

MRP using DOQ and EOQ IoT Sizing Techniques

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ABSTRACT: Material Requirements Planning (MRP) is a time phased priority planning technique that calculates material requirements and schedules supply to meet demand across all products and parts in one or more plants. It focuses on optimizing inventory. This paper demonstrates the functioning of MRP using Discrete Order Quantity (DOQ) and Economic Order Quantity (EOQ) lot sizing techniques. While DOQ orders just as much material as required, EOQ determines the ideal order quantity, so as to minimize the total cost of inventory management and only ordering material in that quantity, whenever required. Each of these methods is suitable for specific demand scenarios that have been demonstrated in this paper. The main objective of the paper is to simplify and illustrate the basic calculations of MRP which is possible with the use of the DOQ and EOQ models.

KEYWORDS: Material Requirements Planning, Lot Sizing, Economic Order Quantity, Discrete Order Quantity, Inventory.

I. INTRODUCTION

Joseph Orlicky (Orlicky, 1975) defined MRP as follows, “A material requirements planning (MRP) system, narrowly defined, consists of a set of logically related procedures, decision rules, and records (alternatively, records may be viewed as inputs to the system) designed to translate a master production schedule into time-phased net requirements, and the planned coverage of such requirements, for each component inventory item needed to implement this schedule”. The chief premise of MRP is, “getting the right materials to the right place, at the right time.” It is a computer based production planning and inventory control system. The three major inputs to an MRP system are the Master Production Schedule (MPS), the Product Structure Record or Bill of Material (BOM) and the inventory status records. The MRP system has the ability to provide management with a fairly broad range of outputs such as Planned Orders, Order Releases, Performance Control Reports, etc. MRP is applicable in situations of multiple items with complex bills of materials and mass production of items. It is not very beneficial for job shops or for continuous processes that are tightly linked.

MRP calculates the net requirements of a particular product based on the total forecasted demand and the existing stock available in the inventory. Calculating the net requirements of the product without taking other factors into consideration can make it unsuitable for placing an order or manufacturing. Thus, to overcome this setback, lot sizing comes into existence. Lot sizing technique is defined as, a process or a technique which is used to determine the lot size (Heizer, 2009). Lot sizing is used to calculate the net requirements of a product by taking factors such as cost reduction and work efficiency into consideration. The motivation behind lot sizing is minimising inventory. It essentially refers to the total quantity of a product ordered for manufacturing. Lot sizing techniques are a balance between ordering cost and holding cost of a product to meet the requirements of material planning (Jacobs, 2008). The problem of lot sizing is a critical issue of material requirements planning. Selecting the appropriate lot sizing technique will reduce both, the ordering cost as well as the holding cost of the material (Ismail, 2011).

Several techniques such as Lot for Lot (LFL), Economic Order Quantity (EOQ), Least Total Cost (LTC), Least Unit Cost (LUC), Part Period Balancing (PPB), and Wagner Within algorithm are used for lot sizing. LFL, also known as

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Discrete Order Quantity (DOQ), is the most common lot sizing technique used. This technique entails ordering only the exact amount of required material. EOQ model is preferred when the demand for the product is independent, which later becomes more or less constant when the demand is identified. LTC is a dynamic lot sizing technique which calculates the lot size by linking carrying cost and order cost associated with different lot sizes and then selects the lot size with the minimum total cost. LUC is also a dynamic lot sizing technique, which sums up the order and holding cost for the size lot experiment, divides it by the number of units in the lot, then selects lot size with the least cost per unit. PPB is an approach to balance the set-up cost and the storage cost. The procedure of Wagner Within is a dynamic programming model which adds some complexities on the calculation of the lot size. This procedure assumes that a horizon in a limited time is beyond a situation where there is no additional requirement. This paper deals with the working of MRP using Discrete Order Quantity (DOQ) and Economic Order Quantity (EOQ).

II. OVERVIEW OF DOQ & EOQ MODELS

Discrete Order Quantity (DOQ) is an approach for lot sizing, where the amount of order each time placed is equal to the net requirements for the product for that duration. This technique is characteristically utilized largely for expensive products and the products whose demands are variable and periodic. The DOQ approach, commonly known as LFL, minimizes the holding cost by producing just-in-time. DOQ is optimal if setup costs and setup times have been reduced to negligible levels, but it may be expensive if setup costs are significant. The motivation behind DOQ is to minimise inventory, but it results in increase in the number of orders placed. This might reduce the holding cost, but it maximises the ordering cost. Since the ordering cost increases in case of this approach, one might try to combine multiple lots into one, in order to cutback the ordering cost. But, this approach increases the holding cost of the material. Therefore, a question arises about the ideal size of the lot. An answer to this question is the Economic Order Quantity (EOQ) model.

