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MATERIAL REQUIREMENT PLANNING

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Material requirement planning is not only a technique for planning “material” requirements. It is also a logic that relates all the activities in a company to customer demands. People can manage all the resources in a company by using MRP logic together with data processing in other areas. This entire system is called a Manufacturing Resources Planning System, or MRP II. With the introduction of technological enhancements such as open systems platforms and client/server architecture, MRP II systems are now evolving into Enterprise Resource Planning Systems (ERP). An ERP system plans not only the allocation of manufacturing resources but also other resources, and has applications in service as well as manufacturing industries. In this book, we concentrate our discussion on manufacturing.

Nature of Demands

All systems are implemented to satisfy customers’ demand. There are different sources of demand for a product and its component items. Some item requirements are determined by the needs of other items while others are specified by customers. The former requirements also come from customers, but indirectly. Item requirements can be classified as dependent and independent demands.

- *Independent demand*

Demand for an item that is unrelated to the demand for other items. Demand for finished goods, parts required for destructive testing, and service part requirements are examples of independent demand.

- *Dependent demand*

Demand that is directly related to or derived from the bill of material structure for other items or end products. Such demands are calculated and need not be forecasted.

A given inventory item may have both dependent and independent demand at any given time. For example, a part may simultaneously be used as a component of an assembly and also sold as a service part. Production to meet dependent demand should be scheduled so as to explicitly recognize its linkage to production intended to meet independent demand.

MRP Input Data

MRP is to translate the requirement of end products stated in MPS into the requirement of components and materials. MPS is the most direct input to MRP. Other input data include inventory status, bill of material (BOM), fundamental data in item master file, and shop calendar.

- *MPS*

MPS is the schedule for end items. It states the quantity and timing of production of specific end items. Master production scheduling is a procedure to determine the production schedules and the available-to-promise (ATP) of the end products. Based on MPS, MRP calculates the replenishment plans from the items in the level below the end products down to the raw materials

- *BOM*

BOM describes the structure of the products. It states, from level to level, the components needed to make the parent items. By using BOM, the requirements of end products are expanded to include the requirements of the components, and hence the requirements of all the lower level materials.

- *Inventory Status*

In expanding the lower level requirements, what we obtain are gross requirements. Gross requirement is not the real requirement. Net requirement is calculated by subtracting the inventory from the gross requirement. Since MRP is time-phased, both on-hand and on-order inventories are considered. On-hand inventory is the present inventory; on-order inventory is the future inventory, and has to be represented by both quantity and receiving date.

- *Fundamental data in item master file*

The attributes of all items including raw materials, works-in-process, semi-finished goods, or finished goods, are expressed in the item master file. Part number, lead-time, safety stock, lot-sizing rule, low level code, etc. are required by the MRP processor. Low level code is used to determine the sequence of MRP calculation. Safety stock and lot-sizing rule are used to decide the quantity of the material replenishments. Lead-time is used to decide the time to replenish the required materials.

- *Shop Calendar*

MRP systems are time-phased. Time bucket is an interval used to break time into discrete chunks. The length of a time bucket is defined according to the characteristics of a business. Commonly used time bucket includes week and day, i.e., numbered-week calendar (00-99) and numbered-day calendar (M-day calendar, 000-999). Planning horizon is the amount of time the master schedule and MRP extend into the future. The planning horizon should cover at least the cumulative lead-time to produce a product.

Integrity of MRP Input Data

Data integrity means completeness, timeliness and accuracy. Input data should be provided by related people or machine in time and accurately. If required data is not entered into the system properly, MRP will produce nothing but garbage. MRP is supposed to provide users with credible data but errors destroy the credibility and turn the MRP into a More Ridiculous Plan.

Discipline, attitude and training are the keys to data integrity. Education of employees is the most important factor. Information or data processing auditing must occur regularly to keep the data valid. Management must accept the responsibility for the training, discipline and motivation of everyone who handles data. All the employees handling data must assume responsibility for quality of data handled.

