

CHAPTER 2

LITERATURE SURVEY

2.1. Material Requirements Planning (MRP)

Material Requirements Planning is essentially the process of determining the schedule for getting the right materials, in the right place, at the right time. This is done by determining the number of parts, components, and raw materials needed to produce each end-item, and providing a time schedule specifying when each of these materials, parts and components should be ordered or produced to meet the production deadline for the final product.

2.2. MRP System Structure

The MRP system works by interacting with the Master Production Schedule (MPS), the Bill of Materials (BOM), and the inventory records file. Forecasted sales and firm orders are used to create the MPS, which states the number of end-items to be produced during specified time periods. The BOM file identifies the specific materials used to make each end-item and the correct quantities of each material. The inventory file stores data such as which materials are on hand and which materials are on order. The MPS, BOM file and the inventory file become the sources of information for the MRP programme, which essentially expands the MRP into a detailed order scheduling plan for the entire production process.

2.2.1. Master Production Schedule (MPS)

The MPS is the plan for specifying how many of each product should be produced and when it should be produced. At the highest level, it usually shows how many units are to be produced for the next month or quarter, and at the lowest level it can show which specific models are to be produced on a daily basis, depending on how short a time period the company is operating on. A shorter time period would facilitate a precise production schedule, but at the cost of extra data processing.

While a longer time period would make computing costs more economical, but would sacrifice some precision. In most cases, companies work on a weekly basis.

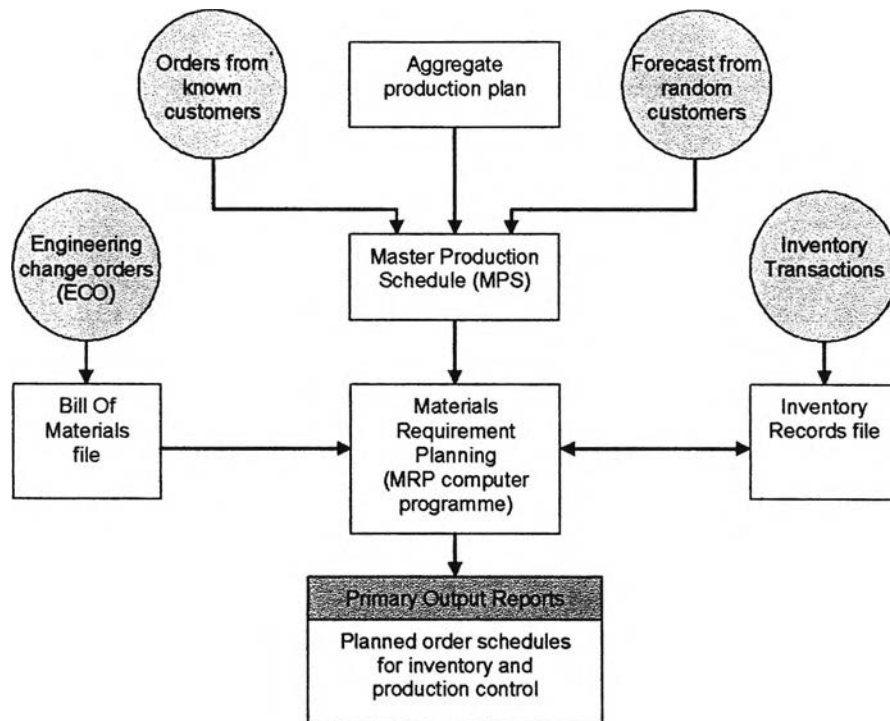


Figure 2.1 MRP System Structure (Davis *et al* 2003 p. 644)

2.2.2. Bill of Materials (BOM)

The BOM file contains the complete product description, which includes all the materials, parts and components required to make the end-item and in what quantity they are needed. The BOM file also contains the order in which they are assembled, and is sometimes referred to as the product structure or the product tree. Figure 2.2 shows an example of a product structure for product A.

In the past, BOM files were stored as an indented file, which clearly shows how the product is assembled as each indent signifies the components of the item. From a computing perspective this method is inefficient, since computing the amounts of each component at the lower levels means expanding every sub-component and summing all the parts, and for highly complex product structures, may take a considerable amount of time. A more efficient method is to store the data in a single-

level explosion (Davis *et al* 2002). A comparison of the two methods is shown in Table 2.1.

