UNIT 9 – PULL VS. PUSH SYSTEM

Structure

Objectives

In this unit, we will discuss manufacturing planning and control system. The two systems of manufacturing planning and control are the push and the pull systems. The push system is exemplified by manufacturing resources planning (MRP II), and the pull system by just-in-time production system (JIT). Accordingly, MRP II and JIT will be discussed in detail in this unit. MRP II is widely used in the batch production environment. However, it has some discernible limitations. To overcome these limitations, elements of JIT and optimized production technology (OPT) can be incorporated. Mixed strategies, such as these, will also be discussed in this unit.

9.1 INTRODUCTION

This block of the course material on materials management is devoted to the discussion of the materials planning and control function. The block consists of two units, namely, units 8 and 9. In unit 8, we had discussed the activity of materials planning and budgeting as it applies to manufacturing and production of end products/finished goods. Also therein we had noted that material requirements planning (MRP), which is the most widely used technique for materials planning and budgeting, is incomplete, since it does not carry out the activities which it facilitates. These are the activities of material control, planning of capacity requirements (determination of man-hours and machine-hours required), and capacity, or shop floor, control, which is referred to as production activity control* in

* We feel that production activity control (PAC) must also include material, or vendor, control, since unless the materials are available from vendors, shops cannot produce components and carry out the assembly tasks.

some text books. In this unit, we will discuss the activity of material control, together with materials planning and budgeting, and thus fulfill the requirement of the title of this block. But this, by itself, will be incomplete and inadequate, since we are discussing the function in the context of manufacturing and production of end products. We have to include herein the discussion of capacity requirements planning, capacity control, and the necessary feedback of information from materials and capacity checks and production activity control (includes both vendor and shop floor activity control) to ensure the viability of the master schedule (MPS). Materials planning and control is done, in the final analysis, to ensure that the end products of the company are produced as per the MPS. Also, since materials and production capacity (in the form of man-hours and machine-hours) are the two basic resources for manufacturing and production of end products, we will, in essence, discuss the manufacturing planning and control (MPC) system in this unit. The function of materials planning and control is a part of this system, and we must look at the whole picture (MPC) to truly appreciate this important function of materials management.

The student must have noticed the title of this unit. Push and pull systems are the two possible systems of linking the production of work centres in a manufacturing setup/ organization. Essentially they are the two systems of operating the manufacturing/ production organization, or the two basic approaches used for manufacturing planing and control (MPC). MPC brings to mind manufacturing resources planning, which has the same acronym as material requirements planning and because of this is commonly referred to as MRPII. MRPII is an example of the push system of production. As opposed to this, the just-in-time (JIT) production system, also sometimes known as the Toyota production system, is an application of the pull system. Instead of discussing the differences between push and pull systems here, we will take up the discussion of MRPII straight away and then bring out the difference between the two systems through the discussion of the JIT production. This way, it is felt that, the difference between the two systems will become much clearer to the student. We will also discuss repetitive manufacturing, the operation of the 'kanban' system, and then the core and enablers of the pull system Thereafter, we will discuss the mixed strategies. Thus in this unit, there are three main sections, namely, MRP II, JIT, and mixed strategies of manufacturing planning and control, in that order.

9.2 MANUFACTURING RESOURCES PLANNING

In unit 8, we have discussed the technique of material requirements planning (MRP). We have noted the difference between independent and dependent demand inventory items, and thereafter having realized that the bulk of the total production inventory (excluding items of maintenance and tooling inventory) is in the form of raw materials, components and subassemblies, we have noted that MRP is the most appropriate technique for planning and budgeting of production inventory items. MRP is used for the planning of production inventories, since production inventory items like raw materials and purchased components are procured and kept in stock to support planned production of end products, and are items of dependent demand since the quantity required depends on the number of end products scheduled for production. But manufacturing operations also require manpower and machines (and other production equipment). Hence one has to take into account the capacity constraints, which must include man-hours in the required skills, such as welding hours etc., and also machine-hours on the required types of machines, namely, turning hours, milling hours, horizontal boring hours, shot-blasting hours etc. required and available in any given time period of the planning horizon. In some cases, it may be necessary to consider other constraints, such as funds required for procurement of materials and even storage space required for in-process and finished goods inventories. Thus for the effective planning of manufacturing and production operations, as an obvious and logical development, capacity requirements planning was also incorporated and integrated with the detailed planning of material requirements. Moreover, a closed-loop system was also conceived so that the control function and feed-back of essential information were also incorporated to make it a complete manufacturing planning and control system. This refinement and extension of MRP was named manufacturing resources planning, and to differentiate it from materials requirements planning, it is called MRP-II.

This section of the unit will be devoted to the discussion of manufacturing resources planning. But before we can take up the evolution of MRP II from MRP and the detailed discussion of the manufacturing planing and control system enabled by MRP II, we must necessarily revisit MRP. The MRP subsection will not just be a recapitulation. Instead of repeating what has already been stated in unit 8, we will concentrate on (i) the things which led to the development of MRP – the basic MRP concepts, (ii) the outputs of MRP and the basic MRP record, and (iii) the deficiencies (or shortcomings) of MRP.

9.2.1 MRP Revisited

The flowchart of the MRP technique is given as Fig. 4 in unit 8. We will not reproduce it here, and instead the student is advised to refer to this figure of unit 8. As we have noted earlier, MRP is essentially a computational technique for bill of materials 'explosion' (or, disaggregation) and then deriving the net requirements from the gross requirements (obtained through explosion) through the use of the inventory status file. Once the net requirements of all sub-assemblies, components and raw materials are known, lead time offsetting is done for determining the time-phased requirements of the individual subassemblies, components, and raw materials. This is also done by the MRP processor. Thereafter, the manufacturing, or shop, orders and purchase orders are released. Thus, the three inputs to the MRP processor are the MPS, BOM file, and inventory status file. The MPS triggers the processor, and thereafter, the BOM file and inventory status file data are accessed and used by the processor for each and every end product listed in the MPS, one after another. The time phasing is done by lead time offsetting, or back scheduling, by the amount of the relevant lead time.

