

"Independent Demand" Inventory Management



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

1. Competitive priorities, Chapter 2, pp. 36–42.
2. Internal and external customers, Chapter 4, p. 102.
3. Advantages of small lot sizes, Chapter 7, pp. 243–244.
4. Forecast error, Chapter 8, pp. 291–294.

LEARNING OBJECTIVES

After studying this chapter you should be able to

- 1 Describe the different types and uses of inventory.
- 2 Describe the objectives of inventory management.
- 3 Calculate inventory performance measures.
- 4 Understand the relevant costs associated with inventory.
- 5 Perform ABC inventory control and analysis.
- 6 Understand the role of cycle counting in inventory record accuracy.
- 7 Understand the role of inventory in service organizations.
- 8 Calculate order quantities.
- 9 Evaluate the total relevant costs of different inventory policies.
- 10 Understand why companies don't always use the optimal order quantity.
- 11 Understand how to justify smaller order sizes.
- 12 Calculate appropriate safety stock inventory policies.
- 13 Calculate order quantities for single-period inventory.

CHAPTER OUTLINE

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WHAT'S IN OM FOR ME?



Have you ever been in a rush to get through the grocery checkout only to be stuck in line behind a person buying numerous varieties of the same general item? Perhaps a person buying 24 cans of pet food, with each can being a different flavor. You watch in dismay as the cashier scans each individual can, wondering why the cashier doesn't just scan one can and enter a quantity of 24. Although it would be much easier to let the cash register do the work, it is critical that the cashier scan each individual can.

Many retailers, like Wal-Mart, Sears, Victoria's Secret, Home Depot, and Kroger, use point-of-sale cash registers to collect data on each item sold. This information is then used to update their inventory records to determine when a replenishment order should be placed.

When the cashier scans only a single flavor and enters a quantity of 24, the register reports that 24 cans of that specific flavor have been bought by this customer and adjusts the inventory record for that item. In reality, the customer bought 1 can each of 24 different varieties. Failure to scan each item results in all 24 inventory records becoming inaccurate. These inaccurate inventory records cause companies to replenish the wrong items and result in shortages on the shelves.

Information collected with point-of-sale registers is the basis for generating automatic replenishment orders. When making replenishment decisions, a business decides what, when, and how much should be purchased. When a company replenishes the wrong item because of inaccurate inventory records, the customer is often not satisfied. If a company replenishes items too soon because of inaccurate records, it has invested money in unnecessary inventory and risks item spoiling or deteriorating. It is also possible that the company might not have the necessary storage space because of ordering the wrong item.

Companies make replenishment decisions when managing inventory. In this chapter we look at different types of inventory and how companies use those inventories, the costs of different inventory policies, inventory management objectives and performance measures, and techniques for determining how much of an item to replenish.



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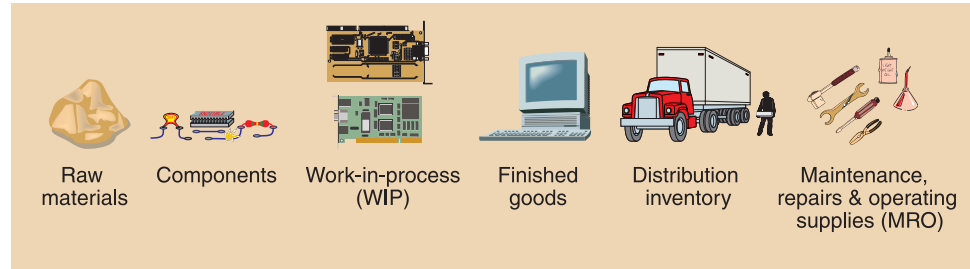
TYPES OF INVENTORY

Inventory comes in many shapes and sizes, as shown in Figure 12-1. Most manufacturing firms have the following types of inventory. **Raw materials** are the purchased items or extracted materials that are transformed into components or products. For example, gold is a raw material that is transformed into jewelry. **Components** are parts or subassemblies used in building the final product. For example, a transformer is a component in an electronic product. **Work-in-process (WIP)** refers to all items in process throughout the plant. Since products are not manufactured instantaneously, there is

- **Raw materials**
Purchased items or extracted materials transformed into components or products.
- **Components**
Parts or subassemblies used in the final product.

FIGURE 12-1

Types of inventory



- **Work-in-process (WIP)**
Items in process throughout the plant.
- **Finished goods**
Products sold to customers.
- **Distribution inventory**
Finished goods in the distribution system.

always some WIP inventory flowing through the plant. After the product is completed, it becomes **finished goods**—the bicycles, stereos, CDs, and automobiles that the company sells to its customers. **Distribution inventory** consists of finished goods and spare parts at various points in the distribution system—for example, stored in warehouses or in transit between warehouses and consumers. *Maintenance, repair, and operational (MRO) inventory* are supplies that are used in manufacturing but do not become part of the finished product. Examples of MRO are hand tools, lubricants, and cleaning supplies.

HOW COMPANIES USE THEIR INVENTORY

Companies have different kinds of inventory. They also use inventory for different purposes. Let's look at six ways of using inventory.

- **Anticipation inventory**
Inventory built in anticipation of future demand.

1. Anticipation Inventory or Seasonal Inventory is built in anticipation of future demand, planned promotional programs, seasonal fluctuations, plant shutdowns, and vacations. Companies build **anticipation inventory** to maintain level production throughout the year. For example, the toy industry builds toys throughout the year in anticipation of high seasonal sales in December.

- **Fluctuation inventory**
Provides a cushion against unexpected demand.

2. Fluctuation Inventory or Safety Stock is carried as a cushion to protect against possible demand variation, “just in case” of unexpected demand. For example, you might keep extra food in the freezer just in case unexpected company drops in. **Fluctuation inventory** or safety stock is also called *buffer stock* or *reserve stock*.

- **Lot-size inventory**
A result of the quantity ordered or produced.

3. Lot-size Inventory or Cycle Stock results when a company buys or produces more than is immediately needed. The extra units of **lot-size inventory** are carried in inventory and depleted as customers place orders. Consider what happens when you buy a 24-can case of soda. You do not normally drink all 24 cans at once. Instead, what you do not need right away, you store for future consumption. You may buy more of an item than you need to take advantage of lower unit costs or quantity discounts. Cycle stock also occurs when making products and the process has a minimum greater than is needed.

- **Transportation inventory**
Inventory in movement between locations.

4. Transportation or Pipeline Inventory is in transit between the manufacturing plant and the distribution warehouse. **Transportation inventory** are items that are not available for satisfying customer demand until they reach the distribution warehouse,

so the company needs to decide between using slower, inexpensive transportation or faster, more expensive transportation. To calculate the average amount of inventory in transit, we use the formula

$$ATI = \frac{tD}{365}$$

where ATI = average transportation inventory (in units)
 t = transit time (in days)
 D = annual demand (in units)

Suppose the Nadan Company, a producer of brass sculptures, needs to ship finished goods from its manufacturing facility to its distribution warehouse. Annual demand at Nadan is 1460 units. The company has a choice of sending the finished goods regular parcel service (three days transit time) or via public carrier, which takes eight days transit time. Calculate the average annual transportation inventory for each of the alternatives. Note that the average transportation inventory does not consider shipment quantity but only transit time and annual demand. To reduce transit inventory, you reduce transit time.

• **Solution:**

When using the regular parcel service,

$$ATI = \frac{3 \times 1460}{365} = 12 \text{ units}$$

When using the public carrier,

$$ATI = \frac{8 \times 1460}{365} = 32 \text{ units}$$

EXAMPLE 12.1

**Calculating
Average
Transportation
Inventory**

5. Speculative or Hedge Inventory is a buildup to protect against some future event such as a strike at your supplier, a price increase, or the scarcity of a product that may or may not happen. A company typically builds **speculative inventory** to ensure a continuous supply of necessary items. Think about booking an airline flight three months in advance so you can take advantage of a reduced fare. You assume that the airfare will not be reduced further and that you will still need the ticket three months from now. It is a gamble.

► **Speculative inventory**
Used to protect against some future event.

6. Maintenance, Repair, and Operating (MRO) Inventory includes maintenance supplies, spare parts, lubricants, cleaning compounds, and daily operating supplies such as pens, pencils, and note pads. **MRO** items support general operations and maintenance but are not part of the product the company builds.

Inventory plays multiple roles in a company's operations. For this reason, companies develop inventory management objectives and performance measures to evaluate how well they are handling their inventory investment. The six functions of inventory are summarized in Table 12-1.

► **Maintenance, repair, and operating inventory (MRO)**
Items used in support of manufacturing and maintenance.

TABLE 12-1
Functions of Inventory

Anticipation inventory	Items built in anticipation of future demand. Allows company to maintain a level production strategy.
Fluctuation inventory	Protects against unexpected demand variations. Assures customer service levels.
Lot-size inventory	Results from the actual quantity purchased. Allows for lower unit costs.
Transportation inventory	Items in movement between locations. Inventory moves from manufacturer to distribution facilities.
Speculative inventory	Extra inventory built up or purchased to protect against some future event. Allows for continuous supply.
MRO	Includes maintenance supplies, spare parts, lubricants, cleaning agents, and daily operating supplies. Facilitates day-to-day operations.

OBJECTIVES OF INVENTORY MANAGEMENT



The objectives of inventory management are to provide the desired level of customer service, to allow cost-efficient operations, and to minimize the inventory investment.

Customer Service

- ▶ **Customer service**
The ability to satisfy customer requirements.
- ▶ **Percentage of orders shipped on schedule**
A customer service measure appropriate for use when orders have similar value.

What is customer service? **Customer service** is a company’s ability to satisfy the needs of its customers. When we talk about customer service in inventory management, we mean whether or not a product is available for the customer when the customer wants it. In this sense, customer service measures the effectiveness of the company’s inventory management. Customers can be either external or internal: any entity in the supply chain is considered a customer.

Suppose your company, Kayaks! Incorporated, offers a line of kayaks and kayaking equipment through catalog sales and an accompanying Web site. As product manager, you need to know whether the inventory management system you introduced is effective. One way to measure its effectiveness would be to measure the level of customer service: are customers getting the kayaking equipment they request, and are their orders shipped on time? To answer your questions, you can measure the percentage of orders shipped on schedule, the percentage of line items shipped on schedule, the percentage of dollar volume shipped on schedule, or manufacturing idle time due to inventory shortages.

Percentage of Orders Shipped on Schedule is a good measure for finished goods customer service, such as your kayaking equipment company, if all orders and customers have similar value and late deliveries are not excessively late. For a different kind of company, such as one that designs computer networks, some customers have much greater value. Obviously, this method does not adequately capture the value of those customers’ orders.

For example, if the book publishing company John Wiley & Sons, Inc. represents 50 percent of your demand but is only 1 out of 20 orders on the schedule, delivering late to Wiley is certainly more harmful to your company than shipping a smaller order late. With this measure, however, all late orders are treated equally. If you have only



Good inventory management results in satisfied customers.

Mike Timo/Stone/Getty Images, Inc.

one late shipment, the customer service level is 95 percent (19 of 20 shipped on schedule). But if the late order is to Wiley, you have met only 50 percent of your demand.

Percentage of Line Items Shipped on Schedule recognizes that not all orders are equal but fails to take into account the dollar value of orders. This measure needs more information—the number of line items instead of the number of orders—than the previous measure. Therefore, this measure is more expensive to use and is most appropriate for finished goods inventory.

As an example of the percentage of line items shipped on schedule, consider the following. Your sister company, White Water Rafts, Inc., determines that from the 20 orders scheduled for delivery this month, customers requested 250 different line items. White Water can ship 225 of these line items on schedule. Their customer service level is 90 percent (225 items shipped on time divided by 250 line items requested).

Percentage of Dollar Volume Shipped on Schedule recognizes the differences in orders in terms of both line items and dollar value. Instead of measuring line items to determine the customer service level, a company totals the value of the orders. For example, if the 20 orders to the Palm Pilot™ handheld-computer manufacturing company had a total value of \$400,000 and the company shipped on schedule handheld computers valued at \$380,000, the customer service level is 95 percent (\$380,000 shipped, divided by \$400,000 ordered).

Idle Time Due to Material and Component Shortages applies to internal customer service. This is an absolute measure of the manufacturing or service time lost because material or parts are not available to the workforce. Absolute measures make sense when a company has historical data to use in comparisons. For example, Kayaks! Incorporated's supplier historically has lost no more than two manufacturing days per year because of material and component shortages. This year, however, it has lost four manufacturing days for this reason. Obviously, this year's case is worse and needs management's attention.

These are only a few of the measures companies use to evaluate customer service. The desired level of customer service should be consistent with the company's overall strategy. If customer service is your company's competitive advantage, the company must achieve a very high level of customer service. Even when customer service isn't the primary focus, your company must still maintain an acceptable level of customer service.

Now let's look at how inventory helps manufacturers operate efficiently.

Cost-Efficient Operations

Companies can achieve *cost-efficient operations* by using inventory in the following ways. First, companies use work-in-process (WIP) inventory to buffer operations. Suppose one of the Hewlett-Packard (HP) printed circuit board (PCB) manufacturing facilities runs two or more operations in a sequence at different rates of output. In this case, buffer inventories build up between the workstations to ensure that each of the operations runs efficiently. For example, PCBs flow from Ken's workstation (tasks take 120 seconds) to Barbara's workstation (tasks take only 90 seconds). If there are no PCBs between the two workstations, Barbara will be idle for 30 seconds out of every 120 seconds because she finishes her tasks 30 seconds before Ken finishes his.

► Percentage of line items shipped on schedule

A customer service measure appropriate when customer orders vary in number of line items ordered.

► Percentage of dollar volume shipped on schedule

A customer service measure appropriate when customer orders vary in value.



Courtesy Palm, Inc.

Customer service of Palm handheld computers can be measured as a percentage of dollar volume shipped on schedule.



If the floor supervisor, Maria, ensures that there is buffer stock between the workstations, Barbara's idle time will be eliminated so she can produce more PCBs.

Second, inventories allow manufacturing organizations to maintain a level workforce throughout the year despite seasonal demand for production. (Level production plans are discussed in Chapter 13.) A company can do this by building inventory in advance of seasonal demands. This in turn allows the company to maintain a level workforce throughout the year and to reduce the costs of overtime, hiring and firing, training, subcontracting, and additional capacity.

Third, by building inventory in long production runs, the **setup cost** is spread over a larger number of units, decreasing the per unit setup cost. Setup costs include the cost of scrap (wasted material and labor), calibration, and downtime to prepare the equipment and materials for the next product to be manufactured. Longer runs mean that the equipment does not need as many setups, so less machine time is lost preparing for production.

Fourth, a company that is willing to acquire inventory can buy in larger quantities at a discount. These larger purchases decrease the ordering cost per unit. For example, the Rustic Garden Furniture Company needs 50,000 pieces of wrought iron annually. Rustic's supplier has offered a unit price of \$1.10 if Rustic buys the wrought iron in orders of 10,000 or more pieces at a time. If Rustic chooses to buy in smaller quantities, the unit price is \$1.29.

Now let's look at ways to measure inventory investment.

► Setup cost

Costs such as scrap costs, calibration costs, and downtime costs associated with preparing the equipment for the next product being produced.

► Inventory turnover

A measure of inventory policy effectiveness.

Minimum Inventory Investment

A company can measure its *minimum inventory investment* by its **inventory turnover**—that is, by the level of customer demand satisfied by the supply on hand. We calculate the inventory turnover measure as

$$\text{Inventory turnover} = \frac{\text{annual cost of goods sold}}{\text{average inventory in dollars}}$$

EXAMPLE 12.2

Computing Inventory Turns

If the annual cost of goods sold at the Nadan Company is \$5,200,000 and the average inventory in dollars is \$1,040,000, what is the inventory turnover?

• Solution:

$$\text{Inventory turnover} = \frac{\$5,200,000}{\$1,040,000} = 5 \text{ inventory turns}$$

The ratio at the Nadan Company should be compared with that achieved by other companies within the industry. Although there is no magic number for inventory turnover, the higher the number, the more effectively the company is using its inventory. One measure of the level of demand that can be satisfied by on-hand inventory is **weeks of supply**. Weeks of supply is calculated by dividing the average on-hand inventory by the average weekly demand.

► Weeks of supply

A measure of inventory policy effectiveness.

$$\text{Weeks of supply} = \frac{\text{average inventory on hand in dollars}}{\text{average weekly usage in dollars}}$$

Suppose that the Nadan Company wants to calculate its weeks of supply. From the previous example, we know that annual cost of goods sold is \$5,200,000.

• **Solution:**

To determine the weekly cost of goods sold, we divide the annual cost of goods sold by 52 weeks (\$5,200,000/52 = \$100,000). Given that Nadan maintains an average inventory of \$1,040,000, we calculate the weeks of supply as follows:

$$\text{Weeks of supply} = \frac{\$1,040,000}{\$100,000} = 10.4 \text{ weeks of supply}$$

EXAMPLE 12.3

Calculating Weeks of Supply

Note that there is a relationship between inventory turnover and weeks of supply. If you divide total weeks per year (52) by the weeks of supply (10.4), you see that the answer is the same as when you calculated inventory turnover. If you divide total number of weeks (52) by the inventory turnover rate (5), the answer is 10.4 weeks of supply. In some companies, inventory performance is measured in either days or hours of supply. To calculate days of supply, we use the formula

$$\text{Days of supply} = \frac{\text{average inventory on hand in dollars}}{\text{average daily usage in dollars}}$$

and hours of supply is calculated as

$$\text{Hours of supply} = \frac{\text{average inventory on hand in dollars}}{\text{average hourly usage in dollars}}$$

Let's look at an example using both of these measures.

