Source: Northampton Symphony Orchestra

Chapter 14

Enterprise resource planning (ERP)

Introduction

One of the most important issues in planning and controlling operations is managing the sometimes vast amounts of information generated by the activity. It is not just the operations function that is the author and recipient of this information, almost every other function of a business will be involved. So, it is important that all relevant information that is spread throughout the organization is brought together. Then it can inform planning and control decisions such as when activities should take place, where they should happen, who should be doing them, how much capacity will be needed and so on. This is what enterprise resource planning (ERP) does (see Figure 14.1). It grew out of a set of calculations known as material requirements planning (MRP), which is also described in this chapter.

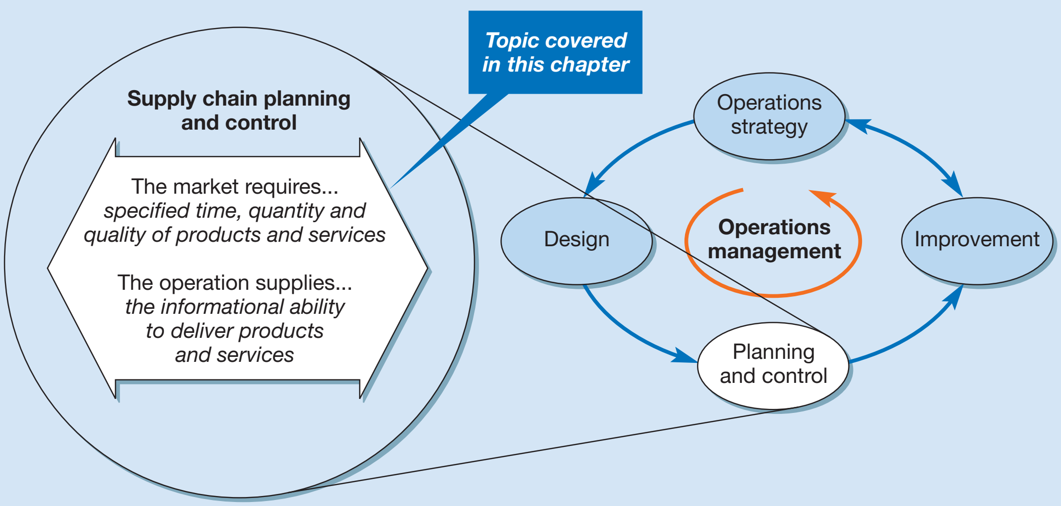

Figure 14.1 This chapter covers enterprise resource planning (ERP)

Key questions ???

- What is ERP?
- How did ERP develop?
- What is MRP?
- What is MRP II?
- How is ERP developing?

Operations in practice
SAP at Rolls-Royce[1]

Source: Rolls-Royce plc

Rolls-Royce is one of the world's largest manufacturers of the gas turbines that are used to propel civil aircraft, military aircraft, ships, and in power generation as well as many other uses. They are exceptionally complex products, typically with around 25,000 parts and hundreds of assemblies and sub-assemblies. Their production is equally complex with over 600 external suppliers and thousands of work centres in many different locations, which is why Rolls-Royce was one of the earliest users of computers to help with planning. Traditionally the company had developed its own software; however, this had become increasingly expensive compared with buying off-the-shelf systems. It was also risky because customized and complex software could be difficult to update and often could not exchange or share data. So the company decided to implement a standard ERP system from the market-leading German SAP company. Because it was a 'commercial' off-the-shelf system it would force the company to adopt a standardized approach. Also it would fully integrate all the company's systems and updates would be made available by SAP. Finally, the whole organization would be able to use a single database, reducing duplication and errors. The database modules included product information, resource information (plant assets, capacities of machines, all human resource data, etc.), inventory, external suppliers, order-processing information and external sales.

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Yet the company knew that many ERP implementations had been expensive disasters. '*We were determined to ensure that this did not happen in Rolls-Royce,*' said Julian Goulder, who led the implementation. '*The project was too important to us; it was the largest single element within our strategic investment plan. So we had a core technical team that led the design of the systems and a large implementation team that was spread around the businesses. We always made sure that we communicated the changes throughout the company and used extensive education and training. We also phased the implementation to avoid any risky "big-bang" approach. There was an extensive data "clean-up" to ensure accuracy and integrity of existing information, and all existing processes were reviewed and standardized. In fact, this implementation forced us to re-examine all of our processes, to make sure that they fitted the SAP system. Within operations we have already seen a significant reduction in inventory, improved customer service and substantially improved business information and controls.*'

What is ERP?

Source: SAP

The SAP company has become one of the leading suppliers of ERP and related systems

Enterprise resource planning (ERP)
The integration of all significant resource planning systems in an organization that, in an operations context, integrates planning and control with the other functions of the business.

Materials requirement planning (MRP)
A set of calculations embedded in a system that helps operations make volume and timing calculations for planning and control purposes.

An easy way of thinking about **enterprise resource planning** is to imagine that you have decided to hold a party in two weeks' time and expect about 40 people to attend. As well as drinks, you decide to provide sandwiches and snacks. You will probably do some simple calculations, estimating guests' preferences and how much people are likely to drink and eat. You may already have some food and drink in the house which you will use, so you will take this into account when making your shopping list. If any of the food is to be cooked from a recipe, you may have to multiply up the ingredients to cater for 40 people. Also, you may wish to take into account the fact that you will prepare some of the food the week before and freeze it, while you will leave the rest to either the day before or the day of the party. So, you will need to decide when each item is required so that you can shop in time. In fact, planning a party requires a series of interrelated decisions about the volume (quantity) and timing of the *materials* needed.[2] This is the basis of **materials requirement planning**. It is a process that helps companies make volume and timing calculations (similar to the party, but on a much larger scale, and with a greater degree of complexity). But your planning may extend beyond 'materials'. You may want to rig up a sound system borrowing a friend's speakers – you will have to plan for this. The party also has financial implications. You may have to agree a temporary increase to your credit card limit. Again, this requires some forward planning and calculations of how much it is going to cost and how much extra credit you require. Both the equipment and financial implications may vary if you increase the number of guests. But if you postpone the party for a month, these arrangements will change. There are also other implications of organizing the party. You will need to give friends, who are helping with the organization, an idea of when they should come and for how long. This will depend on the timing of the various tasks to be done (making sandwiches, etc.).

So, even for this relatively simple activity, the key to successful planning is how we generate, integrate and organize all the information on which planning and control depends. Of course, in business operations it is more complex than this. Companies usually sell many different products to many hundreds of customers who are likely to vary their demand for the products. This is a bit like throwing 200 parties one week, 250 the next and 225 the following week, all for different groups of guests with different requirements who keep changing their minds about what they want to eat and drink. This is what ERP does – it helps companies 'forward plan' these types of decisions and understand all the implications of any changes to the plan.

Bill of material (BOM)
A list of the component parts required to make up the total package for a product or service together with information regarding their level in the product or component structure and the quantities of each component required.

Master production schedule (MPS)
The important schedule that forms the main input to material requirements planning, it contains a statement of the volume and timing of the end products to be made.

Manufacturing resource planning (MRPII)
An expansion of material requirements planning to include greater integration with information in other parts of the organization and often greater sophistication in scheduling calculations.

Web-integrated ERP
Enterprise resource planning that is extended to include the ERP type systems of other organizations such as customers and suppliers.

The origins of ERP

Enterprise resource planning is the latest, and the most significant, development of the original MRP philosophy. The (now) large companies which have grown almost exclusively on the basis of providing ERP systems include SAP and Oracle. Yet to understand ERP, it is important to understand the various stages in its development, summarized in Figure 14.2. The original MRP became popular during the 1970s, although the planning and control logic that underlies it had, by then, been known for some time. What popularized MRP was the availability of computer power to drive the basic planning and control mathematics. It uses product information in the form of a **bill of material (BOM)**, which is similar to the 'component structure' discussed in Chapter 5, together with demand information in the form of a **master production schedule (MPS)**.

Manufacturing resource planning (MRP II) expanded out of MRP during the 1980s. Again, it was a technology innovation that allowed the development. Local area networks (LANs, see Chapter 8), together with increasingly powerful desktop computers, allowed a much higher degree of processing power and communication between different parts of a business. Also MRP II's extra sophistication allowed the forward modelling of 'what-if' scenarios. The strength of MRP and MRP II lay always in the fact that they could explore the *consequences* of any changes to what an operation was required to do. So, if demand changed, the MRP system would calculate all the 'knock-on' effects and issue instructions accordingly.

This same principle applies to ERP, but on a much wider basis. ERP systems allow decisions and databases from all parts of the organization to be integrated so that the consequences of decisions in one part of the organization are reflected in the planning and control systems of the rest of the organization (see Figure 14.3). The potential of web-based communication has provided a further boost to ERP development. Many companies have suppliers, customers and other businesses with which they collaborate which themselves have ERP-type systems. An obvious development is to allow these systems to communicate. However, the technical as well as organizational and strategic consequences of this can be formidable. Nevertheless, many authorities believe that the true value of ERP systems is fully exploited only when such **web-integrated ERP** (known by some people as 'collaborative commerce' or c-commerce) becomes widely implemented.

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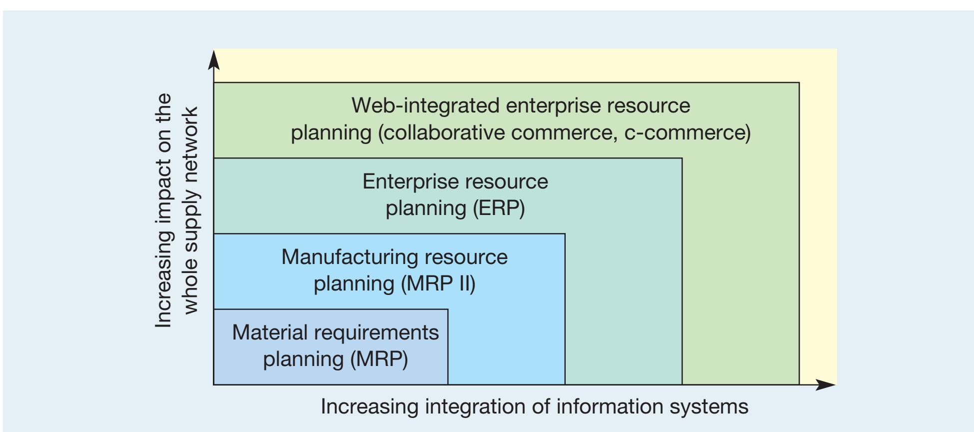