The MRP technique is based on four basic concepts. Of these, in unit 8, we have already discussed the first, namely, the difference between independent and dependent demand inventory items, and we have duly noted that this distinction is fundamental to MRP. The remaining three concepts are the following:

1) Existence of lumpy demand.

2) Existence of two kinds of lead times.

3) Need to take due account of common-use items.

In a reorder point system (used nowadays for independent demand inventory items), it is generally assumed that the demand for an item in inventory occurs at a gradual and continuous rate. This assumption is fundamental for the derivation of the economic order quantity (EOQ) formula. However, in a manufacturing organization, the demand for raw materials and components of an end product occur intermittently in large increments (in lumps), rather than in small and almost continuous amounts. These lumps correspond to the quantities needed to make a given batch of the end product. The student is advised to refer to Table 1 of unit 8 and observe the pattern of demand of end products given in the MPS. Notice that the demand for the end products is also lumpy and not continuous. Thus the EOQ formula does not apply, and use of MRP is the right approach for dealing with inventory situations characterized by lumpy demand. The lead time for a job, or task, is the time that must be allowed to complete the job/task from start to finish. In manufacturing, there are two kinds of lead times, namely, procurement lead time for raw materials and purchased components, and manufacturing lead time for in-house manufacture of components and assembly operations. Procurement lead time is the time required from the initiation of the purchase requisition to the receipt of the item from the vendor. Manufacturing lead time, on the other hand, is the time needed to process the part through the sequence of machines/operations specified in the process plan, or the route sheet. It includes not only the operation times but also the non-productive time that must be allowed, under the given circumstances. Reorder point inventory control problems only consider the procurement lead time, whereas in MRP, the existence of two kinds of lead times is recognized, and the lead times are used to determine the starting times for (i) ordering raw materials, (ii) ordering purchased components and subassemblies, (iii) manufacture of components in-house, and (iv) starting dates for subassembly and final assembly operations. In manufacturing, basic raw materials are often used to produce more than one component/component type. Similarly, a given component may be used in more than one end product. MRP collects these common-use items from different products to effect economies in procurement of raw materials and purchased components, and in-house manufacture of components and subassemblies. This will not be possible without the use of a computer, since a manufacturing organization usually makes a number of end products, including a few multi-model products, and collecting these common-use items manually will be very difficult, if not totally impossible.

				Part Name		Drive Shaft		
				Part Number		FAG159342MXP		
Time Period		1	2	3	4	5	….	12
Gross Requirements			10		40	10	….	….
Scheduled Receipts		50					….	….
Projected available Balance	4	54	44	44	4	44	….	….
Planned Order Releases					50		….	….
Lead Time = 1 period								
Lot Size = 50								

An example of the basic MRP record is shown in Table 1. This record, or statement, is produced by the MRP processor for each individual item (of raw material, component, and subassembly) for all the end products listed in the MPS. For each time period of the

Table I: An Example of the Basic MRP Record

planning horizon * , the record shows the gross requirement, scheduled receipt, projected available balance, and the planned order release for the item. At the heart of the manufacturing planning and control (MPC) system enabled by MRP (and MRP II) is a universal representation of the status and plans for every single item (part number), whether it is a raw material, component, subassembly, or finished product. The explanation of the terms used in the record is given below:

Gross requirement is the anticipated future usage of (or demand for) the item. These are time phased, or in other words, gross requirements are stated on a period – by – period basis. The item must be available at the beginning of the time period.

Scheduled receipts are the existing replenishment orders for the item due at the beginning of each time period.

Projected available balance is the current and projected inventory status for the item *at the end of each period.*

Planned order releases are the planned replenishment orders (purchase orders/shop orders) for the item *released at the beginning of each time period.*

The important point to note here is that the gross requirement in a particular period will not be satisfied unless the item is available during the period and the timing convention used comes from the question of availability. The item must be available at the beginning of the time period in which it is required, and the availability is achieved by having the item in inventory, or by receiving either a scheduled receipt or a planned replenishment order in time to satisfy the gross requirement. This means that plans must be made so that any replenishment order will be in inventory at the beginning of the period in which the gross requirement for that item occurs.

Purchase orders and shop orders are released based on the MRP record. The order release notices, thus, constitute the first of the five primary outputs of MRP. The other outputs are the following:

1. Reports on inventory status.
2. Reports showing planned orders to be released in future periods.
3. Rescheduling notices indicating changes in due dates for open orders – shop orders as well as purchase orders.
4. Cancellation notices indicating cancellation of open orders because of changes in the MPS.

The secondary outputs of MRP include the following:

1. Performance reports on product/component costs, item usage, actual versus planned lead times etc.
2. Exception reports showing deviations from schedule, namely, orders that are overdue, scrap etc.
3. Inventory forecasts indicating projected inventory levels (aggregate inventory as well as item inventory) in future periods.

Whereas the first four reports are primarily directed at the materials management function, the three secondary reports are meant for the senior management personnel.

2.2 MRP to MRP II

MRP provides disaggregation of the MPS into the resultant detailed plans for each manufactured and purchased part number. This, by itself, was a major breakthrough made feasible by random access computers and database management systems. But the problem that was first encountered was one of the need for frequent rescheduling of orders. MRP does not take into account the capacity available in a given time period/periods (and does not even determine the capacity requirements) before releasing shop orders. The result is that the capacity may be exceeded during some periods (that is, the required capacity for a given production lot > available capacity). Moreover, the manufacturing lead time will be longer than what was used for time phasing. Because of this, the actual manufacturing schedule will be different from the planned schedule necessitating rescheduling of orders. Thus, the viability of the MPS is essential for the integrity of the MRP technique. This, in the first instance, not only requires the determination of capacity requirements for the output from the material planning module and incorporation of a capacity requirement module, but also calls for feedback from the capacity planning module before the release of shop orders. If the capacity is not adequate, then this information must be fed back to the MPS for necessary correction/amendment. The data from the amended MPS can then be fed into the MRP processor for detailed material planning and thence the material planning module data fed to the CRP processor for detailed capacity planning. This ensures that the MPS is feasible, or viable.

