Chapter 28

Advanced Issues in Cash Management and Inventory Control[1]

Chapters 22 and 27 presented the basic elements of current asset management and short-term financing. This chapter provides a more in-depth treatment of several working capital topics, including (1) the target cash balance, (2) inventory control systems, (3) accounting treatments for inventory, and (4) the EOQ model.

The Concept of Zero Working Capital

FM e-resource

The textbook's Web site contains an Excel *file that will guide you through the chapter's calculations. The file for this chapter is* ***FM11 Ch 28 Tool Kit.xls,*** *and we encourage you to open the file and follow along as you read the chapter.*

At first glance, it might seem that working capital management is not as important as capital budgeting, dividend policy, and other decisions that determine a firm's long-term direction. However, in today's world of intense global competition, working capital management is receiving increasing attention from managers striving for peak efficiency. In fact, the goal of many leading companies today—including American Standard, Campbell Soup, General Electric, Quaker Oats, and Whirlpool—is *zero working capital*. Proponents of the zero working capital concept claim that a movement toward this goal not only generates cash but also speeds up production and helps businesses make more timely deliveries and operate more efficiently. The concept has its own definition of working capital: Inventories + Receivables − Payables. The rationale here is (1) that inventories and receivables are the keys to making sales, but (2) that inventories can be financed by suppliers through accounts payable.

On average, companies use about 20 cents of working capital for each dollar of sales. So, on average, working capital is turned over five times per year. Reducing working capital and thus increasing turnover has two major financial benefits. First, every dollar freed up by reducing inventories or receivables, or by increasing payables, results in a one-time contribution to cash flow. Second, a movement toward zero working capital permanently raises a company's earnings. Like all capital, funds invested in working capital cost money, so reducing those funds yields permanent savings in capital costs. In addition to the financial benefits, reducing working capital forces a company to produce and deliver faster than its competitors, which helps it gain new business and charge premium prices for providing good services. As inventories disappear, warehouses can be sold off, both labor and handling equipment needs are reduced, and obsolete and/or out-of-style goods are minimized.

To illustrate the benefits of striving for zero working capital, in just one year Campbell Soup pared its working capital by $80 million. It used the cash to develop new products and to buy companies in Britain, Australia, and other countries.

[1]All or parts of this chapter may be omitted without loss of continuity.

Equally important, the company expects to increase annual profits by $50 million over the next few years by lowering overtime labor and storage costs.

The most important factor in moving toward zero working capital is increased speed. If the production process is fast enough, companies can produce items as they are ordered rather than having to forecast demand and build up large inventories that are managed by bureaucracies. The best companies are able to start production after an order is received yet still meet customer delivery requirements. This system is known as *demand flow,* or *demand-based management,* and it builds on the just-in-time method of inventory control that we will discuss later in this chapter. However, demand flow management is broader than just-in-time, because it requires that all elements of a production system operate quickly and efficiently.

Achieving zero working capital requires that every order and part move at maximum speed, which generally means replacing paper with electronic data. Then, orders streak from the processing department to the plant, flexible production lines produce each product every day, and finished goods flow directly from the production line onto waiting trucks or rail cars. Instead of cluttering plants or warehouses with inventories, products move directly into the pipeline. As efficiency rises, working capital dwindles.

Clearly, it is not possible for most firms to achieve zero working capital and infinitely efficient production. Still, a focus on minimizing cash, receivables, and inventories while maximizing payables will help a firm lower its investment in working capital and achieve financial and production economies.

SELF-TEST QUESTION

What is the basic idea of zero working capital, and how is working capital defined for this purpose?

SETTING THE TARGET CASH BALANCE

Recall from Chapter 22 that firms hold cash balances primarily for two reasons: to pay for *transactions* they must make in their day-to-day operations and to maintain *compensating balances* that banks may require in return for loans. In addition, firms maintain additional cash balances as a *precaution* against unforeseen fluctuations in cash flows and in order to take advantage of *trade discounts*. Given that cash is necessary for these purposes, but is also a nonearning asset, the primary goal of cash management is to minimize the amount of cash a firm holds, while maintaining a sufficient *target cash balance* to conduct business.

In Chapter 22, when we discussed MicroDrive Inc.'s cash budget, we took as a given the $10 million target cash balance. We also discussed how lockboxes, synchronizing inflows and outflows, and float can reduce the required cash balance. Now we consider how target cash balances are set in practice.

Note (1) that cash per se earns no return, (2) that it is an asset that appears on the left side of the balance sheet, (3) that cash holdings must be financed by raising either debt or equity, and (4) that both debt and equity capital have a cost. If cash holdings could be reduced without hurting sales or other aspects of a firm's operations, this reduction would permit a reduction in either debt or equity, or both, which would increase the return on capital and thus boost the value of the firm's stock. *Therefore, the general operating goal of the cash manager is to minimize the amount of cash held subject to the constraint that enough cash be held to enable the firm to operate efficiently*.

For most firms, cash as a percentage of assets and/or sales has declined sharply in recent years as a direct result of technological developments in computers and telecommunications. Years ago, it was difficult to move money from one location to another, and it was also difficult to forecast exactly how much cash would be needed in different locations at different points in time. As a result, firms had to hold relatively large "safety stocks" of cash to be sure they had enough when and where it was needed. Also, they held relatively large amounts of short-term securities as a backup, and they also had backup lines of credit that permitted them to borrow on short notice to build up the cash account if it became depleted.

Now think how computers and telecommunications affect the situation. With a good computer system, tied together with good telecommunications links, a company can get real-time information on its cash balances, whether it operates in a single location or all over the world. Further, it can use statistical procedures to forecast cash inflows and outflows, and good forecasts reduce the need for safety stocks. Finally, improvements in telecommunications systems make it possible for a treasurer to replenish his or her cash accounts within minutes by simply calling a lender and stating that the firm wants to borrow a given amount under its line of credit. The lender then wires the funds to the desired location. Similarly, marketable securities can be sold with close to the same speed and with the same minimal transactions costs.

General Telephone (Gen Tel) can be used to illustrate this. Gen Tel knows exactly how much it must pay and when, and it can forecast quite accurately when it will receive checks. For example, the treasurer of Gen Tel's Florida operation knows when the major employers in Tampa pay their workers and how long after that people generally pay their phone bills. Armed with this information, Gen Tel's Florida treasurer can forecast with great accuracy any cash surpluses or deficits on a daily basis. Of course, no forecast will be exact, so light overages or underages will occur. But this presents no problem. The treasurer knows by 11 A.M. the checks that must be covered by 4 P.M. that day, how much cash has come in, and consequently how much of a cash surplus or deficit will exist. Then a simple phone call is made, and the company borrows to cover any deficit or buys securities (or pays off outstanding loans) with any surplus. Thus, Gen Tel can maintain cash balances that are very close to zero, a situation that would have been impossible a few years ago.

Today, cash management in reasonably sophisticated firms is largely a job for systems people, and, except for the very largest firms, it is generally most efficient to have a bank handle the actual operations of the cash management system. Banks do this for a living, and there are economies of scale in operating cash management systems. Also, many banks are willing and able to offer such services, so competition has driven the cost of cash management down to a reasonable level. Still, it is essential that corporate treasurers know enough about cash management procedures to be able to negotiate and then work with the banks to ensure that they get the best price (interest rate) on credit lines, the best yield on short-term investments, and a reasonable cost for other banking services. To provide perspective on these issues, we discuss next a theoretical model for cash balances plus a practical approach to setting the target cash balance.

The Baumol Model

William Baumol first noted that cash balances are, in many respects, similar to inventories, and that the EOQ inventory model, which will be developed in a later section, can be used to establish a target cash balance.[2] Baumol's model assumes that the firm uses cash at a steady, predictable rate—say, $1,000,000 per week—and that the firm's cash inflows from operations also occur at a steady, predictable rate—say, $900,000 per week. Therefore, the firm's net cash outflows, or net need

[2] William J. Baumol, "The Transactions Demand for Cash: An Inventory Theoretic Approach," *Quarterly Journal of Economics,* November 1952, 545–556.

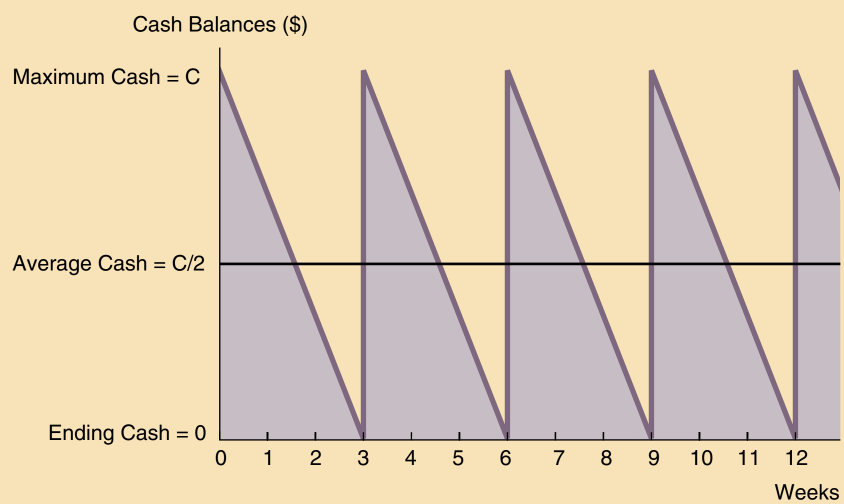
for cash, also occur at a steady rate—in this case, $100,000 per week.[3] Under these steady-state assumptions, the firm's cash position will resemble the situation shown in Figure 28-1.