Economic Order Quantity (EOQ) is used to calculate the optimal quantity of material that can be procured to minimize both the holding cost and ordering cost associated with the material. It can be a treasured device for small business owners who need to make decisions about how much inventory to keep on hand, how many items to order each time, and how often to reorder to sustain the lowest possible expenses.

EOQ can be calculated mathematically with a great deal of accuracy using the formula given below:

$$EOQ = \sqrt{(2 \cdot A \cdot O) / C}$$

where, A = Annual Demand in units

O = Cost incurred for placing a single order

C = Holding Cost per unit per year

The mathematical formula stated above to calculate the Economic Order Quantity is based on the following assumptions:

- The annual demand of the product is known and is uniformly distributed throughout the year.
- There is no time gap between placing an order and receiving the order.
- Order Cost varies directly with the number of orders.
- Holding cost varies directly with the average inventory.
- There is no quantity discount.

III. MRP CALCULATIONS

A. MRP CALCULATIONS USING DOQ MODEL

In order to show the working of MRP using Discrete Order Quantity (DOQ), we have decided to choose a hypothetical

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case of a lawn mower assembly plant. We consider a manufacturing plant that assembles and manufactures a lawn mower. The MRP calculations are implemented using DOQ (also known as LFL) lot sizing technique. The demand for the lawn mowers are considered to be erratic and therefore suitable for LFL technique.

Sr. No	Product	Component	Sub-Component	Qty	Lead Time (in weeks)	Stock Available
	Lawn Mower			1	1 week	20
1		Chassis		1	2 weeks	50
2		Wheels		4	3 weeks	10
3		Engine		1	2 weeks	0
			Carburettor	1	2 weeks	15
			Spark Plug	1	1 week	100
			Cylinder	1	1 week	0
			Piston	1	1 week	10
			Crankshaft	1	1 week	15
4		Grass catcher		1	1 week	35

Table 1

Table 1 shows the Bill of Materials and the Inventory Records of the Lawn Mower. It is divided into Components, some of which are further divided into Sub-Components which form the lowest tier of the product structure. The lead times of components and sub-components have been assumed in weeks. The table also shows the amount of stock present in the inventory for each component and sub-component.

Item	Time (in weeks)											
	1	2	3	4	5	6	7	8	9	10	11	12
Lawn Mower (LT=1 week)												
Gross Requirements						40		100	120			50

Table 2

Table 2 shows the Master Production Schedule for the lawn mower which has been made on the basis of assumed forecasted demand. It shows that the demand for lawn mowers is listed on the 6th, 8th, 9th and 12th week of the timeframe considered.

The MRP calculations based on the MPS, BOM and the Inventory Records is shown below for the lawn mower, its components and its sub-components.

Item	Time (in weeks)											
	1	2	3	4	5	6	7	8	9	10	11	12
Lawn Mower (LT=1 week)												
Gross Requirements						40		100	120			50
Stock Available	20	20	20	20	20	20	0	0	0	0	0	0
Net Requirements						20		100	120			50
Planned Order Release					20		100	120			50	

Table 3

Table 3 shows the MRP calculation for the Lawn Mower. From the Gross Requirements and Stock Available, the Net Requirements are calculated and based on the lead times and the orders for those many Lawn Mowers are placed in the 5th, 7th, 8th and 11th week of the considered timeframe.

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Item	Time (in weeks)											
	1	2	3	4	5	6	7	8	9	10	11	12
Chassis (LT=2 weeks)												
Gross Requirements					20		100	120			50	
Stock Available	50	50	50	50	50	30	30	0	0	0	0	0
Net Requirements							70	120			50	
Planned Order Release					70	120			50			

Table 4

Table 4 shows the MRP calculation for the chassis. From the Gross Requirements and Stock Available, the Net Requirements are calculated and based on the lead times and the orders for those many chassis are placed in the 5th, 6th and 9th week of the considered timeframe.

Item	Time (in weeks)											
	1	2	3	4	5	6	7	8	9	10	11	12
Wheels (LT=3 weeks)												
Gross Requirements					80		400	480			200	
Stock Available	10	10	10	10	10	0	0	0	0	0	0	0
Net Requirements					70		400	480			200	
Planned Order Release		70		400	480			200				

Table 5

Table 5 shows the MRP calculation for the wheels. From the Gross Requirements and Stock Available, the Net Requirements are calculated and based on the lead times and the orders for those many wheels are placed in the 2nd, 4th, 5th and 8th week of the considered timeframe.