Suppose that the Jenny Company, a specialty gift organization, wants to calculate its days of supply. The annual cost of goods sold is \$1,300,000, the average inventory is \$15,600, and the company operates 250 days per year.

• **Solution:**

First, we calculate the average daily usage. We divide the annual cost of goods sold by the number of days the company operates (\$1,300,000 divided by 250 days equals \$5200). Second, using the formula, we divide the average inventory on hand by the average daily usage.

$$\text{Days of supply} = \frac{\$15,600}{\$5200} = 3 \text{ days of supply}$$

Suppose the Jenny Company uses a new process that reduces the average inventory held to \$3250. To calculate its current hours of supply, we first calculate the average hourly usage. Using the data provided and assuming an eight-hour day, we divide the average daily usage (\$5200) by eight hours. The average hourly usage is \$650. Therefore, the hours of supply are

$$\text{Hours of supply} = \frac{\$3250}{\$650} = 5 \text{ hours of supply}$$

EXAMPLE 12.4

Calculating Inventory Supply at the Jenny Company

TABLE 12-2

Inventory Objectives

Inventory Objectives	
Customer service	Measured by any of the following: • Percentage of orders shipped on schedule • Percentage of line items shipped on schedule • Percentage of dollar volume shipped on schedule • Idle time due to component and material shortages
Cost-efficient operations	Inventories help achieve cost-effective operations by • Using buffer stock to assure smooth production flow • Maintaining a level workforce • Allowing longer production runs, which spreads the cost of setups • Taking advantage of quantity discounts
Minimum inventory investment	Measured by any of the following: • Inventory turnover • Weeks of supply • Days of supply

Table 12-2 summarizes the inventory objectives we just discussed.

RELEVANT INVENTORY COSTS

Inventory management policies have cost implications. Decisions about how much inventory to hold affect item costs, holding costs, ordering costs, and stockout (shortage) costs.

Item Costs

► **Item cost**
Includes price paid for the item plus other direct costs associated with the purchase.

The **item costs** of a purchased item include the price paid for the item and any other direct costs for getting the item to the plant, such as inbound transportation, insurance, duty, or taxes. For an item built by the manufacturing company, the item costs include direct labor, direct materials, and factory overhead.

Holding Costs

► **Holding costs**
Include the variable expenses incurred by the plant related to the volume of inventory held.

► **Capital costs**
The higher of the cost of capital or the opportunity cost for the company.

Holding costs include the variable expenses incurred by the firm for the volume of inventory held. As inventory increases, so do the holding costs. We can determine unit holding costs by examining three cost components: capital costs, storage costs, and risk costs. Annual holding costs are typically stated in either dollars per unit (\$3.50 per unit per year) or as a percentage of the item value (25 percent of the unit value).

Capital costs are the higher of either the cost of the capital or the opportunity cost for the company. The cost of the capital is the interest rate the company pays to

borrow money to invest in inventory. The opportunity cost is the rate of return the company could have earned on the money if it were used for something other than investing in inventory. The opportunity cost is at least as much as the interest the company could get at the prevailing interest rate. It may be higher if more lucrative opportunities are available. Suppose you have a startup company and need to finance your inventory with a bank loan at 8 percent. Or the company can invest its capital in the stock market and generate a 20 percent return on the investment. For its capital cost, the company would use the 20 percent opportunity cost rather than the 8 percent cost of the loan. The capital cost is typically expressed as an annual interest rate.

Storage costs usually include the cost of space, workers, and equipment. For our purposes, however, we are concerned only with the additional out-of-pocket expenses resulting from the size of the inventory. For example, we include the cost of storage space if it is public warehousing and varies based on the amount of inventory held. If the company already owns the storage space and incurs no additional expense for storing the inventory, we do not include it in the holding cost. The same is true for employees. If an employee works overtime because of the level of inventory, this is an out-of-pocket expense and needs to be included. However, if the employee's workload is merely higher during the normal day, the cost of the employee is not included.

Risk costs include obsolescence, damage or deterioration, theft, insurance, and taxes. These costs vary based on industry. Companies operating in a high-tech environment typically experience much greater obsolescence and theft. Companies that manufacture consumer products may find higher levels of theft.

In general, risk costs are associated with higher levels of inventory. The more inventory you have, the longer it lasts—therefore, the greater the chance of it becoming obsolete. The more inventory you have sitting around, the more likely it is to be damaged. Think of walking through an overloaded basement: you bump into something; it falls and breaks. Theft also typically increases as inventory increases. When a company has few items in inventory, it is more noticeable when an item disappears. However, if the company has a lot of inventory, it is harder to notice when only one item disappears. Insurance costs are typically based on the value of the inventory, so larger inventories have higher insurance premiums. The same is true for taxes: the more valuable the inventory, the higher the tax.

Although many textbooks use an annual holding cost of between 20 percent and 30 percent, in real life it depends on the type of business. The risk costs can vary significantly. Let's look at how annual holding costs are calculated.

► **Storage costs**

Include the variable expenses for space, workers, and equipment related to the volume of inventory held.

► **Risk costs**

Include obsolescence, damage or deterioration, theft, insurance, and taxes associated with the volume of inventory held.

The Nadan Company currently maintains an average inventory of \$1,040,000. The company estimates its capital cost at 12 percent, its storage costs at 5 percent, and its risk costs at 8 percent. Calculate the annual holding costs for the Nadan Company.

• **Solution:**

Annual holding cost per unit of inventory equals 25 percent (capital cost + storage costs + risk costs).

$$\text{Annual cost of holding inventory} = \$1,040,000 \times 0.25 = \$260,000$$

EXAMPLE 12.5

**Calculating
Annual Holding
Costs**

Ordering Costs

► Ordering costs

The fixed costs associated with either placing an order with a supplier or setup costs incurred for in-house production.

Ordering costs are fixed costs for either placing an order with a supplier for a purchased component or raw material or for placing an order to the manufacturing organization for a product built in-house. When you buy an item, the ordering costs include the cost of the clerical work to prepare, release, monitor, and receive orders and the physical handling of the goods. The ordering costs are considered constant regardless of the number of items or the quantities ordered. For example, if the cost to place an order is estimated at \$100, every time you place an order with a supplier, the ordering cost is constant (\$100).

When an order is released for manufacturing in-house, the ordering or setup costs are the clerical work to prepare the manufacturing order and the list of materials to be picked up and delivered to the manufacturing location, plus the cost to prepare the equipment for the job (calibration, appropriate jigs and fixtures, etc.). Like the ordering costs for purchased items, the ordering or setup costs for jobs done in-house are constant.

Shortage Costs

► Shortage costs

Incurred when demand exceeds supply.

► Back order

Delaying delivery to the customer until the item becomes available.

► Lost sale

Occurs when the customer is not willing to wait for delivery.

Companies incur **shortage costs** when customer demand exceeds the available inventory for an item. Suppose a customer, Tom Martin, places an order through your kayaking equipment Web site for a high-end kayak, but that kayak is out of stock. One of two things happens. Either Tom allows you to **back-order** the kayak—that is, Tom is willing to wait until the kayak is available—or Tom decides to buy the kayak from another company and the result for your company is a **lost sale**.

In both cases, your company incurs shortage costs. In the case of the back order, shortage costs result from the additional paperwork to track the order and the possible added expense of overnight shipping rather than normal delivery. There is also the lost customer goodwill, an intangible cost. Although Tom accepted the delay this time, you have no guarantee that he will buy from your company again. In the case of the lost sale, the shortage costs typically include loss of the possible profit, plus loss of the contribution to overhead costs. Your company also faces the risk that Tom will not return with future orders. Shortage costs can also result from internal parts shortages, including the cost of downtime due to lack of materials, additional setups, premium transportation costs, and so forth.



ABC INVENTORY CLASSIFICATION

► Pareto's law

Implies that about 20 percent of the inventory items will account for about 80 percent of the inventory value.

► ABC classification

A method for determining level of control and frequency of review of inventory items.

All items in a company's inventory are not equal and do not need the same level of control. Fortunately, we can apply **Pareto's law** to determine the level of control needed for individual items. Pareto's law implies that roughly 10 to 20 percent of a company's inventory items account for approximately 60 to 80 percent of its inventory costs. These relatively few high-dollar-volume items are classified as A items. Moderate-dollar-volume items, roughly 30 percent of the items, account for about 25 to 35 percent of the company's inventory investment. These are classified as B items. Low-dollar-volume items, about 50 to 60 percent of the items, represent only 5 to 15 percent of the company's inventory investment and are classified as C items. These percentages are not absolute and are used only as guidelines to determine an item's **ABC classification**.

AAU is considering doing an ABC analysis of its entire inventory but has decided to test the technique on a small sample of 15 of its stock-keeping units. The annual usage and unit cost for these items are shown in the table.

- Calculate the annual dollar volume for each item.
- List the items in descending order based on annual dollar usage.
- Calculate the cumulative annual dollar volume.
- Group the items into classes.

ABC Problem Data

Item	Unit \$ Value	Annual Usage (in units)
101	12.00	80
102	50.00	10
103	15.00	50
104	50.00	40
105	40.00	80
106	75.00	220
107	4.00	250
108	1.50	400
109	2.00	250
110	25.00	500
111	5.00	450
112	7.50	80
113	3.50	250
114	1.00	1200
115	15.00	300

- **Before You Begin:** To do an ABC analysis, you need to know the annual usage and the value of each item. That information is provided for you in the problem data. Multiply the unit value by the annual usage of the item to determine the annual dollar volume for each item. Now list the items in descending order based on annual dollar usage. You can now calculate the percentage of the total inventory value each part represents. This allows you to classify the items into groups.

- **Solution:**

(a)

ABC Annual Usage Values

Item	Unit \$ Value	Annual Usage (in units)	Annual Usage (\$)
101	12.00	80	960
102	50.00	10	500
103	15.00	50	750
104	50.00	40	2,000
105	40.00	80	3,200
106	75.00	220	16,500
107	4.00	250	1,000
108	1.50	400	600
109	2.00	250	500
110	25.00	500	12,500
111	5.00	450	2,250
112	7.50	80	600
113	3.50	250	875
114	1.00	1200	1,200
115	15.00	300	4,500
		Total	\$47,935

EXAMPLE 12.6

ABC Analysis at Auto Accessories Unlimited (AAU)

(b, c, and d)

ABC Solution				
Item	Annual Usage (\$)	Percentage of Total Dollars	Cumulative Percentage of Total Dollars	Item Classification
106	16,500	34.4	34.4	A
110	12,500	26.1	60.5	A
115	4,500	9.4	69.9	B
105	3,200	6.7	76.6	B
111	2,250	4.7	81.3	B
104	2,000	4.2	85.5	B
114	1,200	2.5	88.0	C
107	1,000	2.1	90.1	C
101	960	2.0	92.1	C
113	875	1.8	93.9	C
103	750	1.6	95.5	C
108	600	1.3	96.8	C
112	600	1.3	98.1	C
102	500	1.0	99.1	C
109	500	1.0	100.1*	C
Total	\$47,935			

*Total exceeds 100% due to rounding.

Remember that these are not absolute rules for classifying items. Your company wants to group their more valuable items together to make sure that they get the most control.

Procedure for an ABC Inventory Analysis

The first step for an ABC inventory analysis is to determine the annual usage for each item. We calculate the total annual dollar volume by multiplying the annual usage by the item cost. We then rank items in descending order based on total dollar volume and calculate the total inventory investment.

1. Calculate the annual dollar usage for each item.
2. List the items in descending order based on annual dollar usage.
3. Calculate the cumulative annual dollar volume.
4. Classify the items into groups.

Figure 12-2 graphically depicts the results of the ABC classification. The A items, 106 and 110, combine for 60.5 percent of the total dollar value in inventory and approximately 13.3 percent of the items in inventory. The B items, 115, 105, 111, and 104, account for 25 percent of the total dollar value and 26.7 percent of the items. The C items make up the last 14.5 percent of the total dollar value and 60 percent of the items.

Inventory Control Using ABC Classification

After classifying inventory items into A, B, and C classes, we can determine the appropriate level of inventory control. For our most important and expensive A items, we need very tight control, highly accurate inventory records, and frequent or continuous review. A **continuous review system** keeps track of an inventory item 24/7. It tracks every inventory transaction as it occurs, whether it is more material going into inventory or material being withdrawn from the stockroom. Consequently, the EOQ model

► **Continuous review system**
Updates inventory balances
after each inventory
transaction

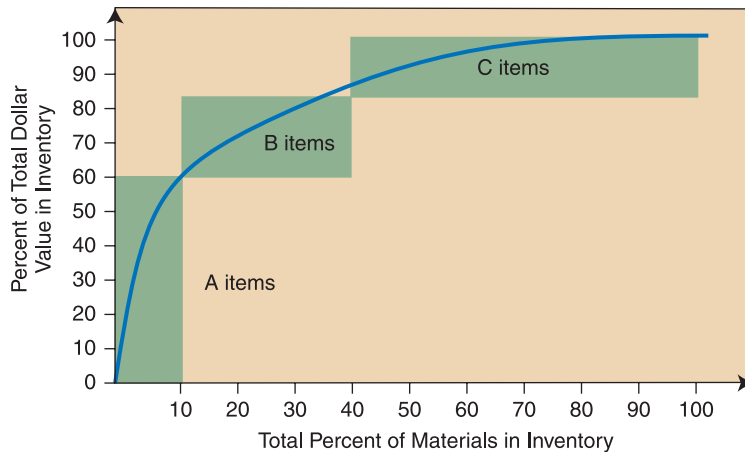


FIGURE 12-2

ABC classification of materials

(discussed later in this chapter) is often used. B items need normal control, moderately accurate inventory records, and a reasonable time period between reviews. For B items, a **periodic review system** (discussed later in this chapter) can be used. A periodic review system reviews the inventory level of the item at regular intervals (daily, weekly, monthly) to determine whether a replenishment order is needed. C items require the least amount of control. Possible options for C items are the **two-bin system** or an infrequent periodic review system. A two-bin system splits an incoming replenishment order into two separate bins. One bin is placed on the factory floor so workers can take what they need. The other bin is kept in the storeroom. This second bin should have enough items to cover normal demand during the replenishment **lead time**. Lead time is the amount of time it takes from order placement until the ordered item is received. When the bin on the floor is empty, workers go to the stockroom to request additional material. The bin in the stockroom is released to the workers on the floor and a replenishment order is placed.

► **Periodic review system**

Requires regular periodic reviews of the on-hand quantity to determine the size of the replenishment order.

► **Two-bin system**

One bin with enough stock to satisfy demand during replenishment time is kept in the storeroom; the other bin is placed on the manufacturing floor.

► **Lead time**

Time from order placement to order receipt.

INVENTORY RECORD ACCURACY

For effective inventory use, the inventory records must accurately reflect the quantity of materials available. Inaccurate inventory records can result in lost sales (finished good not available at time of sale), disrupted operations (not enough of a component or raw material to complete a job), poor customer service (late deliveries to customers), lower productivity (additional setups to complete a job), poor material planning (the inventory records are critical in determining MRP quantities), and excessive expediting (trying to obtain necessary items in less than normal lead time).

One exceptionally productive approach to inventory management is the automated inventory tracking system used by the very successful Cisco Systems—a world leader in providing networking solutions for all types of businesses. This tracking system forms an intricate network of suppliers, manufacturers, and customers and provides for real-time transactions. When a customer places an order via



LINKS TO PRACTICE

Cisco Systems, Inc.
www.cisco.com

the Internet, suppliers can instantaneously see what parts are needed and can quickly respond by shipping the needed parts and then restocking. Such a system provides accurate, timely information, which helps both Cisco and suppliers to schedule, budget, and forecast. Since most of Cisco's orders are transacted over the Web, Cisco is able to save millions of dollars annually.

Inventory record errors occur because of unauthorized withdrawals of material, unsecured stockrooms, inaccurate paperwork, and/or human errors. Since an accurate database is needed to successfully use the information systems, it is important to detect errors in the inventory records. Two methods are available for checking inventory record accuracy: periodically counting all of the items (typically annually) and cyclically counting specified items (typically daily).

► **Periodic counting**

A physical inventory is taken periodically, usually annually.

Periodic counting satisfies auditors that the inventory records accurately reflect the value of the inventory on hand. For material planners, the physical inventory is an opportunity to correct errors. The four steps in taking a physical inventory are

1. Count the quantity of the item and record the count on a ticket attached to the item.
2. Verify by recounting.
3. After verification, collect the tickets.
4. Reconcile inventory records with actual counts. For major discrepancies, investigate further. For minor discrepancies, adjust the inventory records.

Taking physical inventories does not always improve inventory record accuracy. In many cases, companies close down manufacturing to take the physical inventory; the job is often rushed and is typically done by employees not trained for checking inventory. In some cases, inventory record errors are increased rather than reduced. The other alternative method is cycle counting.

► **Cycle counting**

Prespecified items are counted daily.

Cycle counting is a method of counting inventory throughout the year. This is a series of mini-physical inventories done daily of some prespecified items. The frequency of counting a particular item depends on the importance and value of the item. Typically, A items are counted most frequently.

The advantages of cycle counting are

- Timely detection and correction of inventory record problems.
- Elimination of lost production time since the company does not need to shut down operations.
- The use of employees dedicated to cycle counting.

