Inventory Management

CHAPTER 12

CHAPTER OUTLINE

GLOBAL COMPANY PROFILE: *Amazon.com*

Alaska Airlines

10 OM STRATEGY DECISIONS

- Design of Goods and Services
- Managing Quality
- Process Strategy
- Location Strategies
- Layout Strategies
- Human Resources
- Supply-Chain Management
- *Inventory Management*
  - ***Independent Demand (Ch. 12)***
  - Dependent Demand (Ch. 14)
  - Lean Operations (Ch. 16)
- Scheduling
- Maintenance

GLOBAL COMPANY PROFILE
Amazon.com

Inventory Management Provides Competitive Advantage at Amazon.com

When Jeff Bezos opened his revolutionary business in 1995, Amazon.com was intended to be a "virtual" retailer—no inventory, no warehouses, no overhead—just a bunch of computers taking orders for books and authorizing others to fill them. Things clearly didn't work out that way. Now, Amazon stocks millions of items of inventory, amid hundreds of thousands of bins on shelves in over 150 warehouses around the world. Additionally, Amazon's

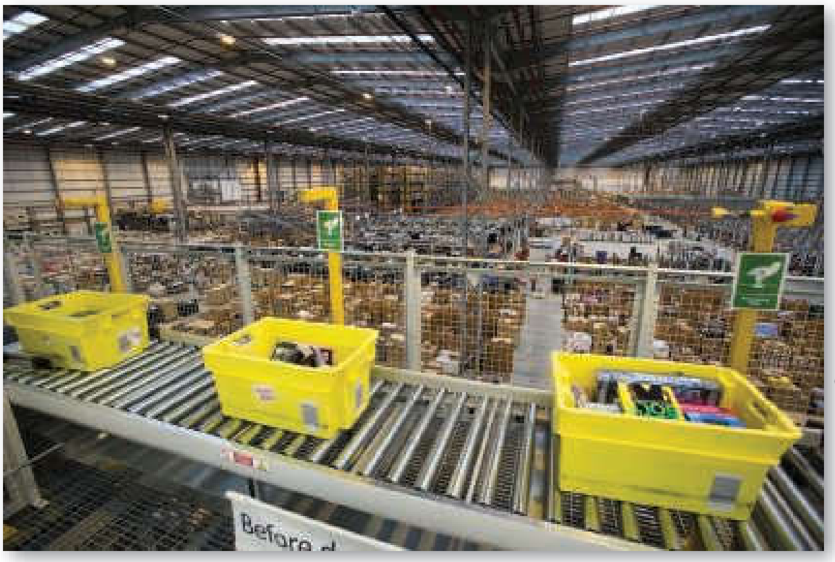
Marilyn Newton/Reno Gazette-Journal

1. You order three items, and a computer in Seattle takes charge. A computer assigns your order—a book, a game, and a digital camera—to one of Amazon's massive U.S. distribution centers.

2. The "flow meister" at the distribution center receives your order. She determines which workers go where to fill your order.

Bernhard Classen/Alamy

3. Amazon's current system doubles the picking speed of manual operators and drops the error rate to nearly zero.



Ben Cawthra/Sipa USA/Newscom

4. Your items are put into crates on moving belts. Each item goes into a large yellow crate that contains many customers' orders. When full, the crates ride a series of conveyor belts that wind more than 10 miles through the plant at a constant speed of 2.9 feet per second. The bar code on each item is scanned 15 times, by machines and by many of the 600 workers. The goal is to reduce errors to zero—returns are very expensive.

LEARNING OBJECTIVES

The Importance of Inventory

As Amazon.com well knows, inventory is one of the most expensive assets of many companies, representing as much as 50% of total invested capital. Operations managers around the globe have long recognized that good inventory management is crucial. On the one hand, a firm can reduce costs by reducing inventory. On the other hand, production may stop and customers become dissatisfied when an item is out of stock. *The objective of inventory management is to strike a balance between inventory investment and customer service.* You can never achieve a low-cost strategy without good inventory management.

All organizations have some type of inventory planning and control system. A bank has methods to control its inventory of cash. A hospital has methods to control blood supplies and pharmaceuticals. Government agencies, schools, and, of course, virtually every manufacturing and production organization are concerned with inventory planning and control.

In cases involving physical products, the organization must determine whether to produce goods or to purchase them. Once this decision has been made, the next step is to forecast demand, as discussed in Chapter 4. Then operations managers determine the inventory necessary to service that demand. In this chapter, we discuss the functions, types, and management of inventory. We then address two basic inventory issues: how much to order and when to order.

Functions of Inventory

VIDEO 12.1
Managing Inventory at Frito-Lay

Inventory can serve several functions that add flexibility to a firm's operations. The four functions of inventory are:

1. *To provide a selection of goods for anticipated customer demand and to separate the firm from fluctuations in that demand.* Such inventories are typical in retail establishments.
2. To *decouple various parts of the production process*. For example, if a firm's supplies fluctuate, extra inventory may be necessary to decouple the production process from suppliers.
3. To *take advantage of quantity discounts*, because purchases in larger quantities may reduce the cost of goods or their delivery.
4. To *hedge against inflation* and upward price changes.

Types of Inventory

Raw material inventory
Materials that are usually purchased but have yet to enter the manufacturing process.

Work-in-process (WIP) inventory
Products or components that are no longer raw materials but have yet to become finished products.

Maintenance/repair/operating (MRO) inventory
Maintenance, repair, and operating materials.

To accommodate the functions of inventory, firms maintain four types of inventories: (1) raw material inventory, (2) work-in-process inventory, (3) maintenance/repair/operating supply (MRO) inventory, and (4) finished-goods inventory.

Raw material inventory has been purchased but not processed. This inventory can be used to decouple (i.e., separate) suppliers from the production process. However, the preferred approach is to eliminate supplier variability in quality, quantity, or delivery time so that separation is not needed. **Work-in-process (WIP) inventory** is components or raw material that have undergone some change but are not completed. WIP exists because of the time it takes for a product to be made (called *cycle time*). Reducing cycle time reduces inventory. Often this task is not difficult: during most of the time a product is "being made," it is in fact sitting idle. As Figure 12.1 shows, actual work time, or "run" time, is a small portion of the material flow time, perhaps as low as 5%.

MROs are inventories devoted to **maintenance/repair/operating** supplies necessary to keep machinery and processes productive. They exist because the need and timing for maintenance and

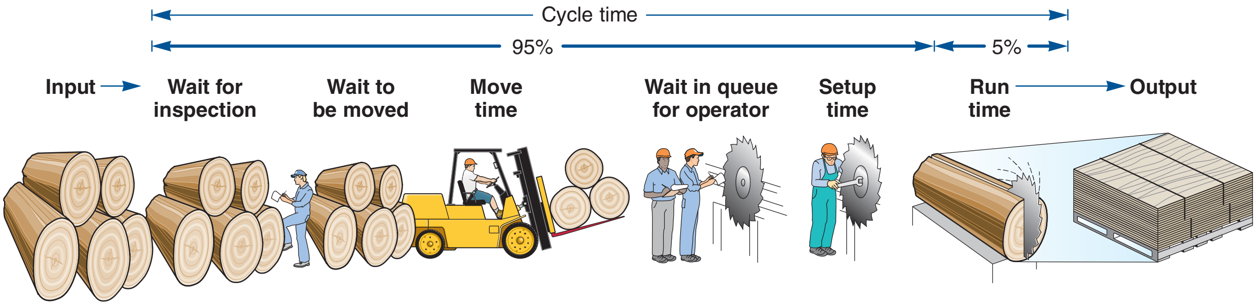


Figure 12.1

The Material Flow Cycle

Most of the time that work is in-process (95% of the cycle time) is not productive time.

repair of some equipment are unknown. Although the demand for MRO inventory is often a function of maintenance schedules, other unscheduled MRO demands must be anticipated. **Finished-goods inventory** is completed product awaiting shipment. Finished goods may be inventoried because future customer demands are unknown.