The objective of data integrity is to find and eliminate the causes of errors. Companies using MRP/ERP systems should incorporate auditing, self-checking and self-correcting features into the systems.

Automatic data integrity checks of input data include existence test (e.g. part number,

transaction code), reasonableness test (e.g. abnormal quantity or unit-of-measure), diagnostic test (e.g. prior transactions required), internal detection (e.g. negative inventory balances), and purging residences of undetected errors (e.g. closing out old shop or purchase orders)

MRP Procedure

MPS procedure consolidates the independent demands of forecasts and customer orders to determine the requirements of the end products in each time bucket in the planning horizon. After netting the on-hand and on-order inventory, and offsetting the lead-time, the production schedule of the end products, MPS, is determined. In MPS procedure, the available-to-promise (ATP) is also determined. MPS is then fed into the MRP procedure to determine the requirements of the lower level components and raw materials.

The gross requirements of components are determined by calculating the planned order releases (POR) of the parents via single level BOM explosion. The net requirements are calculated by subtracting the on-hand inventory and scheduled receipts (on-order) in each time bucket. After the consideration of lot-size, the net requirements are transformed into the planned order receipts. Planned order receipts appear in every period. Lead-time offsetting shifts the planned order receipts backward and derives the POR which are the MRP result of current item. The MRP procedure continues to explode the POR to obtain the gross requirements of its components. The MRP repeat the procedure until the POR of all the items are determined. The flow chart of the MRP procedure is described in Figure 3.

The net requirement in a period is determined in MRP procedure by the following formula,

$$\text{Net requirement} = \text{Gross requirement} - \text{Available inventory}$$

The available inventory for the first period is

$$\begin{aligned} \text{Available inventory} &= \text{On hand inventory} + \text{Scheduled receipts of the first period} \\ &\quad - \text{Allocations} - \text{Backorders} - \text{Safety stock.} \end{aligned}$$

And, for the other periods

$$\text{Available inventory} = \text{Projected available balance at the end of last period}$$

+ Scheduled receipts of the current period

If the calculated net requirement is positive, then it is the net requirement of that item in that period. In this case, the projected on-hand balance at the end of that period is less than the safety stock, and the projected available balance is the projected on-hand balance plus the planned order receipt in that period. If the calculated net requirement is negative, then it is the projected available balance at the end of that period.