Scheduling individual item counts can be done in several ways. An item can be counted just before a replenishment order is placed. At this time, the planner has an accurate count of the item on hand and can determine whether a replenishment order is needed. The quantity to be counted also is relatively low. A planner also can choose to count when new orders arrive. This way, the inventory is at its lowest level. Remember that most replenishment orders arrive just as the on-hand inventory is running out. Another possibility is to schedule a count after a certain number of transactions have occurred. For example, a planner can request a physical count after every 20 transac-

tions involving a particular item. Since errors typically occur during transactions, the greater the number of transactions, the more likely an error will be introduced. One other possibility is to do a count whenever an error is detected. This allows for corrective action to be taken immediately. Regardless of the method, the intent is to improve inventory record accuracy.

In some cases, companies have shifted the burden of inventory accuracy and replenishment decisions to their vendor. **Vendor-managed inventory (VMI)** requires the vendor to maintain an inventory of certain items at the customer's facility. The supplier still owns the inventory until the customer actually withdraws it for use. At that time, the customer pays for the items. The customer does not have to order any of the inventory, as the supplier is responsible for maintaining an adequate supply. Companies use this approach most frequently with lower-level C items that have a relatively standard design.

► **Vendor-managed inventory (VMI)**

The supplier maintains an inventory at the customer's facility.

INVENTORY IN SERVICE ORGANIZATIONS

When we compare service organizations with manufacturing organizations, a major difference is that manufacturers have tangible inventory while service providers typically do not. However, extensive tangible inventory is required in wholesale and retail services. How well this inventory is managed often determines whether a service provider is profitable. Consider the importance of inventory in the food service business, especially highly perishable food items. If a manager orders too much of an item, spoilage can occur; if not enough is ordered, customer orders can be lost. It is a constant struggle to order just the right amount of perishable items. Any inventory that perishes, is damaged, or is stolen prior to its actual sale is an inventory loss. In retailing, it is considered good performance when a company has an inventory loss of only 1 percent or less. Some companies face losses exceeding 3 percent of the value of their inventory. Since retailers deal with desirable consumer goods, it is critical for retailers to practice good inventory control and maintain accurate inventory records. To achieve good inventory control, retailers, wholesalers, and food service providers should do the following:

- Select, train, and discipline personnel. It is critical to select good, honest, reliable personnel because employees have direct access to desirable merchandise.
- Have tight control over incoming shipments. Many firms track incoming shipments through bar code scanning and radio frequency identification systems (RFIDs). Shipments are read into the system, and quantities are reconciled with purchase orders. Each item must have a unique stock-keeping unit (SKU).
- Have tight control over items leaving the facility. This is often done with bar code scanners so that point-of-sale (POS) information can be fed into the system to maintain inventory record accuracy. It is critical that stores train personnel in proper scanning techniques to make sure inventory records remain accurate. Attempts to defeat theft include antitheft magnetic strips or security fixtures attached directly to the merchandise. These are used to activate security alarms as a person exits the facility with unpaid merchandise. Other retailers have personnel stationed near the exits for direct observation of customers leaving the store. In some stores in high-loss areas, one-way mirrors can be used as well as direct video surveillance.

Successful wholesaling, retailing, or food service operations require very good inventory control with accurate records. An additional problem, other than theft, facing many retailers is the inability to locate specific merchandise. It is not uncommon for customers to change their minds and simply place merchandise they no longer want in a convenient spot, not necessarily anywhere close to where it belongs. It is also common for clerks returning merchandise to the floor (either items from dressing rooms or items picked up that had been misplaced) to neglect to place the merchandise exactly where it belongs. Being unable to find items can lead to poorer customer service and unnecessary replenishment orders. The success of service organizations using a tangible product depends on practicing good inventory control.

Before You Go On

Before you continue further into the chapter, you need to be sure that you understand the relevant inventory costs. Item cost, holding cost, ordering cost, and shortage cost are summarized in Table 12-3. The next section of this chapter focuses on determining order quantities and uses inventory cost information.

TABLE 12-3 Relevant Inventory Costs	
Item cost	Price paid per item plus any other direct costs associated with getting the item to the plant
Holding costs	Capital, storage, and risk costs
Ordering costs	Fixed, constant dollar amount incurred for each order placed
Shortage costs	Loss of customer goodwill, back-order handling, and lost sales

DETERMINING ORDER QUANTITIES

The objectives of inventory management are to provide the desired level of customer service, enable cost-efficient operations, and minimize the inventory investment. To achieve these objectives, a company must first determine how much of an item to order at a time.

Inventory management and control are done at the level of the individual item or **stock-keeping unit (SKU)**. An SKU is a specific item at a particular geographic location. For example, a pair of jeans, size 32 × 32, in inventory at the plant and also eight different warehouses, represents nine different SKUs. A pair of the same jeans held at the same locations but a different size (32 × 34) represents nine additional SKUs. The same style of jeans in a different color represents additional SKUs.

Let’s look at how a company determines how much of an SKU to order. We will consider some common approaches in this section, summarized in Table 12-4. In the next section we will look at mathematical models for determining order quantity.

► **Stock-keeping unit (SKU)**
An item in a particular geographic location.

TABLE 12-4

Common Ordering Approaches

Lot-for-lot	Order exactly what is needed.
Fixed-order quantity	Order a predetermined amount each time an order is placed.
Min-max system	When on-hand inventory falls below a predetermined minimum level, order a quantity that will take the inventory back up to its predetermined maximum level.
Order n periods	Order enough to satisfy demand for the next n periods.



SKUs at a retail store

© AP/Wide World Photos

Lot-for-lot is ordering exactly what you need. You adjust the ordering quantity to your ordering needs, which ensures that you will not have leftover inventory. You use lot-for-lot when demand is not constant and you have information about expected needs. Ordering sandwiches for a business lunch meeting is a good example of when to use lot-for-lot. The number of persons attending the meeting can vary based on the meeting topic. Since sandwiches are perishable, you do not want to have leftover inventory. This system is also commonly used in material requirements planning (MRP) systems, which we discuss in Chapter 14.

Fixed-order quantity specifies the number of units to order each time you place an order for a certain SKU or item. The quantity may be arbitrary (perhaps 100 units at a time), or it may be the result of how the item is packaged or prepared (such as 144 per box or a loaf of bread). The advantage of this system is that it is easily understood; the disadvantage is that it does not minimize inventory costs.

The **min-max system** involves placing an order when the on-hand inventory falls below a predetermined minimum level. The quantity ordered is the difference between the quantity available and the predetermined maximum inventory level. For example, if the minimum is set at 50 units, the maximum is set at 250 units, and the quantity available at the time of the order is 40 units, the order quantity is 210 units ($250 - 40$). With this system, both the time between orders and the quantity ordered can vary.

Order n periods means that you determine the order quantity by summing your company's requirements for the next n periods. Suppose you have to order enough each time you place an order to satisfy your company's requirements for the next three periods. If these requirements for the next three weeks are 60, 45, and 100, your order is for 205 units. A concern with this system is determining the number of periods to include in the order.

► Lot-for-lot

The company orders exactly what is needed.

► Fixed-order quantity

Specifies the number of units to order whenever an order is placed.

► Min-max system

Places a replenishment order when the on-hand inventory falls below the predetermined minimum level. An order is placed to bring the inventory back up to the maximum inventory level.

► Order n periods

The order quantity is determined by total demand for the item for the next n periods.

MATHEMATICAL MODELS FOR DETERMINING ORDER QUANTITY

Now let's look at some mathematical models that determine order quantity and minimize inventory costs, beginning with the economic order quantity (EOQ) model.

Economic Order Quantity (EOQ)

The **economic order quantity model (EOQ)** has been around since the early 1900s and remains useful for determining order quantities. EOQ is a continuous review system, used to keep track of the inventory on hand each time stock is added or

► Economic order quantity model (EOQ)

An optimizing method used for determining order quantity and reorder points.

withdrawn. If the withdrawal reduces the inventory level to the reorder point or below, you make a replenishment order.

Thus, EOQ tells you when to place a replenishment order and determines the order quantity that minimizes annual inventory cost. Suppose you decide that your kayaking equipment company needs to place a replenishment order whenever the inventory level of item K310 reaches 100 units. Right now you have 105 units of item K310 in inventory. You withdraw 5 K310s to satisfy a customer order, resulting in an updated inventory level of 100 units. Since the inventory level has reached the reorder point, it is time to place a replenishment order for K310. A key characteristic of the continuous review system is that it keeps track of inventory as it is withdrawn.

In the following section we look at some assumptions made by the basic EOQ model.

EOQ Assumptions The basic EOQ model makes these assumptions:

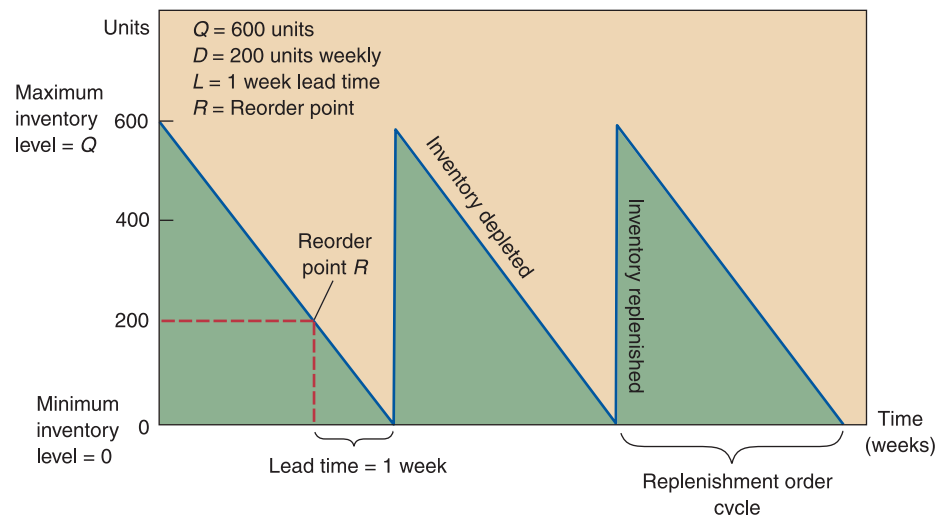
- Demand for the product is known and constant. This means that we know how much the demand is for every time period and that this amount never changes. For example, demand is 50 units per week every week or 10 units per day every day. This assumption is indicated by the straight line that shows the depletion of our inventory in Figure 12-3.
- Lead time is known and constant. It is the amount of time it takes from order placement until it arrives at the manufacturing company (for example, 10 working days between order placement and receipt of merchandise).

Because you know how long it takes for the replenishment order to arrive, you can determine when you need to place the order. By finding the reorder point (shown in Figure 12-3), you schedule the arrival of the replenishment quantity just as your company's inventory level reaches zero. The minimum inventory level with the basic EOQ should be zero.

- Quantity discounts are not considered: the cost of all units is the same, regardless of the quantity ordered. (We discuss this in more detail later in the chapter.)
- Ordering and setup costs are fixed and constant: the dollar amount to place an order is always the same, regardless of the size of the order.

FIGURE 12-3

The EOQ model



- Since the company knows demand with certainty, the assumption is that all demand is met. The basic model does not permit back orders, but more advanced models are less rigid.
- The quantity ordered arrives at once, as shown in Figure 12-3. Since the order is scheduled to arrive just as the company runs out of inventory, the maximum inventory level equals the economic order quantity.

Figure 12-3 shows the basic workings of the EOQ model. The inventory replenishment process begins when the inventory reaches the reorder point. This is the point at which you place an order for Q units, which are timed to arrive just as your company's inventory level reaches zero. The inventory goes from zero to Q and then is depleted at a constant rate. Once the inventory reaches the reorder point, the process begins again.

Since the basic model assumes certainty about demand and lead time, the reorder point is set equal to demand during lead time, or

$$R = dL$$

where R = reorder point
 d = average daily demand
 L = lead time in days

Problem-Solving Tip When solving for R , it is possible to use other than daily demand and lead time in days. Use whatever is convenient. If lead time is given in weeks, then use average weekly demand. If lead time is given in months, then use average monthly demand.

For example, if average daily demand is 40 units and lead time is five days, then the reorder point is 200 (40 units times five days). When the inventory reaches 200, it is time to place an order.

Calculating Inventory Policy Costs Since companies are interested in the costs associated with inventory policies, let's calculate the annual ordering or setup costs and the annual holding costs associated with the basic EOQ model. We do not include shortage costs since all demand is satisfied with the basic EOQ model. We do not include the annual item cost either: no quantity discounts are considered in the basic EOQ model, so the annual item cost remains constant regardless of the quantity ordered each time. Given that, our total costs are

$$\text{Total annual cost} = \text{annual ordering costs} + \text{annual holding costs}$$

Problem-Solving Tip When calculating total annual costs, do not round off the number of orders to whole numbers. Although it is true that a partial order cannot be placed, for purposes of comparison we leave the number of orders as a mixed number.

We calculate annual ordering costs by multiplying the number of orders placed per year by the cost to place an order. To find the number of orders placed per year, we divide the annual demand by the quantity ordered.

Suppose annual demand for motherboards at Palm Pilot, the handheld-computer company, is 10,000 units and it currently orders 500 motherboards each time. The number of orders placed per year is 20 (10,000/500). If the cost to place an order is \$75, then the annual ordering cost is \$1500 (20 orders $\times$ \$75 ordering cost).

Problem-Solving Tip When solving for Q , it is not necessary to always use annual demand and annual holding costs. If you have demand given in a different time frame (days, weeks, or months), you can use that as long as the holding costs are expressed in the same time frame, that is, daily demand and daily holding costs, or weekly demand and weekly holding costs.

We calculate annual holding costs by multiplying the average inventory level by the annual holding cost per unit. The average inventory is equal to the maximum inventory plus the minimum inventory divided by 2. In the EOQ model, the maximum inventory is Q and the minimum is zero. Therefore, the average inventory level is $Q/2$. For example, if the order quantity is 500 units, the holding cost is \$6 per unit per year, and the annual holding cost is \$1500 ($500 \text{ units}/2 \times \6 per unit). Sometimes the holding cost is given as a percentage, such as 20 percent of the item price. In this case, we multiply the item price by the percentage to determine the annual unit holding costs. For example, if the holding cost is 20 percent of the item price and the item price is \$30, then the annual holding cost is \$6 per unit ($\$30 \text{ item price} \times 20 \text{ percent holding cost}$).

The formula for calculating the total relevant annual costs for the basic EOQ model is

$$TC = \left(\frac{D}{Q} S \right) + \left(\frac{Q}{2} H \right)$$

where TC = total annual cost
 D = annual demand
 Q = quantity to be ordered
 H = annual holding cost
 S = ordering or setup cost

For our example, the total cost is

$$TC = \left(\frac{10,000}{500} \$75 \right) + \left(\frac{500}{2} \$6 \right)$$

or

$$TC = \$1500 + \$1500 = \$3000$$

Note that the annual ordering costs equal the annual holding costs. This is true when we use the EOQ model without rounding. In addition, with the EOQ model, the minimum total cost always results when the annual ordering costs equal the annual holding costs, as shown in Figure 12-4. Note, too, in Figure 12-4 that as order quantity increases so do holding costs and, at the same time, ordering costs decrease since fewer orders are placed. The total costs, however, are always higher when we use an order quantity other than the EOQ.

Calculating the EOQ

We calculate the economic order quantity (Q) using the following formula:

$$Q = \sqrt{\frac{2DS}{H}}$$

where Q = optimal order quantity
 D = annual demand
 S = ordering or setup cost
 H = holding cost

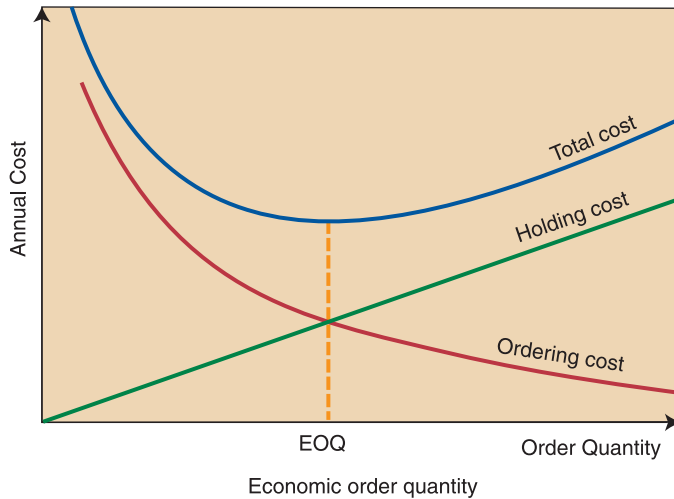


FIGURE 12-4

Holding costs equal ordering costs

Find the economic order quantity and the reorder point, given the following information:

Annual demand (D) = 10,000 units
 Ordering cost (S) = \$75 per order
 Annual holding cost (H) = \$6 per unit
 Lead time (L) = 5 days
 The company operates 250 days per year.

EXAMPLE 12.7
Calculating the Economic Order Quantity

- **Before You Begin:** Identify the appropriate formula to use for calculating the economic order quantity (EOQ) and the reorder point. The formula for the EOQ is

$$Q = \sqrt{\frac{2DS}{H}}$$

and the formula for finding the reorder point is $R = dL$. Remember to make sure that the holding cost is for the same time period as your demand. For example, if demand is annual, then the holding cost must be an annual holding cost per unit. If demand is monthly, then use a monthly holding cost per unit. You also need to convert annual demand into daily demand to use the reorder point formula. Do this by dividing annual demand by the number of days the company operates per year.

