Start Date + Critical path lead-time

Step 32: Add the scheduled production for every week within the production horizon. The aggregated quantities, PS_t is expressed as

$$PS_t = \sum_{x=1}^{y} Q_{tx}$$

$GR_t = PS_t$

Step 33: User will command the system to print PS_t for each week to display the Master Production Schedule (MPS).

Step 40: User will enter inventory transactions for each part. The data required are names and quantities of items received or released, and date and time of inventory transaction.

Step 41: Calculate inventory balances for each component at the end of each transaction

Inventory Balance = Quantity in Stock + Quantity Received (or – Quantity Issued)

Quantity in Stock = Inventory Balance from the last transaction

Step 42: User will enter all order released (schedule receipts) for each part. The data required are quantity of orders released and scheduled delivery week

Step 50: Set code level, c = 0

Step 51: Set t = current time period (current week) i.e. when planning begins

Step 52: Determine gross requirements for each end item assemblies.

For end item assembly at the highest level (with code level 0),

$GR_t = PS_t$

Step 53: Determine the planned on-hand inventory for each part in each week.

Planned on-hand inventory in period t is given by

$OH_t = EI_{t-1}$, for $EI_{t-1} > 0$

$OH_t = 0$, for $EI_{t-1} <= 0$

EI = End inventory

Step 54: Calculate net requirement for each part in each week.

$NR_t = GR_t - (SR_t + OH_t)$

Step 55: Determine the planned end inventory for parts in each period

$EI_t = (SR_t + OH_t) - GR_t$

Step 56: Determine planned order release, $PREL_{t-L}$ for part in week t-L,

Planned Order Release is given by,

$PREL_{t-L} = NR_t$, for $NR_t > 0$

$PREL_{t-L} = 0$, for $NR_t <= 0$

L = Lead-time

Step 57: Compare planned order release $PREL_{t-L}$ with rough-cut capacity, R for part at its work center:

For $PREL_{t-L} > R$, Report = "Above Capacity"

For $PREL_{t-L} <= R$, Report = "Within Capacity"

Step 58: set t = t + 1

Step 59: If t <= T (amount of forward visibility at the MPS for the specified year), go to step 52

Step 60: Check if part has child (or component) parts

If part has no component parts, go to 70

Step 61: Set c = c + 1

Step 62: Compute the gross requirement in week t, GR_{pt} contributed to the gross requirement schedule of component by each of its parent source, p as specified by the product structure:

Gross requirements contributed by each parent source, p in the product structure is given by

$GR_{pt} = PREL_{pt} * N_p$

where:

$PREL_{pt}$ = Planned order releases of child item's parent source p in week t

N_p = Number of units of child component that goes into the production of 1unit of parent source p

Step 63: Add the gross requirements, GR_{pt} obtained in week t from the various parent sources of the product structures for the child component:

Gross Requirement of lower level item in period (or week) t is given by

$$GR_t = \sum_{p=1}^{q} GR_{pt} = \sum_{p=1}^{q} PREL_{pt} * N_p$$

where:

q = Number of parent sources of the lower level item from the various product structure branches

Step 64: Go to step 52

Step 70: Print $PREL_t$ and Report

Step 80: Stop

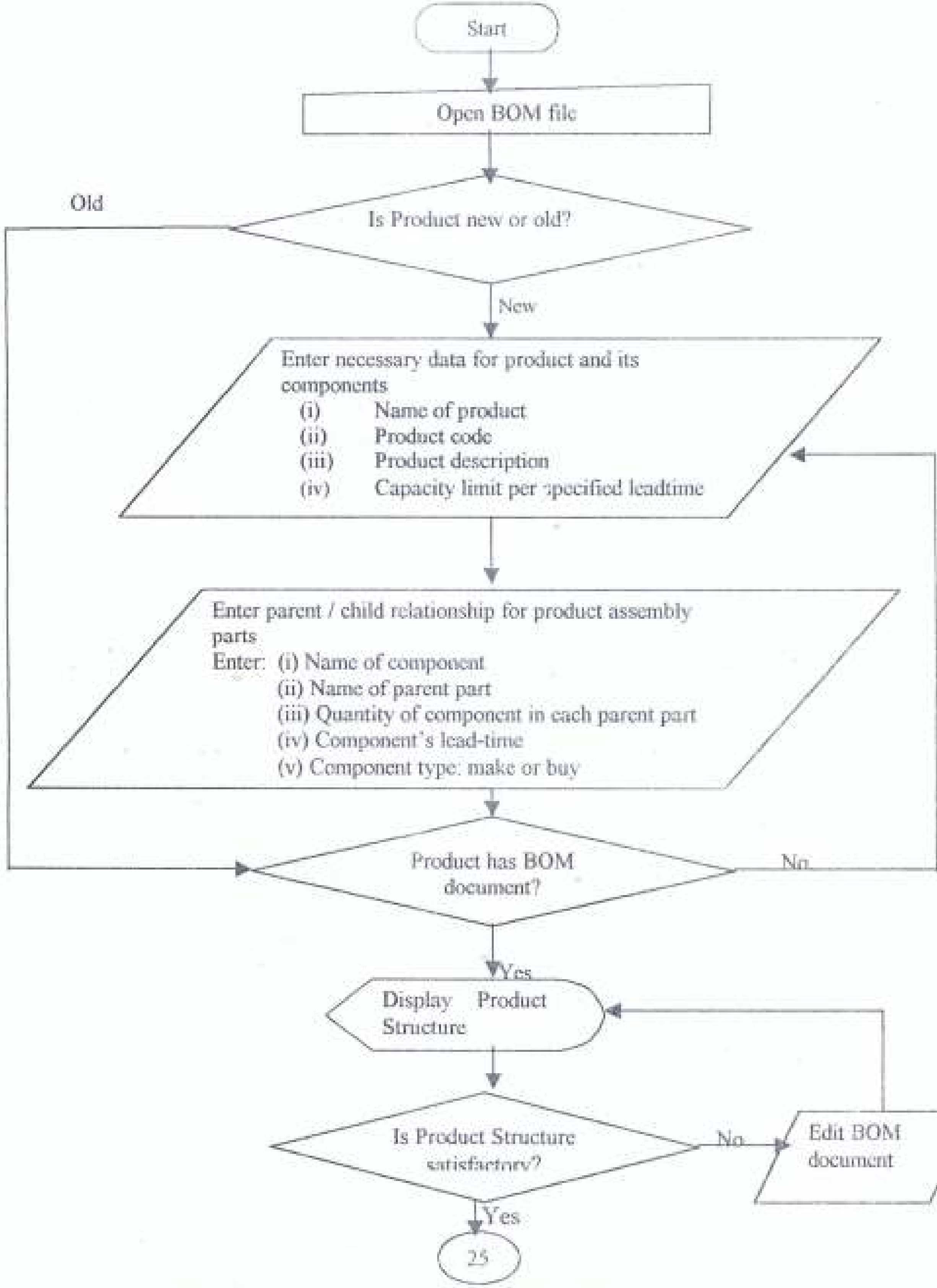


Figure 3.1a: Flowchart of Material Requirements Planning System

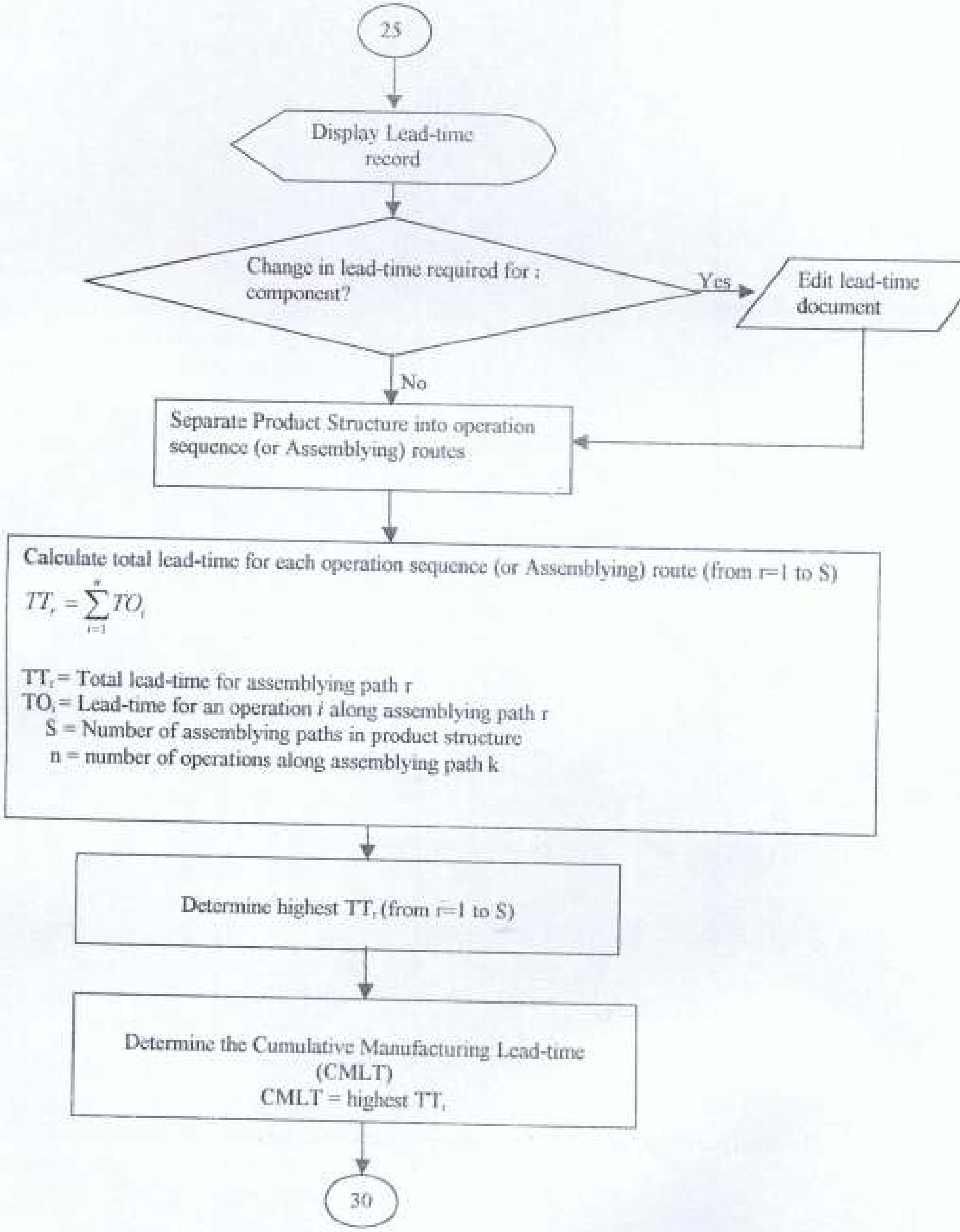


Figure 3.1b: Flowchart of Material Requirements Planning System (contd)

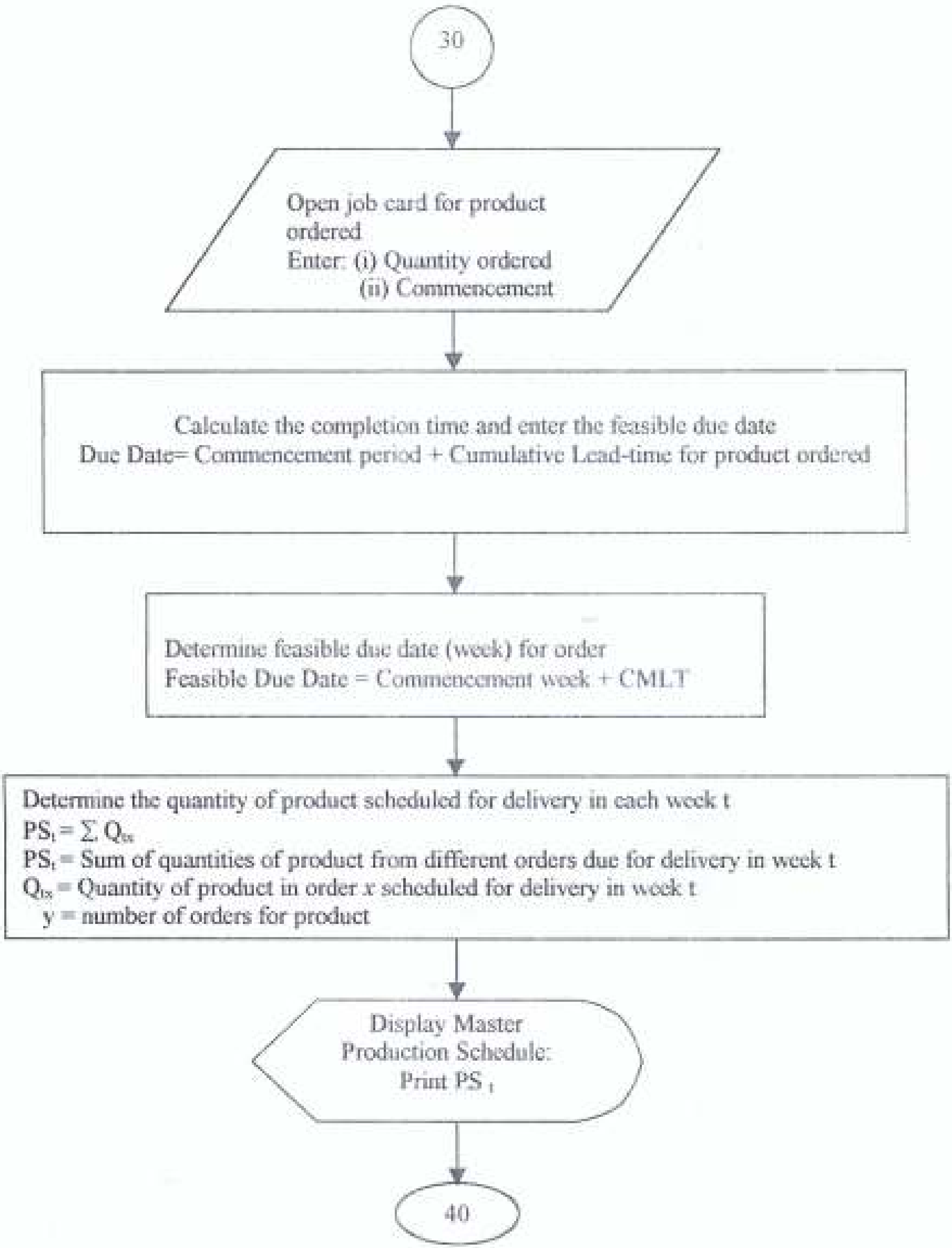


Figure 3.1c: Flowchart of Material Requirements Planning System (contd)

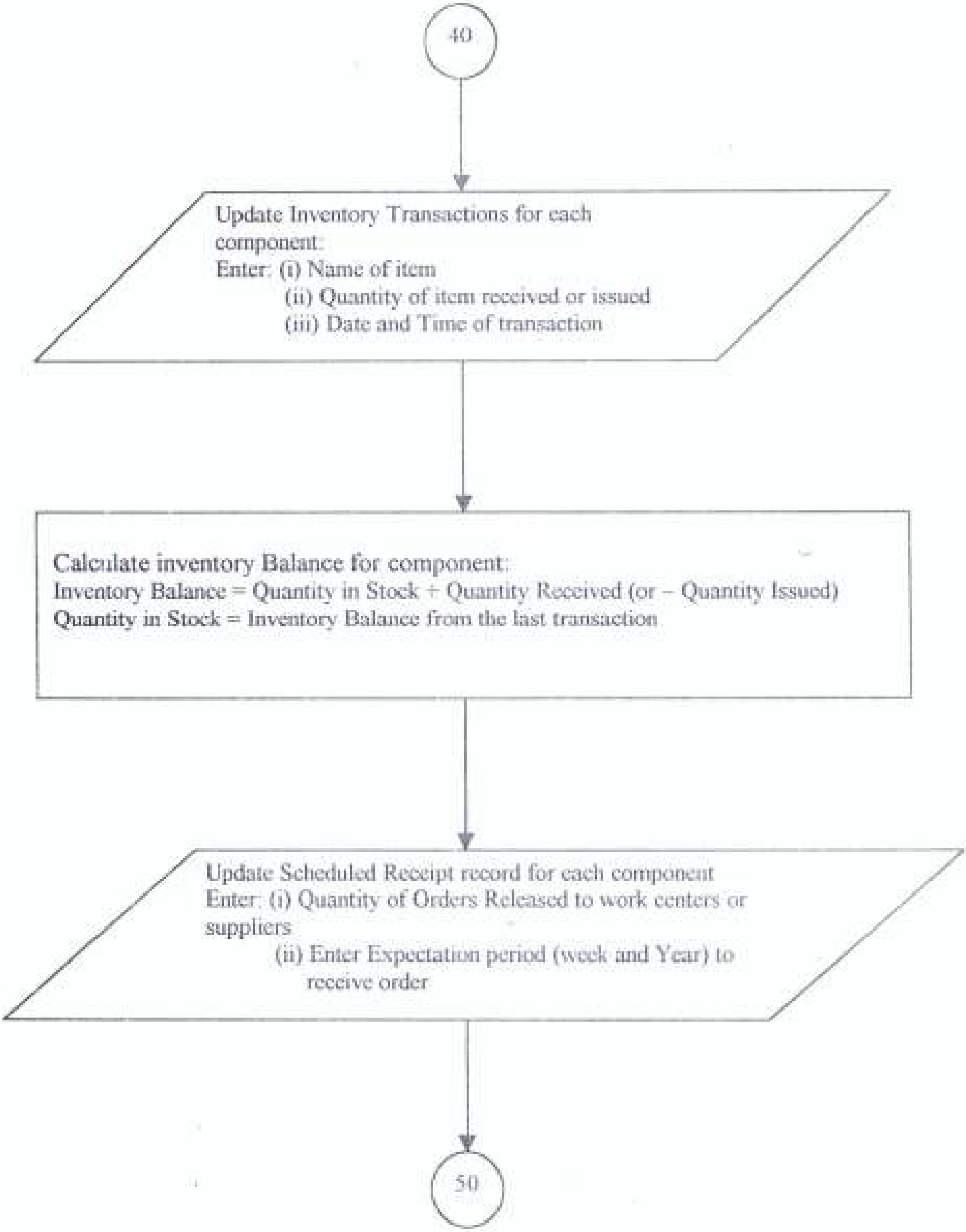


Figure 3.1d: Flowchart of Material Requirements Planning System (contd)

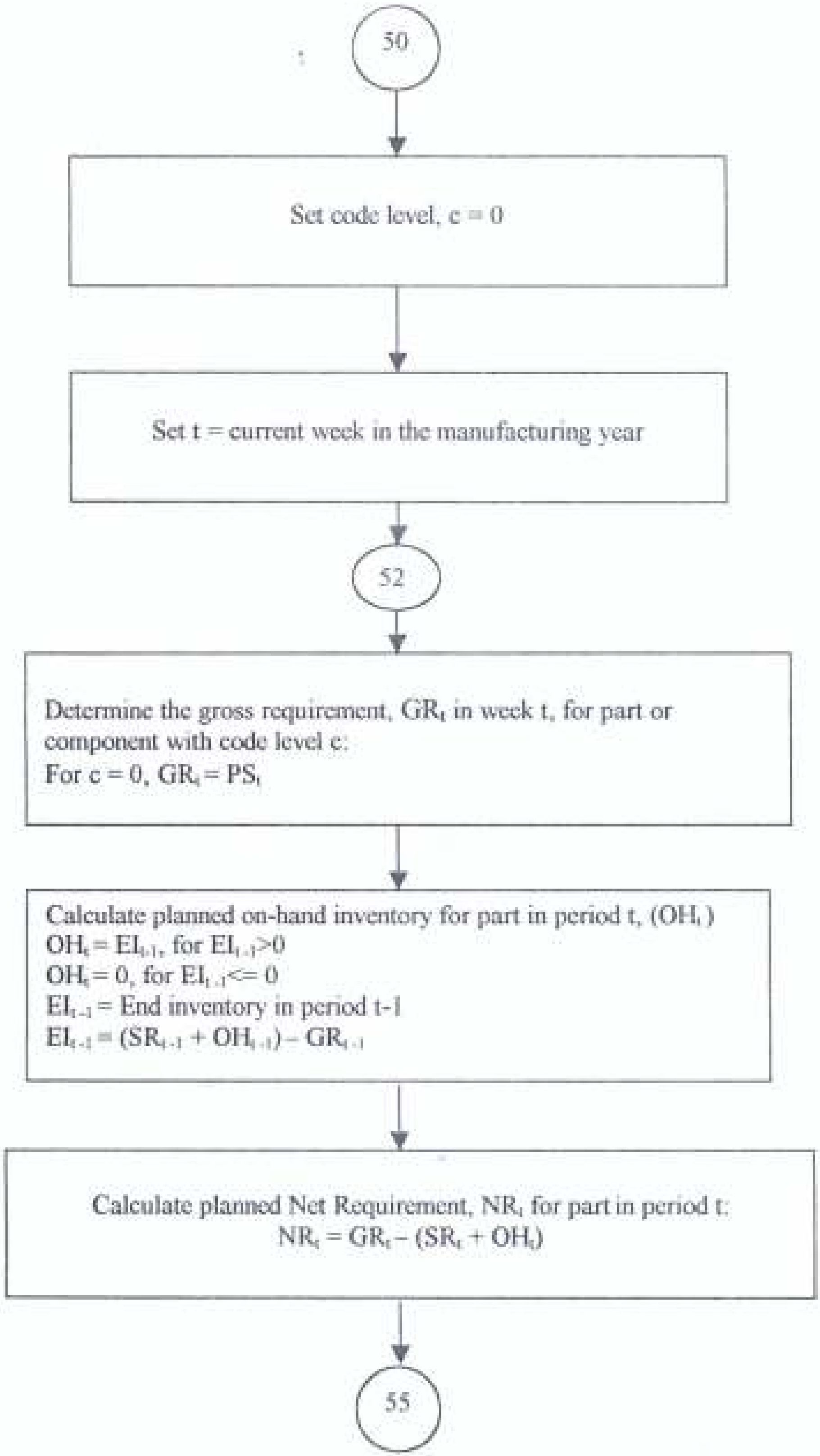


Figure 3.1e: Flowchart of Material Requirements Planning System (contd)

