Location Strategies

8 CHAPTER

CHAPTER OUTLINE

Alaska Airlines

Alaska Airlines

10 OM STRATEGY DECISIONS

- Design of Goods and Services
- Managing Quality
- Process Strategy
- *Location Strategies*
- Layout Strategies
- Human Resources
- Supply-Chain Management
- Inventory Management
- Scheduling
- Maintenance

GLOBAL COMPANY PROFILE
FedEx

Location Provides Competitive Advantage for FedEx

Overnight-delivery powerhouse FedEx has believed in the hub concept for its 46-year existence. Even though Fred Smith, founder and CEO, got a C on his college paper proposing a hub for small-package delivery, the idea has proven extremely successful. Starting with one central location in Memphis, Tennessee (now called its *superhub*), the $45 billion firm has added a European hub in Paris, an Asian hub in Guangzhou, China, a Latin American hub in Miami, and a Canadian hub in Toronto. FedEx's fleet of 667 planes flies into 375 airports worldwide, then delivers to the door with more than 80,000 vans and trucks.

At the FedEx hub in Memphis, Tennessee, approximately 100 FedEx aircraft converge each night around midnight with more than 5 million documents and packages.

Oliver Berg/EPA/Newscom

At the preliminary sorting area, packages and documents are sorted and sent to a secondary sorting area. The Memphis facility covers 1.5 million square feet; it is big enough to hold 33 football fields. Packages are sorted and exchanged until 4 A.M.

Troy Glasgow/AP Images

Lance Murphey/Reuters/Newscom

Packages and documents that have already gone through the primary and secondary sorts are checked by city, state, and zip code. They are then placed in containers that are loaded onto aircraft for delivery to their final destinations in 236 countries.

Matt York/AP Images

FedEx's fleet of 667 planes makes it the largest airline in the world. More than 80,000 trucks complete the delivery process.

Shi Li/shzq/ImagineChina

The $150 million hub opened in Guangzhou in 2009 lies in the heart of one of China's fastest-growing manufacturing districts. FedEx controls 39% of the China-to-U.S. air express market.

Why was Memphis picked as FedEx's central location? (1) It is located in the middle of the U.S. (2) It has very few hours of bad weather closures, perhaps contributing to the firm's excellent flight-safety record. (3) It provided FedEx with generous tax incentives.

Each night, except Sunday, FedEx brings to Memphis packages from throughout the world that are going to cities for which FedEx does not have direct flights. The central hub permits service to a far greater number of points with fewer aircraft than the traditional City-A-to-City-B system. It also allows FedEx to match aircraft flights with package loads each night and to reroute flights when load volume requires it, a major cost savings. Moreover, FedEx also believes that the central hub system helps reduce mishandling and delay in transit because there is total control over the packages from pickup point through delivery.

LEARNING OBJECTIVES

- **LO 8.1** ***Identify*** and explain seven major factors that affect location decisions 342
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The Strategic Importance of Location

VIDEO 8.1
Hard Rock's Location Selection

World markets continue to expand, and the global nature of business is accelerating. Indeed, one of the most important strategic decisions made by many companies, including FedEx, Mercedes-Benz, and Hard Rock, is where to locate their operations. When FedEx opened its Asian hub in Guangzhou, China, it set the stage for "round-the-world" flights linking its Paris and Memphis package hubs to Asia. When Mercedes-Benz announced its plans to build its first major overseas plant in Vance, Alabama, it completed a year of competition among 170 sites in 30 states and two countries. When Hard Rock Cafe opened in Moscow, it ended 3 years of advance preparation of a Russian food-supply chain. The strategic impact, cost, and international aspect of these decisions indicate how significant location decisions are.

Firms throughout the world are using the concepts and techniques of this chapter to address the location decision because location greatly affects both fixed and variable costs. Location has a major impact on the overall risk and profit of the company. For instance, depending on the product and type of production or service taking place, transportation costs alone can total as much as 25% of the product's selling price. That is, one-fourth of a firm's total revenue may be needed just to cover freight expenses of the raw materials coming in and finished products going out. Other costs that may be influenced by location include taxes, wages, raw material costs, and rents. When all costs are considered, location may alter total operating expenses as much as 50%.

The economics of transportation are so significant that companies—and even cities—have coalesced around a transportation advantage. For centuries, rivers and ports, and more recently rail hubs and then interstate highways, were a major ingredient in the location decision. Today airports are often the deciding factor, providing fast, low-cost transportation of goods and people.

Companies make location decisions relatively infrequently, usually because demand has outgrown the current plant's capacity or because of changes in labor productivity, exchange rates, costs, or local attitudes. Companies may also relocate their manufacturing or service facilities because of shifts in demographics and customer demand.

Location options include (1) expanding an existing facility instead of moving, (2) maintaining current sites while adding another facility elsewhere, or (3) closing the existing facility and moving to another location.

The location decision often depends on the type of business. For industrial location decisions, the strategy is usually minimizing costs, although locations that foster innovation and creativity may also be critical. For retail and professional service organizations, the strategy focuses on maximizing revenue. Warehouse location strategy, however, may be driven by a combination of cost and speed of delivery. *The objective of location strategy is to maximize the benefit of location to the firm.*

Location and Costs Because location is such a significant cost and revenue driver, location often has the power to make (or break) a company's business strategy. Key multinationals in every major industry, from automobiles to cellular phones, now have or are planning a presence in each of their major markets. Location decisions to support a low-cost strategy require particularly careful consideration.

Once management is committed to a specific location, many costs are firmly in place and difficult to reduce. For instance, if a new factory location is in a region with high energy costs, even good management with an outstanding energy strategy is starting at a disadvantage. Management is in a similar bind with its human resource strategy if labor in the selected location is expensive, ill-trained, or has a poor work ethic. Consequently, hard work to determine an optimal facility location is a good investment.

Factors That Affect Location Decisions

Selecting a facility location is becoming much more complex with globalization. As we saw in Chapter 2, globalization has taken place because of the development of (1) market economics; (2) better international communications; (3) more rapid, reliable travel and shipping; (4) ease of capital flow between countries; and (5) high differences in labor costs. Many firms now consider opening new offices, factories, retail stores, or banks outside their home country. Location decisions transcend national borders. In fact, as Figure 8.1 shows, the sequence of location decisions often begins with choosing a country in which to operate.

One approach to selecting a country is to identify what the parent organization believes are key success factors (KSFs) needed to achieve competitive advantage. Six possible country KSFs are listed at the top of Figure 8.1. Using such factors (including some negative ones, such as crime) the World Economic Forum biannually ranks the global competitiveness of 144 countries (see Table 8.1). Switzerland placed first because of its high rates of saving and investment, openness to trade, quality education, and efficient government.

Once a firm decides which country is best for its location, it focuses on a region of the chosen country and a community. The final step in the location decision process is choosing a specific site within a community. The company must pick the one location that is best suited for shipping and receiving, zoning, utilities, size, and cost. Again, Figure 8.1 summarizes this series of decisions and the factors that affect them.

TABLE 8.1

Competitiveness of 144 Selected Countries, Based on Annual Surveys of 13,000 Business Executives

COUNTRY	2015 RANKING
Switzerland	1
Singapore	2
U.S.	3
Finland	4
Germany	5
Japan	6
⋮	
Canada	15
⋮	
Israel	27
China	28
⋮	
Russia	53
⋮	
Mexico	61
⋮	
Vietnam	68
⋮	
Haiti	137
⋮	
Chad	143
Guinea	144

Source: www.weforum.org, 2015. Used with permission of World Economic Forum.

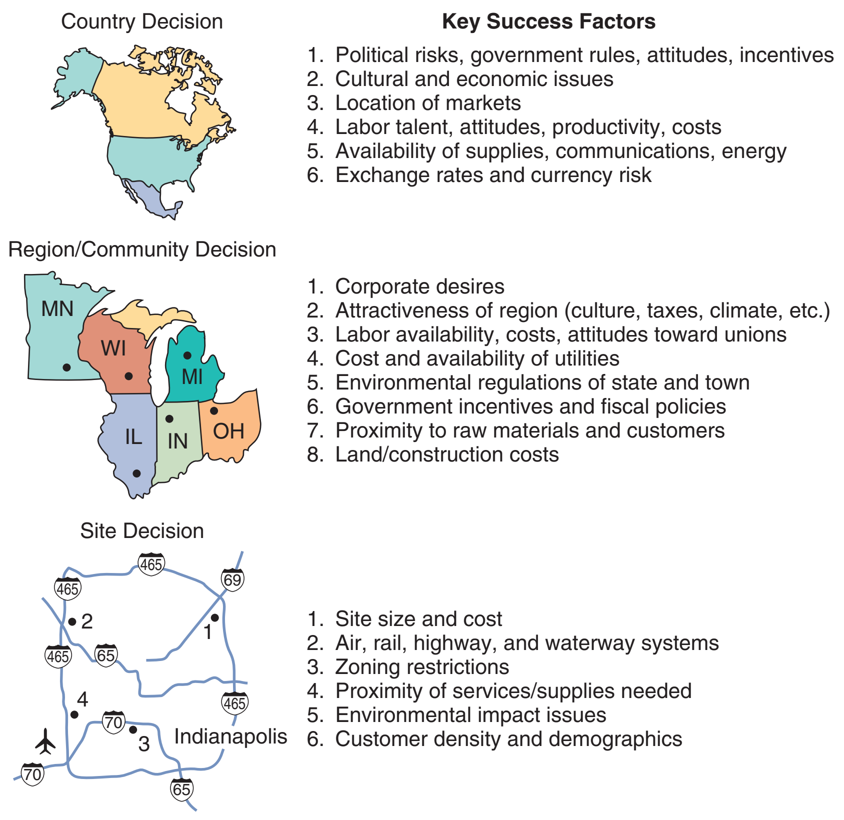


Figure **8.1**

Some Considerations and Factors That Affect Location Decisions

LO 8.1 *Identify* and explain seven major factors that affect location decisions

Besides globalization, a number of other factors affect the location decision. Among these are labor productivity, foreign exchange, culture, changing attitudes toward the industry, and proximity to markets, suppliers, and competitors.

Labor Productivity

LO 8.2 *Compute* labor productivity

When deciding on a location, management may be tempted by an area's low wage rates. However, wage rates cannot be considered by themselves, as Otis Elevator discovered when it opened its plant in Mexico in 1998. But by 2011, Otis found a move to an automated plant in South Carolina more advantageous. Management must also consider productivity.

As discussed in Chapter 1, differences exist in productivity in various countries. What management is really interested in is the combination of production and the wage rate. For example, if Otis Elevator pays $70 per day with 60 units produced per day in South Carolina, it will spend less on labor than at a Mexican plant that pays $25 per day with production of 20 units per day:

$$\frac{\text{Labor cost per day}}{\text{Production (units per day)}} = \text{Labor cost per unit}$$

1. Case 1: South Carolina plant:

$$\frac{\$70 \text{ Wages per day}}{60 \text{ Units produced per day}} = \frac{\$70}{60} = \$1.17 \text{ per unit}$$

2. Case 2: Juarez, Mexico, plant:

$$\frac{\$25 \text{ Wages per day}}{20 \text{ Units produced per day}} = \frac{\$25}{20} = \$1.25 \text{ per unit}$$

STUDENT TIP Final cost is the critical factor, and low productivity can negate low wages.

Employees with poor training, poor education, or poor work habits may not be a good buy even at low wages. By the same token, employees who cannot or will not always reach their places of work are not much good to the organization, even at low wages. (Labor cost per unit is sometimes called the *labor content* of the product.)

Exchange Rates and Currency Risk

Although wage rates and productivity may make a country seem economical, unfavorable exchange rates may negate any savings. Sometimes, though, firms can take advantage of a particularly favorable exchange rate by relocating or exporting to a foreign country. However, the values of foreign currencies continually rise and fall in most countries. Such changes could well make what was a good location in 2015 a disastrous one in 2019. *Operational hedging* describes the situation where firms have excess capacity in multiple countries and then shift production levels from location to location as exchange rates change.

Costs

Tangible costs
Readily identifiable costs that can be measured with some precision.

We can divide location costs into two categories, tangible and intangible. **Tangible costs** are those costs that are readily identifiable and precisely measured. They include utilities, labor, material, taxes, depreciation, and other costs that the accounting department and management can identify. In addition, such costs as transportation of raw materials, transportation of finished goods, and site construction are all factored into the overall cost of a location. Government incentives, as we see in the *OM in Action* box "Iowa—Home of Corn and Facebook," also affect a location's cost.

Intangible costs
A category of location costs that cannot be easily quantified, such as quality of life and government.

Intangible costs are less easily quantified. They include quality of education, public transportation facilities, community attitudes toward the industry and the company, and quality and attitude of prospective employees. They also include quality-of-life variables, such as climate and sports teams, that may influence personnel recruiting.

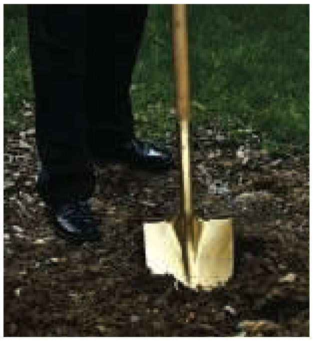
OM in Action Iowa—Home of Corn and Facebook

Among the big draws in Altoona, Iowa, population 15,000, are Adventureland, a Bass Pro Shop, and the Prairie Meadows casino. And now, it has Facebook's new data center. The social network recently opened the $300 million facility, a move that highlights the intense competition and lavish tax breaks available from small communities looking for technology bragging rights. The Altoona facility was built on millions of dollars of tax breaks and about 18 months of negotiation.

Facebook isn't Iowa's first high-tech catch. Microsoft is spending $2 billion on a data center nearby in Des Moines. Google is expanding a facility in Council Bluffs.

States and cities long have vied against each other to lure factories, sports teams and corporate headquarters. Iowa, the country's largest producer of corn, is among many states rolling out a green carpet for those farming bits and bytes. Officials say data centers broaden their tax base, create well-paying technical and construction jobs, and confer bragging rights that will lure companies with bigger hiring plans. They also contribute to the local economy without stressing infrastructure such as roads and sewage plants.

But it remains an open question whether the cost of these facilities, in tax breaks and services, works out in their favor. Altoona provided Facebook a 20-year exemption on paying property taxes, and Iowa agreed to $18 million in sales-tax refunds or investment-tax credits through 2023. "For the tax breaks they often receive, the centers produce few jobs or spinoff benefits," said an Iowa State University professor. Tech companies aren't looking for incentives alone. Availability and pricing of electricity, which can exceed two-thirds of the cost to run a data center, are among the most important factors.


gdbrekke/Fotolia

Proponents argue that businesses expect to trade tax cuts for jobs. But a report by the John Locke foundation summarized the results of 55 studies on the impact of targeted tax incentives. More than 70% of the studies found that incentives either did not substantially contribute to economic performance or produced mixed results. Often the giveaways add up to cronyism, a misallocation of resources, and a huge bill for taxpayers.

Sources: Wall Street Journal (Nov. 15–16, 2014) and (March 13, 2015); and *New York Times* (Dec. 1, 2012).

Political Risk, Values, and Culture

The political risk associated with national, state, and local governments' attitudes toward private and intellectual property, zoning, pollution, and employment stability may be in flux. Governmental positions at the time a location decision is made may not be lasting ones. However, management may find that these attitudes can be influenced by their own leadership.

Worker values may also differ from country to country, region to region, and small town to city. Worker views regarding turnover, unions, and absenteeism are all relevant factors. In turn, these values can affect a company's decision whether to make offers to current workers if the firm relocates to a new location. The case study at the end of this chapter, "Southern Recreational Vehicle Company," describes a St. Louis firm that actively chose *not to relocate* any of its workers when it moved to Mississippi.

One of the greatest challenges in a global operations decision is dealing with another country's culture. Cultural variations in punctuality by employees and suppliers make a marked difference in production and delivery schedules. Bribery and other forms of corruption also create substantial economic inefficiency, as well as ethical and legal problems in the global arena. As a result, operations managers face significant challenges when building effective supply chains across cultures. Table 8.2 provides one ranking of corruption in countries around the world.

TABLE 8.2

Ranking Corruption in Selected Countries (Score of 100 Represents a Corruption-Free Country

RANK	SCORE
1 Denmark	92
2 New Zealand	91
3 Finland	89
⋮	
10 Canada	81
⋮	
17 U.S., Hong Kong	74 (tie)
⋮	
37 Israel	60
⋮	
69 Brazil, Greece	43 (tie)
⋮	
136 Russia	27
⋮	
161 Haiti	19
⋮	
174 Somalia, North Korea	8 (tie)

Source: Transparency International's 2014 survey, at **www.transparency.org.** Used with permission of Transparency International.

Proximity to Markets

For many firms, locating near customers is extremely important. Particularly, service organizations, like drugstores, restaurants, post offices, or barbers, find that demographics and proximity to market are *the* primary location factors. Manufacturing firms find it useful to be close to customers when transporting finished goods is expensive or difficult (perhaps because they are bulky, heavy, or fragile). To be near U.S. markets, foreign-owned auto giants such as Mercedes, Honda, Toyota, and Hyundai are building millions of cars each year in the U.S.

In addition, with just-in-time production, suppliers want to locate near users. For a firm like Coca-Cola, whose product's primary ingredient is water, it makes sense to have bottling plants in many cities rather than shipping heavy (and sometimes fragile glass) containers cross country.

Proximity to Suppliers

Firms locate near their raw materials and suppliers because of (1) perishability, (2) transportation costs, or (3) bulk. Bakeries, dairy plants, and frozen seafood processors deal with *perishable* raw materials, so they often locate close to suppliers. Companies dependent on inputs of heavy or bulky raw materials (such as steel producers using coal and iron ore) face expensive inbound *transportation costs*, so transportation costs become a major factor. And goods for which there is a *reduction in bulk* during production (e.g., trees to lumber) typically need facilities near the raw material.

Proximity to Competitors (Clustering)

Clustering
The location of competing companies near each other, often because of a critical mass of information, talent, venture capital, or natural resources.

Both manufacturing and service organizations also like to locate, somewhat surprisingly, near competitors. This tendency, called **clustering**, often occurs when a major resource is found in that region. Such resources include natural resources, information resources, venture capital resources, and talent resources. Table 8.3 presents nine examples of industries that exhibit clustering, and the reasons why.

Italy may be the true leader when it comes to clustering, however, with northern zones of that country holding world leadership in such specialties as ceramic tile (Modena), gold jewelry (Vicenza), machine tools (Busto Arsizio), cashmere and wool (Biella), designer eyeglasses (Belluma), and pasta machines (Parma). When it comes to clusters for innovations in slaughtering, however (see the *OM in Action* box), Denmark is the leader.

Methods of Evaluating Location Alternatives

Four major methods are used for solving location problems: the factor-rating method, locational cost–volume analysis, the center-of-gravity method, and the transportation model. This section describes these approaches.

TABLE 8.3 Clustering of Companies

INDUSTRY	LOCATIONS	REASON FOR CLUSTERING
Wine making	Napa Valley (U.S.), Bordeaux region (France)	Natural resources of land and climate
Software firms	Silicon Valley, Boston, Bangalore, Israel	Talent resources of bright graduates in scientific/technical areas, venture capitalists nearby
Clean energy	Colorado	Critical mass of talent and information, with 1,000 companies
Theme parks (e.g., Disney World, Universal Studios, and Sea World)	Orlando, Florida	A hot spot for entertainment, warm weather, tourists, and inexpensive labor
Electronics firms (e.g., Sony, IBM, HP, Motorola, and Panasonic)	Northern Mexico	NAFTA, duty-free export to U.S. (24% of all TVs are built here)
Computer hardware manufacturing	Singapore, Taiwan	High technological penetration rates and per capita GDP, skilled/educated workforce with large pool of engineers
Fast-food chains (e.g., Wendy's, McDonald's, Burger King, Pizza Hut)	Sites within 1 mile of one another	Stimulate food sales, high traffic flows
General aviation aircraft (e.g., Cessna, Learjet, Boeing, Raytheon)	Wichita, Kansas	Mass of aviation skills (60–70% of world's small planes/jets are built here)
Athletic footwear, outdoor wear	Portland, Oregon	300 companies, many spawned by Nike, deep talent pool and outdoor culture

OM in Action Denmark's Meat Cluster

Every day, 20,000 pigs are delivered to the Danish Crown company's slaughterhouse in central Denmark. The pigs trot into the stunning room, guided by workers armed with giant fly swats. The animals are hung upside down, divided in two, shaved, and scalded clean. A machine cuts them into pieces, which are then cooled, boned, and packed.

The slaughterhouse is enormous: 10 football fields long with 7 miles of conveyor belts. Its managers attend to the tiniest detail. The workers wear green rather than white because this puts the pigs in a better mood. The cutting machine photographs a carcass before adjusting its blades to the exact carcass contours. The company calibrates not only how to carve the flesh, but also where the various parts will fetch the highest prices.

Denmark is a tiny country, with 5.6 million people and wallet-draining labor costs. But it is an agricultural giant, home to 30 million pigs and numerous global brands. Farm products make up over 20% of its goods exports—and the value of these exports is expected to grow from $5.5 billion in 2001 to $31 billion by 2020.

How is this meat-processing cluster still thriving? It is because clustering can be applied to ancient industries like slaughtering as well as to new ones. The cluster includes several big companies: Danish Crown, Arla, Rose Poultry, and DuPont Danisco, as well as plenty of smaller firms, which act as indicators of nascent trends and incubators of new ideas. Other firms are contributing information technology tools for the cluster. Among these are LetFarm for fields, Bovisoft for stables, Agrosoft for pigs, Webstech for grain, and InOMEGA for food.

The cluster also has a collection of productivity-spurring institutions (the Cattle Research Center, for example, creates ways to boost pork productivity through robotics) and Danish Tech University, where 1,500 people work on food-related subjects.