- **Solution:**

$$Q = \sqrt{\frac{2 \times 10,000 \times \$75}{\$6}} = 500 \text{ units}$$

Daily demand is 40 units per day (10,000 units demanded annually, divided by 250 days of operation).

$$R = 40 \text{ units} \times 5 \text{ days} = 200 \text{ units}$$

The inventory policy for this item is to place a replenishment order for 500 units (Q) when the inventory reaches 200 units (R). The replenishment order will arrive just as the current inventory reaches zero. On the previous page, we calculated total annual cost for this policy (\$3000). *The EOQ model always minimizes total annual costs.*

What Happens When a Non-EOQ Order Quantity Is Used? To illustrate what happens to annual inventory costs when we use an order quantity other than the EOQ, let’s look at an example with a non-EOQ quantity. Determine the total annual costs for your company if you choose to order 1000 units each time a replenishment order is placed.

$$TC = \left(\frac{10,000}{1000} \$75 \right) + \left(\frac{1000}{2} \$6 \right) = \$3750$$

The total annual cost for this non-EOQ inventory policy is \$3750 compared to \$3000 for the EOQ policy. Thus we can say that the *difference* between the EOQ policy and any other policy is a penalty cost incurred by your company for *not* using the EOQ policy.

Economic Production Quantity (EPQ)

The basic EOQ model assumes that the entire replenishment order arrives at one time, but this is not always the case. For example, if we bake four batches each of one-dozen chocolate-chip cookies, our inventory will probably never reach four-dozen cookies. Why? Because we or our friends are sure to eat some of the cookies as soon as we bake them! This means that the maximum inventory level will always be less than the total quantity we produce. If out of every batch of one-dozen cookies, we eat 4 cookies immediately, we will end up with 32 cookies in inventory after baking the four one-dozen batches ((12 baked – 4 used) × 4 batches).

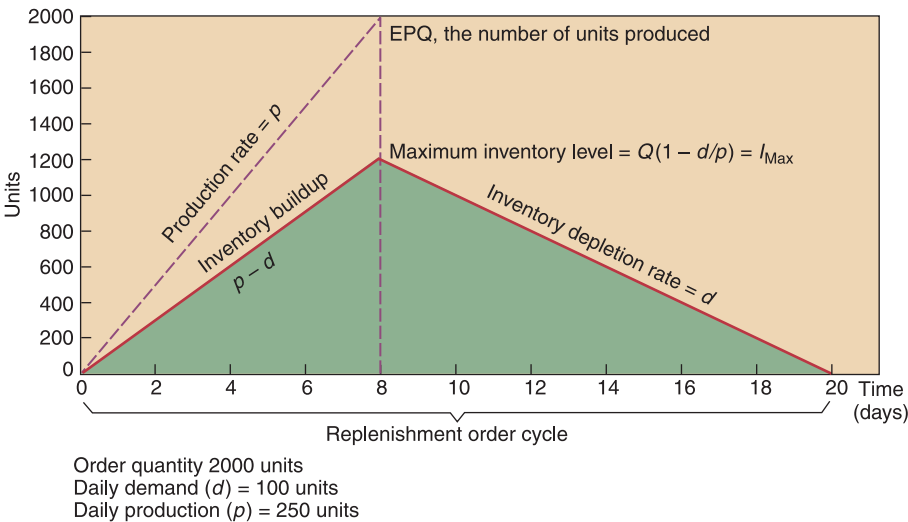
► **Economic production quantity (EPQ)**
A model that allows for incremental product delivery.

Figure 12-5 shows the **economic production quantity (EPQ)** model. The cycle begins when we start making the product. Each day, we use some of what we make to satisfy immediate demand; we put the remainder in inventory. We make the product until we have completed Q units. At that point, the inventory has reached its maximum level. From this point on, we satisfy demand from the on-hand inventory, depleting it daily. When we reach the reorder point, we order another batch. Our company starts producing the new batch just as we run out of the current inventory.

The EPQ model is appropriate when some of the product we make is used as soon as we make it. In manufacturing, this is typical when a single manufacturing facility produces the parts to build the end product. For example, HP builds deskjet printers using printed circuit boards (PCBs). HP’s manufacturing facility builds PCBs in batches; some of these PCBs are assembled into the end product immediately, and the rest are put into inventory.

FIGURE 12-5

The EPQ model



The total cost formula for the EPQ model is

$$TC = \left(\frac{D}{Q} S \right) + \left(\frac{I_{\text{Max}}}{2} H \right)$$

where TC = total annual cost
 D = annual demand
 Q = quantity to be ordered
 H = annual holding cost
 S = ordering or setup cost

$$I_{\text{Max}} = Q \left(1 - \frac{d}{p} \right)$$

where d = average daily demand rate
 p = daily production rate

If HP uses 6 PCBs per day, can produce 20 PCBs, and produces PCBs in batches of 200 units, determine the maximum inventory level.

EXAMPLE 12.8

Calculating the Maximum Inventory Level

• **Before You Begin:** Remember that when calculating I_{Max} , your answer will always be less than the economic production quantity (EPQ) since you are using some items as soon as they are completed. You really don't need a formula to compute I_{Max} . In the following example, you are producing a total of 200 PCBs, which takes a total of 10 days to complete (200 units required/20 units produced daily). Each of the 10 days you produce this PCB, you use 6 of the just completed units to satisfy immediate demand and the remaining 14 units go into inventory. Since we do this for 10 straight days, our maximum inventory is 140 units (14 units per day times 10 days). As shown here, you can also use the equation.

• **Solution:**

$$I_{\text{Max}} = 200 \left(1 - \frac{6}{20} \right) = 140 \text{ units}$$

The production rate must always be greater than the demand rate. Otherwise, a company could never produce enough to satisfy demand and no inventory would be generated. Using the chocolate-chip cookie scenario as an example: it is impossible to eat more than 12 cookies after the batch is baked because no matter how



Making cookies!

Will & Deni McIntyre/Stone/Getty Images, Inc.

much we might *want* to eat more than 12, we must wait for the next batch to be completed.

Although the formula identifies d as daily demand and p as daily production, we can use other time frames for these variables. We can use hourly demand and hourly production, weekly demand and weekly production, monthly demand and monthly production, quarterly demand and quarterly production, or even annual demand and annual production. The important thing to remember is that the time frame must be the same for both demand and production. That way, the ratio always remains the same.

EXAMPLE 12.9

Calculating Ratios

Calculate the ratio of d/p using daily, weekly, and annual demand. Annual demand is 10,000 units and annual production is 25,000 units. The company operates 50 weeks per year, 5 days per week.

- **Before You Begin:** This example is to show you that the most important issue in calculating ratios of demand/production is to use the same time frame. The ratio remains constant whether we use daily demand/daily production, weekly demand/weekly production, or annual demand/annual production. Just make sure that both the demand and production rates are for the same time period

- **Solution:**

When using daily figures,

Average daily demand: $d = 10,000 \text{ units}/250 \text{ days} = 40 \text{ units per day}$

Daily production: $p = 25,000 \text{ units}/250 = 100 \text{ units per day}$

Therefore, the ratio $d/p = 40/100$ or 0.4.

When using weekly figures,

Average weekly demand: $d = 10,000 \text{ units}/50 \text{ weeks} = 200 \text{ units per week}$

Weekly production: $p = 25,000 \text{ units}/50 \text{ weeks} = 500 \text{ units per week}$

Therefore, the ratio $d/p = 200/500$ or 0.4.

When using annual figures,

Average annual demand: $d = 10,000 \text{ units}$

Annual production: $p = 25,000 \text{ units}$

Therefore, the ratio $d/p = 10,000/25,000$ or 0.4.

Calculating EPQ The formula to calculate the economic production quantity is

$$Q = \sqrt{\frac{2DS}{H\left(1 - \frac{d}{p}\right)}}$$

where D = annual demand in units
 S = setup or ordering cost
 H = annual holding costs per unit
 d = average daily demand rate
 p = daily production rate

Ashlee's Beach Chairs Company produces upscale beach chairs. Annual demand for the chairs is estimated at 18,000 units. The frames are made in batches before the final assembly process. Ashlee's final assembly department needs frames at a rate of 1500 per month. Ashlee's frame department can produce 2500 frames per month. The setup cost is \$800, and the annual holding cost is \$18 per unit. The company operates 20 days per month. Lead time is 5 days. Determine the optimal order quantity, the total annual costs, and the reorder point.

EXAMPLE 12.10
Calculating EPQ at Ashlee's Beach Chairs

- **Before You Begin:** To determine the optimal EPQ, use the formula

$$Q = \sqrt{\frac{2DS}{H\left(1 - \frac{d}{p}\right)}}$$

Remember that the demand and production rates used to calculate the ratio must be in the same time frame (daily, weekly, monthly, quarterly, or annually). To calculate the reorder point, use the formula $R = dL$. Don't forget to transform monthly demand into daily demand to find the reorder point. Reorder points should be found using the easiest numbers possible. For example, if lead time is given as three weeks, then you should find average weekly demand and multiply by the three weeks. If lead time is given in months, use average monthly demand.

- **Solution:**

To determine the total cost, you must calculate the maximum inventory level. To do this you must first calculate the economic production quantity:

$$Q = \sqrt{\frac{2 \times 18,000 \times \$800}{\$18 \left(1 - \frac{1500}{2500}\right)}} = 2000 \text{ units}$$

Therefore, I_{Max} is

$$I_{\text{Max}} = 2000 \left(1 - \frac{1500}{2500}\right) = 800 \text{ units}$$

and the total annual cost is

$$\begin{aligned} TC &= \left(\frac{18,000}{2000} \$800\right) + \left(\frac{800}{2} \$18\right) \\ &= \$7200 + \$7200 \\ &= \$14,400 \end{aligned}$$

Note that the ordering cost equals the annual holding cost. The reorder point is calculated as $R = 75 \text{ units} \times 5 \text{ days} = 375 \text{ units}$. Therefore, the inventory policy is to order a quantity of 2000 frames when the inventory reaches 375 units. The total annual cost (excluding item cost) associated with this policy is \$14,400.

Compare this policy to Ashlee's current inventory policy of producing in quantities of 1500 units. First, determine the maximum inventory level.

$$I_{\text{Max}} = 1500 \left(1 - \frac{1500}{2500}\right) = 600 \text{ units}$$

Therefore, total cost is

$$TC = \left(\frac{18,000}{1500} \$800\right) + \left(\frac{600}{2} \$18\right) = \$15,000$$

The extra cost or penalty cost associated with Ashlee's current policy is \$600 (\$15,000 - \$14,400).

► **Perpetual inventory record**

Provides an up-to-date inventory balance.

When you use the EOQ and/or the EPQ model, you need to know when the inventory level reaches the reorder point. A **perpetual inventory record** provides an up-to-date inventory balance by recording all inventory transactions—items received into inventory or items disbursed from inventory—as they happen.

An alternative to using perpetual inventory records is the two-bin system. In a two-bin system, a quantity equal to demand during replenishment time is held back, often in a second bin. When stock available is depleted, the held-back quantity is made available for use and a replenishment order is placed. Deciding on the right quantity replenishment order is complicated when quantity discounts are available. Let's extend the basic EOQ model to consider quantity discounts.

Quantity Discount Model

► **Quantity discount model**

Modifies the EOQ process to consider cases where quantity discounts are available.

The basic EOQ model assumes that no quantity discounts are available. In real life, however, **quantity discounts** are often available, so we need to modify the basic model for these situations. Quantity discounts are price incentives to encourage a company to buy in larger quantities. For example, a supplier charges your company \$7.50 per pound if your company's order is less than 500 pounds. If your order is for 500 to 999 pounds, the price per pound is \$6.90. On orders of 1000 pounds or more, the supplier charges \$6.20 per pound.

Whenever the price per unit is not fixed but varies based on the size of your order, the total annual cost formula for any inventory policy used must include the cost of material, as shown next.

$$TC = \left(\frac{D}{Q} S \right) + \left(\frac{Q}{2} H \right) + CD$$

where D = annual demand in units
 Q = order quantity in units
 S = ordering or setup cost
 H = annual holding cost
 C = unit price

EXAMPLE 12.11

Annual Total Costs at Jeannette's Steak House

Jeannette's Steak House currently orders 200 pounds of single-portion filet mignons at a time (a two-week supply). The annual demand for the filets is 5200 pounds. The ordering cost is estimated at \$50. The annual holding cost is 30 percent of the unit price. Jeannette pays \$7.50 per pound for the steaks. Therefore, the annual holding cost rate is \$2.25 ($\7.50×0.30). What are the annual total costs?

- **Before You Begin:** In this problem we must include the cost of the steaks as we consider quantity discounts. It is never wrong to include the material costs in the total cost calculation, but we usually omit the material cost unless different replenishment policies result in different material costs. If the material cost is not affected by the policy, then it is a constant and does not need to be included.

- **Solution:**

$$TC = \left(\frac{5200}{200} \$50 \right) + \left(\frac{200}{2} \$2.25 \right) + (\$7.50 \times 5200) = \$40,525$$

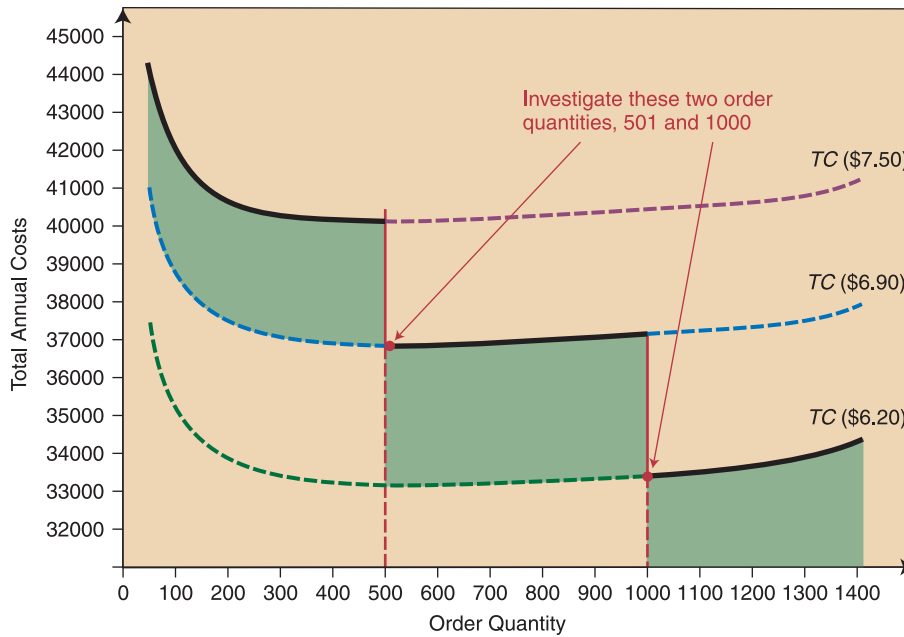


FIGURE 12-6

Quality discount total cost curves

Jeannette's supplier has offered the following price incentives. If Jeannette places an order for 500 or more pounds, the cost per pound is \$6.90. For orders of 1000 pounds or more, the supplier will charge Jeannette \$6.20 per pound. For orders of less than 500 pounds, Jeannette would continue to pay \$7.50 per pound. Now there are three possible prices based on the size of the order. Let's look at how Jeannette can determine the best policy for her business.

Figure 12-6 shows the total annual cost curves for each of the three prices. You can see that the \$7.50 price is only valid when the order quantity falls between 1 and 499 pounds; the \$6.90 price per pound is only valid when the order quantity falls between 500 and 999 pounds; and the \$6.20 price is valid for orders of 1000 or more pounds.

The Quantity Discount Procedure The first step is to calculate the order quantity using the basic EOQ model and the cheapest price available. In our example, Jeannette's cheapest price is \$6.20 per pound. Therefore, the annual holding cost is \$1.86 (that is, $\$6.20 \times 0.30$), and the EOQ is

$$Q = \sqrt{\frac{2 \times 5200 \times \$50}{\$1.86}} = 528.74 \text{ pounds}$$

Now determine whether the order quantity is feasible. If Jeannette orders this quantity, will she be charged the price used to calculate the EOQ? If Jeannette orders 528.74 pounds, the supplier will charge her \$6.90 per pound rather than the \$6.20 she used in calculating the order quantity. Therefore, this is an infeasible quantity. If it were feasible, we would be done calculating Jeannette's optimal inventory policy. Since the order quantity is infeasible, we calculate the order quantity using the next higher price, \$6.90 per pound.

$$Q = \sqrt{\frac{2 \times 5200 \times \$50}{\$2.07}} = 501.20 \text{ pounds}$$

If Jeannette orders 501 pounds, the supplier charges her \$6.90 per pound, which is the same as the price we used in calculating the order quantity. Therefore, this is a feasible order quantity. Once Jeannette finds the feasible quantity, she calculates the total annual costs for this order quantity.

$$TC = \left(\frac{5200}{501} \$50\right) + \left(\frac{501}{2} \$2.07\right) + (\$6.90 \times 5200) = \$36,917.50$$

Jeannette compares the total annual cost of this feasible order quantity with the total annual cost of the minimum order quantities necessary to qualify for any prices lower than the price at which she found the feasible solution. For example, to qualify for a price of \$6.20 per pound, Jeannette must order a minimum of 1000 pounds at a time. The total annual cost of ordering 1000 pounds at a time is

$$TC = \left(\frac{5200}{1000} \$50\right) + \left(\frac{1000}{2} \$1.86\right) + (\$6.20 \times 5200) = \$33,430.00$$

In this case, Jeannette’s annual cost is less if she orders 1000 pounds at a time rather than the EOQ quantity of 501 pounds at a time. The optimal inventory policy for Jeannette is to order 1000 pounds at a time.