Figure 14.2 **The development of ERP**

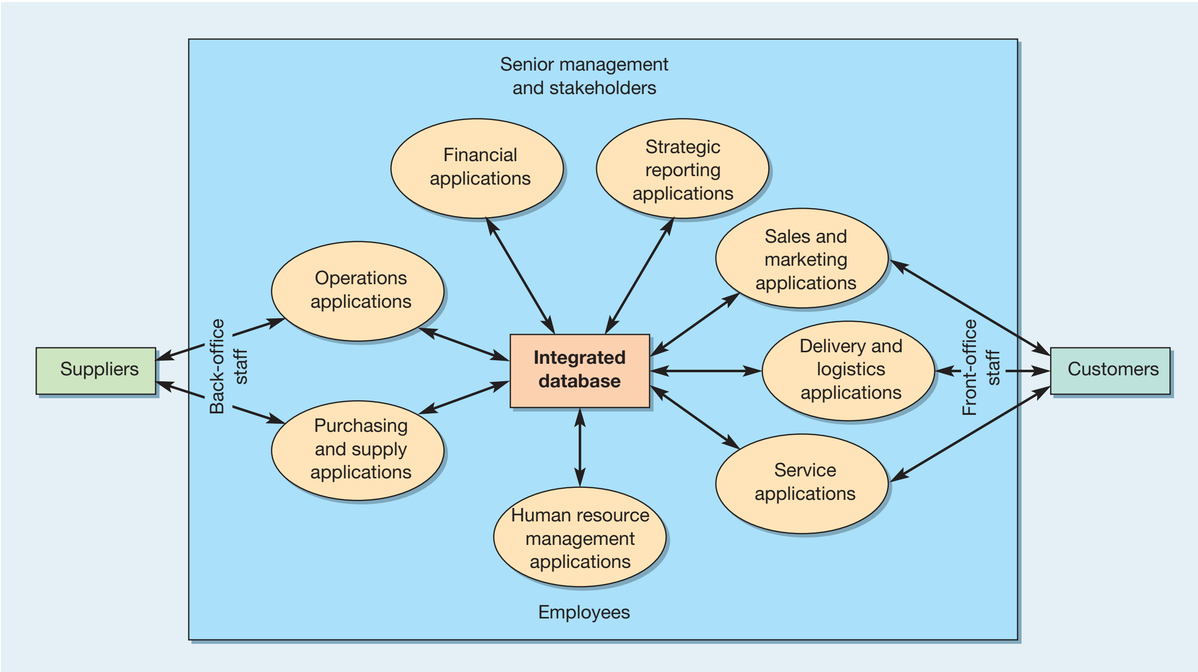


Figure 14.3 ERP integrates information from all parts of the organization

Materials requirements planning (MRP)

Materials requirements planning systems typically require certain data records which the MRP program checks and updates. Figure 14.4 shows the information required to perform MRP and some of the outputs from it. The most obvious inputs are customer orders and forecast demand. MRP performs its calculations based on the combination of both firm and forecast orders. All other requirements calculated within the MRP process are derived from these demands (MRP is what we described in Chapter 10 as a dependent demand system).

Demand management

Taken together, the management of customer orders and sales forecasts is called 'demand management'. This is a set of processes which interfaces with the customer market.

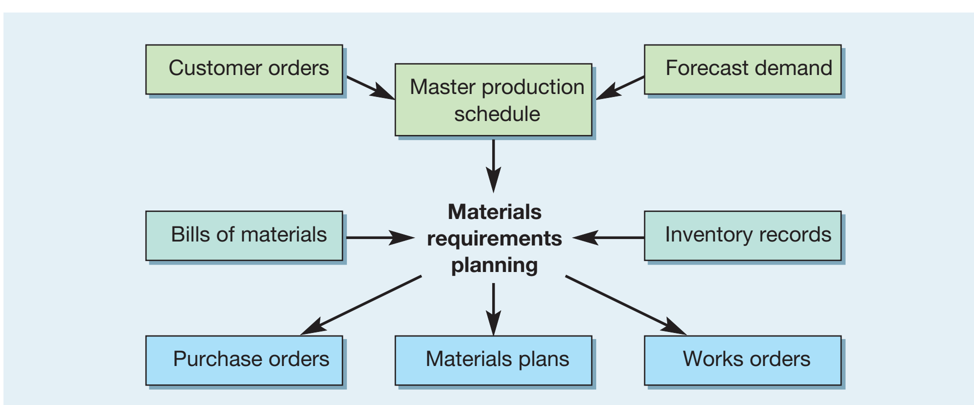


Figure 14.4 Materials requirements planning (MRP) schematic

Depending on the business, these processes may include sales order entry, demand forecasting, order promising, customer service and physical distribution. For example, if you place an order on the internet and ring up a week later to check why your purchase has not arrived, you will deal with a call centre service operator. He or she can access the details of your particular order and advise why there might have been a hold-up in delivery. In addition, you could be given a delivery promise and information regarding the mode of delivery. That single interaction with a customer triggers a chain of events. The item has to be picked from a warehouse; a stores operator must therefore be given the appropriate information, the delivery must be booked and so on. If demand information is not available or communicated, any subsequent plans will be misleading. Therefore we now need to consider some of the implications of managing demand on MRP.

Customer orders

Sales functions typically manage a dynamic, changing order book made up of confirmed orders from customers. Of particular interest to the MRP process are the records of exactly what each customer has ordered, how many they have ordered and when they require delivery. But customers may change their minds after having placed their orders and because customer service and flexibility are increasingly important competitive factors, MRP must be able to react to this. Considering that each of several hundred customers may make changes to their sales orders, not once but possibly several times after the order has been placed, managing the sales order book is a complex and dynamic process.

Forecast demand

Using historical data to predict future trends, cycles or seasonality is always difficult. Driving a business using forecasts based on history has been compared to driving a car by looking only at the rear-view mirror.[3] In spite of the difficulties, many businesses have no choice but to forecast ahead. Take automotive manufacturers, for example. To satisfy customers' demands for delivery speed, at the time a customer places an order the company has already made estimates of the models, the engines and the colours it thinks will be sold. The customer can, at the time of ordering, choose from a wide range of options in terms of upholstery, audio systems and glass tinting, etc., all of which can be added to the main assembly, effectively giving the impression of customization. The manufacturer has to predict ahead the likely required mix of models and colours to manufacture and the likely mix of options to purchase and have available in inventory.

Combining orders and forecasts

A combination of known orders and forecasted orders is used to represent demand in many businesses. This should be the best estimate at any time of what reasonably could be expected to happen. But the further ahead you look into the future, the less certainty there is about demand. Most businesses have knowledge of short-term demand, but few customers place orders well into the future. Based on history and on market information, a forecast is put together to reflect likely demand, although different operations will have a different mix of known and forecast orders. A make-to-order business, such as a jobbing printer, will have greater visibility of known orders over time than a make-for-stock business, such as a consumer durables manufacturer. Purchase-to-order businesses do not order most of their raw materials until they receive a confirmed customer order. For example, a craft furniture maker may not order materials until the order is certain. Conversely, there are some operations that have very little order certainty at the time they take most of their decisions. For example, newspaper publishers distribute newspapers to retail outlets on a sale-or-return basis: that is, real demand is evident to them only after each day's trading has finished and they calculate how many papers were actually sold. Also, many businesses have to operate with a varying combination of known orders and forecasts. The week before Mother's Day, small local florists receive a large volume of orders for bouquets and flower arrangements. At other times of the year, a greater amount of their business is passing trade, which is affected by the weather and shopping patterns.

Master production schedule

Master production schedule (MPS)
The important schedule that forms the main input to material requirements planning, it contains a statement of the volume and timing of the end products to be made.

The master production schedule (MPS) is MRP's most important planning and control schedule. The MPS contains a statement of the volume and timing of the end products to be made; this schedule drives the whole operation in terms of what is assembled, what is manufactured and what is bought. For example, in a hospital theatre there is a master schedule which contains a statement of which surgical procedures are planned and when. This can be used to provision materials for the operations, such as the sterile instruments, blood and dressings. It also governs the scheduling of staff for operations, including anaesthetists, nurses and surgeons.

Sources of information for the MPS

It is important that all sources of demand are considered when the master production schedule is created. Often the miscellaneous requirements in a business can disrupt the entire planning system. For example, if a manufacturer of earth excavators plans an exhibition of its products and allows a project team to raid the stores so that it can build two pristine examples to be exhibited, this is likely to leave the factory short of parts. (If it doesn't, then the inventory was excess to requirements and should not have been there anyway.) Similarly, sister companies may be able to 'borrow' parts at short notice for their own purposes. If such practices are allowed, the planning and control system needs to take them into account. Figure 14.5 shows the inputs that may be taken into account in the creation of a master production schedule.

The master production schedule record

Master production schedules are time-phased records of each end product, which contain a statement of demand and currently available stock of each finished item. Using this information, the available inventory is projected ahead in time. When there is insufficient inventory to satisfy forward demand, order quantities are entered on the master schedule line. Table 14.1 is a simplified example of part of a master production schedule for one item. Demand is shown in the first row and can be seen to be gradually increasing. The second row, 'Available',

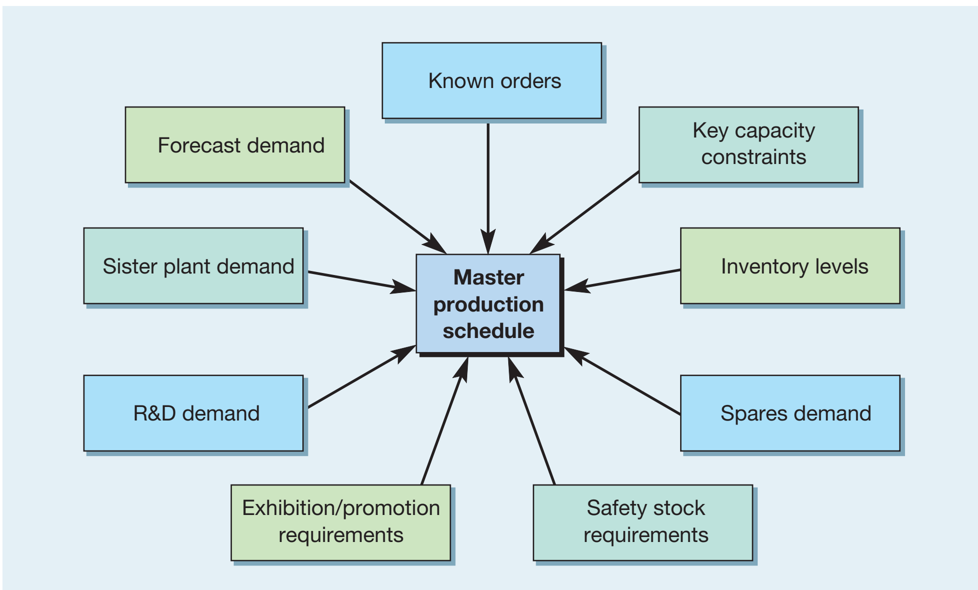


Figure 14.5 Inputs into the master production schedule

Table 14.1 Example of a master production schedule

		Week number								
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Demand		10	10	10	10	15	15	15	20	20
Available		20	10	0	0	0	0	0	0	0
MPS		0	0	10	10	15	15	15	20	20
On hand	30									

shows how much inventory of this item is expected to be in stock at the end of each weekly period. The opening inventory balance, 'On hand', is shown separately at the bottom of the record. Here, 30 of this part are currently in stock in week 0. The Available figure of 20 in the first week is calculated by taking demand of 10 away from the on-hand inventory of 30. The third row is the MPS; this shows how many finished items need to be completed and available in each week to satisfy demand. As there is adequate inventory already available in weeks 1 and 2, no plans are made to complete more in those weeks. However, in week 3, it is necessary for production to complete 10 of these items to satisfy projected demand; if production cannot complete 10 at this time, there is the possibility that customers will be put on back order (that is, they will be made to queue).