Racom/123rf

Sources: The Economist (Jan. 4, 2014); and *GlobalMeatNews.com* (Nov. 1, 2013).

The Factor-Rating Method

There are many factors, both qualitative and quantitative, to consider in choosing a location. Some of these factors are more important than others, so managers can use weightings to make the decision process more objective. The **factor-rating method** is popular because a wide variety of factors, from education to recreation to labor skills, can be objectively included. Figure 8.1 listed a few of the many factors that affect location decisions.

Factor-rating method
A location method that instills objectivity into the process of identifying hard-to-evaluate costs.

The factor-rating method (which we introduced in Chapter 2) has six steps:

1. Develop a list of relevant factors called *key success factors* (such as those in Figure 8.1).
2. Assign a weight to each factor to reflect its relative importance in the company's objectives.
3. Develop a scale for each factor (for example, 1 to 10 or 1 to 100 points).
4. Have management score each location for each factor, using the scale in Step 3.
5. Multiply the score by the weights for each factor and total the score for each location.
6. Make a recommendation based on the maximum point score, considering the results of other quantitative approaches as well.

Example 1

LO 8.3 *Apply* the factor-rating method

FACTOR-RATING METHOD FOR AN EXPANDING THEME PARK

Five Flags over Florida, a U.S. chain of 10 family-oriented theme parks, has decided to expand overseas by opening its first park in Europe. It wishes to select between France and Denmark.

APPROACH ▶ The ratings sheet in Table 8.4 lists key success factors that management has decided are important; their weightings and their rating for two possible sites—Dijon, France, and Copenhagen, Denmark—are shown.

STUDENT TIP These weights do not need to be on a 0–1 scale or total to 1. We can use a 1–10 scale, 1–100 scale, or any other scale we prefer.

TABLE 8.4 Weights, Scores, and Solution

KEY SUCCESS FACTOR	WEIGHT	SCORES (OUT OF 100)		WEIGHTED SCORES	
		FRANCE	DENMARK	FRANCE	DENMARK
Labor availability and attitude	.25	70	60	(.25)(70) = 17.50	(.25)(60) = 15.00
People-to-car ratio	.05	50	60	(.05)(50) = 2.50	(.05)(60) = 3.00
Per capita income	.10	85	80	(.10)(85) = 8.50	(.10)(80) = 8.00
Tax structure	.39	75	70	(.39)(75) = 29.25	(.39)(70) = 27.30
Education and health	.21	60	70	(.21)(60) = 12.60	(.21)(70) = 14.70
Totals	1.00			70.35	68.00

SOLUTION ▶ Table 8.4 uses weights and scores to evaluate alternative site locations. Given the option of 100 points assigned to each factor, the French location is preferable.

INSIGHT ▶ By changing the points or weights slightly for those factors about which there is some doubt, we can analyze the sensitivity of the decision. For instance, we can see that changing the scores for "labor availability and attitude" by 10 points can change the decision. The numbers used in factor weighting can be subjective, and the model's results are not "exact" even though this is a quantitative approach.

LEARNING EXERCISE ▶ If the weight for "tax structure" drops to .20 and the weight for "education and health" increases to .40, what is the new result? [Answer: Denmark is now chosen, with a 68.0 vs. a 67.5 score for France.]

RELATED PROBLEMS ▶ 8.5–8.15, 8.24, 8.25 (8.26, 8.27, 8.28, 8.33, 8.34 are available in MyOMLab)

EXCEL OM Data File **Ch08Ex1.xls** can be found in MyOMLab.

When a decision is sensitive to minor changes, further analysis of the weighting and the points assigned may be appropriate. Alternatively, management may conclude that these intangible factors are not the proper criteria on which to base a location decision. Managers therefore place primary weight on the more quantitative aspects of the decision.

Locational Cost–Volume Analysis

Locational cost–volume analysis
A method of making an economic comparison of location alternatives.

Locational cost–volume analysis is a technique for making an economic comparison of location alternatives. By identifying fixed and variable costs and graphing them for each location, we can determine which one provides the lowest cost. Locational cost–volume analysis can be done mathematically or graphically. The graphic approach has the advantage of providing the range of volume over which each location is preferable.

The three steps to locational cost–volume analysis are as follows:

1. Determine the fixed and variable cost for each location.
2. Plot the costs for each location, with costs on the vertical axis of the graph and annual volume on the horizontal axis.
3. Select the location that has the lowest total cost for the expected production volume.

Example 2

LOCATIONAL COST–VOLUME ANALYSIS FOR A PARTS MANUFACTURER

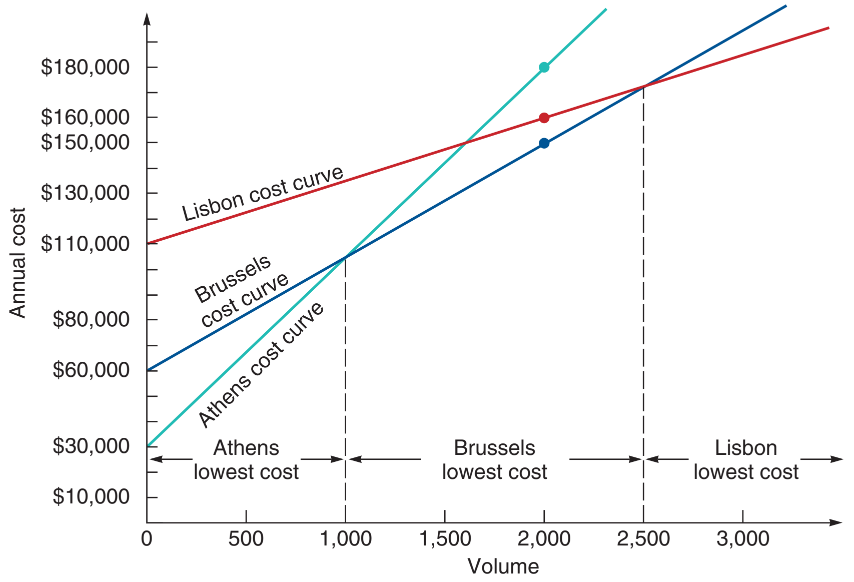
Esmail Mohebbi, owner of European Ignitions Manufacturing, needs to expand his capacity. He is considering three locations—Athens, Brussels, and Lisbon—for a new plant. The company wishes to find the most economical location for an expected volume of 2,000 units per year.

APPROACH ▶ Mohebbi conducts locational cost–volume analysis. To do so, he determines that fixed costs per year at the sites are \$30,000, \$60,000, and \$110,000, respectively; and variable costs are \$75 per unit, \$45 per unit, and \$25 per unit, respectively. The expected selling price of each ignition system produced is \$120.

SOLUTION ▶ For each of the three locations, Mohebbi can plot the fixed costs (those at a volume of zero units) and the total cost (fixed costs + variable costs) at the expected volume of output. These lines have been plotted in Figure 8.2.

Figure **8.2**

Crossover Chart for Locational Cost–Volume Analysis



For Athens:

$$\text{Total cost} = \$30{,}000 + \$75(2{,}000) = \$180{,}000$$

For Brussels:

$$\text{Total cost} = \$60{,}000 + \$45(2{,}000) = \$150{,}000$$

For Lisbon:

$$\text{Total cost} = \$110{,}000 + \$25(2{,}000) = \$160{,}000$$

LO 8.4 *Complete* a locational cost–volume analysis graphically and mathematically

With an expected volume of 2,000 units per year, Brussels provides the lowest cost location. The expected profit is:

$$\text{Total revenue} - \text{Total cost} = \$120(2{,}000) - \$150{,}000 = \$90{,}000 \text{ per year}$$

The crossover point for Athens and Brussels is:

$$30{,}000 + 75(x) = 60{,}000 + 45(x)$$
$$30(x) = 30{,}000$$
$$x = 1{,}000$$

and the crossover point for Brussels and Lisbon is:

$$60{,}000 + 45(x) = 110{,}000 + 25(x)$$
$$20(x) = 50{,}000$$
$$x = 2{,}500$$

INSIGHT ▶ As with every other OM model, locational cost–volume analysis can be sensitive to input data. For example, for a volume of less than 1,000, Athens would be preferred. For a volume greater than 2,500, Lisbon would yield the greatest profit.

LEARNING EXERCISE ▶ The variable cost for Lisbon is now expected to be $22 per unit. What is the new crossover point between Brussels and Lisbon? [Answer: 2,174 units.]

RELATED PROBLEMS ▶ 8.16–8.19 (8.29, 8.30 are available in MyOMLab)

EXCEL OM Data File **Ch08Ex2.xls** can be found in MyOMLab.

Center-of-Gravity Method

Center-of-gravity method
A mathematical technique used for finding the best location for a single distribution point that services several stores or areas.

The **center-of-gravity method** is a mathematical technique used for finding the location of a distribution center that will minimize distribution costs. The method takes into account the location of markets, the volume of goods shipped to those markets, and shipping costs in finding the best location for a distribution center.

The first step in the center-of-gravity method is to place the locations on a coordinate system. This will be illustrated in Example 3. The origin of the coordinate system and the scale used are arbitrary, just as long as the relative distances are correctly represented. This can be done easily by placing a grid over an ordinary map. The center of gravity is determined using Equations (8-1) and (8-2):

$$x\text{-coordinate of the center of gravity} = \frac{\sum_i x_i Q_i}{\sum_i Q_i} \tag{8-1}$$

$$y\text{-coordinate of the center of gravity} = \frac{\sum_i y_i Q_i}{\sum_i Q_i} \tag{8-2}$$

where x_i = x-coordinate of location i
y_i = y-coordinate of location i
Q_i = Quantity of goods moved to or from location i

LO 8.5 *Use* the center-of-gravity method

Note that Equations (8-1) and (8-2) include the term Q_i, the quantity of supplies transferred to or from location i.

Because the number of containers shipped each month affects cost, distance alone should not be the principal criterion. The center-of-gravity method assumes that cost is directly proportional to both distance and volume shipped. The ideal location is that which minimizes the weighted distance between sources and destinations, where the distance is weighted by the number of containers shipped.[1]

Example 3

CENTER OF GRAVITY

Quain's Discount Department Stores, a chain of four large Target-type outlets, has store locations in Chicago, Pittsburgh, New York, and Atlanta; they are currently being supplied out of an old and inadequate warehouse in Pittsburgh, the site of the chain's first store. The firm wants to find some "central" location in which to build a new warehouse.

APPROACH ▶ Quain's will apply the center-of-gravity method. It gathers data on demand rates at each outlet (see Table 8.5).

TABLE 8.5 Demand for Quain's Discount Department Stores

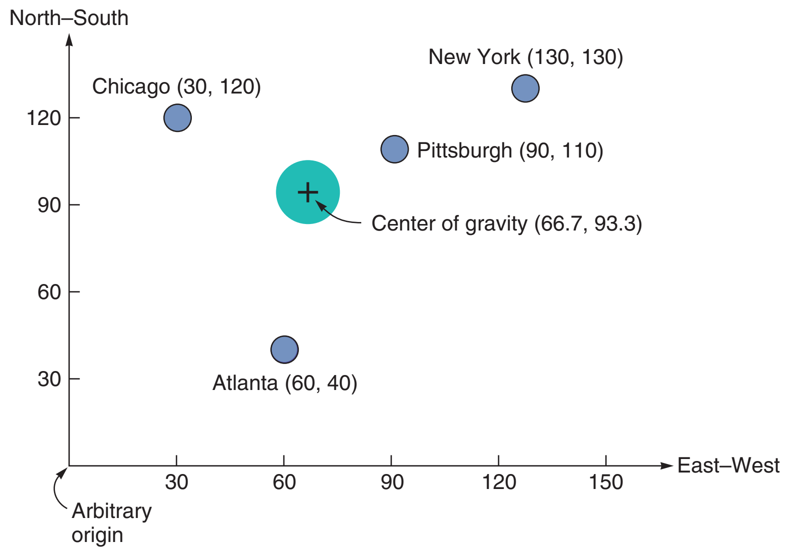
STORE LOCATION	NUMBER OF CONTAINERS SHIPPED PER MONTH
Chicago	2,000
Pittsburgh	1,000
New York	1,000
Atlanta	2,000

Its current store locations are shown in Figure 8.3. For example, location 1 is Chicago, and from Table 8.5 and Figure 8.3, we have:

$$x_1 = 30$$
$$y_1 = 120$$
$$Q_1 = 2{,}000$$

Figure 8.3

Coordinate Locations of Four Quain's Department Stores and Center of Gravity



SOLUTION ▶ Using the data in Table 8.5 and Figure 8.3 for each of the other cities, and Equations (8-1) and (8-2), we find:

x-coordinate of the center of gravity:

$$= \frac{(30)(2000) + (90)(1000) + (130)(1000) + (60)(2000)}{2000 + 1000 + 1000 + 2000} = \frac{400{,}000}{6{,}000}$$

$$= 66.7$$

y-coordinate of the center of gravity:

$$= \frac{(120)(2000) + (110)(1000) + (130)(1000) + (40)(2000)}{2000 + 1000 + 1000 + 2000} = \frac{560{,}000}{6{,}000}$$

$$= 93.3$$

This location (66.7, 93.3) is shown by the crosshairs in Figure 8.3.

INSIGHT ▶ By overlaying a U.S. map on Figure 8.3, we find this location (66.7, 93.3) is near central Ohio. The firm may well wish to consider Columbus, Ohio, or a nearby city as an appropriate location. But it is important to have both north–south and east–west interstate highways near the city selected to make delivery times quicker.

LEARNING EXERCISE ▶ The number of containers shipped per month to Atlanta is expected to grow quickly to 3,000. How does this change the center of gravity, and where should the new warehouse be located? [Answer: (65.7, 85.7), which is closer to Cincinnati, Ohio.]

RELATED PROBLEMS ▶ 8.20–8.23 (8.31, 8.32 are available in MyOMLab)

EXCEL OM Data File **Ch08Ex3.xls** can be found in MyOMLab.

ACTIVE MODEL 8.1 This example is further illustrated in Active Model 8.1 in MyOMLab.

Transportation Model

The objective of the **transportation model** is to determine the best pattern of shipments from several points of supply (sources) to several points of demand (destinations) so as to minimize total production and transportation costs. Every firm with a network of supply-and-demand points faces such a problem. The complex Volkswagen supply network (shown in Figure 8.4) provides one such illustration. We note in Figure 8.4, for example, that VW of Mexico ships vehicles for assembly and parts to VW of Nigeria, sends assemblies to VW of Brasil, and receives parts and assemblies from headquarters in Germany.

Transportation model
A technique for solving a class of linear programming problems.

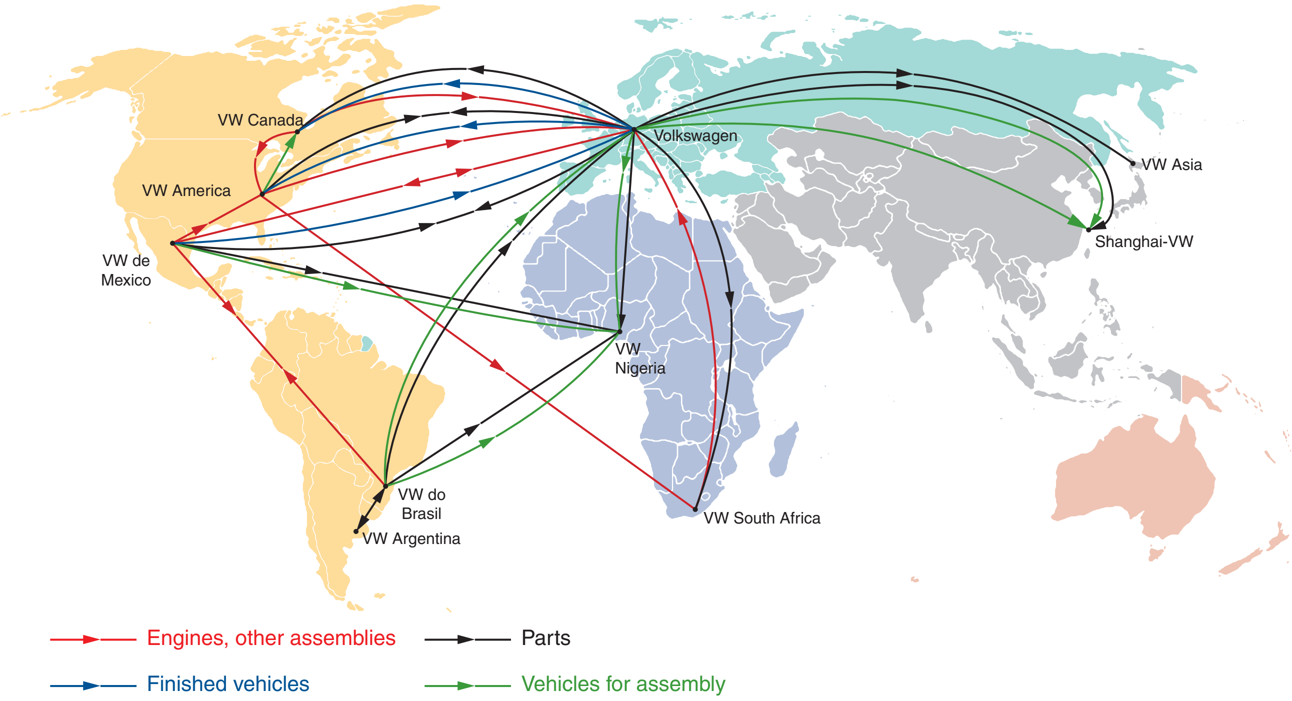


Figure 8.4

Volkswagen, the Third Largest Automaker in the World, Finds It Advantageous to Locate Its Plants Throughout the World

This graphic shows a portion of VW's supply network. There are 61 plants in Europe, along with nine countries in the Americas, Asia, and Africa.

Although the linear programming (LP) technique can be used to solve this type of problem, more efficient, special-purpose algorithms have been developed for the transportation application. The transportation model finds an initial feasible solution and then makes step-by-step improvement until an optimal solution is reached.

Service Location Strategy

STUDENT TIP Retail stores often attract more shoppers when competitors are close.

While the focus in industrial-sector location analysis is on *minimizing cost,* the focus in the service sector is on *maximizing revenue.* This is because manufacturing firms find that costs tend to vary substantially among locations, while service firms find that location often has more impact on revenue than cost. Therefore, the location focus for service firms should be on determining the volume of customers and revenue.

There are eight major determinants of volume and revenue for the service firm:

1. Purchasing power of the customer-drawing area
2. Service and image compatibility with demographics of the customer-drawing area
3. Competition in the area
4. Quality of the competition
5. Uniqueness of the firm's and competitors' locations
6. Physical qualities of facilities and neighboring businesses
7. Operating policies of the firm
8. Quality of management

Realistic analysis of these factors can provide a reasonable picture of the revenue expected. The techniques used in the service sector include regression analysis (see the *OM in Action* box, "How La Quinta Selects Profitable Hotel Sites"), traffic counts, demographic analysis, purchasing power analysis, the factor-rating method, the center-of-gravity method, and geographic information systems. Table 8.6 provides a summary of location strategies for both service and goods-producing organizations.

OM in Action How La Quinta Selects Profitable Hotel Sites

One of the most important decisions a lodging chain makes is location. Those that pick good sites more accurately and quickly than competitors have a distinct advantage. La Quinta Inns, headquartered in San Antonio, Texas, is a moderately priced chain of 800 inns. To model motel selection behavior and predict success of a site, La Quinta turned to regression analysis.

The hotel started by testing 35 independent variables, trying to find which of them would have the highest correlation with predicted profitability, the dependent variable. Variables included: the number of hotel rooms in the vicinity and their average room rates; local attractions such as office buildings and hospitals that drew potential customers to a 4-mile-radius trade area; local population and unemployment rate; the number of inns in a region; and physical characteristics of the site, such as ease of access or sign visibility.

In the end, the regression model chosen, with an R^2 of 51%, included four predictive variables: (1) the price of the inn, (2) median income levels, (3) the state population per inn, and (4) the location of nearby colleges (which serves as a proxy for other demand generators). La Quinta then used the regression model to predict profitability and developed a cutoff that gave the best results for predicting success or failure of a site. A spreadsheet is now used to implement the model, which applies the decision rule and suggests "build" or "don't build." The CEO likes the model so much that he no longer feels obliged to personally select new sites.

Mike Booth/Alamy

Sources: S. Kimes and J. Fitzsimmons, *Interfaces* 20, no. 2: 12–20; and G. Keller, *Statistics for Management and Economics*, 8th ed. Cincinnati-Cengage, 2008: 679.

TABLE 8.6 Location Strategies—Service vs. Goods-Producing Organizations

SERVICE/RETAIL/PROFESSIONAL	*GOODS-PRODUCING*
REVENUE FOCUS	**COST FOCUS**
Volume/revenue Drawing area; purchasing power Competition; advertising/pricing **Physical quality** Parking/access; security/lighting; appearance/image **Cost determinants** Rent Management caliber Operation policies (hours, wage rates)	**Tangible costs** Transportation cost of raw material Shipment cost of finished goods Energy and utility cost; labor; raw material; taxes, and so on **Intangible and future costs** Attitude toward union Quality of life Education expenditures by state Quality of state and local government
TECHNIQUES	**TECHNIQUES**
Regression models to determine importance of various factors Factor-rating method Traffic counts Demographic analysis of drawing area Purchasing power analysis of area Center-of-gravity method Geographic information systems	Transportation method Factor-rating method Locational cost–volume analysis Crossover charts
ASSUMPTIONS	**ASSUMPTIONS**
Location is a major determinant of revenue High customer-interaction issues are critical Costs are relatively constant for a given area; therefore, the revenue function is critical	Location is a major determinant of cost Most major costs can be identified explicitly for each site Low customer contact allows focus on the identifiable costs Intangible costs can be evaluated

STUDENT TIP
This table helps differentiate between service- and manufacturing-sector decisions.