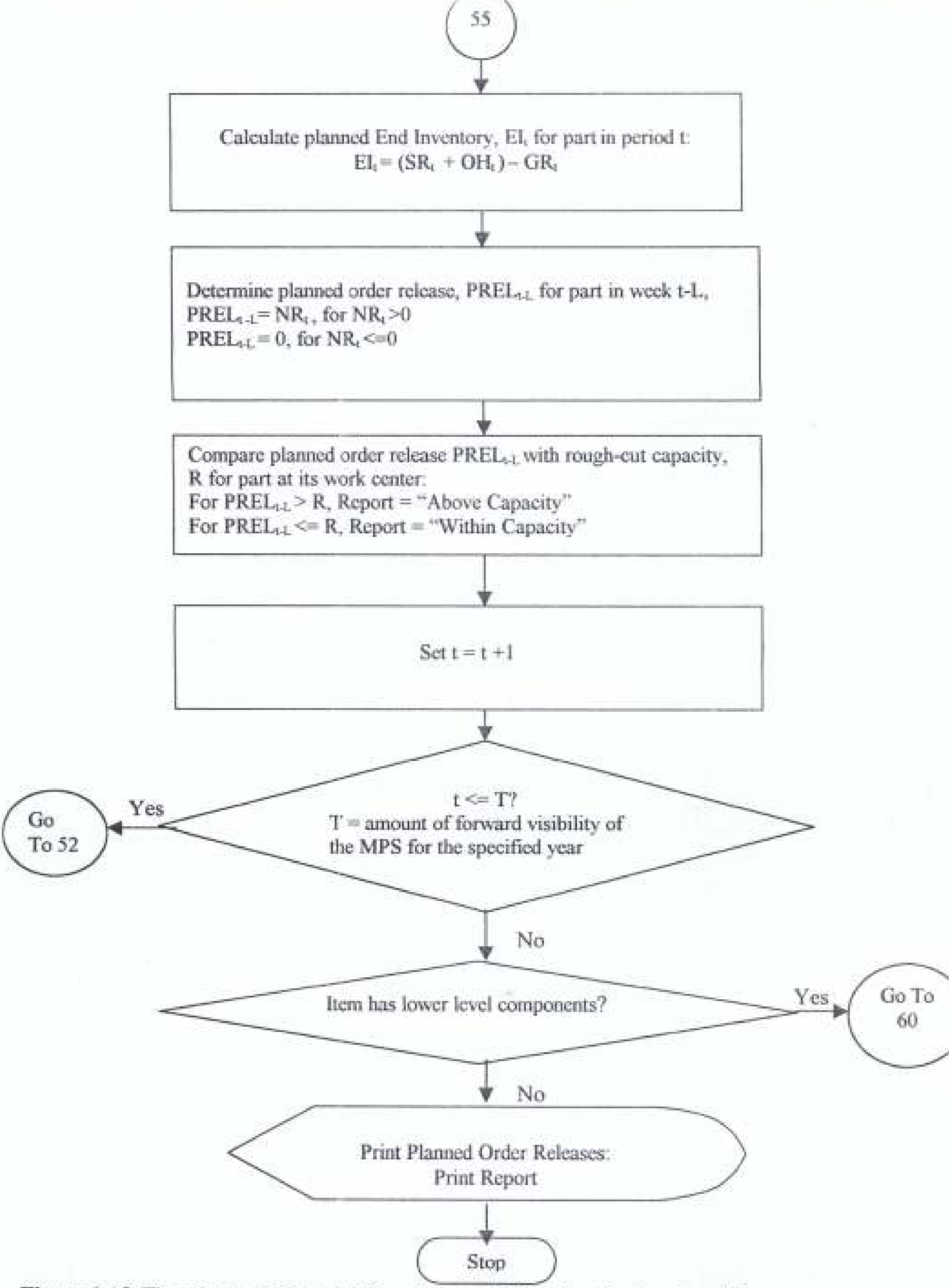


Figure 3.1f: Flowchart of Material Requirements Planning System (contd)

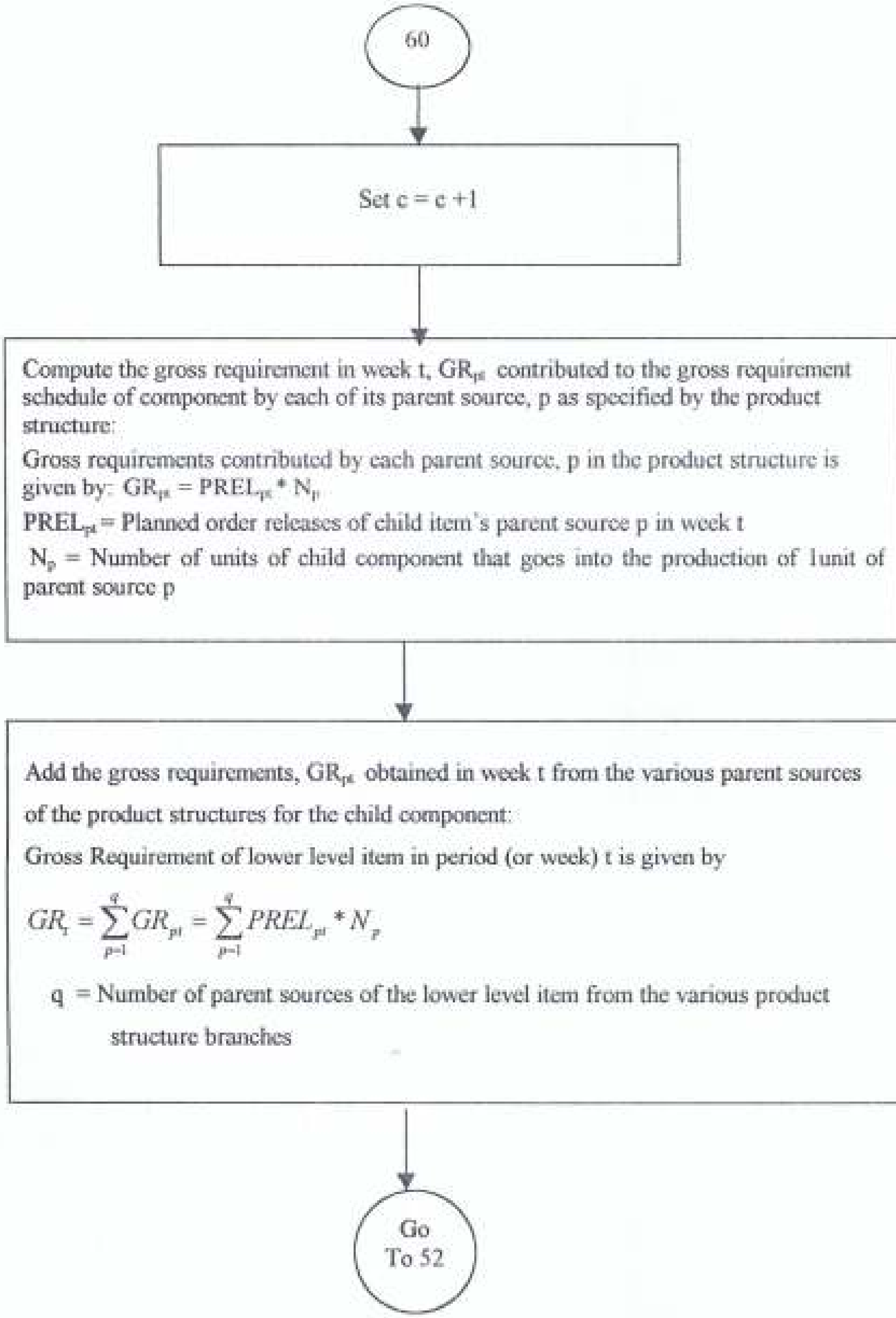


Figure 3.1g: Flowchart of Material Requirements Planning System (contd)

3.3 The Design of User Interface

The MRP system is designed to be a computerized information system, which includes a databank consisting of several master data files, and modules that are dependent on each other. The MRP software is developed in Visual Basic 6.0 programming language, which is a window-based program that can be run in a Microsoft window environment.

In the development of this computer software, the way the system will work is properly documented. This is achieved by preparing a set of specifications for the system. The input requirements, output requirements, file and storage requirements, processing, and controls are clearly specified. The user interface is then designed.

The Material Requirements Planning window is made to be a multiple document interface (MDI) form, which allows more than one window to be displayed on the screen simultaneously. The MRP window (figure 3.2) has four main menu items: File, Tool, Window, and Help. The commands used in the package are grouped under this menu options as submenus.

3.3.1 Input Interface

Input data are entered, updated and edited through the File menu. The file menu consists of six submenu options namely: Add, Inventory, Bill-of-Materials, Lead-Time, Job card, Scheduled Receipt, and Exit. The File menu consists of commands that help user manage the various files in the MRP package.

Data records are created through the File menu. Clicking the File menu on the menu bar displays the following pull-down menu: Add, Inventory, Bill-of-materials, Lead-time, Job card, and Scheduled Receipt. The pull-down menu (submenu) items are clicked to open various forms that are used to input data into the system database.

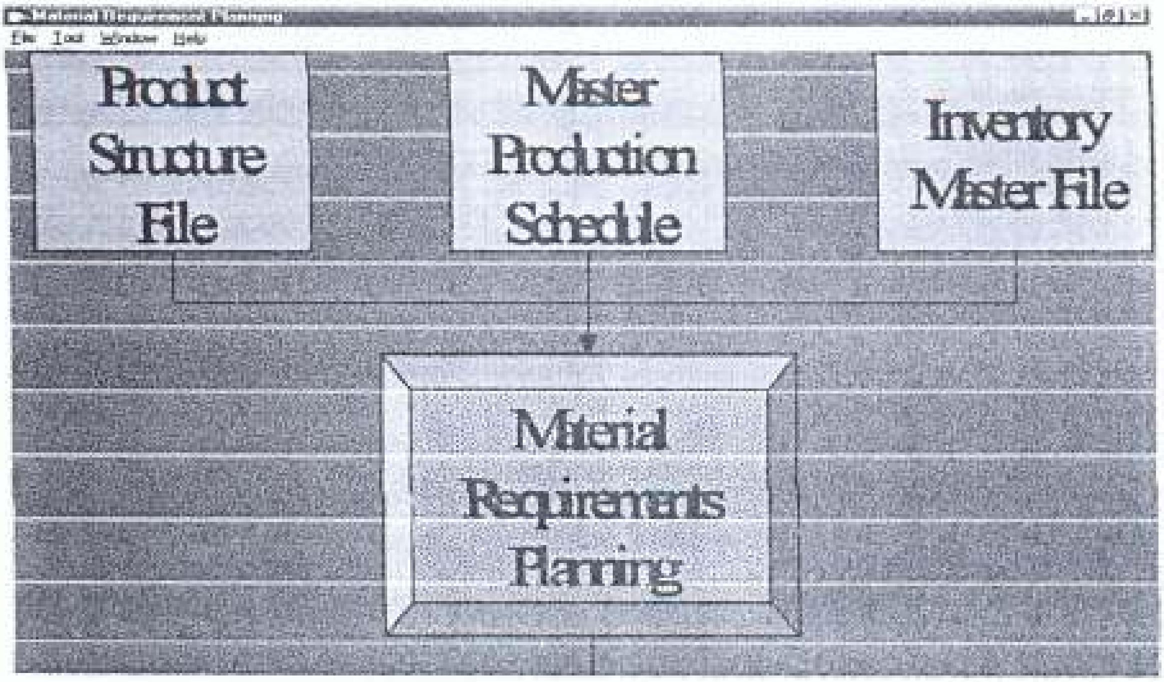


Figure 3.2:Preview of The Material Requirements Planning window

3.3.1.1 Add Submenu

The Add submenu is used for entering, editing and deleting data for products and components in the system database. Data entered in Add file are item's name, item's code, item's description and capacity per specified lead-time. The capacity is measured in terms of number of component that can be produced during the estimated lead-time (Groover, 1987). Data control bar is also available to check through component records in the database. Add forms are shown in Figure 3. 3

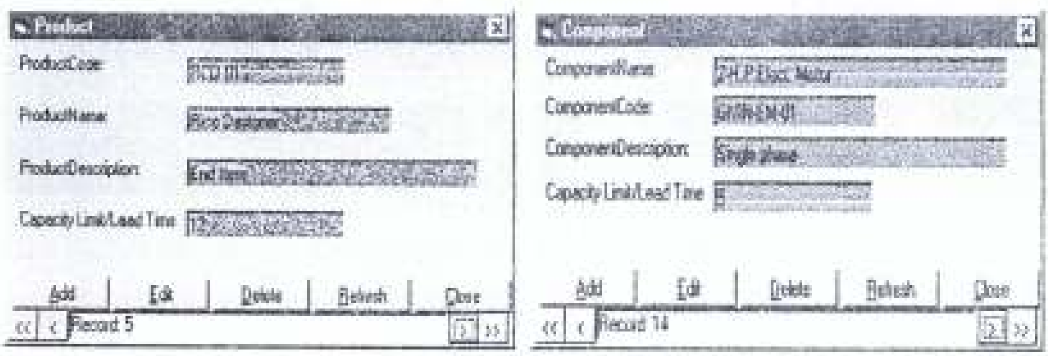


Figure 3.2: Preview of product and component record forms

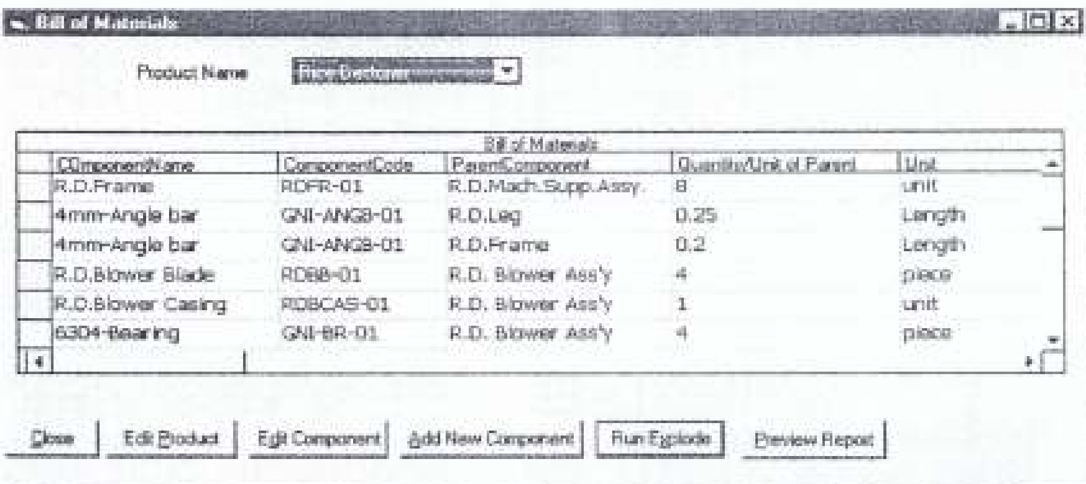
3.3.1.2 Bill of Materials (BOM) Submenu

The BOM submenu option opens the form for writing the BOM document and for making engineering changes to existing designs. The BOM form (Figure 3.4) is provided with a combo box that the user can use to scroll through the list of products in the database to open their BOM document, if they exist, to make necessary change to the BOM document or create a new document.

Edit buttons for parts (products, components and subassemblies) are provided to add or edit data of parts required in the writing of the BOM document. The product or component record forms are designed to display on the screen simultaneously along with the BOM document to enter data for the required part.

The BOM table is designed to be a table recordset, which can be used to update the database if user wants to change the BOM document. To write the BOM document, a BOM Entry form (Figure 3.5) is provided for creating the BOM table record set. The information entered through the Add-Component (or BOM Entry) form are component name, parent component, quantity of component that goes into the making of each unit of parent part, unit in which part is measured, whether part is to be purchased or produced, part's specified lead-time and code level. Two buttons are also provided to show the pick lists of specified orders and to display the BOM document for printing.

Changes can be made to a bill of material document by clicking the cells in any row or column to change the data in the cell. Also a component can be removed entirely from a product's BOM by deleting the row containing its data.



ComponentName	ComponentCode	ParentComponent	Quantity/Unit of Parent	Unit
R.D.Frame	RDFR-01	R.D.Mach.Supp.Assy.	8	unit
4mm-Angle bar	GNI-ANGB-01	R.D.Leg	0.25	Length
4mm-Angle bar	GNI-ANGB-01	R.D.Frame	0.2	Length
R.D.Blower Blade	RDBB-01	R.D. Blower Ass'y	4	piece
R.D.Blower Casing	RDBCAS-01	R.D. Blower Ass'y	1	unit
6304-Bearing	GNI-BR-01	R.D. Blower Ass'y	4	piece

Figure 3.4: Preview of bill of material table recordset

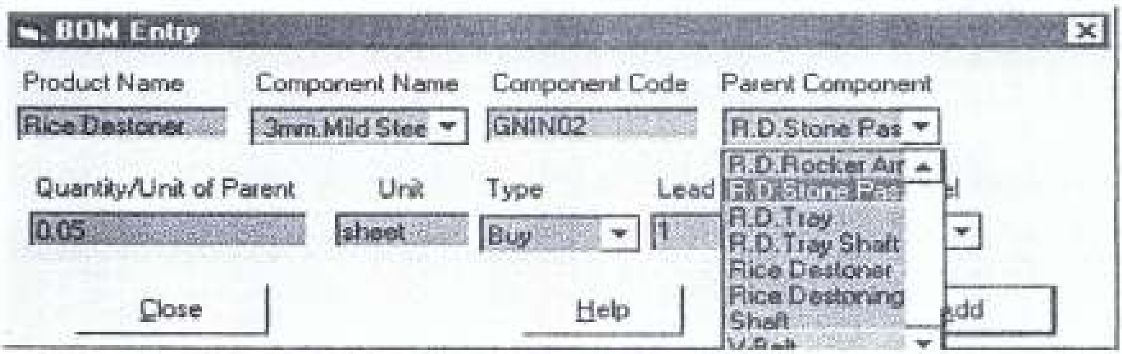


Figure 3.5: Preview of bill of material data entry form

3.3.1.3 Lead-Time Submenu

Lead-time submenu option allows user to access and make changes to the lead-time record for all the components of a product in the database through a lead-time table recordset. The lead-time table recordset is created through the BOM Entry form of the BOM submenu.

Provision is made for capacity changes through the lead-time table recordset. If capacity at a work center is overbooked, increasing lead-time is a way of increasing capacity at such work center (Plossl, 1986). Therefore, when the lead–time of a work center is changed, MRP system is designed to ask user, with the aid of a message box, if he intends to change the capacity of the work center. If the user wants to change the capacity at any work center, the Add component form will be displayed.

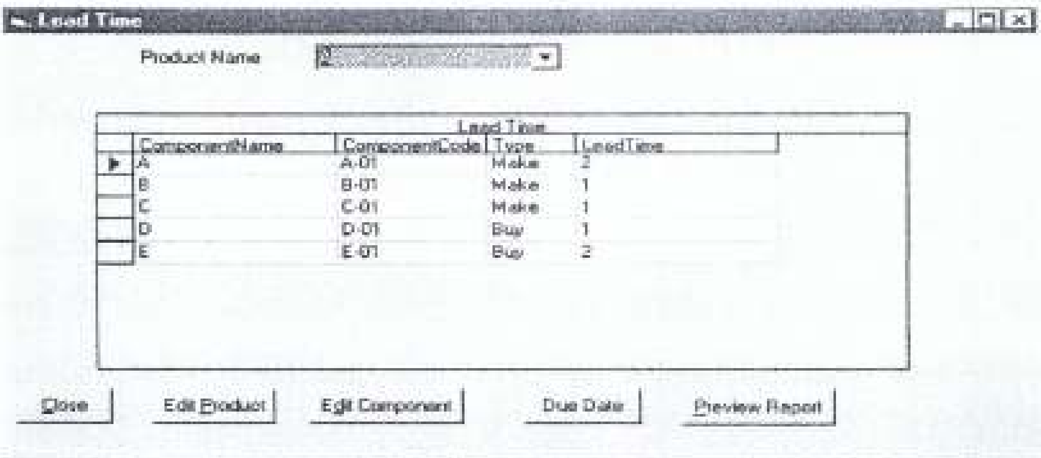


Figure 3.6: Preview of lead-time table recordset

3.3.1.4 Inventory Submenu

The inventory submenu option is designed for opening the inventory file to update the inventory status for all the items in the database whenever items are received or issued out (Figure 3.7). It helps to determine the inventory balance (on-hand) for the items in the database and to keep records of all inventory items.

There is provision for time and date to be entered during inventory transaction to enable the inventory subsystem to provide the most current inventory balance at the beginning of the planning period.

To prevent entering two different inventory transaction in one inventory record card, the textbox of the Quantity issued is made to be disabled when stock are being received and vice versa when stock are being given out (issued).

The inventory form (or bin card) is provided with Add button for opening another card. And the form is designed with a combo box for entering the component name. The combo box contains the list of all components and subassemblies contained in the firm's MRP software database. Although the user can scroll through the list, but he will not be able to select any unless the Add button is pressed to open a new inventory transaction. This is done to prevent the error of swapping the record of one transaction card for another in the course of opening another transaction record.

Buttons for editing and canceling information in an inventory card are also provided. Data control bar is also used to check through inventory records in the database.

