TABLE 7.7
Advantages and Disadvantages of Insourcing and Outsourcing

Insourcing	
ADVANTAGES	**DISADVANTAGES**
High degree of control	Reduced strategic flexibility
Ability to oversee the entire process	Required high investment
Economies of scale and/or scope	Potential suppliers may offer superior products and services
Outsourcing	
ADVANTAGES	**DISADVANTAGES**
High strategic flexibility	Possibility of choosing a bad supplier
Low investment risk	Loss of control over the process and core technologies
Improved cash flow	Communication/coordination challenges
Access to state-of-the-art products and services	Increased risk of supply chain disruption
	Customer social responsibility (CSR) risks

TABLE 7.8
Factors That Affect the Decision to Insource or Outsource

	FAVORS INSOURCING	FAVORS OUTSOURCING
Environmental uncertainty	Low	High
Competition in the supplier market	Low	High
Ability to monitor supplier's performance	Low	High
Relationship of product/service to buying firm's core competencies	High	Low

and supply chain activities and keep current on what customers want and how their products or services meet those demands.

Corporate social responsibility
The economic, legal, ethical, and discretionary expectations that society has of organizations at a given point in time.

Finally, there is the concept of **corporate social responsibility (CSR),** which Carroll defines as "the economic, legal, ethical, and discretionary expectations that society has of organizations at a given point in time."[4] Companies must bear in mind that in today's world, these expectations also extend to their supply chain partners. Various stakeholders, including the government, consumer groups, and individual customers, will hold companies responsible, not just for their own actions, but for the actions of their supply chain partners as well. The *Supply Chain Connections* box ("Outsourcing in the Apparel Industry and Corporate Social Responsibility") dramatically illustrates some of the challenges faced by the apparel industry in this regard. Table 7.7 summarizes the advantages and disadvantages of insourcing and outsourcing.

Table 7.8 looks at the debate from another angle: What factors will influence the decision to insource or outsource? As the table suggests, insourcing will generally be more favorable in situations where environmental uncertainty is low (thereby reducing the risk of investing in capacity), supplier markets are not well developed, and the product or service being considered is directly related to the buying firm's core competencies. In contrast, outsourcing becomes more attractive as competition in supplier markets increases, the product or service is not seen as strategically critical, and environmental uncertainty makes internal investment a risky prospect. Given this, it makes sense that a lot of high-tech companies, facing short product life cycles and uncertain market conditions, outsource more often than do firms in more stable industries.

Total Cost Analysis. Managers must understand the cost issues associated with the make-or-buy decision. Determining the actual cost of a product or service is a complicated task requiring both good judgment and the application of sound quantitative techniques. In this section we will first examine the different costs managers must consider in making such decisions.

[4] A. Carroll, "A Three-Dimensional Conceptual Model of Corporate Performance," *Academy of Management Review* 4, no. 4 (1979): 497–505.

SUPPLY CHAIN CONNECTIONS

OUTSOURCING IN THE APPAREL INDUSTRY AND CORPORATE SOCIAL RESPONSIBILITY

As companies have expanded their supply chains globally, many have outsourced activities that can be done more efficiently by suppliers in other parts of the world. The apparel industry was one of the first to broadly adopt the outsourced supply chain concept. By deploying the "fast fashion" business model, global brands such as Nike, H&M, and Abercrombie & Fitch were able to create extremely responsive supply chains and bring lower-priced apparel to store shelves. They accomplished this in part by outsourcing garment manufacturing to suppliers and subcontractors in low-cost countries, such as China, Vietnam, Malaysia, and Bangladesh. Furthermore, the time to design and deliver new garments to the market was reduced from more than one year in some cases to just a few weeks. More efficient processes, cheaper products, and faster delivery appeared to make for a winning supply chain model.

But in too many cases these supply chains had serious weaknesses that supply chain executives failed to recognize. By chasing cheap labor, Western retailers had put tremendous cost pressure on suppliers who, in turn, minimized capital investments and adopted questionable safety and labor practices. For example, in Bangladesh, many garment workers, including children, are exposed to hazardous conditions that would not be allowed in other parts of the world.

On April 24, 2013, one of the deadliest garment-factory incidents in history occurred in Bangladesh when an eight-story manufacturing plant, Rana Plaza, collapsed near Dhaka, taking the lives of more than 1,100 people.[5] This incident came just a few months after a fire at the Tazreen Fashions factory in Ashulia, Bangladesh, which killed more than 100 people. The Tazreen factory produced sweater jackets for C&A, shorts for Walmart, and lingerie for Sears.[6] These retailers were seen by many as sharing responsibility for these accidents.[7] These cases demonstrate that best practice supply chain thinking must also address the social aspects of running a global supply chain, and that companies who outsource can be held responsible in part for the actions of their supply chain partners.

Source: Adapted from A. Wieland and R. Handfield, "The Socially Responsible Supply Chain: An Imperative for Global Corporations," *Supply Chain Management Review*, September 2013. Used with permission from Bob Treibilock, Editor in Chief, *Supply Chain Management Review*.

[5] 2013 Savar Building Collapse, **http://en.wikipedia.org/wiki/2013_Savar_building_collapse.**

[6] J. Yardley, "Horrific Fire Revealed a Gap in Safety for Global Brands," *New York Times*, December 6, 2012.

[7] S. Al-Mahmood, "Bangladesh Fire: What Wal-Mart's Supplier Network Missed," *Wall Street Journal*, December 1, 2012, **http://online.wsj.com/news/articles/SB10001424127887324024004578169400995615618.**

Total cost analysis
A process by which a firm seeks to identify and quantify all of the major costs associated with various sourcing options.

Direct costs
Costs tied directly to the level of operations or supply chain activities, such as the production of a good or service, or transportation.

Indirect costs
Costs that are not tied directly to the level of operations or supply chain activity.

Total cost analysis is a process by which a firm seeks to identify and quantify all of the major costs associated with various sourcing options. Table 7.9 lists some typical costs. As the table shows, these costs are often divided into direct and indirect costs. **Direct costs** are costs that are tied directly to the level of operations or supply chain activities, such as the production of a good or service, or transportation. If, for example, a product requires 1.3 square feet of sheet metal, and the cost of sheet metal is \$0.90 per square foot, the direct cost of the sheet metal is:

$$\$0.90 \times (1.3 \text{ feet}) = \$1.17$$

Indirect costs, as the name implies, are not tied directly to the level of operations or supply chain activity. Building lease payments and staff salaries are classic examples of indirect costs, which in essence represent costs of doing business. To understand the true total cost of insourcing or outsourcing, managers must allocate indirect costs to individual units of production. That task is not as easy as it may sound, however. Suppose managers are trying to decide whether to make a product in-house or outsource it. They estimate that they will need to spend \$600,000 just to design the new product. If they plan to produce 200,000 units, they might assign the design cost as follows:

$$\$600{,}000 / 200{,}000 \text{ units} = \$3.00 \text{ per unit}$$

But what if the results of the design effort could be applied to *future* products? Should part of the design cost be assigned to those future products, and if so, how? Because of problems such as this, outsourcing costs are usually easier to determine than insourcing costs. With

TABLE 7.9
Insourcing and Outsourcing Costs

	INSOURCING	OUTSOURCING
Direct Costs	Direct material	Price (from invoice)
	Direct labor	Freight costs
	Freight costs	
	Variable overhead	
Indirect Costs	Supervision	Purchasing
	Administrative support	
	Supplies	Receiving
	Maintenance costs	Quality control
	Equipment depreciation	
	Utilities	
	Building lease	
	Fixed overhead	

outsourcing, the indirect costs are included in the direct purchase price shown on the supplier's invoice. Generally, the only additional costs that need to be considered in the outsourcing decision are inbound freight (a direct cost) and administrative costs associated with managing the buyer–supplier relationship (such as purchasing and quality control). In contrast, the bulk of insourcing costs may fall into the indirect category, making the task of estimating the true total cost more difficult.

In determining total costs, managers must also consider the time frame of the make-or-buy decision. If an insourcing arrangement is expected to be of relatively short duration, as it might be for a product with a limited life cycle, then perhaps only direct costs and some portion of the indirect costs should be applied. In the short run, firms are better off recovering their direct costs and some portion of their indirect costs than risking a significant decline in their business. However, if managers expect an insourcing arrangement to become part of ongoing operations, they should consider all relevant costs that might reasonably be incurred over the long term, including all indirect costs.

EXAMPLE 7.5
Total Cost Analysis at the ABC Company

One of ABC's Taiwanese suppliers has bid on a new line of molded plastic parts that are currently being assembled at ABC's facility. The supplier has bid \$0.10 per part, given a forecasted demand of 200,000 parts in year 1, 300,000 in year 2, and 500,000 in year 3. Shipping and handling of parts from the supplier's facility is estimated at \$0.01 per unit. Additional inventory handling charges should amount to \$0.005 per unit. Finally, administrative costs are estimated at \$20 per month.

Although ABC's facility is capable of producing the part, the company would need to invest in another machine that would cost \$10,000, depreciated over the life of the product. Direct materials can be purchased for \$0.05 per unit. Direct labor is estimated at \$0.03 per unit plus a 50% surcharge for benefits; indirect labor is estimated at \$0.011 per unit plus 50% for benefits. Up-front engineering and design costs will amount to \$30,000. Finally, ABC management has insisted that overhead (an indirect cost) be allocated to the parts at a rate of 100% of direct labor cost.

Table 7.10 shows one possible analysis of the total costs. Of course, different managers might come up with slightly different analyses. For instance, ABC's managers might want to experiment with different allocation rates for overhead and depreciation expense to see how a change in the rate might affect the decision. They might also want to consider the effect of exchange rates on the supplier's costs. Suppose that the outsourcing costs are based on an exchange rate of 30 Taiwanese dollars to 1 U.S. dollar. If the exchange rate were to fall to 25 to 1, ABC's outsourcing costs could rise by 20%. The point is that even a relatively simple cost analysis requires managerial judgment and interpretation. Total cost analyses are most useful when they are considered jointly with strategic factors.

TABLE 7.10 Total Cost Analysis for the Sourcing Decision at ABC

INSOURCING OPTION	
Operating Expenses	
Direct labor	$0.0300
Benefits (50%)	$0.0150
Direct material	$0.0500
Indirect labor	$0.0110
Benefits (50%)	$0.0055
Equipment depreciation	$0.0100 ($10,000 absorbed over 1 million units)
Overhead	$0.0300
Engineering/design costs	$0.0300 ($30,000 absorbed over 1 million units)
Total cost per unit	**$0.1815**
OUTSOURCING OPTION	
Purchase price	$0.1000
Shipping and handling	$0.0100
Inventory charges	$0.0050
Administrative costs	$0.0007 [($20 per month) * (36 months)] / 1 million units
Total cost per unit	**$0.1157**
Savings per unit	**$0.0658**
Total savings (1 million units)	**$65,800**

Portfolio Analysis. Sourcing professionals have developed a wide range of approaches to help them in identifying the correct sourcing strategy. Figure 7.5 shows one such approach, called portfolio analysis.[8] In **portfolio analysis,** the products or services to be sourced are assigned to one of four strategic quadrants, based on their relative complexity and/or risk impact to the firm and their value potential. In general, the more money a company spends on a particular good or service, the higher its value potential. Depending on what quadrant a product or service is assigned to, the buying firm can then identify the most appropriate sourcing strategy, tactics, and actions.

Portfolio analysis
A structured approach used by decision makers to develop a sourcing strategy for a product or service, based on the value potential and the relative complexity or risk represented by a sourcing opportunity.

To illustrate, a standardized product available from many sources represents a relatively low level of complexity and sourcing risk to the firm; the product characteristics are well understood, and if one supplier fails to meet the needs of the company, another one will be ready to pick up the business. On the other hand, a highly customized product or service, available from one or a handful of suppliers, introduces greater levels of complexity and risk. Likewise, a service that represents $30 million of annual spending has a greater value potential—and, hence, deserves more attention from the firm—than one with an annual spend of just $10,000.

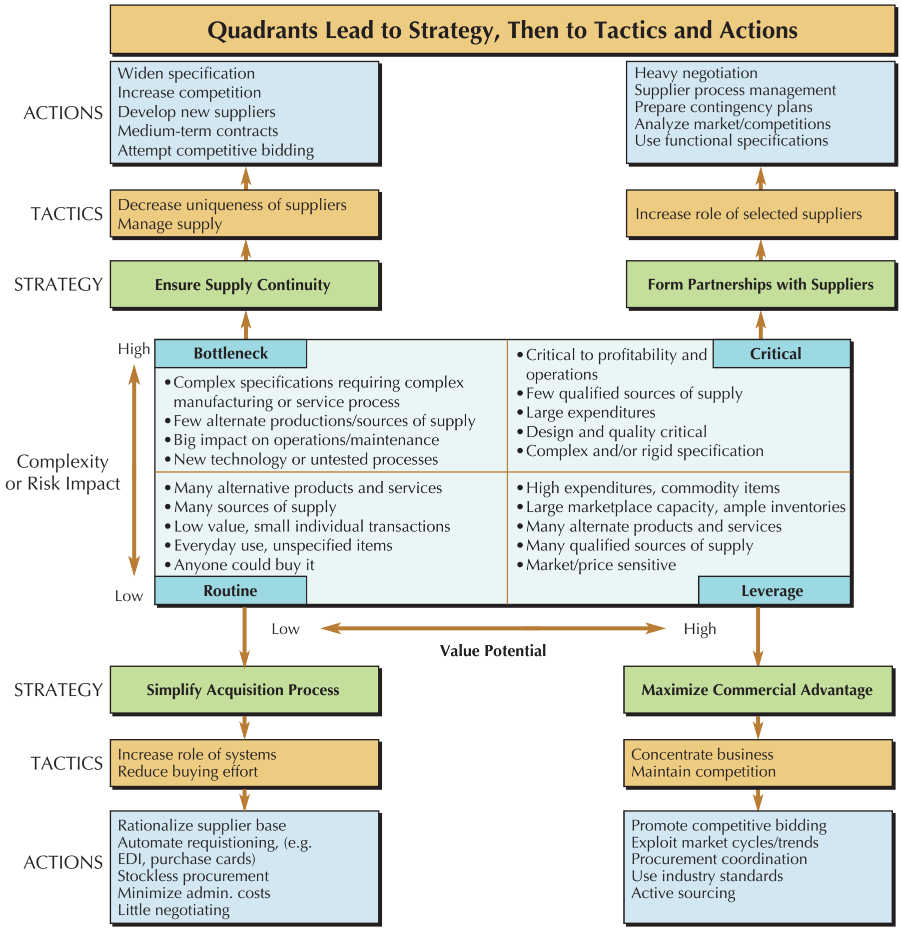
The "Routine" Quadrant. Products or services in the routine quadrant are readily available and represent a relatively small portion of a firm's purchasing expenditures. Typical examples include office supplies, cleaning services, and the like. The sourcing strategy therefore becomes one of simplifying the acquisition process, thereby lowering the costs associated with purchasing items in this quadrant. Specific actions can include automating the purchasing process, reducing the number of suppliers used, and using **electronic data interchange (EDI)** or purchase cards to streamline payment.

Electronic data interchange (EDI)
An information technology that allows supply chain partners to transfer data electronically between their information systems.

The "Leverage" Quadrant. Products or services in the leverage quadrant tend to be standardized and readily available, and they represent a significant portion of spend. The sourcing strategy therefore focuses on leveraging the firm's spending levels to get the most favorable terms

[8]Adapted from R. Monczka, R. B. Handfield, L. C. Giunipero, and J. L. Patterson, *Purchasing and Supply Chain Management,* 5th ed. (Mason, OH: South-Western, 2011).

FIGURE 7.5
Sourcing Portfolio Analysis



Preferred supplier
A supplier that has demonstrated its performance capabilities through previous purchase contracts and therefore receives preference during the supplier selection process.

possible. A **preferred supplier** is a supplier that has demonstrated its performance capabilities through previous purchase contracts and therefore receives preference during the supplier selection process. Preferred suppliers are frequently awarded business, with the understanding that they will reduce the cost of supplying these items in return for significant order volumes and multiple-year contracts. A high level of service is also expected, which may include such services as on-site inventory management by the supplier and e-purchasing.

The "Bottleneck" Quadrant. "Bottleneck" products or services have unique or complex requirements that can be met only by a few potential suppliers. In this case, the primary goal of the sourcing strategy is to not run out; in effect, the goal is to ensure supply continuity. This might involve carrying extra inventory to protect against interruptions in supply or contracting with multiple vendors to reduce supply chain risks.

The "Critical" Quadrant. Like bottleneck items, products or services in the critical quadrant have complex or unique requirements coupled with a limited supply base. The primary difference is that these items can represent a substantial level of expenditure for the sourcing firm. In cases such as this, the sourcing firm will spend considerable time negotiating favorable deals and building partnerships with suppliers, as well as preparing contingency plans in case of an interruption in supply.

This chapter's *Professional Profile* focuses on Amila Dillon of Biogen. As you are reading Amila's profile, ask yourself what quadrant of the sourcing portfolio matrix in Figure 7.5 best describes the "tail spend" she helps manage.

PROFESSIONAL PROFILE

AMILA DILLON, BIOGEN

Biogen, Inc., based in Cambridge, Massachusetts, is a biotechnology company specializing in the research, development, and delivery of therapies for a wide range of diseases. Like many large companies, Biogen uses a variety of approaches to manage its spend dollars, changing the tactics it uses based on the volume levels and strategic importance of the products or services being sourced. For example, for critical pharmaceutical ingredients that are purchased in large volumes, Biogen has dedicated category specialists with deep knowledge of the technical requirements and potential suppliers.

In contrast, Amila Dillon, a program manager in global procurement, and her team focus on what Biogen refers to as "tail spend"; that is, products and services that are under a certain dollar threshold and typically have a high number of transactions and suppliers. The tail spend is equivalent to 10–20% of a company's spend, which can add up to millions of dollars each year. Due to the wide variety of products and services that fall into this category, Amila and her team must be both creative and flexible in how they carry out their sourcing responsibilities. For example, one time a Biogen site was looking to purchase drones that could be used to inspect hard-to-see areas on a building. Amila and her team worked with the site management team to develop detailed product specifications, identify and qualify sources, understand federal regulations, and develop a request for proposal (RFP). Other efforts Amila has been involved with include carrying out sourcing activities for engineering, marketing, as well as research & development (R&D). As Amila puts it, "for every project we take on, our analysis goes beyond solely estimating costs. The suppliers' capabilities, quality, and service must be evaluated prior to awarding the business."

In her career at Biogen, Amila has been involved in a wide range of operations and supply chain activities, including forecasting, process selection efforts, and capacity planning. Her advice for students entering the job market: "Explore careers within your field of interest. Try internships or co-op assignments as learning opportunities to get a better understanding of what that job would entail. A basic understanding of operations and supply chain is important even if you don't go into the field as you will at some point end up working with someone from that department."

Photo courtesy of Ron Carrea, Biogen

Single sourcing
A sourcing strategy in which the buying firm depends on a single company for all or nearly all of a particular item or service.

Multiple sourcing
A sourcing strategy in which the buying firm shares its business across multiple suppliers.

Single and Multiple Sourcing, Cross Sourcing, and Dual Sourcing. An important part of any sourcing strategy is determining how many suppliers to use when sourcing a good or service. In **single sourcing,** the buying firm depends on a single company for all or nearly all of a particular item. In **multiple sourcing,** the buying firm shares its business across multiple suppliers. The advantages and disadvantages of each are shown in Table 7.11.

One way that companies can overcome the dilemma of the single sourcing versus multiple sourcing decision is through a compromise known as **cross sourcing.** In this strategy, a company uses a single supplier for one product or service, and another supplier with the same capabilities for another, similar product or service. Each supplier is then awarded new business

TABLE 7.11 Advantages and Disadvantages of Multiple/Single Sourcing

Multiple Sourcing		*Single Sourcing*	
ADVANTAGES	**DISADVANTAGES**	**ADVANTAGES**	**DISADVANTAGES**
Creates competition	Reduces supplier loyalty—suppliers may not be willing to "go the extra mile" for the purchaser	Volume leveraging as volumes go up, cost per unit decreases as supplier spreads fixed costs over larger volume	Knowing they have the business, suppliers can actually increase prices in the short term
Spreads risk (in event of a fire, strike, etc. at one supplier)	Can increase risk in the event of a shortage—supplier may supply only preferred customers	Transportation economics—fewer shipments and lower per-unit transportation costs	Increased supply risk—if a disaster occurs, the buyer can be left without a source of supply
Required if the purchased volume is too great for one supplier	May result in different product attributes with varying quality	Reduces quality variability; standardized products	Buyer can become "captive" to a supplier's technology—while other suppliers are surging ahead with newer technology that has better performance
Desired if firm wishes to meet obligations to support minority suppliers	Can actually result in increased prices over time, as suppliers are reluctant to provide cost-saving ideas	Builds stronger relationship with supplier, and gains access to design and engineering capabilities	Do not know if you have the "best" supplier available
Can ensure that suppliers do not become "complacent"	Suppliers can let performance slide if volume is not high enough to merit their attention	Required when supplier has a proprietary product	Dangerous strategy if the supplier has limited capacity or quality issues
Can help keep inventory levels down	In a global network, having multiple suppliers can also help reduce inbound freight cost and lower lead times	Required when volume is too small to split between two suppliers	.

Cross sourcing
A sourcing strategy in which a company uses a single supplier for one particular part or service and another supplier with the same capabilities for a different part or service, with the understanding that each supplier can act as a backup for the other supplier.

Dual sourcing
A sourcing strategy in which two suppliers are used for the same purchased product or service.

based on its performance, creating an incentive for both to improve. This also provides for a backup supplier in case the primary supplier cannot meet a company's needs.

A similar purchasing strategy is **dual sourcing.** This strategy is exactly what it sounds like: Two suppliers are used for the same purchased product or service. Typically, the split of the business is 70% to Supplier A and 30% to Supplier B. In this case, Supplier A knows that if performance suffers, it will lose business to Supplier B. Dual sourcing combines the volume benefits of single sourcing with the added protection of multiple or cross sourcing.

Step 4: Screen Suppliers and Create Selection Criteria

While portfolio analysis can help identify the appropriate sourcing strategy for a product or service, the buying firm still needs some way to evaluate potential and current suppliers. Identifying the "best" supplier for a new product or service or evaluating past supplier performance is a difficult task. This is especially true when the criteria include not just quantitative measures (such as costs, on-time delivery rates, etc.) but other, more qualitative factors, such as management stability or trustworthiness. Some of the qualitative criteria that a company might use to evaluate suppliers include:[9]

- **Process and design capabilities.** Since different manufacturing and service processes have inherent strengths and weaknesses (Chapter 3), the buying firm must be aware of these characteristics up front. When the buyer expects suppliers to perform component design and production, it should also assess the supplier's design capability. One way to reduce the time required to develop new products is to use qualified suppliers who are able to perform product design activities.
- **Management capability.** Different aspects of management capability include management's commitment to continuous process and quality improvement, overall professional ability and experience, ability to maintain positive relationships with the workforce, and willingness to develop a closer working relationship with the buyer.
- **Financial condition and cost structure.** Selecting a supplier that is in poor financial condition presents a number of risks. First, there is the risk that the organization will go out of business, disrupting the flow of goods or services. Second, suppliers who are in poor financial condition may not have the resources to invest in required personnel, equipment, or improvement efforts.
- **Longer-term relationship potential.** In some cases, a buying firm may be looking to develop a long-term relationship with a potential supplier. Perhaps the supplier has a proprietary technology or foreign market presence that the sourcing firm wants to tap into.

Request for information (RFI)
An inquiry to a potential supplier about that supplier's products or services for potential use in the business. The inquiry can provide certain business requirements or be of a more exploratory nature.

Organizations often use a **request for information (RFI)** to gather data about potential suppliers. An RFI is an inquiry to a potential supplier about that supplier's products or services for potential use in the business. The inquiry can provide certain business requirements or be of a more exploratory nature.[10] Not only can an RFI provide useful quantitative and qualitative information about a supplier, a completed RFI serves as a signal that a supplier might be interested in entering into a business relationship with the buying firm. Buying firms typically use their own purchasing records and RFI results to develop a supplier long list that will be shortened during the supplier selection process.

Step 5: Conduct Supplier Selection

Multicriteria decision models
Models that allow decision makers to evaluate various alternatives across multiple decision criteria.

The objective of the supplier selection step is to identify a short list of suppliers with whom the buying firm will engage in competitive bidding or negotiations. **Multicriteria decision models,** as the name suggests, are models that allow decision makers to evaluate various alternatives across multiple decision criteria. Multicriteria decision models are especially helpful when there is a mix of quantitative and qualitative decision criteria, when there are numerous decision alternatives to be considered, and when there is no clear "best" choice. They are therefore well suited to supplier selection efforts. Multicriteria decision models can help formalize what would otherwise be an ill-structured, poorly understood process.

The Weighted-Point Evaluation System. A common multicriteria decision model is the weighted-point evaluation system. In this model, the user is asked up front to assign weights to the performance measures (W_Y), and rate the performance of each supplier with regard to each dimension ($Performance_{XY}$). The total score for each supplier is then calculated as follows:

$$Score_X = \sum_{Y=1}^{n} Performance_{XY} \times W_Y \tag{7.3}$$

where:

X = Supplier X
Y = performance dimension Y
$Perfomance_{XY}$ = rated performance of Supplier X with regard to performance dimension Y
W_Y = assigned weight for performance dimension Y, where $\sum_{Y=1}^{n} W_Y = 1$

[9] Ibid.
[10] Adapted from J. H. Blackstone, ed., *APICS Dictionary*, 15th ed. (Chicago, IL: APICS, 2016).

EXAMPLE 7.6

Using the Weighted-Point Evaluation System to Support Supplier Evaluation at Electra Company

Electra Company is looking to award a new contract for 500,000 integrated circuit boards (ICBs). Table 7.12 summarizes the expected performance of three possible suppliers with regard to price, quality, and delivery.

TABLE 7.12 Summary Data for Three Possible Suppliers

PERFORMANCE DIMENSION	AARDVARK ELECTRONICS	BEVERLY HILLS	CONAN THE ELECTRICIAN
Price	$4/unit	$5/unit	$2/unit
Quality	5% defects	1% defects	10% defects
Delivery Reliability	95% on-time	80% on-time	60% on-time

The process begins by developing a weight for each of the criteria used. The sum of the weights must equal one. In this case, the sourcing team assigned to evaluating suppliers for the new contract has decided that quality is the most important criterion, followed closely by delivery and price. The resulting weights are:

$$\begin{aligned} W_{Price} &= 0.3 \\ W_{Quality} &= 0.4 \\ W_{Delivery\ Reliability} &= \underline{0.3} \\ \text{Total} &= 1.0 \end{aligned}$$

Next, the sourcing team evaluates each supplier's performance on each of the criteria, using the scales in Table 7.13.

TABLE 7.13 Scoring Scheme for Weighted-Point Evaluation System

5 = Excellent
4 = Good
3 = Average
2 = Fair
1 = Poor

Based on the product design team's specifications, the Electra sourcing team has assigned performance scores for each criterion, as shown in Table 7.14.

TABLE 7.14 Values for the Three Suppliers

PERFORMANCE DIMENSION	AARDVARK ELECTRONICS	BEVERLY HILLS	CONAN THE ELECTRICIAN
Price	4	3	5
Quality	3	5	1
Delivery Reliability	4	2	1

The total score for each supplier is then calculated by multiplying the respective performance ratings by the weight assigned to each performance dimension and summing the results across all dimensions. For Aardvark Electronics:

$$\begin{aligned} Score_{Aardvark} = {} & Performance_{Aardvark,\ Price} \times W_{Price} \\ & + Performance_{Aardvark,\ Quality} \times W_{Quality} \\ & + Performance_{Aardvark,\ Delivery\ Reliability} \times W_{Delivery\ Reliability} \\ = {} & 4 \times 0.3 + 3 \times 0.4 + 4 \times 0.3 = 3.6 \end{aligned}$$

The scores for Beverly Hills and Conan the Electrician are calculated in a similar manner, and are 3.5 and 2.2, respectively. Based on the results, the Electra team must now decide which suppliers to negotiate with. Conan the Electrician is clearly out of the running. While this supplier has the lowest price by far, its delivery and quality record is abysmal. This leaves Aardvark and Beverly Hills. Aardvark has a lower price but needs to improve its quality. Beverly Hills has excellent quality, but it has a problem delivering on time and must also find a way to reduce prices. Because the final scores for the two suppliers are so close, Electra has several options:

1. Award the contract to Aardvark, after a detailed negotiation in which it asks Aardvark to provide details on how it will improve its quality.
2. Award the contract to Beverly Hills, after a detailed negotiation in which it asks Beverly Hills to reduce its price and explain how it will improve delivery performance.
3. Award a dual source contract, in which the volumes are split between two suppliers. The contract might state that future volumes will be assigned according to which supplier improves its performance more quickly.

Clearly, supplier evaluation requires a significant amount of judgment in awarding points and assigning weights. However, the process of identifying key criteria and assigning numerical scores to performance allows users to be more objective and comprehensive in their decision making. Furthermore, conscientious managers will make every effort to back up their ratings with hard data.

Step 6: Negotiate and Implement Agreements

The strategic sourcing process does not end until the buying firm has reached a formal agreement with one or more suppliers regarding terms and conditions such as the price to be paid, volume levels, quality levels, and delivery performance. In some cases, firms may maintain a list of preferred suppliers that receive the first opportunity for new business. A preferred supplier has demonstrated its performance capabilities through previous purchase contracts and therefore receives preference during the supplier selection process. By maintaining a preferred supplier list, purchasing personnel can quickly identify suppliers that have proven performance capabilities.

Request for quotation (RFQ) A formal request for the suppliers to prepare bids, based on the terms and conditions set by the buyer.

Description by market grade/industry standard A description method that is used when the requirements are well understood and there is common agreement between supply chain partners about what certain terms mean.

Description by brand A description method that is used when a product or service is proprietary or when there is a perceived advantage to using a particular supplier's products or services.

Description by specification A description method that is used when an organization needs to provide very detailed descriptions of the characteristics of an item or a service.

Description by performance characteristics A description method that focuses attention on the outcomes the customer wants rather than on the precise configuration of the product or service.

When there is not a preferred supplier, competitive bidding and negotiation are two methods commonly used to select a supplier. *Competitive bidding* entails a request for bids from suppliers with whom a buyer is willing to do business. The process is typically initiated when the buying firm sends a **request for quotation (RFQ)** to qualified suppliers. The RFQ is a formal request for the suppliers to prepare bids based on the terms and conditions set by the buyer.

In contrast to an RFI, an RFQ often includes a detailed description of the products or services to be purchased. **Description by market grade** or **industry standard** might be the best choice for standard items, where the requirements are well understood and there is common agreement between supply chain partners about what certain terms mean. **Description by brand** is used when a product or service is proprietary or when there is a perceived advantage to using a particular supplier's products or services. A builder of residential communities, for example, might want to purchase R21 insulation (an industry standard) for the walls and finish-grade lumber (a market grade) for the trim and fireplace mantles. In addition, he might specify brands such as Georgia-Pacific's Catawba hardboard siding, Kohler faucets, and TruGreen-Chemlawn lawn treatment for all the homes.

More detailed and expensive methods of description are needed when the items or services to be purchased are more complex, when "standards" do not exist, or when the user's needs are more difficult to communicate. In some cases, the buyer might need to provide potential suppliers very detailed descriptions of the characteristics of an item or a service. We refer to such efforts as **description by specification.** Specifications can cover such characteristics as the materials used, the manufacturing or service steps required, or even the physical dimensions of the product. In contrast, **description by performance characteristics** focuses attention on the *outcomes* the buyer wants, not on the precise configuration of the product or service. The assumption is that the supplier will know the best way to meet the buyer's needs. A company purchasing thousands of laptops from Hewlett-Packard might demand (1) 24-hour support available by computer or phone and (2) a 48-hour turnaround time on defective units. How HP chooses to meet these performance characteristics is its choice.

Competitive bidding is most effective when:[11]

- The buying firm can provide qualified suppliers with clear descriptions of the items or services to be purchased.
- Volume is high enough to justify the cost and effort.
- The buying firm does not have a preferred supplier.

Buying firms use competitive bidding when price is a dominant criterion and the required items or services have straightforward specifications. In addition, government agencies often require competitive bidding. If major nonprice variables exist, then the buyer and seller usually enter into direct negotiation. Competitive bidding can also be used to identify a short list of suppliers with whom the firm will begin detailed purchase contract negotiation.

In recent years, firms have also begun to use electronic competitive bidding tools such as *reverse auctions* and *e-auctions*. These mechanisms work like a regular auction but in reverse: The buyer identifies potential qualified suppliers, who go to a specific Web site at a designated time and bid to get the business. In such cases, the lowest bid often occurs as suppliers see what other suppliers are bidding for the business and submit lower bids in an effort to win the contract.

Negotiation is a more costly, interactive approach to final supplier selection. Negotiation is best when:

- The item is a new and/or technically complex item with only vague specifications.
- The purchase requires agreement about a wide range of performance factors.
- The buyer requires the supplier to participate in the development effort.
- The supplier cannot determine risks and costs without additional input from the buyer.

Contracting. Often, a detailed purchasing contact is required to formalize the buyer–supplier relationship. A contract can be required if the size of the purchase exceeds a predetermined monetary value (e.g., $10,000) or if there are specific business requirements that need to be put in writing. Purchasing contracts can be classified into different categories, based on their characteristics and purpose. Almost all purchasing contracts are based on some form of pricing mechanism and can be categorized as a variation on two basic types: fixed-price and cost-based contracts.

Fixed-price contract
A type of purchasing contract in which the stated price does not change, regardless of fluctuations in general overall economic conditions, industry competition, levels of supply, market prices, or other environmental changes.

The most basic contract is a **fixed-price contract.** In this type of purchase contract, the stated price does not change, regardless of fluctuations in general overall economic conditions, industry competition, levels of supply, market prices, or other environmental changes.

With a fixed-price contract, if market prices for a purchased good or service rise above the stated contract price, the seller bears the brunt of the financial loss. However, if the market price falls below the stated contract price due to outside factors such as competition, changes in technology, or raw material prices, the buyer assumes the risk of financial loss. If there is a high level of uncertainty from the supplier's point of view regarding its ability to make a reasonable profit under competitive fixed-price conditions, then the supplier might add to its price to cover potential increases in component, raw materials, or labor prices. If the supplier increases its contract price in anticipation of rising costs and the anticipated conditions do not occur, then the buyer has paid too high a price for the good or service. For this reason, it is very important for the buying firm to adequately understand existing market conditions prior to signing a fixed-price contract.

Cost-based contract
A type of purchasing contract in which the price of a good or service is tied to the cost of some key input(s) or other economic factors, such as interest rates.

In contrast, a **cost-based contract** ties the price of a good or service to the cost of some key input(s) or other economic factor(s), such as interest rates. Cost-based contracts are often used when the goods or services procured are expensive or complex or when there is a high degree of uncertainty regarding labor and material costs. Cost-based contracts typically represent a lower risk level of economic loss for suppliers, but they can also result in lower overall costs to the buyer through careful contract management. It is important for the buyer to include contractual terms and conditions that require the supplier to carefully monitor and control costs. The two parties must also stipulate how costs are to be included in the calculation of the price of the goods or services procured.

[11] D. Dobler, L. Lee, and D. Burt, *Purchasing and Materials Management* (Homewood, IL: Irwin, 1990).

From the moment of signing, it is the purchasing manager's responsibility to ensure that all of the terms and conditions of the agreement are fulfilled. If the terms and conditions of a contract are breached, purchasing is also responsible for resolving the conflict.

7.3 THE PROCURE-TO-PAY CYCLE

Procure-to-pay cycle
The set of activities required to first identify a need, assign a supplier to meet that need, approve the specification or scope, acknowledge receipt, and submit payment to the supplier.