Finished-goods inventory
An end item ready to be sold, but still an asset on the company's books.

Managing Inventory

Operations managers establish systems for managing inventory. In this section, we briefly examine two ingredients of such systems: (1) how inventory items can be classified (called *ABC analysis*) and (2) how accurate inventory records can be maintained. We will then look at inventory control in the service sector.

ABC Analysis

ABC analysis divides on-hand inventory into three classifications on the basis of annual dollar volume. ABC analysis is an inventory application of what is known as the *Pareto principle* (named after Vilfredo Pareto, a 19th-century Italian economist). The Pareto principle states that there are a "critical few and trivial many." The idea is to establish inventory policies that focus resources on the *few critical* inventory parts and not the many trivial ones. It is not realistic to monitor inexpensive items with the same intensity as very expensive items.

ABC analysis
A method for dividing on-hand inventory into three classifications based on annual dollar volume.

To determine annual dollar volume for ABC analysis, we measure the *annual demand* of each inventory item times the *cost per unit*. *Class A* items are those on which the annual dollar volume is high. Although such items may represent only about 15% of the total inventory items, they represent 70% to 80% of the total dollar usage. *Class B* items are those inventory items of medium annual dollar volume. These items may represent about 30% of inventory items and 15% to 25% of the total value. Those with low annual dollar volume are *Class C*, which may represent only 5% of the annual dollar volume but about 55% of the total inventory items.

STUDENT TIP
A, B, and C categories need not be exact. The idea is to recognize that levels of control should match the risk.

Graphically, the inventory of many organizations would appear as presented in Figure 12.2.

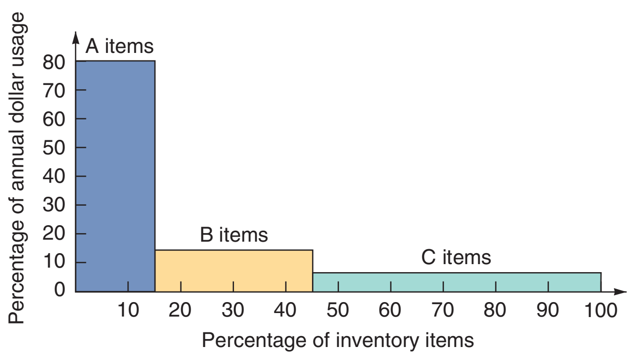


Figure 12.2

Graphic Representation of ABC Analysis

OM in Action — Retail's Last 10 Yards

Retail managers commit huge resources to inventory and its management. Even with retail inventory representing 36% of total assets, nearly 1 of 6 items a retail store thinks it has available to its customers is not! Amazingly, close to two-thirds of inventory records are wrong. Failure to have product available is due to poor ordering, poor stocking, mislabeling, merchandise exchange errors, and merchandise being in the wrong location. Despite major investments in bar coding, RFID, and IT, *the last 10 yards* of retail inventory management is a disaster.

The huge number and variety of stock keeping units (SKUs) at the retail level adds complexity to inventory management. Does the customer really need 32 different offerings of Crest toothpaste or 26 offerings of Colgate? The proliferation of SKUs increases confusion, store size, purchasing, inventory, and stocking costs, as well as subsequent markdown costs. With so many SKUs, stores have little space to stock and display a full case of many products, leading to labeling and "broken case" issues in the back room. Supervalu, the nation's 4th largest food retailer, is reducing the number of SKUs by 25% as one way to cut costs and add focus to its own store-branded items.

Reducing the variation in delivery lead time, improving forecasting accuracy, and cutting the huge variety of SKUs may all help. But reducing the number of SKUs may not improve customer service. Training and educating employees about the importance of inventory management may be a better way to improve the *last 10 yards.*

Sources: The Wall Street Journal (January 13, 2010); *Management Science* (February 2005); and *California Management Review* (Spring 2001).

2. *Tight control of incoming shipments:* This task is being addressed by many firms through the use of Universal Product Code (or bar code) and radio frequency ID (RFID) systems that read every incoming shipment and automatically check tallies against purchase orders. When properly designed, these systems—where each stock keeping unit (SKU; pronounced "skew") has its own identifier—can be very hard to defeat.
3. *Effective control of all goods leaving the facility:* This job is accomplished with bar codes, RFID tags, or magnetic strips on merchandise, and via direct observation. Direct observation can be personnel stationed at exits (as at Costco and Sam's Club wholesale stores) and in potentially high-loss areas or can take the form of one-way mirrors and video surveillance.

A handheld reader can scan RFID tags, aiding control of both incoming and outgoing shipments.

Successful retail operations require very good store-level control with accurate inventory in its proper location. Major retailers lose 10% to 25% of overall profits due to poor or inaccurate inventory records.[1] (See the *OM in Action* box, "Retail's Last 10 Yards.")

Inventory Models

We now examine a variety of inventory models and the costs associated with them.

VIDEO 12.2
Inventory Control at Wheeled Coach Ambulance

Independent vs. Dependent Demand

Inventory control models assume that demand for an item is either independent of or dependent on the demand for other items. For example, the demand for refrigerators is *independent* of the demand for toaster ovens. However, the demand for toaster oven components is *dependent* on the requirements of toaster ovens.

This chapter focuses on managing inventory where demand is *independent*. Chapter 14 presents *dependent* demand management.

Holding, Ordering, and Setup Costs

Holding costs are the costs associated with holding or "carrying" inventory over time. Therefore, holding costs also include obsolescence and costs related to storage, such as insurance, extra staffing, and interest payments. Table 12.1 shows the kinds of costs that need to be evaluated to determine holding costs. Many firms fail to include all the inventory holding costs. Consequently, inventory holding costs are often understated.

Holding cost
The cost to keep or carry inventory in stock.

Ordering cost includes costs of supplies, forms, order processing, purchasing, clerical support, and so forth. When orders are being manufactured, ordering costs also exist, but they are a part

Ordering cost
The cost of the ordering process.

TABLE 12.1 Determining Inventory Holding Costs

CATEGORY	COST (AND RANGE) AS A PERCENTAGE OF INVENTORY VALUE
Housing costs (building rent or depreciation, operating cost, taxes, insurance)	6% (3–10%)
Material-handling costs (equipment lease or depreciation, power, operating cost)	3% (1–3.5%)
Labor cost (receiving, warehousing, security)	3% (3–5%)
Investment costs (borrowing costs, taxes, and insurance on inventory)	11% (6–24%)
Pilferage, scrap, and obsolescence (much higher in industries undergoing rapid change like tablets and smart phones)	3% (2–5%)
Overall carrying cost	26%

Note: All numbers are approximate, as they vary substantially depending on the nature of the business, location, and current interest rates.

STUDENT TIP An overall inventory carrying cost of less than 15% is very unlikely, but this cost can exceed 40%, especially in high-tech and fashion industries.

Setup cost
The cost to prepare a machine or process for production.

Setup time
The time required to prepare a machine or process for production.

of what is called setup costs. **Setup cost** is the cost to prepare a machine or process for manufacturing an order. This includes time and labor to clean and change tools or holders. Operations managers can lower ordering costs by reducing setup costs and by using such efficient procedures as electronic ordering and payment.