Chase or level master production schedules

In the example in Table 14.1, the MPS increases as demand increases and aims to keep available inventory at 0 – the master production schedule is 'chasing' demand (see Chapter 11), that is adjusting resources to match demand. An alternative 'level' MPS for this situation is shown in Table 14.2. Level scheduling involves averaging the amount required to be completed to smooth out peaks and troughs. Table 14.2 shows how this level schedule generates more inventory than the previous MPS. In this case, the average projected inventory of finished items over the nine-week period is 25 per week (that is, more than any one month's demand during this period). In the previous table, the average inventory was only 3.

Available to promise (ATP)

The master production schedule provides the information to the sales function on what can be promised to customers and when delivery can be promised. The sales function can load known sales orders against the master production schedule and keep track of what is **available to promise (ATP)** (see Table 14.3).

Available to promise

The ATP line in the master production schedule shows the maximum in any one week that is still available, against which sales orders can be loaded. If sales promises above that figure, it will not be able to keep its promise. For potential sales over this ATP figure, negotiation will be needed to see whether there is any possibility of satisfying this extra demand by adjusting the MPS. However, this must be run through the MRP process to see the resulting effects on resource requirements.

Table 14.2 Example of a 'level' master production schedule

		Week number								
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Demand		10	10	10	10	15	15	15	20	20
Available		31	32	33	34	30	26	22	13	4
MPS		11	11	11	11	11	11	11	11	11
On hand	30									

Table 14.3 Example of a level master production schedule including available to promise

		Week number								
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Demand		10	10	10	10	15	15	15	20	20
Sales orders		10	10	10	8	4				
Available		31	32	33	34	30	26	22	13	4
ATP		31	1	1	3	7	11	11	11	11
MPS		11	11	11	11	11	11	11	11	11
On hand	30									

The bill of materials

Bills of materials (BOM) A list of the component parts required to make up the total package for a product or service together with information regarding their level in the product or component structure and the quantities of each component required.

Having established this top-level MPS schedule, MRP performs calculations to work out the volume and timing of assemblies, sub-assemblies and materials that are required. To explain the process, a board game called 'Treasure Hunt' will be used. To be able to manufacture this game, Warwick Operations Games Inc. needs to understand what parts are required to go into each boxed game. To do this it requires records of the 'ingredients' or components that go into each item, much the same as a cook requires a list of ingredients to prepare a dish. These records are called **bills of materials (BOM)** and are similar to the idea of product structures discussed in Chapter 5. They show which parts and how many of them are required to go into which other parts. Initially it is simplest to think about these as a product structure. The product structure in Figure 14.6 is a simplified structure showing the parts required to make the game. It shows that to make one game you require the components of the game – board, dice, characters and quest cards – a set of rules and the packaging. The packaging comprises a printed cardboard box and, inside the base, an injection-moulded plastic inner tray. Since the game was launched, finance was provided for television advertis-

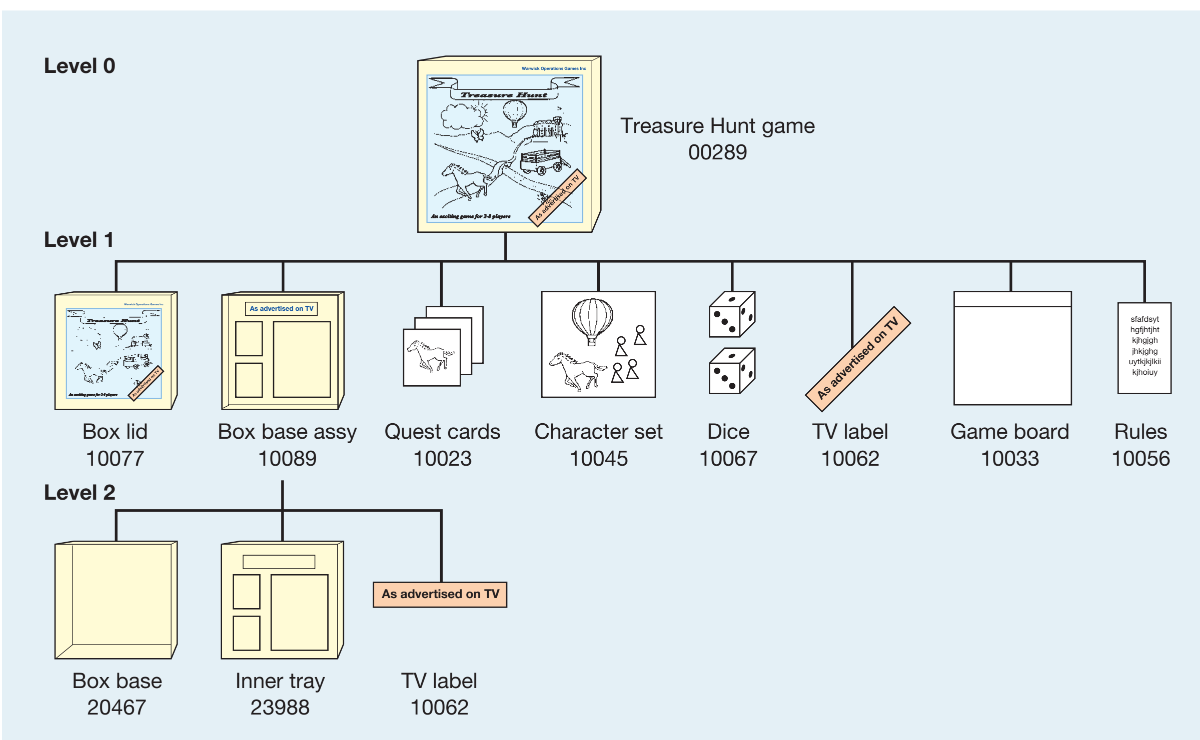


Figure 14.6 Product structure for the 'Treasure Hunt' game

ing, so an additional sticker stating 'As advertised on TV' is now stuck on the plastic inner tray and on the front of the complete box.

Levels of assembly

The product structure shows that some parts go into others, which in turn go into others. In MRP we term these levels of assembly. The finished product – the boxed game – is said to be at level 0. The parts and sub-assemblies that go into the boxed game are at level 1, the parts that go into the sub-assemblies are at level 2 and so on. There are several features of this product structure and of MRP generally that should be noted at this time:

- Multiples of some parts are required; this means that MRP has to know the required number of each part to be able to multiply up the requirements.
- The same part (the TV label, part number 10062) may be used in different parts of the product structure. In this example, the label is needed to make the box base assembly and also to complete the 'Treasure Hunt' game. This means that MRP has to cope with this commonality of parts and, at some stage, aggregate the requirements to check how many labels in total are required.
- The product structure stops when it gets down to parts that are not made by this business; for example, another operation makes and supplies the plastic inner trays. This supplier needs to know the product structure for the trays – the weight of plastic granules and the colour of plastic which is required – but the game manufacturer's MRP system treats the plastic tray as a single, bought-in item. This is true even for complex modules or sub-assemblies, such as those bought in by computer manufacturers. Their product structure is not relevant to the in-house MRP, except in terms of the implications on the 'lead time' required to procure them.

The 'shape' of the component structure

Component structure (product structure) shape Diagram that shows the constituent component parts of a product or service package and the order in which the component parts are brought together (often called components structure).

The nature of the product structure is closely related to the design of the product. This is reflected in the component structure shape. The shape is partly determined by the number of components and parts used at each level – the more that are used, the wider the shape. Therefore, standardizing components to reduce variety slims the shape of the product structure. Shape is also determined by the amount of the item made in-house. If most of the parts are bought in complete, with only assembly occurring in-house, such as with the 'Treasure Hunt' game, the resulting product structure is very shallow, with few levels. However, if all the components are made from raw materials and then assembled under one roof, the resulting product structure is very deep. There are some recognized typical shapes of product structure – 'A', 'T', 'V' and 'X' (see Figure 14.7).

'A'-shape product structures

The implications of an 'A'-shape structure are that the business has only a limited product range to offer the customer. However, because there is little variety, the volumes of standardized production can give some economies of scale. Such products can also be made for stock; therefore the operation can be planned smoothly, rather than having to chase demand.

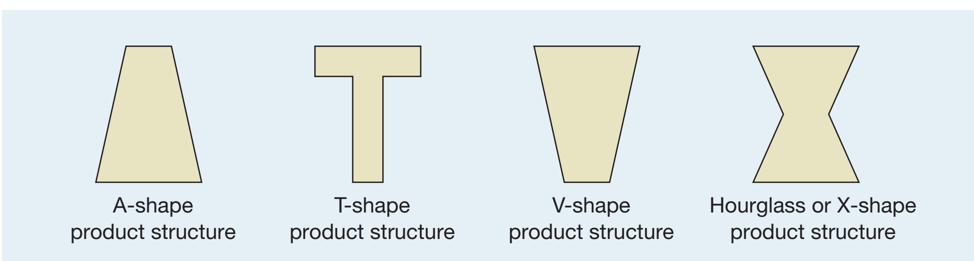


Figure 14.7 Different shapes of product structure

'T'-shape product structures

A 'T'-shape product structure is typical of operations that have a small number of raw materials but which produce a very wide range of highly customized end products. For example, a label manufacturer producing personal name and address labels uses standard materials and processes, but because the final part of the process is highly customized, it must be performed to order.

'V'-shape product structures

This is similar to a 'T'-shape structure, but with less standardization of process. It is typical of the petrochemical industry where a small number of raw materials is used to create a wide range of products. Operations which have these types of products are driven by customer orders. Because of their reliance on a small number of raw materials, any failure of supply of one material can cause disruption of service to much of the customer base.

'X'-shape product structures

Some product designs consist of a small number of standard modules. For example, kitchen unit manufacturers make standardized bodies to which a wide range of doors and fittings can be attached. These standard modules are represented by the cross of the X. They are combined with a customized selection of features and options, giving a wide range of finished products. Automotive manufacturers typically use this 'X'-shape product structure. The same chassis assemblies, transmission assemblies, braking systems and engines are often used on a wide range of vehicles.