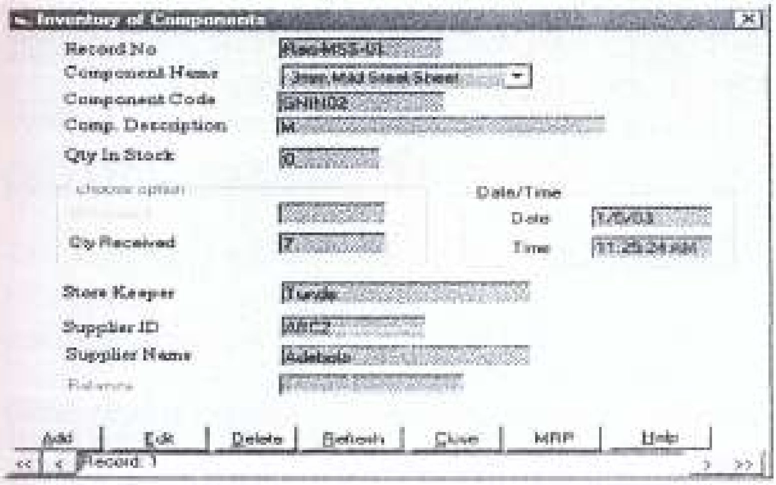


Figure 3.7: Preview of Inventory form

3.3.1.5 Scheduled Receipt Submenu

This submenu option is provided to enter records into the open order file or make changes to open orders. Open orders are orders that have already been given out to suppliers and are scheduled to be received in a stipulated week. Data to be entered for each part include quantity ordered and the expected year.

Data control bar is provided to check through scheduled receipt records in the database.

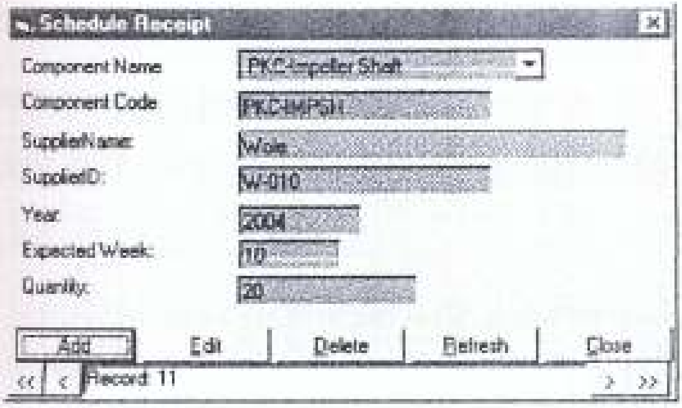


Figure 3.8: Preview of Scheduled Receipt form

3.3.1.6 Job Card Submenu

The job card submenu option is designed primarily to carry to create records for customers' orders. To open a job card, it is important to check if the product is new or old. Therefore, a combo box containing the list of all the products existing in the system database is provided. This enables the user to scroll though to see if the job is new or old before accepting the order.

Order records for each product can be accessed with the aid of the data control bar. Also a delete button is provided for cancellation of orders while Edit button provided on the jobcard form is for changing order records and for order rescheduling.

The jobcard is designed such that user (production planner) can look at the shop's master production schedule or time-table or shop calendar before scheduling a new job and also after scheduling the job. A button captioned 'Preview List' is provided which displays the master production schedule when it is clicked. This will enable the user to assess the situation on ground to avoid violation of capacity limit or over congestion of production timetable.

There is a provision for user to enter the desired commencement date and the due date is fixed based on the commencement date entered. The system is designed to calculate, display and automatically enter the expected due date. If data, such as BOM and lead-time data, required for calculating due date for a product are not present or inadequate in the system database, by design, the system indicates this by informing the user with a message box that the product structure of the product does not exist.

MRP processing starts with end product due dates and uses planned lead-times to compute the component release dates. Since the end item's due date is fixed automatically based on the commencement date entered and the cumulative manufacturing lead-time computed by the system, therefore, the due date text box is disabled such that due date fixed by system cannot be changed by the user. The preview of the job card is shown in figure 3.9

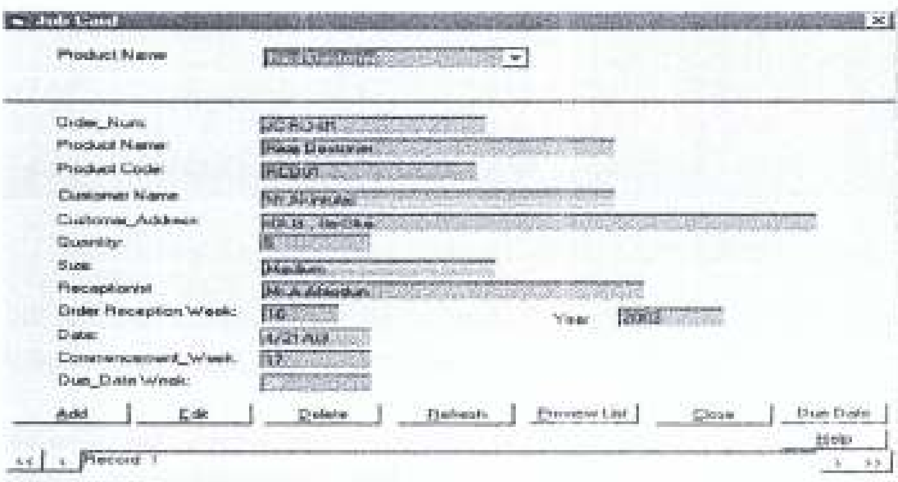


Figure 3.9: Preview of Production Order form

3.3.2 Creation of Database

The system is designed to interact with a database created using Microsoft Access relational database. The organisation of the data is accomplished with the Microsoft database management system.

The tables needed, the names of the fields in each table of the database and the field types are determined. Then database structure is carefully planned to ensure compatibility with the data to be inputted

Data controls are placed on each input files to display data. Furthermore, controls, such as textboxes, used to input and display data on the input forms are bound to their corresponding fields on the tables created for them in the database.

Binding data to their fields involves the setting of the database name property and the Recordsource property of the data control. Then the controls are bound to the appropriate data control by setting the Recordset property to the particular field to be referenced and Recordsource property to the data control from which it will take data.

3.3.3 Report Generation

Report generation of the system is done through use of the Tool menu and most of the output data are designed and reported with Crystal Report.

The Tool menus are used to manage the MRP package. They convert input data into output reports. Selecting the appropriate submenu option under the Tool menu carries out special processing operations. The Tool menu consists of the following submenus:

(i) Material Requirements

(ii) Product Structure

(iii) Pick List

(iv) Time Frame

(v) Master Production Schedule

(vi) Weekly Order Releases

(vii) Gross Requirements

(viii) Manufacturing Calendar

3.3.3.1 Product Structure submenu

The product structure submenu option is used to display the product structure of a product in the form of an indented bill-of-materials (Figure 3.10)The product structure can be displayed on choosing a product from the list displayed by the combo on a query form.

Provision is made for hiding and displaying the children (subassemblies and components) by designing the product structure to be displayed with a + sign in front of an item to display its children (or components). This is like what obtains in the Microsoft Window explorer environment.

Clicking the item on the product structure displayed can also be used to assess the most current inventory balance of an inventory item.

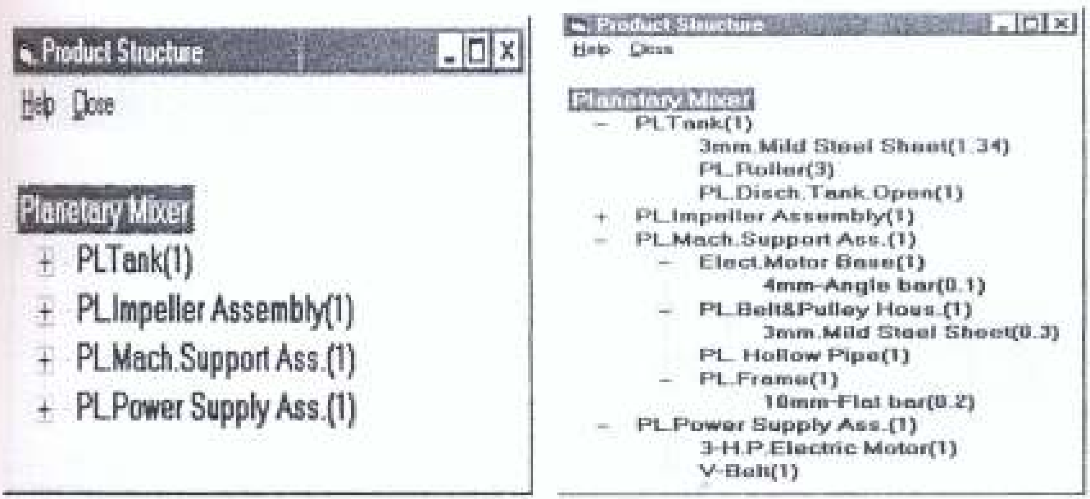


Figure 3.10:Preview of Product Structure for end items

3.3.3.2 Pick List Submenu

The pick list refers to the list of the total quantity of each component item required for the manufacturing a product in a specified job card (customer or production order). The pick list report could be useful for the estimation of the material cost and capacity requirements for an order. The pick list report is displayed by selecting the order number from the list of order numbers available in the database

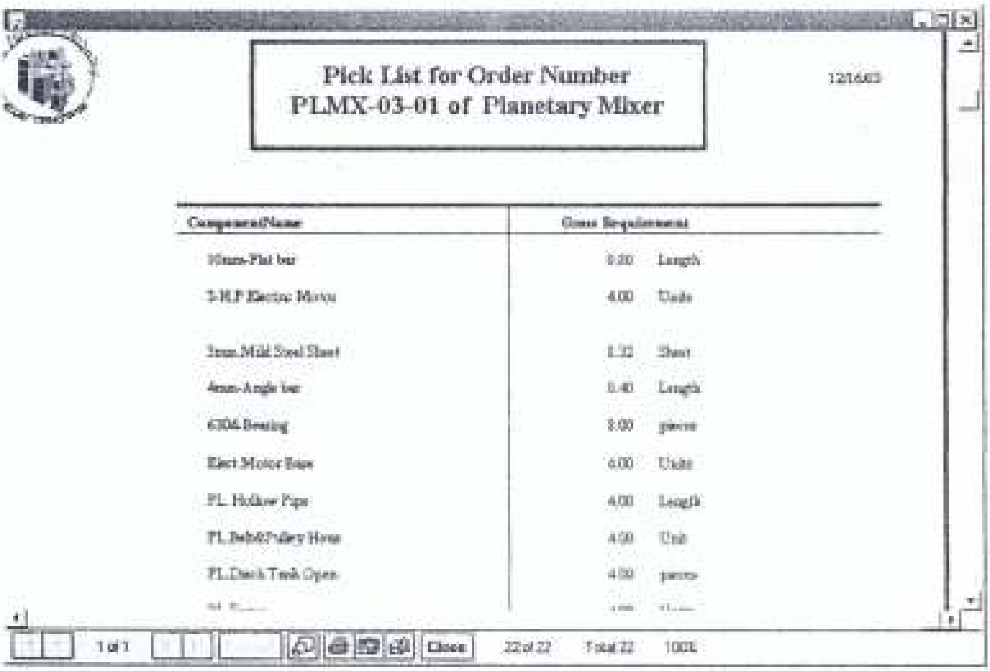


Figure 3.11: Preview of Pick list report

3.3.3.3 Master Production Schedule submenu

Master production schedule is used to display the master production schedule report within a specified manufacturing year. It displays the end items' production schedules on weekly basis.

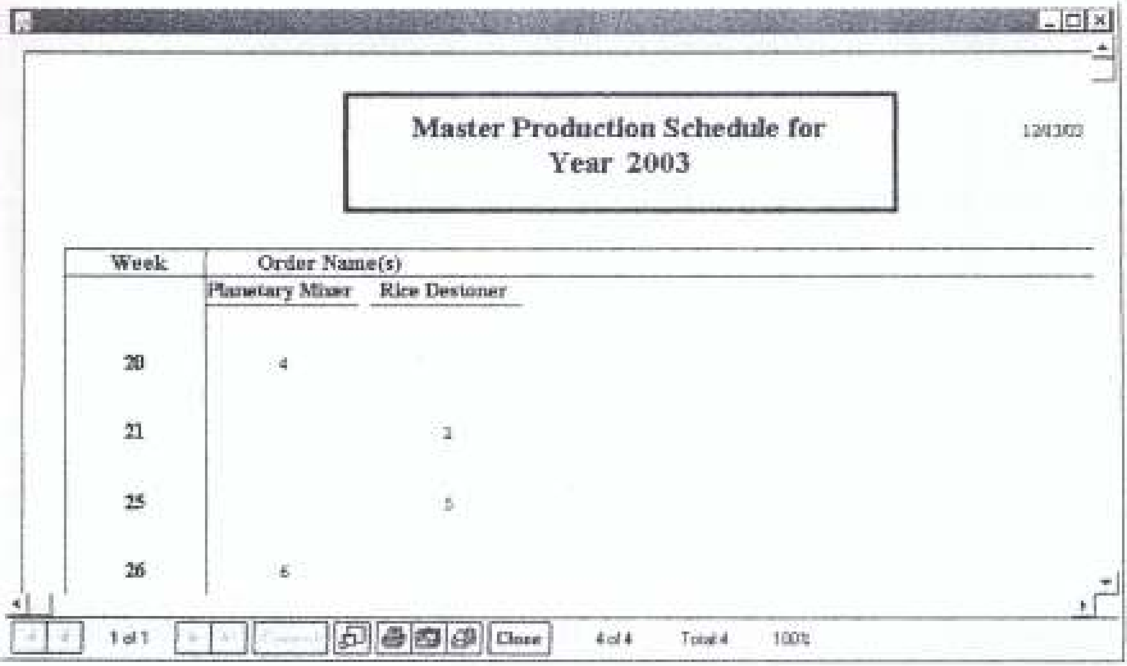


Figure 3.12: Preview of Master Production Schedule report

3.3.3.4 Gross Requirements Submenu

The production scheduling report gives information on the units of items required to be able to meet the production plan for products that are scheduled for completion in a specified week. It is time-phased gross requirements plan to meet the scheduled production plan for an end item. Gross requirements do not take into consideration the quantities of the parts that are in stock.

It reports assigned start dates and due dates to the various parts (and products) that are to meet the scheduled production plan for an order. The production schedule report is useful at the shop floor to determine the quantities of items required at each work center.

The expediter can also use the gross requirement report to compare the actual progress of a production order against the schedule so as to take the necessary corrective action to complete the order on time.

3.3.3.5 Weekly Order Release Submenu

Weekly Order Release Submenu displays the summary of the job shop material requirements plan in two ways.

Firstly, it tells the user all the orders that must be sent to suppliers or the production that must commence at various work centers in a specified week to meet the firm's master production schedule

The first report (Figure 3.13), captioned "weekly order releases" gives the user the following information:

a) The specified week
b) Name of component to be placed on order
c) Quantity to be ordered
d) Names of its order sources: product source and order number
e) Type of order –purchase or manufacture
f) Order Number
g) Capacity report

Secondly, it allows user to view, into the future, all the order releases for each item required to meet the firm's scheduled production of end items. The second report (Figure 3.14), captioned MRP, provides information on the orders to be released over a period of ten weeks. This will enable the material planner to use his common sense to optimize the production or purchase lot sizes to be released during the planning periods.

3.3.3.6 Manufacturing Calendar Submenu

The Shop Calendar subsystem is provided to help user to determine the date of each week within a manufacturing year. The manufacturing calendar is designed to enable user to specify the date the jobshop commenced work in a manufacturing year. Then, user can now enter the week for the calendar to calculate the dates when the week starts and ends. The manufacturing calendar is shown in figure 3.15.

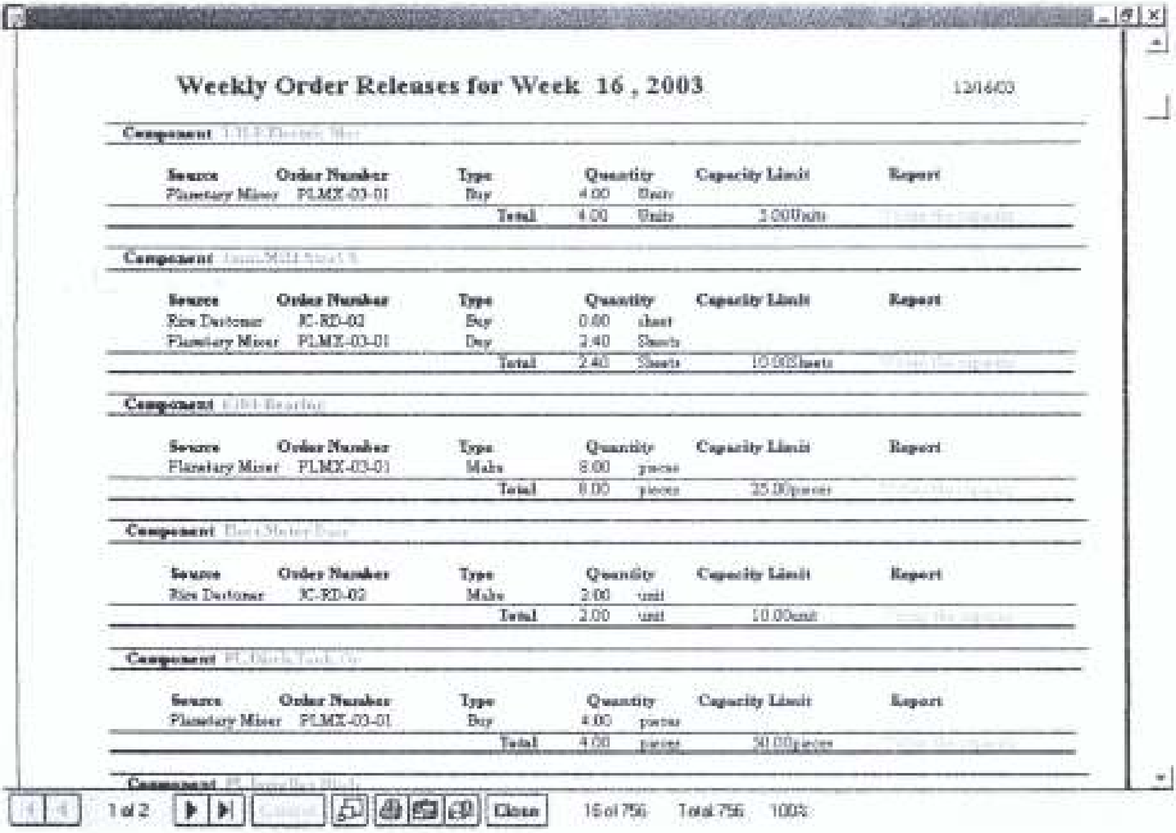


Figure 3.13: Preview of the Planned Order Releases in a specified week

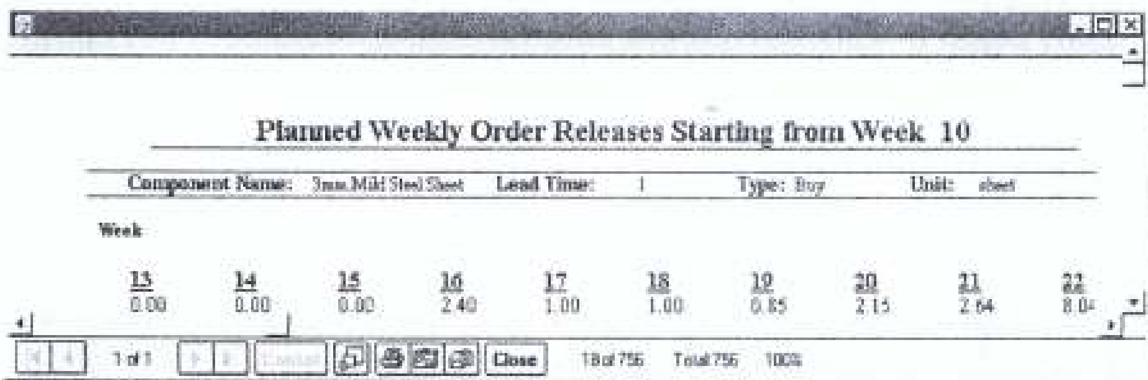


Figure 3.14: Preview of the Planned Order Release report over a specified period

3.3.4 Help Menu

Every good package must come with help system in order to make life easier for the user. The preview of the Help System is shown in figure 3.16

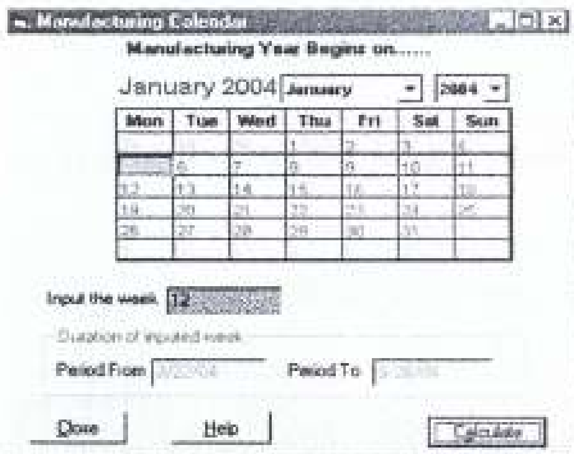


Figure 3.15: Preview of the Manufacturing Calendar

A Help system is designed to assist the user on how to use the MRP package. The Help system explains how to use the MRP package step by step. The Help window is designed to appear simultaneously while using any of the MRP File submenu so that user can be reading the information on the Help system while entering data.

The Help system, shown in figure 3.15 has these sub menu options: Table of Content, Index, Search, and Help About. The Table of content or Search submenu gives the summary of information contained in the Help system. Clicking any of the topics displays the subtopics discussed under the topic. The index submenu is useful for getting information on any term associated with the MRP package while the Help About gives the copyright information on the package and the year it was developed.