Item	Time (in weeks)											
	1	2	3	4	5	6	7	8	9	10	11	12
Engine (LT=2 weeks)												
Gross Requirements					20		100	120			50	
Stock Available	0	0	0	0	0	0	0	0	0	0	0	0
Net Requirements					20		100	120			50	
Planned Order Release			20		100	120			50			

Table 6

Table 6 shows the MRP calculation for the engine. From the Gross Requirements and Stock Available, the Net Requirements are calculated and based on the lead times and the orders for those many engines are placed in the 3rd, 5th, 6th and 9th week of the considered timeframe.

Item	Time (in weeks)											
	1	2	3	4	5	6	7	8	9	10	11	12
Carburettor (LT=2 weeks)												
Gross Requirements			20		100	120			50			
Stock Available	15	15	15	0	0	0	0	0	0	0	0	0
Net Requirements			5		100	120			50			
Planned Order Release	5		100	120			50					

Table 7

Table 7 shows the MRP calculation for the carburettors. From the Gross Requirements and Stock Available, the Net Requirements are calculated and based on the lead times and the orders for those many carburettors are placed in the 1st, 3rd, 4th and 7th week of the considered timeframe.

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Item	Time (in weeks)											
	1	2	3	4	5	6	7	8	9	10	11	12
Spark Plug (LT=1 week)												
Gross Requirements			20		100	120			50			
Stock Available	100	100	100	80	80	0	0	0	0	0	0	0
Net Requirements					20	120			50			
Planned Order Release				20	120			50				

Table 8

Table 8 shows the MRP calculation for the spark plugs. From the Gross Requirements and Stock Available, the Net Requirements are calculated and based on the lead times and the orders for those many spark plugs are placed in the 4th, 5th and 8th week of the considered timeframe.

Item	Time (in weeks)											
	1	2	3	4	5	6	7	8	9	10	11	12
Cylinder (LT=1 week)												
Gross Requirements			20		100	120			50			
Stock Available	0	0	0	0	0	0	0	0	0	0	0	0
Net Requirements			20		100	120			50			
Planned Order Release		20		100	120			50				

Table 9

Table 9 shows the MRP calculation for the cylinders. From the Gross Requirements and Stock Available, the Net Requirements are calculated and based on the lead times and the orders for those many cylinders are placed in the 2nd, 4th, 5th, 8th week of the considered timeframe.

Item	Time (in weeks)											
	1	2	3	4	5	6	7	8	9	10	11	12
Piston (LT=1 week)												
Gross Requirements			20		100	120			50			
Stock Available	10	10	10	0	0	0	0	0	0	0	0	0
Net Requirements			10		100	120			50			
Planned Order Release		10		100	120			50				

Table 10

Table 10 shows the MRP calculation for the pistons. From the Gross Requirements and Stock Available, the Net Requirements are calculated and based on the lead times and the orders for those many pistons are placed in the 2nd, 4th, 5th and 8th week of the considered timeframe.

Item	Time (in weeks)											
	1	2	3	4	5	6	7	8	9	10	11	12
Crankshaft (LT=1 week)												
Gross Requirements			20		100	120			50			
Stock Available	15	15	15	0	0	0	0	0	0	0	0	0
Net Requirements			5		100	120			50			
Planned Order Release		5		100	120			50				

Table 11

Table 11 shows the MRP calculation for the crankshafts. From the Gross Requirements and Stock Available, the Net Requirements are calculated and based on the lead times and the orders for those many crankshafts are placed in the 2nd, 4th, 5th and 8th week of the considered timeframe.

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Item	Time (in weeks)											
	1	2	3	4	5	6	7	8	9	10	11	12
Grass Catcher (LT = 1 week)												
Gross Requirements					20		100	120			50	
Stock Available	35	35	35	35	35	15	15	0	0	0	0	0
Net Requirements							85	120			50	
Planned Order Release						85	120			50		

Table 12: Grass Catcher

Table 12 shows the MRP calculation for the grass catchers. From the Gross Requirements and Stock Available, the Net Requirements are calculated and based on the lead times and the orders for those many grass catchers are placed in the 6th, 7th and 10th week of the considered timeframe.