In manufacturing environments, setup cost is highly correlated with **setup time**. Setups usually require a substantial amount of work even before a setup is actually performed at the work center. With proper planning, much of the preparation required by a setup can be done prior to shutting down the machine or process. Setup times can thus be reduced substantially. Machines and processes that traditionally have taken hours to set up are now being set up in less than a minute by the more imaginative world-class manufacturers. Reducing setup times is an excellent way to reduce inventory investment and to improve productivity.

Inventory Models for Independent Demand

In this section, we introduce three inventory models that address two important questions: *when to order* and *how much to order*. These *independent* demand models are:

1. Basic economic order quantity (EOQ) model
2. Production order quantity model
3. Quantity discount model

The Basic Economic Order Quantity (EOQ) Model

Economic order quantity (EOQ) model
An inventory-control technique that minimizes the total of ordering and holding costs.

The **economic order quantity (EOQ) model** is one of the most commonly used inventory-control techniques. This technique is relatively easy to use but is based on several assumptions:

1. Demand for an item is known, reasonably constant, and independent of decisions for other items.
2. Lead time—that is, the time between placement and receipt of the order—is known and consistent.
3. Receipt of inventory is instantaneous and complete. In other words, the inventory from an order arrives in one batch at one time.
4. Quantity discounts are not possible.
5. The only variable costs are the cost of setting up or placing an order (setup or ordering cost) and the cost of holding or storing inventory over time (holding or carrying cost). These costs were discussed in the previous section.
6. Stockouts (shortages) can be completely avoided if orders are placed at the right time.

LO 12.3 *Explain* and use the EOQ model for independent inventory demand

With these assumptions, the graph of inventory usage over time has a sawtooth shape, as in Figure 12.3. In Figure 12.3, Q represents the amount that is ordered. If this amount is 500 dresses, all 500 dresses arrive at one time (when an order is received). Thus, the inventory

Probabilistic Models and Safety Stock

Probabilistic model
A statistical model applicable when product demand or any other variable is not known but can be specified by means of a probability distribution.

Service level
The probability that demand will not be greater than supply during lead time. It is the complement of the probability of a stockout.

All the inventory models we have discussed so far make the assumption that demand for a product is constant and certain. We now relax this assumption. The following inventory models apply when product demand is not known but can be specified by means of a probability distribution. These types of models are called **probabilistic models**. Probabilistic models are a real-world adjustment because demand and lead time won't always be known and constant.

An important concern of management is maintaining an adequate service level in the face of uncertain demand. The **service level** is the *complement* of the probability of a stockout. For instance, if the probability of a stockout is 0.05, then the service level is .95. Uncertain demand raises the possibility of a stockout. One method of reducing stockouts is to hold extra units in inventory. As we noted earlier such inventory is referred to as safety stock. Safety stock involves adding a number of units as a buffer to the reorder point. As you recall:

$$\text{Reorder point} = \text{ROP} = d \times L$$

where d = Daily demand
L = Order lead time, or number of working days it takes to deliver an order

The inclusion of safety stock (ss) changed the expression to:

$$\text{ROP} = d \times L + ss \quad (12\text{-}11)$$

The amount of safety stock maintained depends on the cost of incurring a stockout and the cost of holding the extra inventory. Annual stockout cost is computed as follows:

$$\begin{aligned}\text{Annual stockout costs} = {} & \text{The sum of the units short for each demand level} \\ & \times \text{The probability of that demand level} \times \text{The stockout cost/unit} \\ & \times \text{The number of orders per year} \quad (12\text{-}12)\end{aligned}$$

Example 10 illustrates this concept.

Example 10

DETERMINING SAFETY STOCK WITH PROBABILISTIC DEMAND AND CONSTANT LEAD TIME

David Rivera Optical has determined that its reorder point for eyeglass frames is 50 ($d \times L$) units. Its carrying cost per frame per year is \$5, and stockout (or lost sale) cost is \$40 per frame. The store has experienced the following probability distribution for inventory demand during the lead time (reorder period). The optimum number of orders per year is six.

NUMBER OF UNITS	PROBABILITY
30	.2
40	.2
ROP → 50	.3
60	.2
70	.1
	1.0

How much safety stock should David Rivera keep on hand?

APPROACH ▶ The objective is to find the amount of safety stock that minimizes the sum of the additional inventory holding costs and stockout costs. The annual holding cost is simply the holding cost per unit multiplied by the units added to the ROP. For example, a safety stock of 20 frames, which implies that the new ROP, with safety stock, is 70 (= 50 + 20), raises the annual carrying cost by \$5(20) = \$100.

However, computing annual stockout cost is more interesting. For any level of safety stock, stockout cost is the expected cost of stocking out. We can compute it, as in Equation (12-12), by multiplying the number of frames short (Demand – ROP) by the probability of demand at that level, by the stockout cost, by the number of times per year the stockout can occur (which in our case is the number of orders per year). Then we add stockout costs for each possible stockout level for a given ROP.[4]

where $\sigma_{dLT} = \sqrt{(5 \text{ days} \times 16^2) + (150^2 \times 1^2)}$

$= \sqrt{(5 \times 256) + (22{,}500 \times 1)}$

$= \sqrt{1{,}280 + 22{,}500} = \sqrt{23{,}780} \cong 154$

So ROP $= (150 \times 5) + 1.645(154) \cong 750 + 253 = 1{,}003$ packs

INSIGHT ▶ When both demand and lead time are variable, the formula looks quite complex. But it is just the result of squaring the standard deviations in Equations (12-15) and (12-16) to get their variances, then summing them, and finally taking the square root.

LEARNING EXERCISE ▶ For an 80% service level, what is the ROP? [Answer: $Z = .84$ and ROP = 879 packs.]

RELATED PROBLEM ▶ 12.48

Single-Period Model

Single-period inventory model
A system for ordering items that have little or no value at the end of a sales period (perishables).

A **single-period inventory model** describes a situation in which *one* order is placed for a product. At the end of the sales period, any remaining product has little or no value. This is a typical problem for Christmas trees, seasonal goods, bakery goods, newspapers, and magazines. (Indeed, this inventory issue is often called the "newsstand problem.") In other words, even though items at a newsstand are ordered weekly or daily, they cannot be held over and used as inventory in the next sales period. So our decision is how much to order at the beginning of the period.

Because the exact demand for such seasonal products is never known, we consider a probability distribution related to demand. If the normal distribution is assumed, and we stocked and sold an average (mean) of 100 Christmas trees each season, then there is a 50% chance we would stock out and a 50% chance we would have trees left over. To determine the optimal stocking policy for trees before the season begins, we also need to know the standard deviation and consider these two marginal costs:

C_s = Cost of shortage (we underestimated) = Sales price per unit − Cost per unit

C_o = Cost of overage (we overestimated) = Cost per unit − Salvage value per unit (if there is any)

The service level, that is, the probability of *not* stocking out, is set at:

$$\text{Service level} = \frac{C_s}{C_s + C_o} \qquad (12\text{-}18)$$

Therefore, we should consider increasing our order quantity until the service level is equal to or more than the ratio of $[C_s/(C_s + C_o)]$.

This model, illustrated in Example 15, is used in many service industries, from hotels to airlines to bakeries to clothing retailers.

Example 15

SINGLE-PERIOD INVENTORY DECISION

Chris Ellis's newsstand, just outside the Smithsonian subway station in Washington, DC, usually sells 120 copies of the *Washington Post* each day. Chris believes the sale of the *Post* is normally distributed, with a standard deviation of 15 papers. He pays 70 cents for each paper, which sells for $1.25. The *Post* gives him a 30-cent credit for each unsold paper. He wants to determine how many papers he should order each day and the stockout risk for that quantity.