MRP II evolved from MRP through a series of extensions to the functionality of the MRP technique. We have, in the preceding paragraph, discussed the first series of extensions, through which MRP was extended to support the following functions:

1. **Resource requirements planning** (RRP) (also called 'master planning') – derived from long range forecasts* of product demands (recall that the long range forecasts look ahead 3-5 years or more).

2. **Aggregate Planning–** based on the resource requirement plan details (recall that these resources do not change in the intermediate range), intermediate range forecasts of product demands, and firm orders for products.

3. **Capacity requirements planning (CRP)–** derived from the material requirement planning output, which in turn, is based on the MPS (and MPS is derived from the aggregate planning output and changes in forecasted demands as obtained from short term forecasts). Capacity requirements planning (CRP) is carried out through the use of a CRP processor (like the MRP processor).

4. **Production activity control (PAC) –** consisting of material, or vendor, control, and manpower and machine capacity, or shop floor, control.

The closed – loop MRP denotes the stage in MRP II system wherein the planning function of MPS (master scheduling), MRP and CRP are linked to the execution function of purchasing and shop floor activity control.

Thereafter MRP II was extended to support business and financial planning. The MRP II software package also includes an extensive 'what if?' capability. Alternative business and manufacturing scenarios can be assessed through the use of the package. The further extension of MRP II involves the integration of financial, accounting, and personnel data and information with the manufacturing planning and control activities of the basic MRP II system.

1.1 Is MRP II the Ultimate Manufacturing Planning and Control System?

Whereas MRP, by itself, is only a technique, or an algorithm, MRP II is a system. It is a manufacturing planning and control system and it carries out all the necessary planning and control activities needed to support the manufacture of end products demanded by customers. The flowchart of MRP II is given in Fig. 1. The top part of the figure upto the MRP processor is the same as that for the MRP technique (a comparison with Fig. 4 of unit 8 will show that herein we have included the forecasting block and resource requirements planning, and this has been done since we want to stress that MRP II represents a manufacturing planning and control system). Thereafter, the material requirements planning output is fed to the capacity requirements planning (CRP) processor to calculate the specific types (skills and machines) of labour and machine capacity requirements, in man-hours and machine-hours, for each time period of the planning horizon. This is done with the help of two important input files, namely, the production, or shop, routing* files, and work centre status file. After this is done, the net requirements of the purchased components (and subassemblies) and raw materials, and also the capacity requirements, in terms of man-hours and machine-hours, are known. Accordingly, the material and capacity plans are prepared. However, based on these plans, the purchase orders and production, or shop, orders are only released after a due check to see whether funds (for purchase of material) and man-hours and machine capacities required are available. If any one or both are not available fully, then such information is fed back to the MPS for necessary amendment(s) and rescheduling. The control process and the feed back from the control process finally closes the loop updating both the inventory and work centre status file.

[FIGURE 1 SHOULD PREFEREBLY GO HERE]

From this point on, in this unit, the term MRP will be used for MRP II (whenever MRP is used, we will actually mean MRP II). MRP is a complete manufacturing planning and control system. Benefits of MRP include the following:

1. Reduction in inventory – raw material, purchased component and WIP inventory.
2. Quicker response to changes in demand and the master schedule (MPS).
3. Productivity increases and labour requirements are also correspondingly reduced – this is obtained through a reduction of lead time.
4. Improved machine utilization.
5. Improved customer service – better delivery performance and reduction in the number of late orders.
6. Increased sales.

Sl.No.	Work Element Description	Percent of the total time
1.	Move to work centre	16.7
2.	Wait in queue	51.6
3.	Being Set-up at work centre	6.3
4.	Being processed at work centre* (run time)	15.1
5.	Wait to be moved to next work centre	10.3

MRP highlighted the fallacy of applying reorder point inventory control techniques for dependent demand inventory items. MRP also showed that hierarchical planning with multiple levels of representational detail of the manufacturing process (RRP ® aggregate planning ® MPS ® MRP ® CRP ® PAC) is a highly effective way of coping with the complexity and variety of manufacturing systems. Another important lesson from the MRP approach is that through the use of a computer and a manufacturing database, the work of people in many different manufacturing functions can be better coordinated and also volumes of common information can be shared by these functions.

However, MRP is, by no means, the ultimate manufacturing planning and control system. The key failing of MRP is that it does not address (and does not even attempt to address) the design of the manufacturing process for the product(s). It accepts the actual manufacturing process, or the production methods used, and the product structure (design of the product) as they are, and uses what is primarily a paperwork system of planning and control. No attempt is made to either redesign the production methods or the product structure. In this context, consider what is generally referred to as the "push system" of linking work centres. MRP is based on the push system, and in the push system, when the work on s lot/batch of items (say, components in process) is completed at a work centre, the lot is pushed to the next work centre where it waits in a queue until the work centre is free and the lot is selected to be worked on at that centre. In this context, the break-up of the time a typical job spends in a plant is given in Table II. From the table, it is clear that a great portion of the time is spent waiting in queues. In some cases, it may even be more

Table II: Break – up of Time a Job Spends in a Factory

* Run time includes inspection and other such (unavoidable) work operations.

than what is given in the table. Thus the manufacturing lead time of the component is also very significantly affected by the queue, that is, the amount of work that builds up in front of a work centre. With a given capacity, a work centre can only perform a fixed amount of work per hour, or per shift. If work flows to this work centre faster than this rate, without a change in the capacity, then the queue will become longer. This points out the need to design (redesign, in many cases) the production methods to facilitate unhindered flow of material through the manufacturing processes. The flow is most affected by the amount of imbalance between production operations. If stress is given on process balance and the operations are designed such that the operation times are approximately equal and all the operations finish within a given cycle time, then the amount of work build up can be effectively kept under control. The next important element is the layout of the shop. It affects the move time, which, the student will notice, is also fairly significant.