3.4 Hardware and Software Requirements

3.4.1 Hardware Requirements

The system requires a PC with the minimum configuration of:

a) One 3.5-inches floppy disk drive.

b) Minimum of 233MHz clock speed processor

c) 8 megabytes (MB) of RAM

d) A hard disk with at least 130 MB capacity

e) A compatible monochrome or coloured monitor

f) A compatible printer

g) Formatted floppy disks for storing back up copies of database file

h) A compatible keyboard

i) A mouse

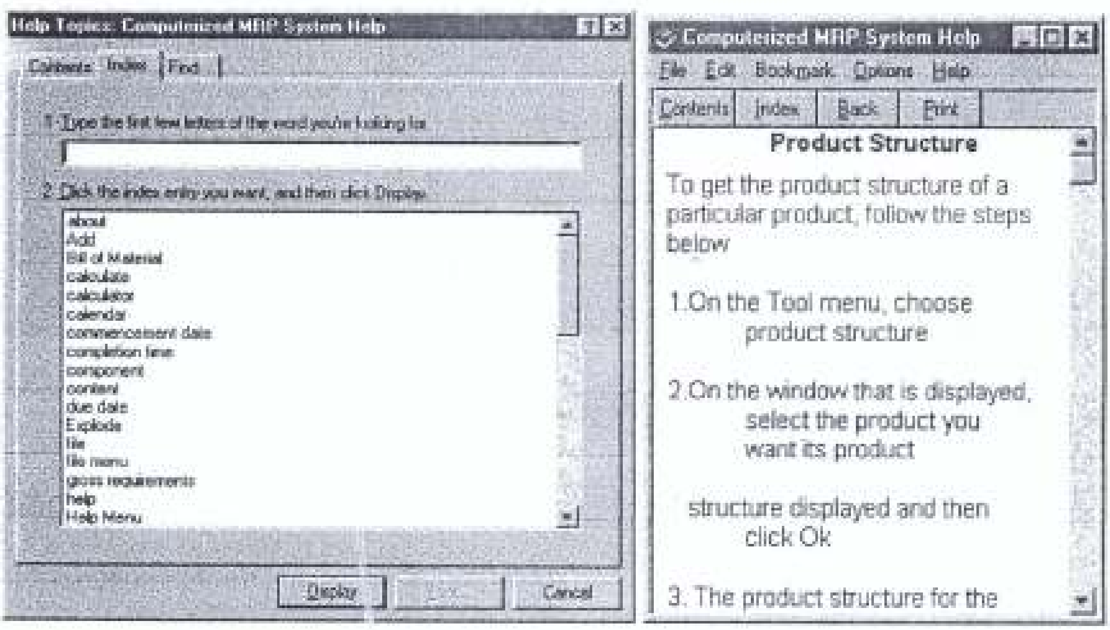


Figure 3.16: Preview of the Computerised MRP Help system

3.4.2 Software Requirement

The package is window-based. As such, Window '98, Window 2000 or Window NT or higher versions of windows operating system is required.

3.4.3 System Installation

There is need to ensure enough space on user's computer system before installation as the package occupies over 5.04 MB of memory. To install the system, place the first compact disk into the compact disk drive and select Run from the Start menu. Then type e:\ setup.exe and press enter. Then follow the installation instructions as the installation progresses.

CHAPTER FOUR

4.0 TESTING OF THE MRP SOFTWARE

Three things are important in determining the computational accuracy of the MRP software. Firstly, it must be verified that the software correctly carries the level-by-level computation of the material requirements and how planned order releases at one level affects the requirements at successive lower levels.

Secondly, it must be confirmed that the time phased planned order releases are determined based on the record lead-time.

Finally, for any component part that is common to several products and several parents in the same product structure, it must be verified that the MRP processor has correctly aggregated the gross requirements obtained from the various parents into a single net requirement from which its planned order releases are derived.

The output of the software was validated by:

(i) Using alphabets to represent parts, which made it possible to verify if the Computerised Material Requirements Planning System computation has taken into consideration all the factors complicating the MRP computational processes.

(ii) Using real life data by manually calculating the material requirements plan for 3mm mild steel sheet in a job shop over a period of time based on scheduled production of Planetary Paint Mixer and Rice Destoning Machine as examples of assembled products.

Validation procedure used in this project is as follows:

(i) The MRP computation is order driven. The MPS quantities are set to the end-item demand

(ii) Scheduling freezing is not performed in the MPS

(iii) There is no safety stock for any item.

(iv) Lead-time is based on planner's discretion

(v) Customer orders, Beginning inventories, Scheduled receipts are set to test MRP computation

(vi) Machines with well-documented Bills-of-Materials are selected as real life end products to be assembled.

4.1 MRP Computation by Using Alphabets to Represent Parts

Two assembly products are represented with alphabets A and H.

The Product Structures for 'A' and 'H' are shown Figure 4.1 and 4.2. The number in parentheses indicates how many units of that particular item are needed to make the item immediately above it. The computer display of the product structures of products 'A' and 'H' based on the bill-of-material file entry is shown in figure 4.3.

The lead-time records for the components of products 'A' and 'H' are shown in Table 4.1 and the printouts are displayed in figures 4.4 and 4.5 respectively.

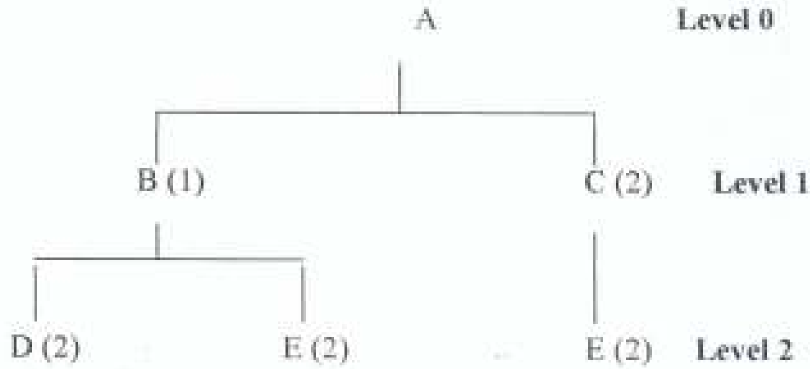


Figure 4.1: Product Structure of product 'A'

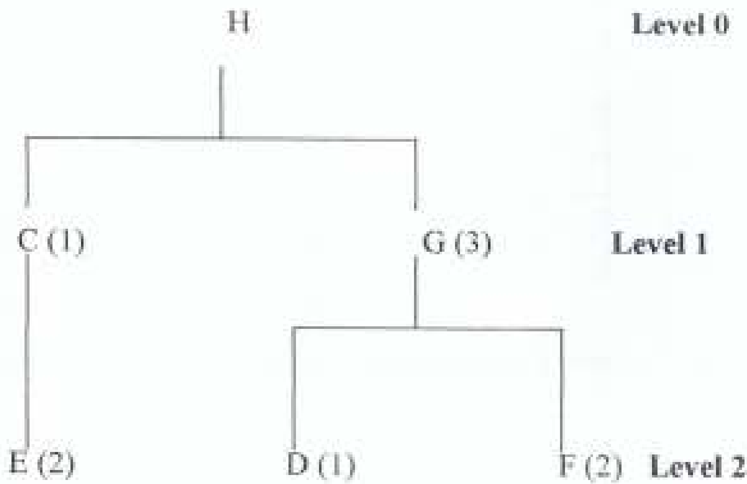


Figure 4.2: Product Structure of product 'H'

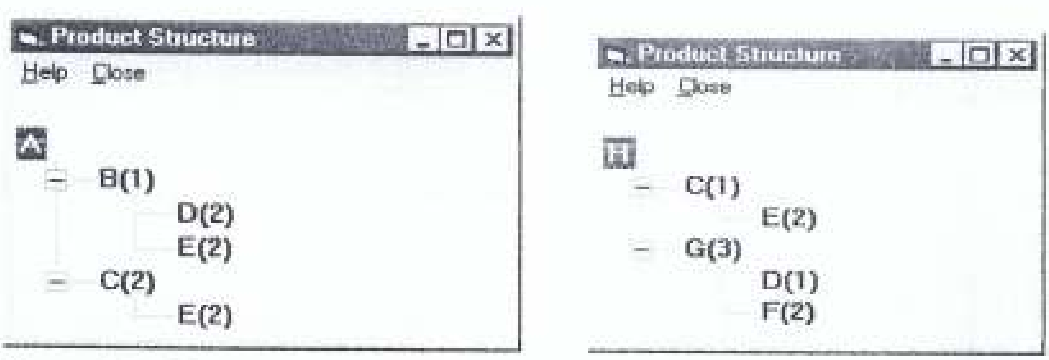


Figure 4.3: Computer display of the Product structures of products 'A' and 'H'

Table 4.1: Lead-time, Inventory balances and Work Center Capacity for parts of products 'A' and 'H'

Component	Lead-time	On-Hand	Work Center Capacity
A	2 weeks	2 units	6 units
B	1 week	0	5 units
C	1 week	10 units	9 units
D	1 week	12 units	16 units
E	2 weeks	15 units	25 units
F	1 week	15 units	30 units
G	1 week	7 units	20 units
H	3 weeks	7 units	10 units

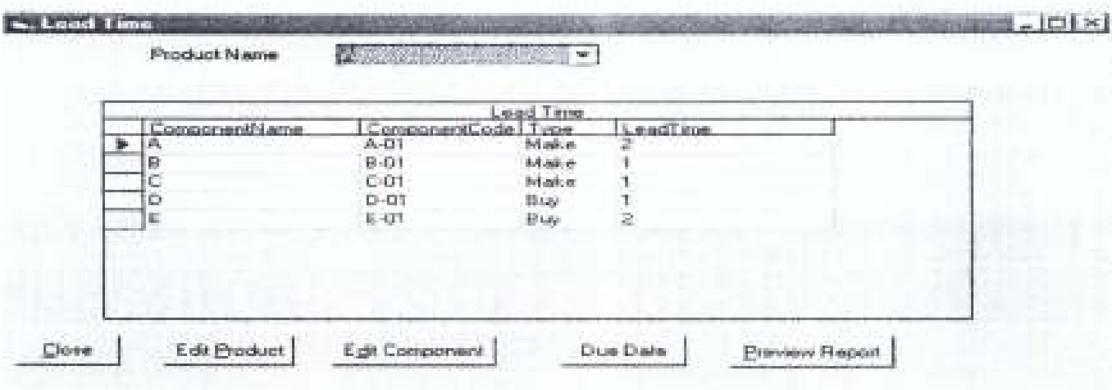


Figure 4.4: Lead-time of components of product 'A'

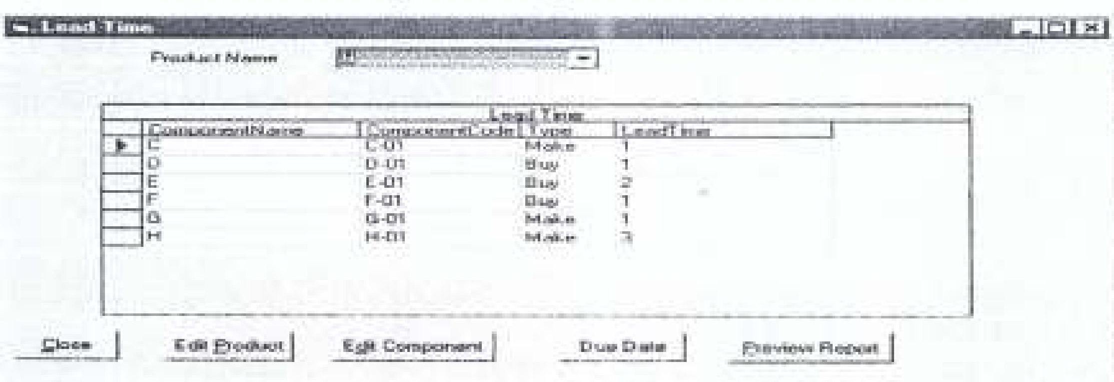


Figure 4.5: Lead-time of components of product 'H'

The Master Production Schedules for products 'A' and 'H' are as shown Table 4.2

Table 4.2: Mater production Schedule for products 'A' and 'H'

Week	Product	
	A	H
11		5
13	3	7
15	5	10
16		6
17	4	
18	5	2

The order entries for the products 'A' and 'H' are shown in the jobcards in figures 4.6a to 4.6j.