APPROACH ▶ Chris's data are as follows:

C_s = cost of shortage = \$1.25 − \$.70 = \$.55

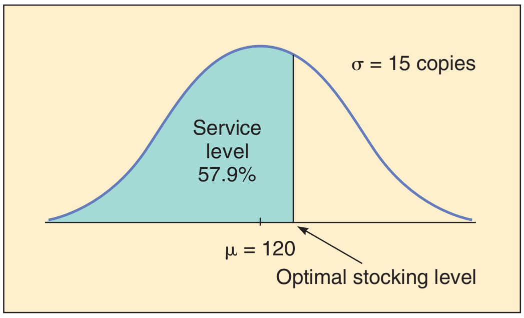
C_o = cost of overage = \$.70 − \$.30 (salvage value) = \$.40

Chris will apply Equation (12-18) and the normal table, using $\mu = 120$ and $\sigma = 15$.

SOLUTION ▶

a) Service level $= \frac{C_s}{C_s + C_o} = \frac{.55}{.55 + .40} = \frac{.55}{.95} = .579$

b) Chris needs to find the Z score for his normal distribution that yields a probability of .579.



So 57.9% of the area under the normal curve must be to the left of the optimal stocking level.

c) Using Appendix I or the Excel formula =NORMSINV(.578), for an area of .578, the Z value ≅ .195.

$$\text{Then, the optimal stocking level} = 120 \text{ copies} + (.195)(\sigma)$$
$$= 120 + (.195)(15) = 120 + 3 = 123 \text{ papers}$$

The stockout risk if Chris orders 123 copies of the *Post* each day is 1 − Service level = 1 − .578 = .422 = 42.2%.

INSIGHT ▶ If the service level is ever under .50, Chris should order fewer than 120 copies per day.

LEARNING EXERCISE ▶ How does Chris's decision change if the *Post* changes its policy and offers *no credit* for unsold papers, a policy many publishers are adopting?
[Answer: Service level = .44, Z = −.15. Therefore, stock 120 + (−.15)(15) = 117.75, or 118 papers.]

RELATED PROBLEMS ▶ 12.51, 12.52, 12.53

Fixed-quantity (Q) system
An ordering system with the same order amount each time.

Perpetual inventory system
A system that keeps track of each withdrawal or addition to inventory continuously, so records are always current.

Fixed-period (P) system
A system in which inventory orders are made at regular time intervals.

Fixed-Period (P) Systems

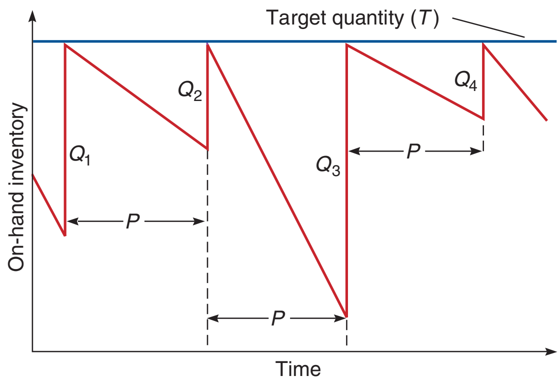
The inventory models that we have considered so far are **fixed-quantity**, or **Q, systems**. That is, the same fixed amount is added to inventory every time an order for an item is placed. We saw that orders are event triggered. When inventory decreases to the reorder point (ROP), a new order for Q units is placed.

To use the fixed-quantity model, inventory must be continuously monitored.[7] This requires a **perpetual inventory system**. Every time an item is added to or withdrawn from inventory, records must be updated to determine whether the ROP has been reached. In a **fixed-period system** (also called a periodic review, or **P system**), on the other hand, inventory is ordered at the end of a given period. Then, and only then, is on-hand inventory counted. Only the amount necessary to bring total inventory up to a prespecified target level (T) is ordered. Figure 12.9 illustrates this concept.

Figure **12.9**

Inventory Level in a Fixed-Period (P) System

Various amounts (Q_1, Q_2, Q_3, etc.) are ordered at regular time intervals (P) based on the quantity necessary to bring inventory up to the target quantity (T).



Fixed-period systems have several of the same assumptions as the basic EOQ fixed-quantity system:

- The only relevant costs are the ordering and holding costs.
- Lead times are known and constant.
- Items are independent of one another.

The downward-sloped lines in Figure 12.9 again represent on-hand inventory levels. But now, when the time between orders (P) passes, we place an order to raise inventory up to the target quantity (T).

The amount ordered during the first period may be Q_1, the second period Q_2, and so on. The Q_i value is the difference between current on-hand inventory and the target inventory level.

STUDENT TIP A fixed-period model potentially orders a different quantity each time.

The advantage of the fixed-period system is that there is no physical count of inventory items after an item is withdrawn—this occurs only when the time for the next review comes up. This procedure is also convenient administratively.

A fixed-period (*P*) system is appropriate when vendors make routine (i.e., at fixed-time interval) visits to customers to take fresh orders or when purchasers want to combine orders to save ordering and transportation costs (therefore, they will have the same review period for similar inventory items). For example, a vending machine company may come to refill its machines every Tuesday. This is also the case at Anheuser-Busch, whose sales reps may visit a store every 5 days.

The disadvantage of the *P* system is that because there is no tally of inventory during the review period, there is the possibility of a stockout during this time. This scenario is possible if a large order draws the inventory level down to zero right after an order is placed. Therefore, a higher level of safety stock (as compared to a fixed-quantity system) needs to be maintained to provide protection against stockout during both the time between reviews and the lead time.

Summary

Inventory represents a major investment for many firms. This investment is often larger than it should be because firms find it easier to have "just-in-case" inventory rather than "just-in-time" inventory. Inventories are of four types:

1. Raw material and purchased components
2. Work-in-process
3. Maintenance, repair, and operating (MRO)
4. Finished goods

In this chapter, we discussed independent inventory, ABC analysis, record accuracy, cycle counting, and inventory models used to control independent demands. The EOQ model, production order quantity model, and quantity discount model can all be solved using Excel, Excel OM, or POM for Windows software.

Key Terms

Ethical Dilemma

Wayne Hills Hospital in tiny Wayne, Nebraska, faces a problem common to large, urban hospitals as well as to small, remote ones like itself. That problem is deciding how much of each type of whole blood to keep in stock. Because blood is expensive and has a limited shelf life (up to 5 weeks under 1–6°C refrigeration), Wayne Hills naturally wants to keep its stock as low as possible. Unfortunately, past disasters such as a major tornado and a train wreck demonstrated that lives would be lost when not enough blood was available to handle massive needs. The hospital administrator wants to set an 85% service level based on demand over the past decade. Discuss the implications of this decision. What is the hospital's responsibility with regard to stocking lifesaving medicines with short shelf lives? How would you set the inventory level for a commodity such as blood?


Ginasanders/Fotolia

Discussion Questions

1. Describe the four types of inventory.
2. With the advent of low-cost computing, do you see alternatives to the popular ABC classifications?
3. What is the purpose of the ABC classification system?
4. Identify and explain the types of costs that are involved in an inventory system.
5. Explain the major assumptions of the basic EOQ model.
6. What is the relationship of the economic order quantity to demand? To the holding cost? To the setup cost?
7. Explain why it is not necessary to include product cost (price or price times quantity) in the EOQ model, but the quantity discount model requires this information.