Single-level and indented bills of materials

Single-level bills of materials

Indented bills of materials

Bills of materials can become unwieldy, with (say) 15 levels of assembly and 5,000 different parts within a finished product. MRP systems cope with this by using **single-level bills of materials** and **indented bills of materials**. In single-level bills of materials, the details of the relationships between parts and sub-assemblies are stored as one single level at a time. For example, the single-level bills for the board game in the example provided previously are shown in Table 14.4. Each single-level bill of materials shows only the parts that go directly into it. Although most MRP systems store information in this way, they can also present them in the form of an indented bill of materials to show several levels at the same time.

Table 14.4 Single-level bills for board game

Part number: 00289
Description: Board game
Level: 0

Level	*Part number*	*Description*	*Quantity*
1	10089	Box base assy	1
1	10077	Box lid	1
1	10023	Quest cards set	1
1	10062	TV label	1
1	10045	Character set	1
1	10067	Die	2
1	10033	Game board	1
1	10056	Rules booklet	1

Part number: 10089
Description: Box base assy
Level: 1

Level	*Part number*	*Description*	*Quantity*
2	20467	Box base	1
2	10062	TV label	1
2	23988	Inner tray	1

Table 14.5 shows the whole indented bill of materials for the board game. The term 'indented' refers to the indentation of the level of assembly, shown in the left-hand column.

Table 14.5 **Indented bill of materials for board game**

Part number: 00289
Description: Board game
Level: 0

Level	*Part number*	*Description*	*Quantity*
0	00289	Board game	1
. 1	10077	Box lid	1
. 1	10089	Box base assy	1
. . 2	20467	Box base	1
. . 2	10062	TV label	1
. . 2	23988	Inner tray	1
. 1	10023	Quest cards set	1
. 1	10045	Character set	1
. 1	10067	Die	2
. 1	10062	TV label	1
. 1	10033	Game board	1
. 1	10056	Rules booklet	1

Worked example

The Novelty Pencil Company is concerned that its computer-based ERP system is preventing production employees from understanding exactly what goes into its products. The technologies employed by the company include wood and graphite processing, injection moulding and extrusion of plastics, and the fine engineering of metals. Modern automated assembly machines allow the low-cost, mass production of volume products such as ballpoint pens. In managing the production of its complex range of over 6,000 products, the company has been aided by the use of a well-tried ERP system. Whereas some items, such as standard pencils, have a bill of materials with only a few levels, some of the more involved products require a breakdown of up to seven as processes have become more complex. Individual operators see only a part of the total process.

We can print out the bill of materials for each product. But it looks too technical and most people don't really look at it. What we need is a more graphical diagram of some sort that will illustrate exactly what each product is made of. That will allow people to understand how their part of the process contributes to the product as a whole.

An example of a typical Novelty Pencil Company bill of materials is shown in Table 14.6. This illustrates the different levels of production involved in manufacturing a 'XXX-HB Pointy Pencil in Box of 10' (level 0). The top level on the bill (shown as .1) gives all the items involved in the final packaging, including the finished pencil itself – coded FPOINT. The next levels in the bill are all required in the production of pencils themselves, with level 2 being the materials required to label the pencils with the Pointy Pencil name and paint for dipping to give the Novelty 'rounded end' on the end of the pencil. At level 3 are the varnishes and paints required to coat the basic pencil, and finally level 4 details the raw materials – slats of wood, pencil lead slips and glue – which are used in the initial production of the pencil.

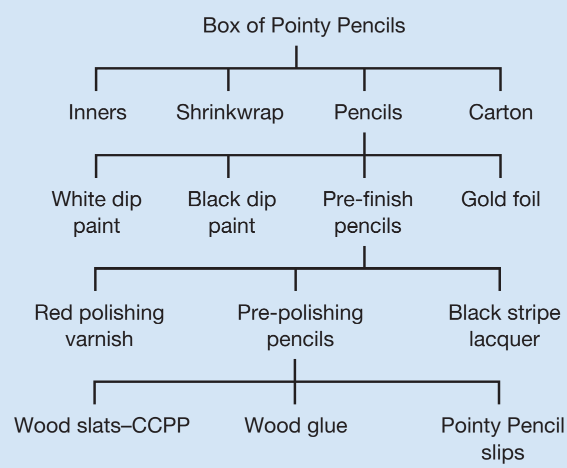
Solution

The likely solution to the company's problem is to translate the 'bill of materials' information into a 'product structure' (also called a 'component structure'). The figure below shows the product structure that is equivalent in Table 14.6.

Table 14.6 The bill of materials for XXX-HB 'Pointy Pencil' in a Box of 10

Production level	*Component*			
	Quantity	*Unit*	*Number*	*description*
. 1	12.000000	PC	P1X34	Pointy Pencil
. 1	0.000500	PC	PX335	Pointy shinkwrap
. 1	0.060000	PC	P12X	Pointy carton
. 1	1.000000	GS	FPOINT	Pre-packging Pointy Pencils
. . 2	0.008000	KG	DLP	White dip paint
. . 2	0.030000	KG	DLP	Black dip paint
. . 2	0.030000	PC	GFP	Pointy gold foil
. . 2	1.000000	GS	PPOINT	Pre-finishing Pointy Pencils
. . . 3	0.100000	KG	PLP	Red polishing varnish
. . . 3	0.070000	KG	SLP	Black stripe lacquer
. . . 3	1.000000	GS	RPOINT	Pre-polishing Pointy Pencils
. . . . 4	0.070000	PC	CCPPP4	Wood slats – CCP
. . . . 4	0.000500	KG	WW8G	Wood glue
. . . . 4	1.000000	GS	SPOINT	Pointy Pencil slips

Units: PC = suppliers' unit; KG = kilogram; GS = gross of pencils.



Product/component structure for Pointy Pencils Box of 10

Inventory records

The bill of materials file therefore provides MRP with the base data on the ingredients or structure of products. Rather than simply taking these ingredients and multiplying them up in line with demand to determine the total materials requirements, MRP recognizes that some of the required items may already be in stock. This stock may be in the form of finished goods, work-in-progress or raw materials. It is necessary, starting at level 0 of each bill, to check how much inventory is available of each finished product, sub-assembly and component, and then to calculate what is termed the 'net' requirements – the extra requirements needed to supplement the inventory so that demand can be met. To do this, MRP requires that inventory records are kept. There are three main files kept in MRP systems that help to manage inventory:

Item master file

- **The item master file** – contains the unique standard identification code for each part or component. In addition to a part number, the item master file contains all the stable data on a part, including the part description, the unit of measure (flour may be recorded in tonnes, washers in 1000s and engines in single discrete units) and a standard cost.

The transaction file

The location file

- The transaction file – keeps a record of receipts into stock, issues from stock and a running balance. This means the transaction file is updated at the time a receipt or issue occurs.
- The location file – identifies where inventory is located. Some operations have fixed locations so that a particular part can always be found at a particular location. But those which cannot do this may simply locate parts in the most convenient place. This requires careful control, as the same item may be kept in several different locations at any one time.

MRP calculations

MRP netting process
The process of calculating net requirements using the master production schedule and the bills of material.

At its core, MRP is a systematic process of taking this planning information and calculating the volume and timing requirements which will satisfy demand. This next part of the chapter examines the way these calculations are performed, starting with what is probably the most important step, the MRP netting process.

The MRP netting process

Figure 14.8 illustrates the process that MRP performs to calculate the volumes of materials required. The master production schedule is 'exploded', examining the implications of the schedule through the bill of materials, checking how many sub-assemblies and parts are required. Before moving down the bill of materials to the next level, MRP checks how many of the required parts are already available in stock. It then generates 'works orders', or requests, for the net requirements of items. These form the schedule which is again exploded

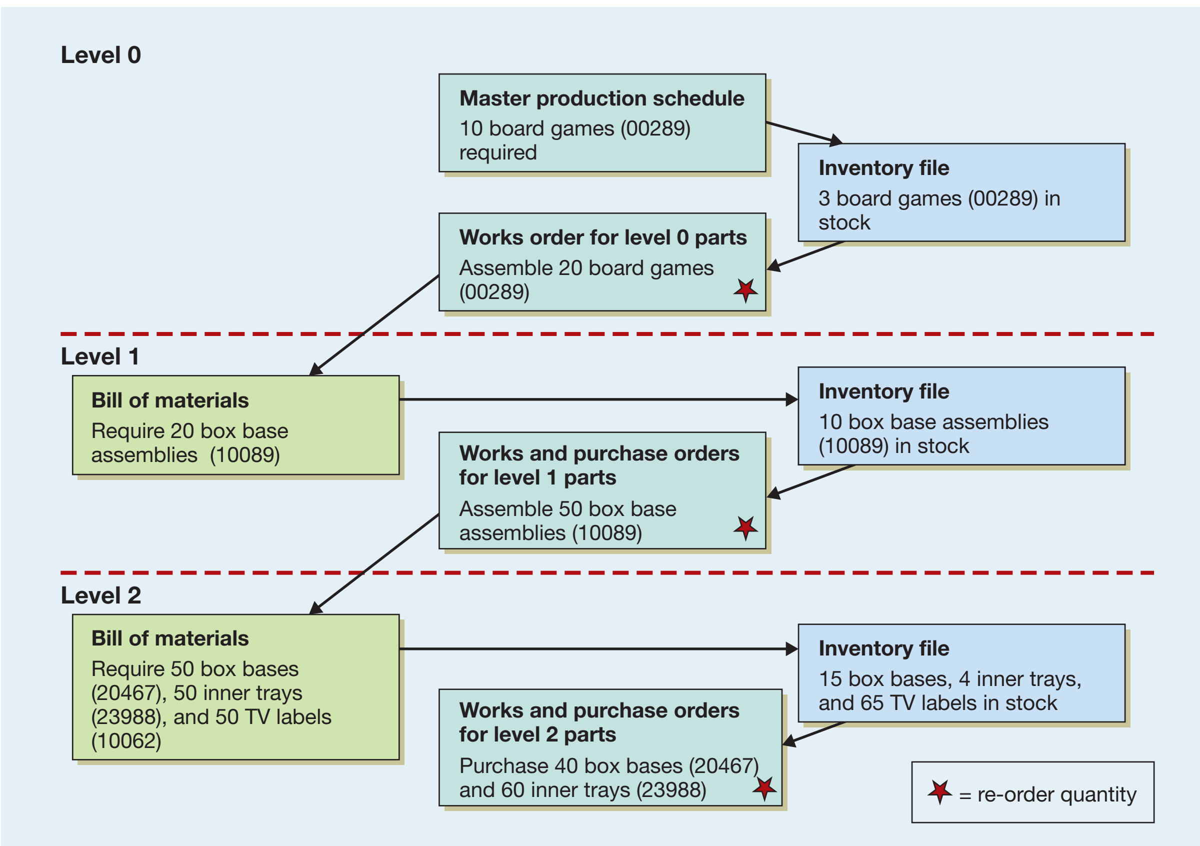


Figure 14.8 Example of the MRP netting process for the board game

through the bill of materials at the next level down. This process continues until the bottom level of the bill of materials is reached.