If our illustrative firm started at Time 0 with a cash balance of C = $300,000, and if its outflows exceeded its inflows by $100,000 per week, then its cash balance would drop to zero at the end of Week 3, and its average cash balance would be C/2 = $300,000/2 = $150,000. Therefore, at the end of Week 3 the firm would have to replenish its cash balance, either by selling marketable securities, if it had any, or by borrowing.

If C were set at a higher level, say, $600,000, then the cash supply would last longer (six weeks), and the firm would have to sell securities (or borrow) less frequently. However, its average cash balance would rise from $150,000 to $300,000. Brokerage or some other type of transactions cost must be incurred to sell securities (or to borrow), so holding larger cash balances will lower the transactions costs associated with obtaining cash. On the other hand, cash provides no income, so the larger the average cash balance, the higher the opportunity cost, which is the return that could have been earned on securities or other assets held in lieu of cash. Thus, we have the situation that is graphed in Figure 28-2. The optimal cash balance is found by using the following variables and equations:

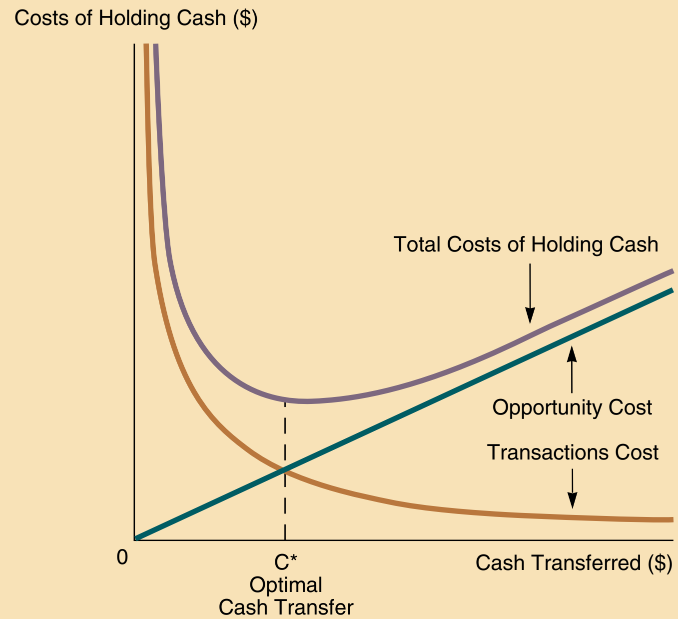
C = amount of cash raised by selling marketable securities or by borrowing.
C/2 = average cash balance.
C* = optimal amount of cash to be raised by selling marketable securities or by borrowing.
C*/2 = optimal average cash balance.
F = fixed costs of selling securities or of obtaining a loan.

Figure 28-1 Cash Balances under the Baumol Model's Assumptions



[3]Our hypothetical firm is experiencing a $100,000 weekly cash shortfall, but this does not necessarily imply that it is headed for bankruptcy. The firm could, for example, be highly profitable and be enjoying high earnings, but be expanding so rapidly that it is experiencing chronic cash shortages that must be made up by borrowing or by selling common stock. Or, the firm could be in the construction business and therefore receive major cash inflows at wide intervals, but have net cash outflows of $100,000 per week between major inflows.

Figure 28-2 Determination of the Target Cash Balance



T = total amount of net new cash needed for transactions during the entire period (usually a year).
r = opportunity cost of holding cash, set equal to either the rate of return foregone on marketable securities or the cost of borrowing to hold cash.

The total costs of cash balances consist of holding (or opportunity) costs plus transactions costs:[4]

$$\begin{aligned}\text{Total costs} &= \text{Holding costs} + \text{Transactions costs}\\ &= \begin{pmatrix}\text{Average cash}\\ \text{balance}\end{pmatrix}\begin{pmatrix}\text{Opportunity}\\ \text{cost rate}\end{pmatrix} + \begin{pmatrix}\text{Number of}\\ \text{transactions}\end{pmatrix}\begin{pmatrix}\text{Cost per}\\ \text{transaction}\end{pmatrix}\\ &= \frac{C}{2}(r) + \frac{T}{C}(F).\end{aligned} \tag{28-1}$$

The minimum total costs are achieved when C is set equal to C*, the optimal cash transfer. C* is found as follows:[5]

$$C^* = \sqrt{\frac{2(F)(T)}{r}}. \tag{28-2}$$

[4]Total costs can be expressed on either a before-tax or an after-tax basis. Both methods lead to the same conclusions regarding target cash balances and comparative costs. For simplicity, we present the model here on a before-tax basis.

[5]Equation 28-1 is differentiated with respect to C. The derivative is set equal to zero, and we then solve for C = C* to derive Equation 28-2. This model, applied to inventories and called the EOQ model, is discussed further in a later section.

Equation 28-2 is the **Baumol model** for determining optimal cash balances. To illustrate its use, suppose F = \$150; T = 52 weeks × \$100,000/week = \$5,200,000; and r = 15% = 0.15. Then

$$C^* = \sqrt{\frac{2(\$150)(\$5{,}200{,}000)}{0.15}} = \$101{,}980.$$

Therefore, the firm should sell securities (or borrow if it does not hold securities) in the amount of \$101,980 when its cash balance approaches zero, thus building its cash balance back up to \$101,980. If we divide T by C*, we have the number of transactions per year: \$5,200,000/\$101,980 = 50.99 ≈ 51, or about once a week. The firm's average cash balance is \$101,980/2 = \$50,990 ≈ \$51,000.

Note that the optimal cash balance increases less than proportionately with increases in the amount of cash needed for transactions. For example, if the firm's size, and consequently its net new cash needs, doubled from \$5,200,000 to \$10,400,000 per year, average cash balances would increase by only 41 percent, from \$51,000 to \$72,000. This suggests that there are economies of scale in holding cash balances, and this, in turn, gives larger firms an edge over smaller ones.[6]

Of course, the firm would probably want to hold a safety stock of cash designed to reduce the probability of a cash shortage. However, if the firm is able to sell securities or to borrow on short notice—and most larger firms can do so in a matter of minutes simply by making a telephone call—the safety stock can be quite low.

The Baumol model is obviously simplistic. Most important, it assumes relatively stable, predictable cash inflows and outflows, and it does not take into account seasonal or cyclical trends. Other models have been developed to deal both with uncertainty and with trends, but all of them have limitations and are more useful as conceptual models than for actually setting target cash balances.

Monte Carlo Simulation

Although the Baumol model and other theoretical models provide insights into the optimal cash balance, they are generally not practical for actual use. Rather, firms generally set their target cash balances based on some "safety stock" of cash that holds the risk of running out of money to some acceptably low level. One commonly used procedure is Monte Carlo simulation.[7] To illustrate, consider the cash budget for MicroDrive Inc. presented back in Table 22-2 in Chapter 22. Sales and collections are the driving forces in the cash budget and, of course, are subject to uncertainty. In the cash budget, we used expected values for sales and collections, as well as for all other cash flows. However, it would be relatively easy to use Monte Carlo simulation, first discussed in Chapter 11, to introduce uncertainty. If the cash budget were constructed using a spreadsheet program with Monte Carlo add-in software, then the key uncertain variables could be specified as continuous probability distributions rather than point values.

The end result of the simulation would be a distribution for each month's net cash gain or loss instead of the single values shown on Line 16 of Table 22-2. Suppose September's net cash loss distribution looked like this (in millions):

[6]This edge may, of course, be more than offset by other factors—after all, cash management is only one aspect of running a business.

[7]See Eugene M. Lerner, "Simulating a Cash Budget," in *Readings on the Management of Working Capital,* 2d ed., Keith V. Smith, ed. (St. Paul, MN: West, 1980).