Note that this assumes Jeannette has adequate storage capacity and can accommodate 1000 pounds at a time. The quantity discount procedure when holding costs are given as a percentage of the unit price is summarized in Table 12-5.

At times, the holding cost can remain constant regardless of the price paid for an item. When the holding cost is a constant dollar amount, there is a common Q . The Q calculated will only be feasible in one of the price ranges. If the Q is in the least expensive price range, that is the optimal order quantity. If the Q is in a higher price range, total costs must be calculated and compared to the total costs of all lower price breaks.

TABLE 12-5
Quantity Discount
Procedure

1. Calculate the order quantity using the basic EOQ model and the cheapest price possible.
2. Determine whether the order quantity is feasible. That is, if we order this quantity will the supplier charge us the price we used to determine our order quantity? If this is a feasible order quantity, you are done. Otherwise, go to Step 3.
3. If the EOQ quantity found in Step 1 was infeasible, calculate the EOQ for the next higher price.
4. Check again to determine if this quantity is feasible. If it is not feasible, repeat Step 3. If it is feasible, move on to Step 5.
5. Calculate the total annual costs associated with your feasible order quantity. You must include ordering, holding, and material costs.
6. Calculate the total annual costs associated with buying the minimum quantity required to qualify for any prices that are lower than the price at which the feasible solution was found.
7. Compare the total annual costs of buying these minimum quantities to receive the cheaper price against the cost of the feasible Q .
8. Recommend whichever order policy has the lowest total annual cost.

VGHC operates its own laboratory on-site. The lab maintains an inventory of test kits for a variety of procedures. VGHC uses 780 A1C kits each year. Ordering costs are \$15 and holding costs are \$3 per kit per year. The new price list indicates that orders of fewer than 73 kits will cost \$60 per kit, 73 through 144 kits will cost \$56 per kit, and orders of more than 144 kits will cost \$53 per kit. Determine the optimal order quantity and the total cost.

- **Before You Begin:** When you have constant holding costs, you only need to calculate a single Q value using the basic EOQ formula:

$$Q = \sqrt{\frac{2DS}{H}}$$

Check to see what price you must pay per unit if this order quantity is used. If it is the cheapest possible price, this is your optimal replenishment order quantity. If cheaper prices are available, calculate the total annual cost if you buy just enough to qualify for the cheaper price. Do this for all prices cheaper than the price you qualified for with the EOQ. Select the policy that has the lowest total costs, making sure that material costs were included.

• Solution:

The first step is to calculate the common Q .

$$Q = \sqrt{\frac{2 \times 780 \times \$15}{\$3}} = 88.3, \text{ or } 89 \text{ kits}$$

This quantity qualifies for a price of \$56 per kit. Since it is not the lowest possible price, we calculate the total cost at this price and compare it to the total cost at any lower price breaks. The total cost when ordering 89 kits is

$$TC = \left(\frac{780}{89} \$15 \right) + \left(\frac{89}{2} \$3 \right) + (\$56 \times 780) = \$43,944.96$$

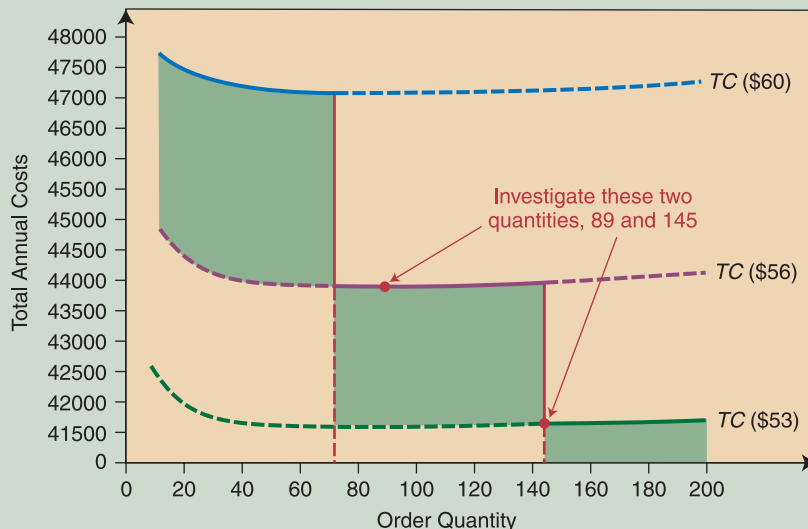
Total cost when ordering 145 kits is

$$TC = \left(\frac{780}{145} \$15 \right) + \left(\frac{145}{2} \$3 \right) + (\$53 \times 780) = \$41,638.19$$

Therefore, the VGHC should order 145 kits at a time since it will save \$2306.77 each year (\$43,944.96 – \$41,638.19). The total annual cost curves are shown in Figure 12-7.

FIGURE 12-7

Quantity discount total annual cost with constant holding cost



EXAMPLE 12.12

Quantity Discounts with Constant Holding Costs at Valley Grand Health Clinic (VGHC)

WHY COMPANIES DON'T ALWAYS USE THE OPTIMAL ORDER QUANTITY

Even though it can be shown mathematically that not using the optimal EOQ quantity results in additional costs for a company, it is not unusual for companies to order a quantity other than the EOQ.

Some companies do not have known uniform demand. In some cases, companies experience lumpy demand (that is, some periods with significant demand and other periods with no demand). This violates one of the underlying assumptions of the EOQ model. In such cases, it is better to use a period-order quantity (discussed later in this chapter).

Some suppliers have a minimum order quantity that they will sell to a company. This minimum order quantity can be based on how the item is packaged. If the item comes in boxes of 1000, the minimum order for the item becomes 1000 pieces. If you need more than one box, you must order additional boxes. To obtain 4000 pieces, you would order four boxes. Some suppliers are willing to break boxes, but many are not. At other times, the minimum order quantity can be based on how the material is shipped. The minimum order quantity may be what is needed to qualify for a full truckload or full railcar load rate. There are also times when a company may not have sufficient storage capacity to accommodate a large order quantity. When that is the case, companies must order less than the EOQ.

Remember that the EOQ must be checked when quantity discounts are available. The basic model did not allow for discounts, so you must confirm what the optimal order policy should be.

The EOQ policy always provides a benchmark to compare against other policies. It is not wrong not to use the EOQ, but it should be more expensive. You need to justify the additional expenses incurred.

JUSTIFYING SMALLER ORDER QUANTITIES

One of the principles of the just-in-time philosophy, discussed in Chapter 7, is to reduce order quantities ideally down to an order size of one unit. Smaller orders improve customer responsiveness, reduce cycle inventory, reduce work-in-process (WIP) inventory, and reduce inventories of raw materials and purchased components. Since many good things happen with smaller order quantities, we need to understand how companies economically reduce their order quantities.

LINKS TO PRACTICE

Kenworth Trucks
www.kenworth.com



M. L. Simibaldi/Corbis

Kenworth Trucks, a manufacturer of elite custom-built trucks, leads the industry in operations due largely to the just-in-time effect. Turning out over 35 trucks a day, Kenworth has been able to cut production time from the industry norm of six to eight weeks down to a mere three weeks. Such an outstanding feat is the result of the implementation of several cutting-edge ideas. Most importantly, there is the use of electronic

transmission, which allows the plant to receive specifications as soon as a buyer has placed an order and which immediately involves parts suppliers in the details of the order. This synchronization results in supplies going almost directly to the assembly line. With such a fine-tuned operation, it is no wonder Kenworth Trucks is known as the premier of its industry!

Let's use the economic production quantity model to illustrate how companies justify smaller lot sizes.

Understanding the EPQ Factors

Looking at the EPQ formulation, we can see that three variables influence the size of the optimal order quantity. The demand, setup cost, and holding cost are the variables used.

$$Q = \sqrt{\frac{2DS}{H\left(1 - \frac{d}{p}\right)}}$$

where D = annual demand
 S = setup cost
 H = annual holding cost per unit
 d = average daily demand
 p = average daily production

To decrease the optimal order quantity, we must reduce the product of the terms under the square root. We can reduce the numerator or increase the denominator. It doesn't make sense for a company to want to increase its holding costs, so we eliminate the idea of increasing the denominator. To reduce the numerator, we can reduce either the annual demand or the setup cost. Most companies are not trying to reduce their annual demand, so we have only one variable left to use: setup cost.

Let's look at an example to see what happens when setup cost is reduced. The Gamma Toy Company has an annual demand of 10,000 units for one of its toys. The daily demand is 50 units. The daily production rate is 75 units. Annual holding cost per unit per period is \$6. Setup cost is estimated to be \$100. When we use these values, the economic production quantity is 1000 units, as shown.

$$Q = \sqrt{\frac{2(10,000)100}{6\left(1 - \frac{50}{75}\right)}} = 1000 \text{ units}$$

Now let's look at what happens if we reduce the setup cost from \$100 down to \$25. When we use the new setup cost, the economic production quantity is 500 units, as shown.

$$Q = \sqrt{\frac{2(10,000)25}{6\left(1 - \frac{50}{75}\right)}} = 500 \text{ units}$$

Let's compare the total annual costs of these two different lot sizes. When $Q = 1000$ units, the total annual cost is

$$TC = \frac{10,000}{1000} \times 100 + \left(\frac{(1000)\left(1 - \frac{50}{75}\right)(6)}{2} \right) = \$2000$$

as opposed to a total cost of \$1000 when using $Q = 500$ units.

$$TC = \frac{10,000}{500} \times 25 + \left(\frac{(500)\left(1 - \frac{50}{75}\right)(6)}{2} \right) = \$1000$$

You can see that reducing the setup cost allows us to economically decrease order quantity. If a company fails to reduce its setup costs and just starts producing in smaller order quantities, it will face higher total annual inventory costs.

DETERMINING SAFETY STOCK LEVELS



Companies are vulnerable to shortages during replenishment lead times, so one function of inventory is to provide safety stock as a cushion for satisfying unexpected customer demand. Remember that you typically place the replenishment order when the inventory level reaches the reorder point. Remember, too, that your company may experience a shortage between the time you place the replenishment order and the time you receive the items you ordered.

When we have no demand uncertainty, we set the reorder point to equal-to-average demand during lead time, or

$$R = dL$$

where R = reorder point in units
 d = daily demand in units
 L = lead time in days

Therefore, if $d = 20$ units and $L = 10$ days, the reorder point is 200 units. Since we know demand and lead time with certainty, the replenishment order arrives just as the on-hand inventory is depleted.

Suppose your kayak suppliers cannot always keep a firm delivery date because of fluctuation in materials availability at their end. As a result, uncertainty is a condition of your kayaking equipment operation. To support your company's customer service objectives, your policy is to carry safety stock. You add the amount of safety stock carried to the reorder point, and the reorder point becomes

$$R = dL + SS$$

where SS = safety stock in units

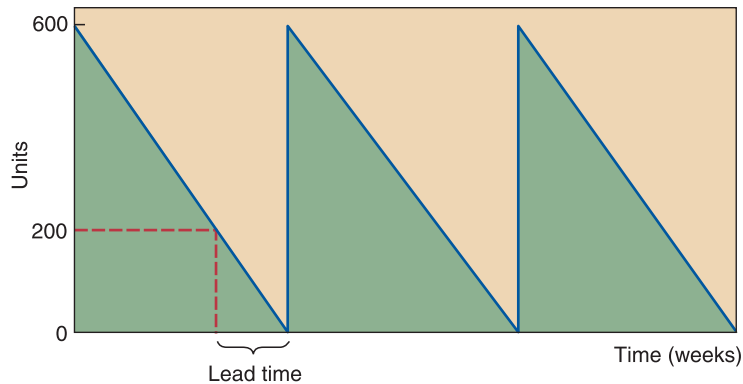
For example, if $d = 20$ units, $L = 10$ days, and $SS = 50$ units, the reorder point is 250 units. When your company carries safety stock, it increases the reorder point, as shown in Figure 12-8. The replenishment order is now expected to arrive when the inventory on hand equals the safety stock level rather than zero. If demand is greater than expected, then your customers are satisfied from the safety stock. If demand is less than expected, the replacement inventory arrives before the on-hand inventory reaches the safety stock level. Figure 12-9 shows when the replenishment order will arrive.

How Much Safety Stock?

As safety stock increases, so does the customer service level, thus decreasing the chance of shortage. At the same time, however, holding safety stock requires additional inventory investment. Thus it is important to limit the amount of safety stock your company holds.

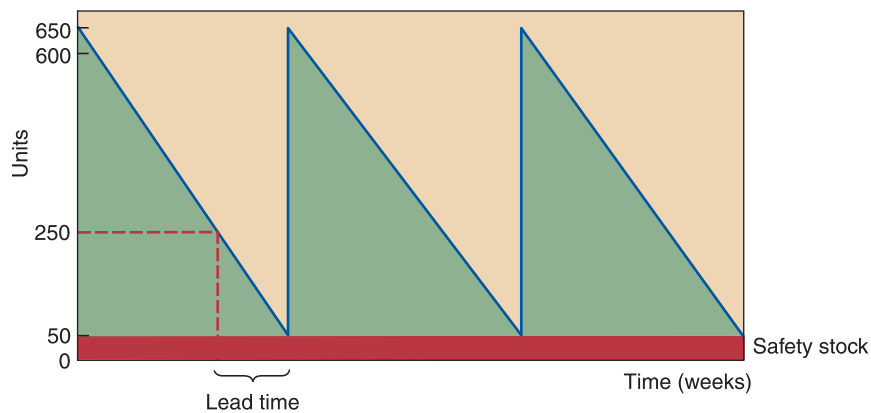
Order-cycle service level is the probability that demand during lead time does not exceed on-hand inventory—that on-hand stock is adequate to meet demand. A service level of 95 percent implies that demand does not exceed supply 95 percent of the time. If your company places 20 orders annually, a 95 percent service level implies that demand will not exceed the on-hand quantity in 19 of the 20 replenishment lead times. We calculate the stockout risk as $(1 - \text{the order-cycle service level})$, or 5 percent in the preceding example.

► **Order-cycle service level**
 The probability that demand during lead time will not exceed on-hand inventory.

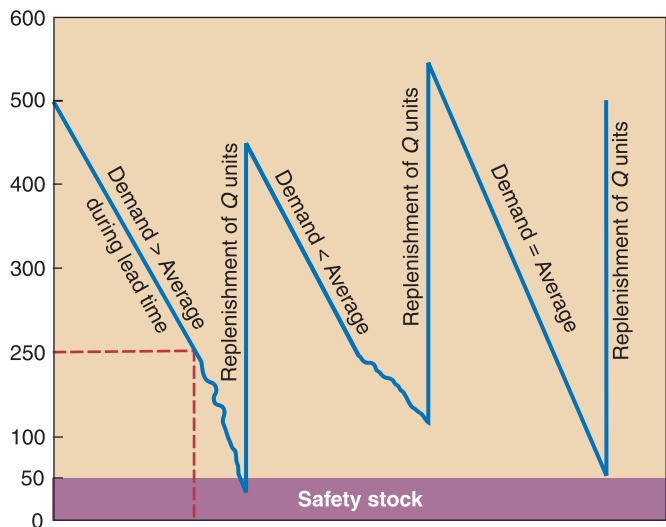


$Q = 600$ units, $R = 200$ units, no safety stock

If demand during lead time equals average demand, then replenishment arrives as on-hand inventory reaches safety stock level.



$Q = 600$ units, safety stock = 50 units, $R = 250$



$Q = 400$ units, $SS = 50$ units, $R = 250$ units

FIGURE 12-8

How safety stock changes the reorder point

FIGURE 12-9

Demand uncertainty

The amount of safety stock to hold depends on the variability of demand and lead time and the desired order-cycle service level. The safety stock needed to achieve a particular order-cycle service level increases as demand and lead time variability increase. The greater the uncertainty, the more safety stock is needed.

Let's look at a case in which an estimate of demand during lead time and its standard deviation are known. In this case, the formula for calculating safety stock is

$$SS = z\sigma_{dL}$$

where SS = safety stock in units

z = number of standard deviations

σ_{dL} = standard deviation of demand during lead time in units

EXAMPLE 12.13

Nick's Safety Stock

Suppose that the owner of the campus bar, Nick's, has determined that demand for beer during lead time averages 5000 bottles. Nick, the owner, believes the demand during lead time can be described by a normal distribution with a mean of 5000 bottles and a standard deviation of 300 bottles. Nick is willing to accept a stockout risk of approximately 4 percent. Determine the appropriate z value to use. Calculate how much safety stock Nick should hold. Also determine the reorder point.

- **Before You Begin:** To determine how much safety stock, should be held, use the formula $SS = z\sigma_{dL}$. You also need to use Appendix B to determine the appropriate z value. To determine the reorder point, use the formula $R = dL + SS$. Note that safety stock always results in a higher reorder point.

- **Solution:**

Go to Appendix B. To find the appropriate z value associated with the order-cycle service level ($1 - 0.04 = 0.9600$), you must understand that the appendix shows only positive z values. A z value of 0 represents 0.5000. You need to find the z value that is the difference between the desired service level and a z value of 0 ($0.9600 - 0.5000 = 0.4600$). Look for the entry closest to 0.4600. If you look at the entry associated with a z value of 1.75, you should see 0.4599, which is as close to 0.4600 as we can get. Therefore, the appropriate z value is 1.75. To determine the appropriate amount of safety stock, do the following calculation:

$$SS = 1.75 \times 300 \text{ bottles} = 525 \text{ bottles of safety stock}$$

The reorder point would now be

$$R = 5000 + 525 = 5525 \text{ bottles}$$

PERIODIC REVIEW SYSTEM

► Target inventory level (TI)

Used in determining order quantity in the periodic review system. Target inventory less on-hand inventory equals order quantity.