Once the buyer and supplier have agreed to enter into a relationship and a contract has been signed, the buyer will signal to the supplier that delivery of the product or service is required. This begins what is known as the **procure-to-pay cycle,** which is defined as the set of activities required to first identify a need, assign a supplier to meet that need, approve the specification or scope, acknowledge receipt, and submit payment to the supplier. In contrast to the strategic sourcing process, the procure-to-pay cycle is decidedly *tactical* in nature: It involves day-to-day communications and transactions between the buyer and supplier, and it is completed once the goods or services have been received, the supplier has been paid, and the information has been recorded into the database.

The five main steps of the procure-to-pay cycle are described next:

1. Ordering
2. Follow-up and expediting
3. Receipt and inspection
4. Settlement and payment
5. Records maintenance

Ordering

Purchase order PO
A document that authorizes a supplier to deliver a product or service and often includes key terms and conditions, such as price, delivery, and quality requirements.

The most common way the ordering step begins is through the release of a purchase order. A **purchase order (PO)** is simply a document that authorizes a supplier to deliver a product or service and often includes terms and conditions, such as price, delivery, and quality requirements. Increasingly, POs are released through EDI, which is a technology that allows supply chain partners to transfer data electronically between their information systems. By eliminating the time associated with the flow of physical documents between supply chain partners, EDI can reduce the time it takes suppliers to respond to customers' needs. This, in turn, leads to shorter order lead times, lower inventory, and better coordination between supply chain partners.

Follow-Up and Expediting

Someone (typically purchasing or materials personnel) must monitor the status of open purchase orders. There may be times when the buying firm has to expedite an order or work with a supplier to avoid shipment delays. The buying firm can minimize order follow-up by selecting only the best suppliers and developing internally stable forecasting and ordering systems.

Receipt and Inspection

When the order for a physical good arrives at the buyer's location, it is received and inspected to ensure that the right quantity was shipped and that it was not damaged in transit. If the product or service was provided on time, it will be entered into the company's purchasing transaction system. Physical products delivered by suppliers then become part of the company's working inventory.

Statement of work, or scope of work (SOW)
Terms and conditions for a purchased service that indicate, among other things, what services will be performed and how the service provider will be evaluated.

In the case of services, the buyer must ensure that the service is being performed according to the terms and conditions stated in the purchase order. For services, the user will typically sign off on a supplier time sheet or another document to signal to purchasing that the supplier satisfied the conditions stated in the **statement of work,** or **scope of work (SOW).** An SOW documents the type of service required, the qualifications of the individual(s) performing the work, and the outcome or deliverables expected at the conclusion of the work, among other things. Deviations from the SOW must be noted and passed on to the supplier and in some cases might require modifications to the original agreement.

SUPPLY CHAIN CONNECTIONS

PROCURE-TO-PAY SOURCING EFFORTS AT DEUTSCHE BANK

Just like manufacturers, banks also have supply chains that involve sourcing from third-party suppliers. Much of the external spend at a bank involves buying services that directly impact the bank's ability to service its own customers. Examples include travel, human resources, information technology, servicing of ATMs, market data services, and many others.

Ken Litton joined Deutsche Bank (DB) AG in June 2004, and serves as managing director, chief procurement officer. Litton's first task was to develop a detailed cross-enterprise spend analysis to provide a detailed view of where dollars were going across all divisions at DB. Not surprisingly, many areas of opportunity were uncovered, including payments for services that weren't being used by anyone yet but were still being billed by suppliers, supplier proliferation in certain spend categories, and the lack of standard contracts in many areas. What was particularly surprising was that only 50% of DB's total spend was managed and monitored through formal contracts with suppliers. The first two years of Litton's time was spent establishing a rigorous procure-to-pay process, which culminated in the adoption of information technology to support a broad array of sourcing relationships across DB's lines of business.

Litton's second task was to ensure that suppliers and DB's managers were complying with existing contracts. Today, for example, almost all sourcing relationships are captured in a contracts database that is readily accessible by sourcing managers. A third effort was directed at driving category management. Category managers were assigned to major spend categories. All spending in a category, such as travel or IT, now goes through an assigned manager. Strict compliance is required to establish a single source of contact for all purchase orders and to capture all payments and transactional data. Aligned with this effort, beginning in 2010, all suppliers were required to submit invoices electronically via the DB's Ariba Supplier Network (ASN). This allowed suppliers not only to view invoice payment status, purchase orders, and exception handling but it also drove DB's ability to capture metrics and build the foundation for a risk management system. Today category management is a well-established way of working at Deutsche Bank.

Settlement and Payment

Once an item or a service is delivered, the buying firm will issue an authorization for payment to the supplier. Payment is then made through the firm's accounts payable department. As with ordering, this is increasingly being accomplished through electronic means. Suppliers are often paid through **electronic funds transfer (EFT),** which is the automatic transfer of payment from the buyer's bank account to the supplier's bank account.

Electronic funds transfer (EFT)
The automatic transfer of payment from a buyer's bank account to a supplier's bank account.

Records Maintenance

After a product or service has been delivered and the supplier paid, a record of critical events associated with the purchase is entered into a supplier performance database. The supplier performance database accumulates critical performance data over an extended period. These data are often used in future negotiations and dealings with the supplier in question. The data gathered here can also support spend analysis efforts, as described earlier in the chapter.

7.4 TRENDS IN SUPPLY MANAGEMENT

This chapter would not be complete without a look at two key trends affecting supply management: environmental sustainability and planning for supply chain disruptions.

Sustainable Supply

As more companies become conscious of the importance of being environmentally friendly, environmental performance is becoming an important criterion in selecting suppliers. Companies want to ensure that suppliers are in compliance with environmental regulations and that

Whitebox Media/Alamy Stock Photo

As sustainability becomes more important, companies will look for suppliers who can provide environmentally friendly products and services, such as the packaging for these soups.

they are well positioned to deal with changes in the regulatory environment. Similarly, companies are looking for ways to reduce packaging, promote recycling, and use other strategies designed to reduce cost while being good for the environment.

Supply Chain Disruptions

As supply chains become more extended and firms depend even more on outside companies to provide critical goods and services, many firms are feeling the sting of disruptions to the supply chain.

The cause of these disruptions can take many forms, from natural disasters to economic or even political events. Some recent examples illustrate this phenomenon. A few years ago, Boeing experienced supplier delivery failure of two critical parts, with an estimated loss to the company of $2.6 billion. In 2002, striking dockworkers disrupted port operations on the U.S. West Coast. As a result, it took six months for some containers to be delivered and schedules to return to normal. In 2005, Hurricane Katrina caused billions of dollars of lost revenue to major retailers such as British Petroleum, Shell, Conoco Phillips, and Lyondell, as well as gasoline shortages in many parts of the United States. The 2010 BP oil spill was another incident that caused major havoc in the Gulf of Mexico and interrupted many supply chains.

In a recent survey of senior executives at Global 1000 companies, the respondents identified supply chain disruptions as the single biggest threat to their companies' revenue streams. Although senior executives now recognize that supply chain disruptions can be devastating to an enterprise's bottom line, strategies to mitigate supply chain disruptions are typically not well developed or even initiated. A concerning statistic is that only between 5% and 25% of Fortune 500 companies are estimated to be prepared to handle a major supply chain crisis or disruption.

One factor that is increasing the risk of supply chain disruptions is the propensity of companies to outsource processes to global suppliers. The complexity associated with multiple links in the supply chain increases the probability of disruptions. For example, as the number of "hand-offs" required to ship products through multiple carriers, multiple ports, and multiple government checkpoints increases, so does the likelihood of poor communication, human error, and missed shipments. An electronics executive we interviewed noted, "We have successfully outsourced production of our products to China. Unfortunately, we now recognize that we do not have the processes in place to manage risk associated with this supply chain effectively." As firms grapple with the risks associated with supply chain disruptions, we can expect to see more firms utilize the tactics and actions associated with bottlenecks and critical products (see Figure 7.5) and to develop comprehensive risk management strategies.

CHAPTER SUMMARY

In this chapter, we introduced you to some of the specific activities and challenges associated with supply management. We began by highlighting the importance of supply management, most notably the profit leverage effect. We then described in detail the strategic sourcing process (Figure 7.1) and demonstrated how spend analysis, total cost analysis, portfolio analysis, and weighted-point evaluation models can be used to support strategic sourcing efforts. We followed with a discussion of the procure-to-pay cycle, as well as some of the major challenges affecting supply management today.

We end this chapter with a brief discussion on the future of the purchasing profession. Every year, purchasing professionals perform fewer procure-to-pay activities and spend more time on strategic sourcing activities such as spend analysis, supplier evaluation and selection, and make-or-buy decisions. These activities require individuals with a solid mix of quantitative and interpersonal skills.

At the same time, information technology is reducing or even eliminating the clerical tasks that were traditionally carried out by purchasing professionals. By relying on information systems, end users can order directly what they require over the Internet. Also, production planning and control systems (Chapter 12) will generate orders automatically, based on production requirements. These systems will use online Web systems and portals to forward component requirements immediately to suppliers, reducing the need for direct purchasing intervention.

Another development that will reduce the clerical work assumed by purchasing is the use of suppliers to manage inventory at the customer's site. This is a classic example of an outsourced activity that was previously performed by purchasing or materials management professionals.

Organizations such as the Institute for Supply Management (ISM) help serve the needs of professionals in the purchasing area. The ISM's Web site, **www.ism.ws,** is an excellent place to learn about trends in purchasing and current research, as well ISM's professional certification programs.

KEY FORMULAS

Profit margin (page 193):

$$\text{Profit margin} = 100\% \times \frac{\text{Earnings}}{\text{Sales}} \tag{7.1}$$

Return on assets (ROA) (page 193):

$$\text{Return on assets (ROA)} = 100\% \times \frac{\text{Earnings}}{\text{Assets}} \tag{7.2}$$

Overall preference score for Supplier X, weighted-point evaluation system (page 208):

$$Score_X = \sum_{Y=1}^{n} Performance_{XY} \times W_Y \tag{7.3}$$

where:

X = Supplier X

Y = performance dimension Y

$Performance_{XY}$ = rated performance of Supplier X with regard to performance dimension Y

W_Y = assigned weight for performance dimension Y, where $\sum_{Y=1}^{n} W_Y = 1$

KEY TERMS

Core competencies 200
Corporate social responsibility 201
Cost of goods sold (COGS) 193
Cost-based contract 211
Cross sourcing 207
Description by brand 210
Description by market grade/industry standard 210
Description by performance characteristics 210
Description by specification 210
Direct costs 202
Dual sourcing 207
Electronic data interchange (EDI) 204
Electronic funds transfer (EFT) 213
Fixed-price contract 211
Indirect costs 202
Industry analysis 197
Insourcing 200
Make-or-buy decision 200
Maverick spending 199
Merchandise inventory 193
Multicriteria decision models 208

SOLVED PROBLEM

PROBLEM

Aitken Engineering

Aitken Engineering (AE) is a Dallas engineering firm that produces customized instrumentation for the aerospace industry. AE is thinking about outsourcing the production of a particular component to a Fort Worth manufacturer. The Fort Worth manufacturer has offered to make the components for a price of \$25 each, based on an annual volume of 32,000. However, there are additional costs associated with maintaining this supplier relationship. AE management has developed the following cost figures:

CURRENT MANUFACTURING OPERATIONS	FORT WORTH MANUFACTURER
Fixed Costs	**Price per Component**
Plant and overhead, \$800,000 per year	\$25
Variable Costs	**Other Costs**
Labor, \$8.50 per unit	Administrative costs, \$50,000 per year
Materials, \$5.00 per unit	Inspection costs, \$65,000 per year
	Shipping cost, \$1.50 per unit

In addition to cost, AE management has identified two other dimensions to consider: quality (specifically, the percentage of defect-free items) and on-time delivery. AE management has established importance weights of 0.2, 0.5, and 0.3 for cost, quality, and on-time delivery, respectively. Finally, purchasing managers at AE have rated the performance of the current assembly operation and the Fort Worth manufacturer with regard to these three dimensions. Their ratings (1 = "poor" to 5 = "excellent") are as follows:

	Performance Ratings	
PERFORMANCE DIMENSION	CURRENT MFG. OPERATIONS	FORT WORTH CONTRACT MANUFACTURER
Cost	3	5
Quality	5	4
On-time delivery	3	3

Calculate the total cost of each option, as well as the overall preference score.

Solution

Total costs for the current manufacturing operations:

$$\$800{,}000 + 32{,}000 \text{ units} \times (\$8.50 + \$5.00) = \$800{,}000 + \$432{,}000 = \$1{,}232{,}000$$

Total cost for the Fort Worth contract manufacturer:

$$\$50{,}000 + \$65{,}000 + 32{,}000 \text{ units} \times (\$25.00 + \$1.50) = \$115{,}000 + \$848{,}000 = \$963{,}000$$

The total cost analysis suggests that the Fort Worth manufacturer has a yearly cost advantage of (\$1,232,000 − \$963,000) = \$269,000. This result would seem to strongly favor the Fort Worth option. However, the overall preference scores suggest that the choice is not so clear:

$$
\begin{aligned}
Score_{Current} &= Performance_{Current,Cost} \times W_{Cost} \\
&\quad + Performance_{Current,Quality} \times W_{Quality} \\
&\quad + Performance_{Current,Delivery} \times W_{Delivery} \\
&= 3 \times 0.2 + 5 \times 0.5 + 3 \times 0.3 = 4
\end{aligned}
$$

and:

$$
\begin{aligned}
Score_{FtWorth} &= Performance_{FtWorth,Cost} \times W_{Cost} \\
&\quad + Performance_{FtWorth,Quality} \times W_{Quality} \\
&\quad + Performance_{FtWorth,Delivery} \times W_{Delivery} \\
&= 5 \times 0.2 + 4 \times 0.5 + 3 \times 0.3 = 3.9
\end{aligned}
$$

What accounts for the discrepancy? Quite simply, the overall preference scores take into consideration more than just cost. This, plus the fact that AE management places higher importance on quality and on-time delivery, tilts the preference scores in favor of the current assembly operation. Given these results, AE might decide to stick with its current manufacturing operations or perhaps work with the Fort Worth contract manufacturer to improve its quality and delivery performance *prior* to outsourcing the business. MS Excel for calculating the weight average score would be a good idea. Excel Formula of SUMPRODUCT is very handy for this.

DISCUSSION QUESTIONS

1. Consider the cafeteria services available at a university. In many cases, these services are outsourced to a private firm. Use Tables 7.6 and 7.7 as guides to explain why this is the case. In what quadrant would such services be positioned when determining a sourcing strategy (Figure 7.5)?
2. Under what conditions might a company prefer to negotiate rather than use competitive bidding to select a supplier?
3. In the chapter, we suggested that advanced information systems will automate some of the more routine purchasing activities. What are the implications for purchasing professionals? Is this a good time to join the purchasing profession? Explain.
4. In Chapter 4, we discussed the Six Sigma methodology for process improvement, including the DMAIC (Define–Measure–Analyze–Improve–Control) process. Give an example of how this process could be used to structure a spend analysis effort.

PROBLEMS

(* = easy; ** = moderate; *** = advanced)

Problems for Section 7.1: Why Supply Management Is Critical

1. Dulaney's Stores has posted the following yearly earnings and expenses:

EARNINGS AND EXPENSES (YEAR ENDING JANUARY 2019)	
Sales	$50,000,000
Cost of goods sold (COGS)	$30,000,000
Pretax earnings	$5,000,000
SELECTED BALANCE SHEET ITEMS	
Merchandise Inventory	$2,500,000
Total assets	$8,000,000

   a. (*) What is Dulaney's current profit margin? What is its current yearly ROA?
   b. (**) Suppose COGS and merchandise inventory were each cut by 10%. What would be the new pretax profit margin and ROA?
   c. (**) Based on the *current* profit margin, how much additional sales would Dulaney have to generate in order to have the same effect on pretax earnings as a 10% decrease in merchandise costs?

Problems for Section 7.2: The Strategic Sourcing Process

2. (**) Looking back at Example 7.6, suppose Conan the Electrician has implemented a Six Sigma program and as a result has brought defect levels down to just 1%, the same as Beverly Hills. Recalculate the weighted performance score for Conan the Electrician, using the weights provided in Example 7.6. Should Electra change its preferred supplier, based on these results?
3. The ABC Company (Example 7.5) has identified another potential supplier for the molded plastic parts. The new supplier has bid $0.08 per part but also will impose a shipping and handling charge of $0.015 per unit. Additional inventory handling charges should amount to $0.007 per unit. Finally, purchasing costs are estimated at $25 per month for the length of the 36-month contract.

   a. (*) Calculate the total costs for the new supplier. Which is cheaper: insourcing or outsourcing with the new supplier?
   b. (**) Suppose the three-year volume is expected to rise to 1.5 million, rather than 1 million, molded plastic parts. Recalculate the total costs associated with insourcing. What explains the difference?

c. (**) What other factors, other than costs, should ABC consider when deciding whether to make the molded parts in-house?

4. Granville Community College is considering outsourcing the maintenance of its buildings and other facilities to an outside firm for $300,000 per year. The 2020 budget is as follows:

Granville Maintenance Budget—2020

Direct expenses (per worker)
- Wages—$2,500 per worker per month
- Benefits—35% of wages per worker per month
- Maintenance, repair, and operating supplies—$2,000 per worker per month

Indirect expenses
- Supervisor salary—$3,000 per month
- Benefits—40% of wages
- Other office expenses—$500 per month

a. (*) Calculate the total costs of insourcing versus outsourcing maintenance.
b. (**) What other reasons, other than costs, might Granville look at when deciding whether to outsource maintenance activities?

5. Lincoln Lights is considering hiring one of three software firms to implement a new IT system. Lincoln management has decided to evaluate the firms on three dimensions—reputation, skill level, and price. Weights for each dimension, as well as performance ratings for each of the firms (1= "poor" to 5 = "excellent") are shown in the following table:

		Software Firm		
DIMENSION	WEIGHT	ALTREX	TGI LTD.	PC ASSOCIATES
Reputation	0.2	3	4	5
Skill level	0.4	5	4	4
Price	0.4	5	3	2

a. (*) Use the weighted-point evaluation system to calculate weighted performance scores for each of the software firms. Would the results change if each dimension had a weight of one-third?
b. (**) In Chapter 2, we described order qualifiers as performance dimensions on which customers demand a *minimum* level of performance. Basically, if a supplier fails to meet the minimum requirements on any of the qualifiers, that supplier would be eliminated from contention. How would you incorporate the concept of order qualifiers into the weighted-point evaluation system?

6. Flynn Industries has outsourced the delivery of its products and now wants to develop a tool to help evaluate its transportation carriers. The table at the bottom of the page shows the rating values associated with different levels of price, quality, and delivery performance, as well as criteria weights that reflect the relative importance of these dimensions. To illustrate how the ratings work, suppose a carrier has a damage level of 0.82%. This would fall between 0.75% and 1.0%, thereby garnering a rating of 2. The second table shows actual average performance levels for three carriers.

a. (*) Use the weighted-point evaluation system to calculate the weighted average performance for each carrier. Which carrier is best under this system?
b. (**) How would the results change if the weights for price, quality, and delivery shifted to 0.6, 0.2, and 0.2, respectively?
c. (**) Based on the results, should Flynn Industries single source or not? What might stop Flynn from single sourcing?

Rating Values for Flynn Industries (Problem 6)

	SUPPLIERS ARE RATED ON A SCALE OF 1–5, DEPENDING ON THEIR SPECIFIC PERFORMANCE LEVELS				
CRITERION (WEIGHT)	1	2	3	4	5
Price (0.20)	>$2.50/lb.	$2.01–$2.50/lb.	$1.51–$2.00/lb.	$1.00–$1.50/lb.	<$1.00/lb.
Quality (0.20)	Damage > 1%	Damage 0.75–1.0%	Damage 0.5–0.74%	Damage 0.25–0.49%	Damage < 0.25%
Delivery (0.60)	<82% on-time	82–84% on-time	85–90% on-time	91–95% on-time	>95% on-time

Carrier Performance for Flynn Industries (Problem 6)

	CARRIER A	CARRIER B	CARRIER C
Price	$1.98/lb.	Price $2.02/lb.	$98.00/100 lb.
Quality	0.35% damaged	Quality 0.26% damaged	0.86% damaged
Delivery	93% on-time	Delivery 98% on-time	83% on-time

7. (***) (*Microsoft Excel problem*) The following worksheet uses a weighted-point evaluation system to calculate weighted performance scores along four dimensions for up to four potential sources. **Re-create this spreadsheet in Microsoft Excel.** Code your spreadsheet so that any change in the highlighted cells will result in recalculated performance scores. Your formatting does not have to be exactly the same, but your numbers should be. (*Hint:* Changing all the importance weights to 0.25 should result in scores of 2.25 and 3.5 for sources X1 and X2, respectively.)

WEIGHTED-POINT EVALUATION SYSTEM

	A	B	C	D	E	F
1	**Weighted-Point Evaluation System**					
2						
3			Potential Sources			
4	Dimension	Importance	X1	X2	X3	X4
5	A	0.20	1	3	2	4
6	B	0.30	2	4	3	2
7	C	0.30	2	4	3	2
8	D	0.20	4	3	2	1
9	Total:	1.00				
10		**Scores:**	**2.2**	**3.6**	**2.6**	**2.2**

CASE STUDY

Pagoda.com

Introduction

Pagoda.com is an Internet service provider (ISP) that caters to individual consumers and small businesses who require a high level of service and are willing to pay a premium for it. Specifically, Pagoda.com offers state-of-the-art email applications and Web-building software, as well as plenty of storage space and the fastest access available. The marketing vice president, Jerry Hunter, puts it this way: "There are a lot of companies out there promising the cheapest Internet access. But what do you get for your money? Slow- or no-access and an endless stream of system crashes. And I won't even mention the lack of support if you have a technical question! For a few dollars more a month, we give our customers the environment they need to be productive. It's no surprise, then, that we have the highest customer satisfaction and retention rates in the industry."

The Online Help Desk

One of Pagoda's services is its online help desk. The online help desk works as follows: Customers who are experiencing technical problems, or who simply have questions about their account, enter a one-on-one chat room, where they can interact directly with an expert. Problems are usually resolved within 10 minutes, and customers have listed it as one of the top three reasons they stick with Pagoda.com. Presently, Pagoda has enough capacity to handle up to 900,000 requests per year, although management doesn't expect the number of requests to change much from the current level of 800,000 per year.

A firm located in New Delhi, India, has approached Pagoda about outsourcing the online help desk. The offer is attractive. The New Delhi firm's own personnel would handle the help desk function. These personnel all speak English fluently and have college degrees or appropriate technical backgrounds. And because they are located in India, labor costs would be a fraction of what they are in the United States. The savings would be passed on, in part, to Pagoda. And since the help desk chat room exists on the Internet, Pagoda's customers should be unaware of the switch.

Pagoda management has put together the following figures, outlining the yearly costs associated with the current system and the Indian proposal:

Current Online Help Desk

Personnel costs:
40 full-time-equivalent (FTE) technical experts @ $40,000 per year (salary and benefits); 3 supervisors @ $70,000 each per year (salary and benefits)

Equipment costs:
4 servers @ $2,000 per year
20 PCs @ $1,000 per year

Variable costs:
$1.50 per request (office supplies, fax paper, etc.)

New Delhi Proposal

Fixed cost:
$1,500,000 per contract year (to cover administrative and IT costs)

Charge:
$0.50 per request

Questions

1. Calculate the total cost of outsourcing the online help desk versus staying with the current solution. Which option is cheaper?
2. What other factors, other than costs, should Pagoda consider? How would you weight these factors? Given the above, how might you use a weighted-point evaluation system to evaluate the two options?
3. Should Pagoda.com outsource its online help desk? Why or why not? Be sure to consider Table 7.7 and 7.8 when framing your answer.

4. A statement of work typically specifies performance measurements that the buying firm can use to determine whether the service provider is meeting the terms of the contract. What performance measurements would you recommend be put in place? What should happen if the service provider fails to meet these requirements?

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Gilles Lougassi/Shutterstock

CHAPTER **eight**

Logistics

CHAPTER OUTLINE

CHAPTER OBJECTIVES

By the end of this chapter, you will be able to:

- Describe why logistics is important and discuss the major decision areas that make up logistics.
- List the strengths and weaknesses of the various modes of transportation and discuss the role of multimodal solutions.
- Identify the major types of warehousing solutions and their benefits.
- Discuss the purpose of a logistics strategy and give examples of how logistics can support the overall business strategy.
- Calculate the percentage of perfect orders.
- Calculate landed costs.
- Explain what reverse logistics systems are and describe some of the unique challenges they create for firms.
- Use the weighted center of gravity method to identify a potential location for a business.
- Develop and then solve, using Microsoft Excel's Solver function, an assignment problem.

KRAFT FOODS[1]

Frank Polich/Reuters

Several years back, Kraft Foods set out to redesign the logistics system it used to deliver products to its various customers, such as major grocery store chains and food distributors. Kraft's efforts were centered on three major customer requirements:

1. Customers wanted to be able to order a wide variety of Kraft's products and receive the shipment the next day. This would give the customers greater flexibility and allow them to hold smaller inventories in their facilities.
2. Customers also wanted the option of being able to place large orders directly with Kraft's plants in return for significant price discounts. Under Kraft's old logistics system, this was not always possible.
3. Customers wanted a single order contact point and to receive volume discounts based on their entire purchase volume. Before, customers had to deal with three different divisions at Kraft, each with its own pricing and logistics system.

In response to these needs, Kraft set up a new logistics system. Figure 8.1 shows how the new system works. First, plant-based warehouses allow customers to place orders for direct plant shipments (DPSs) with any of the plants. At the same time, regional mixing centers hold the entire line of Kraft products. These mixing centers are strategically located to provide overnight shipments to the maximum number of customers. Kraft also consolidated all of its pricing, ordering, and invoicing systems into one single system to ease the administrative burden placed on customers and to ensure that customers received appropriate volume discounts. The ultimate result was that Kraft was able to meet its customers' key requirements, resulting in greater customer satisfaction and high profits for Kraft.

Kraft's efforts didn't end with the implementation of the new logistics system, however. Today, Kraft continues to make improvements with an eye on cutting costs, improving customer service, and reducing the environmental impact of its operations. For example, in Canada and the United States, Kraft is using software at its 20 largest plants and mixing centers to optimize outbound shipments and put more products on fewer trucks. This effort has had the effect of taking 1,500 trucks off the road and reducing highway usage by more than 1 million miles. In Brazil, the company eliminated 2.4 million pounds (1 million kg) of material by redesigning packaging and shipping materials for its *Tang*, *Lacta*, and *Club Social* brands.[2]

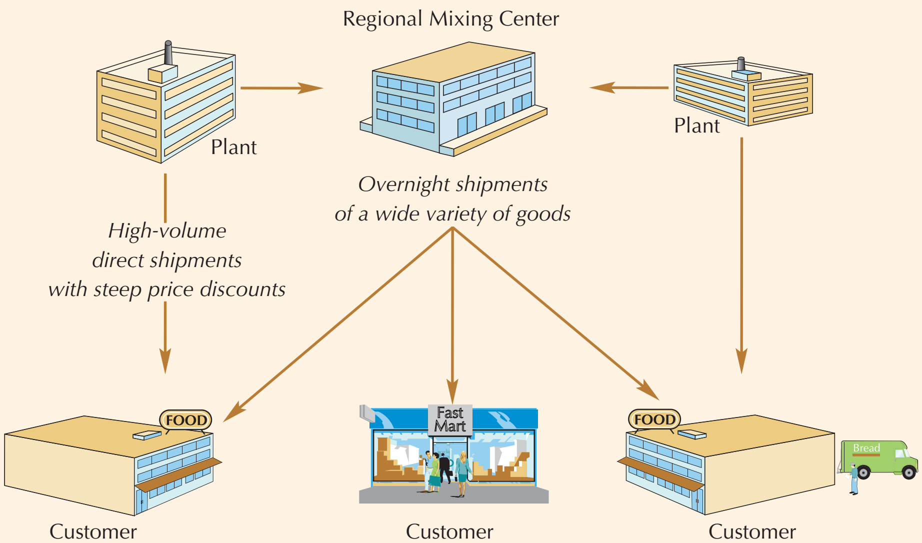

FIGURE 8.1 Redesigning the Logistics System at Kraft Foods to Satisfy Customer Needs

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[1] S. Tibey, "How Kraft Built a 'One-Company' Supply Chain," *Supply Chain Management Review* 3, no. 3 (Fall 1999): 34–42.

[2] "Kraft Foods Sustainability Fact Sheet," April 2009, **www.kraftfoodscompany.com/assets/pdf/KFTFactSustainabilityProgress2009.04FINAL.pdf.**

INTRODUCTION

Logistics management According to the Council of Supply Chain Management Professionals (CSCMP), "that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements."

According to the Council of Supply Chain Management Professionals (CSCMP), **logistics management** is "that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements."[3] Companies depend on their logistics systems to move goods and materials among supply chain partners and to manage the information flows necessary to carry out these tasks. Logistics incorporates a wide range of business activities, including:

- Transportation
- Warehousing
- Material handling
- Packaging
- Inventory management (Chapter 11)
- Logistics information systems (Chapter 12S)

As you can imagine, the interrelationships among these business activities are quite complex. At Kraft, inventory management tasks changed with the introduction of the mixing centers and direct plant shipments. Similarly, the decision to switch to more environmentally friendly packaging can directly affect how transportation and material handling are carried out.

The purpose of this chapter is to introduce you to the field of logistics. After describing its strategic importance, we survey the major decision areas that make up logistics: the choice of transportation modes, warehousing, logistics information systems, and material handling and packaging systems. We also pay particular attention to the interrelationship between inventory management and the other logistics decision areas. Then we turn to the concept of a logistics strategy and examine two measures of logistics performance: the perfect order and landed costs. We also highlight reverse logistics systems, which have become increasingly important as firms look to bring used products back into the supply chain to be repaired, refurbished, or recycled. We end the chapter with a detailed presentation of two commonly used logistics decision models: the weighted center of gravity method and the assignment problem.

8.1 WHY LOGISTICS IS CRITICAL

Sustainability Performing activities in a manner that meet the needs of the present without compromising the ability of future generations to meet their needs.

As the interest in supply chain management continues to grow, more businesses are managing logistics in an effort to improve their cost, flexibility, and delivery performance. Today, advances in information systems, the globalization of markets, and the push toward **sustainability**—that is, performing activities in a manner that meets the needs of the present without compromising the ability of future generations to meet their own needs—continue to create challenges and opportunities that did not exist just a few years ago.

The performance effects of logistics are manifold. In 2012, the cost of logistics in the United States was $1.33 trillion, or 8.5% of gross domestic product (GDP).[4] Interestingly, this percentage has fallen dramatically since 1980, when logistics expenditures represented 17.9% of GDP. This improvement—despite more geographically extended supply chains—suggests that companies operating in the United States have made significant advances in managing their logistics systems. Recent studies show that in the United States, logistics costs account for between 5% and 35% of total sales costs, depending on the business, geographic area, and type of product being sold. These costs are expected to grow as businesses and consumers move toward

[3]CSCMP Supply Chain Management Definitions and Glossary, **http://cscmp.org/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms.aspx?hkey=60879588-f65f-4ab5-8c4b-6878815ef921.**

[4]D. Gilmore, "State of the Logistics Union 2013," *Supply Chain Digest*, June 20, 2013, **www.scdigest.com/assets/FIRSTTHOUGHTS/13-06-20.php?cid=7172.**

PROFESSIONAL PROFILE

DWIGHT HENDRICKSON, CATERPILLAR

Courtesy of Dwight Hendrickson

Throughout this book, we have made the point that supply chains cover everything from sourcing-to-producing-to-delivering the final product or service. Furthermore, supply chain *management* takes place at the strategic planning level, looking years into the future, down to the execution of day-to-day activities.

In over 20 years at Caterpillar, Dwight Hendrickson has experienced all of this firsthand. He has been a commercial purchasing analyst and a lead buyer; a general operations supervisor and certified Six Sigma black belt; and a logistics manager and product program manager. In fact, Dwight's experience is so comprehensive that outside professional organizations regularly look to him for his expertise and leadership. He currently serves on the North Carolina District Export Council (NCDEC), which is made up of professionals who act as consultants to small- and medium-sized businesses that want to export their products into markets outside of the United States. Dwight also served as the executive vice president and president for his local APICS chapter.

In his current role as a supply chain manager in Caterpillar's Building Construction Products (BCP) Division, Dwight is responsible for developing and putting in place distribution strategies for new BCP products, such as backhoe loaders and excavators.[5] Beyond the sheer size of these products (a typical backhoe can weigh around 10 tons), what makes Dwight's job particularly challenging are the "unknowns." For example, what kind of response time does the market require? Is it months, weeks, or days? Also, what will future business volumes be like? Since the demand for building construction products is tightly tied to the overall health of the world economy and other geopolitical factors, Dwight has to make sure Caterpillar is ready to increase volumes dramatically when the economy is strong and scale down activity when markets contract. Other considerations are more micro in nature—for instance, the required shipping configuration for a product (fully assembled or not) can depend on such factors as the actual shipping containers used and local regulations.

Even though his current responsibilities fall primarily in the logistics area, Dwight's experience as a Six Sigma black belt still shows through: "In business, defining the problem is often the most difficult thing to do." He also offers this advice to people entering the business world: "Be curious about whatever field you choose to be in. You can never stop learning."

[5]See **www.cat.com/en_US/products/new/equipment.html** for examples of the type of equipment manufactured by Caterpillar's BCP division.

smaller, more frequent shipments of goods and materials and as more companies depend on foreign sources. For many firms, logistics expenses now are second only to material costs in terms of their impact on cost of goods sold.

Logistics can also have a profound impact on other performance dimensions, such as delivery speed and reliability. Many companies have spent enormous amounts of money on decreasing the lead times within their organizations, only to discover that their customers never saw much benefit due to long shipping times once items left the organizations' facilities. These same companies are now concentrating intensively on the logistics systems that link them to their customers. Because logistics systems often interface directly with customers, they can have considerable impact on overall customer satisfaction. This chapter's *Professional Profile* features Dwight Hendrickson of Caterpillar. As you read Dwight's profile, consider the breadth of experience Dwight brings to his job as a supply chain planner and the importance of delivering his high-cost products to customers in a timely and cost-effective manner.

8.2 LOGISTICS DECISION AREAS

Logistics includes not just physical flows, such as the delivery of products to a customer, but also informational flows. Transportation and warehousing systems define the physical network of a logistics system and play a major role in determining its overall performance in terms of cost, delivery, and flexibility. Logistics information systems create and manage the informational flows in the network. Order management systems, warehouse storage and retrieval systems, transportation scheduling and package routing systems, and even tracking systems like the one UPS uses to track shipments are all part of the logistics information system. In the past 10 years, logistics information systems have seen explosive growth; in many supply chains, they represent the greatest opportunity for improvement in supply chain performance. Typically, a firm's material handling and packaging systems are tightly intertwined with both its transportation and information systems. While a full treatment of material handling and packaging is beyond the scope of this book, we will provide examples in this section to illustrate their importance.

Transportation

There are five widely recognized transportation modes: highway, water, air, rail, and pipeline.[6] Table 8.1 compares the total item value, tons, and ton-miles shipped via each mode in the United States.

Highway. Highway transportation dominates the U.S. logistics infrastructure. In 2012 alone, U.S. businesses and individuals moved over $10 *trillion* in goods via trucking—or 73% of the total value of goods moved. In the same year, trucking accounted for around 1.25 trillion ton-miles—or roughly 42% of the total ton-miles shipped. By whatever metric one uses (the value of goods shipped, tons moved, or ton-miles), highway transportation is dominant. Several factors account for this:

- **Geographic extension of supply chains.** As more companies developed supply chain relationships with nonlocal suppliers and customers, highway traffic increased.
- **Greater emphasis on delivery speed and flexibility.** Highway transportation has stolen market share from slower rail and water systems, which have experienced relatively significant increases in the value of shipments, but a decline in ton-miles shipped. In a world that places great emphasis on delivery speed and flexibility, highway transportation has a clear advantage over both rail and water.