September Cash Loss	Probability of This Loss or More
($83)	10%
(75)	20
(68)	30
(62)	40
(57) Expected loss	50
(52)	60
(46)	70
(39)	80
(31)	90

Now suppose MicroDrive's managers want to be 90 percent confident that the firm will not run out of cash during September, and they do not want to have to borrow to cover any shortfall. They would set the beginning-of-month balance at $83 million, well above the current $10 million, because there is only a 10 percent probability that September's cash flow will be worse than an $83 million outflow. With a balance of $83 million at the beginning of the month, there would be only a 10 percent chance that MicroDrive would run out of cash during September. Of course, Monte Carlo simulation could be applied to the remaining months in the Table 22-2 cash budget, and the amounts obtained to meet some confidence level could be used to set each month's target cash balance instead of using a fixed target across all months.

The same type of analysis could be used to determine the amount of short-term securities to hold, or the size of a requested line of credit. Of course, as in all simulations, the hard part is estimating the probability distributions for sales, collections, and the other highly uncertain variables. If these inputs are not good representations of the actual uncertainty facing the firm, then the resulting target balances will not offer the protection against cash shortages implied by the simulation. There is no substitute for experience, and cash managers will adjust the target balances obtained by Monte Carlo simulation on a judgmental basis.

Self-Test Questions

How has technology changed the way target cash balances are set?
What is the Baumol model, and how is it used?
Explain how Monte Carlo simulation can be used to help set a firm's target cash balance.

Inventory Control Systems

Inventory management requires the establishment of an *inventory control system*. Inventory control systems run the gamut from very simple to extremely complex, depending on the size of the firm and the nature of its inventory. For example, one simple control procedure is the **red-line method—**inventory items are stocked in a bin, a red line is drawn around the inside of the bin at the level of the reorder point, and the inventory clerk places an order when the red line shows. The **two-bin method** has inventory items stocked in two bins. When the working bin is empty, an order is placed and inventory is drawn from the second bin. These procedures work well for parts such as bolts in a manufacturing process, or for many items in retail businesses.

Computerized Systems

Most companies today employ **computerized inventory control systems.** The computer starts with an inventory count in memory. As withdrawals are made, they are recorded by the computer, and the inventory balance is revised. When the reorder point is reached, the computer automatically places an order, and when the order is received, the recorded balance is increased. As we noted earlier, retailers such as Wal-Mart have carried this system quite far—each item has a bar code, and, as an item is checked out, the code is read, a signal is sent to the computer, and the inventory balance is adjusted at the same time the price is fed into the cash register tape. When the balance drops to the reorder point, an order is placed. In Wal-Mart's case, the order goes directly from its computers to those of its suppliers.

A good inventory control system is dynamic, not static. A company such as Wal-Mart or General Motors stocks hundreds of thousands of different items. The sales (or use) of individual items can rise or fall quite separately from rising or falling overall corporate sales. As the usage rate for an individual item begins to rise or fall, the inventory manager must adjust its balance to avoid running short or ending up with obsolete items. If the change in the usage rate appears to be permanent, the safety stock level should be reconsidered, and the computer model used in the control process should be reprogrammed.

Just-in-Time Systems

An approach to inventory control called the **just-in-time (JIT) system** was developed by Japanese firms but is now used throughout the world. Toyota provides a good example of the just-in-time system. Eight of Toyota's ten factories, along with most of Toyota's suppliers, dot the countryside around Toyota City. Delivery of components is tied to the speed of the assembly line, and parts are generally delivered no more than a few hours before they are used. The just-in-time system reduces the need for Toyota and other manufacturers to carry large inventories, but it requires a great deal of coordination between the manufacturer and its suppliers, both in the timing of deliveries and the quality of the parts. It also requires that component parts be perfect; otherwise, a few bad parts could stop the entire production line. Therefore, JIT inventory management has been developed in conjunction with total quality management (TQM).

Not surprisingly, U.S. automobile manufacturers were among the first domestic firms to move toward just-in-time systems. Ford has restructured its production system with a goal of increasing its inventory turnover from 20 times a year to 30 or 40 times. Of course, just-in-time systems place considerable pressure on suppliers. GM formerly kept a 10-day supply of seats and other parts made by Lear Siegler; now GM sends in orders at four- to eight-hour intervals and expects immediate shipment. A Lear Siegler spokesman stated, "We can't afford to keep things sitting around either," so Lear Siegler has had to be tough on its own suppliers.

Just-in-time systems are also being adopted by smaller firms. In fact, some production experts say that small companies are better positioned than large ones to use just-in-time methods, because it is easier to redefine job functions and to educate people in small firms. One small-firm example is Fireplace Manufacturers Inc., a manufacturer of prefabricated fireplaces. The company was having cash flow problems, and it was carrying \$1.1 million in inventory to support annual sales of about \$8 million. The company went to a just-in-time system, trimmed its raw material and work-in-process inventory to \$750,000, and freed up \$350,000 of cash, even as sales doubled.

The close coordination required between the parties using JIT procedures has led to an overall reduction of inventory throughout the production-distribution system, and to a general improvement in economic efficiency. This point is borne out by economic statistics, which show that inventory as a percentage of sales has been declining since the use of just-in-time procedures began. Also, with smaller inventories in the system, economic recessions have become shorter and less severe.

Outsourcing

Another important development related to inventory is **outsourcing,** which is the practice of purchasing components rather than making them in-house. Thus, GM has been moving toward buying radiators, axles, and other parts from suppliers rather than making them itself, so it has been increasing its use of outsourcing. Outsourcing is often combined with just-in-time systems to reduce inventory levels. However, perhaps the major reason for outsourcing has nothing to do with inventory policy—a bureaucratic, unionized company like GM can often buy parts from a smaller, nonunionized supplier at a lower cost than it can make them itself.

The Relationship between Production Scheduling and Inventory Levels

A final point relating to inventory levels is *the relationship between production scheduling and inventory levels.* For example, a greeting card manufacturer has highly seasonal sales. Such a firm could produce on a steady, year-round basis, or it could let production rise and fall with sales. If it established a level production schedule, its inventory would rise sharply during periods when sales were low and then decline during peak sales periods, but its average inventory would be substantially higher than if production rose and fell with sales.

Our discussions of just-in-time systems, outsourcing, and production scheduling all point out the necessity of coordinating inventory policy with manufacturing/procurement policies. Companies try to minimize *total production and distribution costs,* and inventory costs are just one part of total costs. Still, they are an important cost, and financial managers should be aware of the determinants of inventory costs and how they can be minimized.

SELF-TEST QUESTIONS

Describe some inventory control systems that are used in practice.
What are just-in-time systems? What are their advantages? Why is quality especially important if a JIT system is used?
What is outsourcing?
Describe the relationship between production scheduling and inventory levels.

ACCOUNTING FOR INVENTORY

When finished goods are sold, the firm must assign a cost of goods sold. The cost of goods sold appears on the income statement as an expense for the period, and the balance sheet inventory account is reduced by a like amount. Four methods can be used to value the cost of goods sold, and hence to value the remaining inventory: (1) specific identification, (2) first-in, first-out (FIFO), (3) last-in, first-out (LIFO), and (4) weighted average.

Specific Identification

Under **specific identification,** a unique cost is attached to each item in inventory. Then, when an item is sold, the inventory value is reduced by that specific amount. This method is used only when the items are high cost and move relatively slowly, such as cars for an automobile dealer.

First-In, First-Out (FIFO)

In the **FIFO** method, the units sold during a given period are assumed to be the first units that were placed in inventory. As a result, the cost of goods sold is based on the cost of the oldest inventory items, and the remaining inventory consists of the newest goods.

Last-In, First-Out (LIFO)

LIFO is the opposite of FIFO. The cost of goods sold is based on the last units placed in inventory, while the remaining inventory consists of the first goods placed in inventory. Note that this is purely an accounting convention—the actual physical units sold could be either the earlier or the later units placed in inventory, or some combination. For example, Del Monte has in its LIFO inventory accounts catsup bottled in the 1920s, but all the catsup in its warehouses was bottled in 2004 or 2005.

Weighted Average

The **weighted average** method involves calculating the weighted average unit cost of goods available for sale from inventory, and this average is then used to determine the cost of goods sold. This method results in a cost of goods sold and an ending inventory that fall somewhere between the FIFO and LIFO methods.

Comparison of Inventory Accounting Methods

To illustrate these methods and their effects on financial statements, assume that Custom Furniture Inc. manufactured five identical antique reproduction dining tables during a one-year accounting period. During the year, a new labor contract plus dramatically increasing mahogany prices caused manufacturing costs to almost double, resulting in the following inventory costs:

Table Number:	1	2	3	4	5	Total
Cost:	$10,000	$12,000	$14,000	$16,000	$18,000	$70,000

There were no tables in stock at the beginning of the year, and Tables 1, 3, and 5 were sold during the year.

