Resource Planning

CHAPTER 14

Before studying this chapter you should know or, if necessary review

1. E-commerce, Chapter 4, pp. 107–115.
2. Calculating available capacity, Chapter 9, pp. 317–322.
3. Calculating order quantities, Chapter 12, pp. 446–459.
4. Inventory record accuracy, Chapter 12, pp. 443–445.
5. Developing the MPS, Supplement D, pp. D4–D5.

LEARNING OBJECTIVES

After studying this chapter you should be able to

1. Describe enterprise resource management.
2. Describe the evolution of ERP systems.
3. Describe the benefits and costs of ERP systems.
4. Provide an overview of MRP.
5. Explain the different types of demand.
6. Describe the objectives of MRP.
7. Describe the inputs needed for MRP.
8. Explain MRP operating logic.
9. Describe action notices.
10. Use different lot size rules with MRP.
11. Describe the role of capacity requirements planning (CRP).
12. Calculate the workloads at critical work centers using CRP.

CHAPTER OUTLINE

WHAT'S IN OM FOR ME?

Foodpix/Jupiter Images Corp.

Do you remember the first time you invited your fiancée and parents for a very special dinner at your place? You decided to serve salad, grilled steaks, corn-on-the-cob, baked potatoes, and apple pie à la mode. You decided to special order the steaks two days ahead of time. You needed to make the pie the night before, so you made a special trip to get fresh apples and the other necessary ingredients. You bought the ice cream, corn, salad mix, some tomatoes, cucumbers, croutons, and salad dressing the day of the dinner as well as picked up the steaks. You also managed to pick up a special bottle of wine to go with dinner.

The night before the dinner, you baked the apple pie. The day of the dinner, you started the baked potatoes about an hour before dinnertime. You then mixed your salad. You seasoned the steaks and started the grill about 30 minutes before dinner. At the same time, you put a pot of water on to boil to cook the corn. You put the steaks on the grill to cook and the corn in the boiling water. You set the table while you were waiting. Just as you had planned, the dinner was ready on time. The steaks were done just right, the baked potatoes perfect, and the corn hot and juicy.

Your dinner was a huge success because you had used the basic concepts of material requirements planning: a master production schedule, bills of material, inventory records, and backward scheduling. The master production schedule was your planned menu for the dinner. To determine the materials needed, you had to know what you wanted to prepare. After setting the menu, the next step was to look at the bill of material (recipe) for each item. This allowed you to determine how much of each component or material was needed. Once you had the list assembled as to what was needed to make the dinner, you checked your inventory to see what you already had and what still had to be purchased.

▶ **Backward scheduling** Starts with the due date for an order and works backward to determine the start date for each activity.

To use **backward scheduling**, we take a desired completion time or due date, consider all the activities that must be completed, and schedule the activities so that everything is ready at the appropriate time. Not all activities need the same amount of time to be completed, so we schedule when different activities must begin.

Your dinner didn't take too long to prepare, but building products typically takes some time. Consider a company like Dell Computer, well known for its rapidly built-to-order computers. Dell begins assembly of a customer's order almost immediately after receiving the order. To do this, Dell must carefully manage its component inventories, knowing the availability of needed components to complete the assembly. Information regarding the order is sent to members of its supply chain to assure on-time delivery of the finished computer. Dell uses this approach to support the concept of mass customization.

In this chapter, we will examine enterprise resource planning (ERP), as well as learn the basic mechanics of material requirements planning (MRP) and the role of capacity requirements planning (CRP).

ENTERPRISE RESOURCE PLANNING

Enterprise resource planning (ERP) is software designed for organizing and managing business processes (core and administrative) by sharing information across functional areas. Core processes include production planning and control, inventory management, purchasing, and distribution; administrative processes include accounting (cost control, accounts payable and receivable, etc.) and human resource management. Figure 14-1 shows an overview of enterprise resource planning.

▶ **Enterprise resource planning (ERP)** An information system designed to integrate internal and external members of the supply chain.

The number of finished goods sold to final customers is a good example of the type of useful information shared throughout the supply chain. Knowing actual sales figures allows improved decision making by members of the supply chain and can help eliminate the bullwhip effect (discussed later in this chapter). For example, using the information about actual sales to the customer, manufacturing can determine more accurately the quantity and timing for product replenishments. Warehouse management then can plan for the receipt and subsequent distribution of the replenishments. Suppliers can determine the materials and components needed by manufacturing to meet the manufacturing schedule. All members of the supply chain are aware of what is happening and can plan accordingly. The primary objective of ERP is to integrate all departments and functions, internal and external, into a single computer system to serve the enterprise's needs.

The availability of information can increase productivity as well as customer satisfaction. For example, after Master Product Company began using ERP, sales increased by 20 percent while inventory investment decreased 30 percent. Owens Corning reported saving $65 million by using ERP to coordinate customer orders, financial reporting, and global procurement. Currently, ERP systems are used in thousands of medium and large companies globally. These systems typically consist of modules that can be used either alone or in various configurations. Let's look at the typical ERP modules.

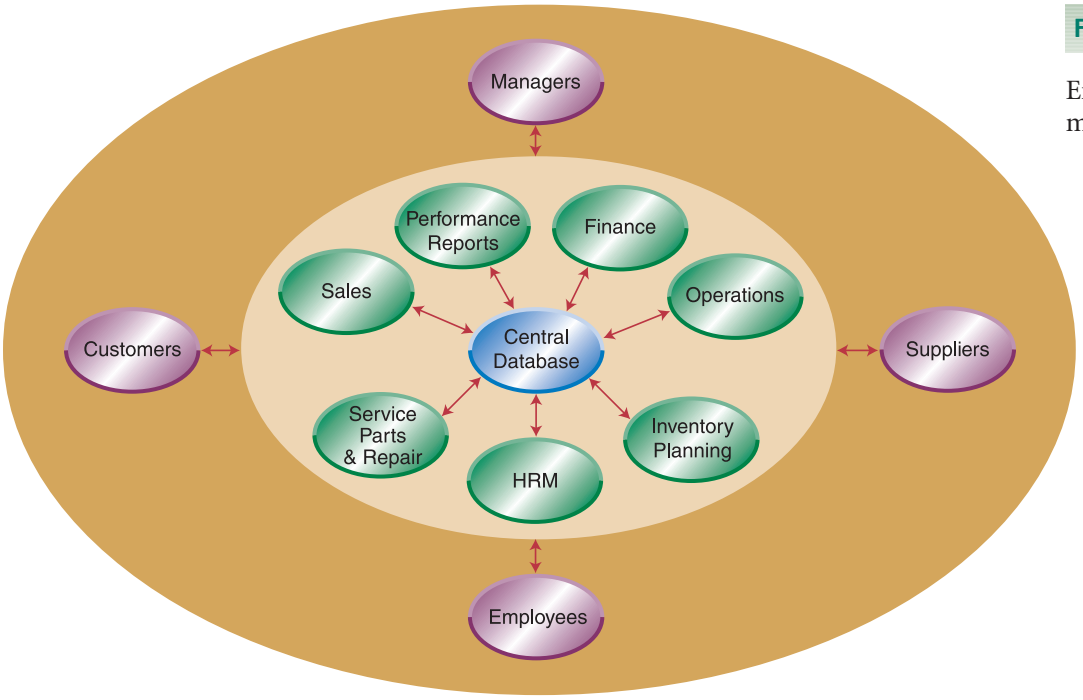

FIGURE 14-1

Enterprise resource management

ERP Modules

All modules are fully integrated, using a common database and support processes that go across functional areas. A transaction in any module is immediately available to all other modules and to all relevant parties. There are four basic categories of ERP modules: finance and accounting, sales and marketing, production and materials management, and human resources.

The finance and accounting module can include the following capabilities: financial report generation, investment management, cost control analysis, asset management, capital management, debt management, and so on. It defines cost and profit centers, uses activity-based costing, facilitates capital budgeting and profitability analysis, and tracks enterprise performance measures. A company can see the financial implication of every transaction.

The sales and marketing function handles customer-related activities. A customer can check for pricing, availability, and shipping options, as well as special promotions. The sales module can do a profitability analysis using different pricing options, discount structures, and rebates. The module also allows more accurate delivery date projections by providing insight into a company's finished goods and work-in-process inventories, as well as access to master scheduling information. Distribution requirements (documentation, packaging, etc.), transportation management (mode of transport), and shipping schedules are included. This module also handles billing, invoicing, rebate processing, product registrations, and customer complaints.

The production and materials module processes planning, bill of material generation, and product costing. The module implements engineer change orders, plans material requirements (MRP), allocates resources, and schedules and monitors production. It links manufacturing, sales, and finance together in real time. In terms of materials, it generates purchasing needs, manages inventory and warehouse functions, and supports supplier evaluations and invoice verification.

The human resources module includes workforce planning, employee scheduling, training and development, payroll and benefits, expense reimbursement, job descriptions, organizational charts, and workflow analysis.

These four modules can be implemented either individually or as a fully integrated system. ERP uses a common database to ensure the same information is used throughout the company to improve decision making across functional areas. Let's look at the evolution of ERP systems.

THE EVOLUTION OF ERP

First-Generation ERP

An ERP system provides a single interface for managing all routine activities performed in manufacturing—from order entry to after-sales customer service. In the later 1990s, ERP systems were extended to external members of the supply chain (suppliers and customers). These extensions provide customer interaction and supplier management modules. Using a single interface can provide significant savings. Large companies—for example, ExxonMobil—consolidated 300 different information systems into one ERP system by implementing SAP R/3 (a leading ERP system) in its U.S. petrochemical operations. Initially, ERP was designed to handle business transactions and not to support supply chains. The second generation of ERP was designed to overcome this deficiency.

Second-Generation ERP

First-generation ERP was designed to automate routine business transactions and did it very well. Merrill Lynch reported that almost 40 percent of U.S. companies with greater than $1 billion in annual revenues had implemented ERP. Most companies had received the major benefits of ERP systems by the late 1990s. The development of second-generation ERP systems has begun. Its objectives are to leverage existing systems to increase efficiency in handling transactions, improve decision making, and support e-commerce.

While first-generation ERP systems gave planners plenty of statistics about what happened in the company, in terms of costs and financial performance, the reports were merely snapshots of the business at a single point in time. These reports did not support the continuous planning needed in supply chain management. This deficiency led to the development of planning systems focused on decision making. These new systems are referred to as SCM (supply chain management) software.

SCM software is designed to improve decision making in the supply chain. It helps answer such questions as: (1) What is the best way to ship a product to a specific customer? (2) What is the optimal production plan? (3) How much product should ship to specific intermediaries? (4) How can outbound and inbound transportation costs be minimized? SCM software typically includes decision-support modules, such as linear programming and simulation, to help answer these questions.

▶ **SCM software**
Designed to improve decision making in the supply chain.

Let's consider how ERP and SCM software can work together. Think about the task of order processing. With SCM software, the question is, "Should I take your order?" while the ERP approach is, "How can I best take or fulfill your order?" Both are merely information systems. SCM systems complement ERP systems, providing intelligent decision support. The SCM system is designed to overlay existing systems and extract data from every part of the supply chain. This way, the company has a clear picture of where it is heading rather than simply having automated processes. **Supply chain intelligence (SCI)** is the capability of collecting business intelligence along the supply chain. This intelligence enables strategic decision making by analyzing data along the entire supply chain.

▶ **Supply chain intelligence (SCI)**
Enables strategic decision making along the supply chain.

An example of a successful SCM system implementation is IBM. IBM restructured its global supply chain to achieve quick responsiveness to customers while holding minimal inventory. To do this, IBM developed an extended-enterprise supply chain analysis tool called the Asset Management Tool (AMT). AMT allows for quantitative analysis of interenterprise supply chains. IBM used AMT to analyze inventory budgets, inventory turnover objectives, customer service target levels, and new-product introductions. AMT benefits have included the saving of over $750 million in material costs and price-protection expenses each year.

Another example of an ERP application with an SCM module is Colgate-Palmolive (C-P). C-P produces oral-care products (mouthwashes, toothpaste, and toothbrushes), personal-care products (baby care, deodorants, shampoos, and soaps), and pet food. Foreign sales account for about 70 percent of C-P's total revenues. An important factor for C-P was whether it could use ERP software across the entire spectrum of its business. The company needed the ability to coordinate globally, yet act locally. C-P's U.S. division opted to use SAP R/3 for this effort.

Another option for businesses wanting ERP functions is to lease applications rather than to build systems. In leased applications, the ERP vendor takes care of the functionalities and internal integration problems. The ERP vendor is typically referred to as an **application service provider (ASP)**. The ASP sets up the system and runs it for

▶ **Application service provider (ASP)**
Sets up and runs ERP systems.

the company. This approach often works well for small to medium companies. The software is usually delivered via the Internet.