B. MRP CALCULATIONS USING EOQ MODEL

In order to show the working of MRP using Economic Order Quantity (EOQ), we have decided to take the hypothetical case of a small-scale luxury pen brand X. We consider the planning for a pen which is manufactured by a vendor and is supplied to the company X. We assume that the demand for the pens remain fixed and uniformly distributed throughout the year. Therefore, this component is suitable for the EOQ lot sizing technique. The unit for the lead times of the components and the sub-components is assumed to be in weeks.

We assume the average forecasted annual demand will be 10,800 units. The ordering cost is assumed to be \$50.00. The annual holding cost is calculated to \$3.00 per pen. The lead time for the pen is anticipated to be 1 week.

The following are the parameters required to calculate the EOQ:

A = Average annual order = 10,800

O = Cost incurred per order = \$50.00

C = Holding Cost per item per year = \$3.00

$$EOQ = \sqrt{(2 \times 10,800 \times 50) / 3} = 600$$

The company X should order about 600 pens, each time it makes an order from the vendor.

$$\text{Number of orders per year} = A / EOQ = 10,800 / 600 = 18$$

The company should make 18 orders of pen according to the forecasted annual demand.

$$\text{Average annual ordering cost} = (\text{Number of orders per year}) \times O = 18 \times 50 = \$900$$

$$\text{Average Inventory} = EOQ / 2 = 600 / 2 = 300$$

$$\text{Annual holding cost} = (\text{Average Inventory}) \times C = 300 \times 3 = \$900$$

Hence, for EOQ, Ordering Cost is equal to the Holding Cost.

$$\text{Total Annual Cost} = \text{Annual average ordering cost} + \text{Annual holding cost} = \$900 + \$900 = \$1800$$

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Item	Time (in weeks)											
	1	2	3	4	5	6	7	8	9	10	11	12
Pens (LT=1 week)												
Gross Requirements	150	250	200	180	210	205	165	150	200	180	250	250

Table 13

Table 13 shows the Master Production Schedule for the pens which has been made on the basis of assumed forecasted demand. The demand is constant every week and therefore this case is suitable for EOQ technique.

Item	Time (in weeks)											
	1	2	3	4	5	6	7	8	9	10	11	12
Pens (LT=1 week)												
Gross Requirements	150	250	200	180	210	205	165	150	200	180	250	250
Stock Available	500	350	100	500	320	110	505	340	190	590	410	160
Scheduled Receipts			600			600			600			600
Planned Order Release		600			600			600			600	

Table 14

Table 14 shows the MRP calculation for the pens. From the available stock, the gross requirements are satisfied and when the stock runs low, new material is ordered in the calculated optimum lot size.

IV. CONCLUSION

Material Requirements Planning (MRP), combined with computer technology, gave the most adequate and successful computerized production requirement system of its time. There is no doubt that production requirements techniques always need a lot more due to the competition in businesses and the growing requirements of manufacturing systems. Therefore, MRP has transformed a great deal since its inception a few decades ago and new material planning techniques have emerged ever since. Unfortunately, the core concepts of MRP and the rules surrounding them, have been neglected and left to stagnate for a long time. Further, there is a complete lack of understanding which further worsens the problem of stagnation.

Despite the issues related to traditional MRP, this paper gives an overview of MRP and its relevance in today's world. It may not be perceived as cutting-edge at this time, but MRP provides accurate answers to the simple questions of what a company possesses, what it needs to produce and purchase, and when it needs to produce and purchase. This can spell the difference between success and failure for any company. When taking into account the increased complexities in the twenty-first century, the failure to answer these questions accurately will cause a company to fail more quickly. In reality, MRP is critical and more relevant than ever. Simply put, MRP has more impact on and is more relevant to the effectiveness of today's supply chain than ever before.

This paper shows the working of MRP with the help of two hypothetical cases. Discrete Order Quantity (DOQ) lot sizing technique was chosen for the manufacturing of a lawn mower, where the demand was considered to be variable. Here, the material was ordered as and when it was required to keep the holding costs low. Whereas, Economic Order Quantity (EOQ) lot sizing technique was chosen for manufacturing of a pen, where the demand was considered to be uniform throughout the year. The material was ordered in a specific lot size which made a compromise between the holding costs and ordering costs. Although there are alternative methods of lot sizing available, we have chosen DOQ and EOQ methods because they are the best ways to simplify and explain the basic calculations involved in MRP, which is the main objective of this paper.

As Joseph Orlicky (Orlicky, 1975) rightly said with respect to the relevance of MRP, "Unlike many other approaches and techniques, Material Requirements Planning 'works' which is its best recommendation."

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