If Custom used the specific identification method, the cost of goods sold would be reported as $10,000 + $14,000 + $18,000 = $42,000, while the end-of-period inventory value would be $70,000 − $42,000 = $28,000. If Custom used the FIFO method, its cost of goods sold would be $10,000 + $12,000 + $14,000 = $36,000, and ending inventory would be $70,000 − $36,000 = $34,000. If Custom used the LIFO method, its cost of goods sold would be $48,000, and its ending inventory would be $22,000. Finally, if Custom used the weighted average method, its average cost per unit of inventory would be $70,000/5 = $14,000, its cost of goods sold would be 3($14,000) = $42,000, and its ending inventory would be $70,000 − $42,000 = $28,000.

If Custom's actual sales revenues from the tables were $80,000, or an average of $26,667 per unit sold, and if its other costs were minimal, the following is a summary of the effects of the four methods:

Method	Sales	Cost of Goods Sold	Reported Profit	Ending Inventory Value
Specific identification	$80,000	$42,000	$38,000	$28,000
FIFO	80,000	36,000	44,000	34,000
LIFO	80,000	48,000	32,000	22,000
Weighted average	80,000	42,000	38,000	28,000

Ignoring taxes, Custom's cash flows would not be affected by its choice of inventory methods, yet its balance sheet and reported profits would vary with each method. In an inflationary period such as in our example, FIFO gives the lowest cost of goods sold and thus the highest net income. FIFO also shows the highest inventory value, so it produces the strongest apparent liquidity position as measured by net working capital or the current ratio. On the other hand, LIFO produces the highest cost of goods sold, the lowest reported profits, and the weakest apparent liquidity position. However, when taxes are considered, LIFO provides the greatest tax deductibility, and thus it results in the lowest tax burden. Consequently, after-tax cash flows are highest if LIFO is used.

Of course, these results apply only to periods when costs are increasing. If costs were constant, all four methods would produce the same cost of goods sold, ending inventory, taxes, and cash flows. However, inflation has been a fact of life in recent years, so most firms use LIFO to take advantage of its greater tax and cash flow benefits.

Self-Test Questions

What are the four methods used to account for inventory?

What effect does the method used have on the firm's reported profits? On ending inventory levels?

Which method should be used if management anticipates a period of inflation? Why?

The Economic Ordering Quantity (EOQ) Model

As discussed in Chapter 22, inventories are obviously necessary, but it is equally obvious that a firm's profitability will suffer if it has too much or too little inventory. Most firms use a pragmatic approach to setting inventory levels, in which past experience plays a major role. However, as a starting point in the process, it is useful for managers to consider the insights provided by the **economic ordering quantity (EOQ)** model. The EOQ model first specifies the costs of ordering and carrying inventories and then combines these costs to obtain the total costs associated with inventory holdings. Finally, optimization techniques are used to find that order quantity, hence inventory level, that minimizes total costs. Note that a third category of inventory costs, the costs of running short (stock-out costs), are not considered in our initial discussion. These costs are dealt with by adding safety stocks, as we will discuss later. Similarly, we shall discuss quantity discounts in a later section. The costs that remain for consideration at this stage are carrying costs and ordering, shipping, and receiving costs.

Carrying Costs

Carrying costs generally rise in direct proportion to the average amount of inventory carried. Inventories carried, in turn, depend on the frequency with which orders are placed. To illustrate, if a firm sells S units per year, and if it places equal-sized orders N times per year, then S/N units will be purchased with each order. If the inventory is used evenly over the year, and if no safety stocks are carried, then the average inventory, A, will be

$$A = \frac{\text{Units per order}}{2} = \frac{S/N}{2}. \quad (28\text{-}3)$$

For example, if S = 120,000 units in a year, and N = 4, then the firm will order 30,000 units at a time, and its average inventory will be 15,000 units:

$$A = \frac{S/N}{2} = \frac{120{,}000/4}{2} = \frac{30{,}000}{2} = 15{,}000 \text{ units.}$$

Just after a shipment arrives, the inventory will be 30,000 units; just before the next shipment arrives, it will be zero; and on average, 15,000 units will be carried.

Now assume the firm purchases its inventory at a price P = $2 per unit. The average inventory value is thus (P)(A) = $2(15,000) = $30,000. If the firm has a cost of capital of 10 percent, it will incur $3,000 in financing charges to carry the inventory for one year. Further, assume that each year the firm incurs $2,000 of storage costs (space, utilities, security, taxes, and so forth), that its inventory insurance costs are $500, and that it must mark down inventories by $1,000 because of depreciation and obsolescence. The firm's total cost of carrying the $30,000 average inventory is thus $3,000 + $2,000 + $500 + $1,000 = $6,500, and the annual percentage cost of carrying the inventory is $6,500/$30,000 = 0.217 = 21.7%.

Defining the annual percentage carrying cost as C, we can, in general, find the annual total carrying cost, TCC, as the percentage carrying cost, C, times the price per unit, P, times the average number of units, A:

$$\text{TCC} = \text{Total carrying cost} = (C)(P)(A). \quad (28\text{-}4)$$

In our example,

$$\text{TCC} = (0.217)(\$2)(15{,}000) \approx \$6{,}500.$$

Ordering Costs

Although we assume that carrying costs are entirely variable and rise in direct proportion to the average size of inventories, ordering costs are often fixed. For example, the costs of placing and receiving an order—interoffice memos, long-distance telephone calls, setting up a production run, and taking delivery—are essentially fixed regardless of the size of an order, so this part of inventory cost is simply the fixed cost of placing and receiving orders times the number of orders placed per year.[8] We define the fixed costs associated with ordering inventories as F, and if we place N orders per year, the total ordering cost is given by Equation 28-5:

[8]Note that in reality both carrying and ordering costs can have variable and fixed-cost elements, at least over certain ranges of average inventory. For example, security and utilities charges are probably fixed in the short run over a wide range of inventory levels. Similarly, labor costs in receiving inventory could be tied to the quantity received, and hence could be variable. To simplify matters, we treat all carrying costs as variable and all ordering costs as fixed. However, if these assumptions do not fit the situation at hand, the cost definitions can be changed. For example, one could add another term for shipping costs if there are economies of scale in shipping, such that the cost of shipping a unit is smaller if shipments are larger. However, in most situations shipping costs are not sensitive to order size, so total shipping costs are simply the shipping cost per unit times the units ordered (and sold) during the year. Under this condition, shipping costs are not influenced by inventory policy, hence they may be disregarded for purposes of determining the optimal inventory level and the optimal order size.

$$\text{Total ordering cost} = \text{TOC} = (\text{F})(\text{N}). \quad (28\text{-}5)$$

Here TOC = total ordering cost, F = fixed costs per order, and N = number of orders placed per year.

Equation 28-3 may be rewritten as N = S/2A, and then substituted into Equation 28-5:

$$\text{Total ordering cost} = \text{TOC} = \text{F}\left(\frac{\text{S}}{2\text{A}}\right). \quad (28\text{-}6)$$

To illustrate the use of Equation 28-6, if F = \$100, S = 120,000 units, and A = 15,000 units, then TOC, the total annual ordering cost, is \$400:

$$\text{TOC} = \$100\left(\frac{120{,}000}{30{,}000}\right) = \$100(4) = \$400.$$

Total Inventory Costs

Total carrying cost, TCC, as defined in Equation 28-4, and total ordering cost, TOC, as defined in Equation 28-6, may be combined to find total inventory costs, TIC, as follows:

$$\begin{aligned}\text{Total inventory costs} = \text{TIC} &= \text{TCC} + \text{TOC} \\ &= (\text{C})(\text{P})(\text{A}) + \text{F}\left(\frac{\text{S}}{2\text{A}}\right).\end{aligned} \quad (28\text{-}7)$$

Recognizing that the average inventory carried is A = Q/2, or one-half the size of each order quantity, Q, we may rewrite Equation 28-7 as follows:

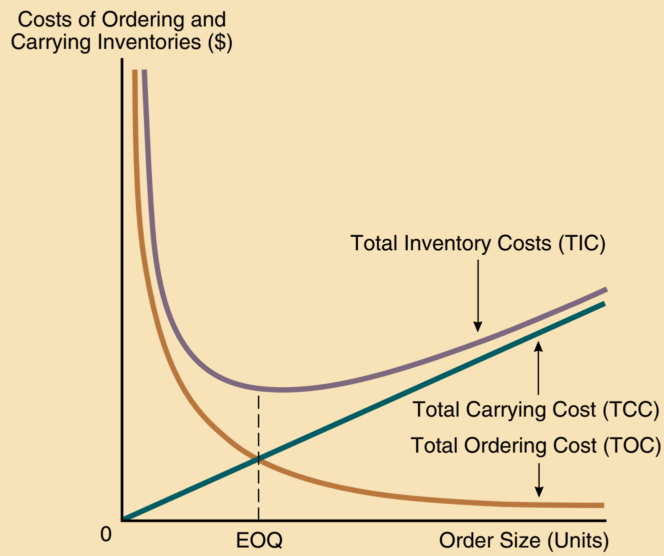
$$\begin{aligned}\text{TIC} &= \text{TCC} + \text{TOC} \\ &= (\text{C})(\text{P})\left(\frac{\text{Q}}{2}\right) + (\text{F})\left(\frac{\text{S}}{\text{Q}}\right).\end{aligned} \quad (28\text{-}8)$$

Here we see that total carrying cost equals average inventory in units, Q/2, multiplied by unit price, P, times the percentage annual carrying cost, C. Total ordering cost equals the number of orders placed per year, S/Q, multiplied by the fixed cost of placing and receiving an order, F. Finally, total inventory costs equal the sum of total carrying cost plus total ordering cost. We will use this equation in the next section to develop the optimal inventory ordering quantity.