With the periodic review system, you determine the quantity of an item your company has on hand at specified, fixed-time intervals (such as every Friday or the last day of every month). You place an order for an amount (Q) equal to the **target inventory level (TI)**, minus the quantity on hand (OH), similar to the min-max system. The difference is that with the periodic review system, the time between orders is constant (such as every hour, every day, every week, or every month) with varying quantities ordered. The min-max system varies both the time between orders and the quantities ordered.

An advantage of the periodic review system is that inventory is counted only at specific time intervals. You do not need to monitor the inventory level between review periods. This system also makes sense when you order several different items from a supplier. For example, if your company buys 10 different items from the same supplier, you can place one order for all 10 items rather than 10 individual orders, one for each item.

Potential disadvantages include the varying replenishment levels. First, since you must have sufficient space to store the largest possible order quantity, often you will have excess space when the replenishment orders are smaller. Second, because of varying quantities, you may not be able to qualify for specific quantity discounts.

One result from using the periodic review system is a larger average inventory level. Your company must carry enough inventory to protect against stockout for the replenishment lead time plus the review period. The two major decisions to be made when using the periodic review system concern the time between orders and the target inventory level.

The time between orders (TBO) may be selected for convenience reasons. That is, it may be easier for you to review your inventory at the end of each week and prepare your replenishment order then. An alternative is to base your TBO on the economic order quantity calculation. For example, if you determine that the $EOQ = 75$ units and that weekly demand is 25 units, it makes sense to place orders every three weeks. You simply divide the EOQ by the average weekly demand.

The target inventory (TI) level is calculated as:

$$TI = d(RP + L) + SS$$

where TI = target inventory level in units
 d = average period demand in units (period can be day, week, month, etc.)
 RP = review period (in days, weeks, or months)
 L = lead time (in days, weeks, or months)
 SS = safety stock in units

The safety stock is calculated as

$$SS = z\sigma_{RP+L}$$

where z = number of standard deviations
 σ_{RP+L} = standard deviation of demand during review period and lead time and is calculated as

$$\sigma_{RP+L} = \sigma_t \sqrt{RP + L}$$

where σ_t = standard deviation of demand during interval t
 RP = review period
 L = lead time

To calculate the replenishment order quantity, use the following formula:

$$Q = TI - OH$$

where Q = replenishment order quantity
 TI = target inventory level
 OH = on-hand quantity

Note that when the lead time is greater than the review period, the on-hand quantity must include any on-order amounts.

EXAMPLE 12.14**Using the Periodic Review System**

Gray's Pharmacy uses a periodic review inventory system. Every Friday, the pharmacist reviews her inventory and determines the size of the replenishment order. For example, she knows that demand for 500-mg metformin tablets, a drug for diabetics, is normally distributed with a mean of 6000 tablets each week with a standard deviation of 500 tablets per week. Lead time is three weeks. The desired cycle-service level is 95 percent. There are currently no outstanding orders.

- Calculate the required safety stock.
- Calculate the target inventory level.
- If, when she reviews her inventory of metformin, the pharmacist finds that she currently has 19,000 tablets, calculate the appropriate replenishment order quantity.

• **Before You Begin:** For this problem, you must determine the target inventory level and make a decision as to the replenishment quantity to order. To calculate the target inventory, find the appropriate safety stock level. Use the formula $SS = z\sigma_{RP+L}$. Calculate the target inventory as $TI = d(RP + L + SS)$. After determining the target inventory, calculate the appropriate order size as $Q = TI - OH$.

• **Solution:**

- Go to Appendix B, the area under the standardized normal curve, and look for the z value that equates to 95 percent of the area under the curve. Since the appendix only uses positive z values, and they start at 0.50, we need to look for a z value that matches the difference between the desired cycle-service level (0.95) and the starting point of 0.50. So we are looking for a value close to 0.4500. In the appendix we can see that $z = 1.64$ has a value of 0.4495 while $z = 1.65$ has a value of 0.4505. By interpolation, a $z = 1.645$ has a value of exactly 0.4500. Therefore, our desired z value is 1.645.

$$SS = 1.645(\sigma_t \sqrt{RP + L})$$

$$SS = 1.645(500\sqrt{1 + 3}) = 1645 \text{ tablets}$$

- The target inventory level is

$$TI = 6000(1 + 3) + 1645 = 25,645 \text{ units}$$

- If the current inventory of metformin is 19,000 tablets, the pharmacist should order 6645 tablets, or $Q = 25,645 - 19,000$ tablets.

Comparison of Continuous Review Systems and Periodic Review Systems

The advantages of continuous review systems (CRS) are the disadvantages of periodic review systems (PRS). For instance, a CRS has no set review periods. This lack of specified review periods means that less inventory is needed to protect against stockouts.

With a PRS, enough inventory must be carried to cover both the lead time and the review period. Since a CRS has no review period, it has a smaller average inventory investment. On the other hand, a CRS means significantly more work because the inventory balances are updated after each transaction rather than periodically. A PRS means less work because inventory balances are only reviewed and updated periodically. So a PRS makes it easier to consolidate orders from a single supplier because you

can review all of those items at the same time interval, whereas the CRS is designed to handle items individually.

In general, companies use CRS for items that are expensive and/or critical to the company because CRS more closely monitors these items and reduces inventory investment. Companies typically use both systems depending on the value and criticality of the items to be monitored.

THE SINGLE-PERIOD INVENTORY MODEL

Some finished goods inventories have very short selling seasons. Items such as holiday decorations, Christmas trees, long-stemmed red roses, newspapers, and magazines are good examples. These products typically have a high value for a relatively short period; then the value diminishes dramatically to either zero or some minimum salvage value. For example, week-old newspapers are inexpensive compared to newspapers offering fresh news. The question is how many of these products you should order to maximize your expected profit.

The **single-period model** is designed for products that share the following characteristics:

- They are sold at their regular price only during a single time period.
- Demand for these products is highly variable but follows a known probability distribution.
- Salvage value of these products is less than their original cost, so you lose money when they are sold for their salvage value.

The objective is to balance the gross profit generated by the sale of a unit with the cost incurred for each unit that is not sold until after the primary selling period has elapsed. When demand follows a discrete probability distribution, we can solve the problem using an expected value matrix.

► **Single-period model**
Designed for use with products that are highly perishable.



Christmas trees for sale.

©AP/Wide World Photos

EXAMPLE 12.15

Walk for Diabetes

Rick Jones is chairman of this year’s Walk for Diabetes event. Each year, the organizers of the event typically have commemorative T-shirts available for purchase by the entrants in the walk. Rick needs to order the shirts well in advance of the actual event. He must place his order in multiples of 10 (60, 70, 80, etc.). Based on past walks, the organizers have determined that the probability of selling different quantities of T-shirts in a given year is as follows:

Demand (shirts)	Probability
80	0.20
90	0.25
100	0.30
110	0.15
120	0.10

Rick plans to sell the T-shirts for \$20 each. He pays his supplier \$8 for each shirt and can sell any unsold shirts for rags at \$2 each. Determine how many T-shirts Rick should order to maximize his expected profits.

- **Before You Begin:** In this problem, you need to determine how many T-shirts to order for the event. If you order too many, you will have leftover shirts with little value. If you don’t order enough, you forgo achieving the profit associated with each shirt plus creating some customer ill will. The easiest way to approach this decision is to develop a payoff table to calculate expected profit with each possible order quantity.
- **Solution:** Based on the information provided, develop a payoff table to determine expected profit with each possible order quantity. Calculate net profit for each combination of order quantity and demand as shown next.

Payoff Table						
Probability of occurrence	0.20	0.25	0.30	0.15	0.10	
Customer demand (shirts)	80	90	100	110	120	
Number of Shirts Ordered						Expected Profit
80	\$960	\$ 960	\$ 960	\$ 960	\$ 960	\$ 960
90	\$900	\$1080	\$1080	\$1080	\$1080	\$1044
100	\$840	\$1020	\$1200	\$1200	\$1200	\$1083
110	\$780	\$ 960	\$1140	\$1320	\$1320	\$1068
120	\$720	\$ 900	\$1080	\$1260	\$1440	\$1026

The numbers in the payoff table are calculated based on what happened. The three possible outcomes are: (1) the number of shirts ordered equals the number of shirts demanded, (2) the number of shirts ordered is greater than the number of shirts demanded, and (3) the number of shirts ordered is less than the number of shirts demanded. To find the payoff when supply equals demand,

Payoff = demand(selling price – unit cost)

In our example, look at what happens when 100 T-shirts are bought and 100 T-shirts are sold.

Payoff = 100(\$20 – \$8) = \$1200

When the number of shirts ordered exceeds demand, the payoff is calculated as

$$\text{Payoff} = (\text{number of items demanded}) \times (\text{selling price} - \text{item cost}) \\ - ((\text{items ordered} - \text{items demanded}) \times (\text{item cost} - \text{item salvage value}))$$

If 100 T-shirts are ordered and demand is for only 80 shirts, the payoff is

$$\text{Payoff} = 80(\$20 - \$8) - ((100 - 80) \times (\$8 - \$2)) = \$840$$

When the number of shirts ordered is less than demand, the payoff is calculated as

$$\text{Payoff} = \text{number of items ordered} \times (\text{selling price} - \text{item cost})$$

Returning to the example, determine the payoff when 100 T-shirts are ordered but 120 shirts are demanded.

$$\text{Payoff} = 100(\$20 - \$8) = \$1200$$

After we calculate the payoffs for each combination, we can determine the expected profit for each order quantity. We do this by multiplying the payoff for an order quantity by the probability for each level of demand. For example, we calculate the payoff for ordering 100 shirts, \$1083, as

$$(\$840 \times 0.20) + (\$1020 \times 0.25) + (\$1200 \times 0.30) + (\$1200 \times 0.15) + (\$1200 \times 0.10)$$

Once we generate the expected profit for each of the possible order quantities, we select the order quantity with the highest expected profit. In our case, Rick should order 100 shirts since doing so has an expected profit of \$1083.

INVENTORY MANAGEMENT WITHIN OM: HOW IT ALL FITS TOGETHER

Inventory management provides the materials and supplies needed to support actual manufacturing or service operations. A product cannot be built unless the required material is available. Inventory replenishment policies guide the master production scheduler when determining which jobs and what quantity should be scheduled (Supplement D). The master production schedule inserted into the material requirements planning (MRP) system generates the replenishment orders. This output is used to guide purchasing in terms of the frequency and size of orders. Too much inventory is costly to the organization, yet too little can create major inefficiencies.

Inventory record accuracy is especially critical for MRP users. MRP relies on inventory records to process material requirements, so inaccurate records make the MRP output worthless. This, in turn, can cause manufacturing to shut down and/or miss a deadline.

Inventory management policies also affect the layout of the facility. A policy of small lot sizes and frequent shipments reduces the space needed to store materials (Chapter 7). Point-of-delivery placement of inventory affects the size of work centers. Inventory management also affects throughput time. As a facility increases its work-in-process, throughput times increase. Longer throughput times reduce an organization's ability to respond quickly to changing customer demands (Chapter 4).

Good inventory management assures continuous supply and minimizes inventory investment while achieving customer service objectives.

INVENTORY MANAGEMENT ACROSS THE ORGANIZATION



Inventory management policies affect functional areas throughout a company. Let's consider why individual functional areas are concerned with inventory management policies.

Accounting is concerned because of the cost implications of inventory, such as the holding costs incurred, the capital needed to invest in inventory, and projected cash flow budgets. Accounting is concerned with all types of inventory.

Marketing is concerned because stocking decisions affect the level of customer service provided. Marketing's primary focus is finished goods inventory, where the goods are held within the distribution system, the response time to satisfy customers, and safety stock levels.

Information systems is involved because a system to track and control inventories is needed, especially when perpetual inventory records are used. Given the large number of SKUs and a high volume of inventory transactions, manual processing is impractical for most companies, so a computerized information system is essential.

Purchasing's workload is directly affected by inventory policies. Policies regarding order frequency, order volume, acceptable suppliers, and inventory investment determine the number of purchases made. Purchasing is concerned primarily with buying raw materials, components, and subassemblies.

Manufacturing's cost efficiency can be affected by inventory decisions. If insufficient material is available, either because items are not ordered on time or not ordered in the right quantities, manufacturing efficiency decreases and unit costs increase. Unit costs can also increase when too much material is ordered or when it is ordered too soon.

As you can see, inventory decisions affect many functional areas in a company and may involve input from management in these areas. In addition, inventory decisions have a significant impact on the company's profitability.

Who makes aggregate inventory decisions? Typically, it is the materials manager. This person is evaluated based on customer service levels achieved and inventory turnover. For individual finished goods products, the master scheduler makes decisions about how much of a particular item to produce and how much to keep in inventory. A master scheduler is evaluated based on customer service levels and manufacturing efficiency.

For raw materials, components, and subassemblies, inventory planners, material planners, or controllers make decisions about when to place replenishment orders, either for in-house manufacturing or for external purchasing. Planners and controllers are typically evaluated according to customer service levels and inventory investment.

THE SUPPLY CHAIN LINK

Inventory management deals with economically based item-replenishment policies, safety stock levels, and the appropriate review system for use within a supply chain. Inventory flows from the suppliers to the manufacturers to the distributors. Inventory management provides an understanding of the total costs of inventory as well as the customer service ramifications of specific policies. By themselves, uncoordinated replenishment policies can



cause the bullwhip effect (discussed in Chapter 4) in the supply chain. Vendor-managed inventory is one approach committed to improving service levels while reducing inventory investment in the supply chain. A policy of making demand information available (point-of-sale information) to all members of the supply chain reduces demand uncertainty and allows a company to achieve its desired customer service levels with a smaller inventory investment. Inventory management is a key component of effective supply chain performance.

Chapter Highlights

- 1** Raw materials, purchased components, work-in-process (WIP), finished goods, distribution inventory and maintenance, repair and operating supplies are all types of inventory. Inventories have several uses: anticipation inventory is built before it is needed; fluctuation stock provides a cushion against uncertain demand; cycle stock is a result of the company's ordering quantity; transportation inventory includes items in transit; speculative inventory is a buildup to protect against some future event; and MRO inventory supports daily operations.
- 2** The objectives of inventory management are to provide the desired level of customer service, to allow cost-efficient operations, and to minimize inventory investment. Customer service can be measured in several ways, including as a percentage of orders shipped on schedule, a percentage of line items shipped on schedule, a percentage of dollar volume shipped on schedule, or idle time due to material and component shortages. Cost-efficient operations are achieved by using inventory as buffer stocks, allowing a stable year-round workforce, and spreading the setup cost over a larger number of units.
- 3** Inventory investment is measured in inventory turnover and/or level of supply. Inventory performance is calculated as inventory turnover or weeks, days, or hours of supply.
- 4** Relevant inventory costs include item costs, holding costs, ordering costs, and shortage costs. Holding costs include capital costs, storage costs, and risk costs. Ordering costs are fixed costs for placing an order or performing a setup. Shortage costs include costs related to additional paperwork, additional shipping expense, and the intangible cost of lost customer goodwill.
- 5** The ABC classification system allows a company to assign the appropriate level of control and frequency of review of an item based on its annual dollar volume.
- 6** Cycle counting is a method for maintaining accurate inventory records. Determining what and when to count are the major decisions.
- 7** Retailers, wholesalers, and food service organizations use tangible inventory even though they are service organizations. Proper inventory control and management for these organizations often is the difference between a profit and loss. Since the items are often desirable, organizations must strive to reduce the amount of theft by customers and employees. Magnetic strips, security devices, and surveillance systems are all means of reducing inventory loss.
- 8** Lot-for-lot, fixed-order quantity, min-max systems, order n periods, periodic review systems, EOQ models, quantity discount models, and single-period models can be used to determine order quantities.
- 9** Ordering decisions can be improved by analyzing total costs of an inventory policy. Total costs include ordering cost, holding cost, and material cost.
- 10** Practical considerations can cause a company to not use the optimal order quantity, that is, minimum order requirements.
- 11** Smaller lot sizes give a company flexibility and shorter response times. The key to reducing order quantities is to reduce ordering or setup costs.
- 12** Calculating the appropriate safety stock policy enables companies to satisfy their customer service objectives at minimum cost. The desired customer service level determines the appropriate z value.
- 13** Inventory decisions about perishable products (like newspapers) can be made using the single-period inventory model. The expected payoff is calculated to assist the quantity decision.

Key Terms

raw materials 431	customer service 434	capital costs 438
components 431	percentage of orders shipped	storage costs 439
work-in-process (WIP) 432	on schedule 434	risk costs 439
finished goods 432	percentage of line items shipped	ordering costs 440
distribution inventory 432	on schedule 435	shortage costs 440
anticipation inventory 432	percentage of dollar volume shipped	back order 440
fluctuation inventory 432	on schedule 435	lost sale 440
lot-size inventory 432	setup cost 436	Pareto's law 440
transportation inventory 432	inventory turnover 436	ABC classification 440
speculative inventory 433	weeks of supply 436	continuous review system 442
maintenance, repair, and operating	item cost 438	periodic review system 443
inventory (MRO) 433	holding costs 438	two-bin system 443

lead time 443	fixed-order quantity 447	perpetual inventory record 456
periodic counting 444	min-max system 447	quantity discount model 456
cycle counting 444	order n periods 447	order-cycle service level 462
vendor-managed inventory (VMI) 445	economic order quantity (EOQ) 447	target inventory level (TI) 464
stock-keeping unit (SKU) 446	economic production quantity (EPQ) 452	single-period model 467
lot-for-lot 447		

Formula Review

1. Calculating average transportation inventory (ATI):

$$ATI = \frac{tD}{365}$$

where t = transit time in days and D = annual demand in units.