LO 8.6 *Understand* the differences between service- and industrial-sector location analysis

Geographic Information Systems

Geographic information system (GIS)
A system that stores and displays information that can be linked to a geographic location.

Geographic information systems are an important tool to help firms make successful, analytical decisions with regard to location. A **geographic information system (GIS)** stores, accesses, displays, and links demographic information to a geographical location. For instance, retailers, banks, food chains, gas stations, and print shop franchises can all use geographically coded files from a GIS to conduct demographic analyses. By combining population, age, income, traffic flow, and density figures with geography, a retailer can pinpoint the best location for a new store or restaurant.

Here are some of the geographic databases available in many GISs:

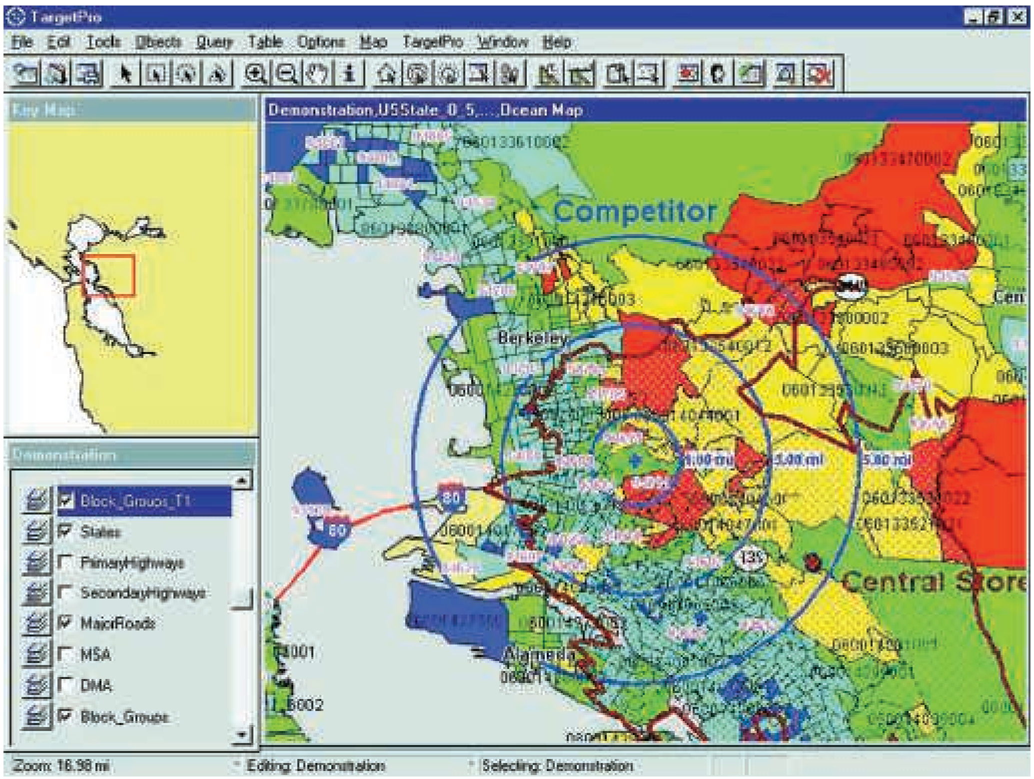
- Census data by block, tract, city, county, congressional district, metropolitan area, state, and zip code
- Maps of every street, highway, bridge, and tunnel in the U.S.
- Utilities such as electrical, water, and gas lines
- All rivers, mountains, lakes, and forests
- All major airports, colleges, and hospitals

For example, airlines use GISs to identify airports where ground services are the most effective. This information is then used to help schedule and to decide where to purchase fuel, meals, and other services.

Commercial office building developers use GISs in the selection of cities for future construction. Building new office space takes several years; therefore, developers value the database approach that a GIS can offer. GIS is used to analyze factors that influence the location decisions by addressing five elements for each city: (1) residential areas, (2) retail shops, (3) cultural and entertainment centers, (4) crime incidence, and (5) transportation options.

Here are five examples of how location-scouting GIS software is turning commercial real estate into a science.

- *Carvel Ice Cream:* This 80-year-old chain of ice cream shops uses GIS to create a demographic profile of what a typically successful neighborhood for a Carvel looks like—mostly in terms of income and ages.
- *Saber Roofing:* Rather than send workers out to estimate the costs for reroofing jobs, this Redwood City, California, firm pulls up aerial shots of the building via Google Earth. The



Geographic information systems (GISs) are used by a variety of firms, including Darden Restaurants, to identify target markets by income, ethnicity, product use, age, etc. Here, data from MapInfo helps with competitive analysis for a retailer. Three concentric blue rings, each representing various mile radii, were drawn around the competitor's store. The heavy red line indicates the "drive" time to the firm's own central store (the red dot).

owner can measure roofs, evaluate their condition, and e-mail the client an estimate, saving hundreds of miles of driving daily. In one case, while on the phone, a potential client was told her roof was too steep for the company to tackle after the Saber employee quickly looked up the home on Google Earth.

- *Arby's:* As this fast-food chain learned, specific products can affect behavior. Using MapInfo, Arby's discovered that diners drove up to 20% farther for their roast beef sandwich (which they consider a "destination" product) than for its chicken sandwich.
- *Home Depot:* Wanting a store in New York City, even though Home Depot demographics are usually for customers who own big homes, the company opened in Queens when GIS software predicted it would do well. Although most people there live in apartments and very small homes, the store has become one of the chain's highest-volume outlets. Similarly, Home Depot thought it had saturated Atlanta two decades ago, but GIS analysis suggested expansion. There are now over 40 Home Depots in that area.
- *Jo-Ann Stores:* This fabric and craft retailer's 70 superstores were doing well a few years ago, but managers were afraid more big-box stores could not justify building expenses. So Jo-Ann used its GIS to create an ideal customer profile—female homeowners with families—and mapped it against demographics. The firm found it could build 700 superstores, which in turn increased the sales from $105 to $150 per square foot.

Other packages similar to MapInfo are Atlas GIS (from Strategic Mapping), ArcGIS (by Esri), SAS/GIS (by SAS Institute), Maptitude (by Caliper), and GeoMedia (by Intergraph).

These GISs can be extensive, including comprehensive sets of map and demographic data. The maps have millions of miles of streets and points of interest to allow users to locate restaurants, airports, hotels, gas stations, ATMs, museums, campgrounds, and freeway exits. Demographic data include statistics for population, age, income, education, and housing. These data can be mapped by state, county, city, zip code, or census tract.

The *Video Case Study* "Locating the Next Red Lobster Restaurant" that appears at the end of this chapter describes how that chain uses its GIS to define trade areas based on market size and population density.

VIDEO 8.2
Locating the Next Red Lobster Restaurant

Summary

Location may determine up to 50% of operating expense. Location is also a critical element in determining revenue for the service, retail, or professional firm. Industrial firms need to consider both tangible and intangible costs. Industrial location problems are typically addressed via a factor-rating method, locational cost–volume analysis, the center-of-gravity method, and the transportation method of linear programming.

For service, retail, and professional organizations, analysis is typically made of a variety of variables including purchasing power of a drawing area, competition, advertising and promotion, physical qualities of the location, and operating policies of the organization.

Key Terms

Tangible costs (p. 342)
Intangible costs (p. 342)
Clustering (p. 344)
Factor-rating method (p. 345)
Locational cost–volume analysis (p. 346)
Center-of-gravity method (p. 348)
Transportation model (p. 349)
Geographic information system (GIS) (p. 351)

Ethical Dilemma

In this chapter, we have discussed a number of location decisions. Consider another: United Airlines announced its competition to select a town for a new billion-dollar aircraft-repair base. The bidding for the prize of 7,500 jobs paying at least $25 per hour was fast and furious, with Orlando offering $154 million in incentives and Denver more than twice that amount. Kentucky's governor angrily rescinded Louisville's offer of $300 million, likening the bidding to "squeezing every drop of blood out of a turnip."

When United finally selected from among the 93 cities bidding on the base, the winner was Indianapolis and its $320 million offer of taxpayers' money.

But a few years later, with United near bankruptcy, and having fulfilled its legal obligation, the company walked away from the massive center. This left the city and state governments out all that money, with no new tenant in sight. The city now even owns the tools, neatly arranged in each of the 12 elaborately equipped hangar bays. United outsourced its maintenance to mechanics at a southern firm (which pays one-third of what United paid in salary and benefits in Indianapolis).

What are the ethical, legal, and economic implications of such location bidding wars? Who pays for such giveaways? Are local citizens allowed to vote on offers made by their cities, counties, or states? Should there be limits on these incentives?

Discussion Questions

1. How is FedEx's location a competitive advantage? Discuss.
2. Why do so many U.S. firms build facilities in other countries?
3. Why do so many foreign companies build facilities in the U.S.?
4. What is clustering?
5. How does factor weighting incorporate personal preference in location choices?
6. What are the advantages and disadvantages of a qualitative (as opposed to a quantitative) approach to location decision making?
7. Provide two examples of clustering in the service sector.
8. What are the major factors that firms consider when choosing a country in which to locate?
9. What factors affect region/community location decisions?
10. Although most organizations may make the location decision infrequently, there are some organizations that make the decision quite regularly and often. Provide one or two examples. How might their approach to the location decision differ from the norm?
11. List factors, other than globalization, that affect the location decision.
12. Explain the assumptions behind the center-of-gravity method. How can the model be used in a service facility location?
13. What are the three steps to locational cost–volume analysis?
14. "Manufacturers locate near their resources, retailers locate near their customers." Discuss this statement, with reference to the proximity-to-markets arguments covered in the text. Can you think of a counter-example in each case? Support your choices.
15. Why shouldn't low wage rates alone be sufficient to select a location?
16. List the techniques used by service organizations to select locations.
17. Contrast the location of a food distributor and a supermarket. (The distributor sends truckloads of food, meat, produce, etc., to the supermarket.) Show the relevant considerations (factors) they share; show those where they differ.
18. Elmer's Fudge Factory is planning to open 10 retail outlets in Oregon over the next 2 years. Identify (and weight) those factors relevant to the decision. Provide this list of factors and weights.

Using Software to Solve Location Problems

This section presents three ways to solve location problems with computer software. First, you can create your own spreadsheets to compute factor ratings, the center of gravity, and locational cost–volume analysis. Second, Excel OM (free with your text and found in MyOMLab) is programmed to solve all three models. Third, POM for Windows is also found in MyOMLab and can solve all problems labeled with a P.

CREATING YOUR OWN EXCEL SPREADSHEETS

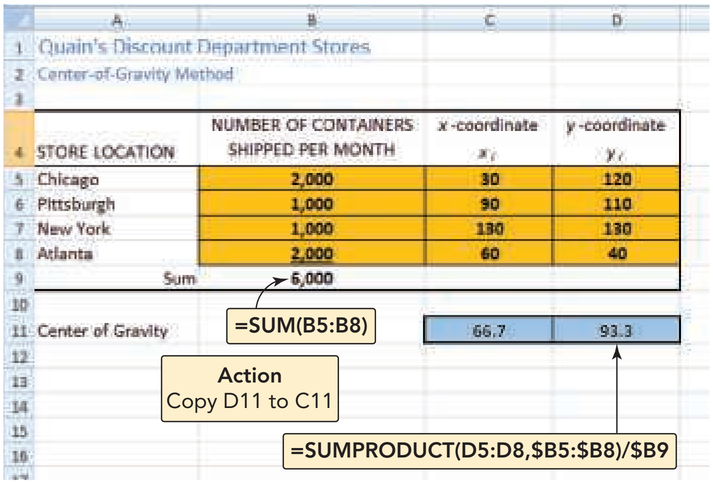
Excel spreadsheets are easily developed to solve most of the problems in this chapter. Consider the Quain's Department Store center-of-gravity analysis in Example 3. You can see from Program 8.1 how the formulas are created.

USING EXCEL OM

Excel OM may be used to solve Example 1 (with the Factor Rating module), Example 2 (with the Cost–Volume Analysis module), and Example 3 (with the Center-of-Gravity module), as well as other location problems. The factor-rating method was illustrated in Chapter 2.

P USING POM FOR WINDOWS

POM for Windows also includes three different facility location models: the factor-rating method, the center-of-gravity model, and locational cost–volume analysis. For details, refer to Appendix IV.



Program **8.1**

An Excel Spreadsheet for Creating a Center-of-Gravity Analysis for Example 3, Quain's Discount Department Stores

Solved Problems

Virtual Office Hours help is available in MyOMLab.

SOLVED PROBLEM 8.1

Just as cities and communities can be compared for location selection by the weighted approach model, as we saw earlier in this chapter, so can actual site decisions within those cities. Table 8.7 illustrates four factors of importance to Washington, DC, and the health officials charged with opening that city's first public drug treatment clinic. Of primary concern (and given a weight of 5) was location of the clinic so it would be as accessible as possible to the largest number of patients. Due to a tight budget, the annual lease cost was also of some concern. A suite in the city hall, at 14th and U Streets, was highly rated because its rent would be free. An old office building near the downtown bus station received a much lower rating because of its cost. Equally important as lease cost was the need for confidentiality of patients and, therefore, for a relatively inconspicuous clinic. Finally, because so many of the staff at the clinic would be donating their time, the safety, parking, and accessibility of each site were of concern as well.

Using the factor-rating method, which site is preferred?

SOLUTION

From the three rightmost columns in Table 8.7, the weighted scores are summed. The bus terminal area has a low score and can be excluded from further consideration. The other two sites are virtually identical in total score. The city may now want to consider other factors, including political ones, in selecting between the two remaining sites.

TABLE 8.7 Potential Clinic Sites in Washington, DC

		POTENTIAL LOCATIONS*			WEIGHTED SCORES		
FACTOR	IMPORTANCE WEIGHT	HOMELESS SHELTER (2ND AND D, SE)	CITY HALL (14TH AND U, NW)	BUS TERMINAL AREA (7TH AND H, NW)	HOMELESS SHELTER	CITY HALL	BUS TERMINAL AREA
Accessibility for addicts	5	9	7	7	45	35	35
Annual lease cost	3	6	10	3	18	30	9
Inconspicuous	3	5	2	7	15	6	21
Accessibility for health staff	2	3	6	2	6	12	4
					Total scores: 84	83	69

*All sites are rated on a 1 to 10 basis, with 10 as the highest score and 1 as the lowest.

SOLVED PROBLEM 8.2

Ching-Chang Kuo is considering opening a new foundry in Denton, Texas; Edwardsville, Illinois; or Fayetteville, Arkansas, to produce high-quality rifle sights. He has assembled the following fixed-cost and variable-cost data:

		PER-UNIT COSTS		
LOCATION	FIXED COST PER YEAR	MATERIAL	VARIABLE LABOR	OVERHEAD
Denton	$200,000	$ .20	$ .40	$ .40
Edwardsville	$180,000	$ .25	$ .75	$ .75
Fayetteville	$170,000	$1.00	$1.00	$1.00

a) Graph the total cost lines.
b) Over what range of annual volume is each facility going to have a competitive advantage?
c) What is the volume at the intersection of the Edwardsville and Fayetteville cost lines?

SOLUTION

a) A graph of the total cost lines is shown in Figure 8.5.
b) Below 8,000 units, the Fayetteville facility will have a competitive advantage (lowest cost); between 8,000 units and 26,666 units, Edwardsville has an advantage; and above 26,666, Denton has the advantage. (We have made the assumption in this problem that other costs—that is, delivery and intangible factors—are constant regardless of the decision.)
c) From Figure 8.5, we see that the cost line for Fayetteville and the cost line for Edwardsville cross at about 8,000. We can also determine this point with a little algebra:

$$\$180{,}000 + 1.75Q = \$170{,}000 + 3.00Q$$
$$\$10{,}000 = 1.25Q$$
$$8{,}000 = Q$$

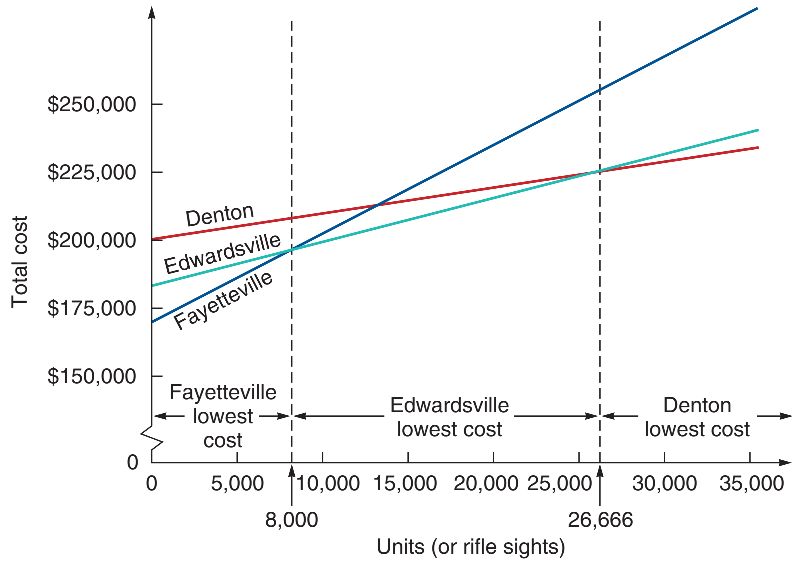


Figure 8.5

Graph of Total Cost Lines for Ching-Chang Kuo

SOLVED PROBLEM 8.3

The Metropolis Public Library plans to expand with its first major branch library in the city's growing north side. The branch will serve six census tracts. Here are the coordinates of each tract and the population within it:

CENSUS TRACT	CENTER OF TRACT	POPULATION IN TRACT
503—Logan Square	(3, 4)	45,000
519—Albany Park	(4, 5)	25,000
522—Rogers Park	(3, 6)	62,000
538—Kentwood	(4, 7)	51,000
540—Roosevelt	(2, 3)	32,000
561—Western	(5, 2)	29,000

Using the center-of-gravity method, what should be the coordinate location of the branch library?

SOLUTION

$$x\text{-coordinate} = \frac{\sum_i x_i Q_i}{\sum_i Q_i} = \frac{3(45{,}000) + 4(25{,}000) + 3(62{,}000) + 4(51{,}000) + 2(32{,}000) + 5(29{,}000)}{244{,}000} = 3.42$$

$$y\text{-coordinate} = \frac{\sum_i y_i Q_i}{\sum_i Q_i} = \frac{4(45{,}000) + 5(25{,}000) + 6(62{,}000) + 7(51{,}000) + 3(32{,}000) + 2(29{,}000)}{244{,}000} = 4.87$$

The new branch library will sit just west of Logan Square and Rogers Park, at the (3.42, 4.87) tract location.

Problems

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

Problems 8.1–8.4 relate to Factors That Affect Location Decisions

• **8.1** In Myanmar (formerly Burma), 6 laborers, each making the equivalent of \$3 per day, can produce 40 units per day. In rural China, 10 laborers, each making the equivalent of \$2 per day, can produce 45 units. In Billings, Montana, 2 laborers, each making \$60 per day, can make 100 units. Based on labor costs only, which location would be most economical to produce the item?

• **8.2** Refer to Problem 8.1. Shipping cost from Myanmar to Denver, Colorado, the final destination, is \$1.50 per unit. Shipping cost from China to Denver is \$1 per unit, while the shipping cost from Billings to Denver is \$.25 per unit. Considering both labor and transportation costs, which is the most favorable production location?

•• **8.3** You have been asked to analyze the bids for 200 polished disks used in solar panels. These bids have been submitted by three suppliers: Thailand Polishing, India Shine, and Sacramento Glow. Thailand Polishing has submitted a bid of 2,000 baht. India Shine has submitted a bid of 2,000 rupees. Sacramento Glow has submitted a bid of \$200. You check with your local bank and find that \$1 = 10 baht and \$1 = 8 rupees. Which company should you choose?

• **8.4** Refer to Problem 8.3. If the final destination is New Delhi, India, and there is a 30% import tax, which firm should you choose?

Problems 8.5–8.34 relate to Methods of Evaluating Location Alternatives

•• **8.5** Subway, with more than 25,000 outlets in the U.S., is planning for a new restaurant in Buffalo, New York. Three locations are being considered. The following table gives the factors for each site.

FACTOR	WEIGHT	MAITLAND	BAPTIST CHURCH	NORTHSIDE MALL
Space	.30	60	70	80
Costs	.25	40	80	30
Traffic density	.20	50	80	60
Neighborhood income	.15	50	70	40
Zoning laws	.10	80	20	90

a) At which site should Subway open the new restaurant?
b) If the weights for Space and Traffic density are reversed, how would this affect the decision? Px

• **8.6** Ken Gilbert owns the Knoxville Warriors, a minor league baseball team in Tennessee. He wishes to move the Warriors south, to either Mobile (Alabama) or Jackson (Mississippi). The table below gives the factors that Gilbert thinks are important, their weights, and the scores for Mobile and Jackson.

FACTOR	WEIGHT	MOBILE	JACKSON
Incentive	.4	80	60
Player satisfaction	.3	20	50
Sports interest	.2	40	90
Size of city	.1	70	30

a) Which site should he select?
b) Jackson just raised its incentive package, and the new score is 75. Why doesn't this impact your decision in part (a)? Px

Andrea Catenaro/Shutterstock

•• **8.7** Northeastern Insurance Company is considering opening an office in the U.S. The two cities under consideration are Philadelphia and New York. The factor ratings (higher scores are better) for the two cities are given in the following table. In which city should Northeastern locate?