Back-scheduling

In addition to calculating the volume of materials required, MRP considers when each of these parts is required, that is, the timing and scheduling of materials. It does this by a process called back-scheduling which takes into account the lead time (the time allowed for completion of each stage of the process) at every level of assembly. Again using the example of the board game, assume that ten board games are required to be finished by a notional planning day which we will term day 20. To determine when we need to start work on all the parts that make up the game, we need to know all the lead times that are stored in MRP files for each part (see Table 14.7).

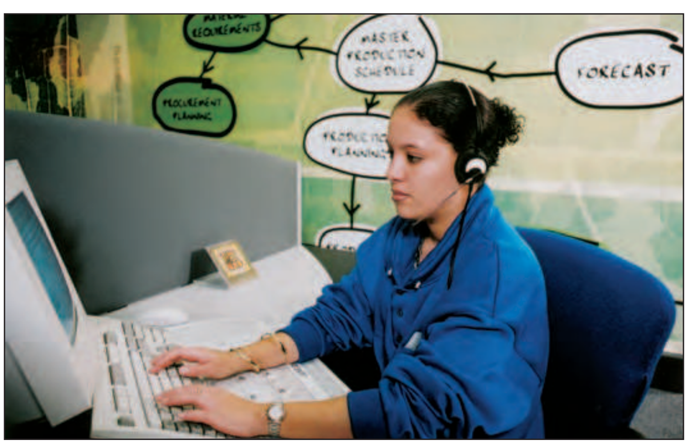
Using the lead-time information, the programme is worked backwards to determine the tasks that have to be performed and the purchase orders that have to be placed. Given the lead times and inventory levels shown in Table 14.7, the MRP records shown in Figure 14.9 can be derived.

Table 14.7 Back-scheduling of requirements in MRP

Part no.	*Description*	*Inventory on-hand day 0*	*Lead time (days)*	*Re-order quantity*
00289	Board game	3	2	20
10077	Box lid	4	8	25
10089	Box base assy	10	4	50
20467	Box base	15	12	40
23988	Inner tray	4	14	60
10062	TV label	65	8	100
10023	Quest cards set	4	3	50
10045	Character set	46	3	50
10067	Die	22	5	80
10033	Game board	8	15	50
10056	Rules booklet	0	3	80

MRP capacity checks

The MRP process needs a feedback loop to check whether a plan was achievable and whether it has actually been achieved. Closing this planning loop in MRP systems involves checking production plans against available capacity and, if the proposed plans are not achievable at any level, revising them (see Figure 14.10). All but the simplest MRP systems are now closed-



Source: Tibbett and Britten

A call centre operator entering customer orders directly into an ERP system

00289: Treasure Hunt game Assembly lead time = 2 Re-order quantity = 20

Day Number:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Requirements Gross																					10
Scheduled Receipts																					
On hand Inventory	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	13
Planned Order Release																			20		

10077: Box lid Purchase lead time = 8 Re-order quantity = 25

Day Number:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Requirements Gross																			20		
Scheduled Receipts																					
On hand Inventory	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	9	9	9
Planned Order Release											25										

10089: Box base assembly Assembly lead time = 4 Re-order quantity = 50

Day Number:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Requirements Gross																			20		
Scheduled Receipts																					
On hand Inventory	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	40	40	40
Planned Order Release															50						

20467: Box base Purchase lead time = 12 Re-order quantity = 40

Day Number:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Requirements Gross															50						
Scheduled Receipts																					
On hand Inventory	15	15	15	15	15	15	15	15	15	15	15	15	15	15	5	5	5	5	5	5	5
Planned Order Release			40																		

23988: Inner tray Purchase lead time = 14 Re-order quantity = 60

Day Number:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Requirements Gross															50						
Scheduled Receipts																					
On hand Inventory	4	4	4	4	4	4	4	4	4	4	4	4	4	4	14	14	14	14	14	14	14
Planned Order Release	60																				

10062: TV label Purchase lead time = 8 Re-order quantity = 100

Day Number:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Requirements Gross															50				20		
Scheduled Receipts																					
On hand Inventory	65	65	65	65	65	65	65	65	65	65	65	65	65	65	15	15	15	15	95	95	95
Planned Order Release											100										

10023: Quest card set Purchase lead time = 3 Re-order quantity = 50

Day Number:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Requirements Gross																			20		
Scheduled Receipts																					
On hand Inventory	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	34	34	34
Planned Order Release																50					

10045: Character set Purchase lead time = 3 Re-order quantity = 50

Day Number:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Requirements Gross																			20		
Scheduled Receipts																					
On hand Inventory	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	26	26	26
Planned Order Release																					

10067: Die Purchase lead time = 5 Re-order quantity = 80

Day Number:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Requirements Gross																			40		
Scheduled Receipts																					
On hand Inventory	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	13
Planned Order Release														80							

10033: Game board Purchase lead time = 15 Re-order quantity = 50

Day Number:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Requirements Gross																			20		
Scheduled Receipts																					
On hand Inventory	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	38	38	38
Planned Order Release				50																	

10056: Rules booklet Purchase lead time = 3 Re-order quantity = 80

Day Number:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Requirements Gross																			20		
Scheduled Receipts																					
On hand Inventory	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	60	60
Planned Order Release																80					

Figure 14.9 Extract of the MRP records for the board game

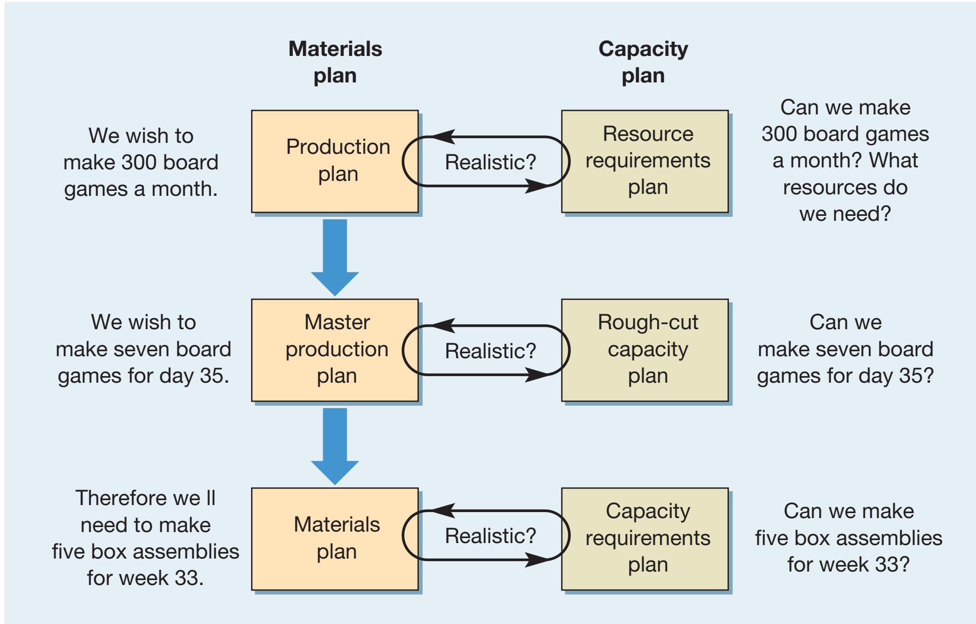


Figure 14.10 Closed-loop MRP

loop systems. They use three planning routines to check production plans against the operation's resources at three levels:

- resource requirements plans (RRPs) involve looking forward in the long term to predict the requirements for large structural parts of the operation, such as the numbers, locations and sizes of new plants;
- rough-cut capacity plans (RCCPs) are used in the medium to short term to check the master production schedules against known capacity bottlenecks, in case capacity constraints are broken. The feedback loop at this level checks the MPS and key resources only;
- capacity requirements plans (CRPs) look at the day-to-day effect of the works orders issued from the MRP on the loading individual process stages.

Manufacturing resource planning (MRP II)

MRP II

MRP was essentially aimed at the planning and control of production and inventory in manufacturing businesses. However, the concepts have been extended to other areas of the business. This extended concept was termed MRP II by Oliver Wight, one of the founders of MRP. Wight[2] defined MRP II as '*a game plan for planning and monitoring all the resources of a manufacturing company: manufacturing, marketing, finance and engineering. Technically it involves using the closed-loop MRP system to generate the financial figures.*'

Without MRP II integrated systems, separate databases are held by different functions. For example, a product structure or bill of materials is held in engineering and also in materials management. If engineering changes are made to the design of products, both databases have to be updated. It is difficult to keep both databases entirely identical and discrepancies between them cause problems, which often are not apparent until a member of staff is supplied with the wrong parts to manufacture the product. Similarly, cost information from finance and accounting, which is used to perform management accounting tasks such as variance analysis against standard costs, needs to be reconciled with changes made elsewhere in the operation, such as changes in inventory-holding or process methods.

MRP II is based on one integrated system containing a database which is accessed and used by the whole company according to individual functional requirements. However, despite its dependence on the information technologies which allow such integration, MRP II still depends on people-based decision making to close the loop.

Enterprise resource planning (ERP)

Enterprise resource planning (ERP)
The integration of all significant resource planning systems in an organization that, in an operations context, integrates planning and control with the other functions of the business.

Enterprise resource planning has been defined as '*a complete enterprise-wide business solution. The ERP system consists of software support modules such as marketing and sales, field service, product design and development, production and inventory control, procurement, distribution, industrial facilities management, process design and development, manufacturing, quality, human resources, finance and accounting, and information services. Integration between the modules is stressed without the duplication of information*'.[3]

ERP is very much a development out of MRP II, which itself was a development out of MRP. Its aim is to integrate the management of different functions within the business as a whole in order to improve the performance of all the interrelated processes in a business. As usual, the improvement of processes can be measured using the operations performance objectives (quality, speed, dependability, flexibility and cost).

The benefits of ERP

ERP is generally seen as having the potential to very significantly improve the performance of many companies in many different sectors. This is partly because of the very much enhanced visibility that information integration gives, but it is also a function of the discipline that ERP demands. Yet this discipline is itself a 'double-edged' sword. On one hand, it 'sharpens up' the management of every process within an organization, allowing best practice (or at least common practice) to be implemented uniformly through the business. No longer will individual idiosyncratic behaviour by one part of a company's operations cause disruption to all other processes. On the other hand, it is the rigidity of this discipline that is both difficult to achieve and (arguably) inappropriate for all parts of the business. Nevertheless, the generally accepted benefits of ERP are usually held to be the following:

- Because software communicates across all functions, there is absolute visibility of what is happening in all parts of the business.
- The discipline of forcing business process-based changes (Chapters 1 and 18 look at business process) is an effective mechanism for making all parts of the business more efficient.
- There is better 'sense of control' of operations that will form the basis for continuous improvement (albeit within the confines of the common process structures).
- It enables far more sophisticated communication with customers, suppliers and other business partners, often giving more accurate and timely information.
- It is capable of integrating whole supply chains including suppliers' suppliers and customers' customers.