Since many companies involved in e-commerce have ERP systems, and since e-commerce needs to interface with the ERP systems, integration is necessary, primarily for order fulfillment and collaboration with business partners.

LINKS TO PRACTICE

Arapahoe County Government

Donovan Reese/Getty Images, Inc.

Let's look at how a nonmanufacturing company might use an ERP system. The Arapahoe Country government serves a population of more than 537,000, nine school districts, 14 incorporated communities (including the county seat of Littleton), and 163 local improvement and service districts. It has an annual operating budget of approximately $300 million and a staff of 1800. Currently, the county has one of the lowest property tax rates in the Denver metropolitan area.

The key challenges facing the county government included multiple, separate, stand-alone financial systems; limited visibility into financial operations; outdated information (six to eight weeks old); difficulty in complying with new government reporting regulations; an inefficient procure-to-payment process; and multiple reconciliations needed to keep information in sync. No vendor payment discounts were taken.

Even though Arapahoe County only has 1800 employees, it has multiple financial systems. Numerous Microsoft Excel spreadsheets and Microsoft Access databases had been developed by individuals over the years. These disparate systems could not communicate with each other, so simple inquiries could take weeks to answer. Vendor payments were often late, resulting in project delays. Monthly reports took six to eight weeks to produce and were out of date before they were completed. Officials had trouble managing the constrained budgets because of the lack of visibility into the future.

After implementing an ERP system, the following strategic and financial benefits were noted: elimination of redundant financial systems; improved timeliness and accuracy of key reports; improved vendor relations and increased negotiating power; improved visibility; compliance with the latest government reporting requirements; more staff time for value-added tasks; and increased vendor payment discounts. The following operational benefits occurred: purchase order cycle time was reduced 80 percent; the age of information in monthly reports was reduced from six to eight weeks to real time; full-time staff equivalents in accounts payable and purchasing were reduced 50 percent; and the financial closing process time (done annually) was reduced by 150 hours.

The use of an ERP system by Arapahoe County illustrates that such systems are useful in nonmanufacturing organizations as well as in traditional manufacturing companies. You should understand that ERP systems deal more often with back-office applications (accounting, inventory, scheduling, etc.), while e-commerce applications deal more with front-office applications such as sales, order entry, customer service, and customer relationship management. You also should understand that order or service fulfillment problems occur since so many customers are served. Companies

operating on-line must find the products or information that are needed, package them in an appropriate manner, arrange for delivery to the customer, collect money from the customers if appropriate, and handle the return of unwanted or defective products or services.

THE BENEFITS OF ERP

One benefit of ERP is that it integrates the complete range of an organization's operations in order to present a holistic view of the business functions from a single information and IT architecture. This single information source improves the organizational information flow. Because of improved information flow, an organization increases its ability to incorporate best practices that facilitate better managerial control, speedier decision making, and cost reductions throughout the organization. The basic architecture of an ERP system builds upon a single database, one application, and a unified interface across the entire enterprise, thus allowing an integrated approach.

A study by Benchmarking Partners for the Deloitte & Touche consulting corporation classifies companies' motivations for implementing ERP systems into two groups: technological and operational. Technological motivation relates to the replacement of disparate systems; improved quality and visibility of information; integration of business processes and systems; replacement of older, obsolete systems; and the acquisition of systems that can support future business growth. For example, ExxonMobil used ERP to replace 300 different systems.

Operational motivation is related to improving inadequate business performance, reducing high-cost structures, improving customer responsiveness, simplifying complex processes, supporting global expansion, and standardizing best practices throughout the enterprise. Cybex International is a good example of an organization using ERP to improve customer responsiveness.

ERP provides both tangible and intangible benefits. Tangible benefits refer to reductions in inventory and staffing, increased productivity, improved order management, quicker closing of financial cycles, reduced IT and purchasing costs, improved cash flow management, increased revenue and profits, reduced transportation and logistics costs, and improved on-time delivery performance. Intangible benefits refer to the improved visibility of corporate data, improved customer responsiveness, better integration between systems, standardization of computing platforms, improved flexibility, global sharing of information, and better visibility into the supply chain management process.

A study of ERP implementations reported that it took companies eight months until after the new system was established to see any benefits. The median annual savings from a new ERP system was $1.6 million.

One company that has developed various ERP software packages to enhance manufacturers' overall productivity is i2 Technologies. By using this software, manufacturers can now improve supply chain activities by monitoring, managing, and optimizing

Ed Horowitz/Stone/Getty Images, Inc.

LINKS TO PRACTICE

i2 Technologies
www.i2.com

their internal and external activities. For example, manufacturers can connect immediately with suppliers and shippers in real time and can examine the supply chain. In addition, manufacturers can obtain reports that discuss efficiency and forecast potential problems. i2 Technologies' Transportation Solutions helps manufacturers optimize delivery schedules. Also, i2 Technologies' Softgoods Matrix.com helps softgoods retailers, manufacturers, and suppliers coordinate online business, improve response to changes in consumer trends, and attract potential customers. Some of the world's largest manufacturing firms have adopted software developed by i2 Technologies.

LINKS TO PRACTICE

SAP AG
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SAP AG, one of the leading developers of enterprise solutions software, provides companies with mySAP.com, a software platform for open systems. Open systems allow users to communicate with another user without being constrained by a particular organization's solution. This software includes functionality for material requirements planning, including manufacturing and financial applications, materials management, product design management, sales and distribution, human resources, production planning, quality assurance, and plant maintenance. SAP also provides functionality that promotes the ability to do collaborative planning on the Web via collaborative exchanges and public marketplaces.

Although enterprise software (formerly known as ERP) is often associated with manufacturing operations, it also has applications in the service sector. SAP Public Sector and Education SAP Public Services, Inc. has announced a plan to offer an offender management system that may revolutionize the corrections industry. The initial implementation will modernize the Commonwealth of Virginia's Department of Corrections. The SAP offender management system will provide Web-based case management. The new system will enable the Virginia Department of Corrections to enter into the e-government world.

THE COST OF ERP SYSTEMS

SAP AG, Peoplesoft, Oracle, and Baan are major suppliers of ERP systems. The cost of an ERP system ranges from hundreds of thousands of dollars to several million dollars. In addition to the software cost is the cost of outside consultants used in the selection, configuration, and implementation of the ERP system. An IT research firm, Gartner Group, reports that companies can expect to spend up to three times as much money for consultants as they do for the ERP system. Additional costs include the human resources needed to work on the implementation of the system, new hardware to run the program, and the development of a new, integrated database.

A review of successful ERP implementations indicates that the most critical factors are leadership and top management commitment. Top management must clearly set the vision and direction for the business, as well as establish a culture that enables the business to benefit by using the technological capabilities of an ERP system. Champions are needed to effectively implement change programs and promote best practices. Let's look at how some companies have used ERP.

When selecting the ERP system to use, a 2008 study by the Aberdeen Group (www.aberdeen.com) reports that functionality, ease of use, and total cost of ownership (TCO) are the top three selection criteria. Total cost of ownership is the software cost, services cost, and three years of maintenance cost.

Service costs are for external professional services. These might include implementation, training, customization, or consulting, but do not include company employees. Maintenance costs are based on average maintenance fees paid in aggregate and on a per user basis. Maintenance costs include technical support and bug fixes as well as new product innovations.

Total cost of ownership varied based on size of the company. For companies with less than $50 million in annual sales, the average total was $366,583. Companies between $50 and $100 million had an average total cost of $892,765. For companies with sales between $500 million and $1 billion, average total costs were $3,483,776. And for companies with sales exceeding $5 billion, the average total cost was $7,148,750. The average number of users in these companies went from a low of 35 up to a high of 3274.

The study also reported the business benefits achieved through ERP. Companies expect to reduce inventory investment, manufacturing operational costs, and administrative costs, improve complete and on-time shipments, and enhance manufacturing schedule compliance. Companies implementing ERP generally reported improvements in the 10 to 20 percent range.

Now that you have a basic understanding of ERP systems, let's examine the manufacturing planning systems that were the basis for today's production and materials modules.

MATERIAL PLANNING SYSTEMS

In the 1960s, manufacturing planning systems focused primarily on traditional inventory control issues (when to order, how much to order, etc.). This led to the development of material requirements planning (MRP) systems. These systems translated the approved master production schedule of final products into time-phased net requirements for subassemblies and final assemblies for manufacturing and components and raw materials for purchasing. The initial MRP systems evolved into closed-loop MRP.

Closed-loop MRP is an MRP system that includes sales and operations planning, master production scheduling, and capacity requirements planning (discussed in Chapter 13). After realistic and attainable plans are developed, manufacturing executes the plan. This involves input–output capacity measurement, detailed scheduling and dispatching (we will discuss these in Chapter 15), anticipated delay reports from the manufacturing facility and the suppliers, as well as scheduling deliveries from suppliers. Closed-loop means that each function is included in the overall system and that feedback mechanisms are in place to make sure that the plan remains valid.

▶ **Closed-loop MRP**
An MRP system that includes production planning, master production scheduling, and capacity requirements planning

In the mid-1970s, **manufacturing resource planning (MRP II)**, the next generation of manufacturing planning systems, was developed. MRP II has three major components: management planning, operations planning, and operations execution. The company's strategy is translated into business objectives for the current year. These objectives drive the development of the marketing plan that in turn drives the development of the production plan. The production plan identifies the resources available to manufacturing to achieve the output needed by marketing. Then the master production schedule shows how the resources from the production plan are to be used. Operations planning is the MRP function. One of the primary inputs to the MRP system is the master production schedule. The output from the system is the order release schedule. Operations execution brings the plan to life. Raw materials and

▶ **Manufacturing resource planning (MRP II)**
A method for the effective planning and integration of all internal resources.

components are purchased, subassemblies and final assemblies scheduled, quality assured, labor managed, and production completed. Problems encountered in production are fed back to the MRP component. Ongoing performance evaluation provides feedback—that is, additional resource requirements, changing market demands, and so on—to business planning for any necessary corrective actions. Shortcomings in MRP II in managing a production facility's orders, production plans, and inventories, along with the need to integrate external functions, led to the development of ERP systems.

AN OVERVIEW OF MRP

▶ **Material requirements planning (MRP)**
A system that uses the MRP, inventory record data, and BOM to calculate material requirements.

▶ **Capacity requirements planning (CRP)**
Determines the labor and machine resources needed to fill the open and planned orders generated by the MRP.

Material requirements planning (MRP) is an information system that uses the concept of backward scheduling. MRP enables companies that produce items in batches to have the right materials in the right amounts available at the right time. While having the material is critical, the company also needs the capacity to process the materials on time. Companies use **capacity requirements planning (CRP)** to check that enough work is scheduled for operations and that the amount of work is feasible. CRP reveals potential problems, which gives operations a chance to prevent problems from occurring. For example, if you know that you need 250 hours of test equipment time four weeks from now and you only have 200 hours of test equipment time available during that week, you can do something about it now. You can change the master schedule so that some of the items needing testing are scheduled for a different time period, or you can authorize additional workers in the test area, or authorize overtime for that work center. You don't wait until four weeks from now and then figure out what to do.

When having your dinner party we described at the beginning of this chapter, you had to do several activities before you served the dinner. First, you planned the menu. Second, you determined the number of servings needed. Third, you reviewed the recipes for each item on the menu to determine the materials needed. Fourth, you checked your cupboards, refrigerator, and freezer to see if you had any of the materials on hand. Fifth, you purchased any materials that you still needed. Sixth, you prepared the dinner.

▶ **Bill of material (BOM)**
Lists all the subassemblies, component parts, and raw materials that go into an end item and shows the usage quantity of each required.

Planning the menu and calculating the number of servings is equivalent to creating an authorized master production schedule (MPS). Reviewing the recipes to determine the materials needed is equivalent to checking the **bill of material (BOM)** file to determine the materials needed to build a product. The BOM file lists all the subassemblies, component parts, and raw materials that go into the end item and shows the usage quantity of each. Using the list of components and materials needed, MRP checks the inventory records to determine if sufficient quantities of those materials are available or if the purchasing department needs to procure these materials. MRP systems are designed to handle dependent demand. Let's look at different types of demand.

TYPES OF DEMAND

▶ **Independent demand**
The demand for an item is unrelated to the demand for other items.