8. What are the advantages of cycle counting?
9. What impact does a decrease in setup time have on EOQ?
10. When quantity discounts are offered, why is it not necessary to check discount points that are below the EOQ or points above the EOQ that are not discount points?
11. What is meant by "service level"?
12. Explain the following: All things being equal, the production order quantity will be larger than the economic order quantity.
13. Describe the difference between a fixed-quantity (Q) and a fixed-period (P) inventory system.
14. Explain what is meant by the expression "robust model." Specifically, what would you tell a manager who exclaimed, "Uh-oh, we're in trouble! The calculated EOQ is wrong; actual demand is 10% greater than estimated."
15. What is "safety stock"? What does safety stock provide safety against?
16. When demand is not constant, the reorder point is a function of what four parameters?
17. How are inventory levels monitored in retail stores?
18. State a major advantage, and a major disadvantage, of a fixed-period (P) system.

Using Software to Solve Inventory Problems

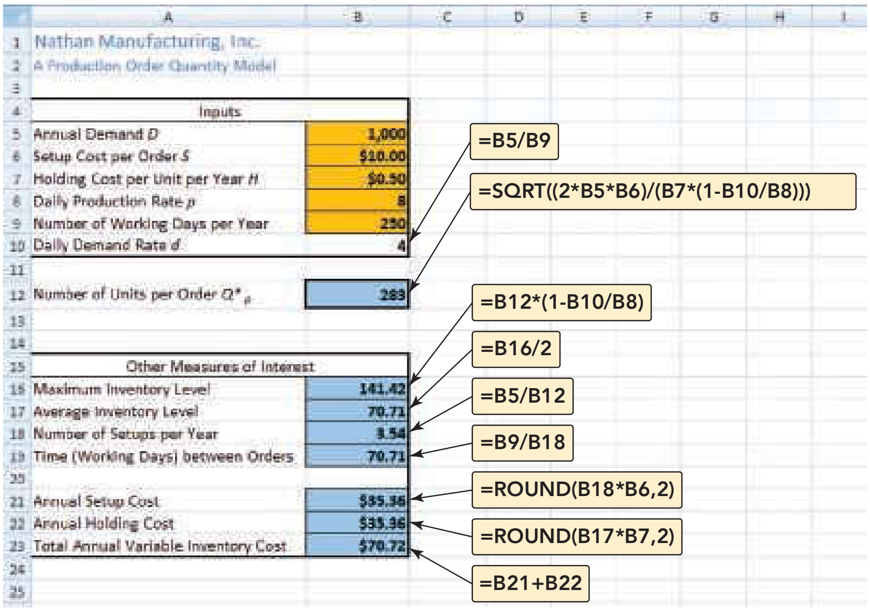
This section presents three ways to solve inventory problems with computer software. First, you can create your own Excel spreadsheets. Second, you can use the Excel OM software that comes free with this text. Third, POM for Windows, also free with this text, can solve all problems marked with a **P**.

CREATING YOUR OWN EXCEL SPREADSHEETS

Program 12.1 illustrates how you can make an Excel model to solve Example 8, which is a production order quantity model.

Program **12.1**

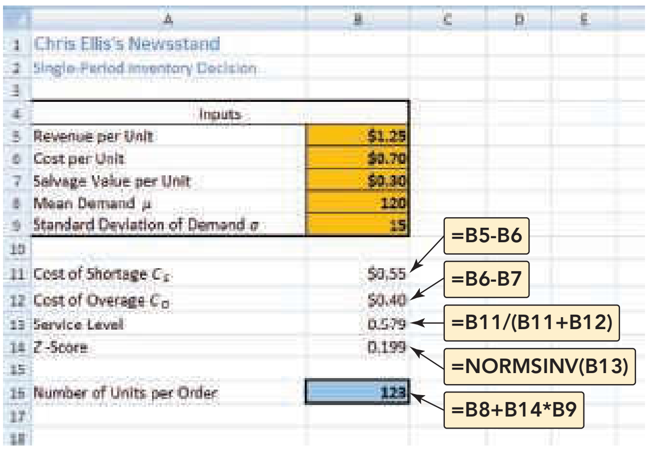
Using Excel for a Production Model, with Data from Example 8



Program 12.2 illustrates how you can make an Excel model to solve Example 15, which is a single-period inventory model.

Program **12.2**

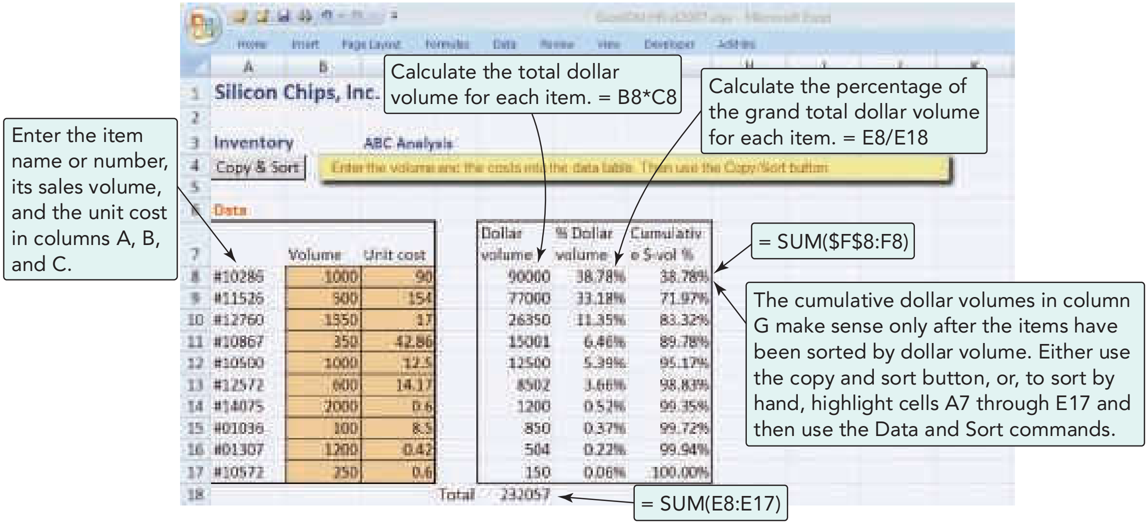
Using Excel for a Single-Period Inventory Model, with Data from Example 15



USING EXCEL OM

Excel OM allows us to easily model inventory problems ranging from ABC analysis, to the basic EOQ model, to the production model, to quantity discount situations.

Program 12.3 shows the input data, selected formulas, and results for an ABC analysis, using data from Example 1. After the data are entered, we use the *Data* and *Sort* Excel commands to rank the items from largest to smallest dollar volumes.



Program **12.3**

Using Excel OM for an ABC Analysis, with Data from Example 1

USING POM FOR WINDOWS

The POM for Windows Inventory module can also solve the entire EOQ family of problems. Please refer to Appendix IV for further details.

Solved Problems

Virtual Office Hours help is available in MyOMLab.

SOLVED PROBLEM 12.1

David Alexander has compiled the following table of six items in inventory at Angelo Products, along with the unit cost and the annual demand in units:

IDENTIFICATION CODE	UNIT COST ($)	ANNUAL DEMAND (UNITS)
XX1	5.84	1,200
B66	5.40	1,110
3CPO	1.12	896
33CP	74.54	1,104
R2D2	2.00	1,110
RMS	2.08	961

Use ABC analysis to determine which item(s) should be carefully controlled using a quantitative inventory technique and which item(s) should not be closely controlled.

SOLUTION

The item that needs strict control is 33CP, so it is an A item. Items that do not need to be strictly controlled are 3CPO, R2D2, and RMS; these are C items. The B items will be XX1 and B66.