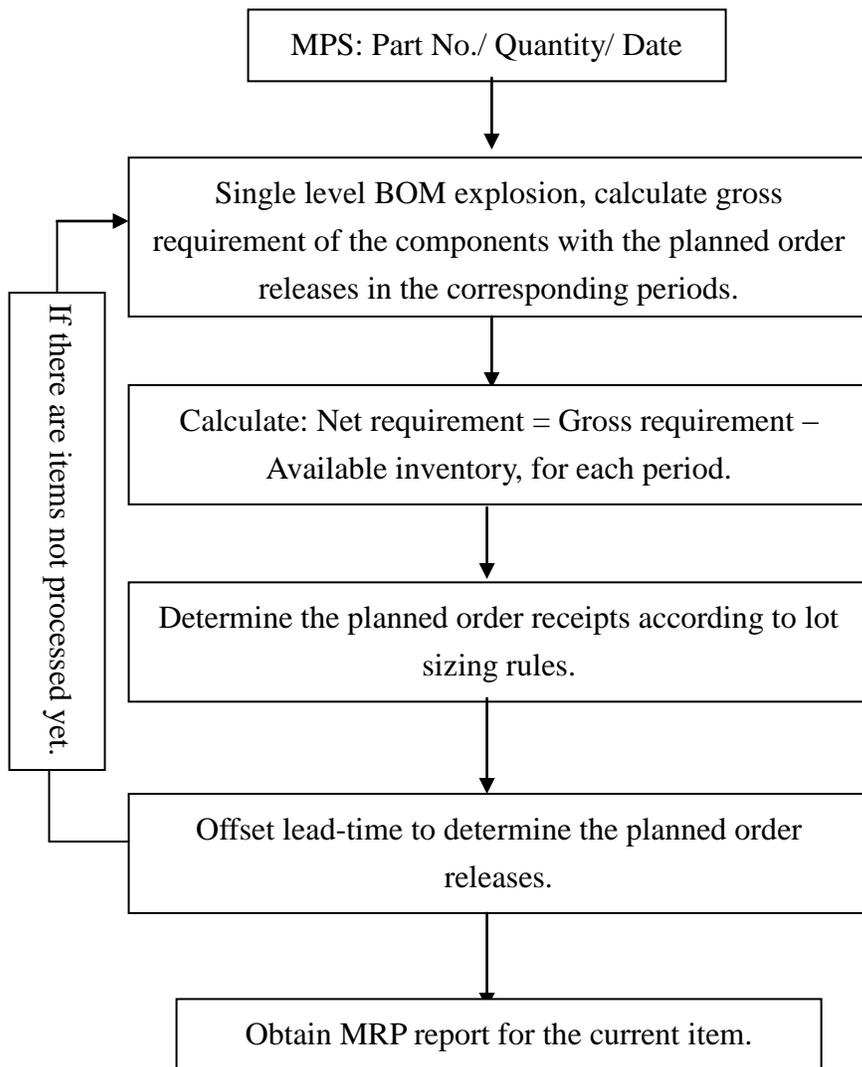


Figure 3: MRP Procedure

Let us examine a simple MRP case first.

MRP Case 1: Sunglasses Sets

Suppose a goggle sunglasses set is illustrated as in Figure 4.

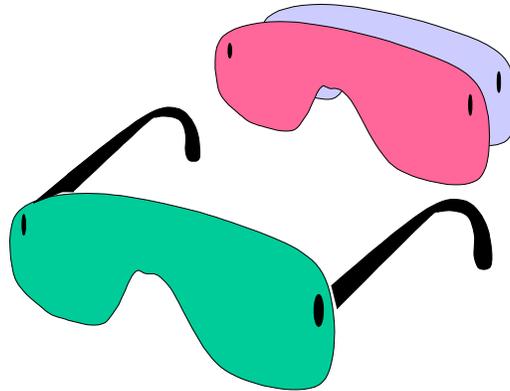


Figure 4: Sunglasses Set

In the end product, two temples are assembled to a single-piece lens to make a pair of sunglasses. Two spare lenses are sold along with the sunglasses. They are put in a plastic bag to form a sunglasses set. We ignore the plastic bag in the end product. The item master file is shown in Table 1.

Table 1: Item Master File of the Sunglasses Set

P_No	Name	LLC	LT	On-hand
A	Sunglasses set	0	1	5
B	sunglasses	1	1	40
C	lens	2	2	0
D	temple	2	3	50

In Figure 5, the quantities of the components required by per parent are expressed in the

parentheses. For example, a sunglasses set is made of a pair of sunglasses and two lenses, and a pair of sunglasses is made of a lens and two temples. The data structure in a BOM file is shown in Table 2.

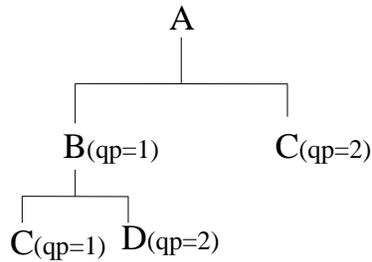


Figure 5: Product Structure for Sunglasses Set

Table 2: BOM File

Parent	Component	Qty-per
A	B	1
A	C	2
B	C	1
B	D	2

The requirements of the sunglasses set are shown in Table 3. The scheduled receipts for lenses and temples are shown in Table 4.

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Table 3: Independent Demand for Sunglasses Sets

Period	1	2	3	4	5	6	7	8
A		40			50			50

Table 4: Schedule Receipts for Lenses and Temples

Period	1	2	3	4	5	6	7	8
C	100							
D		50						

The MPS/MRP procedure starts from the items with zero low level code, i.e., the end products. The calculations of MRP from the top level end product to the lowest level materials are shown in Table 5 to Table 8, and the summary of the MRP results is shown in Table 9.