FACTOR	WEIGHT	PHILADELPHIA	NEW YORK
Customer convenience	.25	70	80
Bank accessibility	.20	40	90
Computer support	.20	85	75
Rental costs	.15	90	55
Labor costs	.10	80	50
Taxes	.10	90	50

•• **8.8** Marilyn Helm Retailers is attempting to decide on a location for a new retail outlet. At the moment, the firm has three alternatives—stay where it is but enlarge the facility; locate along the main street in nearby Newbury; or locate in a new shopping mall in Hyde Park. The company has selected the four factors listed in the following table as the basis for evaluation and has assigned weights as shown:

FACTOR	FACTOR DESCRIPTION	WEIGHT
1	Average community income	.30
2	Community growth potential	.15
3	Availability of public transportation	.20
4	Labor availability, attitude, and cost	.35

Helm has rated each location for each factor, on a 100-point basis. These ratings are given below:

	LOCATION		
FACTOR	PRESENT LOCATION	NEWBURY	HYDE PARK
1	40	60	50
2	20	20	80
3	30	60	50
4	80	50	50

a) What should Helm do?
b) A new subway station is scheduled to open across the street from the present location in about a month, so its third factor score should be raised to 40. How does this change your answer?

•• **8.9** A location analysis for Cook Controls, a small manufacturer of parts for high-technology cable systems, has been narrowed down to four locations. Cook will need to train assemblers, testers, and robotics maintainers in local training centers. Lori Cook, the president, has asked each potential site to offer training programs, tax breaks, and other industrial incentives. The critical factors, their weights, and the ratings for each location are shown in the following table. High scores represent favorable values.

		LOCATION			
FACTOR	WEIGHT	AKRON, OH	BILOXI, MS	CARTHAGE, TX	DENVER, CO
Labor availability	.15	90	80	90	80
Technical school quality	.10	95	75	65	85
Operating cost	.30	80	85	95	85
Land and construction cost	.15	60	80	90	70
Industrial incentives	.20	90	75	85	60
Labor cost	.10	75	80	85	75

a) Compute the composite (weighted average) rating for each location.
b) Which site would you choose?
c) Would you reach the same conclusion if the weights for operating cost and labor cost were reversed? Recompute as necessary and explain.

••• **8.10** Pan American Refineries, headquartered in Houston, must decide among three sites for the construction of a new oil-processing center. The firm has selected the six factors listed below as a basis for evaluation and has assigned rating weights from 1 to 5 on each factor:

FACTOR	FACTOR NAME	RATING WEIGHT
1	Proximity to port facilities	5
2	Power-source availability and cost	3
3	Workforce attitude and cost	4
4	Distance from Houston	2
5	Community desirability	2
6	Equipment suppliers in area	3

Subhajit Chakraborty, the CEO, has rated each location for each factor on a 1- to 100-point basis.

FACTOR	LOCATION A	LOCATION B	LOCATION C
1	100	80	80
2	80	70	100
3	30	60	70
4	10	80	60
5	90	60	80
6	50	60	90

a) Which site will be recommended based on *total* weighted scores?
b) If location B's score for Proximity to port facilities was reset at 90, how would the result change?
c) What score would location B need on Proximity to port facilities to change its ranking?

•• **8.11** A company is planning on expanding and building a new plant in one of three Southeast Asian countries. Chris Ellis, the manager charged with making the decision, has determined that five key success factors can be used to evaluate the prospective countries. Ellis used a rating system of 1 (least desirable country) to 5 (most desirable) to evaluate each factor.

		CANDIDATE COUNTRY RATINGS		
KEY SUCCESS FACTOR	WEIGHT	TAIWAN	THAILAND	SINGAPORE
Technology	0.2	4	5	1
Level of education	0.1	4	1	5
Political and legal aspects	0.4	1	3	3
Social and cultural aspects	0.1	4	2	3
Economic factors	0.2	3	3	2

a) Which country should be selected for the new plant?
b) Political unrest in Thailand results in a lower score, 2, for Political and legal aspects. Does your conclusion change?
c) What if Thailand's score drops even further, to a 1, for Political and legal aspects?

• **8.12** Harden College is contemplating opening a European campus where students from the main campus could go to take courses for 1 of the 4 college years. At the moment, it is considering five countries: The Netherlands, Great Britain, Italy, Belgium, and Greece. The college wishes to consider eight factors in its decision. The first two factors are given weights of 0.2, while the rest are assigned weights of 0.1. The following table illustrates its assessment of each factor for each country (5 is best).

FACTOR	FACTOR DESCRIPTION	THE NETHERLANDS	GREAT BRITAIN	ITALY	BELGIUM	GREECE
1	Stability of government	5	5	3	5	4
2	Degree to which the population can converse in English	4	5	3	4	3
3	Stability of the monetary system	5	4	3	4	3
4	Communications infrastructure	4	5	3	4	3
5	Transportation infrastructure	5	5	3	5	3
6	Availability of historic/cultural sites	3	4	5	3	5
7	Import restrictions	4	4	3	4	4
8	Availability of suitable quarters	4	4	3	4	3

a) In which country should Harden College choose to set up its European campus?
b) How would the decision change if the "degree to which the population can converse in English" was not an issue?

• • 8.13 Daniel Tracy, owner of Martin Manufacturing, must expand by building a new factory. The search for a location for this factory has been narrowed to four sites: A, B, C, or D. The following table shows the results thus far obtained by Tracy by using the factor-rating method to analyze the problem. The scale used for each factor scoring is 1 through 5.

FACTOR	WEIGHT	*SITE SCORES*			
		A	B	C	D
Quality of labor	10	5	4	4	5
Construction cost	8	2	3	4	1
Transportation costs	8	3	4	3	2
Proximity to markets	7	5	3	4	4
Taxes	6	2	3	3	4
Weather	6	2	5	5	4
Energy costs	5	5	4	3	3

a) Which site should Tracy choose?
b) If site D's score for Energy costs increases from a 3 to a 5, do results change?
c) If site A's Weather score is adjusted to a 4, what is the impact? What should Tracy do at this point?

• • • 8.14 An American consulting firm is planning to expand globally by opening a new office in one of four countries: Germany, Italy, Spain, or Greece. The chief partner entrusted with the decision, L. Wayne Shell, has identified eight key success factors that he views as essential for the success of any consultancy. He used a rating system of 1 (least desirable country) to 5 (most desirable) to evaluate each factor.

KEY SUCCESS FACTOR	WEIGHT	*CANDIDATE COUNTRY RATINGS*			
		GERMANY	ITALY	SPAIN	GREECE
Level of education					
Number of consultants	.05	5	5	5	2
National literacy rate	.05	4	2	1	1
Political aspects					
Stability of government	0.2	5	5	5	2
Product liability laws	0.2	5	2	3	5
Environmental regulations	0.2	1	4	1	3
Social and cultural aspects					
Similarity in language	0.1	4	2	1	1
Acceptability of consultants	0.1	1	4	4	3
Economic factors					
Incentives	0.1	2	3	1	5

a) Which country should be selected for the new office?
b) If Spain's score were lowered in the Stability of government factor, to a 4, how would its overall score change? On this factor, at what score for Spain *would* the rankings change?

• • 8.15 A British hospital chain wishes to make its first entry into the U.S. market by building a medical facility in the Midwest, a region with which its director, Doug Moodie, is comfortable because he got his medical degree at Northwestern University. After a preliminary analysis, four cities are chosen for further consideration. They are rated and weighted according to the factors shown below:

FACTOR	WEIGHT	*CITY*			
		CHICAGO	MILWAUKEE	MADISON	DETROIT
Costs	2.0	8	5	6	7
Need for a facility	1.5	4	9	8	4
Staff availability	1.0	7	6	4	7
Local incentives	0.5	8	6	5	9

a) Which city should Moodie select?
b) Assume a minimum score of 5 is now required for all factors. Which city should be chosen?

• • 8.16 The fixed and variable costs for three potential manufacturing plant sites for a rattan chair weaver are shown:

SITE	FIXED COST PER YEAR	VARIABLE COST PER UNIT
1	\$ 500	\$11
2	1,000	7
3	1,700	4

a) Over what range of production is each location optimal?
b) For a production of 200 units, which site is best?

• 8.17 Peter Billington Stereo, Inc., supplies car radios to auto manufacturers and is going to open a new plant. The company is undecided between Detroit and Dallas as the site. The fixed costs in Dallas are lower due to cheaper land costs, but the variable costs in Dallas are higher because shipping distances would increase. Given the following costs:

COST	DALLAS	DETROIT
Fixed costs	$600,000	$800,000
Variable costs	$28/radio	$22/radio

a) Perform an analysis of the volume over which each location is preferable.
b) How does your answer change if Dallas's fixed costs increase by 10%?

••• **8.18** Hyundai Motors is considering three sites—A, B, and C—at which to locate a factory to build its new-model automobile, the Hyundai Sport C150. The goal is to locate at a minimum-cost site, where cost is measured by the annual fixed plus variable costs of production. Hyundai Motors has gathered the following data:

SITE	ANNUALIZED FIXED COST	VARIABLE COST PER AUTO PRODUCED
A	$10,000,000	$2,500
B	$20,000,000	$2,000
C	$25,000,000	$1,000

The firm knows it will produce between 0 and 60,000 Sport C150s at the new plant each year, but, thus far, that is the extent of its knowledge about production plans.
a) For what values of volume, V, of production, if any, is site C a recommended site?
b) What volume indicates site A is optimal?
c) Over what range of volume is site B optimal? Why?

•• **8.19** Peggy Lane Corp., a producer of machine tools, wants to move to a larger site. Two alternative locations have been identified: Bonham and McKinney. Bonham would have fixed costs of $800,000 per year and variable costs of $14,000 per standard unit produced. McKinney would have annual fixed costs of $920,000 and variable costs of $13,000 per standard unit. The finished items sell for $29,000 each.
a) At what volume of output would the two locations have the same profit?
b) For what range of output would Bonham be superior (have higher profits)?
c) For what range would McKinney be superior?
d) What is the relevance of break-even points for these cities?

•• **8.20** The following table gives the map coordinates and the shipping loads for a set of cities that we wish to connect through a central hub.

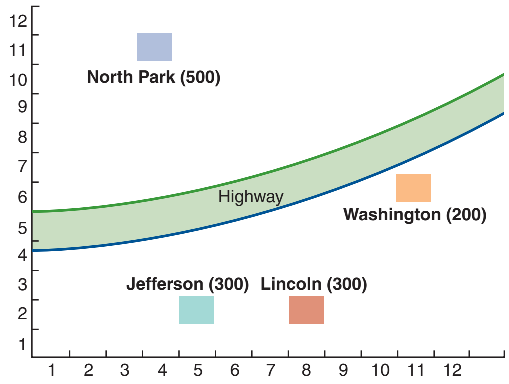
CITY	MAP COORDINATE (*X*, *Y*)	SHIPPING LOAD
A	(5, 10)	5
B	(6, 8)	10
C	(4, 9)	15
D	(9, 5)	5
E	(7, 9)	15
F	(3, 2)	10
G	(2, 6)	5

a) Near which map coordinates should the hub be located?
b) If the shipments from city A triple, how does this change the coordinates?

•• **8.21** A chain of home health care firms in Louisiana needs to locate a central office from which to conduct internal audits and other periodic reviews of its facilities. These facilities are scattered throughout the state, as detailed in the following table. Each site, except for Houma, will be visited three times each year by a team of workers, who will drive from the central office to the site. Houma will be visited five times a year. Which coordinates represent a good central location for this office? What other factors might influence the office location decision? Where would you place this office? Explain.

CITY	*MAP COORDINATES* *x*	*y*
Covington	9.2	3.5
Donaldsonville	7.3	2.5
Houma	7.8	1.4
Monroe	5.0	8.4
Natchitoches	2.8	6.5
New Iberia	5.5	2.4
Opelousas	5.0	3.6
Ruston	3.8	8.5

•• **8.22** A small rural county has experienced unprecedented growth over the past 6 years, and as a result, the local school district built the new 500-student North Park Elementary School. The district has three older and smaller elementary schools: Washington, Jefferson, and Lincoln. Now the growth pressure is being felt at the secondary level. The school district would like to build a centrally located middle school to accommodate students and reduce busing costs. The older middle school is adjacent to the high school and will become part of the high school campus.
a) What are the coordinates of the central location?
b) What other factors should be considered before building a school?



•• **8.23** Todd's Direct, a major TV sales chain headquartered in New Orleans, is about to open its first outlet in Mobile, Alabama, and wants to select a site that will place the new outlet in the center of Mobile's population base. Todd examines the seven census tracts in Mobile, plots the coordinates of the center of each from a map, and looks up the population base in each to use as a weighting. The information gathered appears in the following table.

CENSUS TRACT	POPULATION IN CENSUS TRACT	X, Y MAP COORDINATES
101	2,000	(25, 45)
102	5,000	(25, 25)
103	10,000	(55, 45)
104	7,000	(50, 20)
105	10,000	(80, 50)
106	20,000	(70, 20)
107	14,000	(90, 25)

a) At what center-of-gravity coordinates should the new store be located?

b) Census tracts 103 and 105 are each projected to grow by 20% in the next year. How will this influence the new store's coordinates? Px

•••• **8.24** Eagle Electronics must expand by building a second facility. The search has been narrowed down to locating the new facility in one of four cities: Atlanta (A), Baltimore (B), Chicago (C), or Dallas (D). The factors, scores, and weights follow:

			SCORES BY SITE			
I	FACTOR	WEIGHT (W_i)	A	B	C	D
1	Labor quality	20	5	4	4	5
2	Quality of life	16	2	3	4	1
3	Transportation	16	3	4	3	2
4	Proximity to markets	14	5	3	4	4
5	Proximity to suppliers	12	2	3	3	4
6	Taxes	12	2	5	5	4
7	Energy supplies	10	5	4	3	3

a) Using the factor-rating method, what is the recommended site for Eagle Electronics's new facility?

b) For what range of values for the weight (currently $w_7 = 10$) does the site given as the answer to part (a) remain a recommended site?

•••• **8.25** The EU has made changes in airline regulation that dramatically affect major European carriers such as British International Air (BIA), KLM, Air France, Alitalia, and Swiss International Air. With ambitious expansion plans, BIA has decided it needs a second service hub on the continent, to complement its large Heathrow (London) repair facility. The location selection is critical, and with the potential for 4,000 new skilled blue-collar jobs on the line, virtually every city in western Europe is actively bidding for BIA's business.

After initial investigations by Holmes Miller, head of the Operations Department, BIA has narrowed the list to 9 cities. Each is then rated on 12 factors, as shown in the table below.

a) Help Miller rank the top three cities that BIA should consider as its new site for servicing aircraft.

b) After further investigation, Miller decides that an existing set of hangar facilities for repairs is not nearly as important as earlier thought. If he lowers the weight of that factor to 30, does the ranking change?

c) After Miller makes the change in part (b), Germany announces it has reconsidered its offer of financial incentives, with an additional 200-million-euro package to entice BIA. Accordingly, BIA has raised Germany's rating to 10 on that factor. Is there any change in top rankings in part (b)? Px

Additional problems **8.26–8.34** *are available in* MyOMLab.

DATA FOR PROBLEM 8.25		LOCATION								
		ITALY			FRANCE			GERMANY		
FACTOR	IMPORTANCE WEIGHT	MILAN	ROME	GENOA	PARIS	LYON	NICE	MUNICH	BONN	BERLIN
Financial incentives	85	8	8	8	7	7	7	7	7	7
Skilled labor pool	80	4	6	5	9	9	7	10	8	9
Existing facility	70	5	3	2	9	6	5	9	9	2
Wage rates	70	9	8	9	4	6	6	4	5	5
Competition for jobs	70	7	3	8	2	8	7	4	8	9
Ease of air traffic access	65	5	4	6	2	8	8	4	8	9
Real estate cost	40	6	4	7	4	6	6	3	4	5
Communication links	25	6	7	6	9	9	9	10	9	8
Attractiveness to relocating executives	15	4	8	3	9	6	6	2	3	3
Political considerations	10	6	6	6	8	8	8	8	8	8
Expansion possibilities	10	10	2	8	1	5	4	4	5	6
Union strength	10	1	1	1	5	5	5	6	6	6

CASE STUDIES

Southern Recreational Vehicle Company

In October 2015, the top management of Southern Recreational Vehicle Company of St. Louis, Missouri, announced its plans to relocate its manufacturing and assembly operations to a new plant in Ridgecrest, Mississippi. The firm, a major producer of pickup campers and camper trailers, had experienced 5 consecutive years of declining profits as a result of spiraling production costs. The costs of labor and raw materials had increased alarmingly, utility costs had gone up sharply, and taxes and transportation expenses had steadily climbed upward. Despite increased sales, the company suffered its first net loss since operations were begun in 1982.

When management initially considered relocation, it closely scrutinized several geographic areas. Of primary importance to the relocation decision were the availability of adequate transportation facilities, state and municipal tax structures, an adequate labor supply, positive community attitudes, reasonable site costs, and financial inducements. Although several communities offered essentially the same incentives, the management of Southern Recreational Vehicle Company was favorably impressed by the efforts of the Mississippi Power and Light Company to attract "clean, labor-intensive" industry and the enthusiasm exhibited by state and local officials, who actively sought to bolster the state's economy by enticing manufacturing firms to locate within its boundaries.

Two weeks prior to the announcement, management of Southern Recreational Vehicle Company finalized its relocation plans. An existing building in Ridgecrest's industrial park was selected (the physical facility had previously housed a mobile home manufacturer that had gone bankrupt due to inadequate financing and poor management); initial recruiting was begun through the state employment office; and efforts to lease or sell the St. Louis property were initiated. Among the inducements offered Southern Recreational Vehicle Company to locate in Ridgecrest were:

1. Exemption from county and municipal taxes for 5 years
2. Free water and sewage services
3. Construction of a second loading dock—free of cost—at the industrial site
4. An agreement to issue $500,000 in industrial bonds for future expansion
5. Public-financed training of workers in a local industrial trade school

In addition to these inducements, other factors weighed heavily in the decision to locate in the small Mississippi town. Labor costs would be significantly less than those incurred in St. Louis; organized labor was not expected to be as powerful (Mississippi is a right-to-work state); and utility costs and taxes would be moderate. All in all, the management of Southern Recreational Vehicle Company felt that its decision was sound.

On October 15, the following announcement was attached to each employee's paycheck:

> To: Employees of Southern Recreational Vehicle Company
>
> From: Gerald O'Brian, President
>
> The Management of Southern Recreational Vehicle Company regretfully announces its plans to cease all manufacturing operations in St. Louis on December 31. Because of increased operating costs and the unreasonable demands forced upon the company by the union, it has become impossible to operate profitably. I sincerely appreciate the fine service that each of you has rendered to the company during the past years. If I can be of assistance in helping you find suitable employment with another firm, please let me know. Thank you again for your cooperation and past service.

Discussion Questions

1. Evaluate the inducements offered Southern Recreational Vehicle Company by community leaders in Ridgecrest, Mississippi.
2. What problems would a company experience in relocating its executives from a heavily populated industrialized area to a small rural town?
3. Evaluate the reasons cited by O'Brian for relocation. Are they justifiable?
4. What legal and ethical responsibilities does a firm have to its employees when a decision to cease operations is made?

Source: Reprinted by permission of Professor Jerry Kinard, Western Carolina University.

Locating the Next Red Lobster Restaurant

Video Case

From its first Red Lobster in 1968, the chain has grown to 705 locations, with over $2.6 billion in U.S. sales annually. The casual dining market may be crowded, with competitors such as Chili's, Ruby Tuesday, Applebee's, TGI Friday's, and Outback, but Red Lobster's continuing success means the chain thinks there is still plenty of room to grow. Robert Reiner, director of market development, is charged with identifying the sites that will maximize new store sales without cannibalizing sales at the existing Red Lobster locations.

Characteristics for identifying a good site have not changed in 40 years; they still include real estate prices, customer age, competition, ethnicity, income, family size, population density, nearby hotels, and buying behavior, to name just a few. What *has* changed is the powerful software that allows Reiner to analyze a new site in 5 minutes, as opposed to the 8 hours he spent just a few years ago.

Red Lobster has partnered with MapInfo Corp., whose geographic information system (GIS) contains a powerful module for analyzing a trade area (see the discussion of GIS in the chapter). With the U.S. geo-coded down to the individual block, MapInfo allows Reiner to create a psychographic profile of existing and potential Red Lobster trade areas. "We can now target areas with greatest sales potential," says Reiner.

The U.S. is segmented into 72 "clusters" of customer profiles by MapInfo. If, for example, cluster #7, Equestrian Heights (see MapInfo description below), represents 1.7% of a household base within a Red Lobster trade area, but this segment also accounts for 2.4% of sales, Reiner computes that this segment is effectively spending 1.39 times more than average (Index = 2.4/1.7) and adjusts his analysis of a new site to reflect this added weight.

CLUSTER	PSYTE 2003	SNAP SHOT DESCRIPTION
7	Equestrian Heights	They may not have a stallion in the barn, but they likely pass a corral on the way home. These families with teens live in older, larger homes adjacent to, or between, suburbs but not usually tract housing. Most are married with teenagers, but 40% are empty nesters. They use their graduate and professional school education—56% are dual earners. Over 90% are white, non-Hispanic. Their mean family income is $99,000, and they live within commuting distance of central cities. They have white-collar jobs during the week but require a riding lawn mower to keep the place up on weekends.

When Reiner maps the U.S., a state, or a region for a new site, he wants one that is at least 3 miles from the nearest Red Lobster and won't negatively impact its sales by more than 8%; MapInfo pinpoints the best spot. The software also recognizes the nearness of non-Red Lobster competition and assigns a probability of success (as measured by reaching sales potential).