Derivation of the EOQ Model

Figure 28-3 illustrates the basic premise on which the EOQ model is built, namely, that some costs rise with larger inventories while other costs decline, and there is an optimal order size (and associated average inventory) that minimizes the total costs of inventories. First, as noted earlier, the average investment in inventories depends on how frequently orders are placed and the size of each order—if we order every day, average inventories will be much smaller than if we order once a year. Further, as Figure 28-3 shows, the firm's carrying costs rise with larger orders; larger orders mean larger average inventories, so warehousing costs, interest on funds tied up in

Figure 28-3 Determination of the Optimal Order Quantity



inventory, insurance, and obsolescence costs will all increase. However, ordering costs decline with larger orders and inventories; the cost of placing orders, suppliers' production set-up costs, and order handling costs will all decline if we order infrequently and consequently hold larger quantities.

If the carrying and ordering cost curves in Figure 28-3 are added, the sum represents total inventory costs, TIC. The point where the TIC is minimized represents the economic ordering quantity (EOQ), and this, in turn, determines the optimal average inventory level.

The EOQ is found by differentiating Equation 28-8 with respect to ordering quantity, Q, and setting the derivative equal to zero:

$$\frac{d(TIC)}{dQ} = \frac{(C)(P)}{2} - \frac{(F)(S)}{Q^2} = 0.$$

Now, solving for Q we obtain:

$$\frac{(C)(P)}{2} = \frac{(F)(S)}{Q^2}$$

$$Q^2 = \frac{2(F)(S)}{(C)(P)}$$

$$Q = EOQ = \sqrt{\frac{2(F)(S)}{(C)(P)}}. \quad (28\text{-}9)$$

Here

EOQ = economic ordering quantity, or the optimal quantity to be ordered each time an order is placed.

F = fixed costs of placing and receiving an order.

S = annual sales in units.
C = annual carrying costs expressed as a percentage of average inventory value.
P = purchase price the firm must pay per unit of inventory.

Equation 28-9 is the EOQ model.[9] The assumptions of the model, which will be relaxed shortly, include the following: (1) sales can be forecasted perfectly, (2) sales are evenly distributed throughout the year, and (3) orders are received when expected.

EOQ Model Illustration

To illustrate the EOQ model, consider the following data supplied by Cotton Tops Inc., a distributor of budget-priced, custom-designed T-shirts that it sells to concessionaires at various theme parks in the United States:

S = annual sales = 26,000 shirts per year.
C = percentage carrying cost = 25 percent of inventory value.
P = purchase price per shirt = \$4.92 per shirt. (The sales price is \$9, but this is irrelevant for our purposes here.)
F = fixed cost per order = \$1,000. Cotton Tops designs and distributes the shirts, but the actual production is done by another company. The bulk of this \$1,000 cost is the labor cost for setting up the equipment for the production run, which the manufacturer bills separately from the \$4.92 cost per shirt.

Substituting these data into Equation 28-9, we obtain an EOQ of 6,500 units:

$$\text{EOQ} = \sqrt{\frac{2(F)(S)}{(C)(P)}} = \sqrt{\frac{(2)(\$1{,}000)(26{,}000)}{(0.25)(\$4.92)}}$$
$$= \sqrt{42{,}276{,}423} \approx 6{,}500 \text{ units.}$$

With an EOQ of 6,500 shirts and annual usage of 26,000 shirts, Cotton Tops will place 26,000/6,500 = 4 orders per year. Note that average inventory holdings depend directly on the EOQ. This relationship is illustrated graphically in Figure 28-4, where we see that average inventory = EOQ/2. Immediately after an order is received, 6,500 shirts are in stock. The usage rate, or sales rate, is 500 shirts per week (26,000/52 weeks), so inventories are drawn down by this amount each week. Thus, the actual number of units held in inventory will vary from 6,500 shirts just after an order is received to zero just before a new order arrives. With a 6,500 beginning balance, a zero ending balance, and a uniform sales rate, inventories will average one-half the EOQ, or 3,250 shirts, during the year. At a cost of \$4.92 per shirt, the average investment in inventories will be (3,250)(\$4.92) ≈ \$16,000. If inventories are financed by bank loans, the loan will vary from a high of \$32,000 to a low of \$0, but the average amount outstanding over the course of a year will be \$16,000.

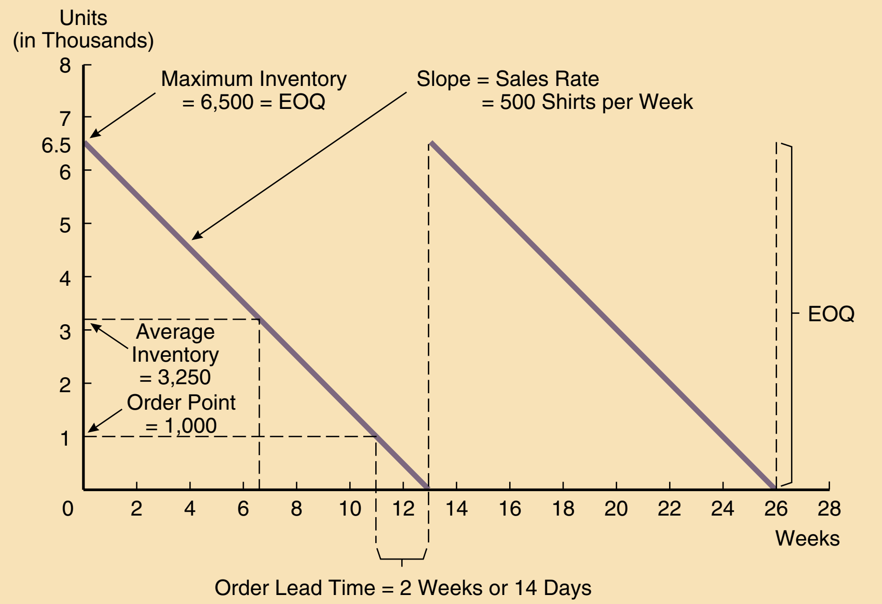
Note that the EOQ, hence average inventory holdings, rises with the square root of sales. Therefore, a given increase in sales will result in a less-than-proportionate increase in inventories, so the inventory/sales ratio will tend to decline as a firm grows. For example, Cotton Tops's EOQ is 6,500 shirts at an annual sales level of

[9]The EOQ model can also be written as

$$\text{EOQ} = \sqrt{\frac{2(F)(S)}{C^*}}$$

where C* is the annual carrying cost per unit expressed in *dollars*.

Figure 28-4 Inventory Position without Safety Stock



26,000, and the average inventory is 3,250 shirts, or $16,000. However, if sales were to increase by 100 percent, to 52,000 shirts per year, the EOQ would rise only to 9,195 units, or by 41 percent, and the average inventory would rise by this same percentage. This suggests that there are economies of scale in holding inventories.[10]

Finally, look at Cotton Tops's total inventory costs for the year, assuming that the EOQ is ordered each time. Using Equation 28-8, we find total inventory costs are $8,000:

$$\begin{aligned}
\text{TIC} &= \quad \text{TCC} \quad + \quad \text{TOC} \\
&= (C)(P)\left(\frac{Q}{2}\right) + (F)\left(\frac{S}{Q}\right) \\
&= 0.25(\$4.92)\left(\frac{6{,}500}{2}\right) + (\$1{,}000)\left(\frac{26{,}000}{6{,}500}\right) \\
&\approx \quad \$4{,}000 \quad + \quad \$4{,}000 \quad = \$8{,}000.
\end{aligned}$$

Note these two points: (1) The $8,000 total inventory cost represents the total of carrying costs and ordering costs, but this amount does *not* include the 26,000($4.92) = $127,920 annual purchasing cost of the inventory itself. (2) As we see both in Figure 28-3 and in the calculation above, at the EOQ, total carrying cost (TCC) equals total ordering cost (TOC). This property is not unique to our Cotton Tops illustration; it always holds.

[10]Note, however, that these scale economies relate to each particular item, not to the entire firm. Thus, a large distributor with $500 million of sales might have a higher inventory/sales ratio than a much smaller distributor if the small firm has only a few high-sales-volume items while the large firm distributes a great many low-volume items.