Highway transportation in the United States continues to grow because it is one of the most flexible modes of transportation: If the source or destination point for goods can be reached by road, then the goods can be shipped by highway. In fact, very few goods are moved without highway transportation at some point in transit. Highway transportation has

TABLE 8.1 Modal Shares of U.S. Domestic Freight for 2012 (% change, 2002–2012)

TRANSPORTATION MODE	VALUE (BILLION $)	TONS (MILLIONS)	TON-MILES (BILLIONS)
Highway (trucking)	$10,132 (+63%)	8,060 (+3%)	1,248 (−1%)
Rail	$473 (+52%)	1,629 (−13%)	1,211 (−4%)
Water	$302 (+238%)	576 (−15%)	193 (−32%)
Air	$451 (+70%)	5 (29%)	6 (0%)
Pipeline	$543 (+264%)	636 (−7%)	Not available
Multimodal	$1,951 (+81%)	357 (+65%)	272 (+20%)

Source: U.S. Department of Transportation, *National Transportation Statistics, April 2017*, Washington, DC, Table 1-58, **www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_01_58.html.**

[6]Unless otherwise stated, the figures given in this section are from U.S. Department of Transportation, *National Transportation Statistics 2010*, Washington, DC.

David R. Frazier/Danita Delimont Photography/Newscom

A truck pulling two pup trailers.

also become more cost-effective over time. Better scheduling and use of vehicle capacity, more efficient and reliable vehicles, and increased cost competition due to deregulation have all contributed to this trend.

Water. Water-based transportation accounts for around 9% of all ton-miles shipped in the United States and is ideal for materials with a high weight-to-value ratio, especially if delivery speed is not critical. Examples of such materials include farm produce, timber, and petroleum-based products. Because of the relatively high weight-to-value ratio of these commodities, shipping can significantly add to their costs. Water-based transportation, with one of the lowest ton-mile rates of any mode, helps to hold down those costs.

Air. At the opposite end of the scale from water transportation, air transportation is ideal for materials with a low weight-to-value ratio, especially if delivery speed or delivery reliability is critical. An example is a high-value electronic component, which might weigh only a few ounces yet be worth hundreds or even thousands of dollars. Spending $10 (or $2.50 per ounce) to guarantee next-day delivery of such a valuable product hardly seems outrageous. While air transportation is the least-used mode in terms of tons and ton-miles, it grew strongly between 2002 and 2012 in terms of the value of goods shipped.

Rail. Rail transportation has cost characteristics similar to those of water transportation, but it is somewhat more flexible. By 2012, rail's percentage of U.S. domestic ton-miles shipped had actually grown to 41%, up significantly from a 1997 estimate of 26.7%. The rail carriers' strategies for accomplishing this have included doubling the number of lines along busy corridors, changing the physical configuration of the trains themselves, and using multimodal solutions, which we describe in more detail in the following paragraphs.

Selecting a Transportation Mode

As Table 8.2 shows, the major transportation modes differ greatly in terms of their relative strengths and weaknesses. Firms must therefore carefully select a mode based on their particular competitive or operational requirements.

TABLE 8.2 Strengths and Weaknesses of the Major Transportation Modes

TRANSPORTATION MODE	STRENGTHS	WEAKNESSES
Highway	Flexibility to deliver where and when needed. Often the best balance among cost, flexibility, and reliability/speed of delivery.	Neither the fastest nor the cheapest option.
Water	Highly cost-effective for bulky items. Most effective when linked to a multimodal system.	Limited locations. Relatively poor delivery reliability/speed.
Rail	Highly cost-effective for bulky items. Can be most effective when linked to a multimodal system.	Limited locations, although less so than with water. Not as fast as highway, but improving over time.
Air	Quickest mode of delivery. Flexible, especially when linked to the highway mode.	Often the most expensive mode on a per-pound basis

EXAMPLE 8.1

Choosing a Transportation Mode at Seminole Glassworks[7]

Seminole Glassworks needs to ship 3,500 pounds of custom-built office windows from Miami, Florida, to Columbus, Ohio. Seminole has three transportation options:

MODE	DELIVERY SPEED	VEHICLES	EXTRA HANDLINGS	COST
Air	8.75 hours	3	2	$12,100
Direct truck	27.75 hours	1	0	$2,680
LTL truck	3 days	3	2	$445

Direct truck shipment
A shipment made directly, with no additional stops, changing of trucks, or loading of additional cargo.

Less than truckload (LTL) shipment
A smaller shipment, often combined with other loads to reduce costs and improve truck efficiencies.

With a **direct truck shipment,** Seminole would contract with a carrier to pick up the windows at its Miami plant and carry them *directly*—no stops, no changing of trucks or loading of additional cargo—to the customer's site in Columbus. With **LTL (less than truckload) shipping,** the carrier could combine Seminole's windows with other loads going to Columbus. Note that if LTL shipping is used, Seminole's windows are likely to switch trucks at a centralized sorting hub, which would result in additional handlings and delays.

Which option should Seminole choose? The answer depends on the firm's business requirements. While LTL shipping has a clear cost advantage, direct trucking is quicker and requires fewer handlings. Air transportation would get the windows to the customer about 19 hours earlier. That advantage might be critical if the glass is needed to replace broken windows in an occupied building or if leaving a new building without windows for just a day can risk damage to the interior.

Multimodal Solutions

Multimodal solution
A transportation solution that seeks to exploit the strengths of multiple transportation modes through physical, information, and monetary flows that are as seamless as possible.

Roadrailer
A specialized rail car the size of a standard truck trailer that can be quickly switched from rail to ground transportation by changing the wheels.

Few companies or supply chains use just one transportation mode. In fact, many depend on multimodal solutions to get goods from one end of the supply chain to the other. A garment manufacturer, for instance, might use ocean freight to move 40-foot containers from Vietnam to Long Beach, California; rail to move those same containers from Long Beach to Atlanta; and trucks to distribute the garments in the containers throughout the southeastern United States.

Multimodal solutions, as the name implies, are transportation solutions that seek to exploit the strengths of multiple transportation modes through physical, information, and monetary flows that are as seamless as possible. For instance, today's rail carriers regularly use standardized containers that can be quickly moved from flatcar to truck with no unloading and reloading of material. The result is significant time and cost savings. Some rail carriers even use **roadrailers,** which are railcars the size of standard truck trailers that can be quickly switched from rail to ground transportation by changing the wheels.

[7]Adapted from J. Childs, "Transportation and Logistics: Your Competitive Advantage or Your Downfall?" *APICS—The Performance Advantage* 6, no. 4 (April 1996): 44–48.

Airports and water ports are other major points of transfer from one mode to another. These ports, which serve as transfer points for global supply chains, have experienced significant growth over the past 15 years. For example, JFK International Airport in New York handled $89 billion worth of goods in 1997; by 2012, this figure had risen to nearly $200 billion.[8] The water port of Long Beach, California, saw similar increases, from $85 billion in 1997 to more than $285 billion in 2013.[9]

Just as important are recent improvements in information technology. Returning to the rail industry, the Union Pacific Railroad (**www.up.com**) has invested heavily in information technologies that allow it to plan and track customers' shipments across multiple transportation modes (rail, water, and highway), as well as multiple logistics firms. To its customers, Union Pacific offers one-stop logistics shopping.

As shipping containers have become more standardized across transportation modes and information systems for tracking and routing shipments have made such systems easier to manage, multimodal transportation has grown in importance. Look again at the data in Table 8.1. In both tons and ton-miles shipped, the use of multimodal solutions in the United States is growing at a faster rate than any single transportation mode. International freight saw similar rates of growth in multimodal shipments.

Warehousing

Transportation systems represent just one part of the physical flow of goods and materials. The other part is warehousing. Many companies have put an emphasis on minimizing inventory levels. As a result, many people now think of warehouses only as places where goods and materials sit idle, taking up space and tying up capital. This negative concept of warehousing is unwarranted, however.

In fact, warehousing plays a much broader role in a firm's operations and supply chain strategy. Formally defined, **warehousing** refers to any operation that stores, repackages, stages, sorts, or centralizes goods or materials. As we will see, warehousing can be used to reduce transportation costs, improve operational flexibility, shorten customer lead times, and lower inventory costs.

Warehousing
Any operation that stores, repackages, stages, sorts, or centralizes goods or materials. Organizations use warehousing to reduce transportation costs, improve operational flexibility, shorten customer lead times, and lower inventory costs.

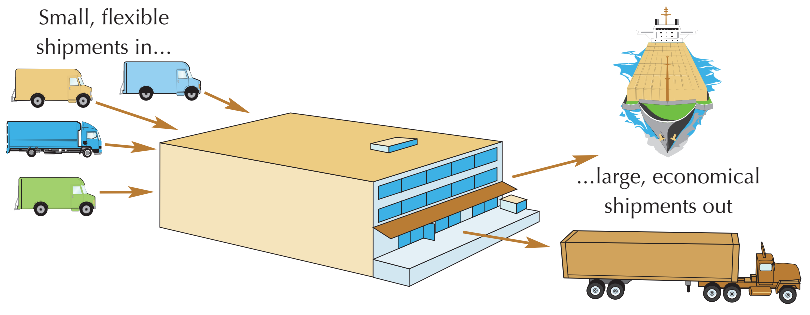
Reducing Transportation Costs. Anyone who thinks warehouses do nothing but store goods should consider consolidation, cross-docking, and hub-and-spoke systems. These systems have little or no long-term storage. Rather, all three are designed primarily to exploit economies of scale in transportation.

Consolidation warehousing pulls together shipments from a number of sources (often plants) in the same geographic area and combines them into larger—and hence more economical—shipping loads. Figure 8.2 shows an example of this.

Consolidation warehousing
A form of warehousing that pulls together shipments from a number of sources (often plants) in the same geographic area and combines them into larger—and hence more economical—shipping loads.

There are several variations of this type of system. A single manufacturer may use a consolidation warehouse to pull together the output from several plants, combining it when possible into a single large shipment to a major customer. In another variation, a contract carrier may use its own consolidation warehouse to combine shipments from several local businesses.

FIGURE 8.2
Consolidation Warehousing



[8]The Port Authority of New York and New Jersey, "2012 Annual Traffic Report," **www.panynj.gov/airports/pdf-traffic/ATR2012.pdf.**
[9]"Port of Los Angeles Fact Sheet," June 2013, **www.portoflosangeles.org/about/facts.asp.**

EXAMPLE 8.2

Consolidation Warehousing at Bruin Logistics

Bruin Logistics handles hundreds of shipments from businesses in the Los Angeles area. At present, Bruin has three shipments to deliver to the Atlanta area:

CUSTOMER	SHIPMENT	WEIGHT
Venetian Artists Supply	100 boxes of drawing paper	3,000 lb.
Kaniko	100 PC printers	3,000 lb.
Ardent Furniture	10 dining room sets	4,000 lb.
	Total:	10,000 lb.

The cost to Bruin of sending a truck from Los Angeles to Atlanta is $2,000. The maximum load per truck is 20,000 pounds. If Bruin were to use a direct truck shipment for each customer, the shipping costs would be $2,000 per customer, or $6,000 total. The weight utilization across all three trucks would be 10,000 pounds/60,000 pounds, or just 17%—hardly an economic or environmentally wise use of resources.

But suppose Bruin has a consolidation warehouse where loads from multiple customers can be combined. Of course, there are costs associated with consolidation. Assume that the cost of running the warehouse is approximately $90 per 1,000 pounds, or in logistics lingo, $9 per hundred-weight. Furthermore, if Bruin decides to consolidate the three shipments, it must consider the additional cost of breaking them up for local delivery, which is not an issue in direct trucking. Suppose the cost of breaking up the shipments is $200 for each customer. Under these conditions, the costs of consolidating the three shipments to Atlanta would be:

Warehousing costs:	$9(10,000 lb./100 lb.) =	$900
Cost of one truck to Atlanta:		$2,000
Delivery to final customer:	3 customers × $200 =	$600
	Total:	$3,500

Note that the cost of consolidating the shipments is just over half the cost of the direct truck shipments. Furthermore, weight utilization increases to 10,000 pounds/20,000 pounds, or 50%.

Cross-docking
A form of warehousing in which large incoming shipments are received and then broken down into smaller outgoing shipments to demand points in a geographic area. Cross-docking combines the economies of large incoming shipments with the flexibility of smaller local shipments.

Break-bulk warehousing
A specialized form of cross-docking in which the incoming shipments are from a single source or manufacturer.

In **cross-docking,** another system that reduces transportation costs, the approach used in consolidation warehousing—large shipments in, small shipments out—is reversed. This type of system achieves essentially the same benefits, however, as is illustrated in Figure 8.3.

Like consolidation, cross-docking can be done in several ways. A manufacturer may use a cross-docking warehouse to break up large rail or truck shipments into smaller shipments to local customers. A cross-docking operation that receives goods from a single source or manufacturer is often referred to as **break-bulk warehousing.**

Retailers also use cross-docking to receive large shipments from multiple suppliers and re-sort the goods into customized shipments to individual stores. The regional distribution center

FIGURE 8.3
Cross-Docking

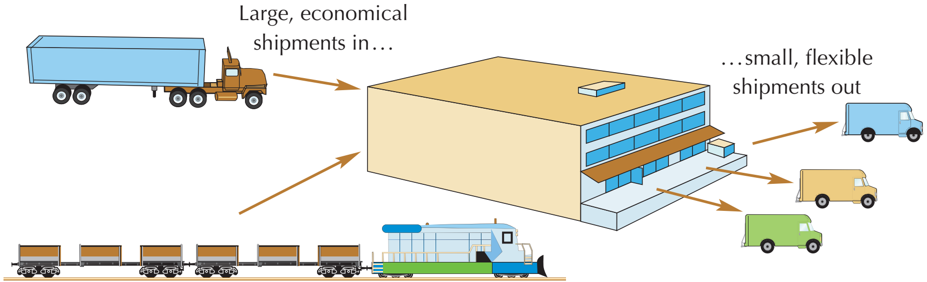
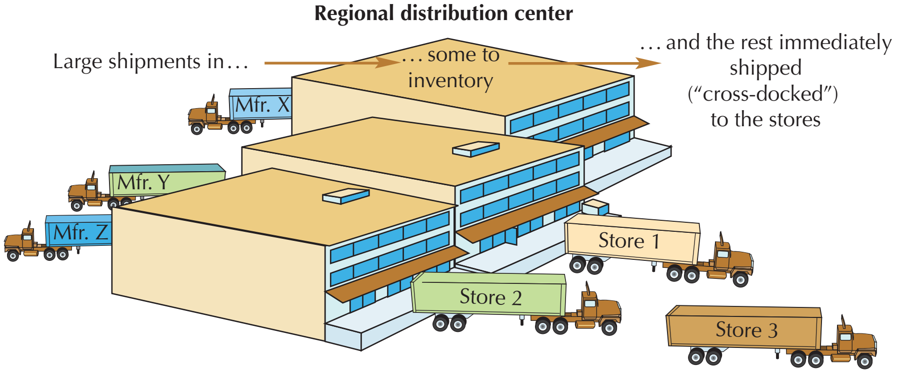


FIGURE 8.4
Cross-Docking at Lowe's



(DCs) network used by Lowe's to get goods to the retail stores is a classic example (Figure 8.4). The DCs receive large truckload shipments from suppliers. Employees then remix the incoming goods and deliver them to individual stores, often multiple times a day. Computer-based information systems closely coordinate *incoming* shipments from suppliers with *outgoing* shipments to individual stores so that more than half the goods that come off suppliers' trucks are immediately loaded onto trucks bound for individual stores. The result is that both the DCs and the retail stores hold minimal amounts of inventory, yet Lowe's receives the cost breaks associated with large shipments from suppliers.

Hub-and-spoke system
A form of warehousing in which strategically placed hubs are used as sorting or transfer facilities. The hubs are typically located at convenient, high-traffic locations. The "spokes" refer to the routes serving the destinations associated with the hubs.

Hub-and-spoke systems combine the benefits of consolidation and cross-docking warehouses, but they differ from them in two important ways. First, the warehouses, or "hubs," in these systems are purely sorting or transfer facilities. Hubs are designed to take advantage of transportation economies of scale; they do not hold inventory. Second, hubs are typically located at convenient, high-traffic locations, such as major airports, water ports, or the intersections of interstate highways. (In contrast, consolidation and cross-docking operations tend to be located close to the source of goods or to final customers.) One of the largest providers of transportation services in the United States, J. B. Hunt (**www.jbhunt.com**), has a comprehensive hub-and-spoke system consisting of 18 major hubs or terminals located throughout the United States, as well as 20 smaller satellite terminals.

EXAMPLE 8.3
Hub-and-Spoke System at Prakston Carriers

Pup trailer
A type of truck trailer that is half the size of a regular truck trailer.

Prakston Carriers is a trucking firm with 15 hubs throughout the United States. Prakston has two customers with shipments coming out of the Northeast. Each shipment is packed in a **pup trailer,** which is half the size of a regular trailer. One is bound for Los Angeles and the other for El Paso, Texas (Figure 8.5).

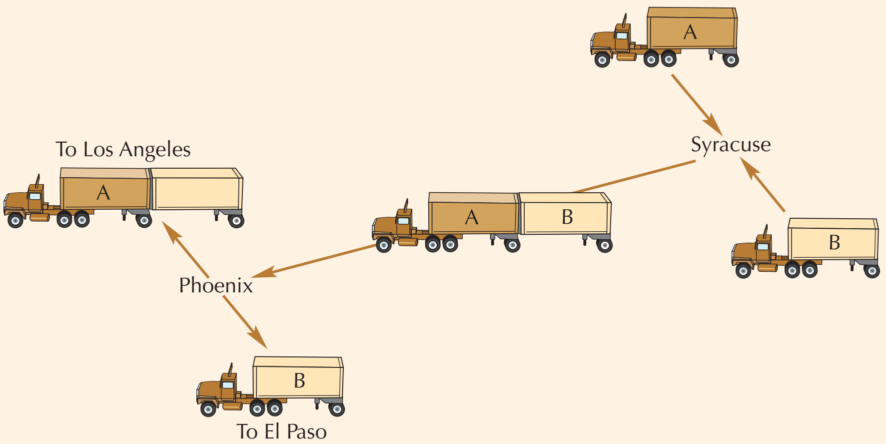


FIGURE 8.5 Hub-and-Spoke System at Prakston Carriers

Prakston might decide that the most economical way to ship the two pup trailers is to join them together at its hub in Syracuse, New York, and use a single truck to haul them to another hub in Phoenix, Arizona. In this case, Syracuse and Phoenix are the "hubs," while the routes to Los Angeles and El Paso are the "spokes." When the truck arrives in Phoenix, the two pup trailers will be separated and perhaps combined with different pup trailers for transport to their final destinations.

Postponement warehousing
A form of warehousing that combines classic warehouse operations with light manufacturing and packaging duties to allow firms to put off final assembly or packaging of goods until the last possible moment.

Improving Operational Flexibility. Warehouses not only help to lower transportation costs but can actually improve operational flexibility as well. **Postponement warehousing** combines classic warehouse operations with light manufacturing and packaging duties to allow firms to put off final assembly or packaging of goods until the last possible moment. This strategy adds flexibility because goods and materials can be maintained in their most generic (and therefore flexible) form as long as possible.

To illustrate, a Korean manufacturer might ship reinforced pallets carrying 1,440 light bulbs each to postponement warehouses throughout the world. At the warehouses, workers receive the pallets, break them down, and repackage the light bulbs in private-label boxes of three or six bulbs each. From the warehouses, the repackaged bulbs are shipped to local retailers. The manufacturer or distributor saves money on shipping costs (because reinforced pallets are less costly to ship than are cartons of smaller boxes) but can still provide customers with a wide variety of packaging options. Furthermore, the manufacturer or distributor can hold off on final packaging until customers' exact requirements are known.

Shortening Customer Lead Times. When the *total* transportation time to customers exceeds customers' requirements, firms can use warehousing to reduce the *realized* lead time to customers. They perform this service by breaking the total transportation time into two parts: (1) time to the warehouse and (2) time to the customer. In theory, goods arrive at the warehouse *prior* to the customer's order. As a result, transportation time to the warehouse is of no concern to the customer; it is "off-line." The only transportation time that is "on-line," or realized by the customer, is the time from the warehouse.

Assortment warehousing
A form of warehousing in which a wide array of goods is held close to the source of demand in order to ensure short customer lead times.

Spot stock warehousing
A form of warehousing that attempts to position seasonal goods close to the marketplace. At the end of each season, the goods are either liquidated or moved back to a more centralized location.

Assortment and spot stock warehousing are the two major approaches used to shorten customer lead times. **Assortment warehouses** tend to carry a wider array of goods than spot stock warehouses and for a longer period. **Spot stock warehouses** focus more on the positioning of seasonal goods such as lawn care products, fashion goods, and recreational equipment. Both are attractive options when distances between the originating source and the customers are long and when customers emphasize high availability or quick delivery.

Lowering Inventory-Related Costs. Used wisely, warehouses can dramatically lower overall inventory levels and related costs throughout the supply chain. To those who associate warehousing with increased inventory levels, this idea may seem counterintuitive. But consider the case of *inventory pooling* at Boyers', a fictional retailer with eight stores in the Seattle area. For its best-selling goods, Boyers' would like to keep extra inventory, called *safety stock*, to meet unexpected spurts in customer demand. However, management doesn't want to keep this safety stock in the stores, where floor space is expensive. And it seems wasteful to keep extra inventory in each store, as it is unlikely that *all* the stores will experience unusually high demand levels at the same time. Instead, Boyers' might consolidate the safety stock for all eight stores into one centralized location, which can provide same-day service to all the stores. Not only would this free up retail floor space, but also, as we will show in Chapter 11, it would actually reduce the amount of inventory needed to protect the stores against demand surges.

Logistics Information Systems

Now that we have discussed the physical infrastructure of a logistics system, we will turn our attention to the information systems piece. In the simplest terms, logistics information systems fall into three major categories: decision support tools, planning systems, and execution systems.

Decision Support Tools. Logistics managers often use decision support tools to design and fine-tune their logistics systems. Such tools help managers choose locations for their warehouses, determine the number of containers or vessels they need, and estimate costs and travel times. Some decision support tools even have simulation and optimization capabilities. For example, a simulation model might be used to simulate actual traffic conditions in order to evaluate the impact of traffic on a proposed warehousing system. An optimization model might be used to identify the warehousing network with the lowest overall cost or shortest average travel time. In the last section of this chapter, we show how optimization modeling can support logistics decisions.

Planning Systems. Planning systems help managers with specific activities, such as selecting a carrier for an outgoing shipment or developing a weekly schedule of deliveries. Of course, such activities have been going on for a long time. But with the aid of computer-based planning systems, today's logistics managers can more quickly analyze a wider range of options and identify the delivery schedule or carrier that best suits their needs.

Execution Systems. Execution systems are the most detailed level of a logistics information system. As the name implies, execution systems take care of the hundreds of small details associated with logistics activities, ensuring that planned activities take place as expected. They oversee order and shipment management, warehouse management, shipper/receiver management, satellite and bar code tracking, and automated payment and billing systems.

Execution systems can also help managers monitor the logistics system and identify problems before they get out of hand. Consider the online tracking system used by FedEx. Every time FedEx handles a package (picking it up, sorting it at a major hub, loading it onto a plane), a bar code is read into its execution system. Authorized users can then go online to track the package's progress. But this same information can also be used to identify potential problems automatically. Suppose the tracking system indicates that a package has not left the hub within a few hours, as expected. The tracking system may automatically generate an exception report, indicating that someone needs to check on the package's status.

One information technology that has garnered much attention recently is *radio-frequency identification (RFID)*. RFID systems use small electronic "tags" to track the position and movement of items. The *Supply Chain Connections* feature shows how businesses are using RFID to track the position and movement of everything from fashion goods to medical supplies.

SUPPLY CHAIN CONNECTIONS

USING RFID TO TRACK FASHION CLOTHING, RAIL CARS, MEDICAL SUPPLIES . . . YOU NAME IT

Radio-frequency identification (RFID) has grown to include applications in almost every industry imaginable, from high-fashion clothing to health care to rail transportation and more.

Brand-name fashion apparel at one Paris warehouse and shipping center that serves five corporate customers now moves out more quickly and more accurately, thanks to a newly installed RFID tracking system. The system improves the speed and accuracy of receiving, packing, storing, and distribution to fashion retail outlets of 5 to 10 million individual items a year. Once the installation of the RFID system at the warehouse is complete, every item will be tagged, and handheld tag readers will be available for warehouse workers looking for specific items to fill orders. Tunnel readers have already been installed at the warehouse docks. The new system replaces a time-consuming bar code scanning operation and will also help warehouse workers verify orders by checking the contents before filled boxes are sealed and shipped. In addition to improving speed and accuracy, the RFID system will allow the logistics company that manages the warehouse to collect data for its customers so they can track the location and status of their goods.

The Finnish state-owned railroad company is now using RFID technology to better manage its rail yards by tracking inventory, maintenance, and the status of shipments for its shipping customers. With more than 10,000 locomotives, wagons, and passenger cars at 50 locations around Finland, the railroad needed an enormous number of RFID tags, two of which were placed on each side of each car, in compliance with regulations of the European Railway Agency. Now, instead of tracking each car with pencil and paper, as in the past, workers can simply walk alongside and read the car's identification information on their handheld tag readers, confirming that each one is in the right place, behind the right locomotive

Chungking/Fotolia

Among its many applications, RFID can be used to track the movement and position of shipping containers at large ports such as this one.

and in the right order. The railroad's shipping customers benefit, too, since they can quickly and reliably find out where their orders are located on the train and which way the relevant car is facing (to ease loading and unloading). Rail workers can now also read maintenance orders on their RFID readers. In fact, maintenance planning and data entry have been so streamlined by RFID technology that only 14 sites are needed to cover the entire rail system's needs, instead of 50, as in the old manual method.

With medical supplies consuming up to 30% of their operating budgets, hospitals may well be next in line to adopt cost-saving RFID technology for stocking and inventory. Because such supplies are expensive, sometimes perishable, and often life-saving, hospitals must monitor their levels carefully to avoid both oversupply and stockout situations and to discourage costly hoarding. A recent study focused on how to improve resupply to nursing stations, the front line of many hospitals' supply distribution needs. The study combined RFID technology with a kanban system, using specially designed storage units and kanban-type cards. Two containers of each supply item were provided, and when the first was empty, a nurse scanned the kanban card into an RFID reader, which automatically logged a refill request for the appropriate item. While details such as how to set resupply levels will vary according to the item's consumption patterns, the hospital, and the department, the application holds much promise for saving costs as well as labor, and, most importantly, for improving patient care.

Sources: Based on Rhea Wessel, "Finnish Railroad Streamlines Operations," *RFID Journal*, July 14, 2011, **www.rfidjournal.com/article/view/8594/1;** Claire Swedberg, "Fashion Tracked by French Logistics Company," *RFID Journal*, July 11, 2011, **www.rfidjournal.com/article/view/8588;** Mary Catherine O'Connor, "Study Shows How to Optimize RFID-Enabled Resupply System for Nurse Stations," *RFID Journal*, June 22, 2011, **www.rfidjournal.com/article/view/8552/1.**

Material Handling and Packaging

Material handling system
A system that includes the equipment and procedures needed to move goods *within* a facility, *between* a facility and a transportation mode, and *between* different transportation modes (e.g., ship-to-truck transfers).

Packaging
From a logistics perspective, the way goods and materials are packed in order to facilitate physical, informational, and monetary flows through the supply chain.

Material handling systems include the equipment and procedures needed to move goods *within* a facility, *between* a facility and a transportation mode, and *between* different transportation modes (e.g., ship-to-truck transfers). Forklifts, cranes, conveyor belts, and computer-controlled automated storage and retrieval systems (ASRS) are just a few examples of material handling equipment. From a logistics perspective, **packaging** refers to the way goods and materials are packed in order to facilitate physical, informational, and monetary flows through the supply chain.

Next, we examine two examples that illustrate how intertwined material handling and packaging are with other aspects of logistics. The first example, Lowe's stores, shows how material handling can be integrated with logistics information systems and how a firm's material handling system can affect the performance characteristics of the overall logistics system. The second example, wine packaging, illustrates how a simple packaging decision can affect transportation costs and operational flexibility.

Material Handling at Lowe's DCs. Recall the discussion of the Lowe's cross-docking operation. In the DCs that perform the cross-docking, Lowe's uses a sophisticated conveyer system to move products to the trucks. Workers place the outgoing items into standardized trays, each of which bears a bar code indicating the item's final destination. The conveyor system "reads" these bar codes and automatically routes the trays to the appropriate trucks.

The Lowe's conveyer system is fast and accurate, and it minimizes labor costs. For the vast majority of goods Lowe's sells, the system is an effective material handling solution. But it does have one major limitation: It can handle only items that fit into the trays. Larger items, such as storage sheds, must be handled in separate warehousing facilities.

Packaging Wine. Many wine producers now ship wine in reinforced, vacuum-sealed plastic bags. While one could argue about the aesthetic appeal of the bags, they make good sense from a logistics perspective. First, plastic bags cost less to ship and handle than glass bottles (because they are lighter and less fragile). Plastic bags also keep the wine fresher, an important consideration for seasonal wines. Finally, the bags give the wine producers greater product flexibility. At postponement warehouses, wine that has been packaged in plastic bags can quickly be repackaged into bottles, wine boxes, or pseudo-"casks," as demand dictates.

Inventory Management

Inventory is such a critical resource in many organizations that we have devoted Chapter 11 to examining the tools and techniques firms used to manage it. However, it is worth taking some time here to consider how inventory decisions are intertwined with the physical network (transportation and warehousing).

In general, using slower and cheaper transportation modes will cause inventory levels within the supply chain to rise, while using faster and more expensive modes will enable firms to lower inventory levels. For example, transportation modes such as water and rail are economical only for high-volume shipments; therefore, the amount of inventory in the physical network will tend to rise when these transportation modes are favored. In contrast, air and truck allow goods to be delivered in a speedy fashion, thereby enabling firms to get by with less inventory in the network. Of course, the lower inventory levels (and associated costs) are offset by higher transportation costs.

With regard to warehousing, the relationship is more complex, and inventory managers have to work closely with warehouse managers to achieve the desired business outcome. For example, spot stock and assortment warehouses need inventory to shorten delivery lead times and provide better customer service. But unilateral efforts on the part of the material managers to cut inventory levels might "starve" such warehouses, reducing their usefulness. On the other hand, to make cross-docking economical, firms must be able to match the large incoming shipments from suppliers with the smaller outgoing shipments to customers or stores. If this doesn't happen, inventory levels can rapidly spin out of control.

8.3 LOGISTICS STRATEGY

Logistics strategy
A functional strategy which ensures that an organization's logistics choices—transportation, warehousing, information systems, and even form of ownership—are consistent with its overall business strategy and support the performance dimensions that targeted customers most value.

Rail or air? Consolidation warehousing or direct shipment? A **logistics strategy** ensures that an organization's logistics choices—transportation, warehousing, information systems, and even form of ownership—are consistent with its overall business strategy and support the performance dimensions that target customers most value. Like sourcing, a firm's logistics strategy is an extension of its overall operations and supply chain strategy.

We saw in Chapter 2 that operations and supply chain strategies address four key performance dimensions: quality, time, flexibility, and cost. Time can be further divided into delivery reliability and delivery speed, and flexibility can be subdivided into mix flexibility, design flexibility, and volume flexibility. Table 8.3 shows the transportation and warehousing choices that are consistent with these performance dimensions.

As Table 8.3 implies, a firm cannot select its transportation and warehousing options without first considering their strategic implications. A firm that is interested in keeping costs to a minimum is likely to favor different transportation and warehousing options from a company that is interested in maximizing flexibility.

TABLE 8.3
The Linkage between Key Performance Measures and Transportation and Warehousing Choices

PERFORMANCE DIMENSION	TRANSPORTATION MODE	WAREHOUSING SYSTEM
Delivery reliability—Deliver on time consistently	Highway Air	None (direct ship) Assortment Spot stock
Delivery speed—Minimal time from order to delivery	Air Highway	None (direct ship) Assortment Spot stock
Mix flexibility—Support a wide range of different products/delivery needs	Highway Air Rail	Assortment Spot stock
Design flexibility—Support design changes/unique customer needs	Highway Air	Postponement
Volume flexibility—Provide products/delivery services in whatever volume the customer needs	Highway Air	None (direct ship) Assortment Spot stock
Cost—Minimize the cost of transportation	Rail Water Pipeline Highway	Consolidation Cross-docking Hub-and-spoke

Owning versus Outsourcing

One topic we have not discussed yet but that is critical to developing a firm's logistics strategy is ownership. Should a firm maintain its own trucks, warehouses, and information systems or outsource those services? As you might imagine, the best choice depends on many factors. Some of the major considerations are reflected in the following questions:

- **Does the firm have the volume needed to justify a private logistics system?** Firms with low volumes or sporadic shipping needs (e.g., transport of seasonal produce) are probably better off contracting for those services.
- **Would owning the logistics system limit the firm's ability to respond to changes in the marketplace or supply chain?** Investing in a private fleet of trucks or network of warehouses ties up capital and commits a firm to managing those systems. While that may be fine for firms with stable supply chains, it can present a problem for firms whose markets or supply chain partners are changing rapidly. A manufacturer that wants the flexibility to quickly change from domestic to foreign suppliers probably should not own the trucks and warehouses it uses.
- **Is logistics a core competency for the firm?** In Chapter 2, core competencies were defined as organizational strengths or abilities, developed over a long period, that customers find valuable and competitors find difficult or impossible to copy. Many firms have decided that logistics is not one of their core competencies. These firms generally outsource the logistics function to **common carriers** (also known as public carriers), which handle shipments on a case-by-case basis, or to **contract carriers,** which enter into long-term agreements with firms. Another choice is **third-party logistics providers (3PLs),** which are service firms that handle all of the logistics requirements for other companies. Using 3PLs allows companies to focus on their core competencies yet still enjoy access to state-of-the-art logistics capabilities.

Common carrier
Also known as a public carrier, a transportation service provider that handles shipments on a case-by-case basis, without the need for long-term agreements or contracts.

Contract carrier
A transportation service provider that handles shipments for other firms based on long-term agreements or contracts.

Third-party logistics provider (3PL)
A service firm that handles all of the logistics requirements for other companies.

The *Supply Chain Connections* feature highlights the logistics strategy employed by Kellogg Company. As you read through it, ask yourself the following questions:

- What product characteristics did managers consider in designing Kellogg's logistics system?
- What performance dimensions are most important to Kellogg?
- Who owns and manages Kellogg's transportation and warehousing systems? Why?
- What informational and physical flows must occur for an order to travel from Kellogg to a customer?

SUPPLY CHAIN CONNECTIONS

LOGISTICS STRATEGY AT THE KELLOGG COMPANY

The Kellogg Company of Battle Creek, Michigan, sells ready-to-eat cereal (RTEC), which accounts for 60% of the company's sales, as well as convenience foods, including Pop-tarts, Nutri-Grain Cereal Bars, Eggo Waffles, and Rice Krispies Treats. Kellogg's primary sales are made to grocery store chains in the United States. The company also has a manufacturing and distribution division in Canada (Kellogg's Canada) and another one in Europe. Competition in the food industry is fierce, and Kellogg is constantly under pressure to keep costs low.

For logistics purposes, Kellogg's products can be divided into two major types: frozen foods (e.g., bagels, waffles) and dry products (everything else). The two product types require different logistics solutions.

Dry Products

Kellogg produces dry products at 15 North American plants. To handle their distribution, the company depends on seven regional distribution centers (managed by outside firms) and multiple carriers. Managers recently went through a strategic sourcing exercise in which they attempted to lower warehousing and transportation costs. On the transportation side, they were able to reduce costs 15% by increasing the number of contract carriers from 25 to 30. But because the volume that the carriers handled decreased, Kellogg's business became less attractive to them. In the end, managers had to raise the prices paid to some key carriers.

Frozen Products

Kellogg's frozen products are more difficult to manage. To handle its frozen foods, Kellogg depends on 35 to 40 carriers with frozen-food capabilities. The company shares six distribution centers with other producers. Companies that specialize in frozen food operate these distribution centers for Kellogg and the other producers.

The Order Process

The order process begins when one of Kellogg's field representatives enters an order on behalf of the customer, typically a large grocery chain. Kellogg's customer service department receives the order and determines whether the quantity requested can be delivered by the desired delivery date. Customer service representatives may encourage customers to increase the size of their orders to take advantage of full truckload shipment rates.