The product structure also affects the manufacturing lead time of the product. The concept of BOM has tended to encourage the development of numerous stages in the build up of the product. The greater the number of stages, the greater will be the move time, in-process waiting time, and the time spent by components in storage waiting for other components. These and other issues stress the importance of the design of the manufacturing process and the end product, and in recent times, the emergence of JIT has focussed attention on the need to look at the basics of manufacturing engineering.

3. JUST – IN – TIME PRODUCTION SYSTEM

Just – in – time production system (or JIT) is also known as the Toyota Production System, since it was developed in Japan at the Toyota automobile plant in the 1960's. It is currently being used by a variety of industries, including automobile, aerospace, machine tools, and computers and communication system manufacturing industries. The philosophy and full intent of JIT is expounded by the following definition of JIT* :

JIT is a disciplined programme for improving overall productivity and reducing waste. It provides for the cost – effective production and delivery of only the necessary quality parts, in the right quantity, at the right time and place, while using a minimum amount of facilities, equipment, materials, and human resources. JIT is dependent upon the balance between the supplier's flexibility and user's stability. It is accomplished through the application of specific techniques, which require total employee involvement and teamwork.

Many people consider JIT as a narrow shop-floor based technique concerned with making very small batches just in time for the next production process using a 'pull system' of production scheduling called 'kanban'. To them JIT is just the use of the kanban technique. However, it should be clear to the discerning student (in the light of what we have discussed) that making of very small batches just in time cannot be done unless accumulation of inventory between successive operations is removed and unhindered flow of material is achieved. This calls for a highly integrated production, sales and distribution system leading to continuous flow through the whole supply chain. This broad view of JIT is held not only by the Japanese but also by some Western companies like IBM, who have successfully implemented the JIT production system.

These companies use the term 'continuous flow manufacturing' for JIT. Kanban technique is the most visible part of JIT, and thus this misconception. However, before we can discuss the kanban technique, we must identify the basic differences between the push and pull systems of linking work centres. We will also discuss repetitive manufacturing, as opposed to batch production used in the push system (recall lumpy demand), to realize its implication for the JIT production system.

3.1 Push Vs Pull System of Linking Work Culture

The basic objective of the pull system is to produce the right components/subassemblies needed, at the time needed, and in the quantities needed, or that the right component/ subassembly should be at the right place at the right time. The primary goal is the elimination of all kinds of waste in the production system. Inventory is also a source of waste, since there is no value added by allowing the accumulation of inventory between work centres. Thus if one gets the component/subassembly to the next work centre just in time for the next step of production, then the inventory between the production stages is reduced. The attainment of this objective of minimizing the stock accumulation between successive manufacturing is enabled fundamentally by action on two fronts, namely, redesign of production methods, and use of an information system for production scheduling supported by the kanban technique. This is shown in Fig. 2.

[FIGURE 2 MUST GO HERE]

Instead of pushing a lot/batch of completed (processed components/subassemblies to the next work centre, the pull system adopts a reverse method in which the following work centre, or operation, withdraws the components/subassemblies from the preceding work centre, or operation. To understand the reason for this, let us consider our example of manufacture of an automobile. In this case where the end product of the company is an assembled car, only the final assembly line is the work centre which knows the exact timing (of receipt) and quantity of the required parts (in this case, major assemblies like engine, transmission, suspension etc.). Therefore, the final assembly line instructs the preceding work centre to supply the necessary parts, or in other words, it goes to the preceding work centre to obtain the necessary parts. The preceding work centre then produces the parts withdrawn by the following work centre (the final assembly line, in this case). Similarly, for the production of these parts, the preceding work centre obtains the necessary parts from the work centre preceding it, and so on.

The student will realize that this simple method of production scheduling can only be achieved if the production methods are redesigned to ensure smoothened unhindered production in which the parts (or components and subassemblies) are manufactured quickly and with the minimum amount of non-productive time on account of in-process waiting and set-up, a balanced production system in which all jobs (operations) finish within the cycle time, and multi-skilled workers and flexible facilities. Such a production system can achieve a smooth, synchronized flow of small lots of parts at a uniform rate.

3.2 Repetitive Manufacturing

In addition to the pull method of linking work centres, quick and inexpensive set-ups, multi-skilled workers and flexible facilities, one of the identifying characteristics of JIT production system is a pre-set uniform production rate. The JIT system works best when the production rate is kept level, and inside the plant, the objective is to achieve a smooth, synchronized flow of small lots of material at an uniform rate. Thus the implementation of JIT requires that the lumpy demand of batch production (please see unit 8) be transformed to a leveled demand to enable the uniform rate of production of repetitive manufacturing. Please recall 'user's stability' in the definition of JIT; repetitive manufacturing ensures user's stability and JIT is thus dependent on repetitive manufacturing.

Repetitive manufacturing is 'the fabrication, machining, assembly and testing of discrete standard units produced in volume, or of products assembled in volume from standard options' to enable the repetitive manufacture of components and sub-assemblies (of the product) and the product (every day and every week during a part of the planning horizon) at a constant rate. Repetitive manufacturing is characterized by long production runs, or flow of parts. Thus the end result of rigorously applying the JIT approach and of using the JIT production method is to move a manufacturing system away from batch production, characterized by lumpy demand, towards repetitive manufacturing with uniform production rate and leveled demand. Repetitive manufacturing falls in between batch production and mass production (in the product variety and production volume grid), and is the result of emulation of mass production for manufacture of large batches of products, in the automobile and appliance industries.

3.3 'Kanban' System

Kanban is the Japanese word for 'card' or 'signal'. Kanban system is a system of scheduling based on the pull system and uses kanbans, or cards, sent from a downstream operation to trigger production (or supply) at an upstream operation (or by the supplier). As noted earlier, JIT is often considered synonymous with this system, and that this system requires a stable, repetitive manufacturing environment. The pull system looks at the manufacturing process from the perspective of the finished (or end) product. The production controller works on the basis that his/her orders represent firm customer requirements. The controller checks whether sufficient components and/or sub-assemblies/assemblies are available at the highest level of the product structure, as for example on the final assembly line, to produce the finished product. If they are, the product is produced. However, if they are not, the necessary components and/or subassemblies/assemblies are pulled from the preceding work centre. A similar procedure is followed right back through each production stage, and extending all the way back to include outside vendors.