Setting the Order Point

If a two-week lead time is required for production and shipping, what is Cotton Tops's order point level? Cotton Tops sells 26,000/52 = 500 shirts per week. Thus, if a two-week lag occurs between placing an order and receiving goods, Cotton Tops must place the order when there are 2(500) = 1,000 shirts on hand. During the two-week production and shipping period, the inventory balance will continue to decline at the rate of 500 shirts per week, and the inventory balance will hit zero just as the order of new shirts arrives.

If Cotton Tops knew for certain that both the sales rate and the order lead time would never vary, it could operate exactly as shown in Figure 28-4. However, sales do change, and production and/or shipping delays are sometimes encountered. To guard against these events, the firm must carry additional inventories, or safety stocks, as discussed in the next section.

Self-Test Questions

What are some specific inventory carrying costs? As defined here, are these costs fixed or variable?
What are some inventory ordering costs? As defined here, are these costs fixed or variable?
What are the components of total inventory costs?
What is the concept behind the EOQ model?
What is the relationship between total carrying cost and total ordering cost at the EOQ?
What assumptions are inherent in the EOQ model as presented here?

EOQ Model Extensions

The basic EOQ model was derived under several restrictive assumptions. In this section, we relax some of these assumptions and, in the process, extend the model to make it more useful.

The Concept of Safety Stocks

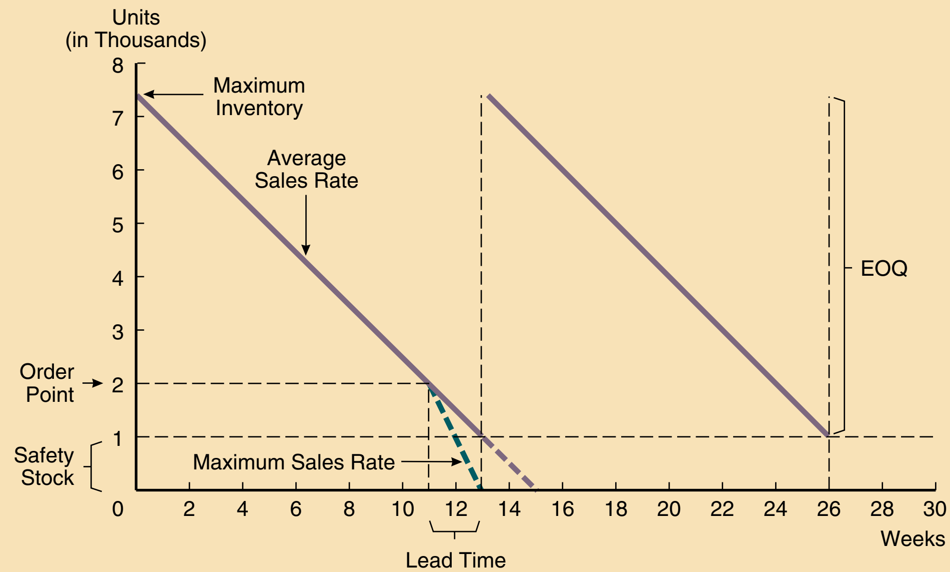
The concept of a **safety stock** is illustrated in Figure 28-5. First, note that the slope of the sales line measures the expected rate of sales. The company *expects* to sell 500 shirts per week, but let us assume that the maximum likely sales rate is twice this amount, or 1,000 units each week. Further, assume that Cotton Tops sets the safety stock at 1,000 shirts, so it initially orders 7,500 shirts, the EOQ of 6,500 plus the 1,000-unit safety stock. Subsequently, it reorders the EOQ whenever the inventory level falls to 2,000 shirts, the safety stock of 1,000 shirts plus the 1,000 shirts expected to be used while awaiting delivery of the order.

Note that the company could, over the two-week delivery period, sell 1,000 units a week, or double its normal expected sales. This maximum rate of sales is shown by the steeper dashed line in Figure 28-5. The condition that makes this higher sales rate possible is the safety stock of 1,000 shirts.

The safety stock is also useful to guard against delays in receiving orders. The expected delivery time is two weeks, but with a 1,000-unit safety stock, the company could maintain sales at the expected rate of 500 units per week for an additional two weeks if something should delay an order.

However, carrying a safety stock has a cost. The average inventory is now EOQ/2 plus the safety stock, or 6,500/2 + 1,000 = 3,250 + 1,000 = 4,250 shirts, and the average inventory value is now (4,250)($4.92) = $20,910. This increase in average

Figure 28-5 Inventory Position with Safety Stock Included



inventory causes an increase in annual inventory carrying costs equal to (Safety stock)(P)(C) = 1,000($4.92)(0.25) = $1,230.

The optimal safety stock varies from situation to situation, but, in general, it *increases* (1) with the uncertainty of demand forecasts, (2) with the costs (in terms of lost sales and lost goodwill) that result from inventory shortages, and (3) with the probability that delays will occur in receiving shipments. The optimal safety stock *decreases* as the cost of carrying this additional inventory increases.

Setting the Safety Stock Level

The critical question with regard to safety stocks is this: How large should the safety stock be? To answer this question, first examine Table 28-1, which contains the probability distribution of Cotton Tops's unit sales for an average two-week period, the time it takes to receive an order of 6,500 T-shirts. Note that the expected sales over an average two-week period is 1,000 units. Why do we focus on a two-week period? Because shortages can occur only during the two weeks it takes an order to arrive.

TABLE 28-1 Two-Week Sales Probability Distribution

Probability	Unit Sales
0.1	0
0.2	500
0.4	1,000
0.2	1,500
0.1	2,000
1.0	Expected sales = 1,000

Cotton Tops's managers have estimated that the annual carrying cost is 25 percent of inventory value. Because each shirt has an inventory value of $4.92, the annual carrying cost per unit is 0.25($4.92) = $1.23, and the carrying cost for each 13-week inventory period is $1.23(13/52) = $0.308 per unit. Even though shortages can occur only during the 2-week order period, safety stocks must be carried over the full 13-week inventory cycle. Next, Cotton Tops's managers must estimate the cost of shortages. Assume that when shortages occur, 50 percent of Cotton Tops's buyers are willing to accept back orders, while 50 percent of its potential customers simply cancel their orders. Remember that each shirt sells for $9.00, so each one-unit shortage produces expected lost profits of 0.5($9.00 − $4.92) = $2.04. With this information, the firm can calculate the expected costs of different safety stock levels. This is done in Table 28-2.

For each safety stock level, we determine the expected cost of a shortage based on the sales probability distribution in Table 28-1. There is an expected shortage cost of $408 if no safety stock is carried; $102 if the safety stock is set at 500 units; and no expected shortage, hence no shortage cost, with a safety stock of 1,000 units. The cost of carrying each safety level is merely the cost of carrying a unit of inventory over the 13-week inventory period, $0.308, times the safety stock; for example, the cost of carrying a safety stock of 500 units is $0.308(500) = $154. Finally, we sum the expected shortage cost in Column 6 and the safety stock carrying cost in Column 7 to obtain the total cost figures given in Column 8. Because the 500-unit safety stock has the lowest expected total cost, Cotton Tops should carry this safety level.

TABLE 28-2 Safety Stock Analysis

Safety Stock (1)	Sales during Two-Week Delivery Period (2)	Probability (3)	Shortage[a] (4)	Shortage Cost (Lost Profits): $2.04 × (4) = (5)	Expected Shortage Cost: (3) × (5) = (6)	Safety Stock Carrying Cost: $0.308 × (1) = (7)	Expected Total Cost: (6) + (7) = (8)
0	0	0.1	0	$ 0	$ 0		
	500	0.2	0	0	0		
	1,000	0.4	0	0	0		
	1,500	0.2	500	1,020	204		
	2,000	0.1	1,000	$2,040	204		
		1.0		Expected shortage cost =	$408	$ 0	$408
500	0	0.1	0	$ 0	$ 0		
	500	0.2	0	0	0		
	1,000	0.4	0	0	0		
	1,500	0.2	0	0	0		
	2,000	0.1	500	1,020	102		
		1.0		Expected shortage cost =	$102	$154	$256
1,000	0	0.1	0	$ 0	$ 0		
	500	0.2	0	0	0		
	1,000	0.4	0	0	0		
	1,500	0.2	0	0	0		
	2,000	0.1	0	0	0		
		1.0		Expected shortage cost =	$ 0	$308	$308

[a]Shortage = Actual sales − (1,000 Stock at order point + Safety stock); positive values only.

Of course, the optimal safety level is highly sensitive to the estimates of the sales probability distribution and shortage costs. Errors here could result in incorrect safety stock levels. Note also that in calculating the $2.04 per unit shortage cost, we implicitly assumed that a lost sale in one period would not result in lost sales in future periods. If shortages cause customer ill will, this could lead to permanent sales reductions. Then the situation would be much more serious, stock-out costs would be far higher, and the firm should consequently carry a larger safety stock.