The two types of demand are independent and dependent. **Independent demand** is the demand for finished products; it does not depend on the demand for other products. Finished products include any item sold directly to a consumer. For example, if a company builds and sells CD cabinets, the demand for the CD cabinet is not dependent on anything else. The company could also sell decorative replacement hinges or handles as independent products. Figure 14-2 is a drawing of the CD cabinet. Although you can't see inside the cabinet, it does have four shelves.

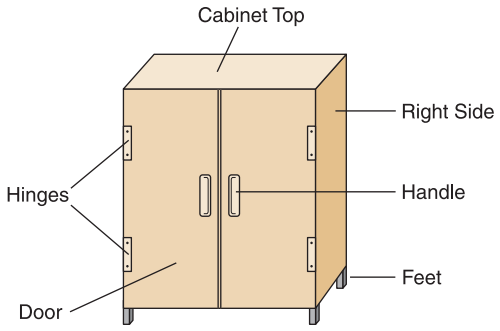


FIGURE 14-2

A CD Cabinet

Dependent demand is derived from finished products. For example, when a company makes CD cabinets (see Figure 14-2), it needs tops, bottoms, feet, doors, door magnets, door hinges, door handles, screws, left sides, right sides, door catches, cabinet shelves, and shelf holders. The company can determine how many of each of these items is needed based on how many CD cabinets the company plans to build. If the company builds 100 CD cabinets, operations needs 100 tops, 100 bottoms, 100 doors, 100 left sides, 100 right sides, 200 door hinges (2 are needed to build one finished product), 400 feet and 400 cabinet shelves (4 are needed to build one finished product), 1000 screws (8 are needed for the door to attach the hinges, magnet, and handle; and 2 are needed for the right side to attach the door catch), and 1600 shelf holders (16 for each finished product). The company does not forecast dependent demand but, rather, calculates the material needs based on the final products to be produced. MRP computerized information systems are designed to manage dependent demand inventory and to schedule necessary replenishment orders. Let's look at a typical MRP system.

▶ **Dependent demand**
Demand for component parts is based on the number of end items being produced.

Figure 14-3 is an overview of an MRP system. The authorized MPS is the primary input to the MRP system. The MPS details the company's planned products, quantity, and the schedule used by marketing when promising deliveries. The product due dates are critical to the MRP system since they set the completion dates used to backward-schedule production. Part of the MRP system is developing a **time-phased** schedule that shows future demand, supply, and inventories by time period. The time-phased schedule

▶ **Time-phased**
Expressing future demand, supply, and inventories by time period.

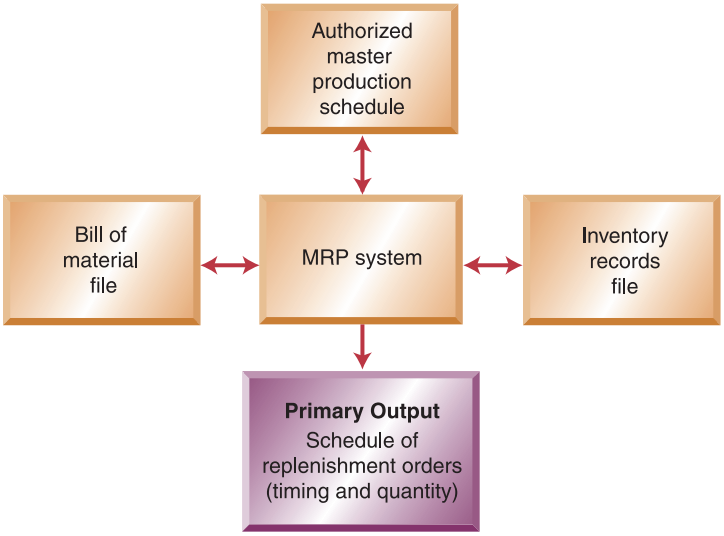


FIGURE 14-3

Overview of the MRP process

shows the production planner when in the production process parts and materials must be available. Not all parts and materials have to be available at the start of production, but they must be available at the stage of production in which they are needed. For example, when you are building a furniture cabinet, you do not need the stain before you start building the cabinet; you need it when you are ready to apply the finish. On the other hand, you must have the wood before you can begin building the cabinet.

▶ **Gross requirements** The total-period demand for an item.

The MRP system checks the BOM file to determine the materials needed, how much, and when. The system generates the **gross requirements** of each part and material needed to accomplish the MPS. The system inserts the gross requirements into the individual inventory records and computes the projected available quantity for each item so that you know if there's enough inventory or if you need a replenishment order. If you need a replenishment order, the MRP system tells you when to place the order, either to a supplier or to the manufacturing floor, to ensure that the parts or material are available when needed. The MRP system generates planned replenishment order release schedules and can generate additional reports, which we discuss later in the chapter. Now let's consider the objectives of an MRP system.

OBJECTIVES OF MRP

The objectives of an MRP system are to determine the quantity and timing of material requirements and to keep priorities updated and valid.

- ***Determine the quantity and timing of material requirements.*** Your company uses MRP to determine what to order (it checks the BOM), how much to order (it uses the lot size rule for the specific item), when to place the order (it looks at when the material is needed and backward-schedules to account for lead time), and when to schedule delivery (it schedules the material to arrive just as it is needed).
- ***Maintain priorities.*** Your company also uses MRP to keep priorities updated and valid. Requirements change. Customers change order quantities and/or timing. Suppliers deliver late and/or the wrong quantities. Unexpected scrap results from manufacturing. Equipment breaks down and production is delayed. In an ever-changing environment, you use an MRP system to respond to changes in the daily environment, to reorganize priorities, and to keep plans current and viable.

Next, we discuss the inputs needed to run an MRP system.

MRP INPUTS

The three inputs to an MRP system are the authorized MPS, the BOM, and the individual item inventory records. Using the CD cabinet from Figure 14-2 as our end item, let's look at each of these inputs.

Authorized MPS

The authorized MPS is a statement of what and when your company expects to build. Table 14-1 shows the first MPS record for the CD cabinet. From the MPS record, we calculate when we need to have replenishment orders of CD cabinets. We calculate the timing of MPS orders by the projected available quantity. When we do not have enough inventory to satisfy the forecast for a particular period, we need an MPS order. The quantity of the replenishment order is based on the lot sizing rule used. Table 14-2 shows the completed MPS record.

Item: CD Cabinet Lead time: 1 week
Lot size rule: FOQ = 100 Beginning inventory: 80

	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirements:	25	25	25	25	30	30	30	30	35	35	35	35
Projected Available:	55	30	5	−20								
MPS												

TABLE 14-1

Initial MPS Record for CD Cabinet

Item: CD Cabinet Lead time: 1 week
Lot size rule: FOQ = 100 Beginning inventory: 80

	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirements:	25	25	25	25	30	30	30	30	35	35	35	35
Projected Available:	55	30	5	80	50	20	90	60	25	90	55	20
MPS				100			100			100		

TABLE 14-2

Updated MPS Record for CD Cabinet

Inventory Records

To determine whether enough inventory is available or whether a replenishment order is needed, the MRP system checks the inventory records of all items listed in the BOM. Table 14-3 shows the CD cabinet's inventory record. Let's look at the information in the record.

The top part of the record contains product or part identification information—typically either a part number, part name, or description. In our example, the part name is the CD cabinet. The top portion also contains **planning factors**. These can include the lot size rule, **lead time**, safety stock requirements, and so forth.

▶ **Planning factors**
Factors include the lot size rule, replenishment lead times, and safety stock requirements.

▶ **Lead time**
The span of time needed to perform an activity or series of activities.

In our example, the lot size rule is lot-for-lot (L4L), and the planned lead time is one week. This information remains relatively constant and is needed by the system to determine how much to order and when to place the replenishment order. Additional information in the records changes with each inventory transaction. These transactions include releasing new orders, receiving previously ordered materials, withdrawing inventory, canceling orders, correcting inventory record errors, and adjusting for rejected shipments. The record shows how much inventory of an item is available, projects future needs, and shows the projected inventory level in different time periods.

One problem with an MRP system is inventory record accuracy. Because the system checks the inventory record to see whether it has to generate a replenishment order, an inaccuracy in the record can cause an error in replenishment ordering. Cycle counting,

Item: CD Cabinet Lead time: 1 week
Lot size rule: L4L Beginning inventory: 0

	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirements:	0	0	0	100	0	0	100	0	0	100	0	0
Scheduled Receipts:												
Projected Available:	0	0	0	−100								
Planned Orders												

TABLE 14-3

First Inventory Record for CD Cabinet

discussed in Chapter 12, is a technique for improving inventory record accuracy. Let's look at the inventory record shown in Table 14-3.

The item is a CD cabinet and the lot size rule is lot-for-lot. The lead time is one week. Thus if we want 100 CD cabinets to be available in week 4, we have to begin the final assembly of the CD cabinets in week 3. For our purposes, gross requirements are due at the beginning of the period (Monday morning), and planned orders are started at the beginning of a time period. Final assembly is done during week 3 so we can have 100 CD cabinets at the beginning of week 4.

Gross requirements for finished products are taken from the authorized MPS. **Scheduled receipts** are replenishment orders that have been placed but not yet received. For example, if we placed an order last week and we know it will arrive in period 1, it would be in the scheduled receipts row.

▶ **Scheduled receipt**
An open order that has an assigned due date.

▶ **Projected available**
The inventory balance projected into the future.

The **projected available** quantity is a period-by-period projection of how much inventory should be available. The projected available quantity equals the beginning inventory, plus any replenishment order due, less the gross requirements for that period. For example, in period 4, we have no beginning inventory and we have 0 units scheduled to arrive, less our gross requirements of 100 units in period 4. Thus our projected available at the end of period 4 is −100, as shown in Table 14-3. The beginning inventory for any time period is equal to the projected available quantity at the end of the previous period.

▶ **Planned orders**
Suggested order quantities, release dates, and due dates created by an MRP system.

Planned orders result when we do not have enough inventory to cover the gross requirements for a period. For example, unless we plan an order to arrive in period 4, we will be short 100 CD cabinets. When we need a replenishment order, we calculate the quantity by the lot size rule and we calculate the timing by the lead time. For example, we need an order to arrive in period 4, the lot size rule L4L dictates that we order just enough to cover our requirement (100 units), and the lead time of one week means that we must place the order one week before we need it (so we have a planned order of 100 units in period 3). Table 14-4 shows the updated inventory record for the CD cabinet.

Bills of Material

A *bill of material* (BOM) lists the subassemblies, intermediate assemblies, component parts, raw materials, and quantities of each needed to produce one final product. It is exactly like a recipe for baking a cake. As we would follow the recipe for the cake, the manufacturer is expected to follow the BOM precisely. No extra parts are added. No substitutions are made without appropriate paperwork. Companies that use MRP systems must have a disciplined workforce that uses only the materials authorized by the BOM. The BOMs used as input to the MRP system are **indented bills of materials**. Table 14-5 shows an indented bill of material for the CD cabinet. In an indented

▶ **Indented bill of material**
Shows the highest-level "parents" closest to the left margin and the "children" indented toward the right. Subsequent levels are indented farther to the right.

TABLE 14-4

Updated Inventory Record for CD Cabinet

Item: CD Cabinet Lead time: 1 week
Lot size rule: L4L Beginning inventory: 0

	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirements:	0	0	0	100	0	0	100	0	0	100	0	0
Scheduled Receipts:												
Projected Available:	0	0	0	0	0	0	0	0	0	0	0	0
Planned Orders			100			100			100			

TABLE 14-5

Indented BOM

Part Number	Description	Quantity Required
CD1001-01	CD Cabinet	1
CD1001T-01	Cabinet top	1
CD1001B-01	Cabinet bottom	1
CD1001F-01	Feet	4
CD1001D-01	Cabinet door	2
CD1001DM-01	Door magnet	1
CD1001DH-01	Door hinges	2
CD1001DK-01	Door handle	1
CD1001DS-01	Screws	8
CD1001S-01	Cabinet sides	2
CD1001SC-01	Door catch	1
CD1001DS-01	Screws	2
CD1001SH-01	Cabinet shelf	4
CD1001SS-01	Shelf holder	16

BOM, the highest-level item ("parent") is closest to the left margin, with components ("children") going into that item indented to the right. In our example, the CD cabinet is the highest-level item and all the components are indented. The components for the cabinet door are indented even farther to the right since these components go directly into the door assembly rather than the CD cabinet.

A **product structure tree** visually represents the BOM for a product. Although product trees are seldom used in the workplace, for our purposes they make it easier to explain the MRP process. Figure 14-4 is a product structure tree for the CD cabinet with the name of the item, the usage quantity per parent item, and the replenishment lead time.