Once an order has been confirmed, the customer service department must decide how to fulfill it. The department follows these general guidelines:

- If an order is for a full truckload and the lead time is long enough, the order will be filled and shipped directly from a plant. Kellogg personnel will take responsibility for arranging transportation.
- If an order is for a mix of products or if lead times are short, the order will be filled from one of Kellogg's distribution centers. In that case, the outside firm responsible for managing the distribution center will arrange for transportation.

Measuring Logistics Performance

To better understand the real impact of their logistics choices, many companies evaluate their logistics performance in terms of two measures: the perfect order and landed costs. The perfect order measure indicates how *effectively* logistics serves the customer. The second measure, landed costs, indicates how *efficiently* logistics provides that service.

Perfect order
A term used to refer to the timely, error-free provision of a product or service in good condition.

The Perfect Order. In theory, the **perfect order** represents the timely, error-free provision of a product or service in good condition. For example, a company might define the perfect order as one that is:

- Delivered on time, according to the buyer's requested delivery date
- Shipped complete
- Invoiced correctly
- Undamaged in transit

Under this concept, performance can be measured as the percentage of orders that meet these criteria. To find this percentage, managers must calculate the number of processed orders that did not meet all the company standards in a particular period:

$$\text{Percentage of perfect orders} = 100\%\left(\frac{\text{total orders} - \text{orders with} \geq 1 \text{ defect}}{\text{total orders}}\right) \quad \textbf{(8.1)}$$

EXAMPLE 8.4

Measuring Perfect Orders at Bartley Company

Last year Bartley Company experienced the following results:

- 5.4 million orders processed
- 30,000 orders delivered late
- 25,000 orders incomplete
- 25,000 orders damaged
- 20,000 orders billed incorrectly

Furthermore, these 100,000 failures were spread across 90,000 orders, which meant that some orders had more than one problem. The percentage of perfect orders is therefore:

$$\text{Percentage of perfect orders} = 100\%\left(\frac{5{,}400{,}000 - 90{,}000}{5{,}400{,}000}\right) = 98.3\%$$

Landed Costs

Landed cost
The cost of a product plus all costs driven by logistics activities, such as transportation, warehousing, handling, customs fees, and the like.

Earlier we noted that U.S. logistics costs account for 5% to 35% of total sales costs. To make sure these costs aren't overlooked, particularly when making sourcing decisions, managers often estimate the landed cost of a product. **Landed cost** is the cost of a product plus all costs driven by logistics activities, such as transportation, warehousing, handling, customs fees, and the like.

EXAMPLE 8.5

Analyzing Landed Costs at Redwing Automotive

Redwing Automotive has requested price quotations from two wiring harness manufacturers, Subassembly Builders Company (SBC) in Atlanta, Georgia, and Product Line Systems (PLS) of Nagoya, Japan. Redwing's estimated demand for the harnesses is 5,000 units a month.

SBC's quote includes the following unit price, packing cost, and freight cost:

$$\text{Unit price} = \$25.00$$
$$\text{Packing cost} = \$0.75 \text{ per unit}$$
$$\text{Freight cost} = \$0.73 \text{ per unit}$$

PLS quotes a lower unit price of $21.50. But each month PLS would also need to pack the harnesses in three containers, ship them overland to a Japanese port, transfer them to a container ship headed for Seattle, and then transport them overland again to Detroit. The costs associated with this movement—costs Redwing will have to pick up—are not reflected in PLS's unit price. The additional logistics-related costs Redwing would have to cover include:

- Packing cost = $1.00 per unit
- Inland transportation cost to the port of export = $200 per container (with three containers needed per month)
- Freight forwarder's fee = $100 per shipment (letter of credit, documentation for international shipments, etc.)
- Ocean transportation cost = $2,067 per container
- Marine insurance = $0.50 per $100 of shipment
- U.S. port handling charges = $640 per container
- Customs duty = 5% of unit price
- Customs broker's fee = $150 per year
- Transportation from Seattle to Detroit = $1.86 per unit
- Additional paperwork = $100 per year

Freight forwarder
An agent who serves as an intermediary between an organization shipping a product and the actual carrier, typically on international shipments.

Customs broker
An agent who handles customs requirements on behalf of another firm. In the United States, customs brokers must be licensed by the Customs Service.

A couple of these cost items deserve further explanation. A **freight forwarder** is an agent who serves as an intermediary between the organization shipping the product and the actual carrier, typically on international shipments. A **customs broker,** in contrast, is an agent who handles customs requirements on behalf of another firm. In the United States, customs brokers must be licensed by the Customs Service. To further complicate things, PLS has told Redwing that shipping lead times can be anywhere from six to eight weeks. To compensate for this uncertainty, Redwing would need to lease additional warehousing space to hold a safety stock of 1,000 harnesses, at a cost of $3.00 per harness per month. Redwing's personnel would also need to spend more time handling international shipments. Finally, each monthly PLS shipment is estimated to require four hours of additional administrative time, at a cost of $25 per hour.

Table 8.4 shows how these costs can add up. For SBC, logistics-related costs account for $1.48 per wiring harness, or approximately 5.6% ($1.48/$26.48) of the total cost of the wiring harnesses. For PLS, logistics-related costs amount to $6.43, or 23% ($6.43/$27.93) of the total cost of the wiring harnesses. In fact, PLS's logistics costs are so high that they eat up any advantage PLS might have with regard to unit price. This example shows why all costs—including logistics—must be considered in a sourcing decision. As more and more firms develop global supply chains, logistics costs will command more attention from managers.

TABLE 8.4 Landed Costs Analysis at Redwing Automotive

SBC QUOTE	PER UNIT	PER MONTH	PER YEAR
Acquisition	$25.00	$125,000.00	$1,500,000
Packing	0.75	3,750.00	45,000
Freight	0.73	3,650.00	43,800
Landed cost:	$26.48	$132,400.00	$1,588,800
PLS QUOTE	**PER UNIT**	**PER MONTH**	**PER YEAR**
Acquisition	$21.50	$107,500.00	$1,290,000
Packing	1.00	5,000.00	60,000
Inland transportation	0.12	600.00	7,200
Freight forwarder's fee	0.02	100.00	1,200
Ocean transportation	1.24	6,201.00	74,412
Marine insurance	0.11	537.50	6,450
U.S. port handling	0.38	1,920.00	23,040
Customs duty	1.08	5,375.00	64,500
Customs broker's fee	0.00	12.50	150
U.S. transportation	1.86	9,300.00	111,600
Warehousing	0.60	3,000.00	36,000
Administrative time	0.02	100.00	1,200
Paperwork	0.00	8.33	100
Landed cost:	$27.93	$139,654.33	$1,675,852

Reverse Logistics Systems

Reverse logistics system According to APICS, "a complete supply chain dedicated to the reverse flow of products and materials for the purpose of returns, repair, remanufacture, and/or recycling."

So far we have spent most of our time talking about how logistics systems move products *from* upstream suppliers *to* downstream customers. In the past several years, however, interest has grown in reverse logistics systems. According to APICS, **reverse logistics system** is "a complete supply chain dedicated to the reverse flow of products and materials for the purpose of returns, repair, remanufacture, and/or recycling."[10] As the definition suggests, firms are interested in reverse logistics for a number of reasons. In the case of returns and repairs, reverse logistics can play a large role in determining overall customer satisfaction. In other cases, firms might find it more economical to harvest used products than to purchase new parts or materials. Also, many governments and consumer groups are putting pressure on firms to incorporate recycling into their operations, thereby reducing the amount of material that eventually gets thrown away.

[10]J. H. Blackstone, ed., *APICS Dictionary*, 15th ed. (Chicago, IL: APICS, 2016).

When incorporating a reverse logistics system into the overall logistics strategy, firms can face a number of challenges. Some of the key ones include:

- In general, firms have less control over the timing, transportation modes used, and packaging for goods flowing back up the supply chain. This often means reverse logistics systems have to be designed to be more flexible and less cost-efficient than forward-based systems.
- Goods can flow back up the supply chain for a variety of reasons. Some might do so for service and repair and others for remanufacturing or recycling, and others may simply represent excess goods that need to be deployed somewhere else. A reverse logistics system must be able to sort and handle these different flows.
- Forward logistics systems typically aren't set up to handle reverse logistics. For example, imagine a cross-docking facility, which usually deals with large inbound shipments, trying to incorporate low-volume return shipments into its operations. The information systems, material handling systems, and procedures simply aren't suited to the challenges of reverse logistics. In many cases, firms are better off setting up separate physical operations for their forward and reverse logistics.

8.4 LOGISTICS DECISION MODELS

Given the critical importance of logistics, it should be no surprise that experts have developed a wide range of tools to help make better decisions in this area. In this section, we look at two common models to demonstrate how modeling techniques can be applied to logistics decisions.

The weighted center of gravity method looks at the strategic location decision. This can be especially important when a firm is developing its logistics network and must decide where to place plants or warehouses. The second model, the assignment problem, is a specialized type of optimization model and looks at the tactical problem of deciding how to serve multiple demand points from various supply points at the least possible cost.

Weighted Center of Gravity Method

Weighted center of gravity method
A logistics decision modeling technique that attempts to identify the "best" location for a single warehouse, store, or plant, given multiple demand points that differ in location and importance.

The **weighted center of gravity method** attempts to identify the "best" location for a single warehouse, store, or plant, given multiple demand points that differ in location and importance. Location is typically expressed in (X, Y) coordinate terms, where the X and Y values represent relative positions on a map. Importance can be captured through weighting factors such as population, shipment quantities, sales dollars, or whatever best suits the situation. The weighted center of gravity works by calculating the weighted average (X, Y) values of the demand locations. Specifically:

$$\text{Weighted } X \text{ coordinate} = X^* = \frac{\sum_{i=1}^{I} W_i X_i}{\sum_{i=1}^{I} W_i} \tag{8.2}$$

$$\text{Weighted } Y \text{ coordinate} = Y^* = \frac{\sum_{i=1}^{I} W_i Y_i}{\sum_{i=1}^{I} W_i} \tag{8.3}$$

where:

(X_i, Y_i) = position of demand point i
W_i = weighting factor for demand point i

The resulting (X^*, Y^*) values represent the ideal location, given the relative weight (i.e., *importance*) placed on each demand point.

EXAMPLE 8.6

Warehouse Location Decision at CupAMoe's

Robbie Roberts, owner of CupAMoe's Coffee, is trying to determine where to locate his newest distribution warehouse. Figure 8.6 shows the location and population of the three major towns to be served by the warehouse.

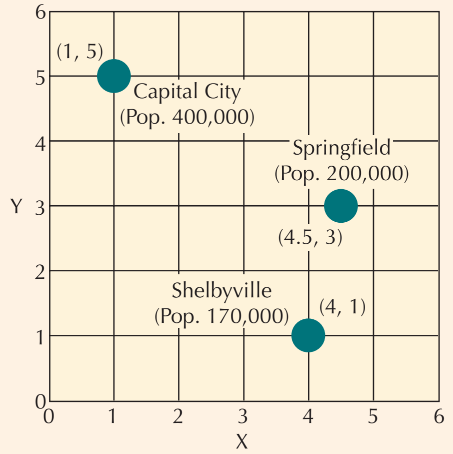


FIGURE 8.6 Coordinate Map of Demand Locations, CupAMoe's Coffee

Robbie would like to locate the warehouse to minimize transportation costs and provide the best overall delivery speed to his three markets. One way to do this is by using a weighted center of gravity method to identify a possible site.

Using the populations as weight, the weighted X and Y coordinates are:

$$X^* = (400{,}000*1 + 200{,}000*4.5 + 170{,}000*4)/770{,}000$$
$$= 1{,}980{,}000/770{,}000 = 2.57$$
$$Y^* = (400{,}000*5 + 200{,}000*3 + 170{,}000*1)/770{,}000$$
$$= 2{,}770{,}000/770{,}000 = 3.60$$

Figure 8.7 shows the suggested location of the new warehouse. Of course, a host of other factors, such as available space, zoning considerations, and labor availability, should be considered before Robbie makes a final decision. Nevertheless, the weighted center of gravity method provides a good first cut at the solution.

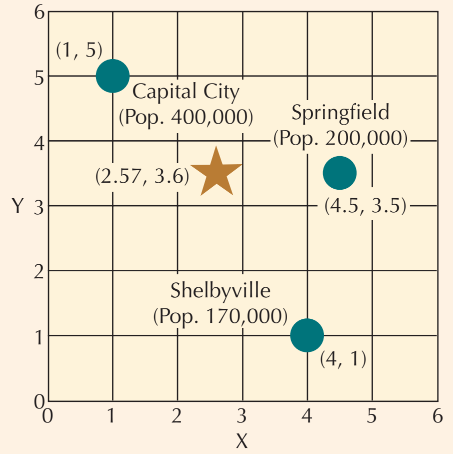


FIGURE 8.7 Suggested Warehouse Location for CupAMoe's, Based on Weighted Center of Gravity Method

Optimization Models

Optimization model
A type of mathematical model used when the user seeks to optimize some objective function subject to some constraints.

Objective function
A quantitative function that an optimization model seeks to optimize (i.e., maximize or minimize).

Constraint
Within the context of optimization modeling, a quantifiable condition that places limitations on the set of possible solutions. The solution to an optimization model is acceptable only if it does not break any of the constraints.

Optimization models are a class of mathematical models used when the decision maker seeks to optimize some objective function subject to some constraints. An **objective function** is a quantitative function that we hope to optimize (i.e., maximize or minimize). **Constraints** are quantifiable conditions that place limitations on the set of possible solutions. A solution is acceptable only if it does not break any of the constraints. Some examples of business problems that can be addressed through optimization modeling are shown in Table 8.5.

In order for optimization modeling to work, the user must be able to state in mathematical terms both the objective function and the constraints, as well as the decision variables that will be manipulated to find the optimal solution. Once the user is able to do this, special modeling algorithms can be used to generate solutions.

The Assignment Problem

Assignment problem
A specialized form of an optimization model that attempts to assign limited capacity to various demand points in a way that minimizes costs.

The **assignment problem** is a specialized form of an optimization model. Specifically, the assignment problem attempts to assign limited capacity (in this case, warehouse capacity) to various demand points in a way that minimizes costs. The generalized form of the assignment problem is as follows:

$$\text{Minimize} \sum_{i=1}^{I} \sum_{j=1}^{J} T_{ij} * S_{ij} \qquad \textbf{(8.4)}$$

subject to the following constraints:

$$\sum_{j=1}^{J} S_{ij} \leq C_i \quad \text{for all warehouses } i \qquad \textbf{(8.5)}$$

$$\sum_{i=1}^{I} S_{ij} \geq D_j \quad \text{for all demand points } j \qquad \textbf{(8.6)}$$

$$S_{ij} \geq 0 \quad \text{for all combinations of shipments from warehouse } i \text{ to demand points } j \qquad \textbf{(8.7)}$$

where:

S_{ij} = number of units shipped from warehouse i to demand point j

T_{ij} = cost of shipping one unit from warehouse i to demand point j (these values are given)

C_i = capacity of warehouse i

D_j = demand at demand point j

Decision variables
Within the context of optimization modeling, variables that will be manipulated to find the best solution.

The explanation behind these equations is actually quite simple. First, the only decision variables are the shipment quantities (S_{ij}). **Decision variables** are variables that will be manipulated to find the best solution. Shipping costs (T_{ij}), warehouse capacity (C_i), and demand values (D_j), in contrast, are not decision variables but known values.

The objective function (Equation [8.4]) reflects the total shipment costs from I warehouses to J demand points. Note that at this point we don't know which shipping routes will actually be used. Therefore, we include all possible S_{ij} values, multiplied by their associated per-unit shipping costs.

TABLE 8.5
Business Problems That Can Be Addressed through Optimization Modeling

OBJECTIVE FUNCTION	CONSTRAINTS
Maximize profits	Limited demand, materials, and processing capabilities
Minimize delivery costs	Need to meet all demand and not exceed warehouse capacities
Minimize health care costs	Need to meet all patient demand

The constraints are found in Equations (8.5) through (8.7). Equation (8.5) requires that the total number of shipments out of a warehouse not exceed the capacity of the warehouse. Similarly, Equation (8.6) requires that the total shipments into a demand point should at least cover the demand. Finally, Equation (8.7) ensures that the modeling algorithm we use to solve the problem doesn't recommend negative shipments.

This last constraint may seem like an odd requirement, but if you look at Equations (8.5) and (8.6), in mathematical terms, negative shipments could be used to bring down shipping costs or to "add" capacity to the warehouses. Equation (8.7) prevents this from happening. In Example 8.7, we illustrate how the assignment problem can be set up and then solved by using Microsoft Excel's Solver function.

EXAMPLE 8.7

The Assignment Problem at Flynn Boot Company

The Flynn Boot Company imports boots from all over the world and ships them to major retail customers in the United States. Flynn currently has three assortment warehouses in the cities of Atlanta, Fort Worth, and Tucson. On the demand side, Flynn has four major customers: BillyBob, DudeWear, Slickers, and CJ's. The weekly capacities for the warehouses and weekly demands for the customers are shown in the Excel spreadsheet in Figure 8.8. The spreadsheet also shows the cost to ship a pair of boots from each warehouse to each customer.

	A	B	C	D	E	F	G
1	**The Assignment Problem: Flynn Boot Company**						
2							
3			Weekly			Weekly	
4			Capacity			Demand	
5		Warehouse	(Ci)		Customer	(Dj)	
6							
7		Atlanta	20,000		BillyBob	27,800	
8		Fort Worth	40,000		DudeWear	8,000	
9		Tucson	30,000		Slickers	13,500	
10		TOTAL:	90,000		CJ's	33,000	
11					TOTAL:	82,300	
12							
13		Cost to ship one pair of boots from Warehouse i to Customer j (Tij)					
14							
15			BillyBob	DudeWear	Slickers	CJ's	
16		Atlanta	$2.00	$3.00	$3.50	$1.50	
17		Fort Worth	$5.00	$1.75	$2.25	$4.00	
18		Tucson	$1.00	$2.50	$1.00	$3.00	
19							

FIGURE 8.8 Spreadsheet for Flynn Boot Company

Total warehouse capacity (90,000 pairs per week) exceeds total demand (82,300), so Flynn has plenty of capacity. One question remains, however, given the different shipping costs: Which warehouse should serve which customer in order to minimize costs?

Following Equations (8.4) through (8.7) and using the first letter for each warehouse and customer as abbreviations, we can express the assignment problem as follows. Minimize total shipping costs (Equation [8.4]):

$$\$2.00{*}S_{AB} + \$3.00{*}S_{AD} + \$3.50{*}S_{AS} + \$1.50{*}S_{AC}$$
$$+ \$5.00{*}S_{FB} + \$1.75{*}S_{FD} + \$2.25{*}S_{FS} + \$4.00{*}S_{FC}$$
$$+ \$1.00{*}S_{TB} + \$2.50{*}S_{TD} + \$1.00{*}S_{TS} + \$3.00{*}S_{TC}$$

subject to the following constraints:

Total shipments out of each warehouse must be less than its capacity (Equation [8.5]):

$$S_{AB} + S_{AD} + S_{AS} + S_{AC} \leq 20{,}000$$
$$S_{FB} + S_{FD} + S_{FS} + S_{FC} \leq 40{,}000$$
$$S_{TB} + S_{TD} + S_{TS} + S_{TC} \leq 30{,}000$$

Total shipments to each customer must at least cover demand (Equation [8.6]):

$$S_{AB} + S_{FB} + S_{TB} \geq 27{,}800$$
$$S_{AD} + S_{FD} + S_{TD} \geq 8{,}000$$
$$S_{AS} + S_{FS} + S_{TS} \geq 13{,}500$$
$$S_{AC} + S_{FC} + S_{TC} \geq 33{,}000$$

All shipment quantities must be nonnegative (Equation [8.7]):

$$S_{AB}, S_{AD}, S_{AS}, S_{AC}, S_{FB}, S_{FD}, S_{FS}, S_{FC}, S_{TB}, S_{TD}, S_{TS}, S_{TC} \geq 0$$

So how do we solve this problem? Many software packages could be used to find the optimal answer. We use the Solver function of Microsoft Excel because it is readily available to most students. Solver is available as an add-on function for Excel.

The first step is to modify our spreadsheet so that we now have spaces to record the S_{ij} values and a cell that contains the formula for the objective function (in this case, total shipping costs). Figure 8.9 shows the expanded worksheet.

	A	B	C	D	E	F	G
1	**The Assignment Problem: Flynn Boot Company**						
2							
3			Weekly			Weekly	
4			Capacity			Demand	
5		Warehouse	(Ci)		Customer	(Dj)	
6							
7		Atlanta	20,000		BillyBob	27,800	
8		Fort Worth	40,000		DudeWear	8,000	
9		Tucson	30,000		Slickers	13,500	
10		TOTAL:	90,000		CJ's	33,000	
11					TOTAL:	82,300	
12							
13		Cost to ship one pair of boots from Warehouse i to Customer j (Tij)					
14							
15			BillyBob	DudeWear	Slickers	CJ's	
16		Atlanta	$2.00	$3.00	$3.50	$1.50	
17		Fort Worth	$5.00	$1.75	$2.25	$4.00	
18		Tucson	$1.00	$2.50	$1.00	$3.00	
19							
20							
21		Number of pairs of boots shipped from Warehouse i to Customer j					
22							
23			BillyBob	DudeWear	Slickers	CJ's	TOTALS:
24		Atlanta	0	0	0	0	0
25		Fort Worth	0	0	0	0	0
26		Tucson	0	0	0	0	0
27		TOTALS:	0	0	0	0	
28							
29		**Objective Function: Minimum Total Shipping Costs:**					$0.00
30							

FIGURE 8.9 Expanded Spreadsheet for Flynn Boot Company

The S_{ij} values are shown in the highlighted cells. For example, cell C24 contains the number of shipments from Atlanta to BillyBob's. These values are initially set to 0; we will let the Solver function determine the S_{ij} values that minimize total costs.

Some of the cells have formulas that calculate key values. In particular:

- **Cells C27 through F27:** Total shipments to each customer
- **Cells G24 through G26:** Total shipments out of each warehouse
- **Cell G29:** The objective function

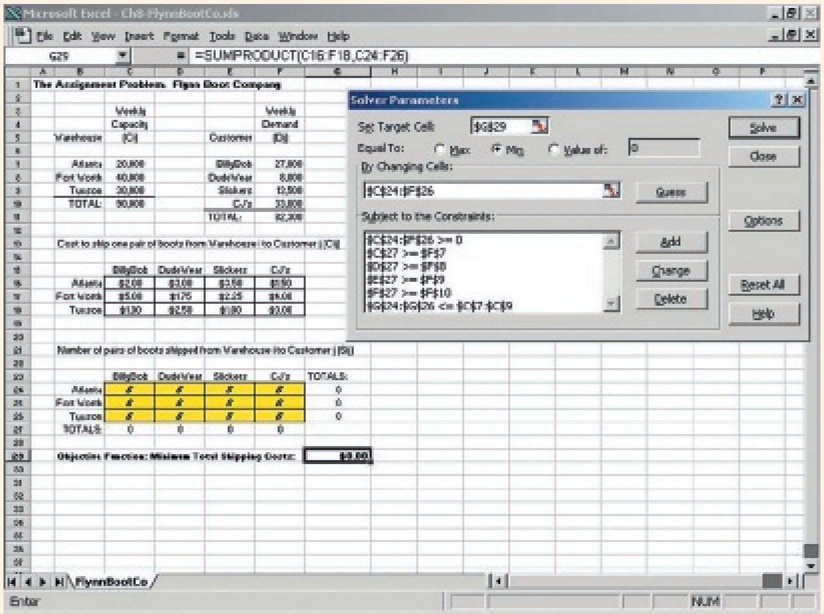
To illustrate the formulas in these cells:

Formula in Cell C27 = ***SUM***(***C24:C26***) = total shipment to BillyBob's

Formula in Cell G24 = ***SUM***(***C24:F24***) = total shipment out of Atlanta

Formula in Cell G29 = ***SUMPRODUCT***(***C16:F18,C24:F26***) = total shipping costs

With all the relevant information now in the spreadsheet, we next code the assignment problem (Equations [8.4] through [8.7]) into Excel's Solver function. Figure 8.10 shows the Solver dialog box used to do this. The "Target Cell" is our objective function, cell G29. Just below, we have selected "Min" to indicate that we want a solution that minimizes the value in cell G29. Below that, there is a space labeled "By Changing Cells." Here we tell Solver where our decision variables are located.



Microsoft Excel, Microsoft Corporation

FIGURE 8.10 Solver Dialog Box for Flynn Boot Company Example

At the bottom of the dialog box is a list of all the constraints that must be met. The first constraint, ***$C$24:$F$26>=0,*** ensures that none of our shipment quantities falls below zero (Equation [8.7]). The next four constraints are the demand constraints; shipments to a customer must at least meet customer demand (Equation [8.6]). Finally, ***$G$24:$G$26 <=$C$7:$C$9*** makes sure that total shipments from any warehouse do not exceed that warehouse's capacity (Equation [8.5]).

Once we have finished defining the objective function, target cells, and constraints, we click the "Solve" button at the top right of the Solver dialog box. The resulting solution is shown in Figure 8.11.

	A	B	C	D	E	F	G
1	**The Assignment Problem: Flynn Boot Company**						
2							
3			Weekly			Weekly	
4			Capacity			Demand	
5		Warehouse	(Ci)		Customer	(Dj)	
6							
7		Atlanta	15,000		BillyBob	27,800	
8		Fort Worth	40,000		DudeWear	8,000	
9		Tucson	30,000		Slickers	13,500	
10		TOTAL:	85,000		CJ's	33,000	
11					TOTAL:	82,300	
12							
13		Cost to ship one pair of boots from Warehouse i to Customer j (Tij)					
14							
15			BillyBob	DudeWear	Slickers	CJ's	
16		Atlanta	$2.00	$3.00	$3.50	$1.50	
17		Fort Worth	$5.00	$1.75	$2.25	$4.00	
18		Tucson	$1.00	$2.50	$1.00	$3.00	
19							
20							
21	Number of pair of boots shipped from Warehouse i to Customer j (Sij)						
22							
23			BillyBob	DudeWear	Slickers	CJ's	TOTALS:
24		Atlanta	0	0	0	20,000	20,000
25		Fort Worth	0	8,000	11,300	13,000	32,300
26		Tucson	27,800	0	2,200	0	30,000
27		TOTALS:	27,800	8,000	13,500	33,000	
28							
29		**Objective Function: Minimum Total Shipping Costs:**					**$151,425.00**

FIGURE 8.11 Lowest-Cost Solution for Flynn Boot Company

Does this answer make sense? First, none of the warehouse capacity limits are violated. Second, all the customer demand requirements are met. Two of the four customers (BillyBob and DudeWear) are completely served by the lowest-cost option, while the remaining two have at least part of their shipment handled from the cheapest warehouse.

But what if conditions change? That is, what if demand levels shift or shipping costs change over time? In that case, we go into the spreadsheet, modify the relevant data, and *re-solve* the problem using Solver.

Suppose, for example, that part of the Atlanta warehouse is shut down for repairs, cutting Atlanta's capacity to just 15,000. What should the new solution look like? Modifying the spreadsheet and using Solver to generate a new solution, we get the results shown in Figure 8.12.

With Atlanta's capacity reduced, Flynn is forced to ship 5,000 more pairs of boots from Fort Worth to CJ's. The resulting change in costs is:

$$5{,}000(T_{FC} - T_{AC}) = 5{,}000(\$4.00 - \$1.50) = \$12{,}500$$

which corresponds to the difference in total shipping costs between Figures 8.11 and 8.12:

$$\$163{,}925 - \$151{,}425 = \$12{,}500$$

	A	B	C	D	E	F	G
1	**The Assignment Problem: Flynn Boot Company**						
2							
3			Weekly			Weekly	
4			Capacity			Demand	
5		Warehouse	(Ci)		Customer	(Dj)	
6							
7		Atlanta	15,000		BillyBob	27,800	
8		Fort Worth	40,000		DudeWear	8,000	
9		Tucson	30,000		Slickers	13,500	
10		TOTAL:	85,000		CJ's	33,000	
11					TOTAL:	82,300	
12							
13		Cost to ship one pair of boots from Warehouse i to Customer j (Tij)					
14							
15			BillyBob	DudeWear	Slickers	CJ's	
16		Atlanta	$2.00	$3.00	$3.50	$1.50	
17		Fort Worth	$5.00	$1.75	$2.25	$4.00	
18		Tucson	$1.00	$2.50	$1.00	$3.00	
19							
20							
21	Number of pair of boots shipped from Warehouse i to Customer j (Sij)						
22							
23			BillyBob	DudeWear	Slickers	CJ's	TOTALS:
24		Atlanta	0.00	0.00	0.00	15,000.00	15,000
25		Fort Worth	0.00	8,000.00	11,300.00	18,000.00	37,300
26		Tucson	27,800.00	0.00	2,200.00	0.00	30,000
27		TOTALS:	27,800	8,000	13,500	33,000	
28							
29		**Objective Function: Minimum Total Shipping Costs:**					**$163,925.00**

FIGURE 8.12 Lowest-Cost Solution for Flynn Boot Company—Atlanta Capacity Reduced to 15,000

CHAPTER SUMMARY

As critical as logistics is today it will continue to grow in importance. In fact, several trends will keep logistics at the forefront of many firms' strategic efforts:

- Growth in the level of both domestic and international logistics
- Outsourcing opportunities
- Increased emphasis on sustainability at the company level

The last two points deserve special mention. As logistics becomes more globalized and information intensive, more firms are outsourcing the logistics function to specialists, most notably third-party logistics providers (3PLs). This trend is expected to continue. However, firms must carefully analyze the strategic benefits and risks of outsourcing. Firms must remember that outsourcing is *part* of a logistics strategy, not a substitute for one.

Second, logistics covers a wide range of business activities that are inherently resource intensive. It is therefore a natural focal point for many firm's sustainability efforts. Often, organizations have found solutions that improve sustainability as well as other important performance dimensions. For example, many manufacturers have switched to using reusable shipping containers that not only reduce the amount of material ending up in landfills but provide superior protection and are cheaper in the long run than one-time-use containers. In other cases, however, efforts to improve sustainability can hurt an individual firm's cost, quality, or delivery performance. When this occurs, government regulations are frequently used to rebalance business costs and societal costs and to "level the playing field" across competitors.

We started off this chapter by discussing why logistics is critical and by examining the major logistics decision areas, with particular emphasis on transportation modes and warehousing. We then discussed the concept of a logistics strategy and introduced some commonly used logistics decision models.

But we encourage you not to let your logistics education end here. The Council of Supply Chain Management Professionals (CSCMP; **www.cscmp.org**) is a valuable source of education materials, white papers on state-of-the-art research into logistics, and professional contacts.

KEY FORMULAS

Percentage of perfect orders (page 236):

$$\text{Percentage of perfect orders} = 100\%\left(\frac{\text{total orders} - \text{orders with} \geq 1 \text{ defect}}{\text{total orders}}\right) \tag{8.1}$$

Weighted center of gravity method (page 239):

$$\text{Weighted } X \text{ coordinate} = X^* = \frac{\sum_{i=1}^{I} W_i X_i}{\sum_{i=1}^{I} W_i} \tag{8.2}$$

$$\text{Weighted } Y \text{ coordinate} = Y^* = \frac{\sum_{i=1}^{I} W_i Y_i}{\sum_{i=1}^{I} W_i} \tag{8.3}$$

where:

(X_i, Y_i) = position of demand point i

W_i = weighting factor for demand point i

Assignment problem (page 241):

$$\text{Minimize} \sum_{i=1}^{I} \sum_{j=1}^{J} T_{ij} {*} S_{ij} \tag{8.4}$$

subject to the following constraints:

$$\sum_{j=1}^{J} S_{ij} \leq C_i \quad \text{for all warehouses } i \tag{8.5}$$

$$\sum_{i=1}^{I} S_{ij} \geq D_j \quad \text{for all demand points } j \tag{8.6}$$

$$S_{ij} \geq 0 \quad \text{for all combinations of shipments from warehouse } i \text{ to demand point } j \tag{8.7}$$

where:

S_{ij} = number of units shipped from warehouse i to demand point j

T_{ij} = cost of shipping one unit from warehouse i to demand point j (these values are given)

C_i = capacity of warehouse i

D_j = demand at demand point j

KEY TERMS

Assignment problem 241
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SOLVED PROBLEM

PROBLEM

Vivette's Importers

Candace Button has just taken a job with Vivette's Importers in New York. Vivette's makes daily shipments to customers in the Boston area. However, the number of customers, shipment sizes, and associated transportation and warehousing costs can vary considerably from one day to the next.

Candace would like to put together a spreadsheet that would allow her to quickly determine whether or not she should consolidate shipments, based on changing demand and cost information. To test the new spreadsheet, Candace has the following information for the next week:

Number of customers: 15
Average shipment size: 1,400 pounds
Truck capacity: 20,000 pounds
Truck costs: $500 per truck going to Boston

For consolidated shipments:

Warehousing cost: $25 per hundred-weight
Delivery cost: $100 per customer

Solution

Figure 8.13 shows the resulting Microsoft Excel worksheet. The shaded cells represent the input variables; changes to these cells will result in changes to the number of trucks needed and the total costs of consolidation versus direct truck shipments.

	A	B	C	D
1	**Consolidation versus Direct Truck Shipments**			
2				
3	No. of customers:	15		
4	Ave. shipment size:	1,400	pounds	
5	Truck capacity:	20,000	pounds	
6	Truck cost:	$500.00	per shipment	
7	Consolidation costs			
8	Warehousing cost:	$25.00	per hundred-weight	
9	Delivery cost:	$100	per customer	
10				
11	**SOLUTION**			
12		Consolidation	Direct ship	
13	No. of trucks needed:	2	15	
14	Warehousing costs:	$5,250.00	$0.00	
15	Delivery cost:	$1,500.00	$0.00	
16	Trucking costs:	$1,000.00	$7,500.00	
17	Total:	$7,750.00	$7,500.00	

FIGURE 8.13 Consolidation versus Direct Truck Shipment Spreadsheet

Three of the spreadsheet cells deserve special mention. Specifically:

$$\text{Cell B14} = \text{warehousing cost under consolidation}$$

$$= \frac{(\text{warehousing cost per hundred-weight}) \times (\text{number of customers}) \times (\text{average shipment size})}{100}$$

$$= \frac{\text{B8} \times \text{B3} \times \text{B4}}{100}$$

$$\text{Cell B13} = \text{number of trucks needed under consolidation}$$

$$= \text{rounded up value of} \left[\frac{(\text{average shipment size}) \times (\text{number of customers})}{\text{truck capacity}} \right]$$

$$= \text{ROUNDUP}(\text{B4*B3/B5,0})$$

$$\text{Cell B14} = \text{number of trucks needed under direct shipment}$$

$$= (\text{number of customers}) \times \left(\text{rounded up value of} \left[\frac{\text{average shipment size}}{\text{truck capacity}} \right] \right)$$

$$= \text{B3*ROUNDUP}(\text{B4/B5,0})$$

The last two formulas ensure that the number of trucks is correct, even if the average shipment size is greater than the load capacity for a single truck.

An added advantage of this spreadsheet is that Candace can use it to understand how the various costs affect the Ωfinal decision. For example, by playing around with the spreadsheet, Candace realizes that if she can lower the delivery cost to just $83 per customer, then the consolidation option looks less expensive (Figure 8.14).