[FIG. 3 MUST GO HERE]

The kanban system generally uses two kanbans, or cards, namely, the move and production kanbans. The operation of the system is shown in Fig. 3. The kanban system focusses on making only what is needed to replace components and/or subassemblies soon after they are used. The use of subassemblies from their container* triggers the issue and delivery of the move card on that container to the source work centre's IN station. The removal of a container (with components or subassemblies) from its OUT station (and the transportation of the container to the IN station of the succeeding work centre, as shown by full line in Fig. 3) releases a production card to the source work centre, and another lot of components is produced to fill one container. This is delivered to the OUT station when completed, usually within one to three days. The use of components in this work centre's IN station to make the lot, in turn, triggers move cards and production cards in upstream work centres. In this manner, all production in the work centres is geared to making only what is used.

Kanbans, or cards, constitute a simple and flexible system of scheduling that promotes close coordination among work centres in repetitive manufacturing. The amount of material in the system is controlled by having a prescribed number of containers in circulation at any time. A user work centre 'pulls' containers from a supplier work centre with a move card. Thus, a supplier work centre cannot 'push' a container out to a user work centre until the user is ready, and its readiness is indicated by the arrival of the move card. Moreover, the supplier work centre cannot produce until it receives a go-ahead in the form of a production card.

There are clearly some limitations to the kanban system. Kanban is intrinsically a system for repetitive manufacturing. Also, since each daily assembly schedule must be very similar to all other daily schedules, it becomes essential to be able to freeze the MPS for a fixed time period, generally at least one month. The final assembly schedule must, thus, be very level and stable. Kanban will not succeed without modification in a batch production (non-repetitive manufacturing) environment. It requires a leveled schedule, standard containers and very strict discipline. It may be considered inflexible in that it cannot easily respond to irregular changes (in the MPS) and to large unexpected changes in market demand. Also, the implementation of kanban scheduling requires great cooperation from outside suppliers (recall supplier's flexibility in the definition). Moreover, from the perspective of the manufacturing process, it places emphases on process technologies, such as product-based flow configurations, and may, therefore, require considerable investment of time and money in developing new production methods, procedures, jigs, fixtures, etc. and perhaps even new capital equipment.

However, if well implemented, kanban stimulates productivity improvement, reduces inventory and manufacturing lead-time, and within the constraints of the product design and manufacturing system design, allows the plant to respond to predictable small market variations. Moreover, kanban is a simple system of flow control with a visible means of inventory control. It is simple to understand and involves very little paper work as compared to a typical MRP system.

3.4 Core of JIT

The core of JIT consists of the following three parts:

1. Flow
2. Flexibility
3. Developing the chain of supply.

The contributors to flow include layout, material handling, cellular manufacturing, a focus on process balance, and use of a number of small machines rather than one large machine. The production steps must be tied closely together. The layout must be like a tree, where the final assembly is the trunk and the subassembly and component manufacturing steps flow smoothly into the trunk like the roots of a tree do. The order quantities of each kanban must take the same (or about the same) amount of time to manufacture. This ensures that each production step is in balance.

Flow is supported by flexibility. The time required to change over from the manufacture of one part to another must be kept to an absolute minimum, so that each production step can readily adapt to new orders. The change-over time of a given production step must also be in balance with the other production steps to avoid bottlenecks. Many Japanese companies use flexible automation to support JIT, but flexibility is more often gained by use of very small batches (made possible by reduced set-up or change-over times), flexibility in the workforce (made possible by training the workforce to be multi-skilled), and availability of spare physical capacity.

Having developed flow in manufacture, companies, who have successfully implemented JIT, emphasize developing the chain of supply. This includes getting suppliers to deliver to the point of use, frequent delivery in small lots at precise times, and giving necessary data to suppliers to allow them to do so. At the manufacturer's end, this includes 'making today what is needed tomorrow', and rate – based production scheduling. Closely associated with this is the great attention paid to developing good forecasts and production plans. MPS is prepared very carefully and used to drive JIT manufacturing.

3.5 Enabling of JIT

The striking aspect of JIT implementation by the Japanese companies is the extent to which the necessary preparatory steps are taken to enable JIT to occur. The following are the important enablers of JIT:

1. Maintenance of plant and equipment

This removes the need for buffering against machine breakdowns. In the Japanese companies, the routine maintenance tasks were handed over to machine operators, and the role of the maintenance function included maintenance planning, major repairs, training of machine operators, and ensuring that the new machines are properly installed and fully debugged. Thus the implementation of productive maintenance and TPM is an enabler of JIT.

2.Management of product and process quality

Minimization of scrap, rejections and rework also removes the need for buffering against poor product quality and quality losses. Quality assurance (the implementation of a quality system like ISO 9000, or QS 9000), statistical process control, and use of participatory approaches like 'kaizen' and quality circles are necessary pre-requisites and implementation of TQM is an enabler of JIT.

3. Design of manufacturing process and selection of production equipment

Although flexible automation is widely use, the selection of equipment should lay greater stress on having appropriate and properly used plant and equipment rather than going in for unnecessary and heavy automation. Also, instead of having special purpose machines and a few large 'super' machines, it may be better to use general purpose machines and have many small machines. This will enable a high degree of routing flexibility. Moreover, the stress should be on developing flexible tooling and simplified set-ups.

4. Development of people and training of the workforce

The steps under this head include the following:

(i) development of teamwork,

(ii) education, particularly of supervisors and also of operators,

(iii) on-the-job training to develop appropriate levels of skill in the workforce, and

(iv) flexibility of work practices and development of flexibility in skills, through multiskilling.

A necessary pre-requisite for these is a management which understands manufacturing systems and production methods.

5. Design for manufacture and wide use of modular designs

Design for manufacture and assembly reduces much of the uncertainties in manufacture, and the use of modular design enables the production of a large variety of finished products, while maintaining simplicity in manufacturing. These two together contribute to greater flow and flexibility in manufacture and at the same time maximizing responsiveness to customer needs.