The specific spot selected depends on Red Lobster's seven real estate brokers, whose list of considerations include proximity to a vibrant retail area, proximity to a freeway, road visibility, nearby hotels, and a corner location at a primary intersection.

"Picking a new Red Lobster location is one of the most critical functions we can do," says Reiner. "And the software we use serves as an independent voice in assessing the quality of an existing or proposed location."

Discussion Questions*

1. Visit the Web site for PSTYE 2003 (**www.gemapping.com/downloads/targetpro_brochure.pdf**). Describe the psychological profiling (PSYTE) clustering system. Select an industry, other than restaurants, and explain how the software can be used for that industry.
2. What are the major differences in site location for a restaurant versus a retail store versus a manufacturing plant?
3. Red Lobster also defines its trade areas based on market size and population density. Here are its seven density classes:

DENSITY CLASS	DESCRIPTION	HOUSEHOLDS PER SQ. MILE
1	Super Urban	8,000+
2	Urban	4,000–7,999
3	Light Urban	2,000–3,999
4	First Tier Suburban	1,000–1,999
5	Second Tier Suburban	600–999
6	Exurban/Small	100–599
7	Rural	0–99

Note: Density classes are based on the households and land area within 3 miles of the geography (e.g., census tract) using population-weighted centroids.

The majority (92%) of the Red Lobster restaurants fall into three of these classes. Which three classes do you think the chain has the most restaurants in? Why?

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

Where to Place the Hard Rock Cafe

Video Case

Some people would say that Oliver Munday, Hard Rock's vice president for cafe development, has the best job in the world. Travel the world to pick a country for Hard Rock's next cafe, select a city, and find the ideal site. It's true that selecting a site involves lots of incognito walking around, visiting nice restaurants, and drinking in bars. But that is not where Mr. Munday's work begins, nor where it ends. At the front end, selecting the country and city first involves a great deal of research. At the back end, Munday not only picks the final site and negotiates the deal but then works with architects and planners and stays with the project through the opening and first year's sales.

Munday is currently looking heavily into global expansion in Europe, Latin America, and Asia. "We've got to look at political risk, currency, and social norms—how does our brand fit into the country," he says. Once the country is selected, Munday focuses on the region and city. His research checklist is extensive, as seen in the accompanying table.

Site location now tends to focus on the tremendous resurgence of "city centers," where nightlife tends to concentrate. That's what Munday selected in Moscow and Bogota, although in both locations he chose to find a local partner and franchise the operation. In these two political environments, "Hard Rock wouldn't dream of operating by ourselves," says Munday. The location decision also is at least a 10- to 15-year commitment by Hard Rock, which employs tools such as locational cost–volume

Hard Rock's Standard Market Report (for offshore sites)

A. Demographics (local, city, region, SMSA), with trend analysis
   1. Population of area
   2. Economic indicators

B. Visitor market, with trend analysis
   1. Tourists/business visitors
   2. Hotels
   3. Convention center
   4. Entertainment
   5. Sports
   6. Retail

C. Transportation
   1. Airport ← subcategories include: (a) age of airport (b) no. of passengers (c) airlines (d) direct flights (e) hubs
   2. Rail
   3. Road
   4. Sea/river

D. Restaurants and nightclubs (a selection in key target market areas)

E. Political risk

F. Real estate market

G. Hard Rock Cafe comparable market analysis

analysis to help decide whether to purchase land and build, or to remodel an existing facility.

Currently, Munday is considering four European cities for Hard Rock's next expansion. Although he could not provide the names, for competitive reasons, the following is known:

FACTOR	EUROPEAN CITY UNDER CONSIDERATION				IMPORTANCE OF THIS FACTOR AT THIS TIME
	A	B	C	D	
A. Demographics	70	70	60	90	20
B. Visitor market	80	60	90	75	20
C. Transportation	100	50	75	90	20
D. Restaurants/ nightclubs	80	90	65	65	10
E. Low political risk	90	60	50	70	10
F. Real estate market	65	75	85	70	10
G. Comparable market analysis	70	60	65	80	10

Discussion Questions*

1. From Munday's Standard Market Report checklist, select any other four categories, such as population (A1), hotels (B2), or restaurants/nightclubs (D), and provide three subcategories that should be evaluated. (See item C1 [airport] for a guide.)
2. Which is the highest rated of the four European cities under consideration, using the table?
3. Why does Hard Rock put such serious effort into its location analysis?
4. Under what conditions do you think Hard Rock prefers to franchise a cafe?

*You may wish to view the video case before answering the questions.

- **Additional Case Study:** Visit MyOMLab for this free case study:
  Southwestern University (E): The university faces three choices as to where to locate its football stadium.

Endnote

1. Equations (8-1) and (8-2) compute a center of gravity (COG) under "squared Euclidean" distances and may actually result in transportation costs slightly (less than 2%) higher than an *optimal* COG computed using "Euclidean" (straight-line) distances. The latter, however, is a more complex and involved procedure mathematically, so the formulas we present are generally used as an attractive substitute. See C. Kuo and R. E. White, "A Note on the Treatment of the Center-of-Gravity Method in Operations Management Textbooks," *Decision Sciences Journal of Innovative Education* 2: 219–227.

Chapter 8 *Rapid* Review

MyOMLab

Main Heading	Review Material	
THE STRATEGIC IMPORTANCE OF LOCATION (pp. 340–341)	Location has a major impact on the overall risk and profit of the company. Transportation costs alone can total as much as 25% of the product's selling price. When all costs are considered, location may alter total operating expenses as much as 50%. Companies make location decisions relatively infrequently, usually because demand has outgrown the current plant's capacity or because of changes in labor productivity, exchange rates, costs, or local attitudes. Companies may also relocate their manufacturing or service facilities because of shifts in demographics and customer demand. Location options include (1) expanding an existing facility instead of moving, (2) maintaining current sites while adding another facility elsewhere, and (3) closing the existing facility and moving to another location. For industrial location decisions, the location strategy is usually minimizing costs. For retail and professional service organizations, the strategy focuses on maximizing revenue. Warehouse location strategy may be driven by a combination of cost and speed of delivery. *The objective of location strategy is to maximize the benefit of location to the firm.* When innovation is the focus, overall competitiveness and innovation are affected by (1) the presence of high-quality and specialized inputs such as scientific and technical talent, (2) an environment that encourages investment and intense local rivalry, (3) pressure and insight gained from a sophisticated local market, and (4) local presence of related and supporting industries.	Concept Questions: 1.1–1.4 **VIDEO 8.1** Hard Rock's Location Selection
FACTORS THAT AFFECT LOCATION DECISIONS (pp. 341–344)	Globalization has taken place because of the development of (1) market economics; (2) better international communications; (3) more rapid, reliable travel and shipping; (4) ease of capital flow between countries; and (5) large differences in labor costs. Labor cost per unit is sometimes called the *labor content* of the product: Labor cost per unit = Labor cost per day ÷ Production (that is, units per day) Sometimes firms can take advantage of a particularly favorable exchange rate by relocating or exporting to (or importing from) a foreign country. ■ **Tangible costs**—Readily identifiable costs that can be measured with some precision. ■ **Intangible costs**—A category of location costs that cannot be easily quantified, such as quality of life and government. Many service organizations find that proximity to market is *the* primary location factor. Firms locate near their raw materials and suppliers because of (1) perishability, (2) transportation costs, or (3) bulk. ■ **Clustering**—Location of competing companies near each other, often because of a critical mass of information, talent, venture capital, or natural resources.	Concept Questions: 2.1–2.4 Problems: 8.1–8.4
METHODS OF EVALUATING LOCATION ALTERNATIVES (pp. 344–350)	■ **Factor-rating method**—A location method that instills objectivity into the process of identifying hard-to-evaluate costs. The six steps of the factor-rating method are: 1. Develop a list of relevant factors called *key success factors.* 2. Assign a weight to each factor to reflect its relative importance in the company's objectives. 3. Develop a scale for each factor (for example, 1 to 10 or 1 to 100 points). 4. Have management score each location for each factor, using the scale in step 3. 5. Multiply the score by the weight for each factor and total the score for each location. 6. Make a recommendation based on the maximum point score, considering the results of other quantitative approaches as well. ■ **Locational cost–volume analysis**—A method used to make an economic comparison of location alternatives. The three steps to locational cost–volume analysis are: 1. Determine the fixed and variable cost for each location. 2. Plot the costs for each location, with costs on the vertical axis of the graph and annual volume on the horizontal axis. 3. Select the location that has the lowest total cost for the expected production volume.	Concept Questions: 3.1–3.4 Problems: 8.5–8.34 Virtual Office Hours for Solved Problems: 8.1, 8.2 **ACTIVE MODEL 8.1**

MyOMLab

Main Heading	Review Material	MyOMLab
	■ **Center-of-gravity method**—A mathematical technique used for finding the best location for a single distribution point that services several stores or areas. The center-of-gravity method chooses the ideal location that minimizes the *weighted* distance between itself and the locations it serves, where the distance is weighted by the number of containers shipped, Q_i: $x\text{-coordinate of the center of gravity} = \sum_i x_i Q_i \div \sum_i Q_i$ (8-1) $y\text{-coordinate of the center of gravity} = \sum_i y_i Q_i \div \sum_i Q_i$ (8-2) ■ **Transportation model**—A technique for solving a class of linear programming problems. The transportation model determines the best pattern of shipments from several points of supply to several points of demand to minimize total production and transportation costs.	Virtual Office Hours for Solved Problem: 8.3
SERVICE LOCATION STRATEGY (pp. 350–351)	The eight major determinants of volume and revenue for the service firm are: 1. Purchasing power of the customer-drawing area 2. Service and image compatibility with demographics of the customer-drawing area 3. Competition in the area 4. Quality of the competition 5. Uniqueness of the firm's and competitors' locations 6. Physical qualities of facilities and neighboring businesses 7. Operating policies of the firm 8. Quality of management	Concept Questions: 4.1–4.4
GEOGRAPHIC INFORMATION SYSTEMS (pp. 351–353)	■ **Geographic information system (GIS)**—A system that stores and displays information that can be linked to a geographic location. Some of the geographic databases available in many GISs include (1) census data by block, tract, city, county, congressional district, metropolitan area, state, and zip code; (2) maps of every street, highway, bridge, and tunnel in the U.S.; (3) utilities such as electrical, water, and gas lines; (4) all rivers, mountains, lakes, and forests; and (5) all major airports, colleges, and hospitals.	Concept Questions: 5.1–5.4 **VIDEO 8.2** Locating the Next Red Lobster Restaurant

Self Test

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

LO 8.1 The factors involved in location decisions include
- **a)** foreign exchange.
- **b)** attitudes.
- **c)** labor productivity.
- **d)** all of the above.

LO 8.2 If Fender Guitar pays $30 per day to a worker in its Ensenada, Mexico, plant, and the employee completes four instruments per 8-hour day, the labor cost/unit is
- **a)** $30.00.
- **b)** $3.75.
- **c)** $7.50.
- **d)** $4.00.
- **e)** $8.00.

LO 8.3 Evaluating location alternatives by comparing their composite (weighted-average) scores involves
- **a)** factor-rating analysis.
- **b)** cost–volume analysis.
- **c)** transportation model analysis.
- **d)** linear regression analysis.
- **e)** crossover analysis.

LO 8.4 On the cost–volume analysis chart where the costs of two or more location alternatives have been plotted, the quantity at which two cost curves cross is the quantity at which:
- **a)** fixed costs are equal for two alternative locations.
- **b)** variable costs are equal for two alternative locations.
- **c)** total costs are equal for all alternative locations.
- **d)** fixed costs equal variable costs for one location.
- **e)** total costs are equal for two alternative locations.

LO 8.5 A regional bookstore chain is about to build a distribution center that is centrally located for its eight retail outlets. It will most likely employ which of the following tools of analysis?
- **a)** Assembly-line balancing
- **b)** Load–distance analysis
- **c)** Center-of-gravity model
- **d)** Linear programming
- **e)** All of the above

LO 8.6 What is the major difference in focus between location decisions in the service sector and in the manufacturing sector?
- **a)** There is no difference in focus.
- **b)** The focus in manufacturing is revenue maximization, while the focus in service is cost minimization.
- **c)** The focus in service is revenue maximization, while the focus in manufacturing is cost minimization.
- **d)** The focus in manufacturing is on raw materials, while the focus in service is on labor.

Answers: LO 8.1. d; LO 8.2. c; LO 8.3. a; LO 8.4. e; LO 8.5. c; LO 8.6. c.

Layout Strategies

CHAPTER 9

CHAPTER OUTLINE

Alaska Airlines

Alaska Airlines

10 OM STRATEGY DECISIONS

- Design of Goods and Services
- Managing Quality
- Process Strategy
- Location Strategies
- *Layout Strategies*
- Human Resources
- Supply-Chain Management
- Inventory Management
- Scheduling
- Maintenance

GLOBAL COMPANY PROFILE
McDonald's

McDonald's Looks for Competitive Advantage Through Layout

In its over half-century of existence, McDonald's has revolutionized the restaurant industry by inventing the limited-menu fast-food restaurant. It has also made seven major innovations. The first, the introduction of *indoor seating* (1950s), was a layout issue, as was the second, *drive-through windows* (1970s). The third, adding *breakfasts* to the menu (1980s), was a product strategy. The fourth, *adding play areas* (late 1980s), was again a layout decision.

In the 1990s, McDonald's completed its fifth innovation, a radically new *redesign of the kitchens* in its 14,000 North American outlets to facilitate a mass customization process. Dubbed the "Made by You" kitchen system, sandwiches were assembled to order with the revamped layout.

In 2004, the chain began the rollout of its sixth innovation, a new food ordering layout: the *self-service kiosk*. Self-service kiosks have been infiltrating the service sector since the introduction of ATMs in 1985 (there are over 1.5 million ATMs in banking). Alaska Airlines was the first airline to provide self-service airport check-in, in 1996. Most passengers of the major airlines now check themselves in for flights. Kiosks take up less space than an employee and reduce waiting line time.

Now, McDonald's is working on its seventh innovation, and not surprisingly, it also deals with restaurant layout. The company, on an unprecedented scale, is redesigning all 30,000 eateries around the globe to take on a *21st-century look*. The dining area will be separated into three sections with distinct personalities: (1) the "linger" zone focuses on young adults and offers

Rick Wilking/Corbis

McDonald's finds that kiosks reduce both space requirements and waiting; order taking is faster. An added benefit is that customers like them. Also, kiosks are reliable—they don't call in sick. And, most important, sales are up 10%–15% (an average of $1) when a customer orders from a kiosk, which consistently recommends the larger size and other extras.

Nancy Siesel/The New York Times/Redux

The redesigned kitchen of a McDonald's in Manhattan. The more efficient layout requires less labor, reduces waste, and provides faster service. A graphic of this "assembly line" is shown in Figure 9.11.

comfortable furniture and Wi-Fi connections; (2) the "grab and go" zone features tall counters, bar stools, and flat-screen TVs; and (3) the "flexible" zone has colorful family booths, flexible seating, and kid-oriented music. The cost per outlet: a whopping $300,000–$400,000 renovation fee.

As McDonald's has discovered, facility layout is indeed a source of competitive advantage.

ZUMA Press, Inc./Alamy

Flexible Zone

This area is geared for family and larger groups, with movable tables and chairs.

McDonald's Corporation

Grab & Go Zone

This section has tall counters with bar stools for customers who eat alone. Flat-screen TVs keep them company.

McDonald's Corporation

Linger Zone

Cozy booths, plus Wi-Fi connections, make these areas attractive to those who want to hang out and socialize.

LEARNING OBJECTIVES

The Strategic Importance of Layout Decisions

Layout is one of the key decisions that determines the long-run efficiency of operations. Layout has strategic implications because it establishes an organization's competitive priorities in regard to capacity, processes, flexibility, and cost, as well as quality of work life, customer contact, and image. An effective layout can help an organization achieve a strategy that supports differentiation, low cost, or response. Benetton, for example, supports a *differentiation* strategy by heavy investment in warehouse layouts that contribute to fast, accurate sorting and shipping to its 5,000 outlets. Walmart store layouts support a strategy of *low cost*, as do its warehouse layouts. Hallmark's office layouts, where many professionals operate with open communication in work cells, support *rapid development* of greeting cards. *The objective of layout strategy is to develop an effective and efficient layout that will meet the firm's competitive requirements*. These firms have done so.

In all cases, layout design must consider how to achieve the following:

- Higher utilization of space, equipment, and people
- Improved flow of information, materials, and people
- Improved employee morale and safer working conditions
- Improved customer/client interaction
- Flexibility (whatever the layout is now, it will need to change)

In our increasingly short-life-cycle, mass-customized world, layout designs need to be viewed as dynamic.This means considering small, movable, and flexible equipment. Store displays need to be movable, office desks and partitions modular, and warehouse racks prefabricated. To make quick and easy changes in product models and in production rates, operations managers must design flexibility into layouts. To obtain flexibility in layout, managers cross-train their workers, maintain equipment, keep investments low, place workstations close together, and use small, movable equipment. In some cases, equipment on wheels is appropriate, in anticipation of the next change in product, process, or volume.

Types of Layout

Layout decisions include the best placement of machines (in production settings), offices and desks (in office settings), or service centers (in settings such as hospitals or department stores). An effective layout facilitates the flow of materials, people, and information within and between areas. To achieve these objectives, a variety of approaches has been developed. We will discuss seven of them in this chapter:

1. *Office layout:* Positions workers, their equipment, and spaces/offices to provide for movement of information.
2. *Retail layout:* Allocates display space and responds to customer behavior.
3. *Warehouse layout:* Addresses trade-offs between space and material handling.
4. *Fixed-position layout:* Addresses the layout requirements of large, bulky projects such as ships and buildings.

TABLE 9.1 Layout Strategies

	OBJECTIVES	EXAMPLES
Office	Locate workers requiring frequent contact close to one another	Allstate Insurance Microsoft Corp.
Retail	Expose customer to high-margin items	Kroger's Supermarket Walgreens Bloomingdale's
Warehouse (storage)	Balance low-cost storage with low cost material handling	Federal-Mogul's warehouse The Gap's distribution center
Project (fixed position)	Move material to the limited storage areas around the site	Ingall Ship Building Corp. Trump Plaza Pittsburgh Airport
Job shop (process oriented)	Manage varied material flow for each product	Arnold Palmer Hospital Hard Rock Cafe Olive Garden
Work cell (product families)	Identify a product family, build teams, cross-train team members	Hallmark Cards Wheeled Coach Ambulances
Repetitive/continuous (product oriented)	Equalize the task time at each workstation	Sony's TV assembly line Toyota Scion

5. *Process-oriented layout:* Deals with low-volume, high-variety production (also called "job shop," or intermittent production).
6. *Work-cell layout:* Arranges machinery and equipment to focus on production of a single product or group of related products.
7. *Product-oriented layout:* Seeks the best personnel and machine utilization in repetitive or continuous production.

Examples for each of these classes of layouts are noted in Table 9.1.

Because only a few of these seven classes can be modeled mathematically, layout and design of physical facilities are still something of an art. However, we do know that a good layout requires determining the following:

- *Material handling equipment:* Managers must decide about equipment to be used, including conveyors, cranes, automated storage and retrieval systems, and automatic carts to deliver and store material.
- *Capacity and space requirements:* Only when personnel, machines, and equipment requirements are known can managers proceed with layout and provide space for each component. In the case of office work, operations managers must make judgments about the space requirements for each employee. They must also consider allowances for requirements that address safety, noise, dust, fumes, temperature, and space around equipment and machines.
- *Environment and aesthetics:* Layout concerns often require decisions about windows, planters, and height of partitions to facilitate air flow, reduce noise, and provide privacy.
- *Flows of information:* Communication is important to any organization and must be facilitated by the layout. This issue may require decisions about proximity, as well as decisions about open spaces versus half-height dividers versus private offices.
- *Cost of moving between various work areas:* There may be unique considerations related to moving materials or to the importance of having certain areas next to each other. For example, moving molten steel is more difficult than moving cold steel.

Office Layout

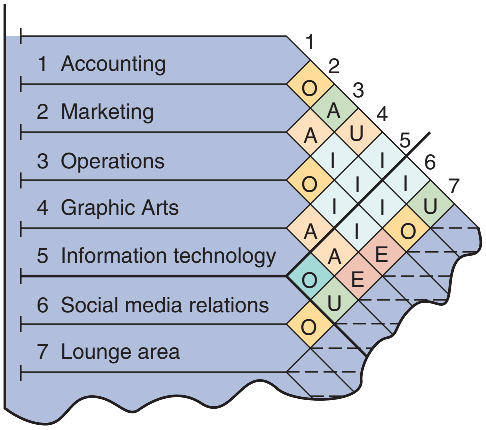
Office layouts require the grouping of workers, their equipment, and spaces to provide for comfort, safety, and movement of information. The main distinction of office layouts is the importance placed on the flow of information. Office layouts are in constant flux as the technological changes sweeping society alter the way offices function.

Office layout
The grouping of workers, their equipment, and spaces/offices to provide for comfort, safety, and movement of information.

Figure 9.1

Office Relationship Chart

The Muther Grid for a software firm.



Code	CLOSENESS
A	Absolutely necessary
E	Especially important
I	Important
O	Ordinary OK
U	Unimportant
X	Not desirable

LO 9.1 *Discuss* important issues in office layout

Even though the movement of information is increasingly electronic, analysis of office layouts still requires a task-based approach. Managers therefore examine both electronic and conventional communication patterns, separation needs, and other conditions affecting employee effectiveness. A useful tool for such an analysis is the *relationship chart* (also called a Muther Grid) shown in Figure 9.1. This chart, prepared for a software firm, indicates that operations must be near accounting and marketing, but it does not need to be near the graphic arts staff.