▶ **Product structure tree** The visual representation of the BOM, clearly defining the parent–child

FIGURE 14-4

Product structure tree

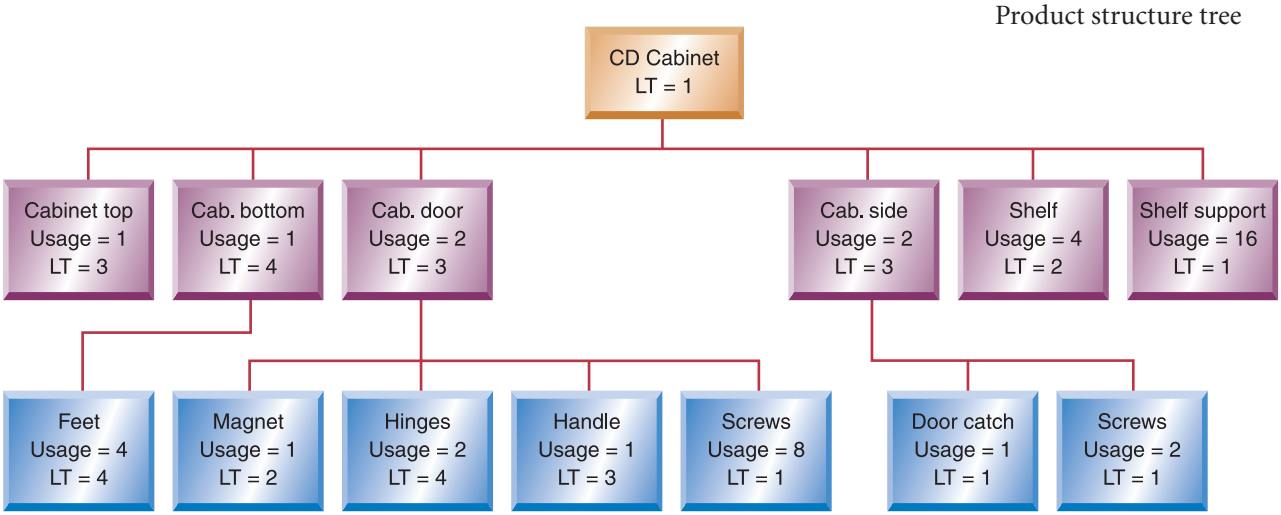


TABLE 14-6

Updated Inventory Record for CD Cabinet

Item: CD Cabinet — Parent: none
Lot size rule: L4L — Children: Top, bottom, doors, sides,
Lead time: 1 week — shelves, shelf supports
Beginning inventory: 0

	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirements:	0	0	0	100	0	0	100	0	0	100	0	0
Scheduled Receipts:												
Projected Available:	0	0	0	0	0	0	0	0	0	0	0	0
Planned Orders			100			100			100			

▶ **End item**
A product sold as a completed item or repair part.

▶ **Parent item**
An item produced from one or more children (components).

▶ **Components**
Raw materials, purchased items, or subassemblies that are part of a larger assembly.

At the top of the product structure tree is the **end item**, the product sold to the customer. In this case, the end item is the CD cabinet, but the end item could also be a repair part such as decorative hinges or door handle.

In the MRP system, a **parent item** is any end item made from one or more **components**. In our example, the CD cabinet is made from these components: a cabinet top, a cabinet bottom, cabinet door, cabinet left side, cabinet right side, 4 cabinet shelves, and 16 shelf holders. To simplify MRP processing logic, we call the end item the "parent" and its components the "children," and we show each item's parents or children in each of the inventory records. Table 14-6 shows the updated inventory record for the CD cabinet with this additional information. Since the CD cabinet is the end item, it has no parents. The immediate components of the CD cabinet are its children.

When your company has inventory on hand, the lead time can be less than the cu-

EXAMPLE 14.1

Calculating Cumulative Lead Time for a CD Cabinet

We need to calculate the cumulative lead time for the end item, a CD cabinet.

• **Before You Begin:** Determine how long it takes to build a CD cabinet if none of the activities has been completed. You need to order every component part, build every subassembly, and complete the final assembly. Start by looking at the product structure tree. Determine the total time required for each connected pathway or route from the bottom to the top. For example, look at the component hinges in Figure 14-4. The lead time for the hinges is four weeks. The parent of the hinges is the cabinet door. Lead time for the cabinet door is three weeks. Continue on to the parent for the cabinet door, the final assembly of the CD cabinet. Its lead time is one week. The total lead time for this connected pathway or route is eight weeks (4 + 3 + 1). Cumulative lead time for this product is the largest value associated with any individual connected path from the lowest level to the final assembly level. Beginning inventories can reduce the amount of time it takes to complete an order. For example, if sufficient hinges were already available, four weeks of lead time is subtracted from the lead time of this connected path.

• **Solution:**
We can use the product structure tree to calculate the cumulative lead time for the end item, a CD cabinet. We do this by summing the individual lead times for each route from the lowest level to the end item. The first possible route includes only the cabinet top and final assembly of the CD cabinet. Thus the total lead time for this route is four weeks (three weeks for the cabinet top and one week for the CD cabinet final assembly). The next path includes the feet, the cabinet bottom, and the final assembly of the CD cabinet for a total of nine weeks, which is the longest path through the product structure tree. Table 14-7 shows all the paths through the product structure tree.

Table 14-7 Paths through the Product Structure Tree

Path from Bottom to Top	Cumulative Lead Time (weeks)
Cabinet top to CD cabinet	4
Feet to cabinet bottom to CD cabinet	9
Magnet to cabinet door to CD cabinet	6
Hinge to cabinet door to CD cabinet	8
Handle to cabinet door to CD cabinet	7
Screws to cabinet door to CD cabinet	5
Cabinet side to CD cabinet	4
Door catch to side to CD cabinet	5
Screws to side to CD cabinet	5
Shelf to CD cabinet	3
Shelf holder to CD cabinet	2

mulative lead time. Suppose all the feet were already in inventory. The lead time of the CD cabinet is reduced to eight weeks, the next-longest path through the product structure tree since the feet to cabinet bottom to CD cabinet path would only need five weeks now, since the feet are already in stock. Thus, having inventory on hand allows you to respond more quickly because you can reduce lead times.

Before You Go On

Be sure that you understand the logic behind MRP. The system checks the gross requirements for each period, compares that with the inventory available (the beginning inventory for that period, plus any replenishment orders due). If the gross requirements exceed the inventory available, an order must be scheduled to arrive in that period. The system calculates the timing of the replenishment order by subtracting the lead time (in weeks) from the period the material is needed to satisfy the gross requirements. The system calculates the quantity of the replenishment order by the lot size rule for that item.

THE MRP EXPLOSION PROCESS

EXAMPLE 14.2

The MRP System at Storage Solutions by Elyssa, Inc.

Complete the MRP records for each of the items in the bill of material for the CD cabinet.

- **Before You Begin:** In this problem, determine the timing of planned orders for each item used in the construction of the CD cabinet. Using input from the master production schedule, determine the timing of the finished CD cabinet (shown in Table 14-6). Process the MRP records, level by level. Complete all of the level-one items before beginning the level-two items, and so on. The end result of this problem should be completed MRP records for every item used in the CD cabinet.

- **Solution:**

This example illustrates the MRP explosion process. Using Table 14-6, we begin the MRP **explosion process**. MRP calculates the materials needed to meet the authorized MPS. *The gross requirements for end items are **always** dictated by the authorized MPS*. When we input these quantities into the proper time frame, MRP calculates the gross requirements for components. The MRP program begins by processing the inventory records of each component of the end item.

▶ **Explosion process** Calculates the demand for the children of a parent by multiplying the parent requirements by the children's usage as specified in the BOM.

We will work through this example starting with the cabinet top. Table 14-8a shows the appropriate inventory record. Let's look at the differences in the inventory record. First, the lot size rule is a fixed-order quantity of 144 units, which means the order quantity is always 144 units. If an order of 144 units is not enough to cover the gross requirements, we can place a double order (288 units) or triple order (432 units). The lead time is three weeks, so we must place the replenishment order three weeks before it is needed. *Gross requirements for a component, or child, are determined by the planned orders of its parent or parents.*

The planned orders of the parent item determine the timing of the gross requirements of the child. In our case, the parent item (the CD cabinet) has planned orders in periods 3, 6, and 9, and its children (the top, bottom, door, sides, shelves, and shelf supports) will all have gross requirements in periods 3, 6, and 9. The quantity of the gross requirement for the child is determined by the usage quantity. Since each CD cabinet needs one cabinet top, the gross requirement for the cabinet top is 100 pieces. This is the planned order quantity of the parent multiplied by the usage rate of the child (100×1). The beginning inventory of the cabinet tops is 120 units.

We can see from the inventory record in Table 14-8a that we need replenishment orders (each for a quantity of 144 units) in periods 3 and 6. If no replenishment order is placed in period 3, we will not have enough cabinet tops to satisfy our gross requirement in period 6.

Table 14-8 (a–f) has the inventory records for all the children of the CD cabinet. Note that all of the CD cabinet children have gross requirements in periods 3, 6, and 9. This is because the timing of gross requirements for a child is derived from the planned orders of its parent or parents. After the system sets the gross requirements, it projects the available inventory and back-schedules replenishment orders using the lead time needed for the order to arrive in the appropriate period. For example, the 144 cabinet tops ordered in period 3 will arrive in period 6 to help satisfy the gross requirement in that period. The next order for cabinet tops will be placed in period 6 to arrive in period 9. Quantities shown as scheduled receipts have already been ordered. See Table 14-8b, period 3.

Table 14-8 Inventory Records for CD Cabinet Components

Table 14-8a Inventory Record for Cabinet Top

Item: Cabinet Top — Parent: CD Cabinet
Lot size rule: FOQ = 144 — Children: none
Lead time: 3 weeks — Beginning inventory: 120

	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirements:	0	0	100	0	0	100	0	0	100	0	0	0
Scheduled Receipts:												
Projected Available:	120	120	20	20	20	64	64	64	108	108	108	108
Planned Orders:			144			144						

Table 14-8b Inventory Record for Cabinet Bottom

Item: Cabinet Bottom — Parent: CD Cabinet
Lot size rule: FOQ = 144 — Children: Feet
Lead time: 3 weeks — Beginning inventory: 20

	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirements:	0	0	100	0	0	100	0	0	100	0	0	0
Scheduled Receipts:			144									
Projected Available:	20	20	64	64	64	108	108	108	8	8	8	8
Planned Orders:			144									

Table 14-8c Inventory Record for Cabinet Door

Item: Cabinet Door — Parent: CD Cabinet
Lot size rule: FOQ = 216 — Children: Magnet, hinge, handle, screws
Lead time: 4 weeks — Beginning inventory: 120

	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirements:	0	0	200	0	0	200	0	0	200	0	0	0
Scheduled Receipts:			216									
Projected Available:	120	120	136	136	136	152	152	152	168	168	168	168
Planned Orders:			216			216						

Table 14-8d Inventory Record for Cabinet Sides

Item: Side — Parent: CD Cabinet
Lot size rule: FOQ = 216 — Children: none
Lead time: 3 weeks — Beginning inventory: 0

	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirements:	0	0	200	0	0	200	0	0	200	0	0	0
Scheduled Receipts:			216									
Projected Available:	0	0	16	16	16	32	32	32	48	48	48	48
Planned Orders:			216			216						

Table 14-8e Inventory Record for Cabinet Shelves

Item: Shelf — Parent: CD Cabinet
Lot size rule: L4L — Children: none
Lead time: 2 weeks — Beginning inventory: 0

	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirements:	0	0	400	0	0	400	0	0	400	0	0	0
Scheduled Receipts:												
Projected Available:	0	0	0	0	0	0	0	0	0	0	0	0
Planned Orders:	400			400			400					

Table 14-8f Inventory Record for Shelf Supports

Item: Shelf Supports — Parent: CD Cabinet
Lot size rule: FOQ = 2500 — Children: none
Lead time: 1 week — Beginning inventory: 0

	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirements:	0	0	1600	0	0	1600	0	0	1600	0	0	0
Scheduled Receipts:												
Projected Available:	0	0	900	900	900	1800	1800	1800	200	200	200	200
Planned Orders:		2500			2500							

After MRP reviews and updates the children of the CD cabinet, it drops to the next lower level in the BOM and processes the inventory records at that level. In our example, those records are for the door magnet, door hinge, handle, screws, door catch, and feet. The cabinet door is the parent item for the magnet, hinge, handle, and screws. The cabinet right side is the parent of the door catch as well as a second parent for the screws. The cabinet bottom is the parent of the feet. Table 14-9 shows the inventory records for these remaining components. The process is the same as for the children of the CD cabinet. You look to the planned order releases of the parent item to determine the gross requirements of the components. For example, look at Table 14-9c (the inventory record for the handle); its parent (cabinet door) has planned orders in periods 3 and 6. Therefore, the handle must have gross requirements in periods 3 and 6. Next, let's look at how MRP provides information to the production and inventory control planners.