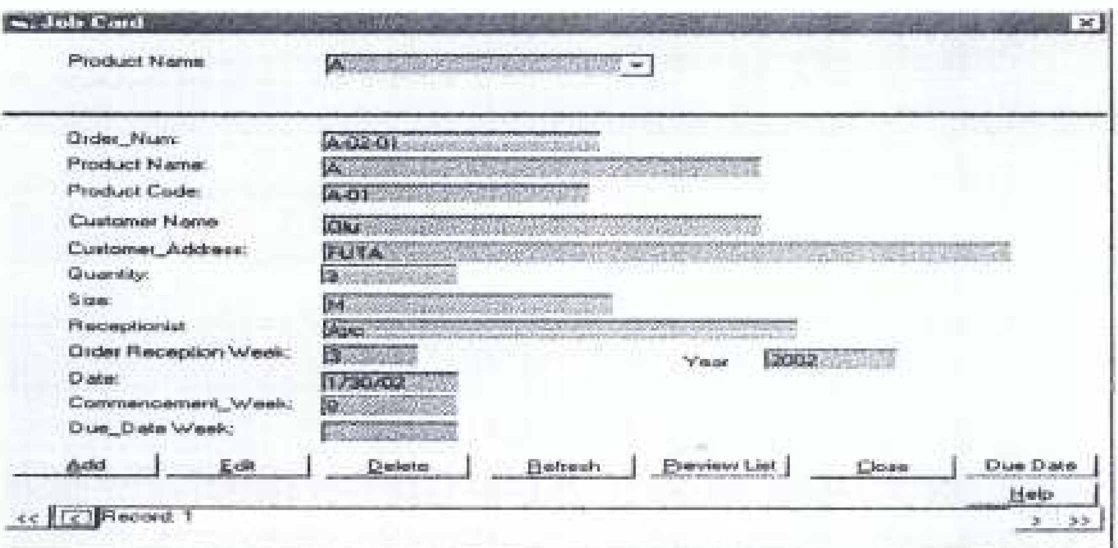


Figure 4.6a: Order for 3 units of 'A' scheduled for completion in week 13

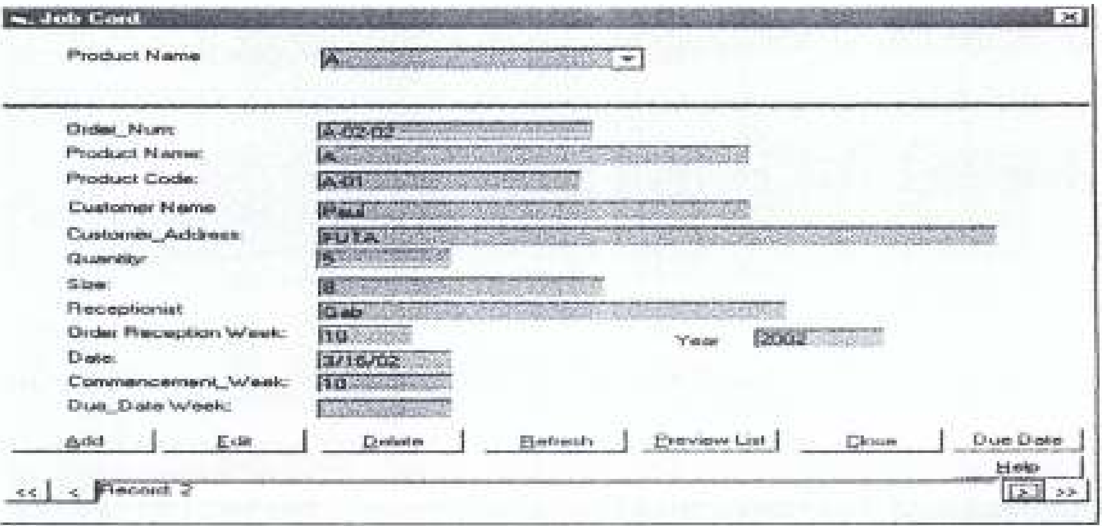


Figure 4.6b: Order for 5 units of 'A' scheduled for completion in week 15

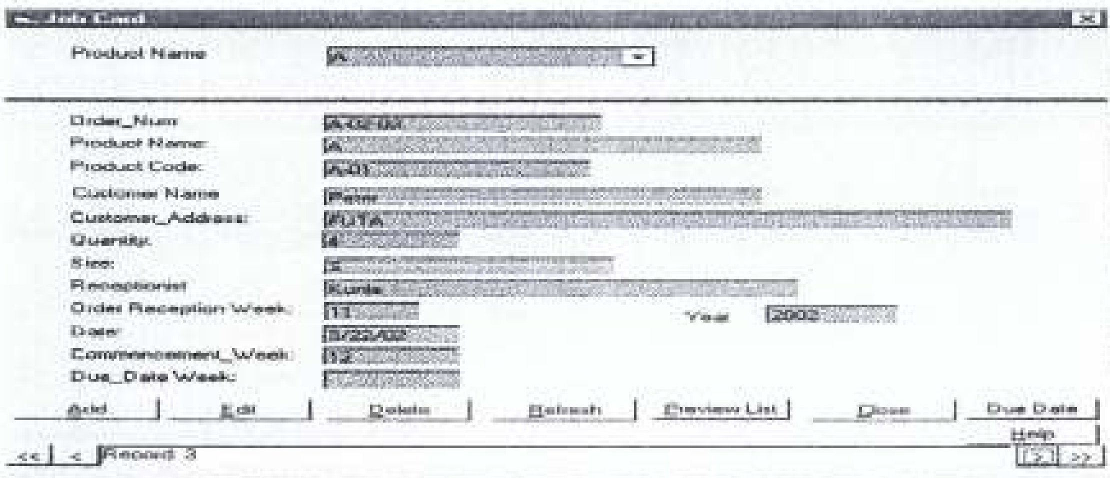


Figure 4.6c: Order for 4 units of 'A' scheduled for completion in week 17

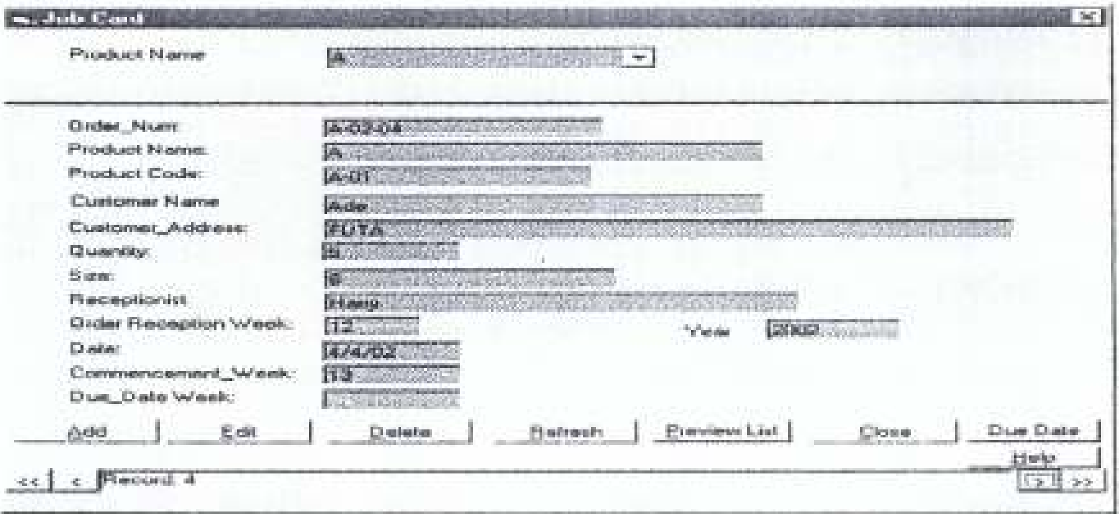


Figure 4.6d: Order for 5 units of 'A' scheduled for completion in week 18

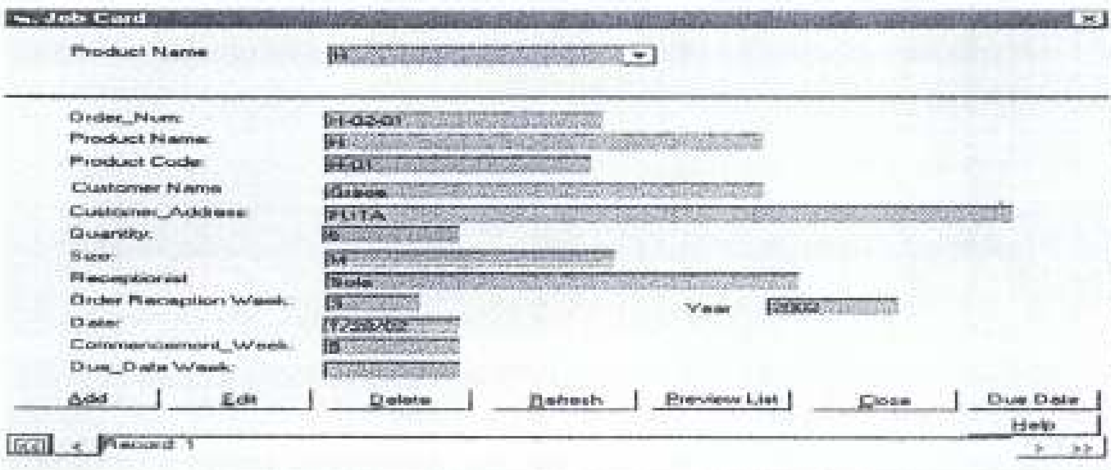


Figure 4.6e: Order for 5 units of 'H' scheduled for completion in week 11

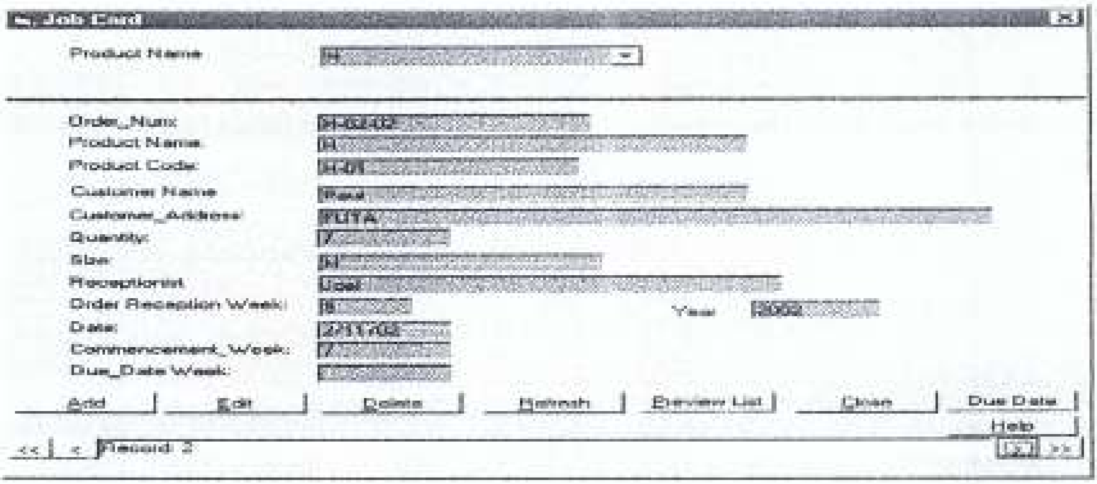


Figure 4.6f: Order for 7 units of 'H' scheduled for completion in week 13

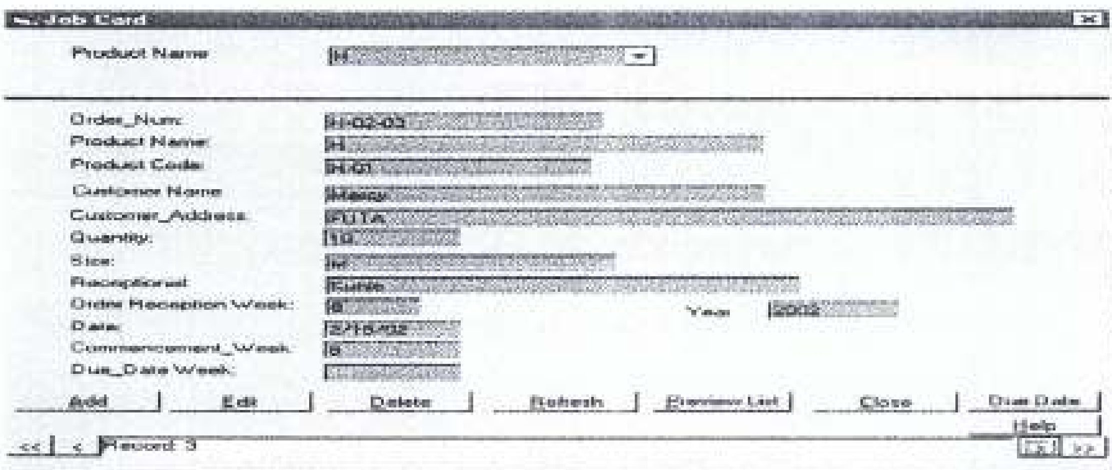


Figure 4.6g: Order for 10 units of 'H' scheduled for completion in week 16

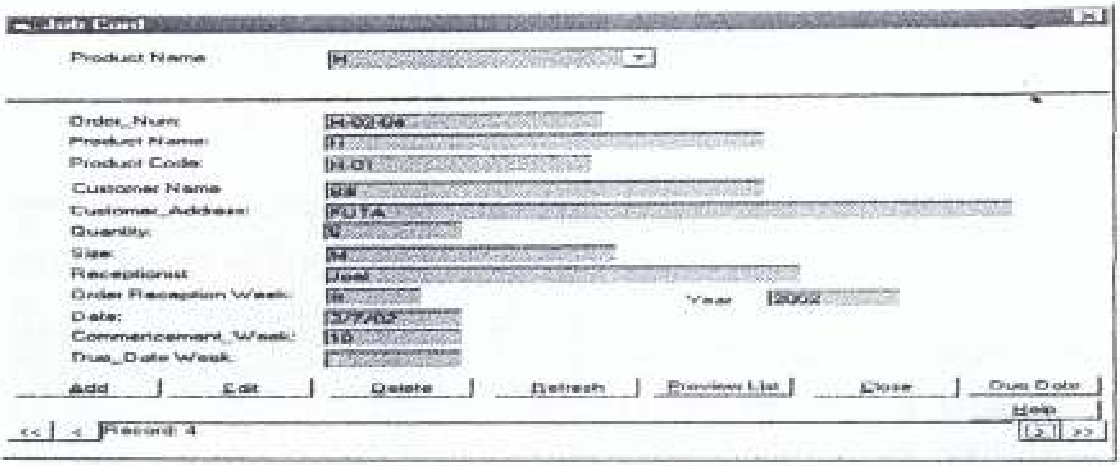


Figure 4.6h: Order for 6 units of 'H' scheduled for completion in week 16

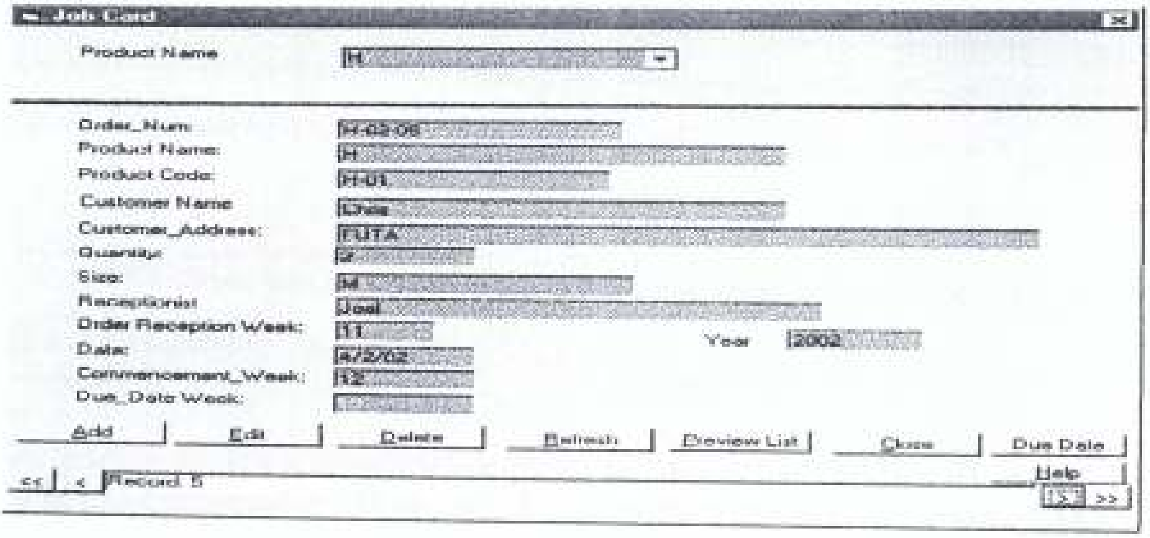


Figure 4.6i: Order for 2 units of 'H' scheduled for completion in week 18

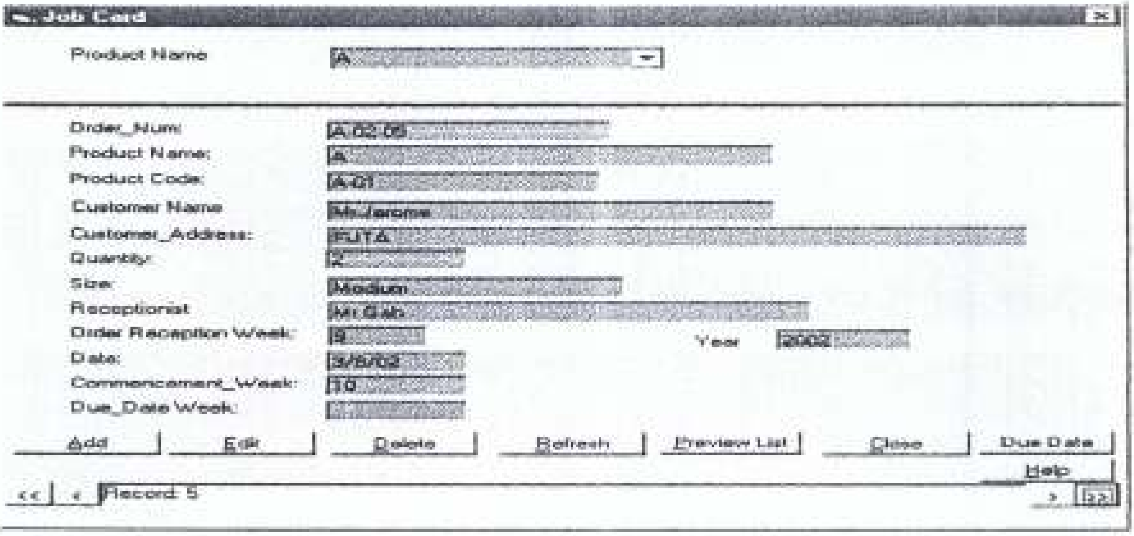
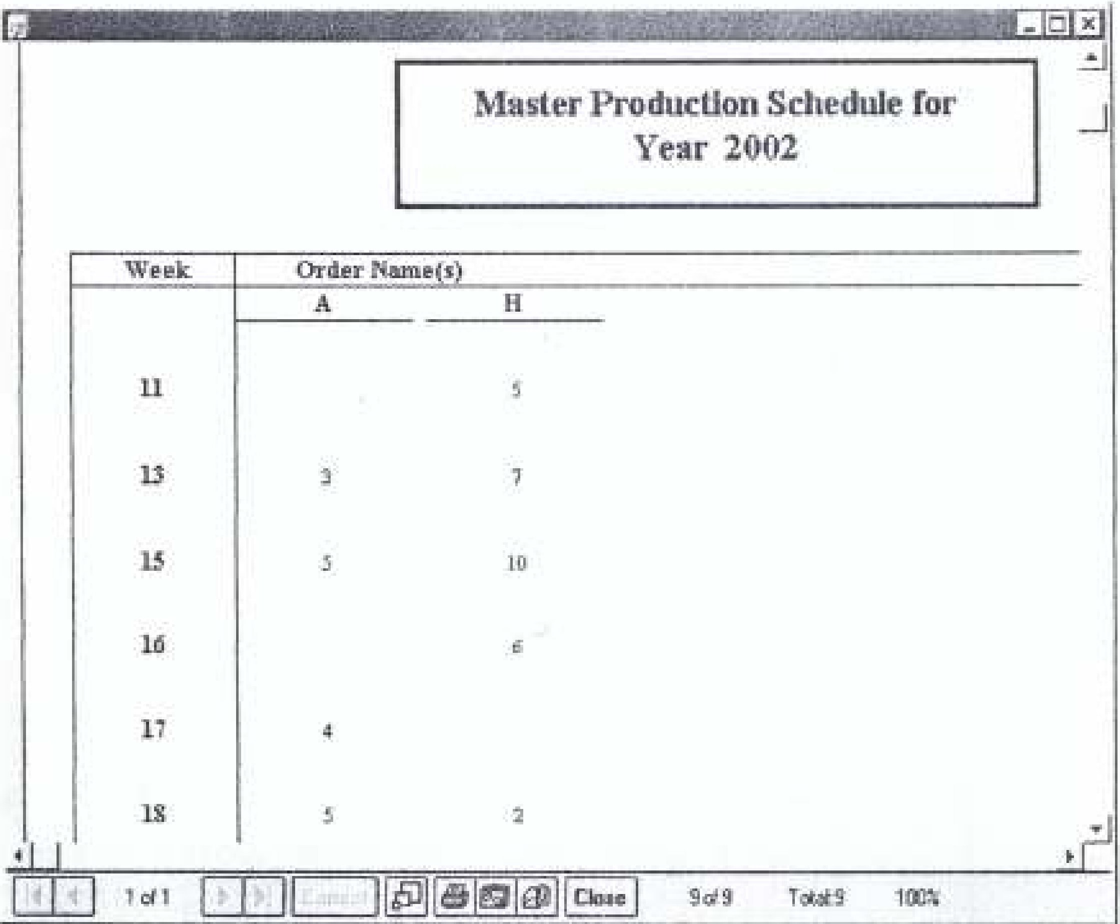


Figure 4.6j: Order for 2 units of 'A' scheduled for completion in week 15

Two different orders for product 'A' are scheduled to be completed in week 15. In figures 4.6b and 4.6j, there are orders for 3 units of 'A' and 2 units of 'A' respectively which are both scheduled to be completed in week 15. Therefore, the quantity of 'A' due for completion in week 15 is 5 units, which is the sum of the two orders. This shows how end item schedules are aggregated. The printout of the master production schedule based on the order entries is shown in figure 4.7.



Master Production Schedule for Year 2002

Week	Order Name(s)	
	A	H
11		5
13	3	7
15	5	10
16		6
17	4	
18	5	2

Figure 4.7: Printout of Master Production Schedule of orders for product 'A' and 'H'

Table 4.3 shows the scheduled receipts of the components of 'A' and 'H' and figures 4.8a – 4.8j show the scheduled receipt records.

Table 4.3: Scheduled Receipts for parts of products 'A' and 'H'

Component	Scheduled Receipts	
	Week	Quantity
A	15	2 units
B	13	1 unit
C	13	2 units
D	11	7 units
	13	5 units
G	11	6 units
H	13	1 unit
	15	4 units

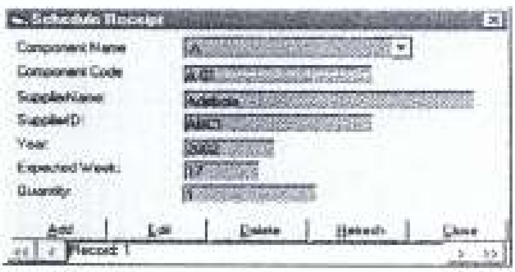


Figure 4.8a

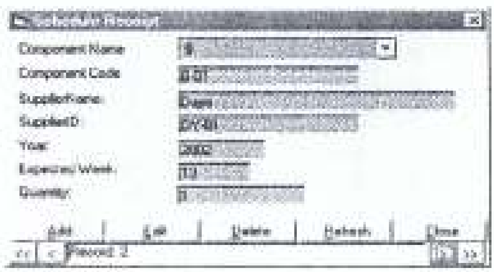


Figure 4.8 b

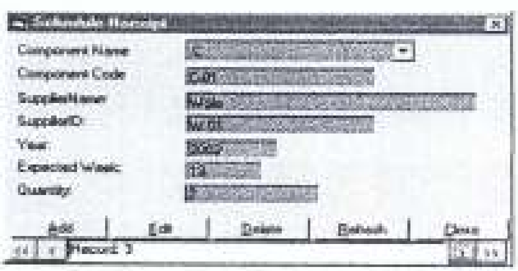


Figure 4.8c

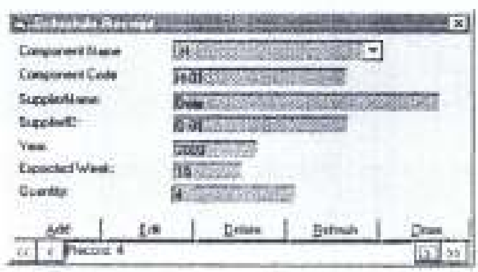


Figure 4.8d

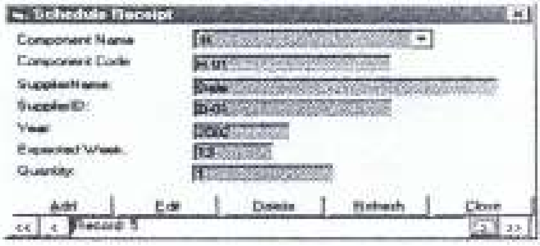


Figure 4.8e

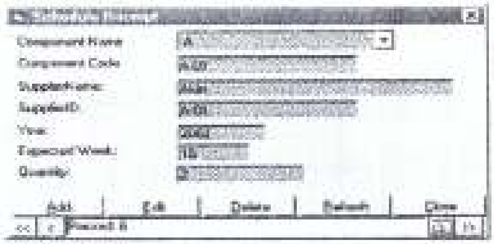


Figure 4.8f

Figure 4.8g

Figure 4.8h

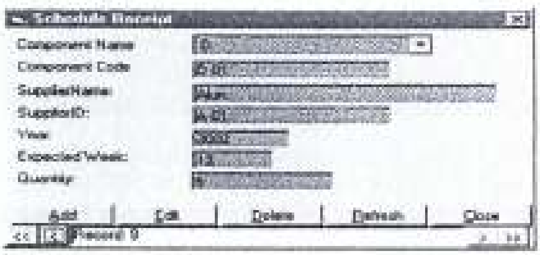


Figure 4.8i

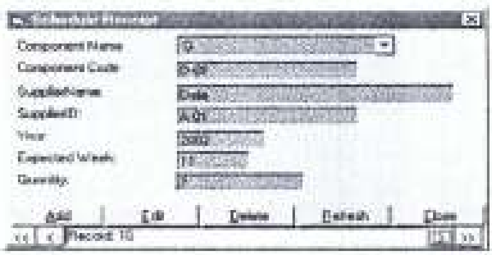


Figure 4.8j

The inventory input data are displayed in Figures 4.9 a to 4.9 k. Figures 4.9a and 4.9 b show the inventory transactions on component 'E'. 20 units of 'E' were received on 1st April 2002 at 11:59:59 AM. There was nothing in stock at the time of this transaction. Therefore the balance at the end of the transaction increased to 20 units. However, at 12:05:00 PM on the same day (1st April 2002), 5 units of 'E' were issued out thereby bringing the balance on-hand to 15 units.

Figures 4.9c and 4.9d show the inventory transactions on assembly 'A'. The inventory on hand at the beginning of the planning period for 'A' is 1unit. For assembly 'H', the inventory on hand is 7units from records shown in figures 4.9e and 4.9f. Inventory balance (on hand) for B is 0 as there is no inventory transaction on it and hence no record of inventory for it. For C, D, F and G, the inventories on hand are 10 units (figure 4.9g), 12 units (Figure 4.9h), 15units (Figures 4. 9i and 4.9j) and 6 units (figures 4.9k)