2. Calculating inventory turnover and periods of supply:

$$\text{Inventory turnover} = \frac{\text{annual cost of goods sold}}{\text{average inventory in dollars}}$$

$$\text{Weeks of supply} = \frac{\text{average inventory on hand in dollars}}{\text{average weekly usage in dollars}}$$

$$\text{Days of supply} = \frac{\text{average inventory on hand in dollars}}{\text{average daily usage in dollars}}$$

3. Calculating target inventory (TI):

$$TI = d(RP + L) + SS$$

where d = average daily demand, RP = review period in days, and SS = safety stock.

4. Calculating safety stock in a periodic review model:

$$SS = z\sigma_{RP+L}$$

Standard deviation of demand during review period and lead time:

$$\sigma_{RP+L} = \sigma_t \sqrt{RP + L}$$

5. Calculating reorder point without safety stock:

$$R = dL$$

where d = average daily demand and L = lead time in days.

6. Calculating the economic order quantity (EOQ):

$$Q = \sqrt{\frac{2DS}{H}}$$

where D = annual demand, S = ordering cost, and H = holding cost.

7. Calculating total costs:

$$TC = \left(\frac{D}{Q}S\right) + \left(\frac{Q}{2}H\right)$$

8. Calculating the economic production quantity (EPQ):

$$Q = \sqrt{\frac{2DS}{H\left(1 - \frac{d}{p}\right)}}$$

9. Calculating total costs:

$$TC = \left(\frac{D}{Q}S\right) + \left(\frac{I_{\text{Max}}}{2}H\right)$$

where I_{Max} is the maximum inventory level.

10. Calculating I_{Max} :

$$I_{\text{Max}} = Q\left(1 - \frac{d}{p}\right)$$

where d = daily demand and p = daily production rate.

11. Calculating total costs for quantity discount comparisons:

$$TC = \left(\frac{D}{Q}S\right) + \left(\frac{Q}{2}H\right) + CD$$

where C = price per unit.

12. Calculating amount of safety stock:

$$SS = z\sigma_{dL}$$

where SS = safety stock, z = number of standard deviations, and σ_{dL} = standard deviation of demand during lead time in units.

Solved Problems



(See student companion site for Excel template.)

• Problem 1

Tacky Souvenirs sells lovely handmade tablecloths at its island store. These tablecloths cost Tacky \$15 each. Customers want to buy the tablecloths at a rate of 240 per week. The company operates 52 weeks per year. Tacky, the owner, estimates his ordering cost at \$50. Annual holding costs are 20 percent of the unit cost. Lead time is 2 weeks. Using the information given,

- Calculate the economic order quantity.
- Calculate the total annual costs using the EOQ.
- Determine the reorder point.

• Before You Begin:

To calculate the economic order quantity, you use the formula

$$Q = \sqrt{\frac{2DS}{H}}$$

Remember that the demand information and the holding cost must be for the same time frame. That is, if you use annual demand, you must use an annual holding cost. Once you have

calculated the EOQ, you calculate total annual costs with the formula

$$TC = \left(\frac{D}{Q} S\right) + \left(\frac{Q}{2} H\right)$$

To find the reorder point, use the formula: $R = dL$. Remember that demand must be in the same time frame as is given for lead time. For example, if lead time is given as three weeks, then use weekly demand. If lead time is given in days, use daily demand.

• Solution

- First, calculate the annual demand and the annual holding cost.

$$\begin{aligned} \text{Annual demand} &= (52 \text{ weeks} \times 240 \text{ units per week}) \\ &= 12,480 \text{ units} \end{aligned}$$

$$\begin{aligned} \text{Annual holding cost} &= (0.20 \times \$15) \\ &= \$3.00 \text{ per unit per year} \end{aligned}$$

	A	B	C
1			
2	Tacky Souvenirs		
3			
4	Problem Inputs		
5	Weekly Demand	240	
6	Operating Weeks per year	52	B7: =B5*B6
7	Annual Demand (units)	12480	
8			
9	Ordering Cost	\$50.00	
10			
11	Annual Holding Cost (%)	20.0%	
12	Unit Cost	\$15.00	B13: =B12*B11
13	Annual Holding Cost (\$/unit)	\$3.00	
14			
15	Lead Time (weeks)	2	
16			
17	Calculations and Solution		B18: =SQRT((2*B7*B9)/B13)
18	EOQ (exact calculation)	644.98062	B19: =ROUND(B18,0)
19	EOQ (rounded to nearest integer)	645	B20: =(B7/B19)*B9
20	Annual Ordering Costs	\$967.44	B21: =(B19/2)*B13
21	Annual Holding Costs	\$967.50	B22: =B20*B21
22	Total Annual Costs	\$1,934.94	B23: =B5*B15
23	Reorder Point (units)	480	

Now calculate the economic order quantity as shown in the spreadsheet.

$$Q = \sqrt{\frac{2 \times 12480 \times \$50}{\$3}} = 644.98, \text{ or } 645 \text{ tablecloths}$$

Examine the spreadsheet to see how you can solve EOQ problems using a spreadsheet. Note that you can use weekly demand since the lead time is given in weekly increments. Just make sure that the average demand time frame matches the time frame used with lead time.

(b) The total costs are

$$TC = \left(\frac{12480}{645} \$50 \right) + \left(\frac{645}{2} \$3 \right) = \$1934.94$$

(c) The reorder point is

$$R = 240 \text{ units} \times 2 \text{ weeks} = 480 \text{ units}$$

• Problem 2

Jack's Packs manufactures backpacks made from microfabrics. The cutting department prepares the material for use by the backpack stitching department. The cutting department can cut enough material to make 200 backpacks per day. The backpack stitching department produces 90 backpacks per day. Annual demand for the product is 22,500 units. The company operates 250 days per year. Estimated setup cost is \$60. Annual holding cost is \$6 per backpack.

- Calculate the economic production quantity for the cutting department.
- Calculate the total annual costs for the EPQ.

• Before You Begin:

For this problem, calculate the EPQ. We use a modified version of the EOQ formula since we have relaxed the assumption regarding all of the items being delivered at one time. With the EPQ model, units are produced daily. Some are used immediately to satisfy demand, while the other units are put into inventory. The appropriate formula is

$$Q = \sqrt{\frac{2DS}{H\left(1 - \frac{d}{p}\right)}}$$

Remember that the ratio d/p does not have to be daily demand divided by daily production. You need only use figures for the

same time frame. The ratio of annual demand divided by annual production is equivalent to the daily demand divided by daily production. You also should check to be sure that the demand rate is smaller than the production rate. Otherwise, you can never produce enough to satisfy demand. When calculating total costs, make sure that you determine the maximum inventory level when assessing holding costs.

• Solution

(a) First, calculate the EPQ as follows:

$$Q = \sqrt{\frac{2 \times 22,500 \times \$60}{\$6\left(1 - \frac{90}{200}\right)}} = 904.53, \text{ or } 905 \text{ backpacks}$$

(b) To calculate total costs, determine the maximum inventory level as follows:

$$I_{\text{Max}} = 905\left(1 - \frac{90}{200}\right) = 497.75, \text{ or } 498 \text{ backpacks}$$

Now that you have determined the maximum inventory level, calculate total costs:

$$TC = \left(\frac{22,500}{905} \$60 \right) + \left(\frac{498}{2} \$6 \right) = \$2985.71$$

• Problem 3

Ye Olde Shoe Repaire has customers requesting leather soles throughout the year. The owner, Warren, buys these soles from The Leather Company (TLC) at a price of \$8 per pair. In an effort to improve profitability by selling in greater quantities, the sales rep for TLC has made the following offer to Ye Olde Shoe Repaire: If Warren orders from 1 to 50 pairs at a time, the cost per pair is \$8.00. If the order is between 51 and 100 pairs at a time, the cost is \$7.60. On orders for more than 100 pairs at a time, the cost per pair is \$7.40. The owner estimates annual demand to be 625 pairs of soles. Holding costs are 20 percent of unit price. The cost to place an order is \$10. Determine the most cost-effective ordering policy for Ye Olde Shoe Repaire.

• Before You Begin:

This is a quantity discount problem with proportional holding costs. You begin by calculating the EOQ for the least expensive unit price. Check to see if this quantity is feasible. Feasibility occurs when you can order the EOQ quantity and pay the unit price that was used in your calculation. For example, if the EOQ turns out to be 92 pairs of leather soles and you used a unit price of \$7.40 per pair, you need to check to see whether or not you will be charged \$7.40 per pair if you place an order for 92 pairs. If the initial price assumption does not match what you would actually pay, then the quantity is infeasible. Once you find a feasible quantity, calculate the total annual costs for that policy, including the annual material costs. You must also calculate the total costs associated with ordering just enough units to qualify for any

cheaper prices available. For example, if the feasible quantity occurs with a cost of \$7.60 per pair and you know that if you buy 100 pairs at a time you qualify for a unit price of \$7.40, you calculate the total annual cost assuming that you would order just enough (100 pairs) to qualify for the lower unit price. You must do this for all prices lower than the price of the feasible EOQ. Your best policy is based on the total annual costs.

• Solution

- (a) First, we need to calculate the EOQ at the lowest price offered. The annual holding cost is 20 percent of the unit cost, or \$1.48—that is, \$7.40 times 20 percent.

$$Q = \sqrt{\frac{2 \times 625 \times \$10}{\$1.48}} = 91.9, \text{ or } 92 \text{ pairs}$$

Since this order quantity does not match the unit price used to calculate the EOQ, this answer is infeasible. This means if we place an order for 92 pairs, we are charged \$7.60 per pair rather than the \$7.40 we used in calculating the EOQ.

- (b) Since the first Q is infeasible, we calculate the EOQ for the next higher price. Make sure to calculate the new annual holding cost, 20 percent of \$7.60, or \$1.52.

$$Q = \sqrt{\frac{2 \times 625 \times \$10}{\$1.52}} = 90.68, \text{ or } 91 \text{ pairs}$$

If we place an order for 91 pairs, we will be charged \$7.60 per pair, which is the price we used to calculate this EOQ. Therefore, this is a feasible order quantity. We are ready to calculate the total annual cost for this policy:

$$\begin{aligned} TC &= \left(\frac{625}{91} \$10 \right) + \left(\frac{91}{2} \$1.52 \right) + (\$7.60 \times 625) \\ &= \$4887.84 \end{aligned}$$

Since the feasible solution was not at the lowest price, we must now compute the total cost of any cheaper price, assuming that we order just enough to qualify for the cheaper price. This means we need to order 101 pairs to qualify for the \$7.40 price. The total cost of this policy is

$$\begin{aligned} TC &= \left(\frac{625}{101} \$10 \right) + \left(\frac{101}{2} \$1.48 \right) + (\$7.40 \times 625) \\ &= \$4761.62 \end{aligned}$$

Since the total annual cost of ordering 101 pairs at a time is less expensive, Ye Olde Shoe Repaire should order 101 pairs each time leather soles are needed.

• Problem 4

Frank's Ribs knows that the demand during lead time for his world-famous ribs is described by a normal distribution with a mean of 1000 pounds and a standard deviation of 100 pounds. Frank is willing to accept a stockout risk of approximately 2 percent.

- (a) Determine the appropriate z value.
(b) Calculate how much safety stock Frank should hold.

• Before You Begin:

In this problem, you need to find out how much safety stock should be held. First, use Appendix B to determine the z value for the desired safety stock level. Then, using the formula $SS = z\sigma_{dL}$, calculate the required safety stock.

• Solution

- (a) Go to Appendix B. You need to find the z value associated with 0.4800, which is the difference between the desired service level, 0.9800, and the z value of 0, 0.5000. Looking at the entry for $z = 2.05$, you should see 0.4798, which is as close to 0.4800 as we can get. Therefore, the appropriate z value is 2.05.
(b) To determine the amount of safety stock Frank should hold, multiply the z value by the standard deviation:

$$SS = 2.05 \times 100 \text{ pounds} = 205 \text{ pounds}$$

Frank should hold 205 pounds of ribs in safety stock.

• Problem 5

Peter sells programs at State University's home football games. Peter must buy the programs before the game in multiples of 100 (2000, 2100, 2200, etc.). Peter has determined that the probability of selling different quantities of programs at a given game is as follows:

Demand for Programs	Probability of Demand
2000	0.10
2100	0.20
2200	0.40
2300	0.20
2400	0.10

Peter plans to sell the programs for \$4 each. He pays \$2.50 for each program and there is no salvage value. Determine how many programs Peter should buy to maximize his profit.

• Before You Begin:

For this problem, we are only able to make a single purchase. Determine which order quantity has the highest expected payoff. Develop a payoff table to show the expected value from each order quantity.

• **Solution**

Based on the information given, we developed a payoff table to determine the expected profit for each possible order quantity. Net profit for each combination of order quantity and demand are calculated as shown. The order quantity with the highest expected profit is 2200 programs. Peter should order 2200 programs.

	Probability of Occurrence				
	0.10	0.20	0.40	0.20	0.10
Actual customer demand (programs)	2000	2100	2200	2300	2400
Number of Programs Ordered					Expected Profit
2000	\$3000	\$3000	\$3000	\$3000	\$3000
2100	\$2750	\$3150	\$3150	\$3150	\$3110
2200	\$2500	\$2900	\$3300	\$3300	\$3140
2300	\$2250	\$2650	\$3050	\$3450	\$3010
2400	\$2000	\$2400	\$2800	\$3200	\$2800

Discussion Questions

1. Visit a local business and identify the different types of inventory used.
2. After visiting a local business, explain the different functions of its inventory.
3. Explain the objectives of inventory management at the local business.
4. Describe how the objectives of inventory management can be measured.
5. Explain the different methods for measuring customer service.
6. Compare the two techniques, inventory turnover and weeks of supply.
7. Describe the relevant costs associated with inventory policies.
8. Explain what is included in the annual holding cost.
9. Describe what is included in ordering or setup costs.

10. Describe what is included in shortage costs.
11. Explain the assumptions of the EOQ model.
12. Describe techniques for determining order quantities other than the EOQ or EPQ.
13. Describe how changes in the demand, ordering cost, or holding cost affect the EOQ.
14. Explain how a company can justify smaller order quantities.
15. Explain what safety stock is for.
16. Explain how safety stock affects the reorder point.
17. Describe the type of products that require a single-period model.
18. Explain the basic concept of ABC analysis.
19. Explain the concept of perpetual review.
20. Explain how two-bin systems work.

Problems

1. Elyssa’s Elegant Eveningwear (EEE) needs to ship finished goods from its manufacturing facility to its distribution warehouse. Annual demand for EEE is 2400 gowns. EEE can ship the gowns via regular parcel service (3 days transit time), premium parcel service (1 day transit time), or via public carrier (7 days transit time). Calculate the average annual transportation inventory for each alternative.
2. Yasuko’s Art Emporium (YAE) ships art from its studio located in the Far East to its distribution center located on the West Coast of the United States. YAE can send the art either via transoceanic ship freight service (15 days transit) or by air freight (2 days transit time). YAE ships 18,000 pieces of art annually.
 - (a) Calculate the average annual transportation inventory when sending the art via transoceanic ship freight service.
 - (b) Calculate the average annual transportation inventory when sending the art via air freight.

- (c) What additional information is needed to compare the two alternatives?
3. Joe, the owner of Genuine Reproductions (GR), a company that manufactures reproduction furniture, is interested in measuring inventory effectiveness. Last year the cost of goods sold at GR was \$3,000,000. The average inventory in dollars was \$250,000.
 - (a) Calculate the inventory turnover for GR.
 - (b) Calculate the weeks of supply. Assume 52 weeks per year.
 - (c) Calculate the days of supply. Assume that GR operates 5 days per week.
 4. Genuine Reproductions (GR) plans on increasing next year’s sales by 20 percent while maintaining its same average inventory in dollars of \$250,000.
 - (a) Calculate the expected inventory turnover for next year.
 - (b) Calculate the expected weeks of supply.

5. What is the inventory turnover for Genuine Reproductions from Problems 3 and 4 if sales actually increase 20 percent but the average inventory rises to \$325,000?

6. Frederick's Farm Factory (FFF) currently maintains an average inventory valued at \$3,400,000. The company estimates its capital cost at 10 percent, its storage cost at 4.5 percent, and its risk cost at 6 percent.

- Calculate the annual holding cost rate for FFF.
- Calculate the total annual holding costs for FFF.

7. The Federal Reserve Board has just increased the interest rate. FFF in Problem 6 now has to pay 12 percent for its capital. Calculate the impact on total annual holding costs for FFF.

8. A technology problem has rendered some of the inventory at FFF (Problem 6) obsolete. FFF estimates that the risk cost of its inventory is now 10 percent.

- Calculate the new annual holding cost rate.
- Calculate the new total annual holding costs for FFF.

9. Custom Computers, Inc. assembles custom home computer systems. The heat sinks needed are bought for \$12 each and are ordered in quantities of 1300 units. Annual demand is 5200 heat sinks, the annual inventory holding cost rate is \$3 per unit, and the cost to place an order is estimated to be \$50. Calculate the following:

- Average inventory level
- The number of orders placed per year
- The total annual inventory holding cost
- The total annual ordering cost
- The total annual cost

10. Custom Computers, Inc. from Problem 9 is considering a new ordering policy. The new order quantity would be 650 heat sinks. Recalculate Problem 9, parts (a) through (e), and compare results.