Table 14-9 Inventory Records for Remaining Components

Table 14-9a Inventory Record for Door Magnet

Item: Door Magnet — Parent: Cabinet Door
Lot size rule: FOQ = 250 — Children: none
Lead time: 2 weeks — Beginning inventory: 12

	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirements:	0	0	216	0	0	216	0	0	0	0	0	0
Scheduled Receipts:												
Projected Available:	12	12	46	46	46	80	80	80	80	80	80	80
Planned Orders:	250			250								

Table 14-9b Inventory Record for Door Hinge

Item: Door Hinge — Parent: Cabinet Door
Lot size rule: FOQ = 932 — Children: none
Lead time: 4 weeks — Beginning inventory: 0

	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirements:	0	0	432	0	0	432	0	0	0	0	0	0
Scheduled Receipts:			932									
Projected Available:	0	0	500	500	500	68	68	68	68	68	68	68
Planned Orders:												

Table 14-9c Inventory Record for Door Handle

Item: Handle — Parent: Cabinet Door
Lot size rule: FOQ = 200 — Children: none
Lead time: 3 weeks — Beginning inventory: 50

	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirements:	0	0	216	0	0	216	0	0	0	0	0	0
Scheduled Receipts:			200									
Projected Available:	50	50	34	34	34	18	18	18	18	18	18	18
Planned Orders:			200									

Table 14-9d Inventory Record for Door Screws

Item: Screw — Parent: Cabinet Door, Cabinet Side
Lot size rule: FOQ = 2000 — Children: none
Lead time: 1 week — Beginning inventory: 500

	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirements:	0	0	2160	0	0	2160	0	0	0	0	0	0
Scheduled Receipts:												
Projected Available:	500	500	340	340	340	180	180	180	180	180	180	180
Planned Orders:		2000			2000							

Table 14-9e Inventory Record for Door Catches

Item: Door Catch — Parent: Cabinet Sides
Lot size rule: FOQ = 252 — Children: none
Lead time: 1 week — Beginning inventory: 0

	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirements:	0	0	216	0	0	216	0	0	0	0	0	0
Scheduled Receipts:												
Projected Available:	0	0	36	36	36	72	72	72	72	72	72	72
Planned Orders:		252			252							

Table 14-9f Inventory Record for Feet

Item: Foot — Parent: Cabinet Bottom
Lot size rule: L4L — Children: none
Lead time: 4 weeks — Beginning inventory: 0

	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirements:	0	0	576	0	0	0	0	0	0	0	0	0
Scheduled Receipts:			576									
Projected Available:	0	0	0	0	0	0	0	0	0	0	0	0
Planned Orders:												

ACTION NOTICES

MRP systems typically provide inventory planners with **action notices**, which indicate the items that need the planner's attention. An action notice is created when a planned order needs to be released, when due dates of orders need to be adjusted, or when there is insufficient lead time for a planned replenishment order. Let's look at the different kinds of action notices.

▶ **Action notices**
Output from an MRP system that identifies the need for an action to be taken.

A positive quantity in the current period's planned order row means that an order must be released. We call the current period the **action bucket** because that is the period in which we take actions such as releasing, rescheduling, or canceling orders.

▶ **Action bucket**
The current time period.

Production and inventory control planners release orders to either an external supplier or to the shop floor. An order released to a supplier authorizes the shipment of the material so that it arrives as needed. An order released to the shop authorizes withdrawal of the needed materials and the start of production. Action notices are generated only for actions taken in the current period. Production and inventory control planners adjust the due dates of orders (both opened and planned) to make sure the material does not arrive too soon or too late but just as it is needed. If an order is scheduled to arrive before it is needed (for example, because the gross requirements changed), the planner delays receipt of the replenishment order until it is needed. If the order is not scheduled to arrive in time, the planner tries to rush or **expedite** the order. Action notices indicate that a decision must be made or an action taken. The production and inventory control planner uses the available information and makes the decision.

▶ **Expedite**
To rush orders that are needed in less than the normal lead time.

COMPARISON OF LOT SIZE RULES

Different lot size rules can be used with MRP systems, such as least unit cost, least total costs, and parts period balancing. In this book, we cover the fixed-order quantity (FOQ), lot-for-lot (L4L), and period-order quantity (POQ). These lot size rules are discussed in Chapter 12. Different lot size rules change the frequency of replenishment orders and determine the quantity of the order. Let's look at an example comparing FOQ, L4L, and POQ.

EXAMPLE 14.3

Comparing Different Lot Size Rules at Storage Solutions by Elyssa, Inc.

Given the following gross requirements, let's calculate the planned replenishment orders needed, then calculate the inventory and ordering costs for the next 13 weeks. The CD cabinet has gross requirements of 25 in periods 2 and 3; 40 in periods 4 and 5; and 60 in periods 7, 8, 9, 11, 12, and 13. The first lot size to try is FOQ = 144, then use L4L, and finally use a POQ = 4 periods. The cost to place an order is $25, and the holding cost per unit per period is $0.10.

- **Before You Begin:** Companies using MRP often use different lot-sizing techniques. Different techniques determine the timing of replenishment orders, the amount of inventory carried, and the frequency of setups. In this problem, you compare three different lot size rules. Calculate the costs associated with each ordering policy and determine which lot size rule makes the most sense. Remember that the fixed-order quantity (FOQ) rule requires you to order the same quantity each time, while lot-for-lot (L4L) means you order just enough for the next period, and period-order quantity (POQ) means that you order enough to satisfy your requirements for the next *n* periods.

• Solution:

Table 14-10a–c shows the completed inventory records. As you can see, the planned replenishment orders vary in frequency and in quantity. Note the different levels of inventory held because of the lot size rule. Lot-for-lot always minimizes a company's inventory investment because it orders only what is needed for one period. However, L4L also maximizes a company's ordering costs.

Table 14-10 Inventory Records Comparing Lot Size Rules

Table 14-10a Inventory Record Using Fixed-Order Quantity

Item: CD Cabinet — Lead Time: 1 week
Lot size rule: FOQ = 144 — Beginning inventory: 0

	1	2	3	4	5	6	7	8	9	10	11	12	13
Gross Requirements:	0	25	25	40	40	0	60	60	60	0	60	60	60
Scheduled Receipts:													
Projected Available:	0	119	94	54	14	14	98	38	122	122	62	2	86
Planned Orders:	144					144		144				144	

Table 14-10b Inventory Record Using Lot-for-Lot

Item: CD Cabinet — Lead Time: 1 week
Lot size rule: L4L — Beginning inventory: 0

	1	2	3	4	5	6	7	8	9	10	11	12	13
Gross Requirements:	0	25	25	40	40	0	60	60	60	0	60	60	60
Scheduled Receipts:													
Projected Available:	0	0	0	0	0	0	0	0	0	0	0	0	0
Planned Orders:	25	25	40	40		60	60	60		60	60	60	

Table 14-10c Inventory Record Using Period-Order Quantity

Item: CD Cabinet — Lead Time: 1 week
Lot size rule: POQ = 4 periods — Beginning inventory: 0

	1	2	3	4	5	6	7	8	9	10	11	12	13
Gross Requirements:	0	25	25	40	40	0	60	60	60	0	60	60	60
Scheduled Receipts:													
Projected Available:	0	105	80	40	0	0	120	60	0	0	120	60	0
Planned Orders:	130					180				180			

Let's calculate the costs for each of these different lot size rules for this 13-week situation. The FOQ lot size rule has ending inventory in all but the first period. In total, 825 units are held for a holding cost of \$82.50 (825 units × \$0.10 per unit per period). The ordering cost is \$100 (4 orders × \$25 per order). Total holding and ordering cost using the FOQ is \$182.50. The L4L lot size rule has no ending inventory during the 13 weeks. However, it does need a total of ten replenishment orders. The total holding and ordering cost for L4L is \$250. The POQ = 4 periods lot size rule has ending inventory in periods 2, 3, 4, 7, 8, 11, and 12. Total units held are 585, for holding costs of \$58.50. POQ requires three replenishment orders (ordering cost equals \$75). Total costs for POQ are \$133.50. In this case, the POQ lot size rule has the lowest total holding and ordering costs. To ensure that costs are minimized, we have to do the cost comparisons.

THE ROLE OF CAPACITY REQUIREMENTS PLANNING (CRP)

A company uses a rough-cut capacity planning technique to determine whether a proposed MPS is feasible. In Supplement D, we see how to evaluate the feasibility of a proposed MPS with capacity planning using overall planning factors (CPOPF). Rough-cut capacity planning techniques use data from the proposed MPS. Capacity requirements planning (CRP) uses data from MRP. We calculate workloads for critical work centers based on **open shop orders** and planned shop orders. Work begins on open shop orders while planned shop orders are scheduled to be done. We translate these orders into hours of work by work center and by time period.

▶ **Open shop orders**
Released manufacturing orders.

EXAMPLE 14.4

Calculating Workloads

Table 14-11 shows items scheduled for Work Center 101. These items are either taken directly from MRP's planned orders or they are already open shop orders. We want to calculate workloads for Work Center 101.

- **Before You Begin:** Capacity requirements planning (CRP) uses the planned order releases from the MRP output to calculate the workload for specific work centers. The workload associated with a planned order has two parts: the setup to do the job and the processing time for the job. The primary difference between rough-cut capacity planning (RCCP) and CRP is that CRP uses the actual planned orders instead of the quantity needed just to complete the final product assembly. For example, using RCCP, if we want to estimate the time needed to build 100 CD cabinets, we assume that we make just enough pieces of everything to build 100 units. We don't take into account beginning inventories. However, with CRP, we take into account only the items that have a planned order scheduled. This also indicates the quantity to be built of the item. If a lot size rule other than L4L (lot-for-lot) is used, more capacity must be used to complete the planned order for the item. CRP provides a better estimate of the total capacity needed.

Table 14-11 Workload for Work Center 101

Period	Item Number	Quantity	Setup Time (hours)	Run Time per Unit in Standard Hours	Total Item Time (hours)	Weekly Workload (hours)
4	DN100	250	3.0	0.20	53.0	
	DP100	250	5.0	0.18	50.0	
	DS119	150	2.5	0.30	47.5	
	DT136	400	3.5	0.27	111.5	262.0
5	EQ555	1000	8.0	0.08	88.0	
	ER616	500	4.0	0.22	114.0	
	ES871	100	2.0	0.35	37.0	239.0
6	FA314	250	3.0	0.30	78.0	
	FF369	100	1.5	0.12	13.5	
	FR766	50	0.5	0.15	8.0	
	FS119	200	3.0	0.35	73.0	
	FY486	500	6.0	0.27	141.0	313.5

- **Solution:**

We calculate the total item time by summing the setup time and the total run time for the item.

$$\text{Total item time} = \text{setup time} + (\text{quantity} \times \text{run time per unit})$$

The setup time is incurred each time the machine is prepared to produce the desired quantity of an item. We calculate the total run time by multiplying the quantity to be produced by the run time per unit. In our example, for item DN100, we plan to produce 250 units, with each unit needing 0.20 hour of run time. The total run time is 50.0 hours (250 units × 0.20 hour per unit). Total workload placed on the work center by item DN100 is 53 hours: 3 hours to set up the machine and 50 hours to run the quantity. We make similar calculations for each of the other items. When we have calculated the workloads, we compare them to the available capacity for the work center in those time period.

We calculate available capacity (discussed in Chapter 9) by multiplying the number of machines available × number of shifts used × number of hours per shift × number of days per week × usage × efficiency.

$$\text{Available capacity} = \text{number of machines available} \times \text{number of shifts used} \times \text{number of hours per shift} \times \text{number of days per week} \times \text{utilization} \times \text{efficiency}$$

In our case, we have four machines and we use two ten-hour shifts for five days per week, so our usage is 85 percent and our efficiency is 95 percent.