CODE	ANNUAL DOLLAR VOLUME = UNIT COST × DEMAND
XX1	$ 7,008.00
B66	$ 5,994.00
3CPO	$ 1,003.52
33CP	$82,292.16
R2D2	$ 2,220.00
RMS	$ 1,998.88

Total cost = $100,516.56

70% of total cost = $70,347.92

SOLVED PROBLEM 12.2

The Warren W. Fisher Computer Corporation purchases 8,000 transistors each year as components in minicomputers. The unit cost of each transistor is $10, and the cost of carrying one transistor in inventory for a year is $3. Ordering cost is $30 per order.

What are (a) the optimal order quantity, (b) the expected number of orders placed each year, and (c) the expected time between orders? Assume that Fisher operates on a 200-day working year.

Problems

Note: Px means the problem may be solved with POM for Windows and/or Excel OM.

Problems 12.1–12.6 relate to Managing Inventory

•• **12.1** L. Houts Plastics is a large manufacturer of injection-molded plastics in North Carolina. An investigation of the company's manufacturing facility in Charlotte yields the information presented in the table below. How would the plant classify these items according to an ABC classification system? Px

L. Houts Plastics' Charlotte Inventory Levels

ITEM CODE #	AVERAGE INVENTORY (UNITS)	VALUE ($/UNIT)
1289	400	3.75
2347	300	4.00
2349	120	2.50
2363	75	1.50
2394	60	1.75
2395	30	2.00
6782	20	1.15
7844	12	2.05
8210	8	1.80
8310	7	2.00
9111	6	3.00

•• **12.2** Boreki Enterprises has the following 10 items in inventory. Theodore Boreki asks you, a recent OM graduate, to divide these items into ABC classifications.

ITEM	ANNUAL DEMAND	COST/UNIT
A2	3,000	$ 50
B8	4,000	12
C7	1,500	45
D1	6,000	10
E9	1,000	20
F3	500	500
G2	300	1,500
H2	600	20
I5	1,750	10
J8	2,500	5

a) Develop an ABC classification system for the 10 items.
b) How can Boreki use this information?
c) Boreki reviews the classification and then places item A2 into the A category. Why might he do so? Px

•• **12.3** Jean-Marie Bourjolly's restaurant has the following inventory items that it orders on a weekly basis:

INVENTORY ITEM	$ VALUE/CASE	# ORDERED/WEEK
Ribeye steak	135	3
Lobster tail	245	3
Pasta	23	12
Salt	3	2
Napkins	12	2
Tomato sauce	23	11
French fries	43	32
Pepper	3	3
Garlic powder	11	3
Trash can liners	12	3
Table cloths	32	5
Fish filets	143	10
Prime rib roasts	166	6
Oil	28	2
Lettuce (case)	35	24
Chickens	75	14
Order pads	12	2
Eggs (case)	22	7
Bacon	56	5
Sugar	4	2

a) Which is the most expensive item, using annual dollar volume?
b) Which are C items?
c) What is the annual dollar volume for all 20 items? Px

• **12.4** Lindsay Electronics, a small manufacturer of electronic research equipment, has approximately 7,000 items in its inventory and has hired Joan Blasco-Paul to manage its inventory. Joan has determined that 10% of the items in inventory are A items, 35% are B items, and 55% are C items. She would like to set up a system in which all A items are counted monthly (every 20 working days), all B items are counted quarterly (every 60 working days), and all C items are counted semiannually (every 120 working days). How many items need to be counted each day?

Additional problems **12.5–12.6** *are available in* MyOMLab.

Problems 12.7–12.40 relate to Inventory Models for Independent Demand

• **12.7** William Beville's computer training school, in Richmond, stocks workbooks with the following characteristics:

$$\text{Demand } D = 19{,}500 \text{ units/year}$$
$$\text{Ordering cost } S = \$25/\text{order}$$
$$\text{Holding cost } H = \$4/\text{unit/year}$$

a) Calculate the EOQ for the workbooks.
b) What are the annual holding costs for the workbooks?
c) What are the annual ordering costs? Px

• **12.8** If $D = 8{,}000$ per month, $S = \$45$ per order, and $H = \$2$ per unit per month,
a) What is the economic order quantity?
b) How does your answer change if the holding cost doubles?
c) What if the holding cost drops in half? Px

•• **12.9** Henry Crouch's law office has traditionally ordered ink refills 60 units at a time. The firm estimates that carrying cost is 40% of the $10 unit cost and that annual demand is about 240 units per year. The assumptions of the basic EOQ model are thought to apply.
a) For what value of ordering cost would its action be optimal?
b) If the true ordering cost turns out to be much greater than your answer to (a), what is the impact on the firm's ordering policy?

• **12.10** Matthew Liotine's Dream Store sells beds and assorted supplies. His best-selling bed has an annual demand of 400 units. Ordering cost is $40; holding cost is $5 per unit per year.

DEMAND DURING LEAD TIME (KILOS)	PROBABILITY
0	0.1
100	0.1
200	0.2
300	0.4
400	0.2

• • • **12.45** Mr. Beautiful, an organization that sells weight training sets, has an ordering cost of $40 for the BB-1 set. (BB-1 stands for Body Beautiful Number 1.) The carrying cost for BB-1 is $5 per set per year. To meet demand, Mr. Beautiful orders large quantities of BB-1 seven times a year. The stockout cost for BB-1 is estimated to be $50 per set. Over the past several years, Mr. Beautiful has observed the following demand during the lead time for BB-1:

DEMAND DURING LEAD TIME	PROBABILITY
40	.1
50	.2
60	.2
70	.2
80	.2
90	.1
	1.0

The reorder point for BB-1 is 60 sets. What level of safety stock should be maintained for BB-1?

• • **12.46** Chicago's Hard Rock Hotel distributes a mean of 1,000 bath towels per day to guests at the pool and in their rooms. This demand is normally distributed with a standard deviation of 100 towels per day, based on occupancy. The laundry firm that has the linens contract requires a 2-day lead time. The hotel expects a 98% service level to satisfy high guest expectations.

a) What is the safety stock?
b) What is the ROP?

• • **12.47** First Printing has contracts with legal firms in San Francisco to copy their court documents. Daily demand is almost constant at 12,500 pages of documents. The lead time for paper delivery is normally distributed with a mean of 4 days and a standard deviation of 1 day. A 97% service level is expected. Compute First's ROP.

• • • **12.48** Gainesville Cigar stocks Cuban cigars that have variable lead times because of the difficulty in importing the product: lead time is normally distributed with an average of 6 weeks and a standard deviation of 2 weeks. Demand is also a variable and normally distributed with a mean of 200 cigars per week and a standard deviation of 25 cigars.

a) For a 90% service level, what is the ROP?
b) What is the ROP for a 95% service level?
c) Explain what these two service levels mean. Which is preferable?

• • • • **12.49** A gourmet coffee shop in downtown San Francisco is open 200 days a year and sells an average of 75 pounds of Kona coffee beans a day. (Demand can be assumed to be distributed normally, with a standard deviation of 15 pounds per day.) After ordering (fixed cost = $16 per order), beans are always shipped from Hawaii within exactly 4 days. Per-pound annual holding costs for the beans are $3.

a) What is the economic order quantity (EOQ) for Kona coffee beans?
b) What are the total annual holding costs of stock for Kona coffee beans?
c) What are the total annual ordering costs for Kona coffee beans?
d) Assume that management has specified that no more than a 1% risk during stockout is acceptable. What should the reorder point (ROP) be?
e) What is the safety stock needed to attain a 1% risk of stockout during lead time?
f) What is the annual holding cost of maintaining the level of safety stock needed to support a 1% risk?
g) If management specified that a 2% risk of stockout during lead time would be acceptable, would the safety stock holding costs decrease or increase?

Additional problem **12.50** *is available in* MyOMLab.