11. Bill Maze, recently hired by Custom Computers, Inc., has suggested using the economic order quantity for the heat sinks. Using the information in Problem 9, calculate the following:

- Economic order quantity
- Average inventory level
- The number of orders placed per year
- The total annual ordering cost
- The total annual holding cost
- The total annual cost

Compare these results with the costs calculated in Problems 9 and 10.

12. A local nursery, Greens, uses 1560 bags of plant food annually. Greens works 52 weeks per year. It costs \$10 to place an order for plant food. The annual holding cost rate is \$5 per bag. Lead time is one week.

- Calculate the economic order quantity.
- Calculate the total annual costs.
- Determine the reorder point.

13. Rapid Grower, the supplier of plant food for Greens in Problem 12, has offered the following quantity discounts. If the nursery places orders of 50 bags or less, the cost per bag is \$20. For orders greater than 50 bags but less than 100 bags, the cost per bag is \$19. For orders of 100 bags or more, the cost is \$18 per

bag. Greens estimates its holding cost to be 25 percent of the unit price. Determine the most cost-effective ordering policy for Greens.

14. In an effort to reduce its inventory, Rapid Grower is offering Greens, a local nursery (Problems 12 and 13), two additional price breaks to consider. If the nursery orders a three-month supply, the cost per bag is \$16. If Greens orders a six-month supply, the cost per bag is \$14.50. Should Greens change its order quantity calculated in Problem 13?

15. In a further attempt to liquidate its inventory, Rapid Grower has offered Greens, the local nursery, an option to buy the entire year's supply at one time. The cost per bag would be \$12. Should Greens take advantage of this offer?

16. Sam's Auto Shop services and repairs a particular brand of foreign automobile. Sam uses oil filters throughout the year. The shop operates 52 weeks per year, and weekly demand is 150 filters. Sam estimates that it costs \$20 to place an order and his annual holding cost rate is \$3 per oil filter. Currently, Sam orders in quantities of 650 filters. Calculate the total annual costs associated with Sam's current ordering policy.

17. Using the information in Problem 16, calculate the following:

- The economic order quantity
- The total annual costs using the EOQ ordering policy
- The penalty costs Sam is incurring by using his current policy

18. The local Office of Tourism sells souvenir calendars. Sue, the head of the office, needs to order these calendars in advance of the main tourist season. Based on past seasons, Sue has determined the probability of selling different quantities of the calendars for a particular tourist season.

Demand for Calendars	Probability of Demand
75,000	0.15
80,000	0.25
85,000	0.30
90,000	0.20
95,000	0.10

The Office of Tourism sells the calendars for \$12.95 each. The calendars cost Sue \$5 each. The salvage value is estimated to be \$0.50 per unsold calendar. Determine how many calendars Sue should order to maximize expected profits.

19. The Office of Tourism (Problem 18) has decided to heavily promote local events this year and anticipates more tourists this season. Sue has changed the probability of selling different quantities of calendars as shown. Given the new probabilities, determine how many calendars Sue should order to maximize expected profits.

Demand for Calendars	Probability of Demand
75,000	0.05
80,000	0.20
85,000	0.25
90,000	0.30
95,000	0.20

20. Given the following list of items,
- Calculate the annual usage cost of each item.
 - Classify the items as A, B, or C.
- | Item | Annual Demand | Ordering Cost (\$) | Holding Cost (%) | Unit Price (\$) |
|------|---------------|--------------------|------------------|-----------------|
| 101 | 500 | 10 | 20 | 0.50 |
| 102 | 1500 | 10 | 30 | 0.20 |
| 103 | 5000 | 25 | 30 | 1.00 |
| 104 | 250 | 15 | 25 | 4.50 |
| 105 | 1500 | 35 | 35 | 1.20 |
| 201 | 10000 | 25 | 15 | 0.75 |
| 202 | 1000 | 10 | 20 | 1.35 |
| 203 | 1500 | 20 | 25 | 0.20 |
| 204 | 500 | 40 | 25 | 0.80 |
| 205 | 100 | 10 | 15 | 2.50 |
21. Using the information provided in Problem 20,
- Calculate the economic order quantity for each item. (Round to the nearest whole number.)
 - Calculate the company’s maximum inventory investment throughout the year.
 - Calculate the company’s average inventory level.
22. Tax Preparers, Inc. works 250 days per year. The company uses adding machine tape at a rate of eight rolls per day. Usage is believed to be normally distributed with a standard deviation of three rolls during lead time. The cost of ordering the tape is \$10, and holding costs are \$0.30 per roll per year. Lead time is two days.
- Calculate the economic order quantity.
 - What reorder point will provide an order-cycle service level of 97 percent?
 - How much safety stock must the company hold to have a 97 percent order-cycle service level?
 - What reorder point is needed to provide an order-cycle service level of 99 percent?
 - How much safety stock must the company hold to have a 99 percent order-cycle service level?
23. Healthy Plants Ltd. (HP) produces its premium plant food in 50-pound bags. Demand for the product is 100,000 pounds per week. HP operates 50 weeks per year and can produce 250,000 pounds per week. The setup cost is \$200 and the annual holding cost rate is \$0.55 per bag. Currently, HP produces its premium plant food in batches of 1,000,000 pounds.
- Calculate the maximum inventory level for HP.
 - Calculate the total annual costs of this operating policy.
24. Using the data provided in Problem 23, determine what will happen if HP uses the economic production quantity model to establish the quantity produced each cycle.
- Calculate the economic production quantity (EPQ).
 - Calculate the maximum inventory level using the EPQ.
 - Calculate the total annual cost of using the EPQ.
 - Calculate the penalty cost HP is incurring with its current policy.
25. Greener Pastures Incorporated (GPI) produces a high-quality organic lawn food and weed eliminator called Super Green (SG). Super Green is sold in 50-pound bags. Monthly demand for Super Green is 75,000 pounds. Greener Pastures has

- capacity to produce 24,000 50-pound bags per year. The setup cost to produce Super Green is \$300. Annual holding cost is estimated to be \$3 per 50-pound bag. Currently, GP is producing in batches of 2500 bags.
- Calculate the total annual costs of the current operating policy at GPI.
 - Calculate the economic production quantity (EPQ).
 - Calculate the total annual costs of using the EPQ.
 - Calculate the penalty cost incurred with the present policy.
26. Lissette Jones, the materials manager for an upscale retailer, wants to measure her customer service level. She has collected the following representative data.
- | Order Number | Number of Line Items | Dollar Value of Order |
|---------------|----------------------|-----------------------|
| 1 | 4 | 1000 |
| 2 | 8 | 1440 |
| 3 | 2 | 1600 |
| 4 | 6 | 920 |
| 5 | 10 | 1800 |
| 6 | 8 | 1200 |
| 7 | 8 | 2700 |
| 8 | 4 | 1560 |
| 9 | 5 | 1780 |
| 10 | 5 | 1000 |
| Totals | 60 | \$15,000 |
- Assuming that orders 1–6 and 8–10 shipped on schedule:
- Calculate the customer service level using the percentage of orders that shipped on schedule.
 - Calculate the customer service level using the percentage of line orders that shipped on schedule.
 - Calculate the customer service level using the percentage of dollar volume that shipped on schedule.
 - Which of these measures would you recommend to Lissette?
27. Your new company has decided to use a periodic review system. You have learned that average weekly demand is 48 units per week with a standard deviation of 8 units. You believe that your cycle-service level should be 94 percent. Lead time is two weeks. Initially, you believe that you should do a review every Friday. Determine the required safety stock and the target inventory level.
- How would this procedure change if the cycle-service level needed to be 98 percent?
 - What is the impact of changing the review period from every Friday to every other Friday, assuming that the cycle-service level is 94 percent?
28. Michael’s Office Supply (MOS) sells office furniture, equipment, and supplies. This week the company has received 50 customer orders. Each order has an average of five line items. The average dollar amount of each order is \$1200. MOS was able to ship 47 of the 50 orders on schedule.
- Using the percentage of orders shipped on time, calculate the customer service level.
 - If Michael’s calculates customer service level by using the percentage of line items shipped on schedule, how many

line items must be shipped to achieve the same customer service level calculated in part (a)?

- (c) If Michael's calculates customer service level by the percentage of dollar volume shipped, how many dollars of product must be shipped to achieve the same customer service level calculated in part (a)?
- (d) What factors determine the customer service level measure that MOS should use?

29. My Kitchen Delights (MKD), a regional producer of gourmet jams and jellies, uses approximately 24,000 glass jars each month during its production. Because of space limitations, MKD orders 5000 jars at a time. Monthly holding cost is \$0.08 per jar, and the ordering cost is \$60 per order. The company operates 20 days per month.

- (a) What penalty cost is the company incurring by its present replenishment policy?
- (b) MKD would prefer to order eight times each month but needs to justify any change in order size. How much would ordering cost need to be reduced to justify a lot size of 3000 jars?
- (c) If MKD can reduce its ordering cost to \$30, what is the optimal replenishment order quantity?

30. My Kitchen Delights (MKD) is considering two new suppliers for the jars used in the production process. The quality at both suppliers is equal. Assume that the annual holding cost is 30 percent of the unit price. Monthly demand averages 20,000 jars. Ordering cost with these two suppliers is \$30 per order. The price lists for the suppliers are as follows:

Supplier A		Supplier B	
Quantity	Unit Price	Quantity	Unit Price
1–2499	\$3.00	1–1999	\$3.50
2500–3499	2.90	2000–2999	3.15
3500–4999	2.80	3000–3999	2.85
5000 or more	2.70	4000–4999	2.75
		5000 or more	2.60

- (a) Determine the optimal order quantity when using Supplier A.
- (b) Determine the optimal order quantity when using Supplier B.
- (c) Given MKD's lack of space, which supplier do you recommend be used? Justify your answer.

CASE: FabQual Ltd.

FabQual Ltd. manufactures parts and subassemblies for a number of small-volume manufacturers of specialized construction equipment, including bulldozers, graders, and cement mixers. FabQual also manufactures and distributes spare parts. The company has made a specialty of providing spare parts for equipment no longer in production; this includes wear parts that are no longer in production for any OEM.

The Materials Management Group (MMG) orders parts—both for delivery to a customer's production line and for spares—from the Fabrication Department. Spares are stocked in a finished goods store. FabQual's part number 650810/ss/R9/o is a wear part made only for spares demand. It has had demand averaging 300 units per week for more than a year, and this level of demand is expected to persist for at least four more years. The standard deviation of weekly demand is 50 units.

The MMG has been ordering 1300 units monthly of part number 650810/ss/R9/o from the Fabrication Department to meet the forecast annual demand of 15,600 units. The order is placed in the first week of each month. In order to provide Fabrication with scheduling flexibility, as well as to help with planning raw material requirements, a three-week manufacturing lead time is allowed for parts.

In the Fabrication Department, two hours is now allowed for each setup for a run of part number 650810/ss/R9/o. This time includes strip-down of the previous setup; delivery of raw materials, drawings, tools and fixtures, and the like; and buildup of the new setup. The two-hour setup time is a recent improvement over the previous four hours, as the result of setup reduction activities in the Fabrication Department. The Fabrication Department charges £20 per hour for setups. (If you prefer to work in

dollars, you can find the current exchange rate in the *Wall Street Journal*.) Part number 650810/ss/R9/o enters the finished goods stores at a full manufacturing cost of £55. The Financial Office requires a 25 percent per item per year cost for inventory planning and control. (This is your annual holding cost rate.)

Case Questions

1. What is the total annual cost of the present ordering policy for part number 650810/ss/R9/o?
2. What would be the lot size for part number 650810/ss/R9/o if FabQual were to use an economic order quantity (EOQ)?
3. What would be the total annual cost of using an economic order quantity for part number 650810/ss/R9/o?
4. What would be the reorder point for part number 650810/ss/R9/o if FabQual wanted a delivery performance of 95 percent? What would it be if the company wanted a delivery performance of 99 percent?
5. Under the present scheme—ordering 1300 units each month in the first week of each month—there are typically 700 to 800 units on hand when the new batch of 1300 units arrives toward the end of each month. What would be the impact on the overall inventory level of part number 650810/ss/R9/o of a change from the present order policy to an EOQ-based policy?
6. What are other implications of a change from the present scheme to one based on the economic order quantity? If this part is representative of a great many spare parts, what would be the overall impact?

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CASE: Kayaks! Incorporated

Kayaks! Incorporated manufactures a line of sea kayaks and accessories in a make-to-stock environment. These products are sold to boat dealers and major department stores throughout North America, which then sell these products to the final customer. Customers expect immediate receipt of the goods, so it is critical to have sufficient inventory held by the dealers and department stores. Aesha Grant, the materials manager at Kayaks! wants to make sure that the customer service level is being correctly calculated before she considers any changes to manufacturing. She has collected the following information for you to analyze and prepare a report on the customer service level being provided by Kayaks! Incorporated to the boat dealers and department stores.

Customer	Line Items	Dollar Value	Line Items Shipped on Schedule	Dollar Value on Schedule
1	2	2,000	2	2,000
2	17	40,000	16	37,500
3	9	16,000	9	16,000
4	7	9,500	6	9,000
5	24	68,000	22	64,000
6	4	6,000	4	6,000
7	7	14,000	7	14,000
8	3	14,000	3	14,000
9	9	6,000	7	4,800
10	12	18,500	11	18,000
11	7	16,000	7	16,000
12	12	14,000	11	11,000
13	11	19,500	9	15,000

Case Questions

1. Kayaks! Incorporated has always measured customer service as the number of complete orders that ship on schedule. Using this measure, calculate the customer service level provided by Kayaks! Incorporated.
2. Does this method of calculating the customer service level make sense for Kayaks! Incorporated?
3. What other methods might be useful in measuring Kayaks! customer service level? How would these affect your analysis of customer service?
4. What is your report to Aesha Grant with regard to the customer service being provided by Kayaks! Incorporated?

Customer	Line Items	Dollar Value	Line Items Shipped on Schedule	Dollar Value on Schedule
14	5	8,000	5	8,000
15	5	6,000	5	6,000
16	7	12,000	6	11,500
17	16	28,000	15	24,500
18	11	12,000	11	12,000
19	9	17,500	9	17,500
20	3	7,500	3	7,500
21	4	11,000	4	11,000
22	8	12,000	8	12,000
23	20	48,000	19	44,000
24	1	2,500	1	2,500
25	12	9,000	12	9,000
Totals	225	417,000	212	392,800

INTERACTIVE CASE Virtual Company

www.wiley.com/college/reid

On-line Case: Cruise International, Inc.

Assignment: *Innventory Management at Cruise International, Inc.*
In this assignment you will work with Andrew Jaworski, the cruise ship’s Medical Officer. He has a special offer from a supplier for a disposable syringe filled with a premeasured dosage of medicine to alleviate motion sickness, which needs to be evaluated. He has provided you with all the necessary information needed to analyze the quantity discount offered by the supplier. One additional concern comes from Peggy Johnson, the Corporate Medical Officer. The Food and Drug Administration (FDA) is currently testing a new motion sickness medicine that would make the other medicine obsolete. She believes there is a 10 percent chance of the new medicine receiving FDA approval and that we will know in approximately nine months. Your job is to

make a recommendation regarding this quantity discount offer. This assignment will enable you to enhance your knowledge of the material in Chapter 12 of your textbook and 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 **Inventory Management at CII**

INTERNET CHALLENGE Community Fund-Raiser (A)

Your nonprofit club holds a major fund-raiser for two weeks each year to support community improvement projects. The club sells packages of cookies throughout the community and donates the proceeds. The goal of the event is to raise at least \$40,000 for the community. This year you are in charge of the fund-raising event. Your first step is to search the Internet and identify at least three potential suppliers of the cookies to be sold this year. At least one of the suppliers should be in the immediate vicinity of your town or city.

From past fund-raisers, the club believes that an acceptable price of the cookies to the customers does not allow for more than a \$1 markup over the regular cost per package. However, if quantity discounts can be obtained, then the profit per package can exceed \$1. It is believed that regardless of the cookies sold, demand will be 40,000 packages. If you decide to buy more than 40,000 packages, any leftover cookies will be do-

nated to local shelters. Since you are a nonprofit organization, no tax advantage is gained.

For each of the potential suppliers, you need to identify the total cost associated with buying the packages of cookies. Be sure to consider transportation costs as well as any quantity discounts. Remember that your objective is to raise at least \$40,000 for the community. It is also important to consider the logistics of your plan. Will all of the cookies arrive at one time or will deliveries be spread over the two-week fund-raiser? Find out how far in advance you need to place your order and when payment for the cookies is due. Explain how you can be sure the cookies will arrive on time. You need to put together a report for your next meeting comparing your three suppliers and make a recommendation as to which supplier should be used, the quantity of cookies to purchase, the expected profit to be donated, and the logistics for the fund-raiser.

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
[Coffman Stairs—Division of Visador Company](#)
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- Find links for *Additional Web Resources* for this chapter
[Coffman Stairs, www.coffmanstairs.com/about.htm](#)
[Folbot, www.folbot.com/plant.tour.html](#)
[Universal Screenprinting, www.simon.ca/simonfr.htm](#)

Additional Resources Available Only in WileyPLUS:

- Use the *e-Book* and launch directly to all interactive resources
- Take the interactive *Quick Test* to check your understanding of the chapter material and get immediate feedback on your responses
- Check your understanding of the key vocabulary in the chapter with *Interactive Flash Cards*
- Use the *Animated Demo Problems* to review key problem types
- Practice for your tests with *additional problem sets*
- *And more!*

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