On the other hand, some layout considerations are universal (many of which apply to factories as well as to offices). They have to do with working conditions, teamwork, authority, and status. Should offices be private or open cubicles, have low file cabinets to foster informal communication or high cabinets to reduce noise and contribute to privacy?

Workspace can inspire informal and productive encounters if it balances three physical and social aspects[1]:

- *Proximity:* Spaces should naturally bring people together.
- *Privacy:* People must be able to control access to their conversations.
- *Permission:* The culture should signal that nonwork interactions are encouraged.

As a final comment on office layout, we note two major trends. First, technology, such as smart phones, scanners, the Internet, laptop computers, and tablets, allows increasing layout flexibility by moving information electronically and allowing employees to work offsite. Second, modern firms create dynamic needs for space and services.

Here are two examples:

- When Deloitte & Touche found that 30% to 40% of desks were empty at any given time, the firm developed its "hoteling programs." Consultants lost their permanent offices; anyone who plans to be in the building (rather than out with clients) books an office through a "concierge," who hangs that consultant's name on the door for the day and stocks the space with requested supplies.
- Cisco Systems cut rent and workplace service costs by 37% and saw productivity benefits of $2.4 billion per year by reducing square footage, reconfiguring space, creating movable, everything-on-wheels offices, and designing "get away from it all" innovation areas.

Retail Layout

Retail layout
An approach that addresses flow, allocates space, and responds to customer behavior.

Retail layouts are based on the idea that sales and profitability vary directly with customer exposure to products. Thus, most retail operations managers try to expose customers to as many products as possible. Studies do show that the greater the rate of exposure, the greater the sales and the higher the return on investment. The operations manager can change

Here are five versions of the office layout.

Everett Collection

Managers and architects have pondered how to design an office to encourage productivity for more than 100 years. In the early 20th century, large offices resembled factories (see the photo of the Jack Lemmon film *The Apartment*, where clerical workers sat in long rows, often performing repetitive tasks).

Starting in the 1960s, layouts changed to foster teamwork where managers and support staff sat together, and groupings were geared toward specific tasks.

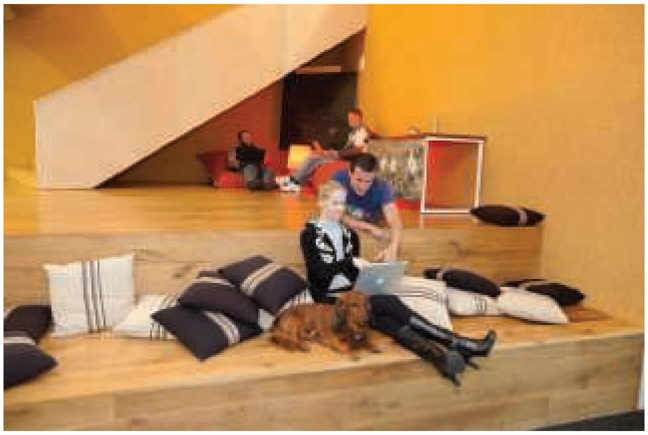
Courtesy of Herman Miller, Inc.

Chad McDermott/Fotolia

With computers, more individual work was possible and the “Cube Farm” era became ubiquitous through the ’80s and ’90s. An office full of high-walled cubicles offered both an open environment and personal office space.

By the turn of the century, looking for innovation and creativity to recruit and inspire college grads, technology firms created the “fun” office. Bright, casual, open office spaces, with amenities such as beanbag chairs, foosball tables, and coffee bars became the fad.

Monkey Business/Fotolia



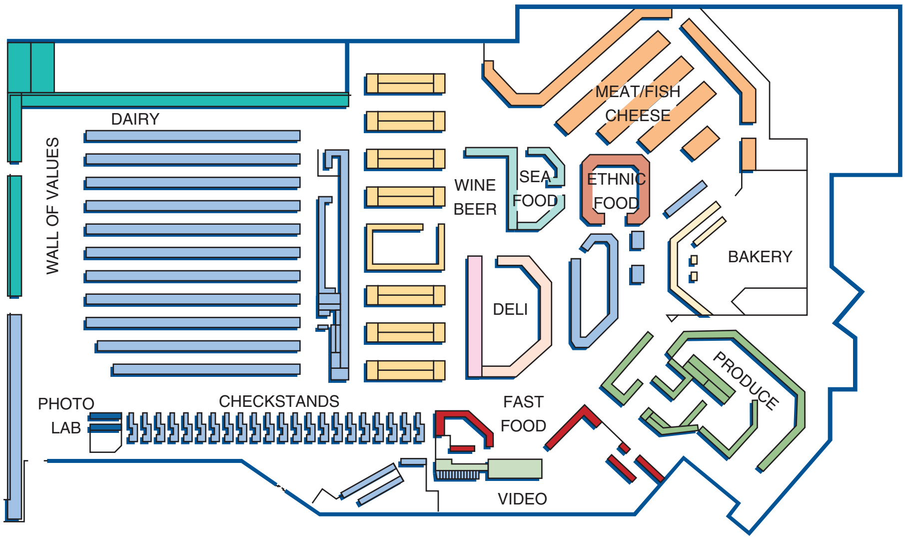
Amruth/Agencja Fotograficzna Caro/Alamy

The buzzwords today are serendipity and collaboration, as companies design office space to engineer encounters between employees. Steve Jobs designed his Pixar headquarters with the cafeteria and bathrooms in a central atrium away from work areas to encourage intermingling and collaboration. Skype achieves similar goals with open lounges.

Sources: Wall Street Journal (April 28, 2014); *USA Today* (Feb. 28, 2013); and *Harvard Business Review* (Oct. 2014).

Figure 9.2

Store Layout with Dairy and Bakery, High-Draw Items, in Different Areas of the Store



exposure with store arrangement and the allocation of space to various products within that arrangement.

Five ideas are helpful for determining the overall arrangement of many stores:

1. Locate the high-draw items around the periphery of the store. Thus, we tend to find dairy products on one side of a supermarket and bread and bakery products on another. An example of this tactic is shown in Figure 9.2.
2. Use prominent locations for high-impulse and high-margin items. Best Buy puts fast-growing, high-margin digital goods—such as cameras and printers—in the front and center of its stores.
3. Distribute what are known in the trade as "power items"—items that may dominate a purchasing trip—to both sides of an aisle, and disperse them to increase the viewing of other items.
4. Use end-aisle locations because they have a very high exposure rate.
5. Convey the mission of the store by carefully selecting the position of the lead-off department. For instance, if prepared foods are part of a supermarket's mission, position the bakery and deli up front to appeal to convenience-oriented customers. Walmart's push to increase sales of clothes means those departments are in broad view upon entering a store.

STUDENT TIP The goal in a retail layout is to maximize profit per square foot of store space.

LO 9.2 *Define* the objectives of retail layout

Once the overall layout of a retail store has been decided, products need to be arranged for sale. Many considerations go into this arrangement. However, the main *objective of retail layout is to maximize profitability per square foot of floor space* (or, in some stores, on linear foot of shelf space). Big-ticket, or expensive, items may yield greater dollar sales, but the profit per square foot may be lower. Computer programs are available to assist managers in evaluating the profitability of various merchandising plans for hundreds of categories: this technique is known as category management.

An additional, and somewhat controversial, issue in retail layout is called slotting. **Slotting fees** are fees manufacturers pay to get their goods on the shelf in a retail store or supermarket chain. The result of massive new-product introductions, retailers can now demand up to $25,000 to place an item in their chain. During the last decade, marketplace economics, consolidations, and technology have provided retailers with this leverage. The competition for shelf space is advanced by POS systems and scanner technology, which improve supply-chain management and inventory control. Many small firms question the legality and ethics of slotting fees, claiming the fees stifle new products, limit their ability to expand, and cost consumers money. Walmart is one of the few major retailers that does not demand slotting fees, removing a barrier to entry. (See the *Ethical Dilemma* at the end of this chapter.)

Slotting fees Fees manufacturers pay to get shelf space for their products.

Servicescapes

Although a major goal of retail layout is to maximize profit through product exposure, there are other aspects of the service that managers consider. The term **servicescape** describes the physical surroundings in which the service is delivered and how the surroundings have a humanistic effect on customers and employees. To provide a good service layout, a firm considers three elements:

Servicescape
The physical surroundings in which a service takes place, and how they affect customers and employees.

1. *Ambient conditions*, which are background characteristics such as lighting, sound, smell, and temperature. All these affect workers *and* customers and can affect how much is spent and how long a person stays in the building.
2. *Spatial layout and functionality*, which involve customer circulation path planning, aisle characteristics (such as width, direction, angle, and shelf spacing), and product grouping.
3. *Signs, symbols, and artifacts*, which are characteristics of building design that carry social significance (such as carpeted areas of a department store that encourage shoppers to slow down and browse).

Examples of each of these three elements of servicescape are:

- *Ambient conditions:* Fine-dining restaurants with linen tablecloths and candlelit atmosphere; Mrs. Field's Cookie bakery smells permeating the shopping mall; leather chairs at Starbucks.
- *Layout/functionality:* Kroger's long aisles and high shelves; Best Buy's wide center aisle.
- *Signs, symbols, and artifacts:* Walmart's greeter at the door; Hard Rock Cafe's wall of guitars; Disneyland's entrance looking like hometown heaven.

Warehouse and Storage Layouts

Warehouse layout
A design that attempts to minimize total cost by addressing trade-offs between space and material handling.

LO 9.3 *Discuss* modern warehouse management and terms such as ASRS, cross-docking, and random stocking

The objective of **warehouse layout** *is to find the optimum trade-off between handling cost and costs associated with warehouse space*. Consequently, management's task is to maximize the utilization of the total "cube" of the warehouse—that is, utilize its full volume while maintaining low material handling costs. We define *material handling costs* as all the costs related to the transaction. This consists of incoming transport, storage, and outgoing transport of the materials to be warehoused. These costs include equipment, people, material, supervision, insurance, and depreciation. Effective warehouse layouts do, of course, also minimize the damage and spoilage of material within the warehouse.

imageBROKER/Alamy

A critical element contributing to the bottom line at Hard Rock Cafe is the layout of each cafe's retail shop space. The retail space, from 600 to 1,300 square feet in size, is laid out in conjunction with the restaurant area to create the maximum traffic flow before and after eating. The payoffs for cafes like this one in London are huge. Almost half of a cafe's annual sales are generated from these small shops, which have very high retail sales per square foot.

OM in Action Amazon Lets Loose the Robots

Amazon's robot army is falling into place.The Seattle online retailer has outfitted several U.S. warehouses with over 10,000 short, orange, wheeled Kiva robots that move stocked shelves to workers, instead of having employees seek items amid long aisles of merchandise. This is similar to the introduction of the moving assembly line with cars moving down the line, rather than the employee moving from workstation to workstation.

At a 1.2-million-square-foot warehouse in Tracy, California, Amazon has replaced 4 floors of fixed shelving with the robots. Now, "pickers" at the facility stand in one place, and robots bring 4-foot-by-6-foot shelving units to them, sparing them what amounted to as much as 20 miles a day of walking through the warehouse. Employees at robot-equipped warehouses are now expected to pick and scan at least 300 items an hour, compared with 100 under the old system.

At the heart of the robot rollout is Amazon's relentless drive to compete with the immediacy of shopping at brick-and-mortar retailers by improving the efficiency of its logistics. If Amazon can shrink the time it takes to sort and pack goods at its 80 U.S. warehouses, it can guarantee same-day or overnight delivery for more products to more customers.

Noah Berger/Reuters

The robots save Amazon $400–$900 million a year in fulfillment costs by reducing the number of times a product is "touched." The Kiva robots pare 20% to 40% from the average $3.50-to-$3.75 cost of sorting, picking, and boxing an order.

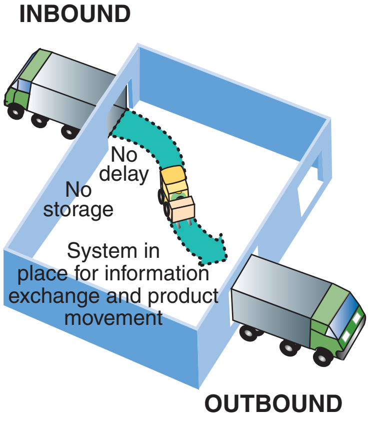
Sources: The Wall Street Journal (Nov. 20, 2014) and (Dec. 9, 2013).

STUDENT TIP
In warehouse layout, we want to maximize use of the whole building—from floor to ceiling.

Management minimizes the sum of the resources spent on finding and moving material plus the deterioration and damage to the material itself. The variety of items stored and the number of items "picked" has direct bearing on the optimum layout. A warehouse storing a few unique items lends itself to higher density than a warehouse storing a variety of items. Modern warehouse management is, in many instances, an automated procedure using *automated storage and retrieval systems* (ASRSs).

The Stop & Shop grocery chain, with 350 supermarkets in New England, has recently completed the largest ASRS in the world. The 1.3-million-square-foot distribution center in Freetown, Massachusetts, employs 77 rotating-fork automated storage and retrieval machines. These 77 ASRS machines each access 11,500 pick slots on 90 aisles—a total of 64,000 pallets of food. The *OM in Action* box, "Amazon Lets Loose the Robots," shows another way that technology can help minimize warehouse costs.

An important component of warehouse layout is the relationship between the receiving/unloading area and the shipping/loading area. Facility design depends on the type of supplies unloaded, what they are unloaded from (trucks, rail cars, barges, and so on), and where they are unloaded. In some companies, the receiving and shipping facilities, or *docks*, as they are called, are even in the same area; sometimes they are receiving docks in the morning and shipping docks in the afternoon.



Cross-Docking

Cross-docking means to avoid placing materials or supplies in storage by processing them as they are received. In a manufacturing facility, product is received directly by the assembly line. In a distribution center, labeled and presorted loads arrive at the shipping dock for immediate rerouting, thereby avoiding formal receiving, stocking/storing, and order-selection activities. Because these activities add no value to the product, their elimination is 100% cost savings. Walmart, an early advocate of cross-docking, uses the technique as a major component of its continuing low-cost strategy. With cross-docking, Walmart reduces distribution costs and speeds restocking of stores, thereby improving customer service. Although cross-docking reduces product handling, inventory, and facility costs, it requires both (1) tight scheduling and (2) accurate inbound product identification.

Cross-docking
Avoiding the placement of materials or supplies in storage by processing them as they are received for shipment.

Random Stocking

Automatic identification systems (AISs), usually in the form of bar codes, allow accurate and rapid item identification. When automatic identification systems are combined with effective management information systems, operations managers know the quantity and location of every unit. This information can be used with human operators or with automatic storage and retrieval systems to load units anywhere in the warehouse—randomly. Accurate inventory quantities and locations mean the potential utilization of the whole facility because space does not need to be reserved for certain stock-keeping units (SKUs) or part families. Computerized **random stocking** systems often include the following tasks:

Random stocking
Used in warehousing to locate stock wherever there is an open location.


Andrew Hetherington/Redux

At Ikea's distribution center in Almhult, Sweden, pallets are stacked and retrieved through a fully automated process.

1. Maintaining a list of "open" locations
2. Maintaining accurate records of existing inventory and its locations
3. Sequencing items to minimize the travel time required to "pick" orders
4. Combining orders to reduce picking time
5. Assigning certain items or classes of items, such as high-usage items, to particular warehouse areas so that the total distance traveled within the warehouse is minimized

Random stocking systems can increase facility utilization and decrease labor cost, but they require accurate records.

Customizing

Although we expect warehouses to store as little product as possible and hold it for as short a time as possible, we are now asking warehouses to customize products. Warehouses can be places where value is added through **customizing**. Warehouse customization is a particularly useful way to generate competitive advantage in markets where products have multiple configurations. For instance, a warehouse can be a place where computer components are put together, software loaded, and repairs made. Warehouses may also provide customized labeling and packaging for retailers so items arrive ready for display.

Customizing
Using warehousing to add value to a product through component modification, repair, labeling, and packaging.

Increasingly, this type of work goes on adjacent to major airports, in facilities such as the FedEx terminal in Memphis. Adding value at warehouses adjacent to major airports also facilitates overnight delivery. For example, if your computer has failed, the replacement may be sent to you from such a warehouse for delivery the next morning. When your old machine arrives back at the warehouse, it is repaired and sent to someone else. These value-added activities at "quasi-warehouses" contribute to strategies of differentiation, low cost, and rapid response.

Fixed-Position Layout

In a **fixed-position layout**, the project remains in one place, and workers and equipment come to that one work area. Examples of this type of project are a ship, a highway, a bridge, a house, and an operating table in a hospital operating room.

Fixed-position layout
A system that addresses the layout requirements of stationary projects.

The techniques for addressing the fixed-position layout are complicated by three factors. First, there is limited space at virtually all sites. Second, at different stages of a project, different materials are needed; therefore, different items become critical as the project develops. Third, the volume of materials needed is dynamic. For example, the rate of use of steel panels for the hull of a ship changes as the project progresses.

Here are three versions of the fixed-position layout.

Craig Ruttle/AP Images

A house built via traditional fixed-position layout would be constructed onsite, with equipment, materials, and workers brought to the site. Then a "meeting of the trades" would assign space for various time periods. However, the home pictured here can be built at a much lower cost. The house is built in two movable modules in a factory. Scaffolding and hoists make the job easier, quicker, and cheaper, and the indoor work environment aids labor productivity.

Dick Blume/The Image Works

A service example of a fixed-position layout is an operating room; the patient remains stationary on the table, and medical personnel and equipment are brought to the site.

Tim Altevogt/Reuters/Corbis

In shipbuilding, there is limited space next to the fixed-position layout. Shipyards call these loading areas platens, and they are assigned for various time periods to each contractor.

LO 9.4 *Identify* when fixed-position layouts are appropriate

Because problems with fixed-position layouts are so difficult to solve well onsite, an alternative strategy is to complete as much of the project as possible offsite. This approach is used in the shipbuilding industry when standard units—say, pipe-holding brackets—are assembled on a nearby assembly line (a product-oriented facility). In an attempt to add efficiency to shipbuilding, Ingall Ship Building Corporation has moved toward product-oriented production when sections of a ship (modules) are similar or when it has a contract to build the same section of several similar ships. Also, as the first photo on this page shows, many home builders are moving from a fixed-position layout strategy to one that is more product oriented. About one-third of all new homes in the U.S. are built this way. In addition, many houses that are built onsite (fixed position) have the majority of components such as doors, windows, fixtures, trusses, stairs, and wallboard built as modules in more efficient offsite processes.

Process-Oriented Layout

Process-oriented layout
A layout that deals with low-volume, high-variety production in which like machines and equipment are grouped together.

A **process-oriented layout** can simultaneously handle a wide variety of products or services. This is the traditional way to support a product differentiation strategy. It is most efficient when making products with different requirements or when handling customers, patients, or clients with different needs. A process-oriented layout is typically the low-volume, high-variety strategy discussed in Chapter 7. In this job-shop environment, each product or each small group of products undergoes a different sequence of operations. A product or small order is produced

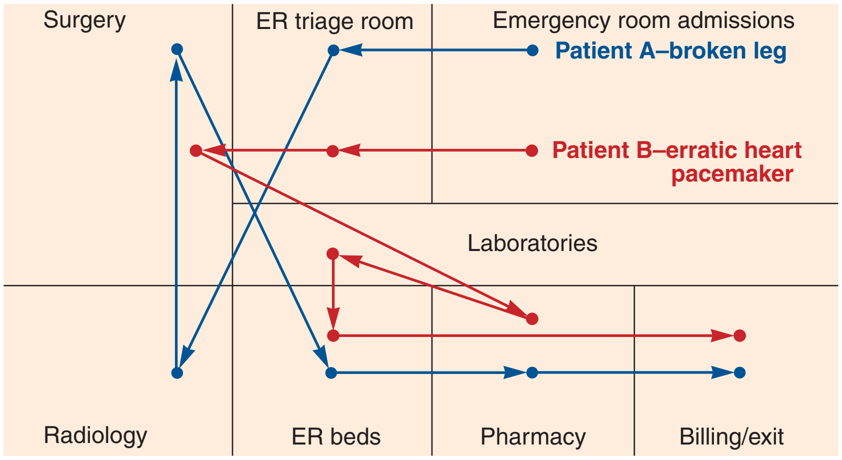


Figure 9.3

An Emergency Room Process Layout Showing the Routing of Two Patients

STUDENT TIP

Patient A (broken leg) proceeds (blue arrow) to ER triage, to radiology, to surgery, to a bed, to pharmacy, to billing. Patient B (pacemaker problem) moves (red arrow) to ER triage, to surgery, to pharmacy, to lab, to a bed, to billing.

by moving it from one department to another in the sequence required for that product. A good example of the process-oriented layout is a hospital or clinic. Figure 9.3 illustrates the process for two patients, A and B, at an emergency clinic in Chicago. An inflow of patients, each with his or her own needs, requires routing through admissions, laboratories, operating rooms, radiology, pharmacies, nursing beds, and so on. Equipment, skills, and supervision are organized around these processes.

VIDEO 9.1
Laying Out Arnold Palmer Hospital's New Facility

A big advantage of process-oriented layout is its flexibility in equipment and labor assignments. The breakdown of one machine, for example, need not halt an entire process; work can be transferred to other machines in the department. Process-oriented layout is also especially good for handling the manufacture of parts in small batches, or **job lots**, and for the production of a wide variety of parts in different sizes or forms.

Job lots
Groups or batches of parts processed together.

The disadvantages of process-oriented layout come from the general-purpose use of the equipment. Orders take more time to move through the system because of difficult scheduling, changing setups, and unique material handling. In addition, general-purpose equipment requires high labor skills, and work-in-process inventories are higher because of imbalances in the production process. High labor-skill needs also increase the required level of training and experience, and high work-in-process levels increase capital investment.