	A	B	C	D
1	**Consolidation versus Direct Truck Shipments**			
2				
3	No. of customers:	15		
4	Ave. shipment size:	1,400	pounds	
5	Truck capacity:	20,000	pounds	
6	Truck cost:	$500.00	per shipment	
7	Consolidation cost:			
8	Warehousing cost:	$25.00	per hundred-weight	
9	Delivery cost:	$83	per customer	
10				
11	**SOLUTION**			
12		Consolidation	Direct ship	
13	No. of trucks needed:	2	15	
14	Warehousing costs:	$5,250.00	$0.00	
15	Delivery cost:	$1,245.00	$0.00	
16	Trucking costs:	$1,000.00	$7,500.00	
17	Total:	$7,495.00	$7,500.00	

FIGURE 8.14 Impact of Lower Delivery Cost per Customer

DISCUSSION QUESTIONS

1. Someone tells you that logistics is really just trucking and warehousing. Explain why this view is inadequate.
2. A colleague tells you that warehousing is inconsistent with efforts to minimize inventory levels throughout the supply chain. Is this true or false? Explain.
3. Can a firm actually be part of the logistics industry without physically touching a product? Explain.
4. Why will landed costs become a more important consideration as firms participate in more international logistics arrangements?
5. Why is it important for firms to have a logistics strategy? What could happen if a firm did not logically link its logistics decisions to the needs of its customers?
6. Can logistics be an area of core competency for a company? Can you think of an example?

PROBLEMS

Additional homework problems are available at www.pearsonhighered.com/bozarth. These problems use Excel to generate customized problems for different class sections or even different students.

(* = easy; ** = moderate; *** = advanced)

Problems for Section 8.2: Logistics Decision Areas

1. Consider the consolidation warehousing decision facing Bruin Logistics (Example 8.2). Recalculate the cost of the consolidation option if all costs remain the same *except*:

   a. (*) The cost of running the warehouse doubles to $18 per hundred-weight.
   b. (*) Delivery costs to each customer fall to $150.
   c. (**) The cost of sending a truck from Los Angeles to Atlanta falls to $1,800, but delivery costs rise to $250 per customer.

2. Every week BosssMustang of Oakland, California, receives shipments from 10 different suppliers in the Los Angeles area. Each supplier's order weighs, on average, 500 pounds. A direct truck shipment from Los Angeles to Oakland costs $800.

   A Los Angeles 3PL provider has offered to run a consolidation warehousing operation for BosssMustang. The 3PL provider would pick up the shipments from each supplier, process them, and put them on a single truck bound for Oakland. The pickup fee would be $100 per supplier, and the warehousing cost would be $55 per hundred-weight. The direct truck shipment cost would be the same as before, $800.

   a. (*) How much would it cost BosssMustang per week to accept direct, single-order shipments from all of its suppliers? What would the utilization levels for the trucks look like, assuming that each truck was capable of carrying 10,000 pounds?
   b. (**) How much would it cost BosssMustang per week to use the consolidation warehousing option? What would the utilization level for the truck look like?
   c. (**) Suppose higher gasoline prices have caused the trucking cost to increase to $1,200. Which option looks best now?

3. Astro Industries of Minneapolis, Minnesota, makes weekly shipments to 20 customers in the Dallas area. Each customer's order weighs, on average, 1,500 pounds. A direct truck shipment from Minneapolis to Dallas costs $1,800. The maximum load per truck is 40,000 pounds.

   a. (*) How much would it cost Astro to make direct, single-order shipments to all of its customers each week? What would the utilization levels for the trucks look like?
   b. (**) Suppose a Dallas-based warehousing firm has agreed to run a break-bulk warehousing operation for Astro at a cost of $75 per hundred-weight. Local deliveries to each customer would tack on another $100 per customer per week. How much money could Astro save by going with the break-bulk solution?
   c. (***) How high would the warehousing cost (currently $75 per hundred-weight) have to be before break-bulk warehousing is no more attractive than direct shipments? Round your answer to the nearest dollar.

Problems for Section 8.3: Logistics Strategy

4. Consider the perfect order calculation for Bartley Company (Example 8.4). Recalculate the percentage of perfect orders if all performance results remained the same *except*:

   a. (*) 25,000 are delivered late, and total failures are now spread across 85,000 orders.
   b. (*) 25,000 are delivered late, but total failures are still spread across 90,000 orders.
   c. (**) According to the logic of the perfect order measure, does an incorrectly billed order have the same impact as a damaged order? Does this seem reasonable? What are the implications for interpreting this measure?

5. MountainMole Foods has decided to use the perfect order measurement approach to track its logistics performance. According to MountainMole, a perfect order is one that (1) is delivered on time, (2) arrives in one complete shipment, (3) arrives undamaged, and (4) is correctly billed. MountainMole has the following performance figures for the past four years:

YEAR	2015	2016	2017	2018
Total shipments	100,000	150,000	175,000	190,000
On-time shipments	95,000	145,000	170,000	180,000
Complete shipments	99,000	142,500	157,500	161,500
Undamaged shipments	98,000	147,500	173,000	189,000
Correctly billed shipments	55,000	97,500	132,000	161,500

   a. (**) Calculate performance for each of the four years. What is the overall trend in the performance, if any? What factors explain the results?
   b. (**) If you were looking to improve MountainMole's logistics performance, what areas might you concentrate on, based on these results?

6. Northcutt manufactures high-end racing bikes and is looking for a source of gear sprocket sets. Northcutt would need 1,550 sets a month. Supplier A is a domestic firm, and Suppliers B and C are located overseas. Cost information for the suppliers is as follows:

   - **Supplier A**—Price of $100 per set, plus packing cost of $2 per set. Total inland freight costs for all 1,550 units would be $800 per month.
   - **Supplier B**—Price of $96 per set, plus packing cost of $3.50 per set. International transportation costs would total $3,500 per month, while total inland freight costs would be $800 per month.
   - **Supplier C**—Price of $93 per set, plus packing cost of $3.00 per set. International transportation costs would total $5,000 per month, while total inland freight costs would be $1,000 per month.

   a. (**) Calculate total landed costs per unit and per month for the three potential suppliers. Who is the cheapest? Who is the most expensive?

b. (***) Suppose that international and inland freight costs are fixed for volumes up to 4,000 units a month. Under this assumption, which supplier would have the lowest landed cost if demand were cut in half? If demand doubled? Whose landed cost is most sensitive to volume changes?

c. (**) What factors other than landed costs might Northcutt consider when selecting the supplier? (*Hint:* Incorporate what you learned in Chapters 5 and 7.

7. Consider the Redwing Automotive total cost example summarized in Table 8.4.

a. (**) By how much would PLS have to cut its per-unit price in order to match SBC's landed costs? What percentage decrease does this translate into?

b. (**) If you were the president of PLS, where would you go about trying to lower your landed costs to better match those of SBC?

c. (**) What logistics performance dimensions other than landed costs might PLS emphasize in order to win Redwing's business?

Problems for Section 8.4: Logistics Decision Models

8. Consider the warehouse location decision facing CupAMoe's (Example 8.6).

a. (**) Suppose Robbie has learned that Capital City's population is expected to grow by just 5% over the next five years, while Springfield's population is expected to increase by 50,000 over the same time period. Recalculate the *X* and *Y* coordinates using this new information.

b. (**) Now suppose Robbie has also learned that Capital City generates $800,000 in sales per year, while Springfield and Shelbyville both generate only $150,000 in sales each. Using sales dollars as the weights, recalculate the *X* and *Y* coordinates.

c. (**) Which do you think is a better weighting factor to consider: population or sales dollars? Explain.

9. The city of Green Valley, Arizona, is trying to determine where to locate a new fire station. The fire station is expected to serve four neighborhoods. The locations and number of homes in the neighborhoods are as follows:

NEIGHBORHOOD	*X* COORDINATE	*Y* COORDINATE	NUMBER OF HOMES
Birchwood	5	4	163
Cactus Circle	7	1	45
De La Urraca	2	2	205
Kingston	3.5	1.5	30

a. (**) Calculate the weighted center of gravity for the new fire station, based on the information provided.

b. (**) What other factors (e.g., zoning laws, maximum response time) might come into play when making the final decision?

10. (***) (*Microsoft Excel problem*) The following figure shows an Excel spreadsheet that calculates weighted *X* and *Y* coordinates, based on values for up to five demand points. **Re-create this spreadsheet in Excel.** While your formatting does not have to be exactly the same, your answers should be. Your spreadsheet should recalculate results whenever any changes are made to the shaded cells. To test your logic, change the weight on demand point D to 250. Your new weighted *X* and *Y* coordinates should be 3.04 and 2.96, respectively.

	A	B	C	D
1	**Weighted Center of Gravity Model for Up to Five Demand Points**			
2				
3	Demand point	*X* coordinate	*Y* coordinate	Weighting factor
4	A	1.00	5.00	300
5	B	2.00	4.00	200
6	C	3.00	3.00	100
7	D	4.00	2.00	300
8	E	5.00	1.00	300
9				
10		Weighted *X* coordinate:		3.08
11		Weighted *Y* coordinate:		2.92

11. (***) (*Microsoft Excel problem*) Re-create the assignment problem spreadsheet for Flynn Boot Company, described in Example 8.7 and Figures 8.9 through 8.11. While your formatting does not have to be exactly the same, your spreadsheet should work the same. Specifically, the user should be able to change the weekly capacity ( ), weekly demand ( ), or shipping cost ( ) values and generate a new solution using Excel's Solver function. Test your spreadsheet by seeing whether you get a new solution when Atlanta's warehouse capacity changes from 20,000 to 15,000. Make sure your answers match those in Example 8.7.

12. (***) (*Microsoft Excel problem*) Consider the following information:

PLANT	CAPACITY	STORE	DEMAND
A	400	X	200
B	500	Y	250
C	100	Z	300
Total:	1,000	Total:	750

Cost to shop from plant to store (per unit of demand)

	STORE		
PLANT	**X**	**Y**	**Z**
A	$2.00	$2.00	$3.50
B	$4.00	$5.00	$4.50
C	$3.00	$3.00	$3.00

a. Write out the assignment problem by hand, using Equations (8.4) through (8.7) and Example 8.7 as a guide.

b. Develop an Excel spreadsheet that uses the Solver function to find the optimal shipping patterns between the plants and the stores. (*Hint:* The objective function for the optimal solution is $2,200.) Interpret your answer. Is there any plant that is underutilized? If so, why do you think this is the case? How might you use this information in any future decision to expand plant capacities?

CASE STUDY

Green Reverse Logistics in the Electronics Industry[11]

The path to a greener supply chain is often paved with forward-looking ideas focused on environmentally friendly manufacturing, transportation, and distribution processes. For some companies, however, the key to jump-starting supply chain sustainability can be found in reverse. By embracing reverse logistics strategies—including returns management, product repair and refurbishment, recycling of goods and materials, and proper disposal of materials from unwanted goods—companies can move the sustainability while also cutting costs and reaping products with a longer shelf life.

One business sector that is championing these activities—and seeing the bottom-line benefits—is the electronics industry, largely because of skyrocketing growth in high-tech gadgets. Thanks to ever-changing technology, top sellers such as digital cameras, cell phones, video game systems, computers, televisions, and other electronic devices become obsolete in a few short years—leaving electronics manufacturers to deal with mountains of unwanted product.

Recycling

For electronics manufacturers, recycling unwanted components is one key aspect of green reverse logistics. In 2007, Samsung, a global leader in the electronics industry, began its Recycling Direct program—partnering with take-back and recycling companies that do not incinerate, send materials to solid waste landfills, or export toxic waste to developing countries—and has since recycled 14 million pounds of waste from its consumer goods and IT products. The company has established drop-off locations across all 50 states in more than 200 fixed locations, where consumers can take unwanted electronics (both Samsung and non-Samsung brands). "Our goal is to make it convenient for Samsung customers to recycle old TVs, phones, camcorders, printers, notebook computers, and other electronics at no charge," explains David Steel, senior vice president of marketing for Samsung North America.

The company has also teamed up with the U.S. Postal Service and third-party logistics company Newgistics to operate the Samsung Take Back & Recycling program, which enables consumers to recycle used printer cartridges. Using a prepaid Smart Label, customers can return old printer cartridges to Samsung by simply dropping them in any mailbox. Through this program, Samsung ensures that empty cartridges are safely reprocessed into their major usable component materials (including plastics, metals, and packaging materials), and then it makes those reprocessed materials available for reuse in new manufacturing for a range of products.

Refurbishing

When consumers return an electronics product because it is outdated or not functioning properly, they don't likely give much thought to what happens next. But what happens next is at the heart of business for companies such as ATC Logistics and Electronics (ATCLE), which performs asset recovery, repair, and refurbishing services. Brian Morris, director of engineering for this Texas-based 3PL, gave a detailed explanation of the process involved in giving a returned product a new life:

> *When we receive returns from customers, we do a test inspection to find out how many faults the product has. If there is nothing wrong with it, we can repackage it for sale. If it's a faulty product, we identify the failure and determine what it takes to repair or refurbish that product.*
>
> *The next step is to weigh the economics of the repair: Given the cost of fixing a product, does it make sense to repair it? This goes back to the cost/benefit of conducting the testing and refurbishment processes. There must be an acceptable ratio to be profitable. The range is typically 70 to 80 percent of the product's original cost.*
>
> *If a product is deemed worth fixing, we put it through our repair and refurbishment operation, and it emerges like new. If the product cannot be repaired, we look at its individual components. If the plastic housing is still in good shape, for instance, the plastic can be reclaimed and used to refurbish another product. Batteries are another key component. Most batteries are not exposed, so if they still hold a charge properly and are in good shape cosmetically, they are often put through reconditioning. After reconditioning, we use them as replacement batteries or sell them to other refurbishing operations. We also find uses for components such as keyboards and USB cables.*
>
> *Products with components that don't make the grade are sorted into containers and sent to a recycling house. Recyclers crush and grind plastic components and send them to an injection mold facility, where that plastic is put back into production for new plastics manufacture. Circuit boards can be crushed and smelted, and the precious metals—such as titanium, copper, and small traces of gold—are removed and sold to another circuit board manufacturer or even a jewelry house.*
>
> *We are working to help manufacturers utilize refurbished and reclaimed parts so they can cut down on purchasing new parts. This helps them reduce costs, and it allows us to keep waste from piling up in landfills.*

Questions

1. Consider the examples of recycling and refurbishing described in the case. Who are the various stakeholders who benefit from these efforts? How do efforts to build sustainable supply chains differ from simple good business practice?
2. Would Samsung have put in place the Take Back & Recycling program in a business environment that did not emphasize sustainability? Why or why not? What about ATCLE's refurbishing services?
3. In your opinion, will sustainability become another core measure of operations and supply chain performance, in addition to cost, quality, delivery, and quality? Why or why not?

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[11]Adapted from A. R. Partridge, "Green Reverse Logistics Brings Many Happy Returns," *Inbound Logistics*, January 2010. Reprinted with permission from *Inbound Logistics* magazine (January 2010). **www.inboundlogistics.com/subscribe.** Copyright Inbound Logistics 2010.

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Paul A. Souders/Corbis/VCG/Getty Images

CHAPTER nine

Forecasting

CHAPTER OUTLINE

CHAPTER OBJECTIVES

By the end of this chapter, you will be able to:

- Discuss the importance of forecasting and select the most appropriate type of forecasting approach, given different forecasting situations.
- Apply a variety of time series forecasting models, including moving average, exponential smoothing, and linear regression models.
- Develop causal forecasting models using linear regression and multiple regression.
- Calculate measures of forecasting accuracy and interpret the results.

CHEEZNAX SNACK FOODS, PART 1


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It's November 2019, and Jamie Favre, demand planner for Cheeznax Snack Foods, is working away at her desk. In just two days, Jamie will need to provide top management with a forecast of 2020 demand, broken down by month. Cheeznax makes three products: puffed cheese balls, cheese nachos, and cheese-flavored potato chips. Currently, Cheeznax's products are sold through 100 convenience stores owned by Gas N' Grub. Jamie knows how important an accurate demand forecast is to the supply chain:

- *On the downstream side of the supply chain,* Gas N' Grub expects Cheeznax to keep the store shelves stocked with fresh products. If Cheeznax fails to deliver, then Gas N' Grub will take its business elsewhere.
- Within Cheeznax, manufacturing needs the forecast to plan production. While manufacturing doesn't want to underproduce, it also doesn't want to overproduce and end up with excessive inventory levels and spoilage costs. Furthermore, the finance department needs the forecast to project revenues for the upcoming year.
- Finally, *on the upstream side of the supply chain,* Cheeznax's suppliers need the forecast to plan their overall production levels of raw ingredients and packaging material.

Jamie looks at the 2019 Cheeznax sales figures, shown in Table 9.1. She knows the 2019 numbers are a good starting point for developing the 2020 forecast, but she also knows that she needs more information. For instance, Gas N' Grub currently has 100 stores, but how many new stores will the company open in 2020? How will this affect demand? Also, in past years Gas N' Grub has launched advertising campaigns for its stores without informing Cheeznax first. Cheeznax was unable to meet the unplanned surges in demand, and Jamie and Gas N' Grub's purchasing manager ended up bickering. Ultimately, things would get smoothed over, but Jamie couldn't help but think about the lost sales opportunity. As Jamie contemplates all this information, she starts to formulate a plan for developing her forecast.

TABLE 9.1 2019 Monthly Sales Totals for Cheeznax

MONTH	SALES ($)
January	$230,000
February	$230,000
March	$240,000
April	$250,000
May	$240,000
June	$250,000
July	$270,000
August	$260,000
September	$260,000
October	$260,000
November*	$280,000
December*	$290,000
TOTAL:	**$3,060,000**

*Estimated demand

INTRODUCTION

Forecast
An estimate of the future level of some variable. Common variables that are forecasted include demand levels, supply levels, and prices.

A **forecast** is an estimate of the future level of some variable. The variable is most often demand, but it can also be something else, such as supply or price. As we shall see throughout this book, forecasting is often the very first step organizations must go through when determining long-term capacity needs, yearly business plans, and shorter-term operations and supply chain activities. For example, could you imagine being a hospital administrator and trying to decide on the physical size of a new hospital, the number of doctors and nurses needed, or even the amount of supplies needed *without* forecasting patient demand first?

In practice, most organizations use a number of different forecasting techniques, depending on the situation they face. Some forecasting approaches depend on informal human judgments; others depend primarily on statistical models and past data. Both types of forecasts are important in predicting the future.

In the first part of this chapter, we discuss the different types of forecasts firms use and the four laws of forecasting. We then differentiate between qualitative and quantitative forecasting techniques. Most of this chapter is devoted to illustrating some of the most common quantitative forecasting methods, as well as measures of model accuracy. Finally, we highlight the role of computer-based forecasting packages and the use of collaborative planning, forecasting, and replenishment (CPFR) programs by some supply chain partners to improve the accuracy of their forecasting efforts.

9.1 FORECAST TYPES

Organizations often need to forecast variables other than demand. In this section, we describe some of the most common forecast types: demand, supply, and price forecasts.

Demand Forecasts

When we talk about demand forecasts, we need to distinguish between overall market demand and firm-level demand. Both types of demand are of interest to businesses but for different reasons. For instance, suppose the worldwide demand for new hybrid vehicles is expected to reach 8 million by 2019. Working from this number, automotive manufacturers must decide what percentage of this overall demand they will capture. But the demand for new hybrid vehicles is not the only demand the automotive manufacturers face. It will combine with other sources of demand—including warranty repairs, spare parts, and the like—to determine firm-level demand for all assemblies and components that go into hybrid vehicles. Once firms have accurately forecasted this firm-level demand, they can begin to plan their business activities accordingly.

Supply Forecasts

Supply forecasts can be just as important as demand forecasts, as an interruption in supply can break the flow of goods and services to the final customer. A supply forecast might provide information on the number of current producers and suppliers, projected aggregate supply levels, and technological and political trends that might affect supply. To illustrate, one of the world's largest supplies of manganese is located in central Africa. Because political turmoil in this region has interrupted manganese shipments in the past, companies whose products depend on this mineral need to pay close attention to what is going on in this area of the world.

Price Forecasts

Many businesses need to forecast prices for key materials and services they purchase. When commodity prices are expected to increase, a good strategy is forward buying, in which companies buy larger quantities than usual, store them in inventory for future use, and save on the price they pay. Alternatively, companies can use futures contracts to protect themselves. A *futures contract* is a legal agreement to buy or sell a commodity at a future date at a price that is fixed at the time of the agreement. If prices are falling, a better strategy is to buy more frequently in smaller quantities than usual, with the expectation that prices will go down over time. But the point is this: In order to decide on a purchasing strategy, firms must first have the price forecasts. The *Supply Chain Connections* feature highlights how forecasts of jet fuel prices can affect a wide range of decisions for airlines.

SUPPLY CHAIN CONNECTIONS

FORECASTED PRICE OF JET FUEL TAKES OFF

Isaiah Shook/Shutterstock

April 2011. A recovering world economy combined with political upheaval in the Middle East threatened to send oil and fuel prices to near-record levels. At the end of the first quarter of 2011, the U.S. Energy Information Administration (EIA) published a report that included a price forecast for jet fuel for the remainder of 2011 and 2012. Figure 9.1 shows these forecasted values, as well as actual average jet fuel prices for 2010 and the first quarter of 2011.

Fuel costs can account for 25% to 35% of total operating expenses for an airline, rivaling (and sometimes even surpassing) labor costs. In the last quarter of 2010, for example, American Airlines spent $6.4 *billion* on jet fuel when the average price was around $2.14 per gallon. As one can imagine, then, with fuel prices forecasted to increase by more than 50%, airlines faced a number of critical decisions in early 2011:

- What type of purchasing strategy should be used? That is, should an airline enter into a futures contract with suppliers and "lock in" prices at the forecasted values, or should it hold off and hope that prices fall? What are the pros and cons of each approach?
- How should ticket prices for future flights be adjusted to account for the expected fuel price increases? What impact would raising ticket prices have on demand?
- Similarly, what impact would fuel prices have on the profitability of operations? Should an airline reexamine some of the less-profitable routes and consider eliminating them?

April 2014. Three years later, the same EIA report that forecasted prices of $3.26 in the latter half of 2011 now suggested that prices would stabilize at around $2.92 per gallon through 2014 and 2015. Several factors accounted for the change—improvements in supply, the deployment of more fuel-efficient jets, and greater political stability. While fuel prices were nowhere near as turbulent as they were just a few years earlier, one can be sure that the major airlines were still keeping a watchful eye on them.

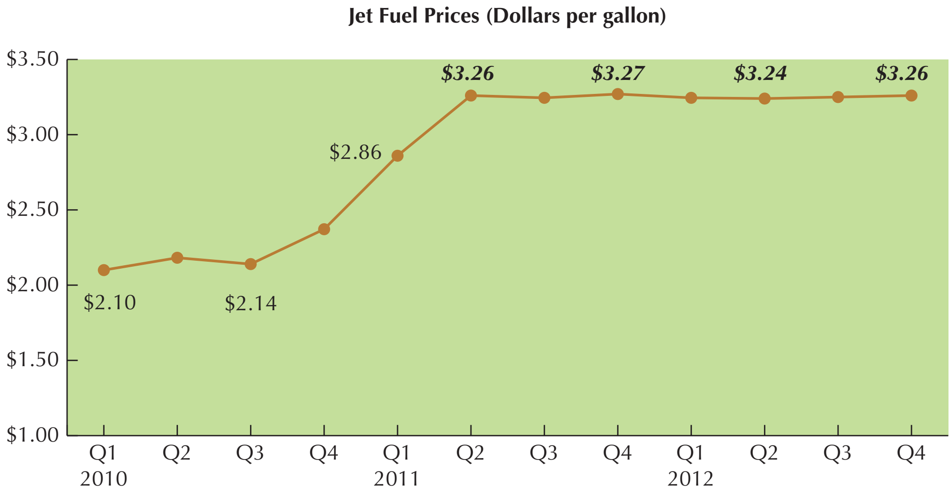


FIGURE 9.1 **Actual and Forecasted Jet Fuel Prices, 2010–2012**
Source: Data from Energy Information Administration, *Short-Term Energy Outlook—April 2011*, **www.eia.gov/emeu/steo/pub/2tab.pdf.**

9.2 LAWS OF FORECASTING

Now that we have discussed some of the major types of forecasts, let's review the basic laws of forecasting. By keeping these laws in mind, users can avoid the misapplication or misinterpretation of forecast results.

Law 1: Forecasts Are Almost Always Wrong (But They Are Still Useful)

Even under the best of conditions, no forecasting approach can predict the *exact* level of future demand, supply, or price. There are simply too many factors that can ultimately affect these numbers. Rather, businesses should use forecasting methods to get *close* estimates. The degree to which a forecast is *accurate* is a function of forecasting laws 2 and 3.

Law 2: Forecasts for the Near Term Tend to Be More Accurate

Law 2 recognizes that in the near term, the factors that affect the forecast variable are not likely to change greatly. Take, for instance, the price of gas. Given your understanding of current economic and political conditions, as well as the current price, you may feel reasonably comfortable predicting the price of gas for the next month or two. But what about 10 or 20 years from now? In addition to economic and political changes, other factors, such as technological breakthroughs and demographic changes, could radically affect the demand, and hence the price, of gas.

Law 3: Forecasts for Groups of Products or Services Tend to Be More Accurate

Many businesses have found that it is easier and more accurate to forecast for groups of products or services than it is to forecast for specific ones. The reason is simple: The demand, supply, or price of a *specific* item is usually affected by many more factors. Take, for example, the demand for dark green cars versus *all* cars. Color fashion may affect the precise demand for green cars. However, when we look at *overall* demand, the impact of color fashion disappears: Higher or lower demand for green cars is balanced out by demand for cars of other colors.

Law 4: Forecasts Are No Substitute for Calculated Values

Quantitative forecasting models
Forecasting models that use measurable, historical data to generate forecasts. Quantitative forecasting models can be divided into two major types: time series models and causal models.

Forecasts should be used only when better approaches to determining the variable of interest are not available. To see what can go wrong when this law is not followed, consider the experiences of a plant visited by one of the authors. The plant made rubber products. Every Wednesday, the management team would determine how many of each product would be made in the coming week. From this production plan, the plant's buyers could have easily calculated *exactly* how much and what grades of raw rubber would be needed. Instead, the buyers chose to forecast rubber requirements. As a result, sometimes the plant had too much rubber on hand, and at other times, it did not have enough. In effect, the plant forecasted demand when it would have been simpler and more accurate to calculate demand.

9.3 SELECTING A FORECASTING METHOD

Forecasting is clearly an important business process. But how should companies go about selecting from the myriad of forecasting methods available? Figure 9.2 provides a road map that highlights the key questions forecasters need to ask, as well as the major categories and types of forecasting models used in practice.

Qualitative forecasting techniques
Forecasting techniques based on intuition or informed opinion. These techniques are used when data are scarce, not available, or irrelevant.

The first set of issues concerns the availability of quantitative, historical data, and evidence that these data can be used to predict the future. When these conditions hold, forecasters can use quantitative forecasting models. **Quantitative forecasting models** are forecasting models that use measurable, historical data to generate forecasts. When these conditions don't hold, qualitative forecasting techniques must be used. **Qualitative forecasting techniques** are forecasting techniques based on intuition or informed opinion. These techniques are used when historical data are scarce, not available, or irrelevant.

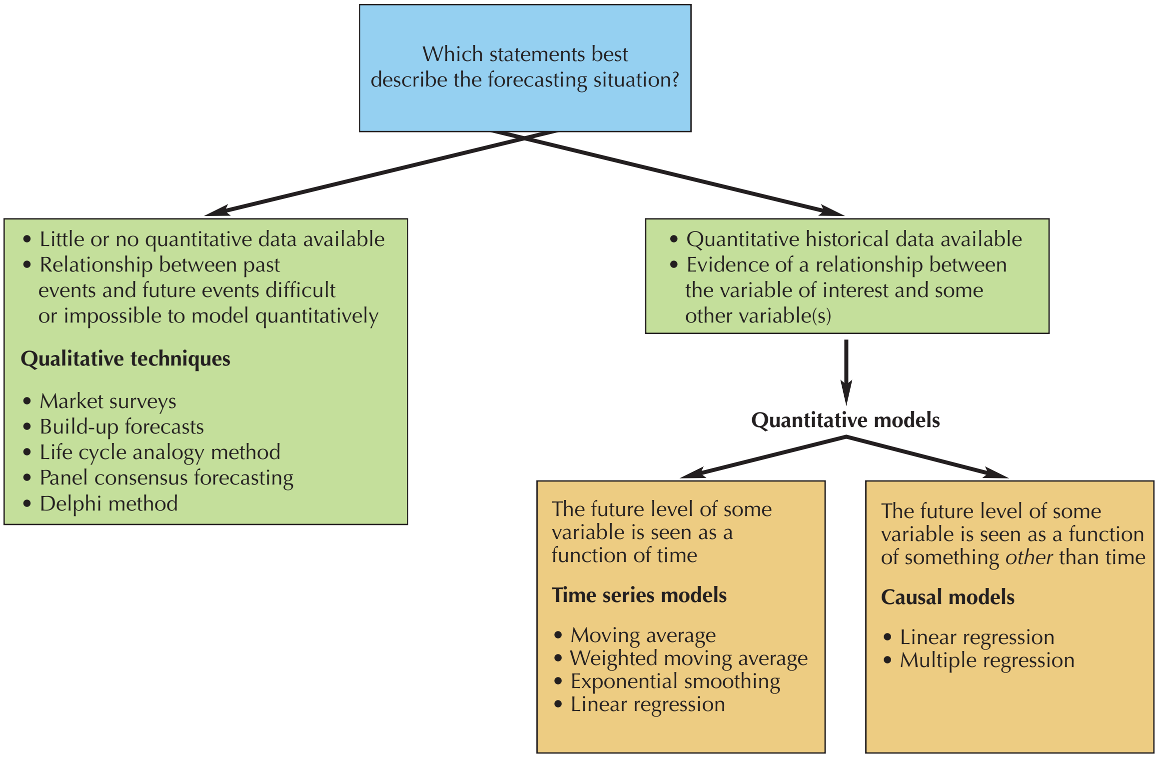


FIGURE 9.2 **Selecting a Forecasting Method**

To illustrate the distinction, consider two forecasting situations facing a large recording company:

- Total music sales, including downloads and CDs, for the year
- Music sales for a new recording artist

In the first case, last year's total sales may be a good predictor of total sales for this year (a classic example of time series modeling). The recording company may even be able to forecast total yearly sales based on the number of 18- to 25-year-olds or average personal disposable income figures (causal forecasting). Quantitative techniques are well suited to this situation.

But what about music sales for a new artist? The recording company might try to draw comparisons to similar artists or even test the new artist with focus groups, but ultimately the company's managers will have to depend more on their opinions than on any "hard" data.

Market survey
A structured questionnaire submitted to potential customers, often to gauge potential demand.

9.4 QUALITATIVE FORECASTING METHODS

Panel consensus forecasting
A qualitative forecasting technique that brings experts together to discuss and develop a forecast.

Delphi method
A qualitative forecasting technique in which experts work individually to develop forecasts. The individual forecasts are shared among the group, and then each participant is allowed to modify his or her forecast based on information from the other experts. This process is repeated until consensus is reached.

Even when qualitative forecasting must be used in situations where hard data does not exist, a forecast can still be developed in a rational manner. **Market surveys** are structured questionnaires submitted to potential customers. They solicit opinions about products or potential products and often attempt to estimate likely demand. If structured well and administered to a representative sample of the defined population, market surveys can be quite effective. A major drawback is that they are expensive and time-consuming to perform.

Both the Delphi method and the panel consensus forecasting method use panels of experts to develop a consensus forecast. The major difference between the two is the process used to collect the data. **Panel consensus forecasting** brings the experts together to discuss and develop forecasts. In contrast, the **Delphi method** has experts work individually to develop forecasts. The individual forecasts are shared among the group, and then each participant is allowed to modify his or her forecast based on information from the other experts. This process is repeated until consensus is reached. As you can imagine, these methods tend to be quite expensive, primarily due to the time requirements. The advantage is that when done correctly, they can be quite accurate.

Life cycle analogy method
A qualitative forecasting technique that attempts to identify the time frames and demand levels for the introduction, growth, maturity, and decline life cycle stages of a new product or service.

The **life cycle analogy method** is used when the product or service is new. The technique is based on the observation that many products and services have a fairly well-defined life cycle, consisting of an introduction stage, a growth stage, a maturity stage, and a decline stage. The major questions that arise include the following:

- How long will each stage last?
- How rapid will the growth be? How rapid will the decline be?
- How large will the overall demand be, especially during the maturity phase?

Build-up forecast
A qualitative forecasting technique in which individuals familiar with specific market segments estimate the demand within these segments. These individual forecasts are then added up to get an overall forecast.

One approach is to base the forecast for the new product or service on the actual history of a similar product or service. This can be especially effective if the new product or service is essentially replacing another in the market and targeted to the same population.

Finally, **build-up forecasts** work by having experts familiar with specific market segments estimate the demand within these segments. These individual market segment forecasts are then added up to get an overall forecast. For instance, a company with sales offices in each of Japan's 47 prefectures might ask each regional sales manager to estimate per-prefecture sales. Overall sales would then be calculated as the sum of these individual forecasts.

9.5 TIME SERIES FORECASTING MODELS

Quantitative forecasting models use statistical techniques and historical data to predict future levels. Such forecasting models are considered objective rather than subjective because they follow certain rules in calculating forecast values. The two main types of quantitative forecasting models are time series and causal models.

Time series
A series of observations arranged in chronological order.

Time series forecasting model
A quantitative forecasting model that uses a time series to develop forecasts. With a time series model, the chronology of the observations and their values are important in developing forecasts.

A **time series** consists of observations arranged in chronological order. **Time series forecasting models,** then, are quantitative forecasting models that analyze time series to develop forecasts. With a time series model, the chronology of the observations, as well as their values, is important in developing forecasts.

For example, suppose the director of an emergency care facility has recorded the number of patients who have arrived at the facility over the past 15 weeks. This demand time series is shown in Table 9.2.

Table 9.2 represents a time series because the values are arranged in chronological order. As Table 9.2 and Figure 9.3 show, this time series has two notable characteristics. First, the weekly values tend to hover around 100, although in some weeks the number of patients is higher, and in other weeks, the number is lower. Logic would suggest that, unless there are significant changes in either the population or the number of emergency care facilities in the area, future demand levels should be similar. Therefore, it would make sense to use the past demand numbers to forecast future demand levels. Second, the 15-week demand pattern shows

TABLE 9.2
Time Series Data for an Emergency Care Facility

WEEK	NUMBER OF PATIENTS
1	84
2	81
3	89
4	90
5	99
6	106
7	127
8	117
9	127
10	103
11	96
12	96
13	86
14	101
15	109
Average:	100.73

FIGURE 9.3
Time Series of Weekly Demand at an Emergency Care Facility

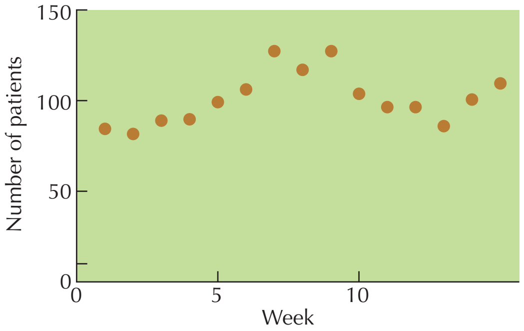
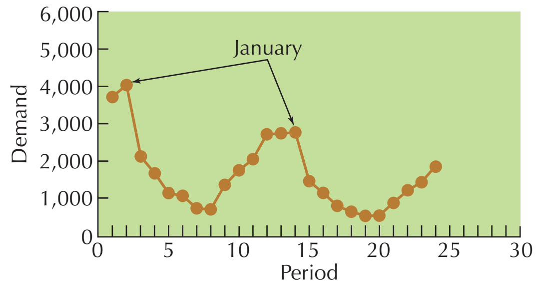


FIGURE 9.4
Time Series Showing Randomness, a Downward Trend, and Seasonality (Higher Demand in the Winter Months)



Randomness
In the context of forecasting, unpredictable movement from one time period to the next.

Trend
Long-term movement up or down in a time series.

Seasonality
A repeated pattern of spikes or drops in a time series associated with certain times of the year.

randomness, or unpredictable movement from one time period to the next. Even though the average number of patients is approximately 101, actual demand numbers range anywhere from 81 to 127. This randomness makes forecasting difficult.

In some cases, time series might also show trend and seasonality, as well as randomness. **Trend** represents a long-term movement up or down, while **seasonality** is a repeated pattern of spikes or drops in the variable of interest associated with certain times of the year. Figure 9.4 shows the time series for a product experiencing randomness, a downward trend, and seasonality in demand. By the end of this chapter, we will have presented methods for developing time series forecasts when all three of these characteristics are present.