6. Provision of adequate technical support

7. Development of management controls

Management controls are essential for minimization of machine breakdowns and quality losses in the form of rejections, scrap and rework.

As a philosophy, JIT's primary goal is the elimination of waste in the production system. Rework and scrap, and loss of production capacity due to machine breakdowns are very visible forms of waste and should quite obviously be eliminated. However, as a source of waste inventory is less obvious. The name just-in-time epitomizes the objective of minimizing inventory and this is done by getting the material to the next work centre, or (internal) customer, just in time for the next production step. This way the inventory build-up between production stages (work-in-process, or WIP, inventory) is minimized. Moreover, the JIT philosophy carries with it an objective of continuous improvement. The goal is to be getting better, and the way to measure a plant's performance is to see how little WIP inventory it requires to operate. Since inventory protects a plant in case of problems, in essence it hides the problems; so they go unnoticed, and unsolved. Problems must be found before they can be solved, and a sure way to find these problems is to reduce the WIP inventory.

4. MIXED STRATEGIES

In section 2.3, we have noted that although MRP II is a complete manufacturing planing and control system and is also widely used in diverse kind of industries, it is by no means perfect and has a few basic shortcomings. The first shortcoming is the result of its being based on the 'push', rather than the 'pull', system of linking work centres. Accordingly, although the use of MRP* is quite logical, particularly in instances of batch production characterized by lumpy demand (as opposed to repetitive manufacturing where JIT is the obvious choice), considerable advantages can be derived if some of the features of JIT production system are incorporated, while maintaining the general structure of the MRP system. In this section, therefore, we will first discuss a mixed strategy in which elements of JIT production are introduced into the MRP system.

The second shortcoming of MRP is that it is a 'poor' scheduler, that is, in MRP, the scheduling of shop order releases is quite ineffective resulting in a situation where rescheduling and frequent changes to the MPS are necessitated, notwithstanding the use of hierarchical planning of capacity. This is primarily because MRP (i) has rigid lot sizing rules and does not permit splitting of lots and sending ahead partial lots, (ii) lacks a finite scheduling logic and does not explicitly recognize the existence of 'bottleneck' work centres and give them due consideration during scheduling. Optimized Production Technology (OPT) is a new technique of production planning and scheduling which explicitly recognizes the existence of such constraints and schedules to maximize the utilization of these work centres. Thus the other mixed strategy of importance is combining MRP and OPT, and this will also be presented and discussed.

4.1 MRP with Elements of JIT

An example cited in the book by Vollmann, Berry, and Whybark (Manufacturing Planning and Control Systems, Galgotia Publishers (P) Ltd., Delhi, 1998, p 284) is reproduced below:

"…. a JIT approach used by a firm that has successfully implemented MRP. The company wanted to use JIT for some of its products, while maintaining the MRP system. The firm schedules these products in daily buckets using firm planned orders (FPOs). The FPOs will, of course, generate dependent demand for components. The firm does not use a stockroom for the components, the FPOs are never converted into scheduled receipts and the components are not issued to any shop orders. The FPO data are communicated to the floor for build purposes and are used to sequence the assembly line. As assembled products are completed, they are received into inventory using normal procedures for MRP inventory transactions. These receipts are also netted against the FPO quantities. Consequently, requirements for corresponding components are also reduced".

This example clearly shows that since many companies have a diversified product range, even in manufacturing establishments engaged in batch production, there do exist some products which have a more regular and continuous demand. In such cases, leveling of demand is feasible and the final assembly can be scheduled on a daily, or weekly, basis, with each daily assembly schedule being quite similar to other daily schedules. The manufacture of these products can be scheduled on a 'pull' basis, while maintaining the general control and paperwork of the MPR system. This example points out that the use of such a mixed strategy can help reduce the WIP (component) inventory level drastically.

Many Indian manufacturing companies are seriously considering the use of the JIT concept in purchasing. In JIT purchasing, the manufacturer prunes the number of vendors (to work closely with supplier firms, it is important to limit the number of suppliers) and treats a vendor exactly like another work centre of the plant. The manufacturer needs to achieve, to whatever extent possible, a stable schedule. Then it works in close cooperation with the vendors, gives them excellent information and instructs them to deliver small batches of material more frequently than before. In many cases, the stockroom inspection process is bypassed and the material is delivered directly to its point of use. Herein again, an example cited in the book by Vollmann, Berry, and Whybark (on page 277 under JIT in Purchasing) is reproduced below:

"A computer disk drive manufacturer has a system, wherein, each day at about 4. P.M., an assembly line worker calls (telephones) a key vendor and tells it how many of a particular expensive item to deliver the day after tomorrow. The units delivered never go into any stockroom for into any inventory records. They are delivered directly to the line without inspection and are assembled that day. The vender is paid on the basis of deliveries of finished disk drives into finished goods inventory. Stability is handled by the customer providing the vendor with weekly MRP projections, using time fences to define stability guarantees".

The use of JIT in purchasing helps overcome poor vendor deliveries and gives the manufacturer much greater control over inputs to its manufacturing processes. Where the cost of transportation is significant (and with frequent deliveries, it may become significant) the manufacturer can request its important vendors (vendors of critical components for its products) to locate their factories near its plant. The vendor will readily agree to such an arrangement if a significant, and large, fraction of its total output (output of the vendor factory) goes to just one customer. Obviously, only very large companies can have important vendors build their factories near their plant. In conclusion, use of JIT in purchasing, while otherwise maintaining the MRP system, can, and does, pay rich dividends in the long run.