The stock-out example is just one example of the many judgments required in inventory management—the mechanics are relatively simple, but the inputs are judgmental and difficult to obtain.

Quantity Discounts

Now suppose the T-shirt manufacturer offered Cotton Tops a **quantity discount** of 2 percent on large orders. If the quantity discount applied to orders of 5,000 or more, then Cotton Tops would continue to place the EOQ order of 6,500 shirts and take the quantity discount. However, if the quantity discount required orders of 10,000 or more, then Cotton Tops would have to compare the savings in purchase price that would result if its ordering quantity were increased to 10,000 units with the increase in total inventory costs caused by the departure from the 6,500-unit EOQ.

First, consider the total costs associated with Cotton Tops's EOQ of 6,500 units. We found earlier that total inventory costs are $8,000:

$$\begin{aligned} \text{TIC} &= \text{TCC} + \text{TOC} \\ &= (\text{C})(\text{P})\left(\frac{\text{Q}}{2}\right) + (\text{F})\left(\frac{\text{S}}{\text{Q}}\right) \\ &= 0.25(\$4.92)\left(\frac{6{,}500}{2}\right) + (\$1{,}000)\left(\frac{26{,}000}{6{,}500}\right) \\ &\approx \$4{,}000 + \$4{,}000 = \$8{,}000. \end{aligned}$$

Now, what would total inventory costs be if Cotton Tops ordered 10,000 units instead of 6,500? The answer is $8,625:

$$\begin{aligned} \text{TIC} &= 0.25(\$4.82)\left(\frac{10{,}000}{2}\right) + (\$1{,}000)\left(\frac{26{,}000}{10{,}000}\right) \\ &= \$6{,}025 + \$2{,}600 = \$8{,}625. \end{aligned}$$

Note that when the discount is taken, the price, P, is reduced by the amount of the discount; the new price per unit would be 0.98($4.92) = $4.82. Also note that when the ordering quantity is increased, carrying costs increase because the firm is carrying a larger average inventory, but ordering costs decrease since the number of orders per year decreases. If we were to calculate total inventory costs at an ordering quantity less than the EOQ, say, 5,000, we would find that carrying costs would be less than $4,000, and ordering costs would be more than $4,000, but the total inventory costs would be more than $8,000, since they are at a minimum when 6,500 units are ordered.[11]

Thus, inventory costs would increase by $8,625 − $8,000 = $625 if Cotton Tops were to increase its order size to 10,000 shirts. *However, this cost increase must be compared with Cotton Tops's savings if it takes the discount*. Taking the discount

[11]At an ordering quantity of 5,000 units, total inventory costs are $8,275:

$$\begin{aligned} \text{TIC} &= (0.25)(\$4.92)\left(\frac{5{,}000}{2}\right) + (\$1{,}000)\left(\frac{26{,}000}{5{,}000}\right) \\ &= \$3{,}075 + \$5{,}200 = \$8{,}275. \end{aligned}$$

would save 0.02($4.92) = $0.0984 per unit. Over the year, Cotton Tops orders 26,000 shirts, so the annual savings is $0.0984(26,000) ≈ $2,558. Here is a summary:

Reduction in purchase price = 0.02($4.92)(26,000)	=	$2,558
Increase in total inventory cost	=	625
Net savings from taking discounts		$1,933

Obviously, the company should order 10,000 units at a time and take advantage of the quantity discount.

Inflation

Moderate inflation—say, 3 percent per year—can largely be ignored for purposes of inventory management, but higher rates of inflation must be explicitly considered. If the rate of inflation in the types of goods the firm stocks tends to be relatively constant, it can be dealt with quite easily—simply deduct the expected annual rate of inflation from the carrying cost percentage, C, in Equation 28-9, and use this modified version of the EOQ model to establish the ordering quantity. The reason for making this deduction is that inflation causes the value of the inventory to rise, thus offsetting somewhat the effects of depreciation and other carrying costs. C will now be smaller, assuming other factors are held constant, so the calculated EOQ and the average inventory will increase. However, higher rates of inflation usually mean higher interest rates, and this will cause C to increase, thus lowering the EOQ and average inventory.

On balance, there is no evidence that inflation either raises or lowers the optimal inventories of firms in the aggregate. Inflation should still be explicitly considered, however, for it will raise the individual firm's optimal holdings if the rate of inflation for its own inventories is above average (and is greater than the effects of inflation on interest rates), and vice versa.

Seasonal Demand

For most firms, it is unrealistic to assume that the demand for an inventory item is uniform throughout the year. What happens when there is seasonal demand, as would hold true for an ice cream company? Here the standard annual EOQ model is obviously not appropriate. However, it does provide a point of departure for setting inventory parameters, which are then modified to fit the particular seasonal pattern. We divide the year into the seasons in which annualized sales are relatively constant, say, summer, spring and fall, and winter. Then, the EOQ model is applied separately to each period. During the transitions between seasons, inventories would be either run down or else built up with special seasonal orders.

EOQ Range

Thus far, we have interpreted the EOQ and the resulting inventory values as single point estimates. It can be easily demonstrated that small deviations from the EOQ do not appreciably affect total inventory costs, and, consequently, that the optimal ordering quantity should be viewed more as a range than as a single value.[12]

To illustrate this point, we examine the sensitivity of total inventory costs to ordering quantity for Cotton Tops. Table 28-3 contains the results. We conclude that the ordering quantity could range from 5,000 to 8,000 units without affecting total inventory costs by more than 3.4 percent. Thus, managers can adjust the ordering quantity within a fairly wide range without significantly increasing total inventory costs.

[12]This is somewhat analogous to the optimal capital structure in that small changes in capital structure around the optimum do not have much effect on the firm's weighted average cost of capital.

TABLE 28-3 EOQ Sensitivity Analysis

Ordering Quantity	Total Inventory Costs	Percentage Deviation from Optimal
3,000	$10,512	+31.4%
4,000	8,960	+12.0
5,000	8,275	+3.4
6,000	8,023	+0.3
6,500	8,000	0.0
7,000	8,019	+0.2
8,000	8,170	+2.1
9,000	8,423	+5.3
10,000	8,750	+9.4

SELF-TEST QUESTIONS

Why are safety stocks required?
Conceptually, how would you evaluate a quantity discount offer from a supplier?
What effect does inflation typically have on the EOQ?
Can the EOQ model be used when a company faces seasonal demand fluctuations?
What is the effect of minor deviations from the EOQ on total inventory costs?

SUMMARY

This chapter discussed the goals of cash management and how a company might determine its optimal cash balance using the Baumol model. It also discussed how an optimal inventory policy might be identified using the economic ordering quantity (EOQ) model. The key concepts covered are listed below:

- A policy that strives for **zero working capital** not only generates cash but also speeds up production and helps businesses operate more efficiently. This concept has its own definition of working capital: Inventories + Receivables − Payables. The rationale is that inventories and receivables are the keys to making sales, and that inventories can be financed by suppliers through accounts payable.
- The primary goal of cash management is to minimize the amount of cash a firm holds while maintaining a sufficient **target cash balance** to conduct business.
- The **Baumol model** provides insights into the optimal cash balance. The model balances the opportunity cost of holding cash against the transactions costs associated with obtaining cash either by selling marketable securities or by borrowing.

$$\text{Optimal cash infusion} = \sqrt{\frac{2(F)(T)}{r}}.$$

- Firms generally set their target cash balances at the level that holds the risk of running out of cash to some acceptable level. **Monte Carlo simulation** can be helpful in setting the target cash balance.
- Firms use inventory control systems such as the **red-line method** and the **two-bin method,** as well as **computerized inventory control systems,** to help them keep track of actual inventory levels and to ensure that inventory levels are

adjusted as sales change. **Just-in-time (JIT) systems** are used to hold down inventory costs and, simultaneously, to improve the production process. **Outsourcing** is the practice of purchasing components rather than making them in-house.

- Inventory can be accounted for in four different ways: (1) **specific identification,** (2) **first-in, first-out (FIFO),** (3) **last-in, first-out (LIFO),** and (4) **weighted average.**
- **Inventory costs** can be divided into three parts: carrying costs, ordering costs, and stock-out costs. In general, **carrying costs** increase as the level of inventory rises, but **ordering costs** and **stock-out costs** decline with larger inventory holdings.
- **Total carrying cost (TCC)** is equal to the percentage cost of carrying inventory (C) times the purchase price per unit of inventory (P) times the average number of units held (A): TCC = (C)(P)(A).
- **Total ordering cost (TOC)** is equal to the fixed cost of placing an order (F) times the number of orders placed per year (N): TOC = (F)(N).
- **Total inventory costs (TIC)** equal total carrying cost (TCC) plus total ordering cost (TOC): TIC = TCC + TOC.
- The **economic ordering quantity (EOQ)** model is a formula for determining the order quantity that will minimize total inventory costs:

$$\text{EOQ} = \sqrt{\frac{(2)(F)(S)}{(C)(P)}}.$$

Here F is the fixed cost per order, S is annual sales in units, C is the percentage cost of carrying inventory, and P is the purchase price per unit.