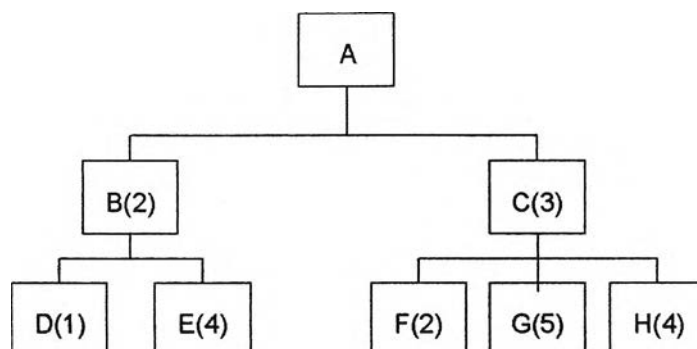


Figure 2.2 Product structure for product A, (numbers in brackets signify the number of components).

Table 2.1 Comparison of indented parts list and single-level parts list for product A.

Subassemblies and indented parts list	Single-level subassemblies and parts list
A B(2) D(1) E(4) C(3) F(2) G(5) H(4)	A B(2) C(3) B D(1) E(4) C F(2) G(5) H(4)

2.2.3. Inventory Records File

Each item in inventory is recorded as a separate file, and the range of details that this file contains varies from system to system. An example in Figure 2.2 shows the variety of information that can be contained in the inventory records file. The MRP

system accesses the status segment of the file according to specific time periods and these files are accessed as needed during the running of the programme.

Item master data segment	Part No.	Description	Lead time		Std. cost		Safety stock				
	Order quantity	Setup	Cycle		Last year's usage		Class				
	Scrap allowance	Cutting data	Pointers		Etc.						
Inventory status segment	Allocated	Control Balance	Period								Totals
			1	2	3	4	5	6	7	8	
	Gross requirements										
	Scheduled receipts										
	On hand										
	Planned order releases										
Subsidiary data segment	Order details										
	Pending action										
	Counters										
	Keeping track										

Figure 2.3 Example of an inventory records file (Davis *et al* 2003 p. 647)

2.3. MRP Process

The MRP programme refers to the inventory records file, the MPS, and the BOM file to work out the materials requirements. It works as follows (Silver *et al* 1998):

1. The MPS provides the timing and quantities of all end-items on a discrete time basis (usually a one-week period).
2. The MRP programme refers to the BOM file to compute the quantities of each component needed for each end-item to produce a set of *gross requirements*.
3. The gross requirements of each component are then adjusted for on-hand amounts and scheduled receipts (from the inventory records file) to obtain a set of *net requirements*.

4. The net requirements are then offset back in time to allow for the leadtimes needed to obtain these components.
5. The next step is the application of a suitable lot-sizing technique to set the timing and sizes of orders for the components.
6. This process continues down through the levels of the BOM for the product until a complete material reorder plan is computed for each end-item.

2.4. Lot Sizing

Lot Sizing affects both the size of orders and the frequency they are released to the shop floor. This means that lot sizes not only affect setup and holding costs, they have an impact on shop load.

There are several methods for determining lot sizes for components. The selection of which technique to use largely depends on the balancing of setup costs and holding costs for that component, but it can also depend on other factors such as system stability and ease of use. This section will look at various lot sizing techniques that are available, and the advantages and disadvantages of each will be looked at.

2.4.1. Lot-for-Lot (LFL)

The LFL technique is the simplest of all the techniques. In this technique, the exact number of components are ordered or produced according to the net requirements for that component.

2.4.2. Economic Order Quantity (EOQ)

The EOQ technique tries to obtain an order quantity that balances the cost of holding the component with setup cost. The economic order quantity for a component is given by the following equation:

$$Q^* = \sqrt{\frac{2ds}{h}}$$

In this equation d is the number of time periods taken into account, s is the setup cost and h is the holding cost. EOQ assumes that demand for a component is constant; therefore its use would not be suitable in a job shop environment.

2.4.3. Minimum Cost per Period (MCP)

This approach is also known as the Silver-Meal (SM) method, after its developers (Silver & Meal 1973). It combines a component's net requirements for two or more periods and the cost per period is calculated. The cost per period is calculated as the cumulative cost, which is the sum of setup costs and holding costs for those periods, divided by the number of periods. The time periods which yield the minimum cost per period are grouped together in terms of net requirements. Table 2.2 shows an example of a MCP calculation.