4.2 MRP With OPT

OPT was developed in the 1970's by Eliyahu Goldratt primarily as a method of increasing the output of a plant, whose capacity constraints prevented it from fully meeting demand. Like JIT, OPT also seeks to reduce the WIP inventory by synchronizing the flow of items through the plant. However, it does not also rely on having downstream work stations pull items from feeder stations to make their rate of flow equal to the rate at which they are used in the final assembly schedule. Instead, OPT seeks to maximize the utilization of the 'bottleneck' work centres and develops coordinated schedules to synchronize the flow of dependent items so that the flow rates are matched to the production rate at the bottleneck. It is a computerized modeling and simulation technique capable of determining schedules that will maximize throughput and minimize inventory for a given production process, containing its own set of operational constraints. We will present a brief exposition of OPT before discussing the strategy of integration of MRP with OPT.

4.2.1 *Optimized Production Technology (OPT)*

It is assumed that the plant makes discrete assembled products and that the demand exceeds the capacity of the plant. Certain critical work stations, or bottlenecks, will limit the production rate of some components of the product(s). Since the products must contain these components, the bottlenecks actually limit the rate at which products can be made. The number of all other components needed (in the products) is determined by the number of components that must flow through the bottlenecks. The use of the non-bottleneck work stations beyond the amount required to match the bottleneck–produced components will produce needless WIP. Thus a large part of the OPT logic is directed towards identifying bottlenecks, ensuring that these resources are fully utilized, and scheduling the use of the non-bottlenecks in synchronization with the bottlenecks (that is, the rate at which the plant is capable of making complete products). Thus, the application of OPT principles involves the following three steps:

***Step 1*:** The company must identify its bottlenecks.

***Step 2*:** It must then schedule and operate to see that these bottlenecks are fully utilized.

***Step 3*:** It should schedule the non-bottleneck operations so that they keep the bottleneck operations well supplied while holding the WIP inventory at a low level.

The bottlenecks are easily identified since they will have the largest quenes if the demand exceeds capacity, or otherwise they will be the busiest work centres. During the stage of planning, the bottlenecks can be identified by calculating the load on the work centre in standard hours (= S (forecast monthly demand x number of components specified in the BOM x standard hours of work per component) and checking whether it exceeds the work centre capacity. Thereafter scheduling of these critical resources is done to ensure that these bottlenecks are fully loaded. Relatively large lot sizes (process batch sizes) are run on the bottlenecks to save set-up time and provide more run time. The non-critical resources will have excess capacity and will provide greater flexibility in scheduling. The components that will flow to the critical resources (bottlenecks) can be loaded on the preceding non-bottleneck operations by backward scheduling. In this regard, it must be realized that the lead time is a function of the lot size rather than some pre-established fixed estimate. This implies that lots may be split. This brings up one of the important principles of OPT scheduling which is that 'the transfer batch may, and should, differ from the process batch'. This can significantly reduce the lead times from what they would be if each operation had to wait until the prior operation had processed the entire lot before it could begin. Thus, additional set-ups may be scheduled on some operations to keep the lot size small so that lead-times and WIP are also small These extra set-ups will not result in overall increase in cost because these resources have excess capacity.

OPT, as a philosophy, embodies nine basic rules of manufacturing that differ significantly from the traditional practice. The nine rules are as follows:

1. Balance flow, not capacity,

2. The level of utilization of a non-bottleneck is not determined by its potential but by some other constraint in the system.

3. Activation and utilization of a resource are not synonymous.

4. An hour lost at a bottleneck is an hour lost for the total system.

5. An hour saved at a bottleneck is a mirage.

6. Bottlenecks govern both throughput and inventories.

7. The transfer batch may not, and should not, be equal to the process batch.

8. The process batch should be variable, not fixed.

9. Schedules should be established by looking at all the constraints simultaneously. Lead-times are the result of a schedule.

Based on this philosophy, different schedules are prepared for critical (bottleneck) and non-critical resources. The first step in the algorithm is the preparation of a detailed product network with the help of the MPS, the BOM files and the routing files. This is then compared with the resource description and the required resources is divided into two parts – critical and non – critical. Serve schedules for non-critical resources start with due dates, assume infinite capacity and are backward scheduled. The OPT, or spilt, schedules for critical resources assume finite capacity and are forward scheduled. A fundamental principle of OPT scheduling is that the bottleneck operations (resources) are of greater concern, since increased throughput can only come through better capacity utilization of the bottleneck resources. OPT calculates different batch sizes depending on whether a work centre is a bottleneck, or not. It also follows that the batch size for one operation on a part may be different for other operations on the same part. The key to lot sizing in OPT is distinguishing between a transfer batch (the quantity that moves from operation to operation) and the process batch (the total lot size released to the shop). In essence, no operation can start until at least a transfer batch is built up behind it. Also, whatever the build up behind the work centre, it only produces a transfer batch unless the finite scheduling routine calls for multiple batches. The basic idea is to move material as quickly as possible through the non-bottleneck work centres until it reaches the bottleneck. There work is scheduled for maximum efficiency (large batches). Thereafter, work again moves at maximum speed to finished goods. This results in very small transfer batches to and from the bottleneck, and a large process batch at the bottleneck.

4.2.2 *Integration of MRP and OPT*

The OPT concept of scheduling can be used in association with MRP II, and a software can be designed to integrate the front and back ends of MRP II with the OPT scheduling algorithm. The integration of MRP II and OPT is shown in Fig. 4.

[FIG. 4 MUST GO HERE]

As shown in Fig. 4, the 'FRONT END' generates the master production schedule using the intermediate range forecasts and resource requirements plan, just as in MRP II (please see Fig. 1). This is used as input by OPT. Moreover, the MRP data files, such as the bill of materials, routing information and work centre information files, are taken as input to the OPT scheduling module in the 'ENGINE'. The reports that are generated in the 'BACK END' are typical MRP reports, which constitute shop – floor control and vendor control systems of production activity control (PAC). The outputs of the integrated systems are as follows:

1. Order release notices.
2. Report on inventory status.
3. Report on available capacity.
4. Report regarding planned order releases in future periods.
5. Rescheduling notices.
6. Performance report.
7. Exception report.

The closed loop and feedback concepts of MRP II are used to update inventory status and work centre status files.