Last Period

The simplest time series model is a last period model, which uses demand for the current period as a forecast for the next period. Stated formally:

$$F_{t+1} = D_t \tag{9.1}$$

where:

F_{t+1} = forecast for the next period, $t + 1$
D_t = demand for the current period, t

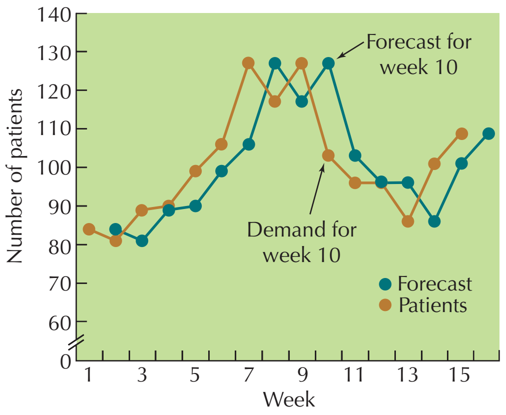
Consider the time series listed in Table 9.2 and graphed in Figure 9.3. Suppose the director of the emergency care facility decides to use a last period forecasting model to predict the number of patients each week. The demand in week 1 becomes the forecast for week 2, the demand in week 2 becomes the forecast for week 3, and so on, as can be seen in Table 9.3.

Figure 9.5 graphs the demand and forecast values from Table 9.3. As the results suggest, the main problem with a last period model is that it is based on only one observation. This makes it overly susceptible to unusually high or low values. Look at the week 10 forecast, which is based on week 9's demand of 127. The forecast turns out to be much higher than actual demand in week 10. In fact, week 10's demand is actually much closer to the average demand of 100.73.

TABLE 9.3
Last Period Forecasting for an Emergency Care Facility

WEEK	NUMBER OF PATIENTS	LAST PERIOD FORECAST
1	84	
2	81	84
3	89	81
4	90	89
5	99	90
6	106	99
7	127	106
8	117	127
9	127	117
10	103	127
11	96	103
12	96	96
13	86	96
14	101	86
15	109	101
16		109

FIGURE 9.5
Last Period Forecasting for an Emergency Care Facility



Moving Average

Moving average model
A time series forecasting model that derives a forecast by taking an average of recent demand values.

In response to the limitations of a last period forecasting model, a **moving average model** derives a forecast by taking an average of a set of recent demand values. By basing the forecast on more than one observed demand value, the moving average model is less susceptible to random swings in demand. The model is stated as follows:

$$F_{t+1} = \frac{\sum_{i=1}^{n} D_{t+1-i}}{n} \tag{9.2}$$

where:

F_{t+1} = forecast for time period $t + 1$
D_{t+1-i} = actual demand for period $t + 1 - i$
n = number of most recent demand observations used to develop the forecast

For example, using the data in Table 9.2, the *three*-period moving average forecast for week 16 is derived from the demand figures for the previous three weeks (weeks 13–15):

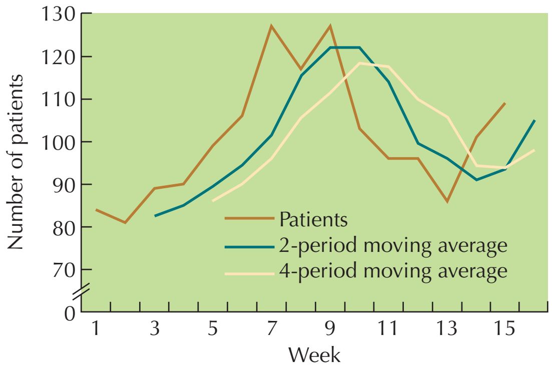
$$F_{16} = \frac{\sum_{i=1}^{3} D_{16-i}}{3} = \frac{D_{15} + D_{14} + D_{13}}{3} = \frac{109 + 101 + 86}{3}$$

$$= 98.7$$

TABLE 9.4
Two-Period and Four-Period Moving Average Forecasts

WEEK	NUMBER OF PATIENTS	TWO-PERIOD MOVING AVERAGE FORECAST	FOUR-PERIOD MOVING AVERAGE FORECAST
1	84		
2	81		
3	89	82.5	
4	90	85.0	
5	99	89.5	86.0
6	106	94.5	89.8
7	127	102.5	96.0
8	117	116.5	105.5
9	127	122.0	112.3
10	103	122.0	119.3
11	96	115.0	118.5
12	96	99.5	110.8
13	86	96.0	105.5
14	101	91.0	95.3
15	109	93.5	94.8
16		105.0	98.0
Average:	100.7	101.0	102.6
Minimum:	81	82.5	86.0
Maximum:	127	122.0	119.3

FIGURE 9.6
Two-Period and Four-Period Moving Average Forecasts for an Emergency Care Facility



By basing the forecast on multiple values, the moving average model generates "smoothed" forecasts that are less susceptible to random fluctuations in demand. It is because of this that moving average models are sometimes called **smoothing models.**

Smoothing model
Another name for a moving average model. The name refers to the fact that using averages to generate forecasts results in forecasts that are less susceptible to random fluctuations in demand.

Table 9.4 shows two-period moving average and four-period moving average results for the emergency medical care center.

The smoothing effect is evident in the minimum and maximum values for the two forecasting models. The same effect can be seen graphically in Figure 9.6. Both the two-period and four-period models smooth out the peaks and valleys in the raw demand numbers. Because their forecasts are averages based on past data, the forecasts also echo the rises and falls in demand. These smoothing and delayed reaction characteristics are more pronounced in the four-period model than in the two-period one.

So which is better here: the two-period or four-period model? Generally speaking, the more randomness there is in the raw data, the more attractive the smoothing and delayed reaction characteristics are. The four-period model would be preferable in such a case. On the other hand, if rises or falls in demand are not random but really do indicate changes in the underlying demand pattern, we would prefer a more reactive model, such as the two-period model. Later in the chapter, we describe measurements that can be used to compare the relative performance of alternative forecasting models.

Weighted Moving Average

Weighted moving average model
A form of the moving average model that allows the actual weights applied to past observations to differ.

A variation of the moving average model is the **weighted moving average model.** In this case, the actual weights applied to past observations are allowed to differ:

$$F_{t+1} = \sum_{i=1}^{n} W_{t+1-i} D_{t+1-i} \tag{9.3}$$

where:

$W_{t+1-i} =$ weight assigned to the demand in period $t + 1 - i$

$\sum_{i=1}^{n} W_{t+1-i} = 1$

As the formulas suggest, the only real restriction is that the weights must add to 1. Allowing the weights to vary lets the user change the emphasis placed on the past observations. Suppose we want to use a three-period weighted moving average model with the following weights:

Weight given to the current time period $= W_t = 0.5$
Weight given to the last time period $= W_t - 1 = 0.3$
Weight given to the time period two periods earlier $= W_{t-2} = 0.2$

The different weights will place more emphasis on the most recent observations. Using the data in Table 9.2, the three-period weighted moving average forecast for week 16 would be:

$$F_{16} = \sum_{i=1}^{3} W_{16-i} D_{16-i} = W_{15}D_{15} + W_{14}D_{14} + W_{13}D_{13}$$

$$= 0.5*109 + 0.3*101 + 0.2*86 = 102$$

EXAMPLE 9.1
Flavio's Pizza

Flavio's Pizza has recorded the following demand history for each Friday night for the past 5 weeks. Develop forecasts for week 6 using a two-period moving average and a three-period weighted moving average. The weights for the three-period moving average model are 0.4, 0.35, and 0.25, starting with the most recent observation.

WEEK	DEMAND
1	62
2	45
3	55
4	73
5	60

The two-period moving average forecast would be:

$$F_6 = (60 + 73)/2 = 66.5 \text{ pizzas}$$

The three-period moving average forecast would be:

$$F_6 = 0.4*60 + 0.35*73 + 0.25*55 = 63.3 \text{ pizzas}$$

Exponential Smoothing

Exponential smoothing model
A special form of the moving average model in which the forecast for the next period is calculated as the weighted average of the current period's actual value and forecast.

The **exponential smoothing model** is a special form of the moving average model in which the forecast for the next period is calculated as the weighted average of the current period's actual value and forecast. The formula for the exponential smoothing model is:

$$F_{t+1} = \alpha D_t + (1 - \alpha)F_t \tag{9.4}$$

where:

F_{t+1} = forecast for time period $t + 1$ (i.e., the *new* forecast)
F_t = forecast for time period t (i.e., the *current* forecast)
D_t = actual value for time period t
α = smoothing constant used to weight D_t and F_t $(0 \leq \alpha \leq 1)$

There are a couple things to note about the exponential smoothing model. First, as Equation (9.4) shows, the exponential smoothing model works by "rolling up" the current period's actual and forecasted values into the next period's forecast. Because all forecasts are based on past actual values, all actual values back to the first period ultimately end up in the most recent forecast.

To show how it works, suppose the Emerald Pool Company has just started selling above-ground pools. In the first month, the company forecasted demand of 40 pools, while actual demand turned out to be 50. If we select an α value of 0.3, the exponential smoothing forecast for period 2 becomes:

$$\begin{aligned} F_2 &= 0.3{*}D_1 + (1 - 0.3)F_1 \\ &= 0.3{*}50 + 0.7{*}40 = 15 + 28 = 43 \text{ pools} \end{aligned}$$

Now suppose period 2 demand turns out to be 46 pools. The forecast for period 3 can now be calculated as:

$$\begin{aligned} F_3 &= 0.3{*}D_2 + (1 - 0.3)F_2 \\ &= 0.3{*}46 + 0.7{*}43 = 13.8 + 13.0 = 43.9 \text{ pools} \end{aligned}$$

Notice how period 3's forecast (F_3) is derived in part from the forecast in period 2 (F_2). Because F_2 is based in part on demand in period 1, so is the forecast for period 3. Table 9.5 shows this "rolling up" effect over the first six periods. By following the arrows, you can see how period 1's demand ultimately becomes part of the forecast for period 6. The same is true for periods 2 through 5.

Another critical feature of the exponential smoothing model is the smoothing constant, α. According to Equation (9.4), the forecast for the next period, F_{t+1}, is really just a weighted average, with α determining the relative weight put on the current period's actual and forecasted values, D_t and F_t. The closer α is to 1, the greater the weight put on the *most recent* actual demand value; the closer α is to 0, the more emphasis is put on *past* forecasts. Therefore, we can control how reactive the model is by controlling α.

The general rule for determining the α value is this: The greater the randomness in the time series data is, the lower the α value should be. Conversely, the less randomness in the time series data, the higher the α value should be.

Figure 9.7 shows a time series of demand data, as well as the resulting forecasts for an exponential smoothing model with a smoothing constant value of $\alpha = 0.2$. The time series contains a spike in demand in period 11 and a trough in period 18. After each of these periods, the actual demand numbers seem to return to the "normal" range of values between 8 and 12.

In a situation like this, we would not want the forecast model to overreact to the extreme demand levels in periods 11 and 18. And in fact, due to the low weight put on the most recent demand level, D_t, the exponential smoothing forecast values are only slightly affected by periods 11 and 18.

Now consider the demand numbers in Figure 9.8. Here, the demand spike in period 11 is followed by a shift up in the demand numbers. In other words, period 11 is *not* a random result

TABLE 9.5 Exponential Smoothing Forecasts for Periods 2–6, Emerald Pool Company

Period	Demand	Forecast
1	50	40
2	46	0.3 * 50 + (1 – 0.3) * 40 = 43
3	52	0.3 * 46 + (1 – 0.3) * 43 = 43.9
4	48	0.3 * 52 + (1 – 0.3) * 43.9 = 46.33
5	47	0.3 * 48 + (1 – 0.3) * 46.33 = 46.83
6		0.3 * 47 + (1 – 0.3) * 46.83 = 46.88

FIGURE 9.7
Exponential Smoothing Forecast (α = 0.2) for Time Series A

α =	0.2	EXPONENTIAL SMOOTHING
PERIOD	DEMAND	FORECAST
1	10	10*
2	11	10.00
3	9	10.20
4	11	9.96
5	10	10.17
6	8	10.14
7	12	9.71
8	9	10.17
9	10	9.94
10	11	9.95
11	20	10.16
12	11	12.13
13	9	11.90
14	11	11.32
15	10	11.26
16	9	11.01
17	11	10.61
18	4	10.68
19	10	9.34
20	11	9.48

*To start the process, the forecast for period 1 was set at 10.

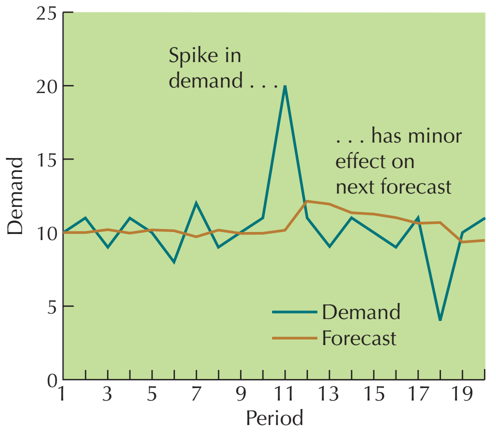
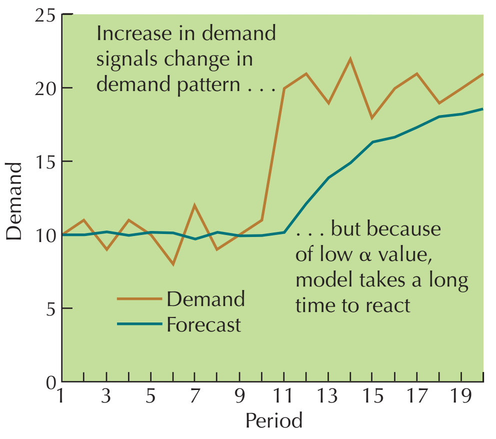


FIGURE 9.8
Exponential Smoothing Forecast (α = 0.2) for Time Series B

α =	0.2	EXPONENTIAL SMOOTHING
PERIOD	DEMAND	FORECAST
1	10	10*
2	11	10.00
3	9	10.20
4	11	9.96
5	10	10.17
6	8	10.14
7	12	9.71
8	9	10.17
9	10	9.94
10	11	9.95
11	20	10.16
12	21	12.13
13	19	13.90
14	22	14.92
15	18	16.34
16	20	16.67
17	21	17.34
18	19	18.07
19	20	18.26
20	21	18.60

*To start the process, the forecast for period 1 was set at 10.



EXAMPLE 9.2

Exponential Smoothing Forecast with $\alpha = 0.8$

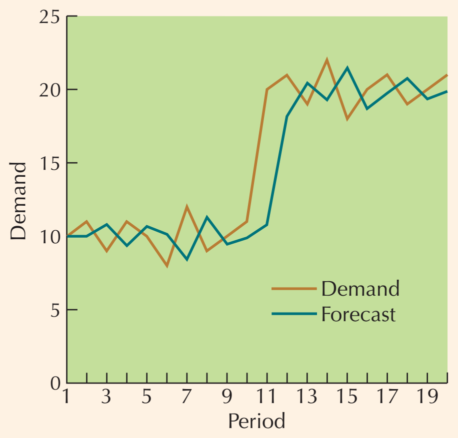
Using the time series data in Figure 9.8, calculate an exponential smoothing forecast for periods 2 through 20, using a smoothing constant value of 0.8. Graph the results.

The detailed calculations for F_2 through F_7 are as follows:

$$F_2 = 0.8{*}D_1 + 0.2{*}F_1 = 0.8{*}10 + 0.2{*}10 = 10$$
$$F_3 = 0.8{*}D_2 + 0.2{*}F_2 = 0.8{*}11 + 0.2{*}10 = 10.8$$
$$F_4 = 0.8{*}D_3 + 0.2{*}F_3 = 0.8{*}9 + 0.2{*}10.8 = 9.36$$
$$F_5 = 0.8{*}D_4 + 0.2{*}F_4 = 0.8{*}11 + 0.2{*}9.36 = 10.67$$
$$F_6 = 0.8{*}D_5 + 0.2{*}F_5 = 0.8{*}10 + 0.2{*}10.67 = 10.13$$
$$F_7 = 0.8{*}D_6 + 0.2{*}F_6 = 0.8{*}8 + 0.2{*}10.13 = 8.43$$

Forecasts for periods 8 through 20 are completed in a similar manner. Figure 9.9 shows the complete set of forecast values and graph. Because of the high α value, the exponential smoothing model now reacts quickly to the increase in demand levels.

α =	0.8	EXPONENTIAL SMOOTHING
PERIOD	DEMAND	FORECAST
1	10	10.00*
2	11	10.00
3	9	10.80
4	11	9.36
5	10	10.67
6	8	10.13
7	12	8.43
8	9	11.29
9	10	9.46
10	11	9.89
11	20	10.78
12	21	18.16
13	19	20.43
14	22	19.29
15	18	21.46
16	20	18.69
17	21	19.74
18	19	20.75
19	20	19.35
20	21	19.87



*To start the process, the forecast for period 1 was set to 10.

FIGURE 9.9 **Exponential Smoothing Forecast ($\alpha = 0.8$) for Time Series B**

but an important indicator of a change in the underlying demand pattern. How does the exponential smoothing model perform in this case? Not as well as before. In fact, because of the low α value, the forecasting model still hasn't "caught up" by period 20.

Adjusted Exponential Smoothing

None of the models we have talked about so far will work when there is a pronounced upward or downward trend in the time series. This is because all of the previous models are just averages of past observations. If there is a strong upward or downward trend, the resulting forecasts will lag.

Adjusted exponential smoothing model
An expanded version of the exponential smoothing model that includes a trend adjustment factor.

In the next two sections, we describe two approaches to dealing with a trend in the time series. The first is the **adjusted exponential smoothing model,** which takes the simple exponential smoothing model and adds a trend adjustment factor to it. Specifically:

$$AF_{t+1} = F_{t+1} + T_{t+1} \tag{9.5}$$

where:

$$\begin{aligned} AF_{t+1} &= \text{adjusted forecast for the next period} \\ F_{t+1} &= \text{unadjusted forecast for the next period} = \alpha D_t + (1 - \alpha)F_t \\ T_{t+1} &= \text{trend factor for the next period} = \beta(F_{t+1} - F_t) + (1 - \beta)T_t \\ T_t &= \text{trend factor for the current period} \\ \beta &= \text{smoothing constant for the trend adjustment factor} \end{aligned} \tag{9.6}$$

To illustrate the adjusted exponential smoothing model, consider the demand time series shown in Table 9.6. Using an α value of 0.3, the unadjusted exponential smoothing forecast for period 2, F_2, is calculated as follows:

$$F_2 = 0.3*30 + 0.7*27 = 27.9$$

The trend adjustment factor for period 2, T_2, is then calculated as a weighted average of the difference between the last two unadjusted forecasts ($F_2 - F_1$) and the previous trend adjustment factor, T_1. Using a trend smoothing factor of $\beta = 0.6$:

$$\begin{aligned} T_2 &= 0.6*(F_2 - F_1) + 0.4*T_1 \\ &= 0.6*(27.9 - 27) + 0.4*0 = 0.54 \end{aligned}$$

And adding F_2 and T_2 gives us the adjusted forecast for period 2:

$$AF_2 = 27.9 + 0.54 = 28.44$$

As can be seen from the results in Table 9.6 and Figure 9.10, the adjusted exponential smoothing model does a better job of picking up on the upward trend in the data than does the unadjusted model. The same would be true if there was a downward trend.

Linear regression
A statistical technique that expresses a forecast variable as a linear function of some independent variable. Linear regression can be used to develop both time series and causal forecasting models.

Linear Regression

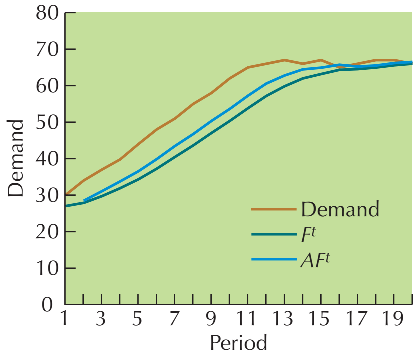
An approach to forecasting when there is a trend in the data is linear regression. **Linear regression** is a statistical technique that expresses the forecast variable as a linear function of some independent variable. In the case of a time series model, the independent variable is the time period itself.

TABLE 9.6
Adjusted Exponential Smoothing Forecast for a Time Series ($\alpha = 0.3, \beta = 0.6$)

PERIOD	DEMAND	UNADJUSTED FORECAST F_t	TREND T_t	ADJUSTED FORECAST AF_t
1	30	27*	0	
2	34	27.90	0.54	28.44
3	37	29.73	1.31	31.04
4	40	31.91	1.83	33.75
5	44	34.34	2.19	36.53
6	48	37.24	2.62	39.85
7	51	40.47	2.98	43.45
8	55	43.63	3.09	46.72
9	58	47.04	3.28	50.32
10	62	50.33	3.29	53.61
11	65	53.83	3.42	57.24
12	66	57.18	3.38	60.56
13	67	59.83	2.94	62.76
14	66	61.98	2.47	64.44
15	67	63.18	1.71	64.90
16	65	64.33	1.37	65.70
17	66	64.53	0.67	65.20
18	67	64.97	0.53	65.50
19	67	65.58	0.58	66.16
20	66	66.01	0.49	66.50

*To start the process, F_1 was set equal to 27.

FIGURE 9.10 Comparing Exponential Smoothing (F_t) and Adjusted Exponential Smoothing (AF_t) Forecasts for a Time Series with a Trend



Linear regression works by using past data to estimate the intercept term and slope coefficient for the following line:

$$\hat{y} = \hat{a} + \hat{b}x \tag{9.7}$$

where:

$\hat{y}$ = forecast for *dependent* variable y
x = *independent* variable x, used to forecast y
$\hat{a}$ = estimated intercept term for the line
$\hat{b}$ = estimated slope coefficient for the line

$\hat{a}$ and $\hat{b}$ are estimated using the raw time series data for variable y (the *dependent* variable) and variable x (the *independent* variable):

$$\hat{b} = \frac{\sum_{i=1}^{n} x_i y_i - \frac{\left[\sum_{i=1}^{n} x_i\right]\left[\sum_{i=1}^{n} y_i\right]}{n}}{\sum_{i=1}^{n} x_i^2 - \frac{\left[\sum_{i=1}^{n} x_i\right]^2}{n}} \tag{9.8}$$

and:

$$\hat{a} = \bar{y} - \hat{b}\bar{x} \tag{9.9}$$

where:

(x_i, y_i) = matched pairs of observed (x, y) values
$\bar{y}$ = average y value
$\bar{x}$ = average x value
n = number of paired observations

Once the line in Equation (9.7) has been estimated, the forecaster can then plug in values for x, the independent variable, to generate the forecast values, $\hat{y}$.

EXAMPLE 9.3

Clem's Competition Clutches

Mike Clem, owner of Clem's Competition Clutches, designs and manufactures heavy-duty car clutches for use in drag racing. In his first 10 months of business, Mike has experienced the demand shown in Table 9.7 and Figure 9.11.

TABLE 9.7 **Ten-Month Time Series of Demand for Clem's Competition Clutches**

MONTH (x)	DEMAND (y)
1	8
2	12
3	25
4	40
5	50
6	65
7	36
8	61
9	88
10	63

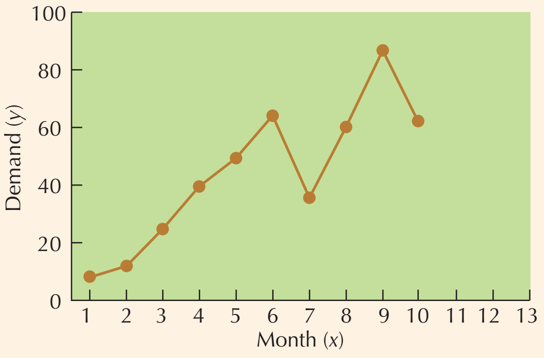


FIGURE 9.11 Ten-Month Time Series of Demand for Clem's Competition Clutches

Using the month as the independent variable (x) to forecast demand (y), Mike wants to develop a linear regression forecasting model and use the model to forecast demand for months 11, 12, and 13. Following Equations (9.8) and (9.9), the first step is to set up columns to calculate the average x and y values, as well as the sums of the x, y, x^2, and xy values for the first 10 months:

	MONTH x	DEMAND y	x^2	xy
	1	8	1	8
	2	12	4	24
	3	25	9	75
	4	40	16	160
	5	50	25	250
	6	65	36	390
	7	36	49	252
	8	61	64	488
	9	88	81	792
	10	63	100	630
Sum:	55	448	385	3,069
Average:	5.50	44.80		

Plugging these values into the equations gives the estimate of the slope coefficient, $\hat{b}$:

$$\hat{b} = \frac{3{,}069 - \dfrac{55*448}{10}}{385 - \dfrac{55^2}{10}} = \frac{3{,}069 - 2{,}464}{385 - 302.5} = 7.33$$

and the intercept term, $\hat{a}$:

$$\hat{a} = \bar{y} - \hat{b}\bar{x} = 44.80 - 7.33*5.50 = 4.49$$

The resulting regression line is:

$$\hat{y} = 4.49 + 7.33x$$

By plugging in 11, 12, and 13 for x, we can generate forecasts for months 11, 12, and 13:

Month 11 forecast: $4.49 + 7.33*11 = 85.12$ clutches
Month 12 forecast: $4.49 + 7.33*12 = 92.45$ clutches
Month 13 forecast: $4.49 + 7.33*13 = 99.78$ clutches

Figure 9.12 plots the regression line forecasts for months 1 through 13 and the first 10 months of demand. The graph shows how the regression line captures the upward trend in the data and projects it out into the future. Of course, these future forecasts are good only as long as the upward trend of around 7.33 additional sales each month continues.

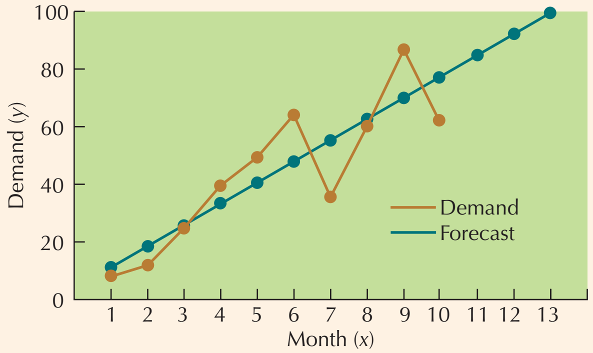


FIGURE 9.12 **Regression Forecast for Clem's Competition Clutches**

One of the data analysis tools available in Microsoft Excel is regression analysis. Figure 9.13 shows the demand data for Clem's Competition Clutches, as well as the dialog box for Excel's regression feature.

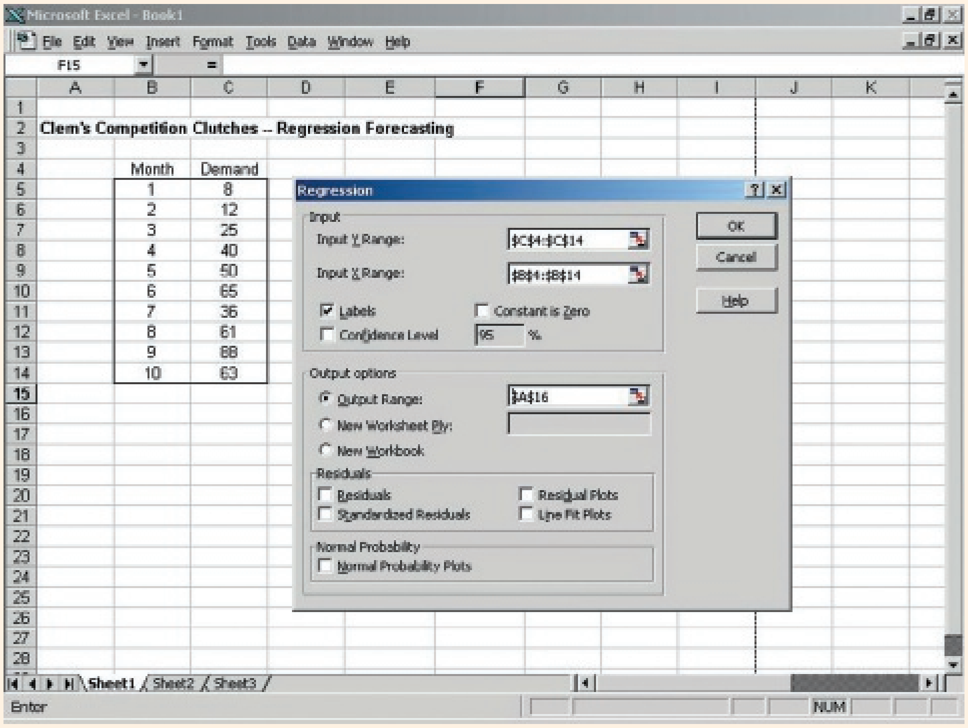


FIGURE 9.13 **Using Excel's Regression Function for Clem's Competition Clutches**
Microsoft Excel, Microsoft Corporation

The "Input Y Range" box shows where the *y* values for the model are located, and "Input X Range" identifies the location of the *x* values. Also note that we have selected the "Labels" box, indicating that the first cell in each range contains an identifying label. Finally, we have instructed Excel to print out the results of the regression starting in cell A16.

After filling out the appropriate boxes and clicking "OK" in the regression dialog box, we get the results shown in Figure 9.14. The "Coefficients" column contains the estimated value for the intercept term, as well as the slope coefficient associated with our independent variable, "Month." These values are 4.467 and 7.333, respectively. Except for some slight rounding differences in the intercept term, these are the same as those generated using Equations (9.8) and (9.9).

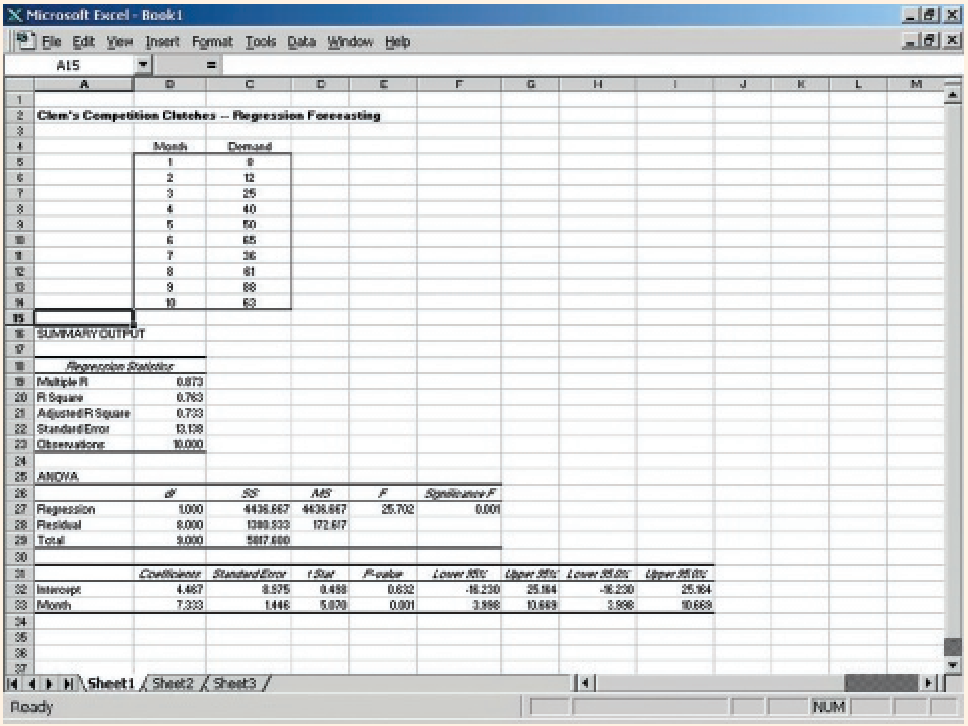


FIGURE 9.14 Excel's Regression Results for Clem's Competition Clutches
Microsoft Excel, Microsoft Corporation

Excel's regression results also include the R^2 ("R-squared") value for the model, as well as some other tests of statistical significance for the coefficients. R^2 indicates what proportion of the variance in the dependent *y* variable ("Demand") is explained by the regression model. In this case, 76.3% of the variance is explained, suggesting that the model fits the data very well.

Seasonal Adjustments

We have already described time series modeling approaches for dealing with randomness and trends in the data. But what about seasonality? As we mentioned earlier, seasonality is a repeated pattern of spikes or drops in a time series associated with certain times of the year. Many products and services have seasonal demand patterns (as well as seasonal supply and price patterns). Table 9.8 lists just a few examples of products or services that demonstrate seasonality.

TABLE 9.8 Examples of Products and Services That Experience Seasonality

PRODUCT OR SERVICE	PEAK SEASON(S)
Gasoline	Summer months, as more people are traveling
Caribbean cruises	Winter months
Cub Scout uniforms	Fall, as new scouts are joining up
Emergency medical care	Summer months, as more people are involved in outdoor activities
Fruitcake	November and December holiday season, after which *no one* buys it (or eats it)

When there is seasonality in the demand pattern, we have to have some way to adjust our forecast numbers to account for this effect. A simple four-step procedure for developing seasonal adjustments is as follows:

1. For each of the demand values in the time series, calculate the corresponding forecast, using the unadjusted forecast model.
2. For each demand value, calculate $\frac{\text{Demand}}{\text{Forecast}}$. If the ratio is less than 1, then the forecast model overforecasted; if it is greater than 1, then the model underforecasted.
3. If the time series covers multiple years, take the average $\frac{\text{Demand}}{\text{Forecast}}$ for corresponding months or quarters to derive the seasonal index. Otherwise, use $\frac{\text{Demand}}{\text{Forecast}}$ calculated in step 2 as the seasonal index.
4. Multiply the unadjusted forecast by the seasonal index to get the seasonally adjusted forecast value.

EXAMPLE 9.4

Linear Regression with Seasonal Adjustments

In this example, we develop a linear regression forecasting model using the following time series data. Based on the results of the regression model, we then develop a seasonal index for each month and reforecast months 1 through 24 (January 2019–December 2020), using the seasonal indices.

MONTH	DEMAND	MONTH	DEMAND
January 2019	51	January 2020	112
February	67	February	137
March	65	March	191
April	129	April	250
May	225	May	416
June	272	June	487
July	238	July	421
August	172	August	285
September	143	September	235
October	131	October	222
November	125	November	192
December	103	December	165

The time series and the corresponding regression forecasts for the first 24 months are shown in Figure 9.15.

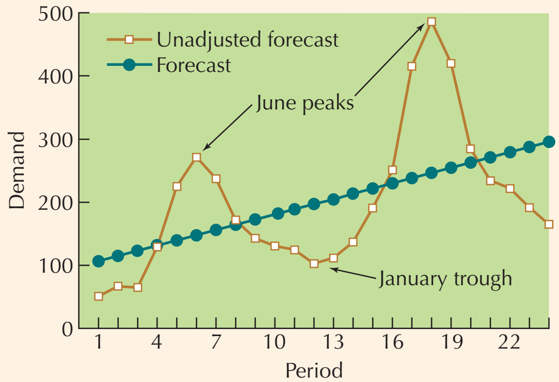


FIGURE 9.15 Plot of Unadjusted Regression Forecast against a Time Series with Seasonality

Notice that the forecast errors (actual demand – unadjusted regression forecast) are all over the place, ranging from –131 to 240.3. The magnitude of these forecast errors implies that the model is only marginally effective.

REGRESSION FORECAST MODEL

$$\text{Forecasted demand} = 98.71 + 8.22 \times \text{period}$$

MONTH	PERIOD	DEMAND	UNADJUSTED REGRESSION FORECAST	FORECAST ERROR
January 2019	1	51	106.9	−55.9
February	2	67	115.2	−48.2
March	3	65	123.4	−58.4
April	4	129	131.6	−2.6
May	5	225	139.8	85.2
June	6	272	148.0	124.0
July	7	238	156.3	81.8
August	8	172	164.5	7.5
September	9	143	172.7	−29.7
October	10	131	180.9	−49.9
November	11	125	189.1	−64.1
December	12	103	197.4	−94.4
January 2020	13	112	205.6	−93.6
February	14	137	213.8	−76.8
March	15	191	222.0	−31.0
April	16	250	230.2	19.8
May	17	416	238.5	177.6
June	18	487	246.7	240.3
July	19	421	254.9	166.1
August	20	285	263.1	21.9
September	21	235	271.3	−36.3
October	22	222	279.6	−57.6
November	23	192	287.8	−95.8
December	24	165	296.0	−131.0

In fact, when the unadjusted regression forecasts are plotted against the actual demand values, it becomes clear that the regression model has picked up on the trend in the data but not the seasonality (Figure 9.15). The result is large positive forecast errors in the summer months and large negative forecast errors in the winter months.