Problems 12.51–12.53 relate to Single-Period Model

• • **12.51** Cynthia Knott's oyster bar buys fresh Louisiana oysters for $5 per pound and sells them for $9 per pound. Any oysters not sold that day are sold to her cousin, who has a nearby grocery store, for $2 per pound. Cynthia believes that demand follows the normal distribution, with a mean of 100 pounds and a standard deviation of 15 pounds. How many pounds should she order each day?

• • **12.52** Henrique Correa's bakery prepares all its cakes between 4 A.M. and 6 A.M. so they will be fresh when customers arrive. Day-old cakes are virtually always sold, but at a 50% discount off the regular $10 price. The cost of baking a cake is $6, and demand is estimated to be normally distributed, with a mean of 25 and a standard deviation of 4. What is the optimal stocking level?

• • • **12.53** University of Florida football programs are printed 1 week prior to each home game. Attendance averages 90,000 screaming and loyal Gators fans, of whom two-thirds usually buy the program, following a normal distribution, for $4 each. Unsold programs are sent to a recycling center that pays only 10 cents per program. The standard deviation is 5,000 programs, and the cost to print each program is $1.

a) What is the cost of underestimating demand for each program?
b) What is the overage cost per program?
c) How many programs should be ordered per game?
d) What is the stockout risk for this order size?

CASE STUDIES

Zhou Bicycle Company

Zhou Bicycle Company (ZBC), located in Seattle, is a wholesale distributor of bicycles and bicycle parts. Formed in 1981 by University of Washington Professor Yong-Pin Zhou, the firm's primary retail outlets are located within a 400-mile radius of the distribution center. These retail outlets receive the order from ZBC within 2 days after notifying the distribution center, provided that the stock is available. However, if an order is not fulfilled by the company, no backorder is placed; the retailers arrange to get their shipment from other distributors, and ZBC loses that amount of business.

Frito-Lay's product-focused facility represents a major capital investment. That investment must achieve high utilization to be efficient. The capital cost must be spread over a substantial volume to drive down total cost of the snack foods produced. This demand for high utilization requires reliable equipment and tight schedules. Reliable machinery requires an inventory of critical components: this is known as MRO, or maintenance, repair, and operating supplies. MRO inventory of motors, switches, gears, bearings, and other critical specialized components can be costly but is necessary.

Frito-Lay's non-MRO inventory moves rapidly. Raw material quickly becomes work-in-process, moving through the system and out the door as a bag of chips in about $1\frac{1}{2}$ shifts. Packaged finished products move from production to the distribution chain in less than 1.4 days.

Discussion Questions*

1. How does the mix of Frito-Lay's inventory differ from those at a machine or cabinet shop (a process-focused facility)?
2. What are the major inventory items at Frito-Lay, and how rapidly do they move through the process?
3. What are the four types of inventory? Give an example of each at Frito-Lay.
4. How would you rank the dollar investment in each of the four types (from the most investment to the least investment)?
5. Why does inventory flow so quickly through a Frito-Lay plant?
6. Why does the company keep so many plants open?
7. Why doesn't Frito-Lay make all its 41 products at each of its plants?

*You may wish to view the video that accompanies this case before addressing these questions.

Inventory Control at Wheeled Coach

Video Case

Controlling inventory is one of Wheeled Coach's toughest problems. Operating according to a strategy of mass customization and responsiveness, management knows that success is dependent on tight inventory control. Anything else results in an inability to deliver promptly, chaos on the assembly line, and a huge inventory investment. Wheeled Coach finds that almost 50% of the cost of every ambulance it manufactures is purchased materials. A large proportion of that 50% is in chassis (purchased from Ford), aluminum (from Reynolds Metal), and plywood used for flooring and cabinetry construction (from local suppliers). Wheeled Coach tracks these A inventory items quite carefully, maintaining tight security/control and ordering carefully so as to maximize quantity discounts while minimizing on-hand stock. Because of long lead times and scheduling needs at Reynolds, aluminum must actually be ordered as much as 8 months in advance.

In a crowded ambulance industry in which it is the only giant, its 45 competitors don't have the purchasing power to draw the same discounts as Wheeled Coach. But this competitive cost advantage cannot be taken lightly, according to President Bob Collins. "Cycle counting in our stockrooms is critical. No part can leave the locked stockrooms without appearing on a bill of materials."

Accurate bills of material (BOM) are a requirement if products are going to be built on time. Additionally, because of the custom nature of each vehicle, most orders are won only after a bidding process. Accurate BOMs are critical to cost estimation and the resulting bid. For these reasons, Collins was emphatic that Wheeled Coach maintain outstanding inventory control. The *Global Company Profile* featuring Wheeled Coach (which opens Chapter 14) provides further details about the ambulance inventory control and production process.

Discussion Questions*

1. Explain how Wheeled Coach implements ABC analysis.
2. If you were to take over as inventory control manager at Wheeled Coach, what additional policies and techniques would you initiate to ensure accurate inventory records?
3. How would you go about implementing these suggestions?

*You may wish to view the video that accompanies this case before addressing these questions.

- **Additional Case Studies:** Visit MyOMLab for these free case studies:
  Southwestern University (F): The university must decide how many football day programs to order, and from whom.
  LaPlace Power and Light: This utility company is evaluating its current inventory policies.

Endnotes

1. See E. Malykhina, "Retailers Take Stock," *Information Week* (February 7, 2005): 20–22, and A. Raman, N. DeHoratius, and Z. Ton, "Execution: The Missing Link in Retail Operations," *California Management Review* 43, no. 3 (Spring 2001): 136–141.
2. This is the case when holding costs are linear and begin at the origin—that is, when inventory costs do not decline (or they increase) as inventory volume increases and all holding costs are in small increments. In addition, there is probably some learning each time a setup (or order) is executed—a fact that lowers subsequent setup costs. Consequently, the EOQ model is probably a special case. However, we abide by the conventional wisdom that this model is a reasonable approximation.
3. The formula for the economic order quantity (Q^*) can also be determined by finding where the total cost curve is at a minimum (i.e., where the slope of the total cost curve is zero). Using calculus, we set the derivative of the total cost with respect to Q^* equal to 0. The calculations for finding the minimum of

$$TC = \frac{D}{Q}S + \frac{Q}{2}H + PD$$

are

$$\frac{d(TC)}{dQ} = \left(\frac{-DS}{Q^2}\right) + \frac{H}{2} + 0 = 0$$

Thus, $Q^* = \sqrt{\frac{2DS}{H}}$

4. The number of units short, Demand–ROP, is true only when Demand–ROP is non-negative.
5. Equations (12-15), (12-16), and (12-17) are expressed in days; however, they could equivalently be expressed in weeks, months, or even years. Just be consistent, and use the same time units for all terms in the equations.
6. Note that Equation (12-17) can also be expressed as:

$$\text{ROP} = \text{Average daily demand} \times \text{Average lead time} + Z\sqrt{(\text{Average lead time} \times \sigma_d^2) + \bar{d}^2\sigma_{LT}^2}.$$