In fact, although the integration of several databases lies at the heart of ERP's power, it is nonetheless difficult to achieve in practice. This is why ERP installation can be particularly expensive. Attempting to get new systems and databases to talk to old (sometimes called *legacy*) systems can be very problematic. Not surprisingly, many companies choose to replace most, if not all, of their existing systems simultaneously. New common systems and relational databases help to ensure the smooth transfer of data between different parts of the organization.

In addition to the integration of systems, ERP usually includes other features which make it a powerful planning and control tool:

- It is based on a client/server architecture; that is, access to the information systems is open to anyone whose computer is linked to central computers.
- It can include decision-support facilities (see Chapter 8) which enable operations decision makers to include the latest company information.
- It is often linked to external extranet systems, such as the electronic data interchange systems which are linked to the company's supply chain partners.
- It can be interfaced with standard applications programs which are in common use by most managers, such as spreadsheets, etc.
- Often, ERP systems are able to operate on most common platforms such as Windows or UNIX or Linux.

Short case **The life and times of a chicken salad sandwich – Part two**[4]

In Chapter 10 we looked at the schedule for the manufacture of a chicken salad sandwich. This concentrated on the lead times for the ordering of the ingredients and the manufacturing schedule for producing the sandwiches during the afternoon and night time of each day for delivery during the evening and the night time and the morning of the following day. But that is only one half of the story, the half that is concerned with planning and controlling the timing of events. The other half concerns how the sandwich company manages the *quantity* of ingredients to order, the quantity of sandwiches to be made and the whole chain of implications for the whole company. In fact, this sandwich company uses an ERP system that has at its core an MRP II package. This MRP II system has the two normal basic drivers of first, a continually updated sales forecast and second, a product structure database. In this case the product structure and/or bill of materials is the 'recipe' for the sandwich; within the company this database is called the 'recipe management system'. The 'recipe' for the chicken sandwich (its bill of materials), is shown in Table 14.8.

Table 14.8 Bill of Materials for a chicken salad sandwich

FUNCTION: MBIL MULTI-LEVEL BILL INQUIRY

PARENT: BTE80058 DESC: HE CHICKEN SALAD TRAY
RV: UM: EA RUN LT: 0 FIXED LT: 0
PLNR: LOU PLN POL: N DRWG: WA1882 LA

LEVEL 1. . . 5. . . 10	PT USE	SEQN	COMPONENT	C T	PARTIAL DESCRIPTION	QTY	UM
1	PACK	010	FTE80045	P	H.E. CHICKENS	9	EA
2	ASSY	010	MBR–0032	P	BREAD HARVESTE	2	SL
3	HRPR	010	RBR–0023	N	BREAD HARVESTE	.04545455	EA
2	ASSY	020	RDY–0001	N	SPREAD BUTTER	.006	KG
2	ASSY	030	RMA–0028	N	MAYONNAISE MYB	.01	KG
2	ASSY	040	MFP–0016	P	CHICKEN FRESH	.045	KG
3	HRPR	010	RFP–0008	N	CHICKEN FRESH	1	KG
	ASSY	050	MVF–0063	P	TOMATO SLICE 4	3	SL
3	ALTI	010	RVF–0026	P	TOMATOES PRE-S	.007	KG
4	HRPR	010	RVF–0018	N	TOMATOES	1	KG
2	ASSY	060	MVF–0059	P	CUCUMBER SLICE	2	SL
3	ALTI	010	RVF–0027	P	CUCUMBER SLICE	.004	KG
4	TRAN	010	RVF–0017	N	CUCUMBER	1	KG
2	ASSY	070	MVF–0073	P	LETTUCE COS SL	.02	KG
3	HRPR	010	RVF–0015	N	LETTUCE COS	1	KG
2	ASSY	080	RPA–0070	N	WEBB BASE GREY	.00744	KG
2	ASSY	090	RPA–0071	N	WEBB TOP WHITE	.00116	KG
2	ASSY	100	RLA–0194	N	LABEL SW H	1	EA
2	ASSY	110	RLA–0110	N	STICKER NE	1	EA
1	PACK	010	RPA–0259	N	SOT LABELL	1	EA
1	PACK	030	RPA–0170	N	TRAY GREEN	1	EA

→

Figure 14.11 shows the ERP system used by this sandwich company. Orders are received from customers electronically through the EDI (see Chapter 8) system. These orders are then checked through what the company calls a validation system that checks the order against current product codes and expected quantities to make sure that the customer has not made any mistakes, such as forgetting to order some products (this happens surprisingly often). After validation the orders are transferred through the central database to the MRP II system that performs the main requirements breakdown. Based on these requirements and forecasted requirements for the next few day, orders are placed to the company's suppliers for raw materials and packaging. Simultaneously, confirmation is sent to customers, accounts are updated, staffing schedules are finalized for the next two weeks (on a rolling basis), customers are invoiced and all this information is made available both to the customers' own ERP systems and the transportation company's planning system.

Interestingly, the company, like many others, found it difficult to implement its ERP system. '*It was a far bigger job than we thought,*' said the operations director. '*We had to change the way we organized our processes so that they would fit in with the ERP system that we bought. But that was relatively easy compared with making sure that the system integrated with our customers', suppliers' and distributors' systems. Because some of these companies were also implementing new systems at the time, it was like trying to hit a moving target.*'

Nevertheless, three years after the start of implementation, the whole process was working relatively smoothly.

Question

1 Why do you think that fitting an ERP system with those of suppliers and customers is so difficult?

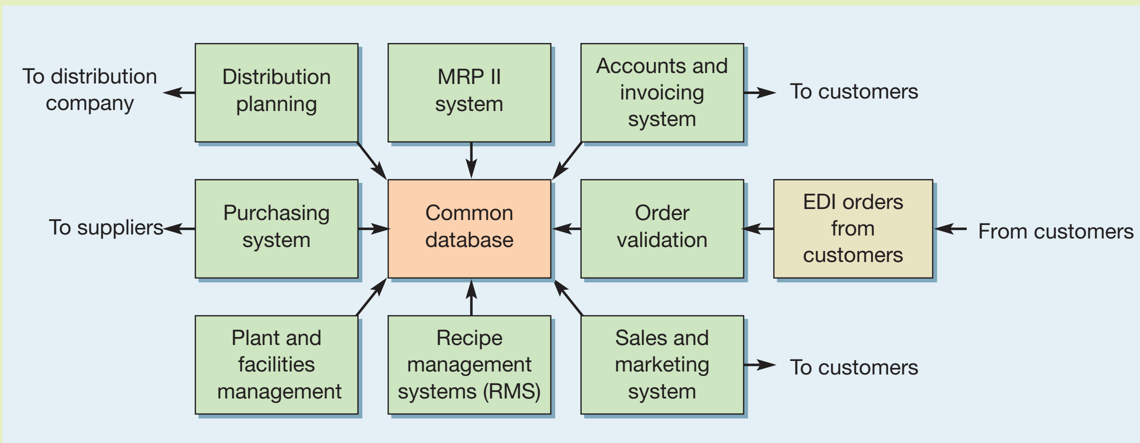


Figure 14.11 The ERP structure for the sandwich company

ERP changes the way companies do business

Arguably the most significant issue in many companies' decision to buy an off-the-shelf ERP system is that of its compatibility with the company's current business processes and practices. The advice emerging from the companies that have adopted ERP (either successfully or unsuccessfully) is that it is extremely important to make sure that their current way of doing business will fit (or can be changed to fit) with a standard ERP package. In fact, one of the most common reasons for companies to decide not to install ERP is that they cannot reconcile the assumptions in the software of the ERP system with their core business processes. If, as most businesses find, their current processes do not fit, they can do one of two things. They could change their processes to fit the ERP package. Alternatively, they could modify the software within the ERP package to fit their processes.

Both of these options involve costs and risks. Changing business practices that are working well will involve reorganization costs as well as introducing the potential for errors to creep into the processes. Adapting the software will both slow down the project and introduce potentially dangerous software 'bugs' into the system. It would also make it difficult to upgrade the software later on.

Why did companies invest in ERP?

If one accepts only some of the criticisms of ERP outlined in the critical commentary box, it does pose the question as to why companies invested such large amounts of money in it. Partly it was the attraction of turning the company's information systems into a 'smooth running and integrated machine'. The prospect of such organizational efficiency is attractive to most managers, even if it does presuppose a very simplistic model of how organizations work in practice. After a while, although organizations could see the formidable problems in ERP implementation, the investments were justified on the basis that 'even if we gain no significant advantage by investing in ERP, we will be placed at a disadvantage by not investing in it because all our competitors are doing so'. There is probably some truth in this; sometimes businesses have to invest just to stand still.

Critical commentary

Far from being the magic ingredient which allows operations to fully integrate all their information, ERP is regarded by some as one of the most expensive ways of getting zero or even negative return on investment. For example, the American chemicals giants Dow Chemical spent almost $500 million and seven years implementing an ERP system which became outdated almost as soon as it was implemented. One company, FoxMeyer Drug, claimed that the expense and problems which it encountered in implementing ERP eventually drove it into bankruptcy.

One problem is that ERP implementation is expensive. This is partly because of the need to customize the system, understand its implications for the organization and train staff to use it. Spending on what some call the *ERP ecosystem* (consulting, hardware, networking and complementary applications) has been estimated as being twice the spending on the software itself. But it is not only the expense which has disillusioned many companies, it is also the returns they have had for their investment. Some studies show that the vast majority of companies implementing ERP are disappointed with the effect it has had on their businesses. Certainly many companies find that they have to (sometimes fundamentally) change the way they organize their operations in order to fit in with ERP systems. This organizational impact of ERP (which has been described as the corporate equivalent of root-canal work) can have a significantly disruptive effect on the organization's operations.

Web-integrated ERP

Perhaps the most important justification for embarking on ERP is the potential it gives the organization to link up with the outside world. For example, it is much easier for an operation to move into internet-based trading if it can integrate its external internet systems into its internal ERP systems. However, as some critics of the ERP software companies have pointed out, ERP vendors were not prepared for the impact of e-commerce and had not made sufficient allowance in their products for the need to interface with internet-based communication channels. The result of this has been that whereas the internal complexity of ERP systems was designed to be intelligible only to systems experts, the internet has meant that customers and suppliers (who are non-experts) are demanding access to the same information. So, important pieces of information such as the status of orders, whether products are in stock, the progress of invoicing, etc. need to be available, via the ERP system, on a company's website.