In step 2, $\dfrac{\text{Demand}}{\text{Forecast}}$ is calculated for each of the time periods. For the two January observations, the calculations are:

$$\text{January 2019: } \frac{\text{Demand}}{\text{Forecast}} = \frac{51}{106.9} = 0.477$$

$$\text{January 2020: } \frac{\text{Demand}}{\text{Forecast}} = \frac{112}{205.6} = 0.545$$

The results confirm what Figure 9.15 suggests: The unadjusted regression model tends to badly *over*forecast demand in January. In fact, actual January demands were only 48% and 55% of the forecasts for 2019 and 2020, respectively. The effect is just the opposite for June, where the regression model badly *under*forecasts.

In step 3, monthly seasonal indices are calculated by averaging the $\dfrac{\text{Demand}}{\text{Forecast}}$ values for corresponding months. Continuing with the January example:

$$\text{Monthly seasonal index, January} = (0.477 + 0.545)/2 = 0.511$$

Finally, the seasonally adjusted forecasts are calculated as follows:

$$\text{Seasonally adjusted forecast} = \text{unadjusted forecast} \times \text{seasonal index}$$

$$\text{January 2019: } 106.9 \times 0.511 = 54.63$$

$$\text{January 2020: } 205.6 \times 0.511 = 105.06$$

Regression forecast model:

Forecasted demand = 98.71 + 8.22 x period

The adjusted forecast is calculated by multiplying the unadjusted forecast by the seasonal index. For January 2019: 106.9 x 0.511 = 54.6.

Month	Period	Demand	Unadjusted Regression Forecast	Demand/ Forecast	Monthly Seasonal Index	Adjusted Regression Forecast	New Forecast Error
January 2019	1	51	106.9	0.477	0.511	54.6	–3.6
February	2	67	115.2	0.582	0.611	70.4	–3.4
March	3	65	123.4	0.527	0.694	85.6	–20.6
April	4	129	131.6	0.980	1.033	135.9	–6.9
May	5	225	139.8	1.609	1.677	234.5	–9.5
June	6	272	148.0	1.837	1.906	282.1	–10.1
July	7	238	156.3	1.523	1.587	248.0	–10.0
August	8	172	164.5	1.046	1.064	175.1	–3.1
September	9	143	172.7	0.828	0.847	146.3	–3.3
October	10	131	180.9	0.724	0.759	137.3	–6.3
November	11	125	189.1	0.661	0.664	125.6	–0.6
December	12	103	197.4	0.522	0.540	106.5	–3.5
January 2020	13	112	205.6	0.545	0.511	105.0	7.0
February	14	137	213.8	0.641	0.611	130.7	6.3
March	15	191	222.0	0.860	0.694	154.0	37.0
April	16	250	230.2	1.086	1.033	237.8	12.2
May	17	416	238.5	1.745	1.677	399.9	16.1
June	18	487	246.7	1.974	1.906	470.1	16.9
July	19	421	254.9	1.652	1.587	404.6	16.4
August	20	285	263.1	1.083	1.064	280.1	4.9
September	21	235	271.3	0.866	0.847	229.8	5.2
October	22	222	279.6	0.794	0.759	212.2	9.8
November	23	192	287.8	0.667	0.664	191.1	0.9
December	24	165	296.0	0.557	0.540	159.7	5.3

The percentages for January 2019 and 2020 are averaged to develop the monthly seasonal index for January. The procedure follows the same pattern for other months.

TABLE 9.9 Adjusted Regression Forecast for a Time Series with Seasonality

MyLab Operations Management
Animation

Table 9.9 shows the complete set of results for this problem. Note that the monthly seasonal indices in 2019 are repeated in 2020. In addition, notice how the new forecast errors (demand – adjusted regression forecast) are much smaller than before. In fact, if we plot actual demand against the adjusted forecast values, we can see how well the new forecast model fits the past data (Figure 9.16).

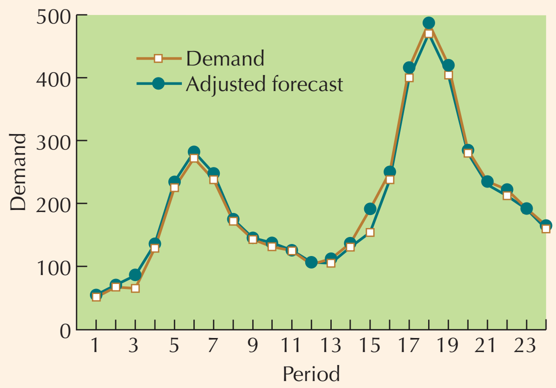


FIGURE 9.16 Plot of Seasonally Adjusted Regression Forecast against a Time Series Showing Seasonality

9.6 CAUSAL FORECASTING MODELS

Causal forecasting model
A class of quantitative forecasting models in which the forecast is modeled as a function of something other than time.

So far, the forecasting models we have dealt with treat the variable of interest as a function of time. In many cases, however, changes in the variable we want to forecast—demand, price, supply, etc.—are caused by something *other* than time. Under these conditions, **causal forecasting models** should be used. Consider the following examples:

VARIABLE	CAUSE OF CHANGE
Dollars spent on drought relief	Rainfall levels
Mortgage refinancing applications	Interest rates
Amount of food eaten at a party	Number and size of guests

Notice that in all three cases, what happened in the recent past is not necessarily a good predictor of what will happen in the future. If rainfall next year is unusually low, then dollars spent on drought relief will increase even if the past few years saw little money spent on drought relief. Similarly, a caterer would be unwise to bring only 10 pounds of barbecue to a party with 50 guests just because the same amount was plenty for yesterday's party of 17 people.

Linear Regression

Linear regression can be used to develop causal forecasting models as well as time series forecasting models. The only difference is that the independent variable, x, is no longer a time period but some other variable. Aside from that, the calculations are the same as before (Equations [9.7] through [9.9]).

EXAMPLE 9.5
SunRay Builders

Karamysh/Shutterstock

SunRay Builders is a large, multistate home builder serving the southwestern United States. Table 9.10 shows the quarterly home sales and corresponding mortgage rates for the past four years. The president of SunRay Builders has asked you to develop a forecasting model that predicts the number of home sales based on the mortgage rate. He would then like you to forecast quarterly home sales when mortgage rates are 6% and 8%.

TABLE 9.10 Quarterly Home Sales and Mortgage Rate Values

QUARTER	30-YEAR MORTGAGE RATE	HOME SALES
1	7.5%	750
2	7.0%	790
3	6.0%	860
4	6.5%	870
5	7.0%	840
6	7.0%	830
7	8.0%	710
8	8.5%	650
9	9.0%	600
10	8.5%	640
11	8.0%	680
12	8.0%	690
13	6.0%	880
14	7.0%	800
15	6.5%	850
16	7.5%	750

Before applying a forecasting technique, let's look at why a causal forecasting model is well suited here. Figure 9.17 shows the time series for home sales. Note that there appears to be no clear relationship between the time period and home sales. We could try fitting one of the time series models to these data, but the apparent randomness in the data would probably result in a weak model.

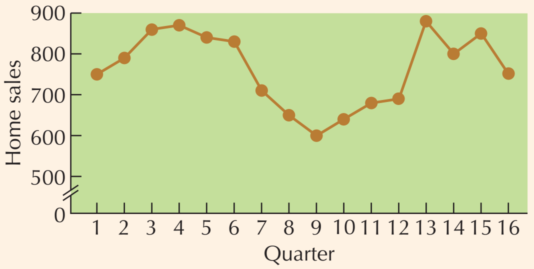


FIGURE 9.17 Plot Showing Weak Relationship between Home Sales and Quarter

Now look at Figure 9.18, which plots mortgage rates against home sales. (Note that this is *not* a time series because the data are *not* arranged in chronological order.) Figure 9.18 shows a strong *negative* relationship between mortgage rates and home sales. Mortgage rates therefore look like an ideal variable for predicting home sales.

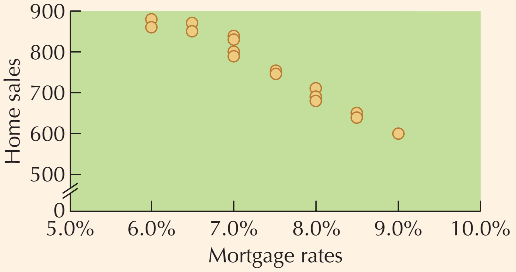


FIGURE 9.18 Plot Showing Strong Relationship between Home Sales and Mortgage Rates

To develop a regression forecasting model using mortgage rates as the independent variable, *x*, we follow the same procedures outlined earlier. Using Equations (9.8) and (9.9), we first set up columns to calculate the average x and y values, as well as the sums of the x, y, x^2, and xy values for the 16 pairs of observations:

	30-YEAR MORTGAGE RATE, x	HOME SALES, y	x^2	xy
	0.075	750	0.005625	56.25
	0.070	790	0.004900	55.3
	0.060	860	0.003600	51.6
	0.065	870	0.004225	56.55
	0.070	840	0.004900	58.8
	0.070	830	0.004900	58.1
	0.080	710	0.006400	56.8
	0.085	650	0.007225	55.25
	0.090	600	0.008100	54
	0.085	640	0.007225	54.4
	0.080	680	0.006400	54.4
	0.080	690	0.006400	55.2
	0.060	880	0.003600	52.8
	0.070	800	0.004900	56
	0.065	850	0.004225	55.25
	0.075	750	0.005625	56.25
Sum:	1.180	12,190	0.088250	886.95
Average:	0.0738	761.875		

Plugging these values into Equation (9.8) gives the estimate of the slope coefficient, $\hat{b}$:

$$\hat{b} = \frac{886.95 - \dfrac{1.18 * 12{,}190}{16}}{0.08825 - \dfrac{1.18^2}{16}} = -9{,}846.94$$

and, from Equation (9.9), the intercept term, $\hat{a}$

$$\hat{a} = \bar{y} - \hat{b}\bar{x} = 761.875 + 9{,}846.94 * .0738 = 1{,}488.58$$

The resulting regression model is:

$$\text{Forecasted home sales} = 1{,}488.58 - 9{,}846.94(\text{mortgage rate\%})$$

Using the regression model to forecast home sales at 6% and 8% gives us the following results:

Forecasted home sales at 6% mortage rate: $1{,}488.58 - 9{,}846(6\%) = 898$ home sales
Forecasted home sales at 8% mortage rate: $1{,}488.58 - 9{,}846(8\%) = 701$ home sales

The results make intuitive sense: As mortgage rates rise, homes become less affordable, and the number of home sales should go down.

Multiple Regression

Multiple regression
A generalized form of linear regression that allows for more than one independent variable.

In some cases, there may be more than one causal variable. The amount of barbecue eaten at a party may be a function of not only the number of guests but also the average size of the guests. (After all, 20 football players will probably eat more than 20 normal-sized people.) In such cases, we can use a generalized form of linear regression that allows for more than one independent variable, called **multiple regression.** The multiple regression forecast model is defined as follows:

$$\hat{y} = \hat{a} + \sum_{i=1}^{k} \hat{b}_i x_i \tag{9.10}$$

where:

$\hat{y}$ = forecast for *dependent* variable y
k = number of independent variables
x_i = ith *independent* variable, where $i = 1 \ldots k$
$\hat{a}$ = estimated intercept term for the line
$\hat{b}_i$ = estimated slope coefficient associated with variable x_i

The formulas for calculating $\hat{a}$ and $\hat{b}_i$ in a multiple regression setting are far too cumbersome to do by hand. Fortunately, many software packages, such as Excel's regression function, can easily handle multiple independent variables. Example 9.6 illustrates how Excel can be used to develop a multiple regression forecasting model.

EXAMPLE 9.6

Lance's BBQ Catering Service

Lance's BBQ Catering Service is a favorite of sports teams in the Raleigh, North Carolina, area. By counting and surreptitiously weighing each guest as he or she arrived at the party, Lance's BBQ Catering Service was able to capture the amount of barbecue eaten, the number of guests, and the average weight of each guest for 15 recent parties:

BARBECUE EATEN (LB.)	NUMBER OF GUESTS	AVERAGE WEIGHT (LB.)
46.00	50	150
40.00	20	175
60.00	30	250
45.00	25	200
44.00	40	150
42.50	15	200
58.50	25	250
43.00	30	175
43.50	15	200
36.00	10	150
49.00	80	250
63.00	70	200
39.00	20	175
46.00	60	150
65.00	40	250

Lance has a party coming up for members of the North Carolina State football team. He expects around 60 guests, with each having an average weight of around 240 pounds. Lance wants to use multiple regression to estimate how much barbecue these guests will eat, based on number of guests and average weight.

Figure 9.19 shows the Excel spreadsheet containing the historical demand data and independent variables, as well as the regression dialog box. In this example, the independent x variables are found in two columns, C and D ("\$C\$4:\$D\$19"), and we have chosen to print the regression results on this worksheet starting in cell A21.

The multiple regression results are shown in Figure 9.20. (We have scrolled down the spreadsheet to show the entire set of results.)

The R^2 value for the model is 0.63, indicating that the model explains 63% of the variance in the dependent variable. The model parameters are:

$$\begin{aligned} \text{Intercept term} &= 12.52 \\ \text{Slope coefficient for number of guests} &= 0.15 \\ \text{Slope coefficient for average weight} &= 0.15 \end{aligned}$$

Therefore, Lance's forecasting model would be:

$$\text{Barbecue eaten(lb.)} = 12.52 + 0.15(\text{no. of guests}) + 0.15(\text{average weight})$$

According to the multiple regression model, then, Lance would expect 60 guests with an average weight of 240 pounds to consume:

$$12.52 + 0.15(60) + 0.15(240) = 57.52 \text{ lb. of barbecue}$$

How much barbecue should Lance bring to the party? If you said *more* than 57.52 pounds, your intuition is correct because 57.52 pounds represents Lance's best estimate

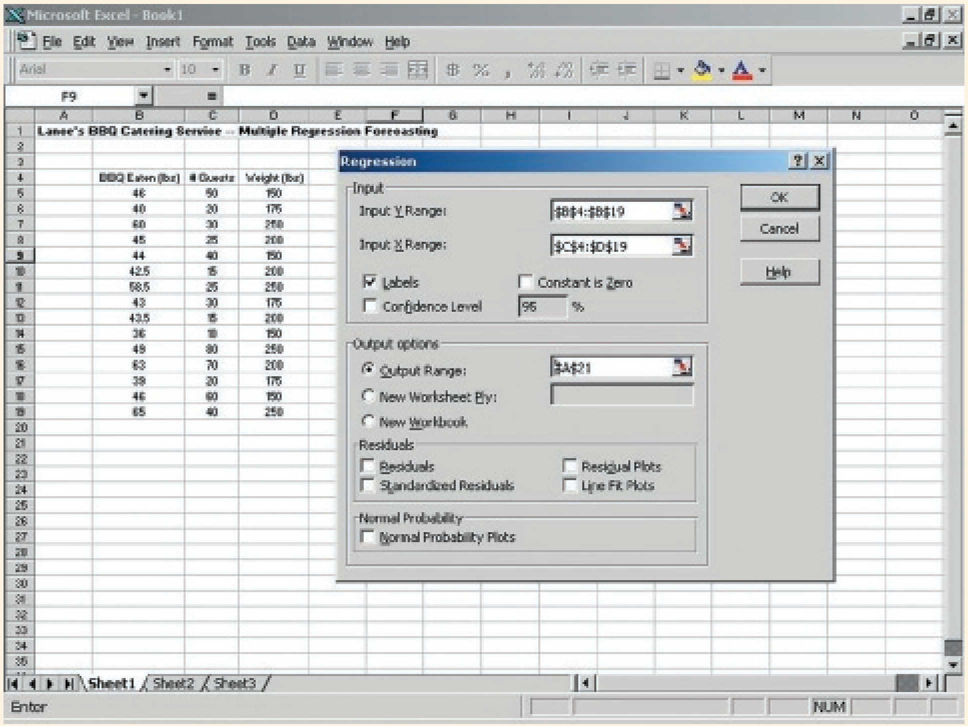


FIGURE 9.19 Multiple Regression Using Excel, Lance's BBQ Catering Service
Microsoft Excel, Microsoft Corporation

of what the guests will eat; the actual amount will probably be higher or lower. To ensure that he doesn't run out of barbecue (and anger an entire football team), Lance should plan on taking more than just 57.52 pounds.

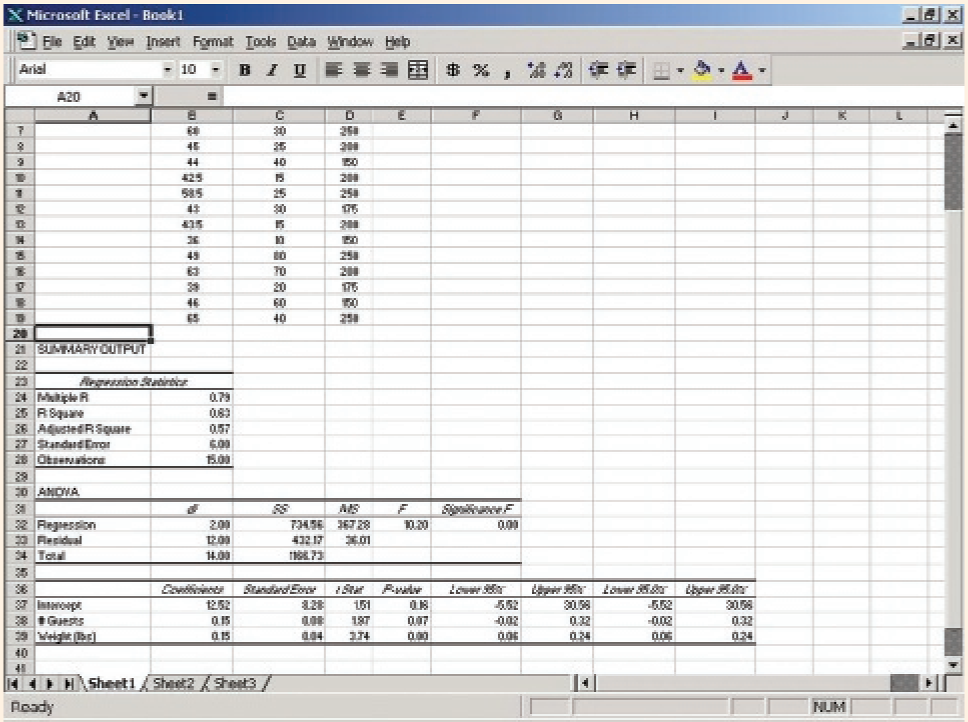


FIGURE 9.20 Multiple Regression Results for Lance's BBQ Catering Service
Microsoft Excel, Microsoft Corporation

9.7 MEASURES OF FORECAST ACCURACY

In this section, we introduce five simple measures of forecast accuracy. These measures are commonly used to assess how well an individual model is performing or to compare multiple forecast models to one another. The five measures are:

$$\text{Forecast error for period } i\ (FE_i) = D_i - F_i \tag{9.11}$$

$$\text{Mean forecast error } (MFE) = \frac{\sum_{i=1}^{n} FE_i}{n} \tag{9.12}$$

$$\text{Mean absolute deviation } (MAD) = \frac{\sum_{i=1}^{n} |FE_i|}{n} \tag{9.13}$$

$$\text{Mean absolute percentage error } (MAPE) = \frac{\sum_{i=1}^{n} 100\% \left|\frac{FE_i}{D_i}\right|}{n} \tag{9.14}$$

$$\text{Tracking signal} = \frac{\sum_{i=1}^{n} FE_i}{MAD} \tag{9.15}$$

where:

D_i = Demand for time period i

F_i = Forecast for time period i

$\sum_{i=1}^{n} FE_i$ = sum of the forecast errors for periods 1 through n

MFE measures the bias of a forecast model, or the propensity of a model to under- or overforecast. A completely unbiased model would have an *MFE* of 0. A model with a negative *MFE* suggests that, on average, the model overforecasts, while a positive *MFE* suggests that the model underforecasts.

By taking the average of the absolute value of the forecast errors, *MAD* tracks the average *size* of the errors, regardless of direction. From the perspective of *MAD*, overforecasting or underforecasting by some value—say, 10—has the same impact. *MAD* will always be ≥ 0, with the ideal model having a *MAD* value of 0. We need to know *MAD* as well as *MFE* because a model could have, *on average*, forecast errors of 0 but still make large errors in over- and underforecasting.

MAPE is similar to *MAD* in that it considers the absolute value of the forecast errors. By dividing the absolute forecast error in each period by the actual period demand, *MAPE* also gives us an indication of the *magnitude* of the errors.

Finally, the tracking signal is used to flag a forecasting model that is getting out of control. In general, as long as the tracking signal value remains between −4 and 4, the forecasting model is considered to be performing normally. If, however, the tracking signal falls outside this range, the computer program or person responsible for the forecast will typically try to identify a better-fitting model or at least bring the poor performance of the model to the users' attention.

EXAMPLE 9.7
Walk-In Advising at Wolf State University

Andi Irby, director of advising at Wolf State University, is trying to decide which of two forecasting models does a better job at predicting walk-in demand for student advising. Once she has selected a model, she would like to establish a tracking signal for it. Suppose Andi has demand and forecast information for the past 10 weeks, as shown in Table 9.11.

TABLE 9.11 Forecast Results for Walk-In Advising at Wolf State University

WEEK	ACTUAL WALK-IN DEMAND	FORECAST MODEL 1	FORECAST MODEL 2
1	**18**	20	21
2	**14**	18	21
3	**21**	19	21
4	**26**	21	25
5	**26**	23	25
6	**29**	24	25
7	**19**	25	19
8	**19**	22	19
9	**25**	23	19
10	**15**	24	19

For each model, Andi first calculates the forecast error for each week, as well as the absolute deviation of the forecast error (*AD*) and absolute percentage error (*APE*). Finally, she calculates the mean values for the relevant columns by summing up the values and dividing by the number of observations (10 weeks):

WEEK	ACTUAL WALK-IN DEMAND	FORECAST MODEL 1	FORECAST ERROR	ABSOLUTE DEVIATION	ABSOLUTE PERCENTAGE ERROR	FORECAST MODEL 2	FORECAST ERROR	ABSOLUTE DEVIATION	ABSOLUTE PERCENTAGE ERROR
1	**18**	20	−2	2	11.11%	21	−3	3	16.67%
2	**14**	18	−4	4	28.57%	21	−7	7	50.00%
3	**21**	19	2	2	9.52%	21	0	0	0.00%
4	**26**	21	5	5	19.23%	25	1	1	3.85%
5	**26**	23	3	3	11.54%	25	1	1	3.85%
6	**29**	24	5	5	17.24%	25	4	4	13.79%
7	**19**	25	−6	6	31.58%	19	0	0	0.00%
8	**19**	22	−3	3	15.79%	19	0	0	0.00%
9	**25**	23	2	2	8.00%	19	6	6	24.00%
10	**15**	24	−9	9	60.00%	19	−4	4	26.67%
		Mean values:	−0.70	4.10	21.26%		−0.20	2.60	13.88%

Because model 2 has the *MFE* value closest to 0, it appears to be the least biased. On average, model 2 overforecasted by 0.20 walk-ins, while model 1 overforecasted by 0.70. In addition, model 2 has the lowest *MAD* and *MAPE* values. Based on these results, model 2 appears to be the superior forecasting model.

Finally, for model 2, Andi develops a tracking signal for the first 10 weeks. For each week, she takes the most recent sum of forecast errors and divides it by the most recent estimate of MAD. The most recent sum of forecast errors is often called the *running sum* *of forecast errors* to emphasize the fact that it is updated each period. The results are as follows:

WEEK	ACTUAL WALK-IN DEMAND	FORECAST MODEL 2	FORECAST ERROR	ABSOLUTE DEVIATION	RUNNING SUM OF FORECAST ERRORS	*MAD*	TRACKING SIGNAL
1	**18**	21	−3	3	−3	3.00	−1.00
2	**14**	21	−7	7	−10	5.00	−2.00
3	**21**	21	0	0	−10	3.33	−3.00
				1			
4	**26**	25	1		−9	2.75	−3.27
5	**26**	25	1	1	−8	2.40	−3.33
6	**29**	25	4	4	−4	2.67	−1.50
7	**19**	19	0	0	−4	2.29	−1.75
8	**19**	19	0	0	−4	2.00	−2.00
9	**25**	19	6	6	2	2.44	0.82
10	**15**	19	−4	4	−2	2.60	0.77

Although the tracking signal for model 2 gets dangerously close to −4.0 in week 5, the model has since recovered, with a tracking signal after week 10 of −0.77. For future weeks, Andi will continue to update the tracking signal, making sure it doesn't get too high or low.

9.8 COMPUTER-BASED FORECASTING PACKAGES

While the logic behind the various quantitative forecasting models is straightforward, the amount of data that needs to be tracked, as well as the number of calculations, can grow quickly for realistic business situations. Imagine a large retailer that needs to forecast next month's demand for hundreds of thousands of different items, and you can see why developing forecasts by hand is not practical.

Companies use computer-based forecasting packages to develop, evaluate, and even change forecasting models as needed. With enough demand history (i.e., time series data), a computer-based forecasting package could quickly evaluate alternative forecasting methods for each item and select the model that best fits the past data. Furthermore, such packages can use *MFE*, *MAD*, *MAPE*, or tracking signal criteria to flag a poor forecasting model and *automatically* kick off a search for a better one. Many companies also use forecasting packages to develop *multiple* forecasts for a single item. These multiple forecasts can then be compared to one another or even combined to come up with a single forecast.

9.9 COLLABORATIVE PLANNING, FORECASTING, AND REPLENISHMENT (CPFR)

Throughout this book, we have made a point of highlighting ways in which practitioners implement the various concepts and tools. For example, in Chapter 4 we discussed the Six Sigma processes for improving existing processes. In Chapter 4, we also described the Supply Chain Operations Reference (SCOR) model, which outlines the core management processes and individual process types that, together, define the domain of supply chain management. In Chapter 14 , we point to the *Project Management Body of Knowledge* (PMBOK Guide). This guide, published by the Project Management Institute, serves as a basic reference source for project management.

Collaborative planning, forecasting, and replenishment (CPFR)
A set of business processes, backed up by information technology, in which supply chain partners agree to *mutual* business objectives and measures, develop *joint* sales and operational plans, and *collaborate* to generate and update sales forecasts and replenishment plans.

We have incorporated these discussions to emphasize a point: Operations and supply chain management is a *practice*, and companies really do use the concepts and tools presented here. It is in this spirit that we introduce **collaborative planning, forecasting, and replenishment (CPFR).** CPFR is a set of business processes, backed up by information technology, in which supply chain partners agree to *mutual* business objectives and measures, develop *joint* sales and operational plans, and *collaborate* to generate and update sales forecasts and replenishment plans. What distinguishes CPFR from traditional planning and forecasting approaches is the emphasis on *collaboration*. Experience shows that supply chains are better at meeting demand and managing resources when the partners synchronize their plans and actions. The increased communication among partners means that when demand, promotions, or policies change, managers can adjust jointly managed forecasts and plans immediately, minimizing or even eliminating costly after-the-fact corrections. The *Supply Chain Connections* feature highlights how one division at Black & Decker used both organizational and information technology solutions to implement CPFR.

SUPPLY CHAIN CONNECTIONS

BLACK & DECKER HHI PUTS CPFR INTO ACTION

When your biggest customer comes calling with a new requirement, you must race to comply no matter your size or situation in order to maintain the much-coveted collaborative retail relationship. To better support its existing alliances with two superstore retailers—Home Depot and Lowe's—supply chain leaders at Black & Decker Hardware and Home Improvement (HHI) sought one synchronized view of demand throughout its supply chain. Upon project completion, a reformed collaborative planning, forecasting, and replenishment (CPFR) strategy backed by enabling technologies and an aligned business/information systems (IS) team allowed the manufacturer to realize benefits beyond improved collaboration at retail.

A Fixer Upper

Black & Decker HHI is one of three divisions under Black & Decker, the global manufacturer and marketer of quality power tools and accessories, hardware and home improvement products as well as technology-based fastening systems. Black & Decker HHI manufactures and markets architecturally inspired building products for the residential and commercial markets. With manufacturing and distribution facilities in the United States, Canada, Mexico, and Asia, Black & Decker HHI faced the challenge of managing both offshore and domestic supply chains where various products with complex product structures were produced. The complexities were compounded by the demands imparted by Black & Decker HHI's distribution model: "Two of our superstore retailers have high fill rate expectations—greater than 98 percent—and on-time delivery requirements. At the same time, homebuilders require made-to-order configured products within 14 days," explained Scott Strickland, vice president of information systems, Black & Decker HHI. "Both of these customer group requirements must be balanced against internal inventory investments."

With a large amount of its sales tied to big-box corporations, Black & Decker HHI had dedicated demand forecasting teams in place working exclusively with personnel employed by Home Depot and Lowe's. These planners actually worked in the same cities where their clients were headquartered to enable close cooperation in efforts to maintain supply levels on par with consumer demand. However, with no central planning software in use, CPFR was a labor-intensive process; planners juggled massive amounts of product data downloaded in spreadsheets from retailers and eyeballed historical sales, projecting demand based on judgment analysis of trending and seasonality. Further compounding matters was a third set of planners who managed demand for the thousands of other distributors, retailers, and builders making up the remainder of sales. "In addition, the previous process and solution prevented us from analyzing the impact of a significant demand change in our manufacturing and distribution plan," said Strickland. As a result, the company was experiencing manufacturing overtime, expedited shipments, and flat inventory levels.

Solution Toolkit

In order to obtain full visibility of its supply chain, Black & Decker HHI developed essentially three software implementations, each customized to meet the requirements of the various planning groups yet all with a unified business purpose. Leveraging the process, system, and change management expertise from Plan4Demand, Black & Decker HHI embarked on a three-phased approach that targeted its worst pain point first: supply chain planning.

After holding a functionality and software review, the company chose to implement JDA Demand from JDA Software Group, starting with its manufacturing facilities in Mexico in 2006. The technology was rolled out to its Asian and U.S. facilities shortly thereafter.

The solution was configured to incorporate point-of-sale (POS) data from Home Depot and Lowe's, allowing one single process for its frequent line reviews, product promotions, and introductions as well as frequent price changes. The solution also helps determine the appropriate product mix and gauges the effectiveness of various promotions.

"We can compare forecasts, shipment history as well as POS and order history for any of our SKUs at any given time," said Strickland. "At the end of 2007, this resulted in a 10.4 percent improvement in forecast accuracy."

Next, Black & Decker HHI turned its attention to improving the demand signal by addressing the forecasting process. Implementing JDA Master Planning at the plant level helped to establish operational efficiency, create supply flexibility, and achieve fill rate commitments to customers.

Soon after, JDA Fulfillment was added into the technology mix to completely synchronize supply and demand. This tool leverages forecast and end-consumer demand signals to create an optimized, multi-level replenishment plan down to the store level.

Unlocking the Benefits

With full visibility into its supply chain operations, Black & Decker HHI had built truly collaborative relationships with its retail customers. But the benefits extended inside the organization as well. With process improvements, including transformed sales and operations planning as well as the realignment of the supply chain organization along category lines, Black & Decker HHI realized the following:

- 60 percent reduction in forecast creation cycle time
- 50 percent reduction in supply plan creation time
- 80 percent reduction in monthly production cycles

Source: A. Ackerman and A. Padilla, "Black and Decker HHI Puts CPFR into Action," *Consumer Goods Technology*, October 20, 2009, **https://consumergoods.com/black-decker-hhi-puts-cpfr-action.**

EXAMPLE 9.8

Cheeznax Snack Foods Revisited

We end this chapter by returning to Jamie Favre, the demand manager for Cheeznax Snack Foods. Cheeznax and its primary customer, Gas N' Grub, are interested in coordinating their supply chain activities so that Gas N' Grub stores can be stocked with fresh products at the lowest possible cost to both companies. With this in mind, the two supply chain partners enter into a CPFR arrangement. As part of the arrangement, Gas N' Grub agrees to share with Cheeznax its 2020 plans for promotions and new store openings:

1. Gas N' Grub plans to open 10 new convenience stores each month, starting in *June and ending in September*. This means that by the end of September, Gas N' Grub will have 140 stores.
2. Gas N' Grub will also launch an advertising campaign that is expected to raise sales in all stores by 5%. This advertising campaign will run from *July through September*, at which time store sales are expected to settle back down to previous levels.

Jamie now feels she is ready to start developing the monthly sales forecasts for 2020. As a first step, Jamie plots the 2019 sales data to see if there are discernable patterns. The results are shown in Figure 9.21.

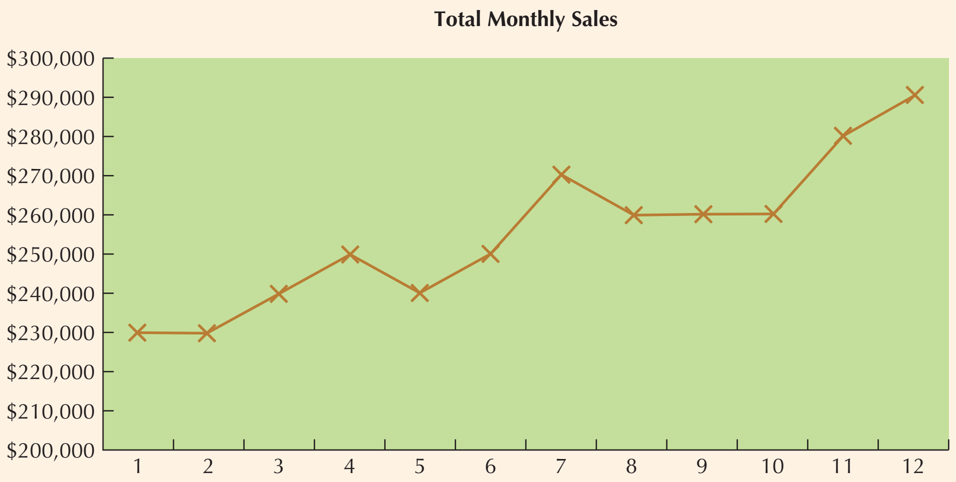


FIGURE 9.21 2019 Sales Data for Cheeznax Snack Foods

Jamie notes that sales appear to show a slight upward trend over the year. Based on this information, Jamie uses Equations (9.8) and (9.9) to fit a regression model to the 2019 data. She chooses monthly total sales as her dependent variable, y, and month (January = 1, February = 2, etc.) as her independent variable, x. She then calculates the values she needs to plug into the formulas:

	MONTH (x)	SALES (y)	x^2	xy
	1	230,000	1	230,000
	2	230,000	4	460,000
	3	240,000	9	720,000
	4	250,000	16	1,000,000
	5	240,000	25	1,200,000
	6	250,000	36	1,500,000
	7	270,000	49	1,890,000
	8	260,000	64	2,080,000
	9	260,000	81	2,340,000
	10	260,000	100	2,600,000
	11	280,000	121	3,080,000
	12	290,000	144	3,480,000
Sum:	78	3,060,000	650	20,580,000
Average:	6.5	255,000		

Next, Jamie uses these values to calculate the slope coefficient, $\hat{b}$:

$$\hat{b} = \frac{\sum_{i=1}^{n} x_i y_i - \frac{\left[\sum_{i=1}^{n} x_i\right]\left[\sum_{i=1}^{n} y_i\right]}{n}}{\sum_{i=1}^{n} x_i^2 - \frac{\left[\sum_{i=1}^{n} x_i\right]^2}{n}} = \frac{\$20{,}580{,}000 - \frac{78 \times \$3{,}060{,}000}{12}}{650 - \frac{78^2}{12}}$$

$$= \$4{,}825.17$$

And then the intercept term, $\hat{a}$:

$$\hat{a} = \bar{y} - \hat{b}\bar{x} = \$255{,}000 - \$4{,}825.17 \times 6.5 = \$223{,}636.36$$

These calculations result in the following regression forecasting model:

$$\text{Forecasted total monthly sales} = \$223{,}636.36 + \$4{,}825.17 \times \text{period}$$

Jamie compares her model against actual 2019 demand. The results, including *MFE* and *MAPE*, are shown in Table 9.12. While the results seem promising, Jamie still remains cautious: She realizes that fitting a model to past data is *not* the same as forecasting future demand.