7. OM managers also call these *continuous review systems*.

Chapter 12 *Rapid* Review

Main Heading	Review Material	MyOMLab
THE IMPORTANCE OF INVENTORY (pp. 490–491)	Inventory is one of the most expensive assets of many companies. *The objective of inventory management is to strike a balance between inventory investment and customer service.* The two basic inventory issues are how much to order and when to order. ■ **Raw material inventory**—Materials that are usually purchased but have yet to enter the manufacturing process. ■ **Work-in-process (WIP) inventory**—Products or components that are no longer raw materials but have yet to become finished products. ■ **MRO inventory**—Maintenance, repair, and operating materials. ■ **Finished-goods inventory**—An end item ready to be sold but still an asset on the company's books.	Concept Questions: 1.1–1.4 **VIDEO 12.1** Managing Inventory at Frito-Lay
MANAGING INVENTORY (pp. 491–495)	■ **ABC analysis**—A method for dividing on-hand inventory into three classifications based on annual dollar volume. ■ **Cycle counting**—A continuing reconciliation of inventory with inventory records. ■ **Shrinkage**—Retail inventory that is unaccounted for between receipt and sale. ■ **Pilferage**—A small amount of theft.	Concept Questions: 2.1–2.4 Problems: 12.1–12.6 Virtual Office Hours for Solved Problem: 12.1
INVENTORY MODELS (pp. 495–496)	■ **Holding cost**—The cost to keep or carry inventory in stock. ■ **Ordering cost**—The cost of the ordering process. ■ **Setup cost**—The cost to prepare a machine or process for production. ■ **Setup time**—The time required to prepare a machine or process for production.	Concept Questions: 3.1–3.4 **VIDEO 12.2** Inventory Control at Wheeled Coach Ambulance
INVENTORY MODELS FOR INDEPENDENT DEMAND (pp. 496–507)	■ **Economic order quantity (EOQ) model**—An inventory-control technique that minimizes the total of ordering and holding costs: $Q^* = \sqrt{\frac{2DS}{H}}$ (12-1) Expected number of orders $= N = \frac{\text{Demand}}{\text{Order quantity}} = \frac{D}{Q^*}$ (12-2) Expected time between orders $= T = \frac{\text{Number of working days per year}}{N}$ (12-3) Total annual cost = Setup (order) cost + Holding cost (12-4) $TC = \frac{D}{Q}S + \frac{Q}{2}H$ (12-5) ■ **Robust**—Giving satisfactory answers even with substantial variation in the parameters. ■ **Lead time**—In purchasing systems, the time between placing an order and receiving it; in production systems, the wait, move, queue, setup, and run times for each component produced. ■ **Reorder point (ROP)**—The inventory level (point) at which action is taken to replenish the stocked item. *ROP for known demand:* ROP = Demand per day × Lead time for a new order in days $= d \times L$ (12-6) ■ **Safety stock (*ss*)**—Extra stock to allow for uneven demand; a buffer. ■ **Production order quantity model**—An economic order quantity technique applied to production orders: $Q_p^* = \sqrt{\frac{2DS}{H[1-(d/p)]}}$ (12-7) $Q_p^* = \sqrt{\frac{2DS}{H\left(1 - \frac{\text{Annual demand rate}}{\text{Annual production rate}}\right)}}$ (12-8) ■ **Quantity discount**—A reduced price for items purchased in large quantities: $TC = \frac{D}{Q}S + \frac{Q}{2}H + PD$ (12-9) $Q^* = \sqrt{\frac{2DS}{IP}}$ (12-10)	Concept Questions: 4.1–4.4 Problems: 12.7–12.40 Virtual Office Hours for Solved Problems: 12.2–12.5 **ACTIVE MODELS 12.1, 12.2**

Chapter 12 Rapid Review continued

Main Heading	Review Material	MyOMLab
PROBABILISTIC MODELS AND SAFETY STOCK (pp. 508–513)	■ **Probabilistic model**—A statistical model applicable when product demand or any other variable is not known but can be specified by means of a probability distribution. ■ **Service level**—The complement of the probability of a stockout. *ROP for unknown demand:* $\text{ROP} = d \times L + ss$ (12-11) Annual stockout costs = The sum of the units short for each demand level × The probability of that demand level × The stockout cost/unit × The number of orders per year (12-12) *ROP for unknown demand and given service level:* $\text{ROP} = \text{Expected demand during lead time} + Z\sigma_{dLT}$ (12-13) $\text{Safety stock} = Z\sigma_{dLT}$ (12-14) *ROP for variable demand and constant lead time:* $\text{ROP} = (\text{Average daily demand} \times \text{Lead time in days}) + Z\sigma_{dLT}$ (12-15) *ROP for constant demand and variable lead time:* $\text{ROP} = (\text{Daily demand} \times \text{Average lead time in days}) + Z \times \text{Daily demand} \times \sigma_{LT}$ (12-16) *ROP for variable demand and variable lead time:* $\text{ROP} = (\text{Average daily demand} \times \text{Average lead time in days}) + Z\sigma_{dLT}$ (12-17) In each case, $\sigma_{dLT} = \sqrt{(\text{Average lead time} \times \sigma_d^2) + \bar{d}^2\sigma_{LT}^2}$ but under constant demand: $\sigma_d^2 = 0$, and under constant lead time: $\sigma_{LT}^2 = 0$.	Concept Questions: 5.1–5.4 Problems: 12.41–12.50 Virtual Office Hours for Solved Problems: 12.6–12.9
SINGLE-PERIOD MODEL (pp. 513–514)	■ **Single-period inventory model**—A system for ordering items that have little or no value at the end of the sales period: $\text{Service level} = \dfrac{C_s}{C_s + C_o}$ (12-18)	Concept Questions: 6.1–6.4 Problems: 12.51–12.53
FIXED-PERIOD (*P*) SYSTEMS (pp. 514–515)	■ **Fixed-quantity (*Q*) system**—An ordering system with the same order amount each time. ■ **Perpetual inventory system**—A system that keeps track of each withdrawal or addition to inventory continuously, so records are always current. ■ **Fixed-period (*P*) system**—A system in which inventory orders are made at regular time intervals.	Concept Questions: 7.1–7.4

Self Test

■ **Before taking the self-test,** refer to the learning objectives listed at the beginning of the chapter and the key terms listed at the end of the chapter.

LO 12.1 ABC analysis divides on-hand inventory into three classes, based on:
- **a)** unit price.
- **b)** the number of units on hand.
- **c)** annual demand.
- **d)** annual dollar values.

LO 12.2 Cycle counting:
- **a)** provides a measure of inventory turnover.
- **b)** assumes that all inventory records must be verified with the same frequency.
- **c)** is a process by which inventory records are periodically verified.
- **d)** all of the above.

LO 12.3 The two most important inventory-based questions answered by the typical inventory model are:
- **a)** when to place an order and the cost of the order.
- **b)** when to place an order and how much of an item to order.
- **c)** how much of an item to order and the cost of the order.
- **d)** how much of an item to order and with whom the order should be placed.

LO 12.4 Extra units in inventory to help reduce stockouts are called:
- **a)** reorder point.
- **b)** safety stock.
- **c)** just-in-time inventory.
- **d)** all of the above.

LO 12.5 The difference(s) between the basic EOQ model and the production order quantity model is(are) that:
- **a)** the production order quantity model does not require the assumption of known, constant demand.
- **b)** the EOQ model does not require the assumption of negligible lead time.
- **c)** the production order quantity model does not require the assumption of instantaneous delivery.
- **d)** all of the above.

LO 12.6 The EOQ model with quantity discounts attempts to determine:
- **a)** the lowest amount of inventory necessary to satisfy a certain service level.
- **b)** the lowest purchase price.
- **c)** whether to use a fixed-quantity or fixed-period order policy.
- **d)** how many units should be ordered.
- **e)** the shortest lead time.

LO 12.7 The appropriate level of safety stock is typically determined by:
- **a)** minimizing an expected stockout cost.
- **b)** choosing the level of safety stock that assures a given service level.
- **c)** carrying sufficient safety stock so as to eliminate all stockouts.
- **d)** annual demand.

Answers: LO 12.1. d; LO 12.2. c; LO 12.3. b; LO 12.4. b; LO 12.5. c; LO 12.6. d; LO 12.7. b.