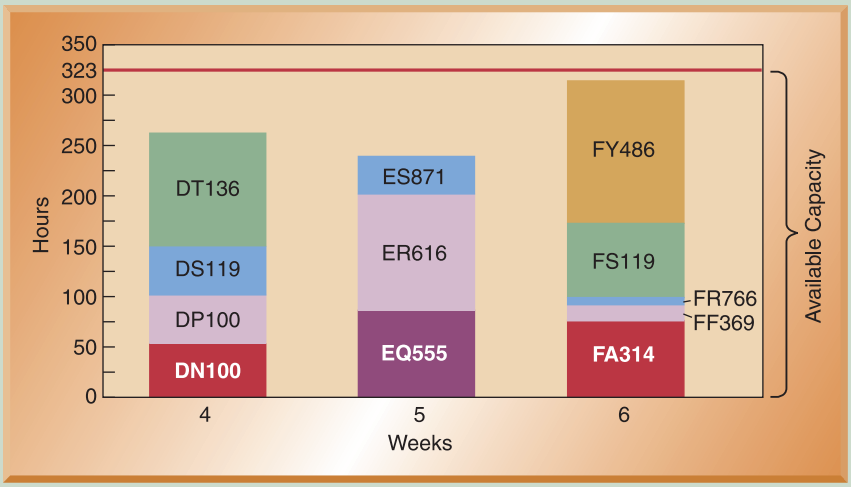
$$\text{Available capacity} = 4 \text{ machines} \times 2 \text{ shifts} \times \frac{10 \text{ hours}}{\text{per shift}} \times \frac{5 \text{ days}}{\text{per week}} \times 0.85 \text{ utilization} \times 0.95 \text{ efficiency}$$

The available capacity per week is 323 standard hours. Figure 14-5 shows the workload compared to available capacity.

If the available capacity is not adequate, the company has a number of options. The easiest and quickest way to increase available capacity may be to authorize overtime at the work center. Another approach is to reduce the capacity needed by doing some of the work at an alternate work center. If the gap between available and needed capacity is significant, the company can hire a subcontractor

FIGURE 14-5

Workload for Work Center 101



CRP enables a company to evaluate both the feasibility of the MRP system and how well the company is using its critical work centers.

RESOURCE PLANNING WITHIN OM: HOW IT ALL FITS TOGETHER

Enterprise resource planning provides a common database for use by an organization, its suppliers, and its customers. Second-generation ERP systems are designed to support supply chain management and e-commerce. These systems automate routine transactions and provide real-time information to all members of the enterprise. ERP systems typically have a production and materials module (MRP) to determine what is needed, how much is needed, and when it is needed.

MRP reports are used by the production and inventory planners to (1) generate purchasing requisitions and (2) develop schedules of different activities to be done on the manufacturing floor. Techniques for sequencing activities are discussed in Chapter 15. The authorized MPS, the bill of material (BOM) file, and the inventory records are inputs to the MRP system. It is critical that the MPS be feasible and that the BOM file and the inventory records be accurate. This implies that the time standards (Chapter 11) are valid and that cycle counting (Chapter 12) is used to maintain inventory record accuracy. If not, material is not ordered at the appropriate time in the right quantity. The

master scheduler is responsible for the feasibility of the MPS, and a manufacturing engineer is probably responsible for the BOM file. The production and inventory planners are often held accountable for the accuracy of the inventory records.

Even though rough-cut capacity planning (RCCP) using MPS data was done to check for feasibility, it is still important to do capacity requirements planning (CRP) for any critical work centers (bottlenecks or potential bottlenecks). CRP operates at a greater level of detail than does RCCP, using information generated by the MRP system. Production planners do this to make sure the detailed schedule of production is feasible.

Resource planning is designed to ensure that the right materials, in the right quantities, are available at the right time. And to ensure that the right job is being done on the right equipment.

RESOURCE PLANNING ACROSS THE ORGANIZATION

Since MRP determines the quantity and timing of materials needed, it affects several functional areas in the company. Let's first look at how each functional area is affected by MRP and then consider the effects of ERP.

Accounting calculates future material commitments based on MRP output. Accounting then develops cash flow budgets and the inventory investment to support the current MPS. With a common database, accounting should be able to determine the exact status of outstanding orders, including cost, quantity, and delivery date. Since there is a common database, discrepancies between supplier and manufacturer should be reduced.

Marketing is primarily concerned with the MPS, which identifies when finished goods will be completed. MRP reveals potential material shortages that directly affect marketing since the shortages may delay product completion. Marketing can also use MRP for allocating scarce materials to maximize customer service. One major advantage of ERP is that marketing can track actual sales at the final product level (using POS) to determine what actions, if any, need to be taken to maximize customer service.

Information systems maintains MRP, which is a large database that includes the BOM, the inventory records, and the MPS. Minimizing errors in the database is essential to producing useful reports. ERP will help IS by using a single integrated database for both internal and external members of the supply chain.

Purchasing uses the planned orders generated by MRP to evaluate the feasibility of long-term or blanket contracts and to determine delivery need. The lead times that are input into MRP often come directly from purchasing. ERP will facilitate supplier-managed inventory approaches and reduce transaction costs for purchasing.

Manufacturing uses the output generated by MRP to develop daily manufacturing schedules. MRP ensures that the right materials in the right quantity are available to support the MPS. Manufacturing also uses MRP to allocate scarce materials. ERP will provide manufacturing with improved insight into actual customer demand. It should increase the probability that manufacturing is working on products actually needed to satisfy customer demand.

In most manufacturing operations, production or inventory control planners are responsible for working with MRP. Planners are typically responsible for certain inventory items, including end items, subassemblies, and components. Planners check the MRP output for action notices related to the items for which they are responsible. Planners schedule, reschedule, and expedite materials to support the MPS. A planning position is often an entry-level job in the materials field.

As companies continue to move toward ERP, all functional areas will work from a central database. The database gives all areas in the company access to the same information simultaneously and improves organizational effectiveness.

THE SUPPLY CHAIN LINK

Enterprise resource planning provides the structure for common databases across the organization, its suppliers, and its customers. Suppliers can access the master production schedule (MPS) to see projected build dates for products that use materials supplied by them. The current trend is to integrate e-commerce and ERP systems. Tangible benefits of an ERP system include reduced inventory levels, reduced staffing, improved order launching, reduced IT and purchasing costs, improved cash flow, and increased profits. Intangible benefits include improved visibility of system demand, improved customer responsiveness, and improved flexibility. Enterprise resource planning systems provide the structure needed for effective supply chain management.

Chapter Highlights

1. Enterprise resource planning (ERP) is software designed for organizing and managing business processes by sharing information across functional areas using a common database and a single computer system. ERP systems typically have modules for finance and accounting, sales and marketing, production and materials management, and human resources.

2. First-generation ERP systems provide a single interface for managing routine activities performed in manufacturing. Second-generation ERP systems or SCM software is designed to improve decision making in the supply chain. The current trend is integrating e-commerce and ERP systems.

3. Tangible benefits from ERP systems include reductions in inventory and staffing, increased productivity, improved order management, quicker closing of financial cycles, reduced IT and purchasing costs, improved cash flow management, and increased revenue and profits. Intangible benefits include improved visibility of corporate data, improved customer responsiveness, and improved flexibility. The cost of ERP systems ranges from hundreds of thousands of dollars to several million dollars.

4. Material requirements planning (MRP) systems are designed to calculate material requirements for items with dependent demand. MRP systems use backward scheduling to determine when each activity starts so that the finished product or service is completed on time.

5. Independent demand is the demand for finished products, whereas dependent demand is demand that is derived from finished products. MRP systems use dependent demand.

6. The objectives of MRP are to determine the quantity and timing of material requirements and to keep schedule priorities updated and valid. MRP determines what to order, how much to order, when to place the order, and when to schedule the order's arrival. It maintains priorities by recognizing changes in the operations environment and making the necessary adjustments.

7. MRP needs three inputs: the authorized MPS, the BOM file, and the inventory records file. The MPS is the planned build schedule, the BOM file shows the materials needed to build an item, and the inventory records file shows the inventory on hand.

8. Once the MPS has been input, MRP checks the inventory records to determine if enough end-item inventory is available. If sufficient end item inventory is not on hand, MRP checks the end item's BOM file to determine what materials are needed and in what quantities. The MRP system then generates planned replenishment orders.

9. Action notices show when to release planned orders, reschedule orders, or adjust due dates. They allow the planner to use the MRP output information effectively.

10. Different lot size rules are used with MRP systems to generate different order quantities and order frequencies. The lot-for-lot (L4L) rule always minimizes inventory investment but maximizes ordering costs. A cost comparison shows the effect of using different lot sizing rules.

11. Planned orders generated by MRP, plus any open shop orders, are inputs to capacity requirements planning (CRP). CRP checks to see if available capacity is sufficient to complete the orders scheduled in a particular work center during a specific time period.

12. CRP calculates the workloads at critical work centers by using the planned orders generated by the MRP system. These planned orders are multiplied by the standard times to calculate individual work center loads.

Key Terms

backward scheduling 518
enterprise resource planning (ERP) 519
SCM software 521
supply chain intelligence (SCI) 521
application service provider (ASP) 521
closed-loop MRP 525
manufacturing resource planning (MRP II) 525
material requirements planning (MRP) 526
capacity requirements planning (CRP) 526
bill of material (BOM) 526
independent demand 526
dependent demand 527
time-phased 527
gross requirements 528
planning factors 529
lead time 529
scheduled receipt 530
projected available 530
planned orders 530
indented bill of material 530
product structure tree 531
end item 532
parent item 532
components 532
explosion process 533
action notices 537
action bucket 537
expedite 537
open shop orders 538

Formula Review

1. To calculate total item time:

Total item time = setup time
+ (quantity × run time per unit)

2. To calculate available capacity:

Available capacity = number of machines available
× number of shifts used
× number of hours per shift
× utilization × efficiency

Solved Problems

(See student companion site for Excel template.)

• Problem 1

Using the product tree shown in Figure 14-6, calculate the cumulative lead time for Item 100 if you have no inventory.

How long is the lead time if you have enough inventory for Parts 102, 104, 201, and 203?

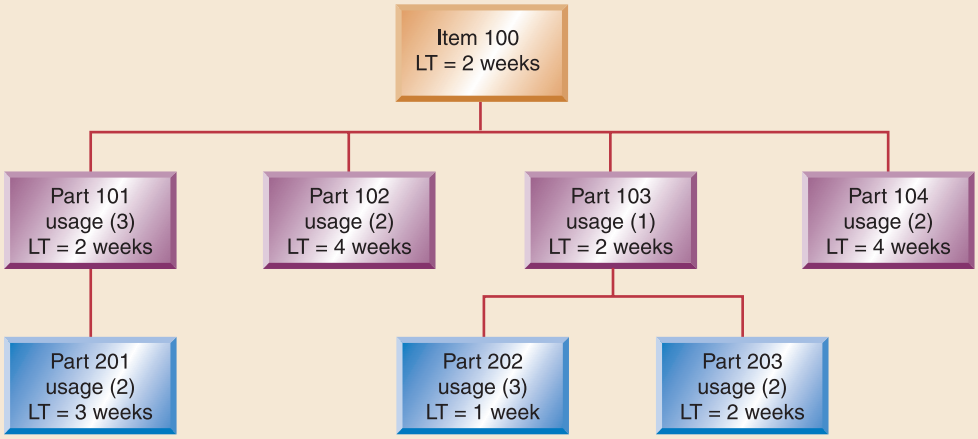


FIGURE 14-6

Product structure tree

• *Before You Begin:*

Determine the minimum amount of time needed to build Item 100. To find the cumulative lead time, calculate the total time it takes for each connected pathway from the lowest level up to the finished product. If there is no inventory in stock, this represents the quickest way you can respond to an order for this item. Then, consider the effect of having some inventory on hand. Inventory of component parts and/or subassemblies can reduce the amount of time it takes to respond to an order.

• *Solution*

Check all the paths through the product structure tree to find the longest path.

Path through the Product Structure	Total Lead Time (weeks)
Part 201 to Part 101 to Item 100	7
Part 102 to Item 100	6
Part 202 to Part 103 to Item 100	5
Part 203 to Part 103 to Item 100	6
Part 104 to Item 100	6

The path from Part 201 to Part 101 to Item 100 is the longest (7 weeks), so it is the cumulative lead time.

When we have enough inventory for some parts, we can eliminate that segment of the path and all levels below that inventory. For example, if we have enough of Part 101, we do not need any more of its component parts (201). The new paths when we have sufficient inventory for Parts 102, 104, 201, and 203 are shown here.

Path through the Product Structure	Total Lead Time (weeks)
Part 101 to Item 100	4
Part 202 to Part 103 to Item 100	5

Given that we have enough inventory, we are concerned with only two paths through the product tree. In this situation, the minimum time to produce this item is 5 weeks.

• Problem 2

Complete the inventory record for Item 500 and do an MRP explosion of its component parts. Figure 14-7 shows the product structure tree for Item 500.