But Jamie is not finished. She still needs to do a 2020 forecast that takes into account the 10 stores being added each month from June through September, as well as the advertising campaign that is expected to increase demand by 5% from July through September.

TABLE 9.12 Comparison of Regression Forecast Model to Historical Demand

Forecasted Total Monthly Sales = \$223,636.40 + \$4,825.17 × Period

MONTH	PERIOD	TOTAL SALES	REGRESSION FORECAST	FORECAST ERROR (*FE*)	ABSOLUTE DEVIATION (*AD*)	ABSOLUTE PERCENTAGE ERROR (*APE*)
January	1	\$230,000	\$228,462	\$1,538	\$1,538	0.67%
February	2	\$230,000	\$233,287	−\$3,287	\$3,287	1.43%
March	3	\$240,000	\$238,112	\$1,888	\$1,888	0.79%
April	4	\$250,000	\$242,937	\$7,063	\$7,063	2.83%
May	5	\$240,000	\$247,762	−\$7,762	\$7,762	3.23%
June	6	\$250,000	\$252,587	−\$2,587	\$2,587	1.03%
July	7	\$270,000	\$257,413	\$12,587	\$12,587	4.66%
August	8	\$260,000	\$262,238	−\$2,238	\$2,238	0.86%
September	9	\$260,000	\$267,063	−\$7,063	\$7,063	2.72%
October	10	\$260,000	\$271,888	\$11,888	\$11,888	4.57%
November	11	\$280,000	\$276,713	\$3,287	\$3,287	1.17%
December	12	\$290,000	\$281,538	\$8,462	\$8,462	2.92%
				MFE = \$0	*MAD* = \$5,804	
						MAPE = 2.24%

Jamie uses a three-step approach to develop her 2020 forecast. These steps are outlined in Figure 9.22. First, Jamie uses the regression forecast model to develop an initial forecast for January through December 2020 (periods 13–24). Next, Jamie reasons that each new store should generate sales at a level similar to the existing stores. Therefore, if there are 100 stores to start with, adding 10 more stores in June will increase sales by 110/100 = 110% over what the sales would have been otherwise. By the end of the year, there will be 40% more stores than at the beginning of the year. Jamie uses this logic to develop lift factors to account for the new stores. These percentages are shown in the "Increase in Stores" column of Figure 9.22. Similarly, Jamie uses lift factors to reflect the impact of the July–September advertising campaign.

		1	2		3
Month	Period	Forecast, Total Monthly Sale	Increase in Stores (Base = 100%)	Advertising Campaign Lift (Base = 100%)	Adjusted Forecast, Total Monthly Sale
January	13	\$286,364	100%	100%	\$286,364
February	14	\$291,189	100%	100%	\$291,189
March	15	\$296,014	100%	100%	\$296,014
April	16	\$300,839	100%	100%	\$300,839
May	17	\$305,664	100%	100%	\$305,664
June	18	\$310,489	110%	100%	\$341,538
July	19	\$315,315	120%	105%	\$397,297
August	20	\$320,140	130%	105%	\$436,991
September	21	\$324,965	140%	105%	\$477,699
October	22	\$329,790	140%	100%	\$461,706
November	23	\$334,615	140%	100%	\$468,461
December	24	\$339,440	140%	100%	\$475,216
					\$4,538,978

FIGURE 9.22 Adjusting Cheeznax Forecast to Take into Account Gas N' Grub's Store Openings and Advertising Campaign

In the third and final step, Jamie multiplies the initial monthly forecast by *both* the store and the advertising lift factors to get a final, adjusted forecast. To illustrate, the adjusted forecast for June 2020 is now:

$$(\$310{,}489) \times (110\%) \times (100\%) = \$341{,}538$$

Figure 9.23 plots the adjusted monthly forecasts for 2020. The dashed line shows what the forecasts would be if Jamie did *not* adjust for the store openings and advertising campaign. The impact of the store openings, as well as the advertising campaign, can clearly be seen. Looking at the graph, Jamie realizes that developing this forecast required not just the proper application of quantitative tools but also the sharing of critical information between Cheeznax and its major customer, Gas N' Grub.

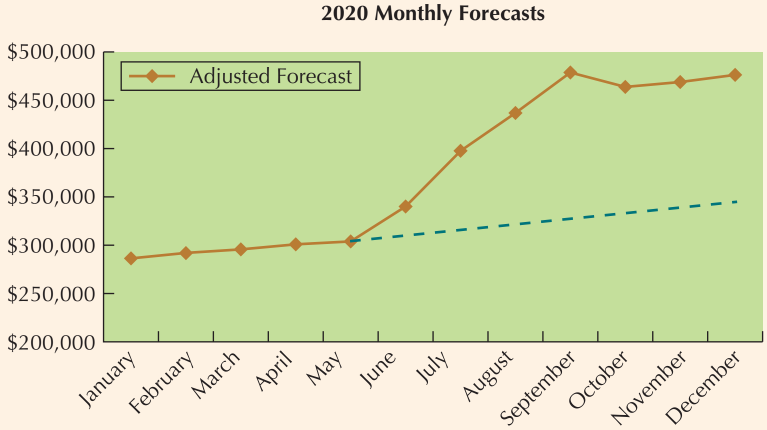


FIGURE 9.23 **Cheeznax Adjusted Monthly Sales Forecasts for 2020**

CHAPTER SUMMARY

Forecasting is a critical business process for nearly every organization. Whether the organization is forecasting demand, supply, prices, or some other variable, forecasting is often the first step an organization must take in planning future business activities. In this chapter, we described the different types of forecasts companies use and the four laws of forecasting. We also talked about when to use qualitative and quantitative forecasting techniques and explained several approaches to developing time series and causal forecasting models.

Of course, forecasting is not just about the "numbers." As the discussion and CPFR examples illustrate, organizations can collaborate with one another to improve the accuracy of their forecasting efforts or even reduce the need for forecasts.

KEY FORMULAS

Last period forecasting model (page 261):

$$F_{t+1} = D_t \tag{9.1}$$

where:

F_{t+1} = forecast for the next period, $t + 1$
D_t = demand for the current period, t

Moving average forecasting model (page 262):

$$F_{t+1} = \frac{\sum_{i=1}^{n} D_{t+1-i}}{n} \tag{9.2}$$

where:

F_{t+1} = forecast for time period $t + 1$
D_{t+1-i} = actual demand for period $t + 1 - i$
n = number of most recent demand observations used to develop the forecast

Weighted moving average forecasting model (page 264):

$$F_{t+1} = \sum_{i=1}^{n} W_{t+1-i} D_{t+1-i} \tag{9.3}$$

where:

W_{t+1-i} = weight assigned to the demand in period $t + 1 - i$

$\sum_{i=1}^{n} W_{t+1-i} = 1$

Exponential smoothing forecasting model (page 264):

$$F_{t+1} = \alpha D_t + (1 - \alpha) F_t \tag{9.4}$$

where:

F_{t+1} = forecast for time period $t + 1$ (i.e., the *new* forecast)
F_t = forecast for time period t (i.e., the *current* forecast)
D_t = actual value for time period t
α = smoothing constant used to weight D_t and $F_t (0 \leq \alpha \leq 1)$

Adjusted exponential smoothing forecasting model (page 268):

$$AF_{t+1} = F_{t+1} + T_{t+1} \tag{9.5}$$

where:

AF_{t+1} = adjusted forecast for the next period
F_{t+1} = unadjusted forecast for the next period $= \alpha D_t + (1 - \alpha)F_t$
T_{t+1} = trend factor for the next period $= \beta(F_{t+1} - F_t) + (1 - \beta)T_t$
T_t = trend factor for the current period
β = smoothing constant for the trend adjustment factor **(9.6)**

Linear regression forecasting model (page 269):

$$\hat{y} = \hat{a} + \hat{b}x \tag{9.7}$$

where:

$\hat{y}$ = forecast for *dependent* variable y
x = *independent* variable x, used to forecast y
$\hat{a}$ = estimated intercept term for the line
$\hat{b}$ = estimated slope coefficient for the line

Slope coefficient $\hat{b}$ and intercept coefficient $\hat{a}$ for linear regression model (page 269):

$$\hat{b} = \frac{\sum_{i=1}^{n} x_i y_i - \dfrac{\left[\sum_{i=1}^{n} x_i\right]\left[\sum_{i=1}^{n} y_i\right]}{n}}{\sum_{i=1}^{n} x_i^2 - \dfrac{\left[\sum_{i=1}^{n} x_i\right]^2}{n}} \tag{9.8}$$

and:

$$\hat{a} = \bar{y} - \hat{b}\bar{x} \tag{9.9}$$

where:

(x_i, y_i) = matched pairs of observed (x, y) values
$\bar{y}$ = average y value
$\bar{x}$ = average x value
n = number of paired observations

Multiple regression forecasting model (page 278):

$$\hat{y} = \hat{a} + \sum_{i=1}^{k} \hat{b}_i x_i \tag{9.10}$$

where:

$\hat{y}$ = forecast for *dependent* variable y
k = number of independent variables
x_i = the ith *independent* variable, where $i = 1 \ldots k$
$\hat{a}$ = estimated intercept term for the line
$\hat{b}_i$ = estimated slope coefficient associated with variable x_i

Measures of forecast accuracy (page 281):

$$\text{Forecast error for period } i\ (FE_i) = D_i - F_i \tag{9.11}$$

$$\text{Mean forecast error } (MFE) = \frac{\sum_{i=1}^{n} FE_i}{n} \tag{9.12}$$

$$\text{Mean absolute deviation } (MAD) = \frac{\sum_{i=1}^{n} |FE_i|}{n} \tag{9.13}$$

$$\text{Mean absolute percentage error } (MAPE) = \frac{\sum_{i=1}^{n} 100\% \left|\frac{FE_i}{D_i}\right|}{n} \tag{9.14}$$

$$\text{Tracking signal} = \frac{\sum_{i=1}^{n} FE_i}{MAD} \tag{9.15}$$

where:

D_i = Demand for time period i
F_i = Forecast for time period i
$\sum_{i=1}^{n} FE_i$ = sum of the forecast errors for periods 1 through n

KEY TERMS

Adjusted exponential smoothing model 268
Build-up forecast 260
Causal forecasting model 276
Collaborative planning, forecasting, and replenishment (CPFR) 284
Delphi method 259
Exponential smoothing model 264
Forecast 255
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Weighted moving average model 264

SOLVED PROBLEM

PROBLEM

Chris Boote Industries

Chris Boote Industries makes rebuild kits for old carbureted snowmobiles. (Newer snowmobiles have fuel-injected engines.) The demand values for the kits over the past two years are as follows:

	PERIOD	DEMAND
January 2017	1	3,420
February	2	3,660
March	3	1,880
April	4	1,540
May	5	1,060

(Continued)

	PERIOD	DEMAND
June	6	900
July	7	660
August	8	680
September	9	1,250
October	10	1,600
November	11	1,920
December	12	2,400
January 2018	13	2,500
February	14	2,540
March	15	1,300
April	16	1,060
May	17	740
June	18	620
July	19	460
August	20	480
September	21	880
October	22	1,100
November	23	1,340
December	24	1,660

Chris would like to develop a model to forecast demand for the upcoming year.

Solution

As a first attempt, Chris develops a three-period moving average model to forecast periods 19 through 24 and evaluates the results by using *MAD*, *MFE*, and *MAPE*. The three-period moving average forecast for period 19 is calculated as follows:

$$F_{19} = (620 + 740 + 1060)/3 = 806.67 \text{ rebuild kits}$$

The rest of the forecasts are calculated in a similar manner. The results are shown in the following table:

	PERIOD	DEMAND	FORECAST	FORECAST ERROR	ABSOLUTE DEVIATION	ABSOLUTE PERCENTAGE ERROR
April	16	1,060				
May	17	740				
June	18	620				
July	19	460	806.67	−346.67	346.67	75.4%
August	20	480	606.67	−126.67	126.67	26.4%
September	21	880	520	360	360	40.9%
October	22	1,100	606.67	493.33	493.33	44.8%
November	23	1,340	820	520	520	38.8%
December	24	1,660	1,106.67	553.33	553.33	33.3%
Mean forecast error (*MFE*) = 242.22						
Mean absolute deviation (*MAD*) = 400.00						
Mean absolute percentage error (*MAPE*) = 43.3%						

Because of the relatively large *MFE*, *MAD*, and *MAPE* values, Chris decides to try another model: a regression model with seasonal adjustments. To keep it simple, Chris wants to develop seasonal indices for the months of January and June and to forecast demand for January and June 2019.

First, Chris sets up the table to calculate the values that go into Equations (9.8) and (9.9):

	PERIOD DEMAND			
	x	*y*	x^2	*x*y*
January 2017	1	3,420	1	3,420
February	2	3,660	4	7,320
March	3	1,880	9	5,640
April	4	1,540	16	6,160
May	5	1,060	25	5,300
June	6	900	36	5,400
July	7	660	49	4,620
August	8	680	64	5,440
September	9	1,260	81	11,340
October	10	1,600	100	16,000
November	11	1,920	121	21,120
December	12	2,400	144	28,800
January 2018	13	2,500	169	32,500
February	14	2,540	196	35,560
March	15	1,300	225	19,500
April	16	1,060	256	16,960
May	17	740	289	12,580
June	18	620	324	11,160
July	19	460	361	8,740
August	20	480	400	9,600
September	21	880	441	18,480
October	22	1,100	484	24,200
November	23	1,340	529	30,820
December	24	1,660	576	39,840
Sum:	300	35,660	4,900	380,500
Average:	12.50	1,485.83		

By plugging these terms into Equations (9.8) and (9.9), Chris gets:

$$\frac{380{,}500 - \dfrac{300 \times 35{,}660}{24}}{4{,}900 - \dfrac{300^2}{24}} = -56.74$$

$$\hat{a} = \bar{y} - \hat{b}\bar{x} = 1{,}485.83 + 56.74 \times 12.50 = 2{,}195.07$$

And Chris gets the resulting forecast model:

$$\text{Demand} = 2{,}195.07 - 56.74(\text{period})$$

Note that the negative slope coefficient suggests that there is a downward trend in demand. To calculate seasonal indices for January and June, Chris needs to generate the *unadjusted* forecasts for the past two years:

January 2017: $2{,}195.07 - 56.74(1) = 2{,}128.33$
January 2018: $2{,}195.07 - 56.74(13) = 1{,}457.46$

June 2017: $2{,}195.07 - 56.74(6) = 1{,}854.64$
June 2018: $2{,}195.07 - 56.74(18) = 1{,}173.77$

He then needs to calculate $\frac{\text{Demand}}{\text{Forecast}}$ values, using the unadjusted forecasts:

MONTH	PERIOD	DEMAND	UNADJUSTED FORECAST	DEMAND/ FORECAST
January 2017	1	3,420	2,138.33	1.60
June 2017	6	900	1,854.64	0.49
January 2018	13	2,500	1,457.46	1.72
June 2017	18	620	1,173.77	0.53

Next, Chris calculates the seasonal index for January by taking the average of the $\frac{\text{Demand}}{\text{Forecast}}$ ratio for 2017 and 2018:

$$(1.60 + 1.72)/2 = 1.66$$

He follows the same logic for June:

$$(0.49 + 0.53)/2 = 0.51$$

Finally, Chris can calculate the adjusted regression forecasts for January 2019 (period 25) and June 2019 (period 30):

January 2019: $[2{,}195.07 - 56.74(25)] * 1.66 = 1{,}289$ rebuild kits
June 2019: $[2{,}195.07 - 56.74(30)] * 0.51 = 251$ rebuild kits

An interesting thing to note is that eventually the forecast model will result in negative forecasts as the period count grows higher. In reality, demand will probably level off at some low level.

DISCUSSION QUESTIONS

1. Which forecasting techniques do you think should be used in calculating fuel prices? Time series models? Causal models? Qualitative models? In causal modeling, what types of independent variables might be used? Justify your answer.
2. Are time series forecast techniques such as moving average and exponential smoothing models well suited to developing forecasts for multiple periods into the future? Why or why not?
3. What are the advantages of having computer-based forecasting packages handle the forecasting effort for a business? What are the pitfalls?
4. Explain the differences in using linear regression to develop a time series forecasting model and a causal forecasting model.
5. If forecasting is so important, why do firms look to approaches such as CPFR as a way to reduce the need for forecasting?

PROBLEMS

Additional homework problems are available at www.pearsonhighered.com/bozarth. These problems use Excel to generate customized problems for different class sections or even different students.

(* = easy; ** = moderate; *** = advanced)

Problems for Section 9.5: Time Series Forecasting Models—Basic Problems

For problems 1 through 3, use the following time series data:

PERIOD	DEMAND
10	248
11	370
12	424
13	286
14	444

1. (*) Develop a three-period moving average forecast for *periods 13–15*.
2. (*) Develop a two-period weighted moving average forecast for *periods 12 through 15*. Use weights of 0.7 and 0.3, with the most recent observation weighted higher.
3. (*) Develop an exponential smoothing forecast ($\alpha = 0.25$) for *periods 11 through 15*. Assume that your forecast for period 10 was 252.

For problems 4 through 6, use the following time series data:

MONTH	DEMAND
January 2019	119
February	72
March	113
April	82
May	82
June	131
July	111
August	116
September	89
October	95
November	88
December	90

4. (**) Develop a three-period moving average forecast for *April 2019 through January 2020*. Calculate the *MFE, MAD*, and *MAPE* values for *April through December 2019*.

5. (**) Develop a two-period weighted moving average forecast for *March 2019 through January 2020*. Use weights of 0.6 and 0.4, with the most recent observation weighted higher. Calculate the *MFE, MAD*, and *MAPE* values for *March through December*.

6. (**) Develop an exponential smoothing forecast ($\alpha = 0.3$) for *February 2019 through January 2020*. Assume that your forecast for January 2019 was 100. Calculate the *MFE, MAD*, and *MAPE* values for *February through December 2020*.

For problems 7 through 9, use the following time series data:

PERIOD	DEMAND
1	221
2	247
3	228
4	233
5	240
6	152
7	163
8	155
9	167
10	158

7. (*) Develop a last period forecast for *periods 2 through 11*. Calculate the *MFE, MAD*, and *MAPE* values for *periods 2 through 10*. Is this a good model? Why?

8. (**) Develop a three-period weighted moving average forecast for *periods 4 through 11*. Use weights of 0.4, 0.35, and 0.3, with the most recent observation weighted the highest. Calculate the *MFE, MAD*, and *MAPE* values for *periods 4 through 10*. How do your results compare with those for problem 7?

9. (**) Develop *two* exponential smoothing forecasts for *periods 2 through 11*. For the first forecast, use $\alpha = 0.2$. For the second, use $\alpha = 0.7$. Assume that your forecast for period 1 was 250. Plot the results. Which model appears to work better? Why?

10. After graduating from college, you and your friends start selling birdhouses made from recycled plastic. The idea has caught on, as shown by the following sales figures:

MONTH	DEMAND
March	220
April	2,240
May	1,790
June	4,270
July	3,530
August	4,990

a. (*) Prepare forecasts for *June through September* by using a three-period moving average model.

b. (**) Prepare forecasts for *June through September* by using an exponential smoothing model with $\alpha = 0.5$. Assume that the forecast for May was 2,000.

c. (**) Prepare forecasts for *June through September* by using an adjusted exponential smoothing model with $\alpha = 0.5$ and $\beta = 0.3$. Assume that the unadjusted forecast (F_t) for May was 2,000 and the trend factor (T_t) for May was 700.

11. (***) Consider the time series data shown in Table 9.1. Use an adjusted exponential smoothing model to develop a forecast for the 12 months of 2019. (Assume that the unadjusted forecast and trend factor for January are 220,000 and 10,000, respectively.) How do your results compare to the regression model results shown in Table 9.12?

Cooper Toys sells a portable baby stroller called the Tot n' Trot. The past two years of demand for Tot n' Trots are shown in the following table. Use this information for problems 12 and 13.

	PERIOD	DEMAND
January 2018	1	1,200
February	2	1,400
March	3	1,450
April	4	1,580
May	5	1,796
June	6	2,102
July	7	2,152
August	8	2,022
September	9	1,888
October	10	1,938
November	11	1,988
December	12	1,839
January 2019	13	1,684
February	14	1,944
March	15	1,994
April	16	2,154
May	17	2,430
June	18	2,827
July	19	2,877
August	20	2,687
September	21	2,492
October	22	2,542
November	23	2,592
December	24	2,382

12. (***) (*Microsoft Excel problem*) Prepare forecasts for *February 2018 through 2020* for Cooper Toys, using an adjusted exponential smoothing model with $\alpha = 0.25$ and $\beta = 0.4$. Assume that the initial unadjusted forecast (F_1) for January 2018 was 1,100 and the trend factor (T_1) was 60.

13. (***) (*Microsoft Excel problem*) Using regression analysis, develop a forecasting model with monthly seasonal indices for Cooper Toys. Forecast demand for each of the months in the six-month period covering *January through June 2020*.

14. (***) (*Microsoft Excel problem*) The following figure shows an Excel spreadsheet that calculates a two-period weighted moving average and exponential smoothing model for a set of demand numbers, as well as the resulting *MFE* and *MAD* values. **Re-create this spreadsheet in Excel.** While your formatting does not have to be exactly the same, your answers should be. (*Hint:* Format the cells for the exponential smoothing model to show only two decimal places. Otherwise, the number of decimal places that shows will increase with each new forecast.)

Your spreadsheet should recalculate results whenever any changes are made to the shaded cells. If your logic is correct, changing the initial forecast for the exponential smoothing model to 50 will result in new *MFE* and *MAD* values of 0.76 and 5.62, respectively. Similarly, changing both weights for the two-period model to 0.5 should result in new *MFE* and *MAD* values of −0.077 and 7.692, respectively.

Problems for Section 9.6: Causal Forecasting Models

15. After graduation, you take a position at Top-Slice, a well-known manufacturer of golf balls. One of your duties is to forecast monthly demand for golf balls. Using the following data, you developed a regression model that expresses monthly sales as a function of average temperature for the month:

$$\text{Monthly sales} = -767.7 + 98.5\ (\text{average temperature})$$

	MONTHLY SALES	AVERAGE TEMPERATURE
March 2017	4,670	52
April	5,310	58
May	6,320	69
June	7,080	75
July	7,210	83
August	7,040	82
September	6,590	78
October	5,520	65
November	4,640	54
December	4,000	48
January 2018	2,840	41
February	3,170	42

	A	B	C	D	E	F	G	H	I
1	**Comparing a Two-Period Moving Average and an Exponential Smoothing Model**								
2									
3		Two-period moving average model					Exponential smoothing model		
4		Weight on Period t-2:		0.35			Initial forecast:		65
5		Weight on Period t-1:		0.65			Alpha (a):		0.3
6									
7	Period	Demand	Forecast	Forecast Error	Absolute Deviation		Forecast	Forecast Error	Absolute Deviation
8	1	60					65.00	–5.00	5.00
9	2	53					63.50	–10.50	10.50
10	3	65	55.45	9.55	9.55		60.35	4.65	4.65
11	4	72	60.8	11.2	11.2		61.75	10.26	10.26
12	5	72	66.55	2.45	2.45		64.82	7.18	7.18
13	6	74	72	2	2		66.98	7.02	7.02
14	7	50	73.3	–23.3	23.3		69.08	–19.08	19.08
15	8	60	58.4	1.6	1.6		63.36	–3.36	3.36
16	9	72	56.5	15.5	15.5		62.35	9.65	9.65
17	10	53	67.8	–14.8	14.8		65.25	–12.25	12.25
18	11	56	59.65	–3.65	3.65		61.57	–5.57	5.57
19	12	51	54.95	–3.95	3.95		59.90	–8.90	8.90
20	13	51	52.75	–1.75	1.75		57.23	–6.23	6.23
21	14	54	51	3	3		55.36	–1.36	1.36
22	15	55	52.95	2.05	2.05		54.95	0.05	0.05
23			MFE =	–0.008			MFE =	–1.380	
24				MAD =	7.292			MAD =	7.350

a. (**) Using Equations (9.8) and (9.9) from the text, show how the $\hat{a}$ and $\hat{b}$ values of −767.7 and 98.5 were calculated.

b. (*) Use the regression forecasting model to forecast total golf ball sales for *June and July 2018*. Average temperatures are expected to be 76 degrees in June and 82 degrees in July.

c. (*) Is this regression model a time series or a causal forecasting model? Explain.

16. (**) The following table lists the number of home improvement loans approved by a finance company, along with the loan interest rate:

MONTH	INTEREST RATE	NUMBER OF LOANS
1	7%	20
2	5%	30
3	4%	35
4	8%	18
5	10%	15
6	6%	22
7	11%	15
8	9%	20
9	5%	27
10	12%	10

a. Develop a regression forecast model using the interest rate as the predictor (i.e., independent) variable. Is this a time series or a causal forecasting model? Explain.

b. How many loans should the bank expect to make if the interest rate is 10%? 6.5%? Do these results make sense?

17. (**) While searching through your class notes, you stumble across the following forecasting model:

$$\text{Demand} = (35{,}000 + 4.8^{*}\text{period})\ \text{seasonal index}$$

SEASONAL INDICES	
Summer	1.25
Fall	0.90
Winter	0.75
Spring	0.90

Based *only* on this information, answer the following true/false questions. Justify your answers.

a. True or false? The forecast model is a time series model.

b. True or false? The forecast model suggests that the variable being forecasted is experiencing an upward trend in demand.

c. True or false? The variable being forecasted experiences a sharp increase during the summer months, followed by lower levels in the winter months.

18. (**) Suppose you are given the following demand and forecast data for the past four quarters:

QUARTER	DEMAND	FORECAST
Winter	285	250
Spring	315	300
Summer	300	350
Fall	400	400

Develop a seasonal index for each of the quarters. Does the fall quarter really need a seasonal adjustment index? Explain.

19. (***) After developing her 2020 forecast (Example 9.8), Jamie Favre gets a visit from Cheeznax's production manager, Mark Mobley. Mark says, "I think the forecast is fine, but I really need estimates of demand broken out by product type. In other words, how much of each month's demand do we think will consist of cheese balls, cheese nachos, and cheese potato chips?" Jamie goes back to the 2019 sales results and finds the following figures:

MONTH	CHEESE BALLS	CHEESE NACHOS	CHEESE POTATO CHIPS	TOTAL SALES
January	$126,500	$69,000	$34,500	$230,000
February	$119,600	$73,600	$36,800	$230,000
March	$115,200	$81,600	$43,200	$240,000
April	$125,000	$70,000	$55,000	$250,000
May	$112,800	$64,800	$62,400	$240,000
June	$115,000	$75,000	$60,000	$250,000
July	$126,900	$75,600	$67,500	$270,000
August	$124,800	$75,400	$59,800	$260,000
September	$135,200	$83,200	$41,600	$260,000
October	$135,200	$78,000	$46,800	$260,000
November	$151,200	$72,800	$56,000	$280,000
December	$142,100	$98,600	$49,300	$290,000
				$3,060,000

Using this information and the 2020 adjusted forecast results shown in Figure 9.22, develop a forecast for each product in each month of 2020. The sum of the individual product forecasts should equal the monthly total sales forecast. (*Hint:* Use the 2019 figures to estimate what percentage of demand is accounted for by each product type.)

20. (***) (*Microsoft Excel problem*) Wayne Banker is in charge of planning water usage for agriculturally intensive Burke County. August is the peak month of water usage for Burke County. Wayne has collected the following statistics from the past 15 years, showing the total March–June rainfall (in inches), average daily high temperature in July, and number of acre-feet of water used in August by farms in the area. Wayne wants to know if he can predict how much water will be needed in August, given the March–June rainfall and July temperature data.

YEAR	INCHES OF RAINFALL, MARCH–JUNE	AVERAGE PEAK DAILY TEMPERATURE, JULY	ACRE-FEET OF WATER USED, AUGUST
2005	12.5	78.4	39,800
2006	11.2	74.9	43,700
2007	12.2	84.1	45,100
2008	10.6	85.1	54,500
2009	9.3	70.6	32,900
2010	11.7	71.0	31,500
2011	10.0	87.4	35,500
2012	13.3	91.4	35,800
2013	8.4	98.3	69,700
2014	14.9	99.6	48,100
2015	10.0	91.7	53,700
2016	12.6	91.6	40,300
2017	10.6	81.5	32,600
2018	7.1	77.0	34,100
2019	11.3	83.9	36,800

Use Excel's regression function to develop a multiple regression forecast for Wayne. What is the R^2 for the model? Use the model to forecast water usage for 2005–2019. Calculate the *MFE* and *MAPE* for the model. In your opinion, how good is the model?

Problems for Section 9.7: Measures of Forecast Accuracy

21. (**) Your manager has come to you with the following data, showing actual demand for five periods and forecast results for two different models. He has asked you to tell him which forecast model is "best" and why. Using *MFE*, *MAD*, and *MAPE*, tell him which model is best and why.

PERIOD	ACTUAL DEMAND	FORECAST MODEL 1	FORECAST MODEL 2
8	248	364	486
9	357	280	341
10	423	349	295
11	286	416	364
12	444	354	380

22. (*) Consider the following forecast results. Calculate *MFE*, *MAD*, and *MAPE*, using the data for the months January through June. Does the forecast model under- or overforecast?

MONTH	ACTUAL DEMAND	FORECAST
January	1,040	1,055
February	990	1,052
March	980	900
April	1,060	1,025
May	1,080	1,100
June	1,000	1,050

CASE STUDY

Top-Slice Drivers

Introduction

Two years ago, Top-Slice Company moved from just making golf balls to also producing oversized drivers. Top-Slice makes three different models: the Bomber, the Hook King, and the Sir Slice-A-Lot. As the names suggest, the last two clubs help correct for golfers who either hook or slice the ball when driving.

While Top-Slice is pleased with the growing sales for all three models (see the following tables), the numbers present Jacob Lee, the production manager, with a dilemma. Jacob knows that the current manufacturing work cell is capable of producing only 2,700 drivers per month, and total sales seem to be rapidly approaching that number. Jacob's staff has told him it will take at least three months to plan for and implement an expanded work cell.

MONTH	BOMBER	HOOK KING	SIR SLICE-A-LOT
April 2017	1,410	377	343
May	1,417	381	344
June	1,434	387	346
July	1,452	391	349
August	1,466	396	350

(Continued)

MONTH	BOMBER	HOOK KING	SIR SLICE-A-LOT
September	1,483	400	352
October	1,490	403	354
November	1,505	409	357
December	1,521	412	359
January 2018	1,536	420	363
February	1,547	423	365
March	1,554	426	367
April	1,562	431	369
May	1,574	437	371
June	1,587	441	375
July	1,595	445	377
August	1,613	454	381
September	1,631	461	384
October	1,642	464	386
November	1,656	471	389
December	1,673	477	392
January 2019	1,685	480	394
February	1,703	485	396
March	1,720	490	399

Questions

1. Develop a quantitative forecast model for Jacob. Which modeling technique did you choose, and why? What are the assumptions behind your model?
2. According to your model, when will Top-Slice need to have the expanded work cell up and running? What are the implications for when Jacob should start the expansion effort?
3. Now suppose that over lunch the marketing vice president says to Jacob:

   We're feeling a lot of heat from Chinese manufacturers who are offering very similar clubs to ours, but at significantly lower prices. The legal department is working on a patent infringement case, but if we can't block these clubs from entering the market, I expect to see our sales flatten, and maybe even fall, over the rest of the year.

   What questions should Jacob ask? How would the answers to these questions affect the forecast? Does it still make sense to use quantitative forecasting under these circumstances? Why?

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Paul A. Souders/Corbis/VCG/Getty Images

CHAPTER
ten

CHAPTER OUTLINE

Sales and Operations Planning (Aggregate Planning)

CHAPTER OBJECTIVES

By the end of this chapter, you will be able to:

- Distinguish among strategic planning, tactical planning, and detailed planning and control.
- Describe why sales and operations planning (S&OP) is important to an organization and its supply chain partners.
- Generate multiple alternative sales and operations plans for a firm.
- Describe the differences between top-down and bottom-up S&OP and discuss the strengths and weaknesses of level, chase, and mixed production strategies.
- Discuss the organizational issues that arise when firms decide to incorporate S&OP into their efforts.
- Examine how S&OP can be used to coordinate activities up and down the supply chain.
- Apply optimization modeling techniques to the S&OP process.

COVOLO DIVING GEAR, PART 1

Khoroshunova Olga/Shutterstock

June 1, 2020—The senior staff members for Covolo Diving Gear were sitting down for their semiannual planning meeting. As it had been too often before, the mood was tense.

"This is nuts," complained David Griffin, the vice president of manufacturing. "Last January, marketing sat here and presented us with a sales forecast of 30,000 gauge sets each month, so that's what I planned on producing. But by March, they'd upped it to 33,000. How can I be expected to keep a smooth-running manufacturing organization under these conditions? I can't handle another six months like the last."

"We do the best we can, but it's hard to develop a dead-on forecast, especially for more than a few months in advance," countered Patricia Rodriguez, the vice president of marketing. "Besides, manufacturing was able to increase production to only 31,000, even though we both finally agreed on the higher number. Why is *that*?"

"I'll tell you why," said Jack Nelson, head of supply management. "Each gauge set we make requires special parts that come from Germany, and our German suppliers just can't increase their shipments to us without *some* notice. Next time you guys plan on changing production levels, why don't you include me in on the conversation?"

At this point, Gina Covolo, the CEO, spoke up: "OK, folks, settle down. We work for the same company, remember? I've been reading up on something called sales and operations planning. If I understand it right, it will help us coordinate our efforts better than we have in the past. We will have to meet more often, probably monthly, but if we do it right, we will all be working from the same sales forecast, and we will know exactly what each of our areas has to do to execute the plan. I think that's a whole lot better than getting angry at one another." And to the accompanying groans of everyone in the room, Gina added: "Who knows, we might even be able to keep our heads above water."

INTRODUCTION

Sales and operations planning (S&OP)
A process to develop tactical plans by integrating marketing plans for new and existing products with the management of the supply chain. The process brings together all the plans for the business into one integrated set of plans. Also called *aggregate planning*.

Aggregate planning
See sales and operations planning (S&OP).

Throughout this book, we have emphasized how critical it is to coordinate operations and supply chain decisions with other functional areas and the firm's supply chain partners. This theme appears in our discussions of strategy, new product development, capacity planning, and process choice, to name a few. This chapter takes the concept of cross-functional and interfirm coordination a step further, through a process known as **sales and operations planning (S&OP)** (sometimes called **aggregate planning**). Adapting from the APICS definition, we define sales and operations planning as a process to develop tactical plans by integrating marketing plans for new and existing products with the management of the supply chain. The process brings together all the plans for the business (sales, marketing, development, manufacturing, sourcing, and financial) into one integrated set of plans. It is performed at least once a month and is reviewed by management at an aggregate (product family) level.[1]

We start by describing how S&OP fits into an organization's planning scheme. We then present several methods for generating and selecting plans and for implementing the S&OP process in an organization.

10.1 S&OP IN THE PLANNING CYCLE

Strategic planning
Planning that takes place at the highest levels of the firm, addressing needs that might not arise for years into the future.

In most organizations, planning actually takes place at several levels, each covering a certain period of time into the future (Figure 10.1). **Strategic planning** takes place at the highest levels of the firm; it addresses needs that might not arise for years into the future. **Tactical planning**

[1] J. H. Blackstone, ed., *APICS Dictionary*, 15th ed. (Chicago, IL: APICS, 2016).