One problem is that different types of external company often need different types of information. Customers need to check the progress of their orders and invoicing, whereas suppliers and other partners want access to the details of operations planning and control. Not only that, but they want access all the time. The internet is always there, but **web-integrated ERP** systems are often complex and need periodic maintenance. This can mean that every time the ERP system is taken off-line for routine maintenance or other changes, the website also goes off-line. To combat this some companies configure their ERP and e-commerce links in such a way that they can be decoupled so that ERP can be periodically shut down without affecting the company's web presence.

Web-integrated ERP
Enterprise resource planning that is extended to include the ERP type systems of other organizations such as customers and suppliers.

Supply chain ERP

The step beyond integrating internal ERP systems with immediate customers and suppliers is to integrate all the ERP and similar systems along a supply chain. Of course, this can never be straightforward and is often exceptionally complicated. Not only do different ERP systems have to communicate, they have to integrate with other types of system. For example, sales and marketing functions often use systems such as customer relationship management (CRM, see Chapter 13) which manage the complexities of customer requirements, promises and transactions. Getting ERP and CRM systems to work together is itself often difficult. Sometimes the information from ERP systems has to be translated into a form that CRM and other e-commerce applications are able to understand. Nevertheless, such web-integrated ERP or c-commerce applications are emerging and starting to make an impact on the way companies do business.

Although a formidable task, the benefits are potentially great. The costs of communicating between supply chain partners could be dramatically reduced and the potential for avoiding errors as information and products move between partners in the supply chain is significant. Yet as a final warning note, it is well to remember that although integration can bring all the benefits of increased transparency in a supply chain, it may also transmit systems failure. If the ERP system of one operation within a supply chain fails for some reason, it may block the effective operation of the whole integrated information system throughout the chain.

Optimized production technology (OPT)

Other concepts and systems have been developed which also recognize the importance of planning to known capacity constraints rather than overloading part of the production system and failing to meet the plan. Perhaps the best known is the **theory of constraints (TOC)** which has been developed to focus attention on the capacity constraints or bottleneck parts of the operation. By identifying the location of constraints, working to remove them, then looking for the next constraint, an operation is always focusing on the part that critically determines the pace of output. The approach which uses this idea is called **optimized production technology (OPT)**. Its development and the marketing of it as a proprietary software product were originated by Eliyahu Goldratt.[5] In some ways it is difficult to know where to place OPT in this book. We have placed it alongside ERP because of the importance it places on capacity. Yet it can be seen as being the third approach (along with ERP and JIT, which is treated in the next chapter) to operations planning and control. However, along with JIT, OPT takes a more 'improvement-oriented' approach than ERP.

Theory of constraints (TOC)
Philosophy of operations management that focused attention on capacity constraints or bottleneck parts of an operation; uses software known as optimized production technology (OPT).

Optimized production technology (OPT)
Software and concept originated by Eliyahu Goldratt to exploit his theory of constraints (TOC).

OPT is a computer-based technique and tool which helps to schedule production systems to the pace dictated by the most heavily loaded resources, that is, bottlenecks. If the rate of activity in any part of the system exceeds that of the bottleneck, then items are being produced that cannot be used. If the rate of working falls below the pace at the bottleneck, then the entire system is under-utilized.

There are principles underlying OPT which demonstrate this focus on bottlenecks.

OPT principles

1. Balance flow, not capacity. It is more important to reduce throughput time rather than achieving a notional capacity balance between stages or processes.
2. The level of utilization of a non-bottleneck is determined by some other constraint in the system, not by its own capacity. This applies to stages in a process, processes in an operation and operations in a supply network.
3. Utilization and activation of a resource are not the same. According to the TOC a resource is being *utilized* only if it contributes to the entire process or operation creating more output. A process or stage can be *activated* in the sense that it is working, but it may only be creating stock or performing other non-value-added activity.
4. An hour lost (not used) at a bottleneck is an hour lost for ever out of the entire system. The bottleneck limits the output from the entire process or operation, therefore the under-utilization of a bottleneck affects the entire process or operation.
5. An hour saved at a non-bottleneck is a mirage. Non-bottlenecks have spare capacity anyway. Why bother making them even less utilized?
6. Bottlenecks govern both throughput and inventory in the system. If bottlenecks govern flow, then they govern throughput time, which in turn governs inventory.
7. You do not have to transfer batches in the same quantities as you produce them. Flow will probably be improved by dividing large production batches into smaller ones for moving through a process.
8. The size of the process batch should be variable, not fixed. Again, from the EBQ model, the circumstances that control batch size may vary between different products.
9. Fluctuations in connected and sequence-dependent processes add to each other rather than averaging out. So, if two parallel processes or stages are capable of a particular average output rate, in parallel they will never be able to achieve the same average output rate.
10. Schedules should be established by looking at all constraints simultaneously. Because of bottlenecks and constraints within complex systems, it is difficult to work out schedules according to a simple system of rules. Rather, all constraints need to be considered together.

OPT should not be viewed as a replacement to MRP; nor is it impossible to run both together. However, the philosophical underpinnings of OPT outlined above do show that it could conflict with the way that many businesses run their MRP systems in practice. While MRP as a concept does not prescribe fixed lead times or fixed batch sizes, many operations run MRP with these elements fixed for simplicity. However, demand, supply and the process within a manufacturing operation all present unplanned variations on a dynamic basis; therefore, bottlenecks are dynamic, changing their location and their severity. For this reason, lead times are rarely constant over time. Similarly, if bottlenecks determine schedules, batch sizes may alter throughout the plant depending on whether a work centre is a bottleneck or not.

OPT uses the terminology of 'drum, buffer, rope' to explain its planning and control approach (we explained this idea in Chapter 10). Briefly, the bottleneck work centre becomes a 'drum', beating the pace for the rest of the factory. This 'drum beat' determines the schedules in non-bottleneck areas, pulling through work (the rope) in line with the bottleneck capacity, not the capacity of the work centre. A bottleneck should never be allowed to be working at less than full capacity; therefore, inventory buffers should be placed before it to ensure that it never runs out of work.

Some of the arguments for using OPT in MRP environments are that it helps to focus on critical constraints and that it reduces the need for very detailed planning of non-bottleneck areas, therefore cutting down computational time in MRP. The effect of this is to concentrate on major areas of inefficiency such as bottlenecks, quality, set-up times and so on. Nor does it necessarily require large investment in new process technology. Because it attempts to improve the flow of products through a system, it can release inventory that in turn releases invested capital. Claims of the financial payback from OPT are often based on this release of capital and fast throughput.

Summary answers to key questions

The Companion Website to the book – **www.pearsoned.co.uk/slack** *– also has a brief 'Study Guide' to each chapter.*

What is ERP?

- ERP is an enterprise-wide information system that integrates all the information from many functions that is needed for planning and controlling operations activities. This integration around a common database allows for transparency.
- It often requires very considerable investment in the software itself, as well as its implementation. More significantly, it often requires a company's processes to be changed to bring them in line with the assumptions built into the ERP software.

How did ERP develop?

- ERP can be seen as the latest development from the original planning and control approach known as materials requirements planning (MRP).
- Increased computer capabilities allowed MRP systems to become more sophisticated and to interface with other information technology systems within the business to form manufacturing resources planning or MRP II.

What is MRP?

- MRP stands for materials requirements planning which is a dependent demand system that calculates materials requirements and production plans to satisfy known and forecast sales orders. It helps to make volume and timing calculations based on an idea of what will be necessary to supply demand in the future.
- MRP works from a master production schedule which summarizes the volume and timing of end products or services. Using the logic of the bill of materials (BOM) and inventory records, the production schedule is 'exploded' (called the MRP netting process) to determine how many sub-assemblies and parts are required and when they are required.
- Closed-loop MRP systems contain feedback loops which ensure that checks are made against capacity to see whether plans are feasible.

What is MRP II?

- MRP II systems are a development of MRP. They integrate many processes that are related to MRP, but which are located outside the operation's function.
- A system which performs roughly the same function as MRP II is optimized production technology (OPT). It is based on the theory of constraints, which has been developed to focus attention on capacity bottlenecks in the operation.

How is ERP developing?

- Although ERP is becoming increasingly competent at the integration of internal systems and databases, there is the even more significant potential of integration with other organizations' ERP (and equivalent) systems.
- In particular, the use of internet-based communication between customers, suppliers and other partners in the supply chain has opened up the possibility of web-based integration.

Case study
Psycho Sports Ltd

Peter Townsend knew that he would have to make some decisions pretty soon. His sports goods manufacturing business, Psycho Sports, had grown so rapidly over the last two years that he would soon have to install some systematic procedures and routines to manage the business. His biggest problem was in manufacturing control. He had started making specialist high-quality table tennis bats but now made a wide range of sports products, including tennis balls, darts and protective equipment for various games. Furthermore, his customers, once limited to specialist sports shops, now included some of the major sports retail chains.

'*We really do have to get control of our manufacturing. I keep getting told that we need what seems to be called an MRP system. I wasn't sure what this meant and so I have bought a specialist production control book from our local bookshop and read all about MRP principles. I must admit, these academics seem to delight in making simple things complicated. And there is so much jargon associated with the technique, I feel more confused now than I did before.*

'*Perhaps the best way forward is for me to take a very simple example from my own production unit and see whether I can work things out manually. If I can follow the process through on paper then I will be far better equipped to decide what kind of computer-based system we should get, if any!*'

Source: Corbis/Mark Cooper

Peter decided to take as his example one of his new products: a table tennis bat marketed under the name of the 'high-resolution' bat, but known within the manufacturing unit more prosaically as Part Number 5654. Figure 14.12 shows the product structure for this table tennis bat, showing the table tennis bat made up of two main assemblies: a handle assembly and a face assembly. In order to bring together the two main assemblies to form the finished bat, various fixings are required, such as nails, connectors, etc.

The gross requirements for this particular bat are shown below. The bat is not due to be launched until

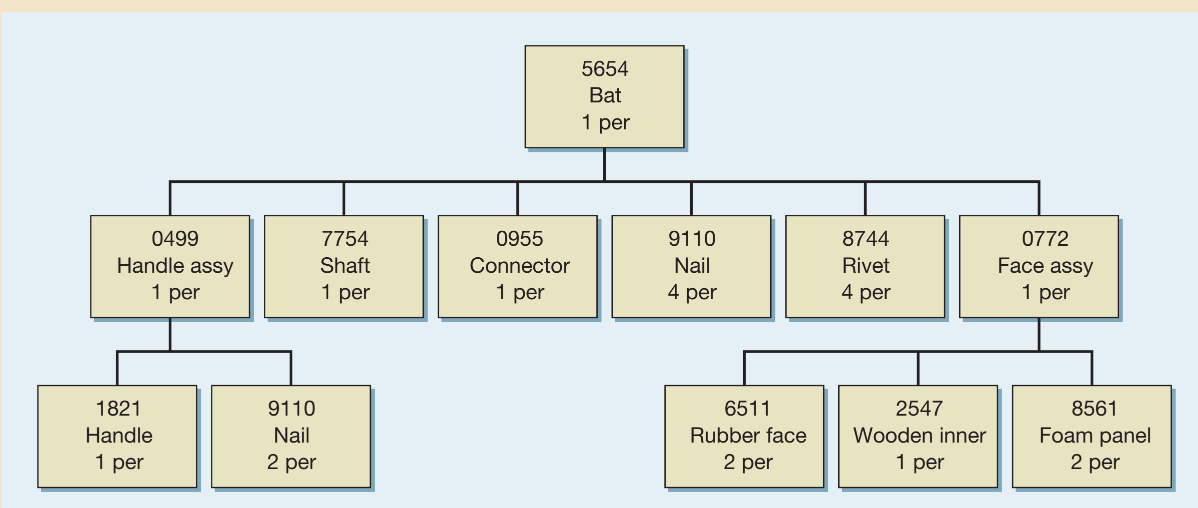


Figure 14.12 Product structure for bat 5654

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Week 13 (it is now Week 1) and sales forecasts have been made for the first 23 weeks of sales:

Weeks 13–21 inclusive, 100 per week
Weeks 22–29 inclusive, 150 per week
Weeks 30–35 inclusive, 200 per week.