- The **reorder point** is the inventory level at which new items must be ordered.
- **Safety stocks** are held to avoid shortages, which can occur (1) if sales increase more than was expected or (2) if shipping delays are encountered on inventory ordered. The cost of carrying a safety stock, which is separate from that based on the EOQ model, is equal to the percentage cost of carrying inventory times the purchase price per unit times the number of units held as the safety stock.

Questions

(28-1) Define each of the following terms:

a. Baumol model
b. Total carrying cost; total ordering cost; total inventory costs
c. Economic ordering quantity (EOQ); EOQ model; EOQ range
d. Reorder point; safety stock
e. Red-line method; two-bin method; computerized inventory control system
f. Just-in-time system; outsourcing

(28-2) Indicate by a (+), (−), or (0) whether each of the following events would probably cause average annual inventory holdings to rise, fall, or be affected in an indeterminate manner:

a. Our suppliers change from delivering by train to air freight. __________
b. We change from producing just-in-time to meet seasonal demand to steady, year-round production. __________
c. Competition in the markets in which we sell increases. __________
d. The general rate of inflation rises. __________
e. Interest rates rise; other things are constant. __________

(28-3) Assuming the firm's sales volume remained constant, would you expect it to have a higher cash balance during a tight-money period or during an easy-money period? Why?

(28-4) Explain how each of the following factors would probably affect a firm's target cash balance if all other factors were held constant.

a. The firm institutes a new billing procedure that better synchronizes its cash inflows and outflows.
b. The firm develops a new sales forecasting technique that improves its forecasts.
c. The firm reduces its portfolio of U.S. Treasury bills.
d. The firm arranges to use an overdraft system for its checking account.
e. The firm borrows a large amount of money from its bank and also begins to write far more checks than it did in the past.
f. Interest rates on Treasury bills rise from 5 percent to 10 percent.

PROBLEMS

(28-1) Economic Ordering Quantity

The Gentry Garden Center sells 90,000 bags of lawn fertilizer annually. The optimal safety stock (which is on hand initially) is 1,000 bags. Each bag costs the firm \$1.50, inventory carrying costs are 20 percent, and the cost of placing an order with its supplier is \$15.

a. What is the economic ordering quantity?
b. What is the maximum inventory of fertilizer?
c. What will be the firm's average inventory?
d. How often must the company order?

(28-2) Optimal Cash Transfer

Barenbaum Industries projects that cash outlays of \$4.5 million will occur uniformly throughout the year. Barenbaum plans to meet its cash requirements by periodically selling marketable securities from its portfolio. The firm's marketable securities are invested to earn 12 percent, and the cost per transaction of converting securities to cash is \$27.

a. Use the Baumol model to determine the optimal transaction size for transfers from marketable securities to cash.
b. What will be Barenbaum's average cash balance?
c. How many transfers per year will be required?
d. What will be Barenbaum's total annual cost of maintaining cash balances? What would the total cost be if the company maintained an average cash balance of \$50,000 or of \$0 (it deposits funds daily to meet cash requirements)?

SPREADSHEET PROBLEM

(28-3) Build a Model: Inventory Management

FM e-resource

Start with the partial model in the file ***FM11 Ch 28 P3 Build a Model.xls*** from the textbook's Web site. The following inventory data have been established for the Adler Corporation:

(1) Orders must be placed in multiples of 100 units.
(2) Annual sales are 338,000 units.
(3) The purchase price per unit is \$3.
(4) Carrying cost is 20 percent of the purchase price of goods.
(5) Cost per order placed is \$24.
(6) Desired safety stock is 14,000 units; this amount is on hand initially.
(7) Two weeks are required for delivery.

a. What is the EOQ?
b. How many orders should the firm place each year?
c. At what inventory level should a reorder be made? [Hint: Reorder point = (Safety stock + Weeks to deliver × Weekly usage) − Goods in transit.]
d. Calculate the total costs of ordering and carrying inventories if the order quantity is (1) 4,000 units, (2) 4,800 units, or (3) 6,000 units. What are the total costs if the order quantity is the EOQ?
e. What are the EOQ and total inventory costs if
   (1) Sales increase to 500,000 units?

(2) Fixed order costs increase to $30? Sales remain at 338,000 units.
(3) Purchase price increases to $4? Leave sales and fixed costs at original values.

Cyberproblem

Please go to our Web site, **http://brigham.swlearning.com**, to access any Cyberproblems.

THOMSON ONE Business School Edition

Please go to **http://brighamxtra.swlearning.com** to access any Thomson ONE problems.

Mini Case

Andria Mullins, financial manager of Webster Electronics, has been asked by the firm's CEO, Fred Weygandt, to evaluate the company's inventory control techniques and to lead a discussion of the subject with the senior executives. Andria plans to use as an example one of Webster's "big ticket" items, a customized computer microchip that the firm uses in its laptop computer. Each chip costs Webster $200, and in addition it must pay its supplier a $1,000 setup fee on each order. Further, the minimum order size is 250 units; Webster's annual usage forecast is 5,000 units; and the annual carrying cost of this item is estimated to be 20 percent of the average inventory value.

Andria plans to begin her session with the senior executives by reviewing some basic inventory concepts, after which she will apply the EOQ model to Webster's microchip inventory. As her assistant, you have been asked to help her by answering the following questions:

a. Why is inventory management vital to the financial health of most firms?

b. What assumptions underlie the EOQ model?

c. Write out the formula for the total costs of carrying and ordering inventory, and then use the formula to derive the EOQ model.

d. What is the EOQ for custom microchips? What are total inventory costs if the EOQ is ordered?

e. What is Webster's added cost if it orders 400 units at a time rather than the EOQ quantity? What if it orders 600 per order?

f. Suppose it takes 2 weeks for Webster's supplier to set up production, make and test the chips, and deliver them to Webster's plant. Assuming certainty in delivery times and usage, at what inventory level should Webster reorder? (Assume a 52-week year, and assume that Webster orders the EOQ amount.)

g. Of course, there is uncertainty in Webster's usage rate as well as in delivery times, so the company must carry a safety stock to avoid running out of chips and having to halt production. If a 200-unit safety stock is carried, what effect would this have on total inventory costs? What is the new reorder point? What protection does the safety stock provide if usage increases, or if delivery is delayed?

h. Now suppose Webster's supplier offers a discount of 1 percent on orders of 1,000 or more. Should Webster take the discount? Why or why not?

i. For many firms, inventory usage is not uniform throughout the year, but, rather, follows some seasonal pattern. Can the EOQ model be used in this situation? If so, how?

j. How would these factors affect an EOQ analysis?

(1) The use of just-in-time procedures.

(2) The use of air freight for deliveries.

(3) The use of a computerized inventory control system, wherein as units were removed from stock, an electronic system automatically reduced the inventory account and, when the order point was

hit, automatically sent an electronic message to the supplier placing an order. The electronic system ensures that inventory records are accurate, and that orders are placed promptly.

(4) The manufacturing plant is redesigned and automated. Computerized process equipment and state-of-the-art robotics are installed, making the plant highly flexible in the sense that the company can switch from the production of one item to another at a minimum cost and quite quickly. This makes short production runs more feasible than under the old plant setup.

k. Webster runs a $100,000 per month cash deficit, requiring periodic transfers from its portfolio of marketable securities. Broker fees are $32 per transaction, and Webster earns 7 percent on its investment portfolio. How can Andria use the EOQ model to determine how Webster should liquidate part of its portfolio to provide cash?

Selected Additional References and Cases

Key references on cash balance models include the following:

Daellenbach, Hans G., "Are Cash Management Optimization Models Worthwhile?" *Journal of Financial and Quantitative Analysis,* September 1974, 607–626.

Miller, Merton H., and Daniel Orr, "The Demand for Money by Firms: Extension of Analytic Results," *Journal of Finance,* December 1968, 735–759.

Mullins, David Wiley, Jr., and Richard B. Homonoff, "Applications of Inventory Cash Management Models," in *Modern Developments in Financial Management,* Stewart C. Myers, ed. (New York: Praeger, 1976).

Stone, Bernell K., "The Use of Forecasts for Smoothing in Control-Limit Models for Cash Management," *Financial Management,* Spring 1972, 72–84.

The following cases from the Finance Online Case Library *cover many of the concepts discussed in this chapter and are available at* ***http://www.textchoice.com:***

Case 33, "Upscale Toddlers, Inc.," Case 50, "Mitchell Lumber Co.," and Case 62, "Western Supply," which deal with credit policy changes.

Case 34, "Texas Rose Company," and Case 34A, "Bridgewater Pool Company," which focus on receivables management.