LO 9.5 *Explain* how to achieve a good process-oriented facility layout

When designing a process layout, the most common tactic is to arrange departments or work centers so as to minimize the costs of material handling. In other words, departments with large flows of parts or people between them should be placed next to one another. Material handling costs in this approach depend on (1) the number of loads (or people) to be moved between two departments during some period of time and (2) the distance-related costs of moving loads (or people) between departments. Cost is assumed to be a function of distance between departments. The objective can be expressed as follows:

$$\text{Minimize cost} = \sum_{i=1}^{n}\sum_{j=1}^{n} X_{ij}C_{ij} \qquad (9\text{-}1)$$

where n = total number of work centers or departments
i, j = individual departments
X_{ij} = number of loads moved from department i to department j
C_{ij} = cost to move a load between department i and department j

Process-oriented facilities (and fixed-position layouts as well) try to minimize loads, or trips, multiplied by distance-related costs. The term C_{ij} combines distance and other costs into one factor. We thereby assume not only that the difficulty of movement is equal but also that the pickup and setdown costs are constant. Although they are not always constant, for simplicity's sake we summarize these data (that is, distance, difficulty, and pickup and setdown costs) in this one variable, cost. The best way to understand the steps involved in designing a process layout is to look at an example.

Example 1

DESIGNING A PROCESS LAYOUT

Walters Company management wants to arrange the six departments of its factory in a way that will minimize interdepartmental material-handling costs. They make an initial assumption (to simplify the problem) that each department is 20 × 20 feet and that the building is 60 feet long and 40 feet wide.

APPROACH AND SOLUTION ▶ The process layout procedure that they follow involves six steps:

Step 1: *Construct a "from–to matrix"* showing the flow of parts or materials from department to department (see Figure 9.4).

Figure **9.4**

Interdepartmental Flow of Parts

STUDENT TIP The high flows between 1 and 3 and between 3 and 6 are immediately apparent. Departments 1, 3, and 6, therefore, should be close together.

Number of loads per week

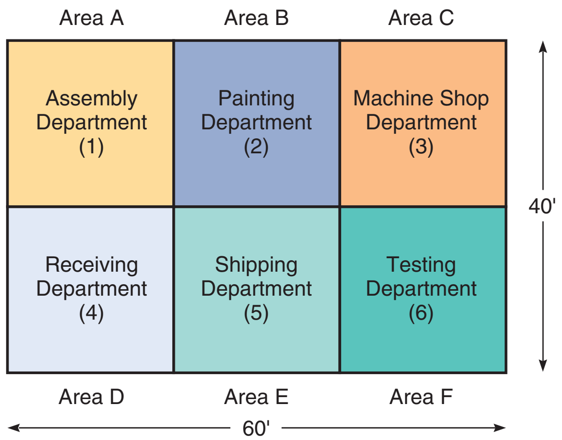
Department	Assembly (1)	Painting (2)	Machine Shop (3)	Receiving (4)	Shipping (5)	Testing (6)
Assembly (1)		50	100	0	0	20
Painting (2)			30	50	10	0
Machine Shop (3)				20	0	100
Receiving (4)					50	0
Shipping (5)						0
Testing (6)						

Step 2: *Determine the space requirements* for each department. (Figure 9.5 shows available plant space.)

Figure **9.5**

Building Dimensions and One Possible Department Layout

STUDENT TIP Think of this as a starting, initial, layout. Our goal is to improve it, if possible.

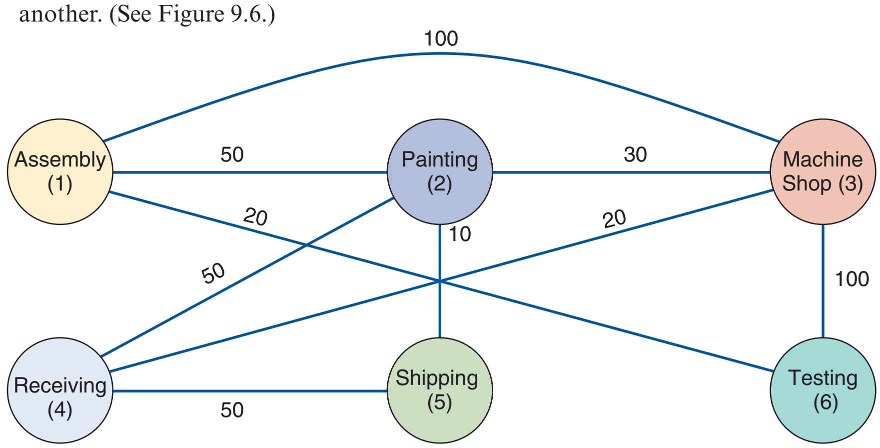


Step 3: *Develop an initial schematic diagram* showing the sequence of departments through which parts must move. Try to place departments with a heavy flow of materials or parts next to one another. (See Figure 9.6.)

Figure **9.6**

Interdepartmental Flow Graph Showing Number of Weekly Loads

STUDENT TIP This shows that 100 loads also move weekly between Assembly and the Machine Shop. We will probably want to move these two departments closer to one another to minimize the flow of parts through the factory.



Step 4: *Determine the cost of this layout* by using the material-handling cost equation:

$$\text{Cost} = \sum_{i=1}^{n}\sum_{j=1}^{n} X_{ij}C_{ij}$$

For this problem, Walters Company assumes that a forklift carries all interdepartmental loads. The cost of moving one load between adjacent departments is estimated to be $1. Moving a load between nonadjacent departments costs $2. Looking at Figures 9.4 and 9.5, we thus see that the handling cost between departments 1 and 2 is $50 ($1 × 50 loads), $200 between departments 1 and 3 ($2 × 100 loads), $40 between departments 1 and 6 ($2 × 20 loads), and so on. Work areas that are diagonal to one another, such as 2 and 4, are treated as adjacent. The total cost for the layout shown in Figure 9.6 is:

$$\begin{aligned}\text{Cost} &= \underset{(1\text{ and }2)}{\$50} + \underset{(1\text{ and }3)}{\$200} + \underset{(1\text{ and }6)}{\$40} + \underset{(2\text{ and }3)}{\$30} + \underset{(2\text{ and }4)}{\$50}\\ &\quad + \underset{(2\text{ and }5)}{\$10} + \underset{(3\text{ and }4)}{\$40} + \underset{(3\text{ and }6)}{\$100} + \underset{(4\text{ and }5)}{\$50}\\ &= \$570\end{aligned}$$

Step 5: By trial and error (or by a more sophisticated computer program approach that we discuss shortly), *try to improve the layout* pictured in Figure 9.5 to establish a better arrangement of departments.

By looking at both the flow graph (Figure 9.6) and the cost calculations, we see that placing departments 1 and 3 closer together appears desirable. They currently are nonadjacent, and the high volume of flow between them causes a large handling expense. Looking the situation over, we need to check the effect of shifting departments and possibly raising, instead of lowering, overall costs.

One possibility is to switch departments 1 and 2. This exchange produces a second departmental flow graph (Figure 9.7), which shows a reduction in cost to $480, a savings in material handling of $90:

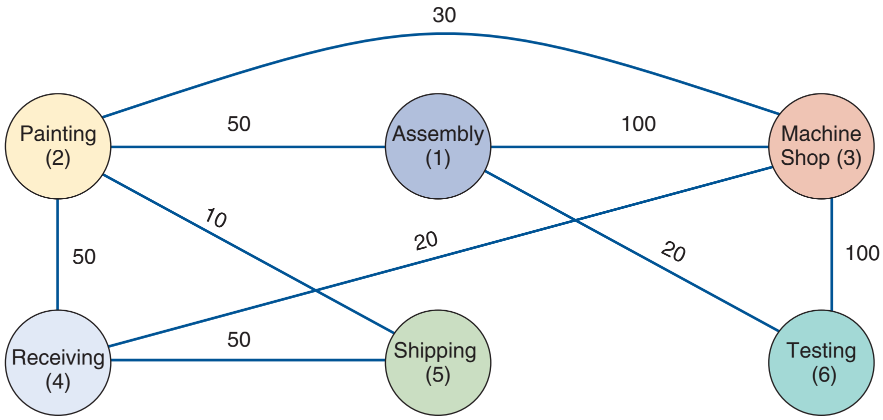
$$\begin{aligned}\text{Cost} &= \underset{(1\text{ and }2)}{\$50} + \underset{(1\text{ and }3)}{\$100} + \underset{(1\text{ and }6)}{\$20} + \underset{(2\text{ and }3)}{\$60} + \underset{(2\text{ and }4)}{\$50}\\ &\quad + \underset{(2\text{ and }5)}{\$10} + \underset{(3\text{ and }4)}{\$40} + \underset{(3\text{ and }6)}{\$100} + \underset{(4\text{ and }5)}{\$50}\\ &= \$480\end{aligned}$$

Figure 9.7

Second Interdepartmental Flow Graph

STUDENT TIP

Notice how Assembly and Machine Shop are now adjacent. Testing stayed close to the Machine Shop also.



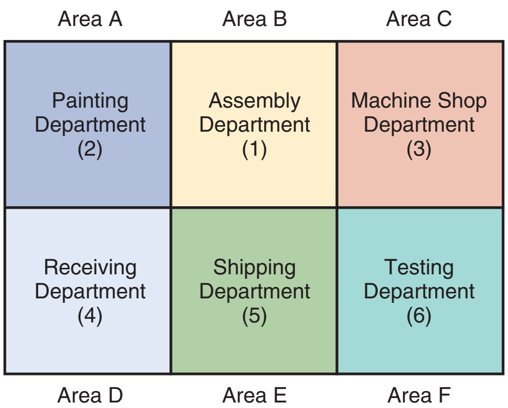
Suppose Walters Company is satisfied with the cost figure of $480 and the flow graph of Figure 9.7. The problem may not be solved yet. Often, a sixth step is necessary:

Step 6: *Prepare a detailed plan* arranging the departments to fit the shape of the building and its nonmovable areas (such as the loading dock, washrooms, and stairways). Often this step involves ensuring that the final plan can be accommodated by the electrical system, floor loads, aesthetics, and other factors.

In the case of Walters Company, space requirements are a simple matter (see Figure 9.8).

Figure 9.8

A Feasible Layout for Walters Company



STUDENT TIP

Here we see the departments moved to areas A–F to try to improve the flow.

INSIGHT ▶ This switch of departments is only one of a large number of possible changes. For a six-department problem, there are actually 720 (or $6! = 6 \times 5 \times 4 \times 3 \times 2 \times 1$) potential arrangements! In layout problems, we may not find the optimal solution and may have to be satisfied with a "reasonable" one.

LEARNING EXERCISE ▶ Can you improve on the layout in Figures 9.7 and 9.8? [Answer: Yes, it can be lowered to $430 by placing Shipping in area A, Painting in area B, Assembly in area C, Receiving in area D (no change), Machine Shop in area E, and Testing in area F (no change).]

RELATED PROBLEMS ▶ 9.1–9.9 (9.10 is available in MyOMLab)

EXCEL OM Data File **Ch09Ex1.xls** can be found in MyOMLab.

ACTIVE MODEL 9.1 Example 1 is further illustrated in Active Model 9.1 in MyOMLab.

Computer Software for Process-Oriented Layouts

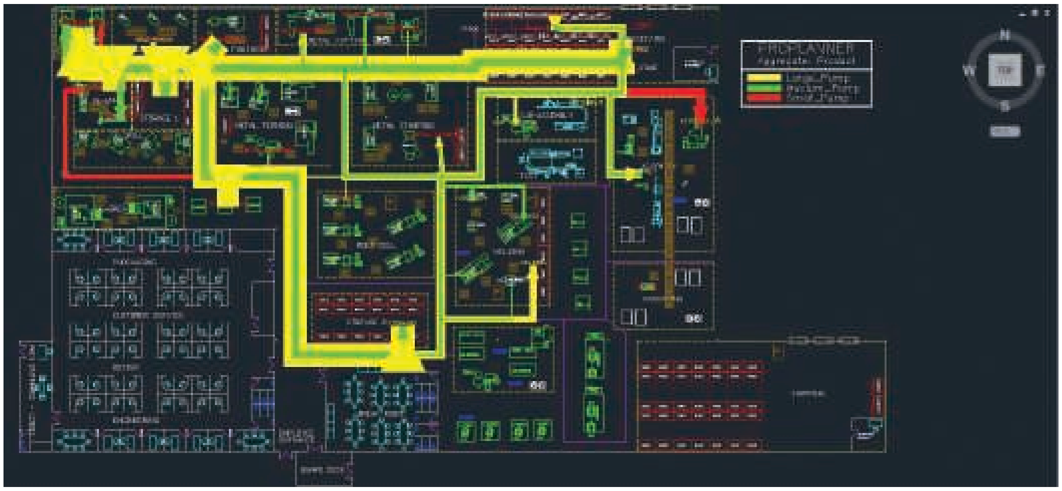
The graphic approach in Example 1 is fine for small problems. It does not, however, suffice for larger problems. When 20 departments are involved in a layout problem, more than 600 *trillion* different department configurations are possible. Fortunately, computer programs have been written to handle large layouts. These programs (see the Flow Path Calculator graphic on the next page) often add sophistication with flowcharts, multiple-story capability, storage and container placement, material volumes, time analysis, and cost comparisons. These programs tend to be interactive—that is, require participation by the user. And most only claim to provide "good," not "optimal," solutions.

Julian Stratenschulte/picture-alliance/dpa/AP Images

Siemens Corp. software such as this allows operations managers to quickly place factory equipment for a full three-dimensional view of the layout. Such presentations provide added insight into the issues of facility layout in terms of process, material handling, efficiency, and safety. (Images created with Tecnomatix Plant Simulation software, courtesy of Siemens PLM Software)

Proplanner Software for Process-Oriented Layouts

Working with computer-aided design software, analysts with the click of a mouse can use Proplanner's Flow Path Calculator to generate material flow diagrams and calculate material handling distances, time, and cost. Variable-width flow lines, color-coded by product, part, or material handling method, allow users to identify how layouts should be arranged and where to eliminate excessive material handling.



Work Cells

A **work cell** reorganizes people and machines that would ordinarily be dispersed in various departments into a group so that they can focus on making a single product or a group of related products (Figure 9.9). Cellular work arrangements are used when volume warrants a special arrangement of machinery and equipment. These work cells are reconfigured as product designs change or volume fluctuates. The advantages of work cells are:

Work cell
An arrangement of machines and personnel that focuses on making a single product or family of related products.

1. *Reduced work-in-process inventory* because the work cell is set up to provide one-piece flow from machine to machine.
2. *Less floor space* required because less space is needed between machines to accommodate work-in-process inventory.
3. *Reduced raw material and finished goods inventories* because less work-in-process allows more rapid movement of materials through the work cell.
4. *Reduced direct labor cost* because of improved communication among employees, better material flow, and improved scheduling.
5. *Heightened sense of employee participation* in the organization and the product: employees accept the added responsibility of product quality because it is directly associated with them and their work cell.
6. *Increased equipment and machinery utilization* because of better scheduling and faster material flow.
7. *Reduced investment in machinery and equipment* because good utilization reduces the number of machines and the amount of equipment and tooling.

LO 9.6 *Define* work cell and the requirements of a work cell

Requirements of Work Cells

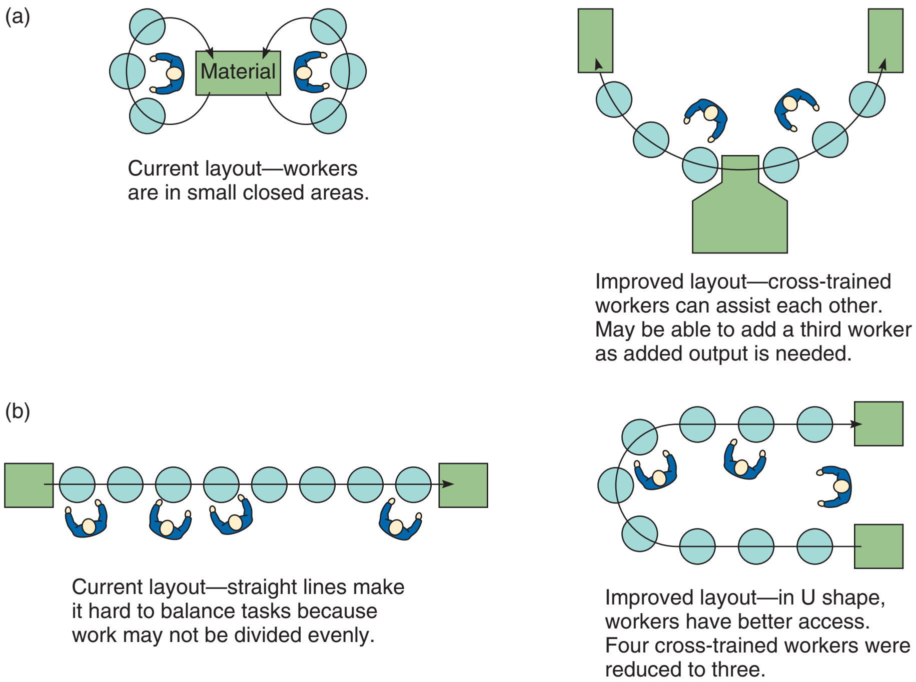
The requirements of cellular production include:

- Identification of families of products, often through the use of group technology codes or equivalents
- A high level of training, flexibility, and empowerment of employees
- Being self-contained, with its own equipment and resources
- Testing (poka-yoke) at each station in the cell

Figure 9.9

Improving Layouts by Moving to the Work Cell Concept

Note in both (a) and (b) that U-shaped work cells can reduce material and employee movement. The U shape may also reduce space requirements, enhance communication, cut the number of workers, and make inspection easier.



STUDENT TIP
Using work cells is a big step toward manufacturing efficiency. They can make jobs more interesting, save space, and cut inventory.

Work cells have at least five advantages over assembly lines and focused process facilities: (1) because tasks are grouped, inspection is often immediate; (2) fewer workers are needed; (3) workers can reach more of the work area; (4) the work area can be more efficiently balanced; and (5) communication is enhanced. Work cells are sometimes organized in a U shape, as shown on the right side of Figure 9.9. The shape of the cell is secondary to the process flow. The focus should be on a flow that optimizes people, material, and communication.

Why did Canon's copier factories in Japan switch from assembly lines to work cells? First, the move freed up 12 miles of conveyor-belt space, at 54 plants, saving $280 million in real estate costs. Second, the cells enabled Canon to change its product mix more quickly, to accommodate short life cycles. And third, morale increased because workers can now assemble a whole copier, not just one part. Some of Canon's fastest workers are so admired that they have become TV celebrities!

Staffing and Balancing Work Cells

Once the work cell has the appropriate equipment located in the proper sequence, the next task is to staff and balance the cell. Efficient production in a work cell requires appropriate staffing.

Takt time
Pace of production to meet customer demands.

This involves two steps. First, determine the **takt time**,[2] which is the pace (frequency) of production units necessary (time per unit) to meet customer orders:

$$\text{Takt time} = \text{Total work time available}/\text{Units required to satisfy customer demand} \quad (9\text{-}2)$$

Second, determine the number of operators required. This requires dividing the total operation time in the work cell by the takt time:

$$\text{Workers required} = \text{Total operation time required}/\text{Takt time} \quad (9\text{-}3)$$

Example 2 considers these two steps when staffing work cells.

Example 2

STAFFING WORK CELLS

Stephen Hall's company in Dayton makes auto mirrors. The major customer is the Honda plant nearby. Honda expects 600 mirrors delivered daily, and the work cell producing the mirrors is scheduled for 8 hours. Hall wants to determine the takt time and the number of workers required.

APPROACH ▶ Hall uses Equations (9-2) and (9-3) and develops a work balance chart to help determine the time for each operation in the work cell, as well as total time.

SOLUTION ▶

$$\text{Takt time} = (8 \text{ hours} \times 60 \text{ minutes})/600 \text{ units} = 480/600 = .8 \text{ minute} = 48 \text{ seconds}$$

Therefore, the customer requirement is one mirror every 48 seconds.

The *work balance chart* in Figure 9.10 shows that 5 operations are necessary, for a total operation time of 140 seconds:

$$\begin{aligned} \text{Workers required} &= \text{Total operation time required/Takt time} \\ &= (50 + 45 + 10 + 20 + 15)/48 \\ &= 140/48 = 2.92 \end{aligned}$$

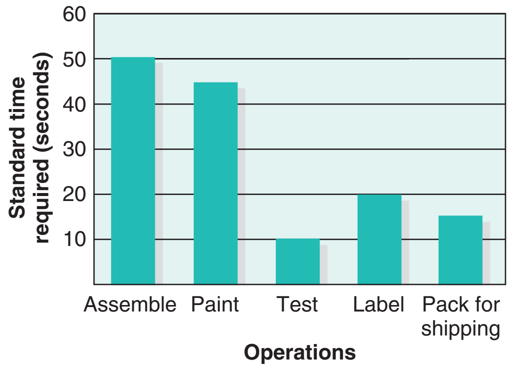


Figure **9.10**

Work Balance Chart for Mirror Production

INSIGHT ▶ To produce one unit every 48 seconds will require 2.92 people. With three operators this work cell will be producing one unit each 46.67 seconds (140 seconds/3 employees = 46.67) and 617 units per day (480 minutes available × 60 seconds/46.67 seconds for each unit = 617).

LEARNING EXERCISE ▶ If testing time is expanded to 20 seconds, what is the staffing requirement? [Answer: 3.125 employees.]

RELATED PROBLEM ▶ 9.11

A *work balance chart* (like the one in Example 2) is also valuable for evaluating the operation times in work cells. Some consideration must be given to determining the bottleneck operation. Bottleneck operations can constrain the flow through the cell. Imbalance in a work cell is seldom an issue if the operation is manual, as cell members by definition are part of a cross-trained team. Consequently, the inherent flexibility of work cells typically overcomes modest imbalance issues within a cell. However, if the imbalance is a machine constraint, then an adjustment in machinery, process, or operations may be necessary. In such situations the use of traditional assembly-line-balancing analysis, the topic of our next section, may be helpful.