• *Before You Begin:*

This problem requires an MRP explosion for Item 500. Begin the explosion process with the finished good, and then work downward level by level through the product structure tree. Remember that the timing and quantity of the gross requirements for children are determined by the planned orders of the parents. After the explosion, you will have the planned orders necessary to produce the units listed in the master production schedule.

Item: 500 **Parent: none**
Lot Size Rule: L4L **Children: 501, 502, 503, 504**
Lead Time: 2 weeks **Beginning inventory: 0**

	1	2	3	4	5
Gross Requirements:	0	0	0	250	0
Scheduled Receipts:					
Projected Available:					
Planned Orders:					
	6	**7**	**8**	**9**	**10**
Gross Requirements:	250	0	250	0	250
Scheduled Receipts:					
Projected Available:					
Planned Orders:					

• *Solution*

Given the gross requirements, we will need planned orders for Item 500 in weeks 2, 4, 6, and 8. Each of the planned orders is for 250 units, exactly the quantity needed to satisfy the gross requirements. The completed record is shown here.

Item: 500 **Parent: none**
Lot Size Rule: L4L **Children: 501, 502, 503, 504**
Lead Time: 2 weeks **Beginning inventory: 0**

	1	2	3	4	5
Gross Requirements:	0	0	0	250	0
Scheduled Receipts:					
Projected Available:	0	0	0	0	0
Planned Orders:	0	250	0	250	0
	6	**7**	**8**	**9**	**10**
Gross Requirements:	250	0	250	0	250
Scheduled Receipts:					
Projected Available:	0	0	0	0	0
Planned Orders:	250	0	250	0	0

Now that we have a completed inventory record for the end item, we can do the MRP explosions for its children. Remember that each of the children will have gross requirements in the periods that the parent has a planned order (weeks 2, 4, 6, and 8). The completed records for the four children follow.

Since the usage rate for Item 501 is (2) per parent item, the gross requirement is double the planned order quantity of the parent, or $250 \times 2 = 500$ units. The lot size rule is a fixed-order quantity of 1000 pieces. Each time an order is placed, it is for 1000 pieces. Thus, Item 501 has two planned orders, one in period 2 and one in period 6.

Item: 501 **Parent: 500** **Usage: 2**
Lot Size Rule: FOQ = 1000 **Children: none**
Lead Time: 2 weeks **Beginning inventory: 600**

	1	2	3	4	5
Gross Requirements:	0	500	0	500	0
Scheduled Receipts:					
Projected Available:	600	100	100	600	600
Planned Orders:	0	1000	0	0	0
	6	**7**	**8**	**9**	**10**
Gross Requirements:	500	0	500	0	0
Scheduled Receipts:					
Projected Available:	100	100	600	600	600
Planned Orders:	1000	0	0	0	0

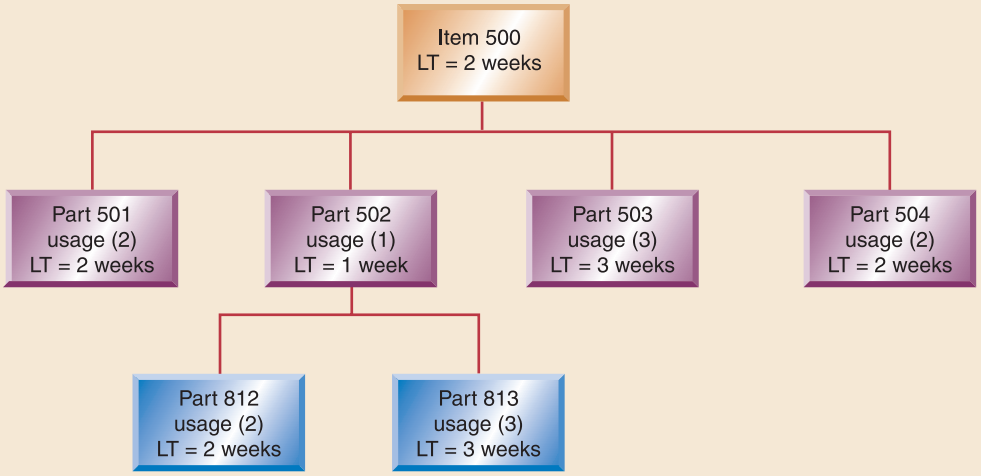


FIGURE 14-7

Product structure tree

Using lot-for-lot as our lot size rule, we need to place four orders for Item 502. We have planned orders in periods 1, 3, 5, and 7.

Item: 502 **Parent: none** **Usage: 1**
Lot Size Rule: L4L **Children: 812, 813**
Lead Time: 1 week **Beginning inventory: 0**

	1	2	3	4	5
Gross Requirements:	0	250	0	250	0
Scheduled Receipts:					
Projected Available:	0	0	0	0	0
Planned Orders:	250	0	250	0	250
	6	**7**	**8**	**9**	**10**
Gross Requirements:	250	0	250	0	0
Scheduled Receipts:					
Projected Available:	0	0	0	0	0
Planned Orders:	0	250	0	0	0

Once again, we calculate the gross requirements by multiplying the parent's planned order quantity by the usage factor (3) shown in the product structure tree. This results in the gross requirement for Item 503, which is triple the order quantity of the parent's planned order.

Item: 503 **Parent: 500** **Usage: 3**
Lot Size Rule: FOQ = 1500 **Children: 812, 813**
Lead Time: 3 weeks **Beginning inventory: 800**

	1	2	3	4	5
Gross Requirements:	0	750	0	750	0
Scheduled Receipts:					
Projected Available:	800	50	50	800	800
Planned Orders:	1500	0	0	0	1500
	6	**7**	**8**	**9**	**10**
Gross Requirements:	750	0	750	0	0
Scheduled Receipts:					
Projected Available:	50	50	800	800	800
Planned Orders:	0	0	0	0	0

Given the lot size rule for this item, we need only one planned order.

Item: 504 **Parent: 500** **Usage: 2**
Lot Size Rule: FOQ = 2000 **Children: none**
Lead Time: 2 weeks **Beginning inventory: 600**

	1	2	3	4	5
Gross Requirements:	0	500	0	500	0
Scheduled Receipts:					
Projected Available:	600	100	100	1600	1600
Planned Orders:	0	2000	0	0	0
	6	**7**	**8**	**9**	**10**
Gross Requirements:	500	0	500	0	0
Scheduled Receipts:					
Projected Available:	1100	1100	600	600	600
Planned Orders:	0	0	0	0	0

Now let's look at the children of Item 502. The gross requirements for Item 812 are double the quantity of its parent's planned orders. The lot size rule, POQ = 4 periods, means that the planned order quantity should be enough to cover the requirements in the period it is scheduled to arrive plus the next three periods. For example, we need an order to arrive in period 3. This planned order must be large enough to cover the gross requirements in periods 3, 4, 5, and 6. The inventory records for both 812 and 813 follow.

Item: 812 **Parent: 502** **Usage: 2**
Lot Size Rule: POQ = 4 periods **Children: none**
Lead Time: 2 weeks **Beginning inventory: 500**

	1	2	3	4	5
Gross Requirements:	500	0	500	0	500
Scheduled Receipts:					
Projected Available:	0	0	500	500	0
Planned Orders:	1000	0	0	0	500

Item: 812 **Parent: 502** **Usage: 2**
Lot Size Rule: POQ = 4 periods **Children: none**
Lead Time: 2 weeks **Beginning inventory: 500**

	6	7	8	9	10
Gross Requirements:	0	500	0	0	0
Scheduled Receipts:					
Projected Available:	0	0	0	0	0
Planned Orders:	0	0	0	0	0

Item: 813 **Parent: 502** **Usage: 3**
Lot Size Rule: FOQ = 1500 **Children: none**
Lead Time: 3 weeks **Beginning inventory: 1500**

	1	2	3	4	5
Gross Requirements:	750	0	750	0	750
Scheduled Receipts:					
Projected Available:	750	750	0	0	750
Planned Orders:	0	1500	0	0	0
	6	**7**	**8**	**9**	**10**
Gross Requirements:	0	750	0	0	0
Scheduled Receipts:					
Projected Available:	750	0	0	0	0
Planned Orders:	0	0	0	0	0

• Problem 3

EJ Fabricators operates six machines, three eight-hour shifts, five days per week. EJ's usage rate is 82 percent and its efficiency rate is 90 percent. Calculate the available capacity. Calculate EJ's workload in periods 7 and 8 and determine whether there is a capacity problem.

• *Before You Begin:*

In this problem, determine if adequate capacity is available. Calculate available capacity by multiplying the number of machines available for use by the number of shifts operated by the number of days per week by the utilization level by the efficiency level. This, in effect, reduces the output expected by factoring in utilization and efficiency. This allows more realistic expectations from manufacturing.

• *Solution*

We calculate the available capacity by multiplying the number of machines by the number of shifts by the number of hours per shift by the number of days per week by the utilization rate by the efficiency rate:

$$6 \text{ machines} \times 3 \text{ shifts} \times 8 \text{ hours per shift} \times 5 \text{ days per week} \times 0.82 \text{ utilization} \times 0.90 \text{ efficiency}$$

which equals 531.36 hours of available capacity. To calculate the workload, we need information about the jobs scheduled in each period. We have shown you how to calculate the capacity available. Now go to Spreadsheet 14.3 on your CD to calculate the workload for each period.

Discussion Questions

1. Describe enterprise resource planning and its role in an organization.
2. Describe the basic modules of an ERP system.
3. Describe the evolution of ERP systems.
4. Describe the role of SCM software and give examples of how it differs from first-generation ERP.
5. Explain what independent demand is and give examples of products with independent demand.
6. Explain what dependent demand is and give examples of how you can use dependent demand in your personal life.
7. Explain the concept of backward scheduling and give examples of how you use backward scheduling in your personal life.
8. What are the objectives of MRP?
9. Describe how MRP works.
10. Describe the inputs needed for MRP.
11. For each input needed, describe problems that might arise when you run MRP.
12. Explain what happens when you use different lot size rules in MRP.
13. Explain why companies do capacity requirements planning.
14. Describe the inputs needed for capacity requirements planning.
15. Describe how MRP II differs from MRP.
16. Describe enterprise resource planning.

Problems

Use the information given here for the next five problems.

Item	Usage per Parent	Lead Time (weeks)
Q	—	2
R	2	3
S	1	4
T	3	2
X	2	3
Y	1	2
V	1	3
Z	3	2

1. Will's Welded Widgets (WWW) makes its Q Model from components R, S, and T. Component R is made from two units of component X and one unit of component Y. Component T is made from one unit of component V and three units of component Z. Draw the product structure tree for the Q Model.

2. Using the given information, calculate the replenishment lead time for the Q Model assuming that you have no beginning inventories.

3. Using the given information, calculate the gross requirements for each of the components if the company plans to build 100 of its Q Models. Assume that there are no beginning inventories.

4. Using the given information, calculate the gross requirements for each of the components when the company plans to build 100 of its Q Models if you have these inventories: 150 units of component T and 200 units of component R.

5. Using the given information and the beginning inventories from Problem 4, calculate the minimum replenishment time for the 100 Q Models.

Use the following information for Problems 6 through 10.

Component	Immediate Parent	Usage per Parent	Lead Time (weeks)	Beginning Inventory
A	none	—	1	0
B	A	2	2	250
C	A	1	6	500
D	A	3	3	750
E	A	2	2	750
F	B	4	2	3000
G	B	2	4	1000
H	D	3	2	5000
I	D	2	4	5000
J	E	1	8	1000
K	E	5	1	5000
L	E	2	4	2500
M	F	3	3	250
N	F	6	3	2560
O	H	2	4	0
P	K	1	2	500
Q	K	2	3	1000

6. Flora's Fabulous Fountains' (FFF) top product is its Model A. Using the information given, draw the product structure tree for the Model A.

7. Using the information given, calculate the replenishment time when no beginning inventory exists.

8. Flora is preparing for her busy season and is building 2500 Model A fountains. Calculate the gross requirements for each component assuming that there is no beginning inventory.

9. Using the information given and assuming that 2500 Model A fountains are scheduled for completion, calculate the gross requirements of each component. Use the beginning inventories given.

10. Calculate the minimum replenishment time for the Model A fountains given the beginning inventories.

11. Fill in the partially completed inventory record shown here.

Item: AB500 **Parent: None**
Lot Size Rule: L4L **Children: AB501, AB511, AB521**
Lead Time: 2 weeks

	1	2	3	4	5
Gross Requirements:			150	250	150
Scheduled Receipts:					
Projected Available:					
Planned Orders:					
	6	**7**	**8**	**9**	**10**
Gross Requirements:	250	150	250	150	250
Scheduled Receipts:					
Projected Available:					
Planned Orders:					

12. Using the planned orders generated in Problem 11, complete inventory records for components AB501, AB511, and AB521. The lot size rule, lead time, and usage information are shown here.