Table 2.2 An example of MCP calculations, where setup cost is equal to £200 and holding cost is equal to £2 per unit.

Trial Periods Combined	Trial Lot Size (Cumulative Net Requirements)	Cumulative Cost	Cost Per Period
2	30	200	£200.00
2, 3	70	280	£140.00
2, 3, 4	70	280	£93.33
2, 3, 4, 5	80	340	£85.00
2, 3, 4, 5, 6	120	660	£132.00
(Combine periods 2, 3, 4, and 5 because cost per period is a minimum.)			
6	40	200	£200.00
6, 7	70	260	£130.00
6, 7, 8	70	260	£86.67
6, 7, 8, 9	100	440	£110.00
(Combine periods 6, 7, and 8 because cost per period is a minimum.)			

2.4.4. Period Order Quantity (POQ)

POQ is the quantity to cover P^* periods of net requirements, where $P^* = N/D/EOQ$, N is the number of periods in a year, D is the annual requirements, and EOQ is the economic order quantity. In effect, this is taking the EOQ for a component and converting into a time period.

Even though POQ is based on EOQ , it performs better in situations where demand is variable, because it adapts to the requirements of a set of periods.

2.4.5. Least Unit Cost (LUC)

Instead of trying to minimise the cost per period, the LUC approach attempts to minimise cost per unit. Table 2.3 shows an example of a LUC calculation.

Table 2.3 An example of LUC calculations, where setup cost is equal to £200 and holding cost is equal to £2 per unit.

Trial Periods Combined	Trial Lot Size (Cumulative Net Requirements)	Cumulative Cost	Cost Per Unit
2	30	200	£6.67
2, 3	70	280	£4.00
2, 3, 4	70	No change – hence ignore	
2, 3, 4, 5	80	340	£4.25
(Combine periods 2 and 3 at a cost of £4 per unit)			
4, 5	10	200	£20.00
4, 5, 6	50	280	£5.60
4, 5, 6, 7	80	400	£5.00
4, 5, 6, 7, 8	80	No change – hence ignore	
4, 5, 6, 7, 8, 9	110	640	£5.80
(Combine periods 4, 5, 6, and 7 at £5 per unit)			
8, 9	30	200	£6.67
8, 9, 10	85	310	£3.65
(Combine periods 8, 9, and 10 at £3.65 per unit)			

2.4.6. Least Total Cost (LTC)

The LTC approach tries to balance holding and setup costs. A lot size is started in first period. In the next period, the demand is added to the lot if the cumulative carrying costs are less than or close to the setup cost. This is done until the total cumulative cost exceeds the setup cost. An example of a LTC calculation is given in Table 2.4.

Table 2.4 An example of LTC calculations, where setup cost is equal to £200 and carrying cost is equal to £2 per unit.

Period	Demand	Periods Carried	Carrying Cost	Cumulative Carrying Cost
2	30	0	0	0
2, 3	40	1	80	80
2, 3, 4	0	2	0	80
2, 3, 4, 5	10	3	60	140
2, 3, 4, 5, 6	40	4	320	460
The addition of period 6 would make the cumulative cost exceed the setup cost of £200. Do not include period 6 demand. The lot in period 2 will be 80.				
6	40	0	0	0
6, 7	30	1	60	60
6, 7, 8	0	2	0	60
6, 7, 8, 9	30	3	180	240
The addition of period 9 would make the cumulative cost exceed the setup cost of £200. Do not include period 9 demand. The lot in period 6 will be 70.				
9	30	0	0	0
9, 10	55	1	110	110
End of the horizon. The lot in period 9 will be 85.				

2.4.7. Part Period Balancing (PPB)

The PPB technique is a variation of the LTC method. The PPB procedure attempts to balance setup and holding costs through the use of economic part periods. An economic part period (EPP) is the ratio of setup cost to holding cost. For example, if the setup cost was equal to £200 and the holding cost was equal to £2 per unit, then the EPP would be 100 units. Therefore, holding 100 units for one period would cost £200. Also, carrying 50 units for two periods would cost £200. So in a PPB

calculation the requirements are combined until the number of part periods nearly approximates the EPP.