Table 5: MPS Calculation for A

Period	1	2	3	4	5	6	7	8
GR		40			50			50
SR								
NR	5	-5	35		50			50
POR	35			50			50	

Table 6: MRP Calculation for B

Period	1	2	3	4	5	6	7	8
GR	35			50			50	
SR								
NR	40	-5	-5	45		50		50
POR			45			50		

Table 7: MRP Calculation for C

Period		1	2	3	4	5	6	7	8
GR		70		45	100		50	100	
SR		100							
NR	0	-30	-30	15	100		50	100	
POR		15	100		50	100			

Table 8: MRP Calculation for D

Period		1	2	3	4	5	6	7	8
GR				90			100		
SR			50						
NR	50	-50	-100	-10	-10	-10	90		
POR				90					

Table 9: Summarized MRP Report

P_No	source	1	2	3	4	5	6	7	8
A	make	35			50			50	
B	make			45			50		
C	purchase	15	100		50	100			
D	purchase			90					

MRP Case 2: International Airport Services

When an aircraft arrives at an international airport, a towing tractor marshals the aircraft to an indicated gate. Ramp services and cabin services are proceeded during the period when the aircraft stays. Ramp services include the toilet cleaning, gas refueling, etc. Cabin services include catering load, garbage dumping, etc. Figure 6 is a simplified aircraft

services flow chart.

Since the times for the aircraft arrival and departure are scheduled, the marshaling services must be performed at predetermined times. The other services can be scheduled between the earliest start time (EST) and the latest start time (LST) as shown in Figure 7.



Figure 6: Simplified Aircraft Services

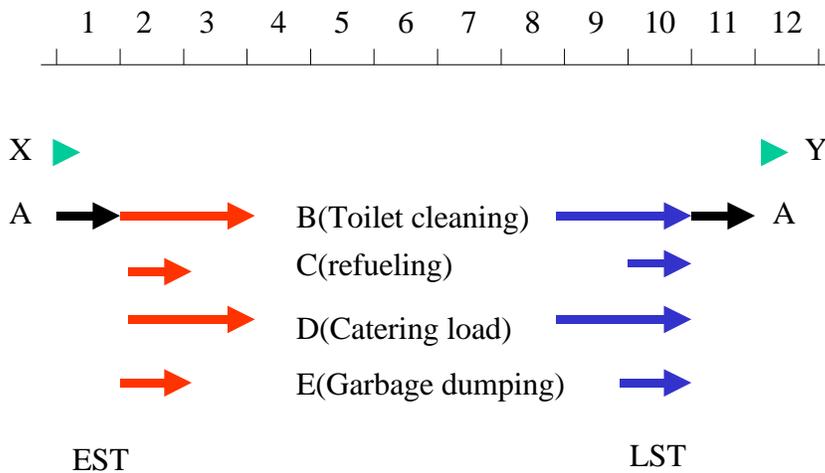


Figure 7: Scheduling of Airport Services

As item master files in the manufacturing, we now create a “service master file” shown in Table 10.

Table 10: Service Master File of Airport Services

Service Number	Service Name	Service Time	Phantom
X	Arrival	0	y
Y	Departure	0	y
A	Marshaling	1	n
B	Toilet cleaning	2	n
C	Refueling	1	n
D	Catering load	2	n
E	Garbage dumping	1	n

The structure of the services is shown in Figure 8. Since the service-time of a service means its duration, we have to count the loads of the resources in all time buckets from the start to the end of services. For example, the toilet cleaning service lasts two time units, its service-time is set as 2 in the service master file, and two records are defined in the “bill of service” file with offset-time (OT) 1 and 2. The quantity-per (QP) defined in bill of service file is the load of the service. The quantity-per of the toilet cleaning service is 2, which means two lavatory trucks are needed during the service. The offset-time and the quantity-per determine that two lavatory trucks are required during a period of two consecutive time buckets. Note that the service times in the service master file are used to create the offset-times in the BOM file, and the lead-times used by MRP are all zero.