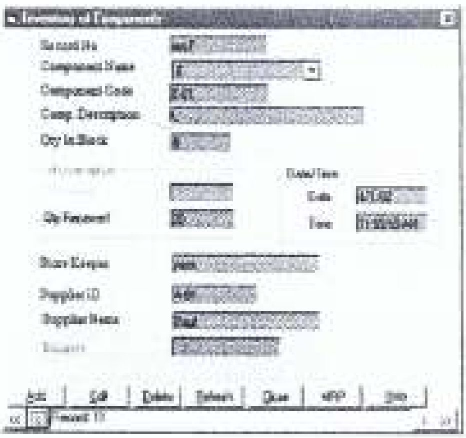


Figure 4.9a

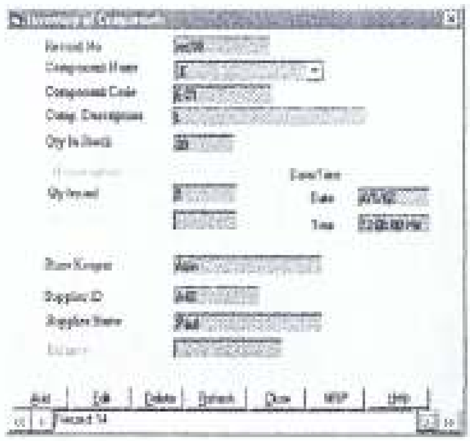


Figure 4.9b

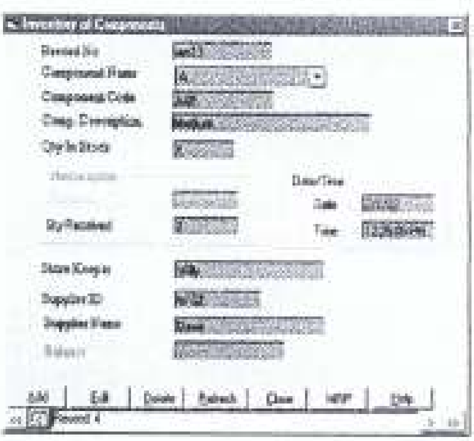


Figure 4.9c

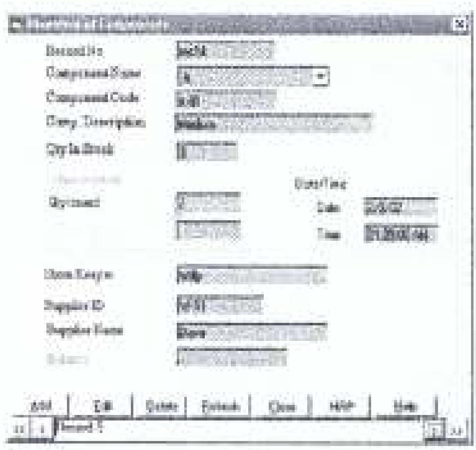


Figure 4.9d

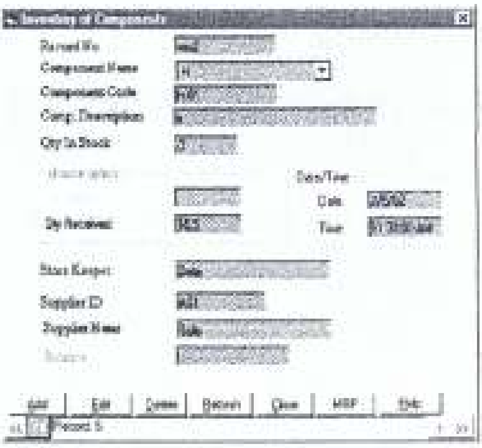


Figure 4.9e

Figure 4.9f

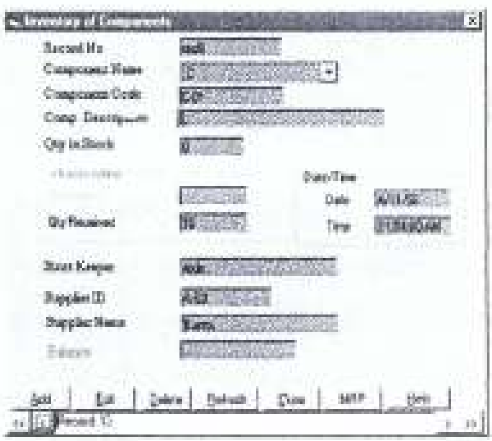


Figure 4.9g

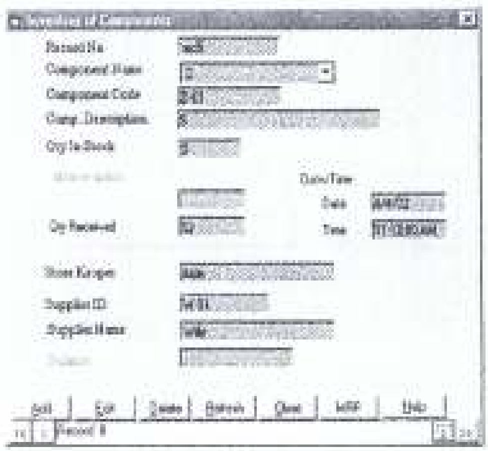


Figure 4.9h

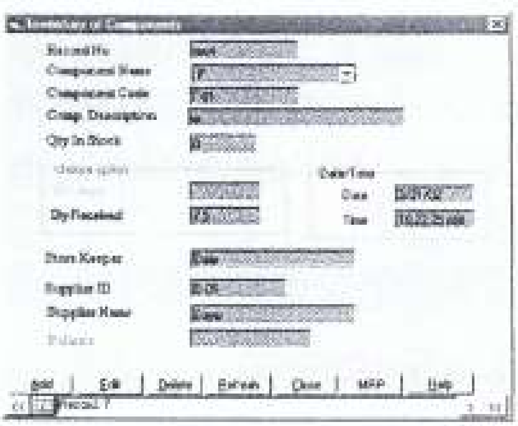


Figure 4.9i

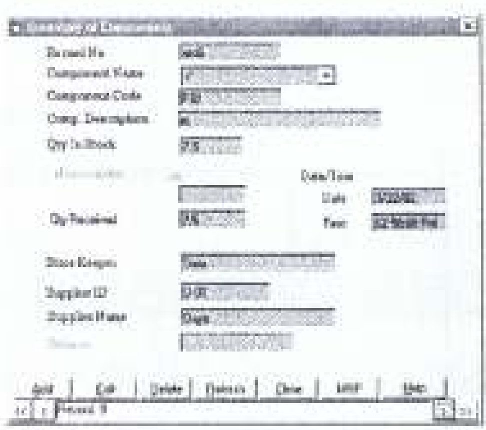


Figure 4.9j

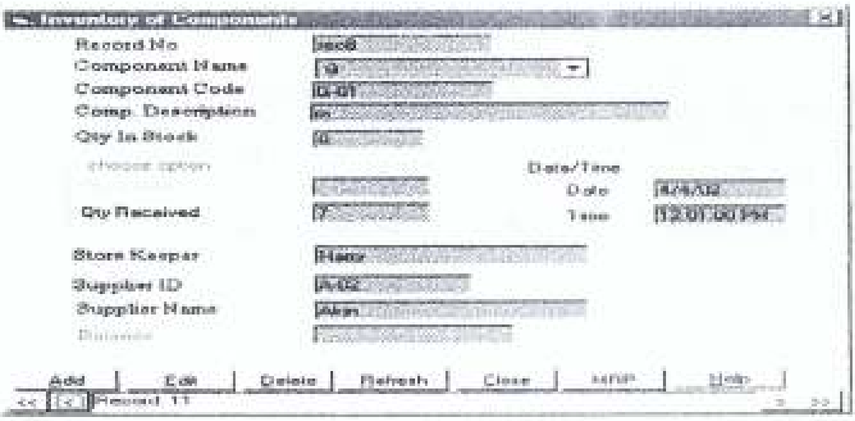


Figure 4.9k

4.1.1. Calculation of Manufacturing Lead-Time of 'A' And 'H'

The total lead-times for processing (assemblying) paths of 'A' are the following:

Path A---B---D, TT_{ABD} = 4 weeks

Path A---B---E, TT_{ABE} = 5 weeks

Path A---C---E, TT_{ACE} = 5 weeks

The critical paths for product 'A' are path A---B---E and path A---C---E

Therefore, the Cumulative Manufacturing Lead-time of 'A' is 5 weeks

The total lead-times for processing (assemblying) paths of 'H' are the following:

Path H---C---E, TT_{HCE} = 6 weeks

Path H---G---D, TT_{HGD} =5 weeks

Path H---G---F, TT_{HGF} = 5 weeks

The critical paths for product 'A' is path H---C---E

Therefore, the Cumulative Manufacturing Lead-time of 'H' is 6 weeks

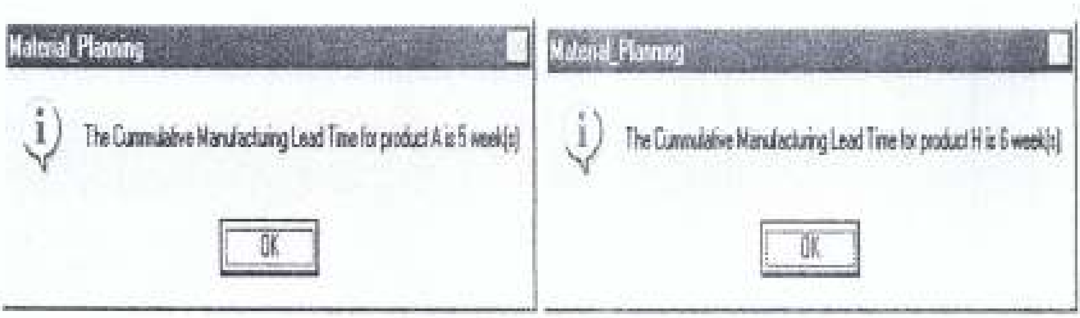


Figure 4.10: The computer printout of the critical path lead-times of 'A' and 'H'

4.1.2 Manual Computations of Material Requirements Plan For 'A' And 'H' and their Components

The manual Material Requirements Plan computations for 'A' and 'H' and their parts are shown in Tables 4.4 to 4.11. The alphabets in superscript indicate the parent source of the component.

On-hand inventories and schedule inventories were introduced in end item assemblies and level 1 components to demonstrate how the MRP processing at one level affects processing at other levels. Also, part 'E' is introduced as a component, such as raw material, which is common to both products 'A' and 'H', and also present in two branches of the product structure of product 'A'. The parents of 'E' in product 'A' are 'B' and 'C'. Another component that is also like 'E' is 'D', which has 'B' as its parent in product 'A' and 'G' as its parent in product 'H'.

In Table 4.4, the gross requirements of final assemblies 'A' and 'H' are the values on the master production schedule.

The determination of the planned order releases of 'E' and 'D' will require the addition of the gross requirements contributed by their parents. Tables 4.9 and 4.10 show how these aggregate gross requirements are obtained.

The computer printouts of the order releases for the components of products 'A' and 'H' over a planning horizon are shown in Figures 4.11 to 4.18. Figures 4.19 and 4.20 show the preview of the planned order releases of components in weeks 10 and 12

Table 4.4: MRP computations for 'A'

Week	8	9	10	11	12	13	14	15	16	17	18
Gross Requirement						3	0	5	0	4	5
Scheduled Receipts						0	0	2	0	0	0
On-Hand 1						1	0	0	0	1	0
Net Requirements						2	0	3	0	3	5
End Inventory						0	2	1	1	0	0
Planned Order Receipt						2	0	3	0	3	5
Planned Order Release				2	0	3	0	3	5		

Table 4.5: MRP computations for 'H'

Week	8	9	10	11	12	13	14	15	16	17	18
Gross Requirement				5		7		10	6		2
Scheduled Receipts						1		4	0		0
On-Hand 7				7		2			0		0
Net Requirements				-2		4		6	6		2
End Inventory				2		0		0	0		0
Planned Order Receipt				0		4		6	6		2
Planned Order Release	0		4		6	6		2			

Table 4.6: MRP computations for 'B'

Week		8	9	10	11	12	13	14	15	16	17	18
Gross Requirement					2^A		3^A		3^A	5^A		
Scheduled Receipts					0		1		0	0		
On-Hand	**0**				0		0		0	0		
Net Requirements					2		2		3	5		
End Inventory					0		0		0	0		
Planned Order Receipt					2		2		3	5		
Planned Order Release				2		2		3	5			

Table 4.7: MRP computations for 'C'

Week		8	9	10	11	12	13	14	15	16	17	18
Gross Requirement				4^B	4^A	6^B	6^A 6^B		6^A 2^B	10^A		
Aggregate GR				4	4	6	12		8	10		
Scheduled Receipts				0	0		2					
On-Hand	**10**			10	6	2	0		0	0		
Net Requirements				-6	-2	4	10		8	10		
End Inventory				6	2	0	0		0	0		
Planned Order Receipt				0	0	4	10		8	10		
Planned Order Release			0	0	4	10		8	10			

Table 4.8: MRP computations for 'G'

Week		8	9	10	11	12	13	14	15	16	17	18
Gross Requirement				12^{B}	0	18^{B}	18^{B}		6^{B}			
Scheduled Receipts				0	6	0	0		0			
On-Hand	7			7	0	6			0			
Net Requirements				5	-6	12	18		6			
End Inventory				0	6	0	0		0			
Planned Order Receipt				5	0	12	18		6			
Planned Order Release			5	0	12	18		6				

Table 4.9: MRP computations for 'E'

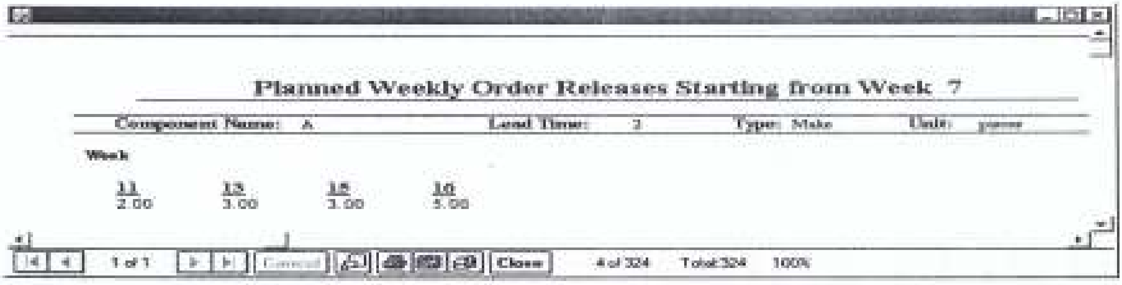
Week		8	9	10	11	12	13	14	15	16	17	18
Gross Requirement				4^{B}	8^{C}	20^{C} 4^{B}		16^{C} 6^{B}	20^{C} 10^{B}			
Aggregate GR				4	8	24		22	30			
Scheduled Receipts				0	0	0		0	10			
On-Hand	15			15	11	3		0	0			
Net Requirements				-11	-3	21		22	20			
End Inventory				11	3	0		0	0			
Planned Order Receipt				0	0	21		22	20			
Planned Order Release		0	0	21		22	20					

Table 4.10: MRP computations for 'D'

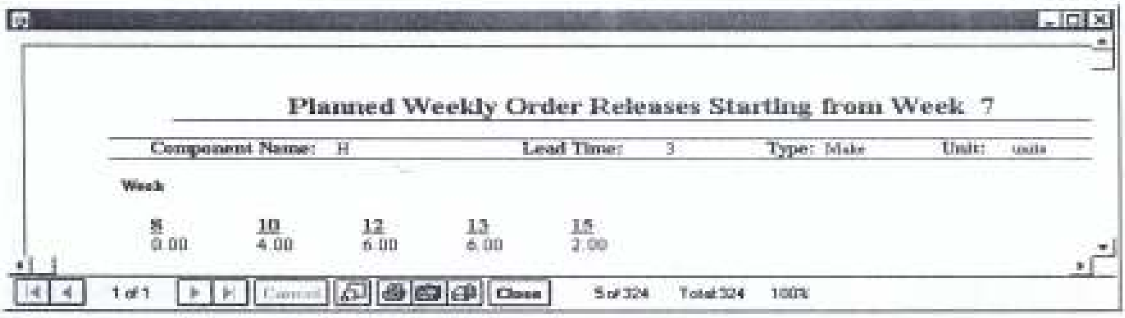
Week	8	9	10	11	12	13	14	15	16	17	18
Gross Requirement		5^{G}	4^{B}	12^{G}	4^{B} 18^{G}		6^{B} 6^{G}	10^{B}			
Aggregate GR		5	4	12	22		12	10			
Scheduled Receipts		0	0	7	0	5	0	0			
On-Hand 12		12	7	3	0	0	5	0			
Net Requirements		-7	-3	2	22	-5	7	10			
End Inventory		7	3	0	0	5	0	0			
Planned Order Receipt		0	0	2	22	0	7	10			
Planned Order Release	0	0	2	22	0	7	10				

Table 4.11: MRP computations for 'F'

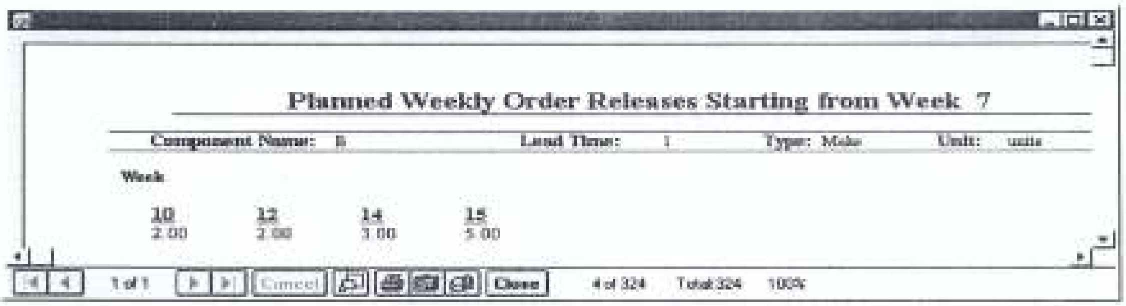
Week	8	9	10	11	12	13	14	15	16	17	18
Gross Requirement		10^{G}		24^{G}	36^{G}		12^{G}				
Scheduled Receipts		0	0	0	0	0	0				
On-Hand 15		15	5	5	0	0	0				
Net Requirements		-5	-5	19	36		12				
End Inventory		5	5	0	0		0				
Planned Order Receipt		0	0	19	36		12				
Planned Order Release	0	0	19	36		12					



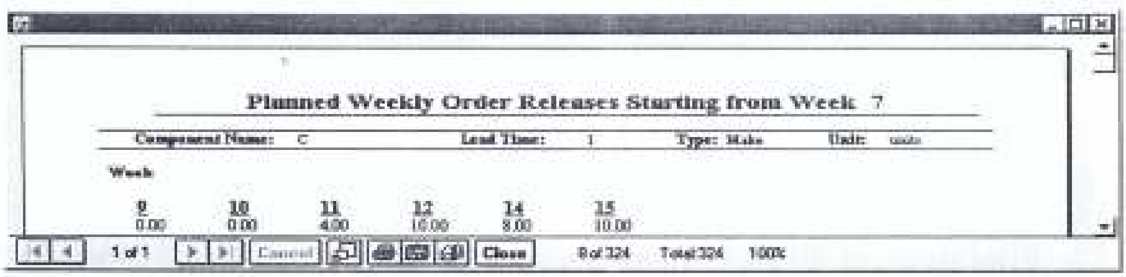
Figures 4.11: Requirements Plan for assembly 'A' over the planning horizon



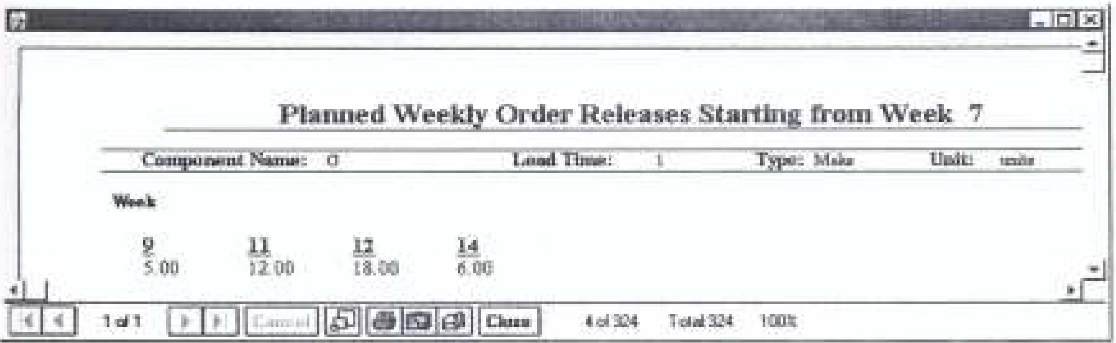
Figures 4.12: Requirements Plan for assembly 'H' over the planning horizon



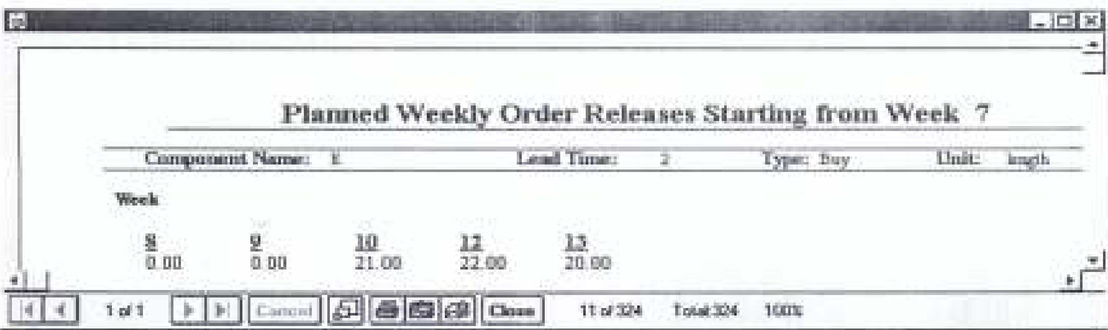
Figures 4.13 Requirements Plan for component 'B' over the planning horizon



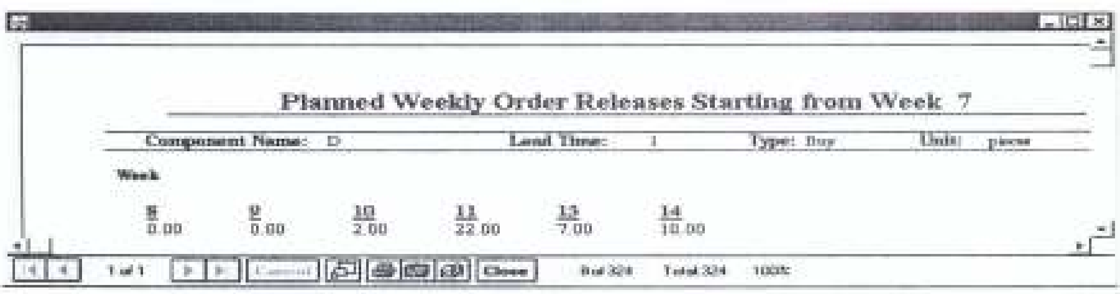
Figures 4.14: Requirements Plan for component 'C' over the planning horizon



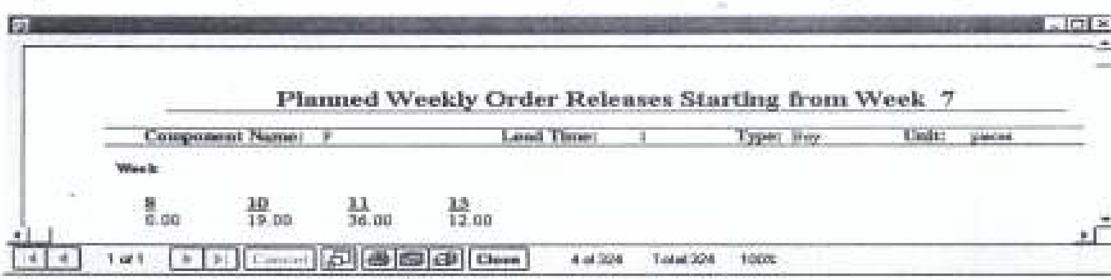
Figures 4.15: Requirements Plan for component 'G' over the planning horizon