2.4.8. Lot Sizing Technique Comparison

Research has been carried out to evaluate how well these lot-sizing models perform in terms of cost and MRP performance. Melnyk & Piper (1985) performed various simulations to address why some models perform well at minimising cost, but contribute to poor MRP performance, and vice versa. It was found that PPB and SM could achieve any given level of on time delivery performance with less inventory cost than either EOQ or POQ. Also, LFL and SM models exhibited a higher than expected performance for on time delivery, although LFL should be avoided if setup costs are high. Lot sizing rules such as POQ that generate more variable order queues yield less than desired service levels. It has been suggested that if the MRP system has no Capacity Requirements Planning (CRP), the lot-for-lot rule should be used for all jobs, except for those with high setup cost where SM would be more appropriate. When CRP has been implemented, SM can be extended to other components, and PPB can be considered for items where late delivery costs are small compared to setup and carrying cost.

In practice, one discrete lot sizing algorithm is about as good as another and LFL should be used unless there are significant setup costs (Orlicky 1975 p. 137). Although, early studies have found that most companies use fixed lot sizes at the end-item level, heuristics such as PPB and POQ at the lowest level of produced components, and items at intermediate levels tend to have a LFL rule (Theisen 1974). Later studies by Wemmerlov (1979) and Haddock & Hubicki (1989) have shown that LFL method has been the most popular with companies, while dynamic lot-sizing techniques such as LTC and PPB were the least popular. The reason for this is that the LFL technique helps to maintain stability and minimises the amount of material tied up, while the dynamic lot-sizing techniques tended to produce system nervousness if changes were made at the top level, and caused exaggerated responses at component levels (Wemmerlov 1979).

2.5. Leadtimes

Peterson (1975) states that planned leadtimes are an important part in the operation of MRP. They are used both to time-phase replenishment orders and to maintain valid and credible priorities. Components needed at a particular due date must be ordered at a time that takes into account the component's waiting and processing time. The waiting time will vary with shop load and it is difficult to estimate (Karmarkar 1993).

2.6. Coping with Process Uncertainty

Uncertainty in demand and production leadtimes can adversely affect the accuracy of an MRP system, therefore making the system useless. Uncertainty in production leadtimes usually arises out of being unable to estimate the waiting times involved, which is largely depended on shop load (Karmarkar 1993). However, demand uncertainty arises from being unable to accurately forecast demand for a product.

It has been suggested that safety stock would be appropriate in situations where demand uncertainty occurs, and safety times would be appropriate when uncertainty occurs in leadtimes (Whybark & William 1976), which has been confirmed in a computer simulation study by Melnyk (1980). Buzacott and Shanthikumar (1994) conclude that safety time is usually only preferable to safety stock when it is possible to make accurate forecasts of future required shipments over that leadtime.

Gross & Taylor (1984) have shown that a LFL technique should be used for lot-sizing when leadtimes for components exhibit the most variability, and EOQ should be avoided as it resulted in more inventory being carried without a significant decrease in average lateness penalty.

Another method of dealing with process uncertainty would be to use time fences on the MPS (Davis *et al* 2003). These are defined as periods of time, with each period having a specified level of opportunity for changes to be made. For example, the first four weeks would be frozen, the next four weeks would be moderately firm, and after

that the MPS would be flexible. The purpose of time fences is to prevent last minute changes that could adversely affect the production system.

2.7. Capacity Constraints

If the MRP programme does not take into account capacity constraints (i.e. not a closed loop system) then the master scheduler must perform some capacity balancing manually, which can be done by feeding a draft MPS into the MRP system and the resulting output can be examined for production feasibility (Silver *et al* 1998). Adjustments are then made to the MPS and re-fed into the MRP system to recheck production feasibility. This is redone until the output is acceptable.

2.8. Primary Outputs

The output from the system should include the following (Smith 1989 p. 272-276):

- MRP report
 - Header – Item no., description, order quantity policy, lead times, safety stock, etc.
 - Time periods
 - Gross requirements by period
 - Scheduled receipts
 - Current available balance and projection by period
 - Planned order releases

- Pegging report – relates a component type to the parent products that it is required for.

2.9. MRP System Development

The following sections discuss the elements that need to be considered for MRP system development.