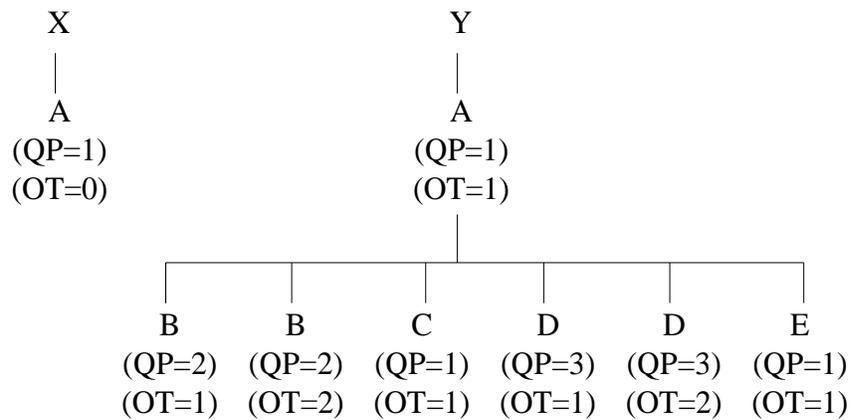


Figure 8: Service Structure for Airport Services

The data structure of the bill of service file is shown in Table 11.

Table 11: Bill of Service File

Parent	Component	Qty-per	Offset-time
X	A	1	0
Y	A	1	1
A	B	2	1
A	B	2	2
A	C	1	1
A	D	3	1
A	D	3	2
A	E	1	1

Suppose a certain aircraft is scheduled to arrive at time 1 and depart at time 12, the schedule is stated similar to MPS in the manufacturing cases, now we name it the master service schedule (MSS), as shown in Table 12.

Table 12: MSS for aircraft arrival and departure

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Time	1	2	3	4	5	6	7	8	9	10	11	12
X	1											
Y												1

Services have neither inventories nor scheduled receipts as in the cases of manufacturing. Services must be provided at the moment when customers use it. In the MRP calculation procedure, gross requirements are the services that customers need. Since there is no on-hand or on-order inventory, the net requirement equals the gross requirement. Only two rows remain in the MRP reports. MRP is now renamed as “service requirement planning”, and the rows are named “required” and “scheduled”. The MRP procedure is described in Table 13.

In table 13, the scheduled service of A in time 1 required by X should not be exploded further. This can be done with a field of X-A record in the BOM file indicating no further explosion. The above example is for a single aircraft. The system will schedule all the flights in MSS, then use MRP procedure to calculate all the services required. The service requirements are scheduled by MRP at the latest start time. The system also calculates the EST schedule. Schedules are then adjusted manually or automatically between EST and LST to balance the load and capacity.

Table 13: Service Requirement Planning for Airport Services

P_No	time	1	2	3	4	5	6	7	8	9	10	11	12
X	Req	1											
	Schl	1											
Y	Req												1
	Schl												1
A	Req	1											1
	Schl	1										1	
B	Req											4	
	Schl									2	2		
C	Req											1	
	Schl										1		
D	Req											6	
	Schl									3	3		
E	Req											1	
	Schl										1		

Material Requirement Planning

This example explains how ERP is used in a service business. Time buckets are sliced as small as the minimal unit a service requires. All service times are multiple of the time bucket length. Lead-times are all set to 0 because the start time of the parent operation is exactly the end time of the child operation, or differs by 1, which can be controlled by offset-time. The service time determines how many time buckets are needed by an operation. An operation repeats, as a child item, the required time buckets times, say n , with offset-time from 1 to n in each BOM record. The service requirement planning uses the same functions of item master, BOM, MPS, and MRP in the ERP system. The idea can also be applied to manufacturing operations.