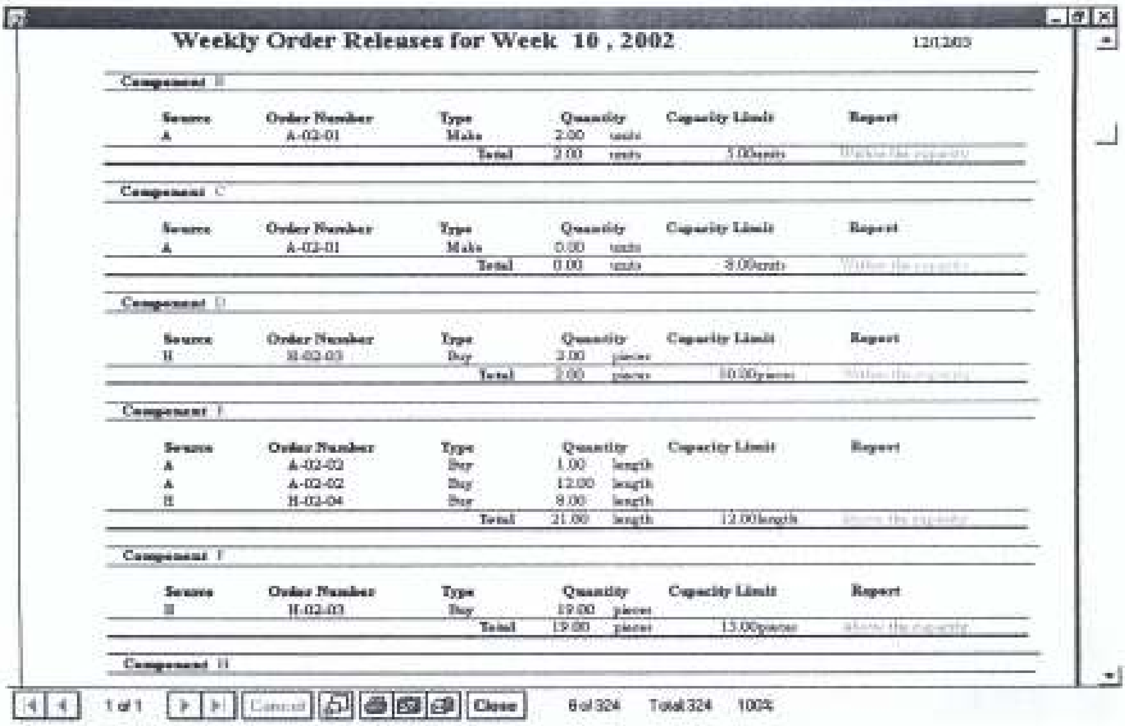
Figures 4.16: Requirements Plan for component 'E' over the planning horizon



Figures 4.17: Requirements Plan for component 'D' over the planning horizon



Figures 4.18: Requirements Plan for component 'F' over the planning horizon

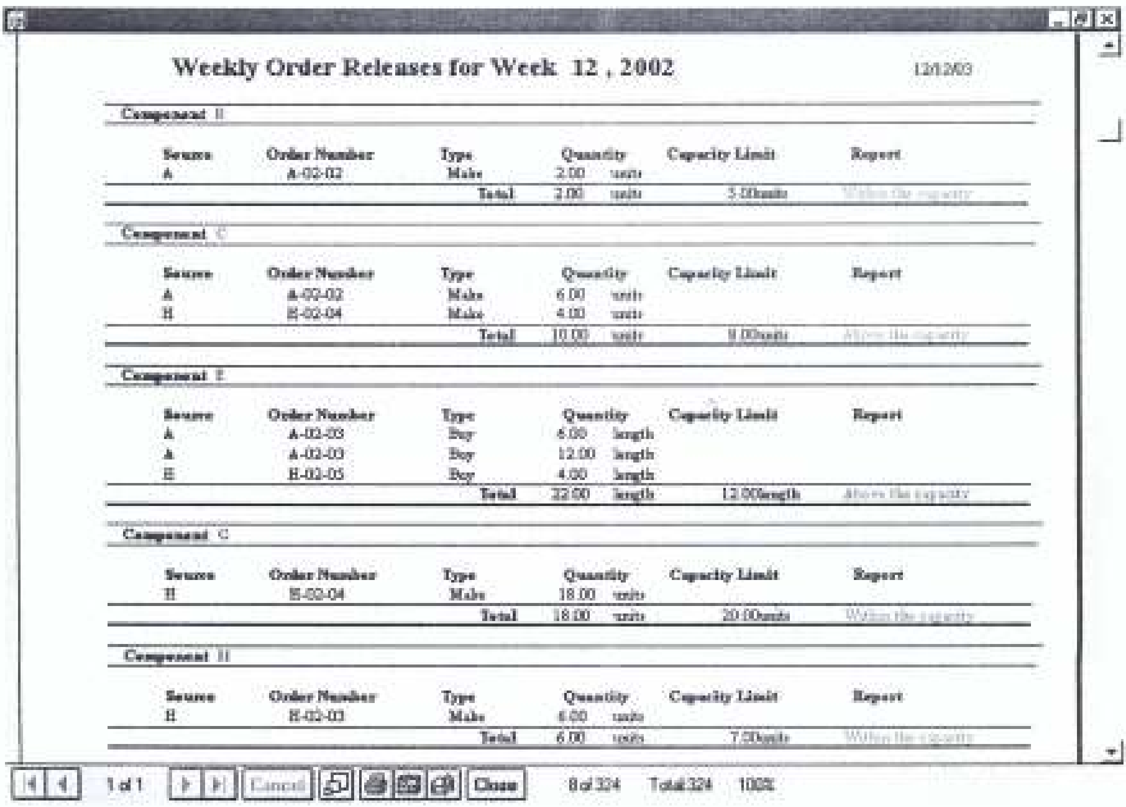


Weekly Order Releases for Week 10 , 2002 12/12/03

Source	Order Number	Type	Quantity		Capacity Limit	Report
Component [illegible]						
A	A-02-01	Make	2.00	units		
		Total	2.00	units	5.00units	Within the capacity
Component C						
A	A-02-01	Make	0.00	units		
		Total	0.00	units	8.00units	Within the capacity
Component [illegible]						
H	H-02-03	Buy	2.00	pieces		
		Total	2.00	pieces	10.00pieces	Within the capacity
Component [illegible]						
A	A-02-02	Buy	1.00	length		
A	A-02-02	Buy	12.00	length		
H	H-02-04	Buy	8.00	length		
		Total	21.00	length	12.00length	Above the capacity
Component [illegible]						
H	H-02-03	Buy	19.00	pieces		
		Total	19.00	pieces	13.00pieces	Above the capacity
Component [illegible]						

1 of 1 Cancel Close 8 of 324 Total 324 100%

Figures 4.19: Printout of Planned Orders Releases in week 10, 2002



Weekly Order Releases for Week 12 , 2002 12/12/03

Source	Order Number	Type	Quantity		Capacity Limit	Report
Component [illegible]						
A	A-02-02	Make	2.00	units		
		Total	2.00	units	5.00units	Within the capacity
Component C						
A	A-02-02	Make	6.00	units		
H	H-02-04	Make	4.00	units		
		Total	10.00	units	8.00units	Above the capacity
Component [illegible]						
A	A-02-03	Buy	6.00	length		
A	A-02-03	Buy	12.00	length		
H	H-02-05	Buy	4.00	length		
		Total	22.00	length	12.00length	Above the capacity
Component C						
H	H-02-04	Make	18.00	units		
		Total	18.00	units	20.00units	Within the capacity
Component [illegible]						
H	H-02-03	Make	6.00	units		
		Total	6.00	units	7.50units	Within the capacity

1 of 1 Cancel Close 8 of 324 Total 324 100%

Figures 4.20: Printout of Planned Orders Releases in week 12, 2002

4.2 Determination of the Material Requirement Plans for 3mm-Mild Steel Sheet in the Production of Planetary Mixer and Rice Destoning Machine

The component parts in Planetary Mixer and Rice Destoning Machine are many. Therefore, calculating the material requirements plan for each part may be cumbersome and not ideal for the purpose of testing the software computation for accuracy.

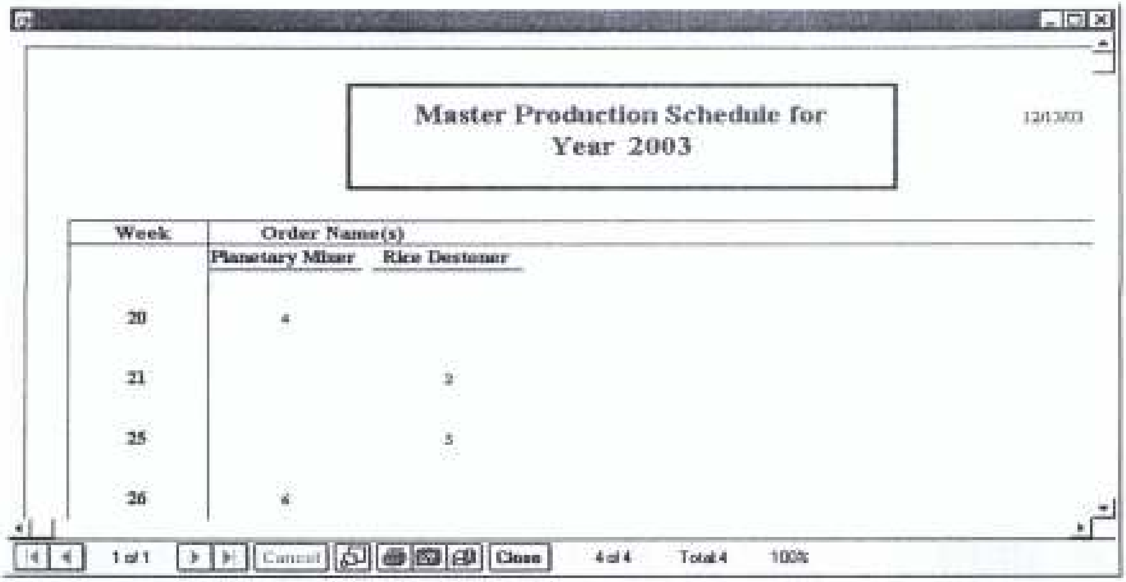
Hence 3mm mild steel sheet was selected because it is a raw material that appeared in several branches of the product structures of planetary mixer and rice destoning machine.

4.2.1 Input Data

The Master Production Schedules for Planetary Mixer and Rice Destoning Machine are as shown Table 4.12

Table 4.12: Master production Schedule for Planetary Mixer and Rice Destoning Machine

Week	Product	
	Planetary Mixer	Rice Destoning Machine
20	4	
21		2
25		5
26	6	



Master Production Schedule for
Year 2003

Week	Order Name(s)	
	Planetary Mixer	Rice Destoner
20	4	
21		3
25		5
26	6	

1 of 1 Cancel Close 4 of 4 Total 4 100%

Figure 4.21: Printout of the master production schedule showing the orders for Planetary Mixer and Rice Destoning Machine.

The product structures of Planetary Mixer designed by Ayodeji (2003) and Rice Destoning Machine designed by Adewoyin (2002) are shown in figures 4.22a - b and 4.24a – c respectively. The computer print outs of the product structures are shown in figures 4.23 and 4.25

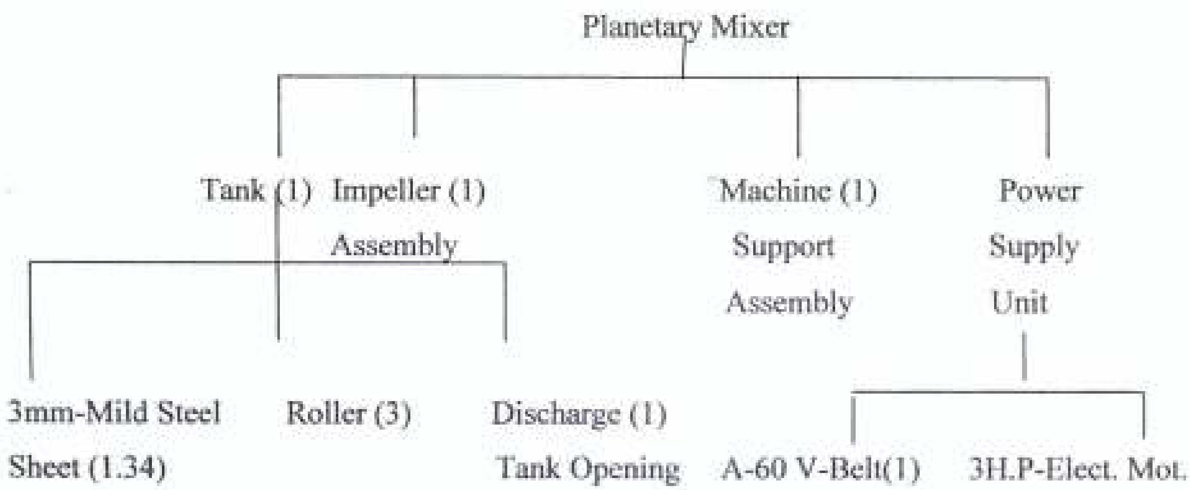


Figure 4.22a: Product Structure of Planetary Mixer

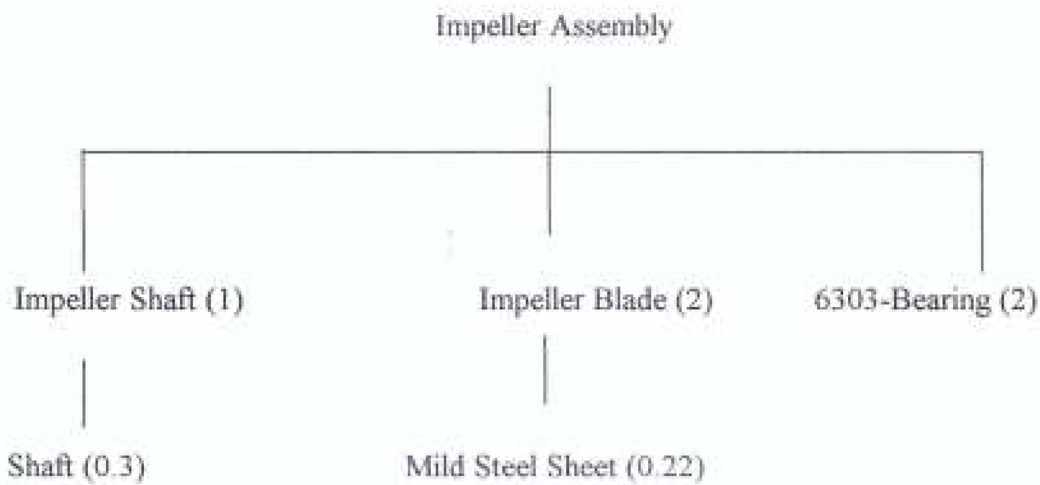


Figure 4.22b: Product Structure of Planetary Mixer (contd)

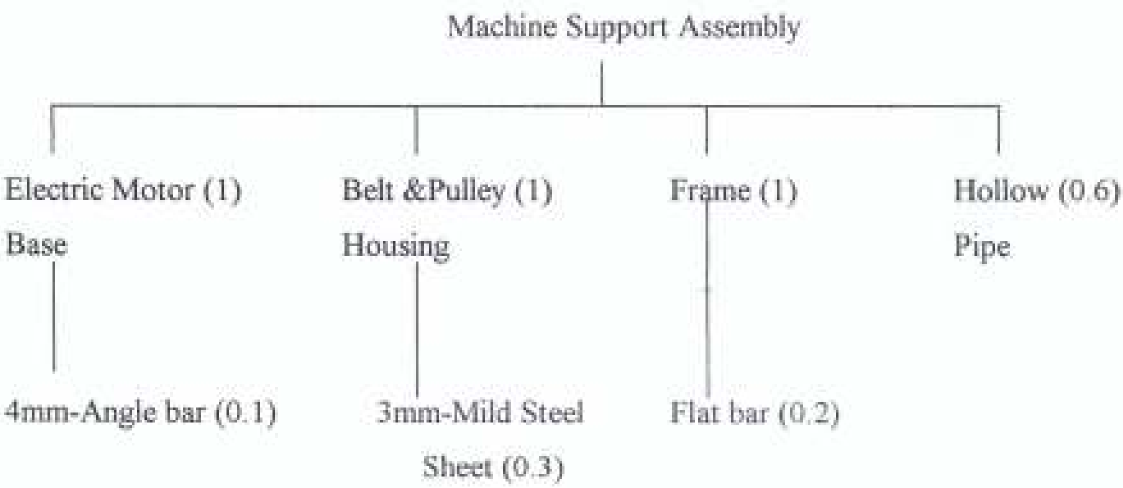


Figure 4.22c: Product Structure of Planetary Mixer (contd)