Component	Lot Size Rule	Lead Time (weeks)	Usage Factor	Beginning Inventory
AB501	L4L	2	2	1100
AB511	FOQ = 350	3	1	650
AB521	POQ = 3	2	3	1650

13. Using the inventory records completed in Problem 12, calculate the average inventory level of AB501, AB511, and AB521.

14. Use the planned orders generated in Problem 11. Calculate the average inventory records if the company decides to switch the lot size rule for AB511 and AB521 to lot-for-lot. Compare the number of replenishment orders using the new lot size rules.

15. Using the information given, fill in the partially completed inventory record shown here.

Item: AB500 **Parent: None**
Lot Size Rule: FOQ = 200 **Children: AB501, AB511, AB521**
Lead Time: 2 weeks

	1	2	3	4	5
Gross Requirements:			150	250	150
Scheduled Receipts:					
Projected Available:					
Planned Orders:					
	6	**7**	**8**	**9**	**10**
Gross Requirements:	250	150	250	150	250
Scheduled Receipts:					
Projected Available:					
Planned Orders:					

16. Using the planned orders generated in Problem 15, complete the inventory record for components AB501, AB511, and AB521. Use the lot size rule, lead time, and usage information given in Problem 12. Indicate any problems that occur.

17. Fill in the partially completed inventory record shown here.

Item: AB500 **Parent: None**
Lot Size Rule: POQ = 3 **Children: AB501, AB511, AB521**
Lead Time: 2 weeks

	1	2	3	4	5
Gross Requirements:			150	250	150
Scheduled Receipts:					
Projected Available:					
Planned Orders:					
	6	**7**	**8**	**9**	**10**
Gross Requirements:	250	150	250	150	250
Scheduled Receipts:					
Projected Available:					
Planned Orders:					

18. Using the planned orders generated in Problem 17, complete inventory records for components AB501, AB511, and AB521. Use the lot size rule, lead time, and usage information given in Problem 12.

19. The Yankee Machine Shop has the following orders scheduled in Work Center 111 for week 12. Calculate the capacity needed.

Orders	Quantity	Setup Time (hours)	Run Time per Piece (hours)
LL110	10	2.0	1.2
LL118	25	4.0	0.4
LL131	100	6.0	0.6
LL140	50	4.0	0.2

20. The Yankee Machine Shop currently has three machines working in Work Center 111, eight hours per day, five days per week, a utilization rate of 90 percent, and an efficiency rate of 90 pecent.

(a) Calculate the available capacity.

(b) Is the available capacity enough to complete the orders given in Problem 19 that are already scheduled in Work Center 111? If not, how much additional capacity is needed?

21. The Yankee Machine Shop has decided to schedule its workforce to work ten hours per day, five days per week. Does this new policy provide enough capacity to complete the orders shown in Problem 19?

22. Unfortunately, after extending the work day from eight hours to ten hours, the Yankee Machine Shop has noted that efficiency has decreased to 80 percent. Given this new piece of information, is there enough capacity to complete the orders given in Problem 19?

23. In week 13, the Yankee Machine Shop, has the following orders scheduled for Work Center 111. Calculate the capacity needed.

Orders	Quantity	Setup Time (hours)	Run Time per Piece (hours)
MM078	100	4.0	0.3
MM118	250	6.0	0.1
MM213	100	3.0	0.3
MM240	500	8.0	0.1

24. In an effort to increase capacity in Work Center 111 for week 13, Yankee Machine Shop has authorized overtime. The work center will be staffed 12 hours per day for six days. Because of the additional stress on the three machines, it is expected that the utilization rate will drop to 85 percent. The efficiency rate is expected to fall to 80 percent.

(a) Calculate the capacity available in Work Center 111 for week 13.

(b) Will this plan provide sufficient capacity to complete the orders given in Problem 23? If not, what do you recommend be done?

25. The Gamma Ray Company produces two products, the Gamma Blaster (GB) and the Gamma Disaster (GD). Each product is made from three components: A, B, and C. The Gamma Blaster is made from the following components: A (2), B (3), and C (4). The Gamma Disaster is made from A (3), B (2), and C (1). All other relevant information is provided. Complete the appropriate inventory records.

Item	On Hand	Scheduled Receipts	Lot Size Rule	MPS	Lead Time
GB	0	0	L4L	150, period 8	1
GD	0	0	L4L	100, period 6	2
A	250	200, period 4	FOQ = 200		4
B	25	0	FOQ = 300		2
C	0	0	L4L		3

26. Using the information in Problem 25, determine the minimum lead time to satisfy a new order for the Gamma Blaster. Determine the minimum lead time required to satisfy a new order for the Gamma Disaster.

CASE: Newmarket International Manufacturing Company (B)

The Newmarket International Manufacturing Company (NIMCO) was started by Marcia Blakely just two years after she finished graduate school. Her knowledge of mass customization has been the driving force behind NIMCO. The company produces three major custom products. Volume on the products is high even though each item is customized specifically for the customer. The products are processed through up to four different work centers. Even though each item is unique, the processing time at each work center is constant due to the sophisticated equipment used.

TABLE 14-12 Authorized MPS

Period	14	15	16	17	18	19	20
A	7600		8700		9000		8700
B	4000	4000	4000	3800	3800	3800	3600
C		5300		6300		6400	
Period	**21**	**22**	**23**	**24**	**25**	**26**	
A		8000		6800		3000	
B	3600	3600	3800	3800	3800	4000	
C	6000		5600		5200		

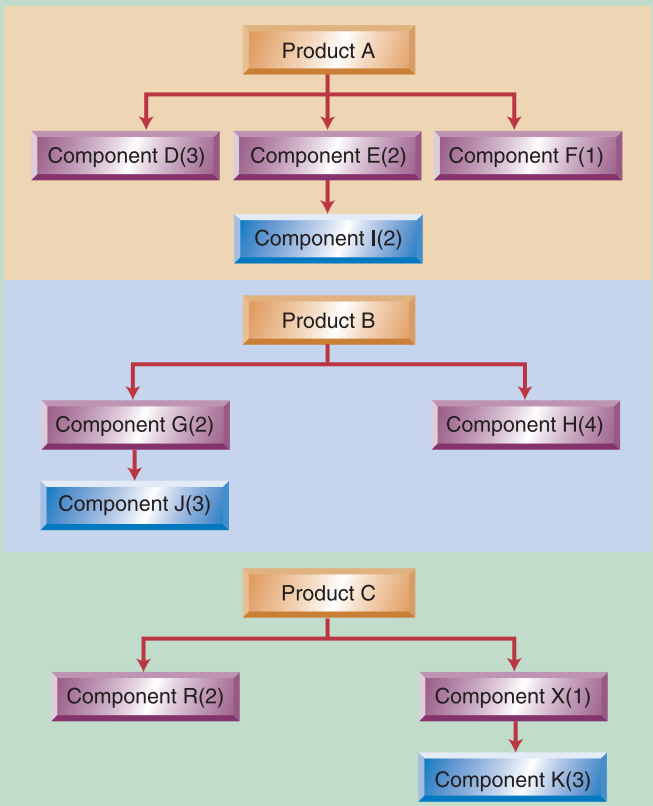
Developing a Material Requirements Plan

Joe Barnes, the production manager, reviewed your rough-cut capacity planning report and developed a new MPS that better uses capacity at each work center. Joe has given you an authorized MPS and has asked you to generate the schedule of material requirements. The authorized master production schedule is shown in Table 14-12.

(a) Generate the material requirements. You need a BOM for each of the three products (A, B, and C), beginning inventory levels, and scheduled receipts. The BOMs are shown in Figure 14-8. All items use lot-for-lot as the lot size rule. No beginning inventories exist. Lead time is two weeks for all items except items D and F, which have

FIGURE 14-8

Product structure tree



a lead time of three weeks. All other information is provided for you in Table 14-13.

(b) After completing the material requirements plan, develop a load profile for each work center for each week of the second quarter. Use the planned order releases and calculate the workload at each work center for weeks 14 through 26. The standard times are shown in the table. Use the load profiles to identify potential problems. The effective capacity at each work center is 960 hours each period.

TABLE 14-13 Additional Information

Item	Scheduled Receipts	Work Done at Work Center	Standard Hours per Piece
A	0	4	0.04
B	0	4	0.10
C	0	4	0.06
D	22,800 in Period 12	1	0.02
	26,100 in Period 14		
E	15,200 in Period 12	3	0.02
F	7,600 in Period 12	3	0.02
	8,700 in Period 14		
G	8,000 in Period 12	2	0.02
H	16,000 in Period 12	1	0.0375
I	34,800 in Period 12	3	0.02
J	48,000 in Period 12	2	0.015
	22,800 in Period 13		
K	15,900 in Period 12	3	0.03
	18,900 in Period 13		
R	none scheduled	2	0.04
X	none scheduled	3	0.04

CASE: Desserts by J.B.

Jay Brown (J.B. to his friends) is a student at the Northwest Culinary Institute and specializes in preparing elaborate desserts. After graduation, J.B. wants to open up a bakery. The bakery, Desserts by J.B., would offer elaborate, European-style desserts. As J.B. prepares his business plan, the issues of material and capacity planning arise. At the Institute, J.B. never worried about such issues. Someone else was responsible for assuring material was available and for scheduling the equipment.

Since J.B. knows that you are studying business, he has asked for your help. He needs some guidance on material planning and capacity management. In order to assist your analysis, J.B. has asked you to compile a list of necessary information. Once you have adequate information, J.B. needs to know how to determine his material requirements and how to determine his capacity needs.

(a) Develop a list of the information you will need before you can help J.B.

(b) Using at least five recipes for elaborate European-styled desserts, demonstrate how you would plan for materials.

(c) Discuss the factors J.B. needs to consider when determining his capacity needs.

(d) Explain to J.B. how he will be able to use an MRP approach in his bakery. Be sure to explain issues such as planned orders, projected available quantities, lot sizing rules, BOMs, and inventory records.

INTERACTIVE CASE Virtual Company

www.wiley.com/college/reid

On-line Case: Cruise International, Inc.

Assignment: *ERP systems at Cruise International, Inc.* Bob Bristol wants you to examine the possible benefits from implementing an ERP system. Since planning and coordination of a wide range of resources is critical to CII, Bob believes that an ERP system will be useful. He wants a concise research report for top management at CII addressing ERP issues relevant to CII. Completion of this assignment will enable you to enhance your knowledge of the material covered in Chapter 14 of the text. It will also better prepare you for future assignments.

To access the Web site:

- Go to **www.wiley.com/college/reid**
- Click **Student Companion Site**
- Click **Virtual Company**
- Click **Consulting Assignments**
- Click **ERP Systems at CII**

INTERNET CHALLENGE The Gourmet Dinner

Your university's Department of Hospitality Management hosts several gourmet dinners throughout the year. To show how OM concepts are useful in the service industry, the department has asked you to help manage the next gourmet dinner from the standpoint of materials planning.

The dinner is typically a five-course meal: appetizer, soup, salad, entrée, and dessert. Your Internet challenge is to develop the menu using the many cooking Web sites available and then to calculate the kinds and quantities of raw material you will need. Assume that the facility where the dinner is hosted will take care of the beverages and that the kitchen and staff have enough capacity for your menu selections. The gourmet dinner will have 300 attendees. If any menu items need more than 12 hours of preparation (remember you are planning for 300 guests), be sure the items arrive in time. Based on your menu, make a list of the raw materials you will need. Specify delivery dates for each item. Calculate how long each item on the menu will take to prepare for 300 guests. Decide what time the staff needs to start preparation for the dinner to be served beginning at 8:00 p.m. Calculate the time the staff needs to start preparing each item, assuming that the appetizers will be served at 8:00, the soup at 8:20, the salad at 8:35, the entrée at 8:50, and the dessert at 9:15. Bon appetit!

On-line Resources

Companion Website www.wiley.com/college/reid:

- Take interactive *practice quizzes* to assess your knowledge and help you study in a dynamic way
- Review *PowerPoint slides* or print slides for notetaking
- Download *Excel Templates* to use for problem solving
- Access the *Virtual Company: Cruise International, Inc.*
- Find links to *Company Tours* for this chapter
  The Ashford Group
  Marrs Printing, Inc
- Find links for *Additional Web Resources* for this chapter
  IBM, *http://houns54.clearlake.ibm.com*
  Hershey Foods Corporation, *www.hersheys.com/tour/index.html*
  Mars, Inc., *www.m-ms.com/factory/tour*