2.9.1. Development Planning

This stage is critical to the successful execution of the entire project. As with the total implementation of an MRP system, there are factors that must be addressed before the project can begin, and these will minimise any problems that might occur in the future. Since the development of the MRP system is a part of the implementation process; therefore the critical success factors for this development project should be taken from the critical success factors of MRP implementation where applicable. Critical Success Factors for MRP implementation in small and medium-sized companies include (Petroni 2002):

- Top management support
- Formal project planning
- Data accuracy
- Organisational arrangements
- Education/Training
- Software/Hardware characteristics
- Formal planning/control policies and procedures
- Employees' individual characteristics

2.9.2. Data Collection and Analysis

Data collection and analysis is required to facilitate the design of the MRP system. Information that will need to be considered for collection and analysis should include (Esteal & Davis 1989):

- Management expectations of the system
- User requirements
- System constraints (i.e. hardware and software constraints)
- Existing business processes and systems

2.9.2.1. Interviews

One of the primary ways of collecting data is through the use of interviews. It is a way of gaining an insight into how systems work from the people who have first hand knowledge. Some of the guidelines for effective interviewing are shown below (Hoffer *et al* 2002):

- Plan the interview
 - Prepare the interview
Appointment, priming questions
 - Prepare a checklist, agenda, and questions
- Listen carefully and take notes
- Review notes within 48 hours of interview
- Be neutral
- Seek diverse views

The interviewer should be thoroughly prepared before the interview. An appointment should be made a convenient time for the interviewee, and the interviewee should be informed of what to expect in the interview, so they are able to prepare themselves. In addition the interviewer may provide an interview guide or checklist for the interviewee (Hoffer *et al* 2002).

2.9.3. Overall System Design Specification

Specifying the overall system design is an important step, as it will save a lot of unnecessary work that would arise from design changes and system requirement alterations at a later date.

Design factors that need to be taken into account include (Esteal & Davis 1989):

- **Information requirements of the users**

This is to ensure that everyone's information needs are met for efficient running of production. This will include what data outputs are expected from the system, and what information will be needed to do this.

- **Hardware and software constraints**

These constraints will determine what is available to the developers, and is important in deciding what can and cannot be done with the system.

- **Database and Design**

How the data will be stored and accessed is an important consideration, because the design has to take into account the hardware and software constraints.

2.9.4. Programme Design

The programme should be designed according to the information gained in the previous steps (Esteal & Davis 1989), and the logic that a MRP programme goes through to obtain a material requirements plan.

2.10. Structured Query Language (SQL)

Structured Query Language is the most widely used commercial relational database language. It was originally developed by IBM in the mid-seventies, and almost immediately, other vendors introduced database management systems (DBMS) based on SQL, and it has now become a standard (Ramakrishnan & Gehrke 2000). SQL has several aspects to it, but the most common application is the use of statements for manipulating data, which form the Data Manipulation Language (DML). These statements are used to retrieve data, insert new data into the database, and edit or delete existing data.

2.10.1. Form of a SQL Query

SQL is a nonprocedural language, so it does not provide traditional programming structures. Instead, it is a language for specifying the operation that needs to be performed at a relatively high level. The basic form of a SQL query is as follows:

```

SELECT    fields
FROM      tables
WHERE     condition

```

Every query must have a SELECT clause, which specifies fields to be retained in the result, and a FROM clause, which specifies the tables from which the data is to be obtained. The optional WHERE clause specifies selection conditions on the tables mentioned in the FROM clause.

In the following example, the aim is to find the names of the sailors that have reserved boat number 103. In table 2.5, 'sid' is the id of the sailor that reserved the boat, 'bid' is the boat ID, and day is when the boat is reserved for. In table 2.6, 'sid' is the sailor's ID and 'sname' is the name of the sailor.

Table 2.5 Table 'R' of boat reserves

sid	bid	day
22	101	10/10/96
58	103	11/12/96

Table 2.6 Table 'S' of sailors

sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

The SQL statement would be as follows:

```

SELECT    S.sname
FROM      S, R
WHERE     S.sid = R.sid, R.bid = 103

```

This would read as: select the field 'sname' in table 'S', from tables 'S' and 'R', where 'sid' in table 'S' is equal to 'sid' in table 'R', and 'bid' in table 'R' is equal to 103. The result of this query is shown in Table 2.7.

Table 2.7 Result of example query

<u>sname</u>
rusty

2.10.2. Transact-SQL

Transact-SQL (T-SQL) is an extension of SQL, and it is used to write stored procedures, which are executed at the server end. T-SQL recognises statements that fetch rows from one or more tables, flow-control statements like IF ... ELSE and WHILE, and numerous functions to manipulate strings, numeric values, and dates (Petroustos 2000).