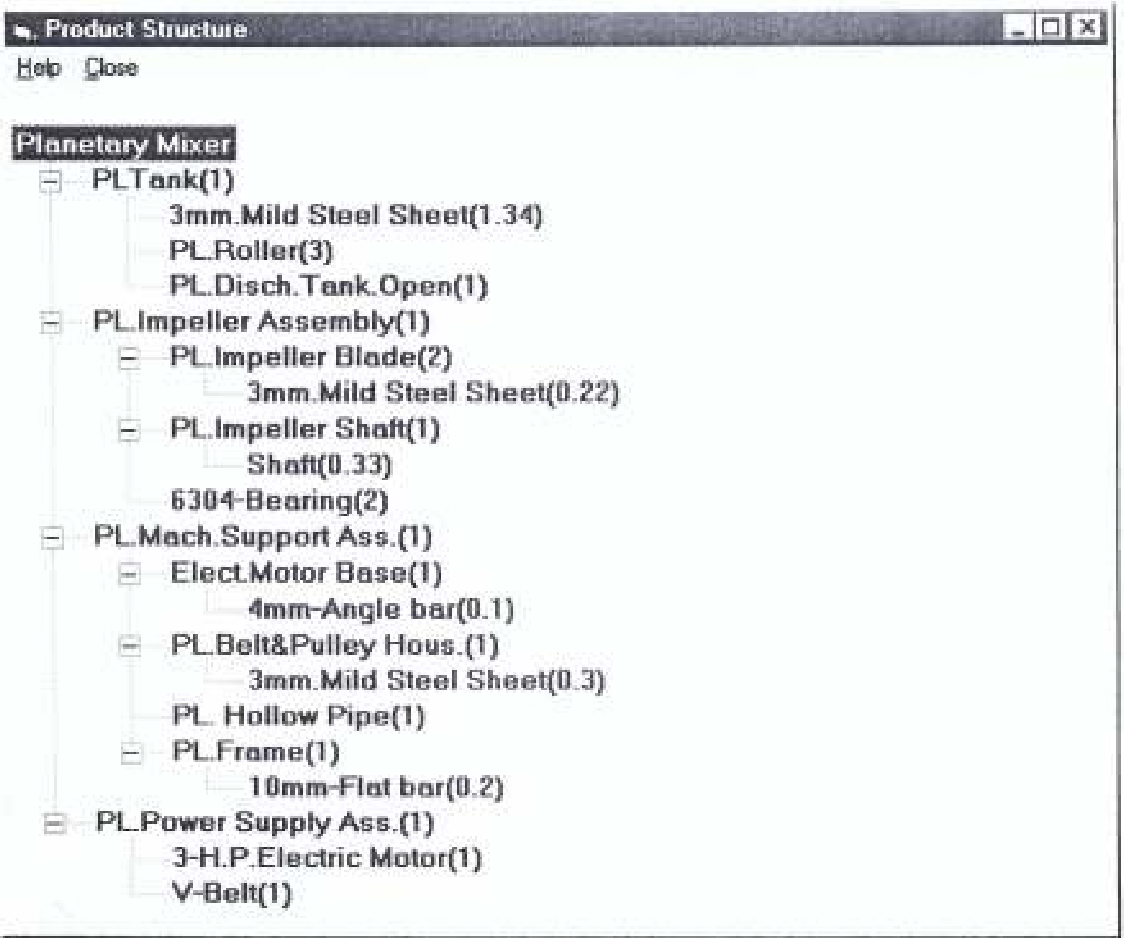


Figure 4.23: Print out of Product Structure of Planetary Mixer

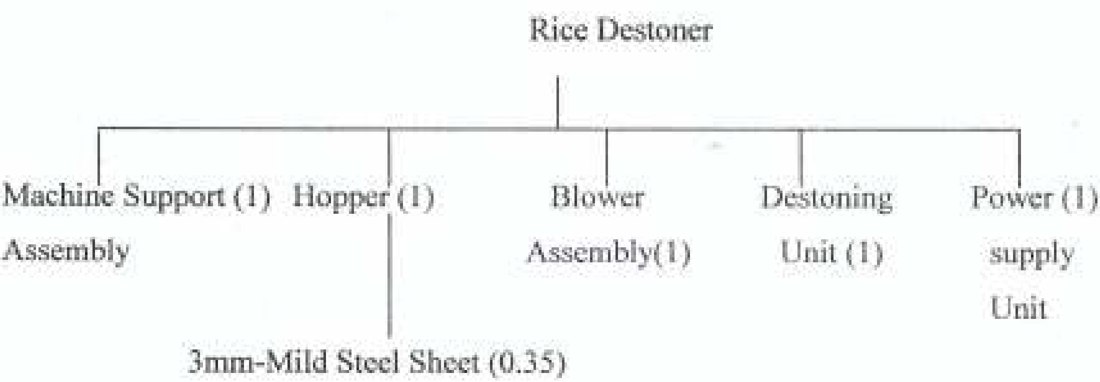


Figure 4.24a: Product Structure of Rice Destoning Machine

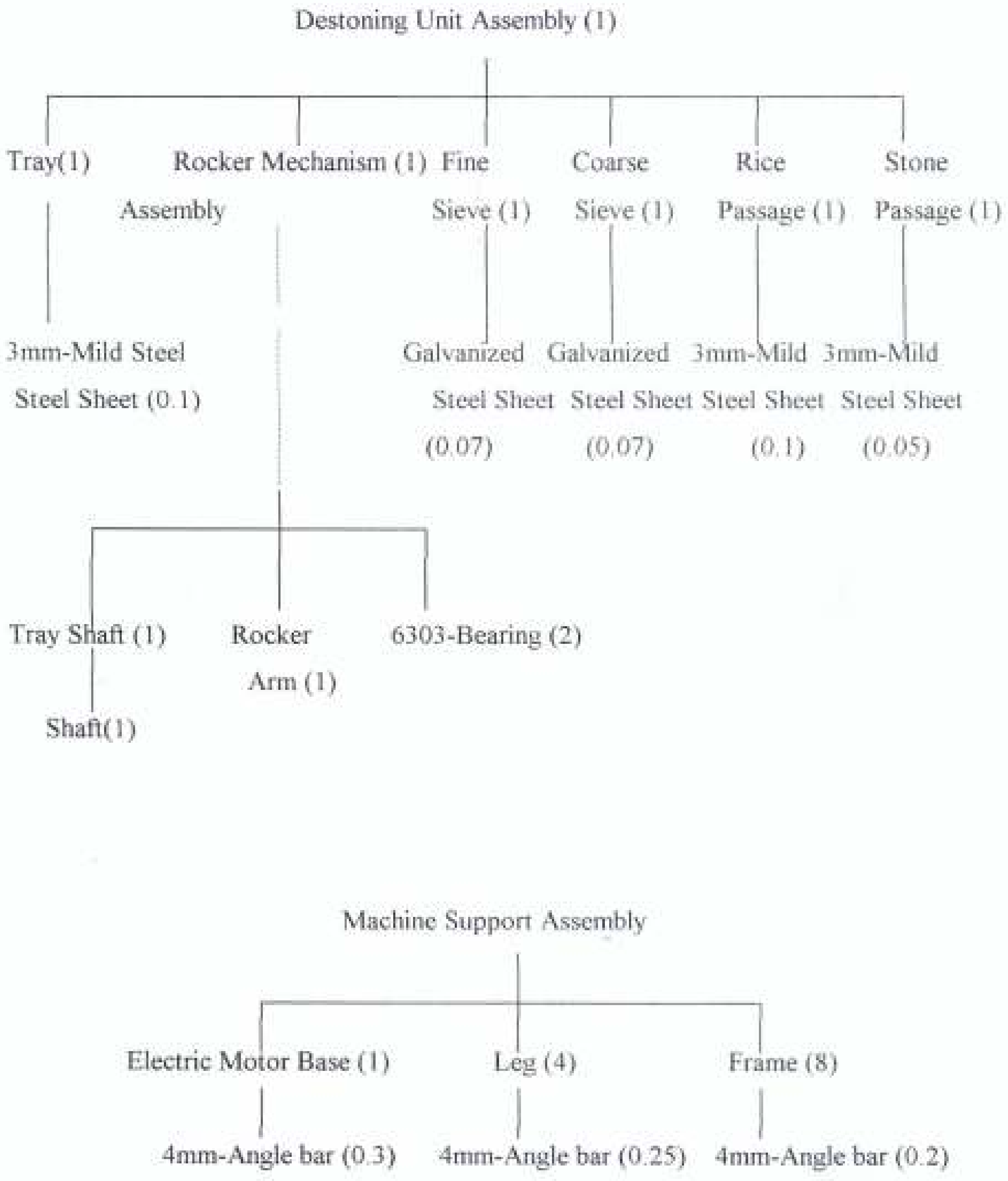
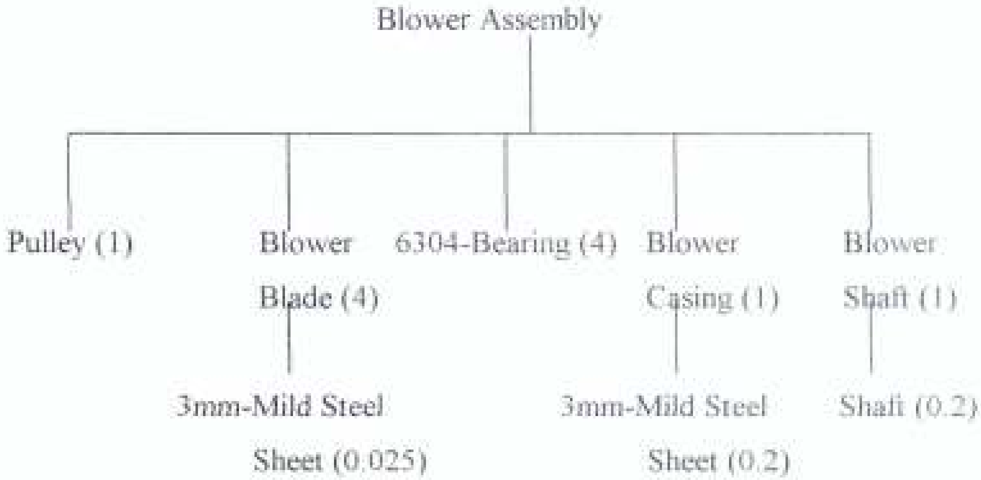


Figure 4.24b: Product Structure of Rice Destoning Machine



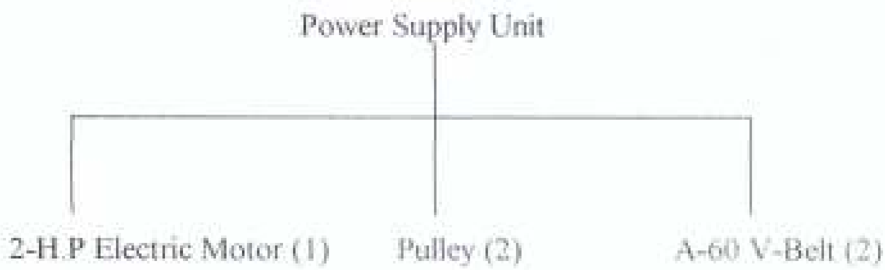


Figure 4.24c: Product Structure of Rice Destoning Machine (contd.)

Figure 4.25: Print out of Product Structure of Rice Destoning Machine

Note: Quantities of raw material items (such as mild steel sheet, Angle Bar etc.) that were needed to make the item immediately above them (Figure 4.22 to 4.25) were determined by:

a) Calculating the surface area of the parent item from the machine drawing and expressing it as a fraction of the area of a standard sheet available in the market. This is applicable to items such as mild steel sheets.

b) Determining the length required for fabricating the parent item and expressing the length as a fraction of standard lengths available in the market. This is applicable to items such as Angle bars, shafts etc.

The material requirements plan for 3mm mild steel sheets was manually determined and its result compared with the computer output.

4.2.2 Manual Computation of Material Requirements Plan for 3mm-Mild Steel Sheet

The manual material requirements computation for mild steel sheet was computed by tracing only the parts that are the parent sources aggregating into the gross requirements schedule of 3mm mild steel sheet are shown in Tables 4.13 to 4.27. Table 4.14 shows the aggregation of the gross requirements plan, while Table 4.15 shows the computation of the planned order releases of 3mm mild steel sheet. The computer print out is shown in Figure 4.27

Table 4.13: MRP computations for Planetary Mixer Assembly

Week		14	15	16	17	18	19	20	21	22	23	24	25	26
Gross Requirement								4						6
Scheduled Receipts								0						0
On-Hand	0							0						0
Net Requirements								4						6
End Inventory								0						0
Planned Order Receipt								4						6
Planned Order Release						4						6		

Table 4.14: MRP computations for Tank

Week	14	15	16	17	18	19	20	21	22	23	24	25	26
Gross Requirement					4^{PLMX}						6^{PLMX}		
Scheduled Receipts					0						0		
On-Hand 0					0						0		
Net Requirements					4						6		
End Inventory					0						0		
Planned Order Receipt					4						6		
Planned Order Release				4						6			

PLMX = Planetary Mixer; Lead-time = 2 weeks

Table 4.15: MRP computations for Impeller Assembly

Week	14	15	16	17	18	19	20	21	22	23	24	25	26
Gross Requirement					4^{PLMX}						6^{PLMX}		
Scheduled Receipts					0						0		
On-Hand 0					0						0		
Net Requirements					4						6		
End Inventory					0						0		
Planned Order Receipt					4						6		
Planned Order Release				4						6			

Table 4.16: MRP computations for Machine Support Assembly

Week		14	15	16	17	18	19	20	21	22	23	24	25	26
Gross Requirement						4^{PLMX}						6^{PLMX}		
Scheduled Receipts						0						0		
On-Hand	0					0						0		
Net Requirements						4						6		
End Inventory						0						0		
Planned Order Receipt						4						6		
Planned Order Release				4						6				

Table 4.17: MRP computations for Impeller Blade

Week		14	15	16	17	18	19	20	21	22	23	24	25	26
Gross Requirement					8^{IMA}						12^{IMA}			
Scheduled Receipts					0						0			
On-Hand	0				0						0			
Net Requirements					8						12			
End Inventory					0						0			
Planned Order Receipt					8						12			
Planned Order Release				8						12				

IMA = Impeller Assembly; Lead-time = 1 weeks

Table 4.18: MRP computations for Belt and Pulley Housing

Week		14	15	16	17	18	19	20	21	22	23	24	25	26
Gross Requirement				4^MSA						6^MSA				
Scheduled Receipts				0						0				
On-Hand	0			0						0				
Net Requirements				4						6				
End Inventory				0						0				
Planned Order Receipt				4						6				
Planned Order Release			4						6					

MSA = Machine Support Assembly; Lead-time = 2 weeks

Table 4.19: MRP computations for Rice Destoning Machine Assembly

Week		14	15	16	17	18	19	20	21	22	23	24	25	26
Gross Requirement									2				5	
Scheduled Receipts									0				0	
On-Hand	0								0				0	
Net Requirements									2				5	
End Inventory									0				0	
Planned Order Receipt									2				5	
Planned Order Release							2				5			

Table 4.20: MRP computations for Rice Destoner Hopper

Week		14	15	16	17	18	19	20	21	22	23	24	25	26
Gross Requirement							2RDA				5RDA			
Scheduled Receipts							0				0			
On-Hand	0						0				0			
Net Requirements							2				5			
End Inventory							0				0			
Planned Order Receipt							2				5			
Planned Order Release					2				5					

RDA = Rice Destoning Machine Assembly; Lead-time = 2 weeks

Table 4.21: MRP computations for Destoning Unit Assembly

Week		14	15	16	17	18	19	20	21	22	23	24	25	26
Gross Requirement							2RDA				5RDA			
Scheduled Receipts							0				0			
On-Hand	0						0				0			
Net Requirements							2				5			
End Inventory							0				0			
Planned Order Receipt							2				5			
Planned Order Release					2				5					

Table 4.22: MRP computations for Destoning UnitTray

Week		14	15	16	17	18	19	20	21	22	23	24	25	26
Gross Requirement					2^{DUA}				5^{DUA}					
Scheduled Receipts					0				0					
On-Hand	**0**				0				0					
Net Requirements					2				5					
End Inventory					0				0					
Planned Order Receipt					2				5					
Planned Order Release				2				5						

DUA = Destoning Unit Assembly; Lead-time = 2 weeks

Table 4.23: MRP computations for Destoning Unit Stone Passage

Week		14	15	16	17	18	19	20	21	22	23	24	25	26
Gross Requirement					2^{DUA}				5^{DUA}					
Scheduled Receipts					0				0					
On-Hand	**0**				0				0					
Net Requirements					2				5					
End Inventory					0				0					
Planned Order Receipt					2				5					
Planned Order Release				2				5						

Table 4.24: MRP computations for Destoning Unit Rice Passage

Week		14	15	16	17	18	19	20	21	22	23	24	25	26
Gross Requirement					2^{DUA}				5^{DUA}					
Scheduled Receipts					0				0					
On-Hand	0				0				0					
Net Requirements					2				5					
End Inventory					0				0					
Planned Order Receipt					2				5					
Planned Order Release			2				5							

Table 4. 25: MRP computations for Blower Assembly

Week		14	15	16	17	18	19	20	21	22	23	24	25	26
Gross Requirement							2^{RDA}				5^{RDA}			
Scheduled Receipts							0				0			
On-Hand	0						0				0			
Net Requirements							2				5			
End Inventory							0				0			
Planned Order Receipt							2				5			
Planned Order Release				2				5						

Table 4.26: MRP computations for Blower Blade

Week		14	15	16	17	18	19	20	21	22	23	24	25	26
Gross Requirement				8 BLA				20 BLA						
Scheduled Receipts				0				0						
On-Hand	0			0				0						
Net Requirements				8				20						
End Inventory				0				0						
Planned Order Receipt				8				20						
Planned Order Release			8				20							

BLA = Blower Assembly; Lead-time = 3 weeks

Table 4.27: MRP computations for Blower Casing

Week		14	15	16	17	18	19	20	21	22	23	24	25	26
Gross Requirement				2 BLA				5 BLA						
Scheduled Receipts				0				0						
On-Hand	1			1				0						
Net Requirements				1				5						
End Inventory				0				0						
Planned Order Receipt				1				5						
Planned Order Release			1				5							

Table 4.28: Aggregation of the schedules contributing to the gross requirements schedule of mild steel sheet

Wk	14	15	16	17	18	19	20	21	22	23
GR	0.20^{RDBC}	1.20^{PMBPH} 0.20^{RDBB} 0.20^{RDRP}	1.76^{PMIMB} 0.24^{RDTR} 0.10^{RDSP}	5.36^{PMTK} 0.14^{RDHP}	1.00^{RDBC}	0.50^{RDBB} 0.50^{RDRP}	0.6^{RDTR} 0.25^{RDSP}	1.80^{PMBPH} 0.35^{HP}	2.64^{PMIMB}	8.04^{PMTK}
	0.20	1.60	2.10	5.50	1.00	1.00	0.85	2.15	2.64	8.04

Superscripts represent the sources of requirement for mild steel sheet

RDBC = Rice Destoner Blower Casing;

RDBB = Rice Destoner Blower Blade; Lead-time = 1 week

RDTR = Rice Destoner Tray; Lead-time = 1 week

RDSP = Rice Destoner Stone Passage; Lead-time = 1 week

RDRP = Rice Destoner Rice Passage; Lead-time = 1 week

RDHP = Rice Destoner Hopper; Lead-time = 2 weeks

PMBPH = Planetary Mixer Belt & Pulley Housing; Lead-time = 1week

PMIMB = Planetary Mixer Impeller Blade; Lead-time = 1 week

PMTK = Planetary Mixer Tank; Lead-time = 2 weeks

Table 4.29: MRP computations for mild steel sheet

Week	13	14	15	16	17	18	19	20	21	22	23	24
Gross Requirement		0.20	1.60	2.10	5.50	1.00	1.00	0.85	2.15	2.64	8.04	
Scheduled Receipts		0	0	0	0	0	0	0	0	0	0	
On-Hand 7		7.00	6.80	5.20	3.10	0	0	0	0	0	0	
Net Requirements		-6.80	-5.20	-3.10	2.40	1.00	1.00	0.85	2.15	2.64	8.04	
End Inventory		6.80	5.20	3.10	0	0	0	0	0	0	0	
Planned Order Receipt		0	0	0	2.40	1.00	1.00	0.85	2.15	2.64	8.04	
Planned Order Release	0	0	0	2.40	1.14	1.00	0.85	2.15	2.64	8.04		

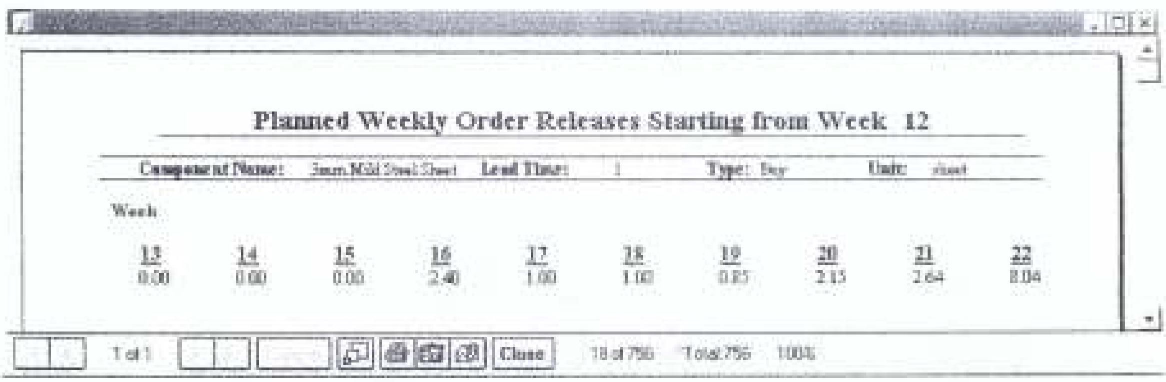


Figure 4.26: Computer Report for Planned Order Releases for 3mm – Mild Steel Sheet

The report of planned order releases for all parts in week 17 shown in figure 4.27, for example, corroborates the report shown in figure 4.26 showing that order for1.00 unit of mild steel sheet needs to be released in week 17.

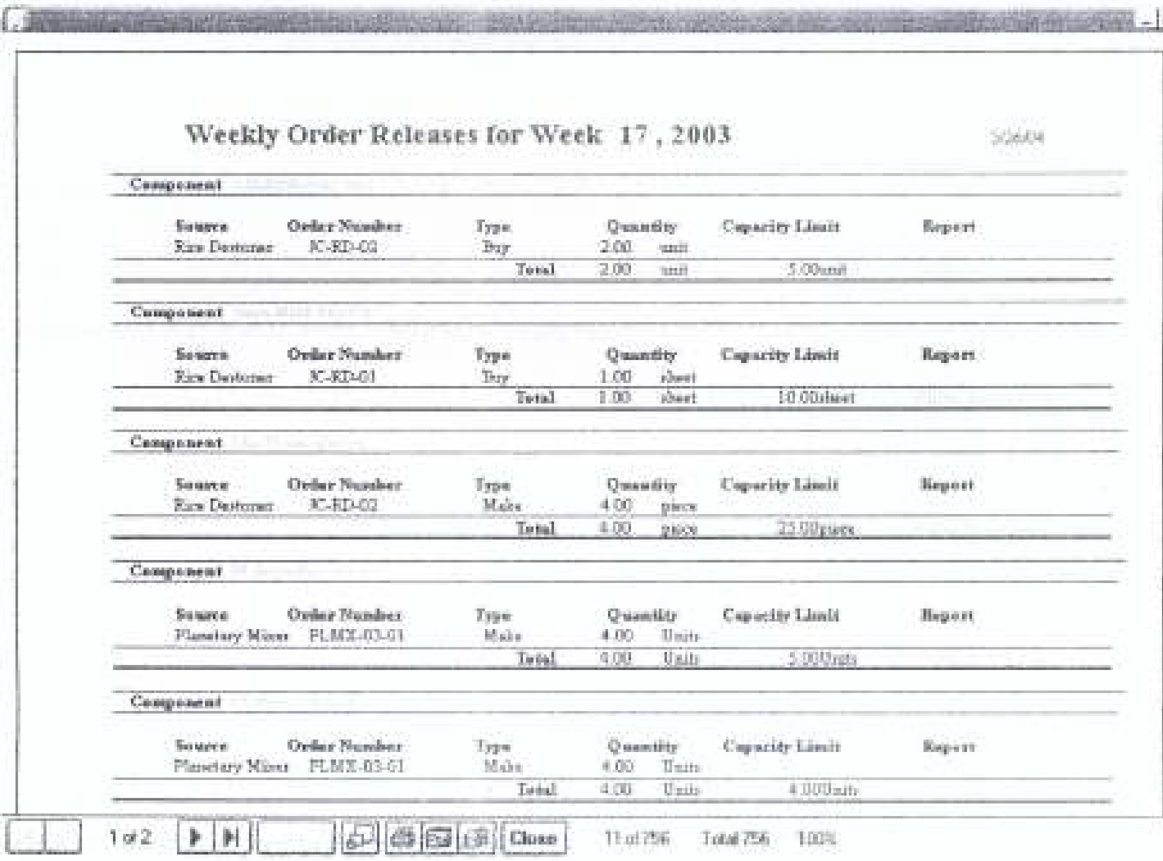


Figure 4.27: Computer Report for Planned Order Releases in week 17, 2003

The output of the software for the material requirements plan of mild steel sheet is found to be the same with the manual computation. Therefore, the computerized MRP output may be concluded to be correct and able to give an accurate output when the product structure of an assembly product is so complicated.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

A software for material requirements planning (MRP) has been developed for keeping inventory cost low and meeting due dates promised to customers. It is expected that the software will remove the difficulty experienced when material requirements are computed manually and also eliminate the errors to which such processes are prone.

The accuracy of the software was tested with products that have multi-level bills-of-materials. The test was carried out by comparing the material requirements plan generated by the MRP software for a component that is commonly found in the various branches of the product structures of each of the end items in the master production schedule used with the manually computed material requirements plan.

The software is easy to use and the report generated by the MRP software was found to be accurate. The application is expected to promote the adoption of computer integrated manufacturing system in developing countries.

5.2 Recommendation

Lot-for-lot sizing technique was used in developing this software to facilitate the practice of the Just-In-Time (JIT) ordering philosophy. However, it is recommended that appropriate alternative lot sizing techniques, such as part period cost balancing, should be provided alongside the lot-for-lot sizing technique. This will enable users to make a choice if lot-for-lot is considered too expensive to operate for some items and also to help dampen system nervousness, which is most generated in lot-for-lot technique.

Also, the world is moving towards Enterprise Resource Planning (ERP). Therefore, other complementary softwares, such as capacity requirements planning system, costing system etc., that will cover the various business practices in jobshops should be developed and integrated with the MRP softwares so as to have a complete ERP package for jobshops.

In developing these softwares, appropriate statistical techniques should be employed to take care of the uncertainties of lead-time, stock, and capacities etc, which are prevalent in most jobshops. It is not enough to just use arbitrary buffer lead-times, but there is the need to develop softwares, which will assist production planners in determining the buffer (or safety) lead-times at each work center using a suitable statistical technique that will use historical data available in the firm's records.

However, it is recommended that the software should first be validated by actual field studies to discover the areas where it needs to be improved.

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