Peter also managed to obtain information on the current inventory levels of each of the parts which made up the finished bat, together with cost data and lead times. He was surprised, however, how long it took him to obtain this information. '*It has taken me nearly two days to get hold of all the information I need. Different people held it, nowhere was it conveniently put together, and sometimes it was not even written down. To get the inventory data, I actually had to go down to the stores and count how many parts were in the boxes*.'

The data Peter collected are shown in Table 14.8.

Table 14.8 Inventory, cost and lead-time information for parts

Part no.	*Description*	*Inventory*	*EQ*	*LT*	*Std cost*
5645	Bat	0	500	2	12.00
0499	Handle assy	0	400	3	4.00
7754	Shaft	15	1000	5	1.00
0955	Connector	350	5000	4	0.02
9110	Nail	120	5000	4	0.01
8744	Rivet	3540	5000	4	0.01
0772	Face assy	0	250	4	5.00
1821	Handle	0	500	4	2.00
6511	Rubber face	0	2000	10	0.50
2547	Wooden inner	10	300	7	1.50
8561	Foam panel	0	1000	8	0.50

EQ = economic quantity for ordering; LT = lead time for ordering (in weeks); Std cost = standard cost in £

Peter set himself six exercises which he knew he would have to master if he was to understand fully the basics of MRP.

Exercise 1

Draw up:

(a) the single-level bill of materials for each level of assembly;
(b) a complete indented bill of materials for all levels of assembly.

Exercise 2

(a) Create the materials requirements planning records for each part and sub-assembly in the bat.
(b) List any problems that the completed MRP records identify.
(c) What alternatives are there that the company could take to solve any problems? What are their relative merits?

Exercise 3

Based on the first two exercises, create another set of MRP records, this time allowing one week's safety lead time for each item: that is, ensuring the items are in stock the week prior to when they are required.

Exercise 4

Over the time period of the exercise, what effect would the imposition of a safety lead time have on average inventory value?

Exercise 5

If we decided that our first task was to reduce inventory costs by 15 per cent, what action would we recommend? What are the implications of our action?

Exercise 6

How might production in our business be smoothed?

Questions

1 Why did Peter have such problems getting to the relevant information?

2 Perform all the exercises which Peter set for himself. Do you think he should now fully understand MRP?

Other short cases and worked answers are included in the Companion Website to this book – **www.pearsoned.co.uk/slack**

Problems

1 Your company has developed a simple but amazingly effective mango peeler. It is constructed from a blade and a supergrip handle that has a top piece and a bottom piece. The assembled mango peeler is packed in a simple recycled card pack. All the parts simply clip together and are bought in from suppliers, which can deliver the parts within one week of orders being placed. Given enough parts, your company can produce products within a day of firm orders being placed. Initial forecasts indicate that demand will be around 500 items per week.

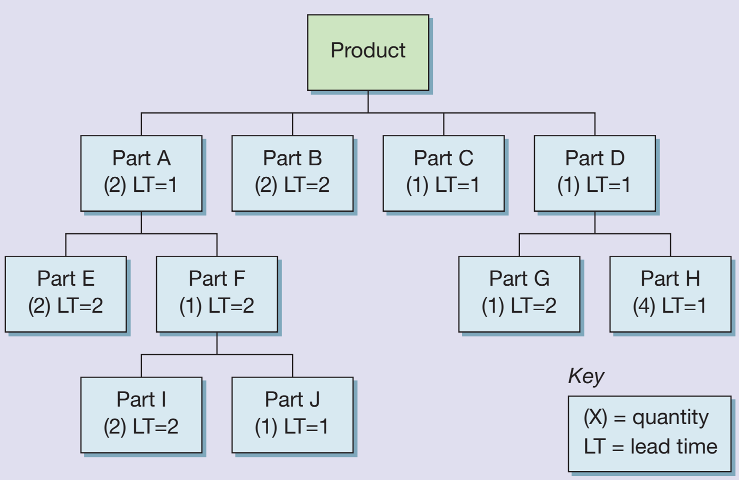
(**a**) Draw a component structure and bill of materials for the mango peeler.
(**b**) Develop a master production schedule for the product.
(**c**) Develop a schedule indicating when and how many of each component should be ordered (your scheduler tells you that the economic order quantity, EOQ, for all parts is 2500).

2 The mango peeler described above was a huge success. Demand is now level at 800 items per week. You have also developed two further products, a melon baller and a passion fruit pulper. Both new products use the same handle, but each has their own specially designed blade and pack. Demand for the new products is expected to be 400 items per week. Also your suppliers have indicated that, because of the extra demand, they will need two weeks to deliver orders. Similarly, your own assembly department is now taking a week to assemble the products.

(**a**) Draw new component structures and bills of material for the new products.
(**b**) Develop a master production schedule for all the products.
(**c**) Develop a schedule indicating when and how many of each component should be ordered.

3 The Novelty Pencil Company described in the worked example in this chapter has asked you to calculate its ordering schedules for the first and second levels of its 'Pointy Pencil' product. Assuming a demand forecast of 500 boxes per week, order lead times of three weeks for all components, a one-week lead time for the company production process and virtually no stockholding charges, develop a schedule for the company.

4 Figure 14.13 shows component structure, lead time in weeks, order quantities and inventory 'on hand' quantities for a product. Calculate the net requirements in week 10 for each part if demand for the product will be 100 per week.



Part	On hand inventory	Order quantities
A	0	600
B	30	600
C	60	500
D	0	600
E	100	600
F	20	500
G	0	500
H	50	500
I	100	600
J	60	600

Figure 14.13 Component structure for a product

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5 For the previous problem, at week 6 you discover that the lead time for components E and I will be 4 weeks in the future.

(**a**) How will it affect the net requirements at week 10?
(**b**) What will be the net requirements at week 14?

Study activities

Some study activities can be answered by reading the chapter. Others will require some general knowledge of business activity and some might require an element of investigation. All have hints on how they can be answered on the Companion Website for this book that also contains more discussion questions – **www.pearsoned.co.uk/slack**

1 Using a web search, find information on three different ERP suppliers' products. Compare and contrast, ideally using a tabular presentation:

(**a**) the main modules offered;
(**b**) the extent to which customization is claimed to be possible;
(**c**) the apparent advantages and disadvantages of the systems.

2 Based on web searches, identify two examples of 'successful' ERP implementation, one from manufacturing and the other from a service or government organization. Summarize the claimed benefits that are stated as having been achieved in each case. If available, highlight the underlying conditions and/or reasons for success and compare these to those outlined in the Rolls-Royce example at the beginning of this chapter.

3 Using a cookery book, choose three similar, fairly complex recipe items such as layered and decorated gateaux (cakes) or desserts. For each, construct the indented bill of materials and identify all the different materials, sub-assemblies and final products with one set of part numbers (i.e. no duplication). Using the times given in the recipes (or your own estimates), construct a table of lead times (e.g. in minutes or hours) for each stage of production and for procurement of the ingredients. Using these examples (and a bit of your own imagination!), show how this information could be used with a MRP system to plan and control the batch production processes within a small cake or dessert factory making thousands of each product every week. Show part of the MRP records and calculations that would be involved.

4 (**Advanced**) Working in a small study group, construct a model of the information systems that you think would be needed to plan and control the most important day-to-day operations and finances of a large university or college. In particular, identify and include at least three processes that cross departmental and functional boundaries, and show how ERP might be used to improve the quality, speed, dependability, flexibility and/or costs of such processes. Then discuss:

(**a**) If ERP is not already in use at your chosen organization, should it be introduced and if so why? What would be the difficulties in doing this and how could they be overcome?
(**b**) If ERP is already in use, what advantages and disadvantages are already apparent to the staff? (For example, ask a lecturer, an administrator and a support services manager, such as someone who runs cleaning or catering services.)

Notes on chapter

1 With thanks to Julian Goulder, Director, Logistics Processes and IT, Rolls-Royce.
2 Wight, O. (1984) *Manufacturing Resource Planning: MRP II*, Oliver Wight Ltd.
3 Attributed to Christopher Koch.
4 Source: Thanks to Lawrence Wilkins for this example.
5 Goldratt, E.M. and Cox, J. (1986) *The Goal*, North River Press.

Selected further reading

Curran, T., Keller, G. and Ladd, A. (1998) *Business Blueprint: Understanding SAP's R/3 Reference Model*, Prentice Hall, NJ. A practitioner's guide. Helpful if you are really doing it.

Davenport, T.H. (1998) 'Putting the Enterprise into the Enterprise System', *Harvard Business Review*, July–August. Covers some of the more managerial and strategic aspects of ERP.

Vollmann,T.W., Berry, D.C., Whybark, F.R. and Jacobs, F.R. (2004) *Manufacturing Planning and Control Systems for Supply Chain Management: The Definitive Guide for Professionals*, McGraw-Hill Higher Education. The latest version of the 'bible' of manufacturing planning and control. Explains the 'workings' of MRP and ERP in detail.

Wallace, T.F. and Krezmar, M.K. (2001) *ERP: Making it happen*, Wiley. Another practitioner's guide but with useful hints on the interior mechanisms of MRP.

Useful websites

http://www.bpic.co.uk/ Some useful information on general planning and control topics.

http://www.cio.com/research/erp/edit/erpbasics.html Several descriptions and useful information on ERP-related topics.

http://www.erpfans.com/ Yes, even ERP has its own fan club! Debates and links for the enthusiast.

http://www.sap.com/index.epx 'Helping to build better businesses for more than three decades', SAP has been the leading worldwide supplier of ERP systems for ages. They should know how to do it by now!

http://www.sapfans.com/ Another fan club, this one is for SAP enthusiasts.

http://www.apics.org. The American professional and education body that has its roots in planning and control activities.

www.opsman.org Definitions, links and opinion on operations management.