A brief description of the various files and modules, shown in Fig. 4, are as follows:

PRODUCT NETWORK: This is formed by combining the bill of materials (BOM) file, routing files and the master production schedule (MPS). Customer orders are linked to the final assembly process, which, in turn, is linked to the completed components, detailed manufacturing steps, and raw materials.

RESOURCE DESCRIPTION: Additional data typically included in the OPT files are capacities, maximum inventories, minimum batch quantities, order quantities, due dates, alternate machine routings, labour constraints and other data typically used in finite loading models. Such data would be part of the resource description.

BUILDNET: This routine combines the product network and resource information to form the OPT/SERVE master engineering network.

INITIAL SERVE ANALYSIS: The SERVE module uses this information to backward schedule the order due dates specified in the product network. SERVE assumes that infinite capacity is available at each resource. The system incorporates a rough-cut capacity planning routine. Lot sizes at this rough-cut stage are based on the lot – for – lot rule. The resultant capacity needs, when divided by the number of weeks in the planning horizon, are the average capacity requirements for each resource. When divided by the resource capacities, the result is the average expected loads. Thus a report showing utilization of each resource is developed. The purpose of this analysis is the identification of bottleneck, or critical, resources. Those near or more than 100% utilization are identified as bottlenecks, and this information is important to the split operation performed next.

SPLIT: This module separates the master engineering network into two sections. The lower section (SERVE network) includes all operations that precede the bottleneck, and all succeeding operations. The upper section of the engineering network is scheduled using the OPT module. The OPT forward scheduling is based on the algorithm developed by Goldratt and it takes the finite capacity of the resources into account. Once the critical part of the network has been scheduled, the non-critical, or the lower, part of the network is scheduled using SERVE.

SERVE: This is a backward scheduling procedure, which assumes infinite capacity of the resources. In the initial use of SERVE (initial SERVE analysis), the due dates used are the order due dates. At this stage of the algorithm, the due dates used are determined by the OPT module for the bottleneck resources, in the critical section. In particular, the purpose of this module is to develop schedules which will make the material available for the first operation in the critical path of the network. Referred to as OPT/ SERVE schedules, these involve the composite schedules developed using the finite forward loading OPT module on the critical part of the network, followed by infinite backward loading of the non-critical part.

5. CONCLUDING REMARKS

In keeping with the title of the unit, we have discussed, in this unit, manufacturing resources planning (MRP II) and just – in – time production system (JIT), which are applications of the push and pull systems of manufacturing planning and control. Continuing from unit 8, we first recapitulated some important aspects of material requirements planing (MRP), and noted that in addition to planning and control of dependent demand inventory items, MRP is applied to situations characterized by the existence of (I) lumpy demand (of products), (ii) two lead-times, namely, both manufacturing and procurement, and (iii) common use items. The basic MRP record has also been presented and discussed adequately. This has prepared the ground for the discussion of the evolution of MRP II from MRP. MRP II is much more than just an obvious and natural extension of MRP. Instead of being just a technique, or algorithm, MRP II is a complete manufacturing planning and control (MPC) system. It has many benefits, but at the same time, it has some shortcomings. The discussion of these shortcomings led us to the pull system of linking work centres and JIT. The pull system and repetitive manufacturing have been discussed adequately before presenting an exposition of the 'kanban' system. The core and enablers of JIT have been enumerated and discussed.

After completing the discussion of MRP II and JIT, some mixed strategies of manufacturing planning and control have also been presented and discussed. MRP II is a poor scheduler, and the recognition of this fact has brought up the need to introduce and discuss optimized production technology (OPT). Under mixed strategies, the use of MRP II with JIT and MRP II with OPT have been suggested and discussed.

Under batch production conditions, characterized by lumpy demand, MRP II should be used as the chosen manufacturing planning and control system. Under these conditions, it is the most effective. However, as noted earlier, MRP is a poor scheduler and to overcome this defect, the use of OPT in the 'ENGINE' part of the MPC system is recommended, with MRP II being used in the 'FRONT END' and the 'BACK END'. This will help the user to overcome this defect of MRP II to a very large extent. Further, if either a repetitive manufacturing environment exists, as in the automobile and appliance manufacturing industries, or the batch production situation can be transformed into an environment with a stable and leveled demand (with a uniform rate of production and leveled demand), then the use of JIT is much more effective. But, in this context, it must be noted that JIT is a disciplined programme, and in addition to manufacturer's stability (discussed above) and supplier's flexibility, it requires total employee involvement and teamwork. Flow, flexibility, and development of a chain of supply form the core of JIT. But ensuring these three core elements is not sufficient. To enable the implementation of JIT, the manufacturer has to take up developmental and improvement activities in maintenance, quality, manufacturing processes and production equipment, product design, human resource development and training. Thus the enablers of JIT include, among others, TQM and TPM, and it is wise to remember that the goal of zero inventory cannot be attained without zero breakdowns and zero defects.

Certain elements of JIT, like JIT purchasing, can be incorporated in a batch production environment using MRP II, and MRP with JIT may be quite useful and effective in bringing down inventory levels, particularly WIP inventory. Thus MRP with JIT is a mixed strategy with great promise.

6. BIBLIOGRAPHY & SUGGESTED TEXT BOOKS FOR FURTHER READING

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* The number of time periods in the record is called the planning horizon. Time periods can vary in length from a day, or a week, to a month, or even longer. A time period is also called a time bucket.

* In unit 8, we had noted that master planning is part of the strategic planning exercise which checks the available resources – technology, type of equipment, skills, machine-hours and man-hours – against the requirements of products and product demands of the long range forecasts.

* The term routing is used to refer to process planning streets. Thus the routing file contains the process planning data for all in-house manufactured components, and assembly operations (subassemblies and the final assembly). The work centre status file gives the actual status of all work centres – machines/equipment and assembly stations.

* This is the word – for – word English translation of the Japanese definition. For this reason, the language seems a little odd. We shall use this definition in the following subsections for development of the JIT philosophy and essentials of JIT production system.

* Each item-component or subassembly – has its own container, and the container contains the required number of the component/subassembly.

* In this section, MRP will be used in a generic fashion and will denote MRP II.