The success of work cells is not limited to manufacturing. Kansas City's Hallmark, which has over half the U.S. greeting card market and produces some 40,000 different cards, has modified the offices into a cellular design. In the past, its 700 creative professionals would take up to 2 years to develop a new card. Hallmark's decision to create work cells consisting of artists, writers, lithographers, merchandisers, and accountants, all located in the same area, has resulted in card preparation in a fraction of the time that the old layout required. Work cells have also yielded higher performance and better service for the American Red Cross blood donation process.

The Focused Work Center and the Focused Factory

Focused work center

A permanent or semipermanent product-oriented arrangement of machines and personnel.

Focused factory

A facility designed to produce similar products or components.

When a firm has *identified a family of similar products that have a large and stable demand*, it may organize a focused work center. A **focused work center** (also called a "plant within a plant") moves production to a large work cell that remains part of the present facility. For example, bumpers and dashboards in Toyota's Texas plant are produced in a focused work center, and the Levi's departments in JCPenney are managed and run in a stand-alone boutique setting.

If the focused work center is in a separate facility, it is often called a **focused factory**. For example, separate plants that produce seat belts, fuel tanks, and exhaust systems for Toyota are focused factories. A fast-food restaurant is also a focused factory—most are easily reconfigured for adjustments to product mix and volume. Burger King changes the number of personnel and task assignments rather than moving machines and equipment. In this manner, Burger King balances the assembly line to meet changing production demands. In effect, the "layout" changes numerous times each day.

The term *focused factories* may also refer to facilities that are focused in ways other than by product line or layout. For instance, facilities may focus on their core competence, such as low cost, quality, new product introduction, or flexibility.

Focused facilities in both manufacturing and services appear to be better able to stay in tune with their customers, to produce quality products, and to operate at higher margins. This is true whether they are auto manufacturers like Toyota; restaurants like McDonald's and Burger King; or a hospital like Arnold Palmer.

Repetitive and Product-Oriented Layout

Product-oriented layouts are organized around products or families of similar high-volume, low-variety products. Repetitive production and continuous production, which are discussed in Chapter 7, use product layouts. The assumptions are that:

LO 9.7 *Define* product-oriented layout

1. Volume is adequate for high equipment utilization
2. Product demand is stable enough to justify high investment in specialized equipment
3. Product is standardized or approaching a phase of its life cycle that justifies investment in specialized equipment
4. Supplies of raw materials and components are adequate and of uniform quality (adequately standardized) to ensure that they will work with the specialized equipment

Fabrication line

A machine-paced, product-oriented facility for building components.

Assembly line

An approach that puts fabricated parts together at a series of workstations; used in repetitive processes.

Two types of a product-oriented layout are fabrication and assembly lines. The **fabrication line** builds components, such as automobile tires or metal parts for a refrigerator, on a series of machines, while an **assembly line** puts the fabricated parts together at a series of workstations. However, both are repetitive processes, and in both cases, the line must be "balanced"; that is, the time spent to perform work on one machine must equal or "balance" the time spent to perform work on the next machine in the fabrication line, just as the time spent at one workstation by one assembly-line employee must "balance" the time spent at the next workstation by the next employee. The same issues arise when designing the "disassembly lines" of slaughterhouses and automobile recyclers.

Assembly-line balancing

Obtaining output at each workstation on a production line so delay is minimized.

A well-balanced assembly line has the advantage of high personnel and facility utilization and equity among employees' workloads. Some union contracts require that workloads be nearly equal among those on the same assembly line. The term most often used to describe this process is **assembly-line balancing**. Indeed, the *objective of the product-oriented layout is to minimize imbalance in the fabrication or assembly line*.

The main advantages of product-oriented layout are:

1. The low variable cost per unit usually associated with high-volume, standardized products
2. Low material-handling costs
3. Reduced work-in-process inventories
4. Easier training and supervision
5. Rapid throughput

The disadvantages of product layout are:

1. The high volume required because of the large investment needed to establish the process
2. Work stoppage at any one point can tie up the whole operation
3. The process flexibility necessary for a variety of products and production rates can be a challenge

Because the problems of fabrication lines and assembly lines are similar, we focus our discussion on assembly lines. On an assembly line, the product typically moves via automated means, such as a conveyor, through a series of workstations until completed. This is the way fast-food hamburgers are made (see Figure 9.11), automobiles and some planes (see the photo of the Boeing 737 on the next page) are assembled, and television sets and ovens are produced. Product-oriented layouts use more automated and specially designed equipment than do process layouts.

VIDEO 9.2
Facility Layout at Wheeled Coach Ambulances

Assembly-Line Balancing

Line balancing is usually undertaken to minimize imbalance between machines or personnel while meeting a required output from the line. To produce at a specified rate, management must know the tools, equipment, and work methods used. Then the time requirements for each assembly task (e.g., drilling a hole, tightening a nut, or spray-painting a part) must be determined. Management also needs to know the *precedence relationship* among the activities—that is, the sequence in which various tasks must be performed. Example 3 shows how to turn these task data into a precedence diagram.

LO 9.8 *Explain* how to balance production flow in a repetitive or product-oriented facility

Elapsed time	0:00	0:11	0:31	0:45		1:30
Task time (seconds)		11	20	14	0	45
Task	1. Order	2. Bun toasting	3. Assembly with condiments	4. Wrapping of patty with bun	5. Order picked up immediately to keep it fresh	6. Customer service (order and payment)

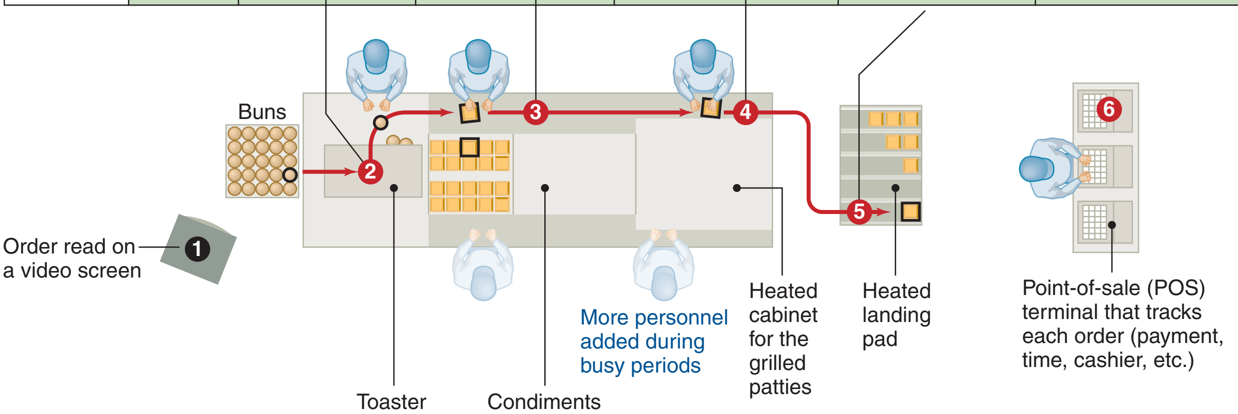


Figure **9.11**

McDonald's Hamburger Assembly Line

The Boeing 737, the world's most popular commercial airplane, is produced on a moving production line, traveling at 2 inches a minute through the final assembly process. The moving line, one of several lean manufacturing innovations at the Renton, Washington, facility, has enhanced quality, reduced flow time, slashed inventory levels, and cut space requirements. Final assembly is only 11 days—a time savings of 50%—and inventory is down more than 55%.

Copyright Boeing

Example 3

DEVELOPING A PRECEDENCE DIAGRAM FOR AN ASSEMBLY LINE

Boeing wants to develop a precedence diagram for an electrostatic wing component that requires a total assembly time of 65 minutes.

APPROACH ▶ Staff gather tasks, assembly times, and sequence requirements for the component in Table 9.2.

TABLE 9.2 Precedence Data for Wing Component

TASK	ASSEMBLY TIME (MINUTES)	TASK MUST FOLLOW TASK LISTED BELOW	
A	10	—	This means that tasks B and E cannot be done until task A has been completed.
B	11	A	
C	5	B	
D	4	B	
E	11	A	
F	3	C, D	
G	7	F	
H	11	E	
I	3	G, H	
	Total time 65		

SOLUTION ▶ Figure 9.12 shows the precedence diagram.

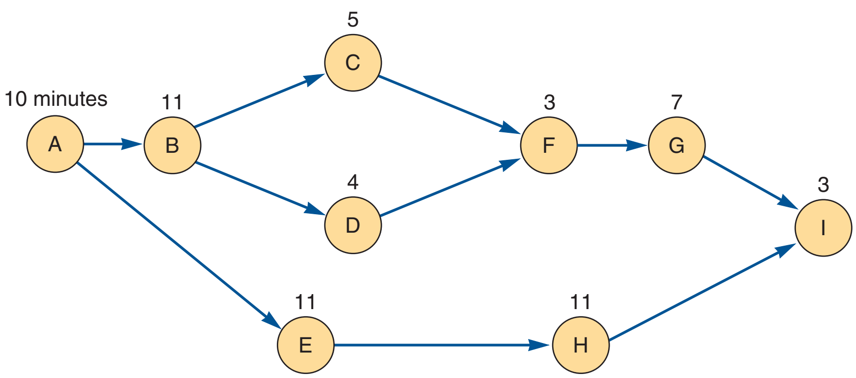


Figure **9.12**

Precedence Diagram

INSIGHT ▶ The diagram helps structure an assembly line and workstations, and it makes it easier to visualize the sequence of tasks.

LEARNING EXERCISE ▶ If task D had a second preceding task (C), how would Figure 9.12 change? [Answer: There would also be an arrow pointing from C to D.]

RELATED PROBLEMS ▶ 9.13a, 9.15a, 9.16a, 9.17a, 9.20a (9.25a,d, 9.26a, 9.27 are available in MyOMLab)

Once we have constructed a precedence chart summarizing the sequences and performance times, we turn to the job of grouping tasks into job stations so that we can meet the specified production rate. This process involves three steps:

1. Take the units required (demand or production rate) per day and divide them into the productive time available per day (in minutes or seconds). This operation gives us what is called the **cycle time**[3]—namely, the maximum time allowed at each workstation if the production rate is to be achieved:

$$\text{Cycle time} = \frac{\text{Production time available per day}}{\text{Units required per day}} \tag{9-4}$$

2. Calculate the theoretical minimum number of workstations. This is the total task-duration time (the time it takes to make the product) divided by the cycle time. Fractions are rounded to the next higher whole number:

$$\text{Minimum number of workstations} = \frac{\sum_{i=1}^{n} \text{Time for task } i}{\text{Cycle time}} \tag{9-5}$$

where n is the number of assembly tasks.

3. Balance the line by assigning specific assembly tasks to each workstation. An efficient balance is one that will complete the required assembly, follow the specified sequence, and keep the idle time at each workstation to a minimum. A formal procedure for doing this is the following:
   - **a.** Identify a master list of tasks.
   - **b.** Eliminate those tasks that have been assigned.
   - **c.** Eliminate those tasks whose precedence relationship has not been satisfied.
   - **d.** Eliminate those tasks for which inadequate time is available at the workstation.
   - **e.** Use one of the line-balancing "heuristics" described in Table 9.3. The five choices are (1) longest task time, (2) most following tasks, (3) ranked positional weight, (4) shortest task time, and (5) least number of following tasks. You may wish to test several of these **heuristics** to see which generates the "best" solution—that is, the smallest number of workstations and highest efficiency. Remember, however, that although heuristics provide solutions, they do not guarantee an optimal solution.

Cycle time
The maximum time that a product is allowed at each workstation.

Heuristic
Problem solving using procedures and rules rather than mathematical optimization.

TABLE 9.3 Layout Heuristics That May Be Used to Assign Tasks to Workstations in Assembly-Line Balancing

1. *Longest task (operation) time*	From the available tasks, choose the task with the largest (longest) time.
2. *Most following tasks*	From the available tasks, choose the task with the largest number of following tasks.
3. *Ranked positional weight*	From the available tasks, choose the task for which the sum of the times for each following task is longest. (In Example 4 we see that the ranked positional weight of task C = 5(C) + 3(F) + 7(G) + 3(I) = 18, whereas the ranked positional weight of task D = 4(D) + 3(F) + 7(G) + 3(I) = 17; therefore, C would be chosen first, using this heuristic.)
4. *Shortest task (operations) time*	From the available tasks, choose the task with the shortest task time.
5. *Least number of following tasks*	From the available tasks, choose the task with the least number of subsequent tasks.

Example 4 illustrates a simple line-balancing procedure.

Example 4

BALANCING THE ASSEMBLY LINE

On the basis of the precedence diagram and activity times given in Example 3, Boeing determines that there are 480 productive minutes of work available per day. Furthermore, the production schedule requires that 40 units of the wing component be completed as output from the assembly line each day. It now wants to group the tasks into workstations.

APPROACH ▶ Following the three steps above, we compute the cycle time using Equation (9-4) and minimum number of workstations using Equation (9-5), and we assign tasks to workstations—in this case using the *most following tasks* heuristic.

SOLUTION ▶

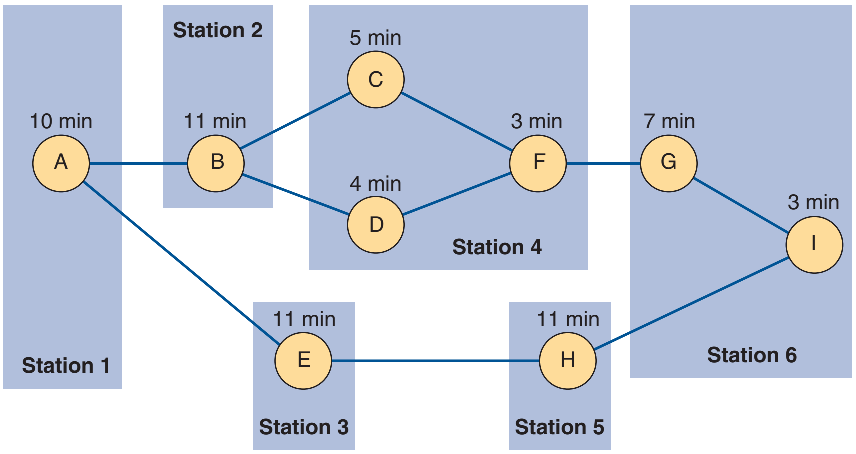
$$\text{Cycle time (in minutes)} = \frac{480 \text{ minutes}}{40 \text{ units}}$$
$$= 12 \text{ minutes/unit}$$

$$\text{Minimum number of workstations} = \frac{\text{Total task time}}{\text{Cycle time}} = \frac{65}{12}$$
$$= 5.42, \text{ or } 6 \text{ stations}$$

Figure 9.13 shows one solution that does not violate the sequence requirements and that groups tasks into six one-person stations. To obtain this solution, activities with the most following tasks were moved into workstations to use as much of the available cycle time of 12 minutes as possible. The first workstation consumes 10 minutes and has an idle time of 2 minutes.

Figure **9.13**

A Six-Station Solution to the Line-Balancing Problem



STUDENT TIP
Tasks C, D, and F can be grouped together in one workstation, provided that the physical facilities and skill levels meet the work requirements.

INSIGHT ▶ This is a reasonably well-balanced assembly line. The second and third workstations use 11 minutes. The fourth workstation groups three small tasks and balances perfectly at 12 minutes. The fifth has 1 minute of idle time, and the sixth (consisting of tasks G and I) has 2 minutes of idle time per cycle. Total idle time for this solution is 7 minutes per cycle.

LEARNING EXERCISE ▶ If task I required 6 minutes (instead of 3 minutes), how would this change the solution? [Answer: The cycle time would not change, and the *theoretical* minimum number of workstations would still be 6 (rounded up from 5.67), but it would take 7 stations to balance the line.]

RELATED PROBLEMS ▶ 9.12–9.24 (9.25–9.27 are available in MyOMLab)

EXCEL OM Data File **Ch09Ex4.xls** can be found in MyOMLab.

There are two measures of effectiveness of a balance assignment. The first measure computes the *efficiency* of a line balance by dividing the total task times by the product of the number of workstations required times the assigned (actual) cycle time of the *longest* workstation:

$$\text{Efficiency} = \frac{\sum \text{Task times}}{(\textit{Actual}\text{ number of workstations}) \times (\text{Largest assigned cycle time})} \qquad \text{(9-6)}$$

Operations managers compare different levels of efficiency for various numbers of workstations. In this way, a firm can determine the sensitivity of the line to changes in the production rate and workstation assignments.

The second measure computes the *idle time* for the line.

$$\text{Idle time} = (\text{Actual number of workstations} \times \text{Largest assigned cycle time}) - \sum \text{Task times} \qquad \text{(9-7)}$$

Example 5

DETERMINING LINE EFFICIENCY

Boeing needs to calculate the efficiency for Example 4.

APPROACH ▶ Equation (9-6) is applied.

SOLUTION ▶

$$\text{Efficiency} = \frac{65 \text{ minutes}}{(6 \text{ stations}) \times (12 \text{ minutes})} = \frac{65}{72} = 90.3\%$$

Note that opening a seventh workstation, for whatever reason, would decrease the efficiency of the balance to 77.4% (assuming that at least one of the workstations still required 12 minutes):

$$\text{Efficiency} = \frac{65 \text{ minutes}}{(7 \text{ stations}) \times (12 \text{ minutes})} = 77.4\%$$

INSIGHT ▶ Increasing efficiency may require that some tasks be divided into smaller elements and reassigned to other tasks. This facilitates a better balance between workstations and means higher efficiency. Note that we can also compute efficiency as 1 − (% Idle time), that is, [1 − (Idle time)/(Total time in workstations)].

LEARNING EXERCISE ▶ What is the efficiency if an eighth workstation is opened? [Answer: Efficiency = 67.7%.]

RELATED PROBLEMS ▶ 9.13f, 9.14c, 9.15f, 9.17c, 9.18b, 9.19b, 9.20e,g (9.25e, 9.26c, 9.27 are available in MyOMLab)

Large-scale line-balancing problems, like large process-layout problems, are often solved by computers. Computer programs such as Assembly Line Pro, Proplanner, Timer Pro, Flexible Line Balancing, and Promodel are available to handle the assignment of workstations on assembly lines with numerous work activities. Such software evaluates the thousands, or even millions, of possible workstation combinations much more efficiently than could ever be done by hand.

Summary

Layouts make a substantial difference in operating efficiency. The seven layout situations discussed in this chapter are (1) office, (2) retail, (3) warehouse, (4) fixed position, (5) process oriented, (6) work cells, and (7) product oriented. A variety of techniques have been developed to solve these layout problems. Office layouts often seek to maximize information flows, retail firms focus on product exposure, and warehouses attempt to optimize the trade-off between storage space and material handling cost.

The fixed-position layout problem attempts to minimize material handling costs within the constraint of limited space at the site. Process layouts minimize travel distances times the number of trips. Product layouts focus on reducing waste and the imbalance in an assembly line. Work cells are the result of identifying a family of products that justify a special configuration of machinery and equipment that reduces material travel and adjusts imbalances with cross-trained personnel.

Often, the issues in a layout problem are so wide-ranging that finding an optimal solution is not possible. For this reason, layout decisions, although the subject of substantial research effort, remain something of an art.

Key Terms

Office layout (p. 371)
Retail layout (p. 372)
Slotting fees (p. 374)
Servicescape (p. 375)
Warehouse layout (p. 375)
Cross-docking (p. 376)
Random stocking (p. 377)
Customizing (p. 377)
Fixed-position layout (p. 377)
Process-oriented layout (p. 378)
Job lots (p. 379)
Work cell (p. 383)
Takt time (p. 384)
Focused work center (p. 386)
Focused factory (p. 386)
Fabrication line (p. 386)
Assembly line (p. 386)
Assembly-line balancing (p. 386)
Cycle time (p. 389)
Heuristic (p. 389)

Ethical Dilemma

Although buried by mass customization and a proliferation of new products of numerous sizes and variations, grocery chains continue to seek to maximize payoff from their layout. Their layout includes a marketable commodity—shelf space—and they charge for it. This charge is known as a *slotting fee*. Recent estimates are that food manufacturers now spend some 13% of sales on trade promotions, which is paid to grocers to get them to promote and discount the manufacturer's products. A portion of these fees is for slotting, but slotting fees drive up the manufacturer's cost. They also put the small company with a new product at a disadvantage because small companies with limited resources may be squeezed out of the marketplace. Slotting fees may also mean that customers may no longer be able to find the special local brand. How ethical are slotting fees?


Image Source/Alamy

Discussion Questions

1. What are the seven layout strategies presented in this chapter?
2. What are the three factors that complicate a fixed-position layout?
3. What are the advantages and disadvantages of process layout?
4. How would an analyst obtain data and determine the number of trips in:
   (a) a hospital?
   (b) a machine shop?
   (c) an auto-repair shop?
5. What are the advantages and disadvantages of product layout?
6. What are the four assumptions (or preconditions) of establishing layout for high-volume, low-variety products?
7. What are the alternative forms of work cells discussed in this textbook?
8. What are the advantages and disadvantages of work cells?
9. What are the requirements for a focused work center or focused factory to be appropriate?
10. What are the two major trends influencing office layout?
11. What layout variables would you consider particularly important in an office layout where computer programs are written?

12. What layout innovations have you noticed recently in retail establishments?
13. What are the variables that a manager can manipulate in a retail layout?
14. Visit a local supermarket and sketch its layout. What are your observations regarding departments and their locations?
15. What is random stocking?
16. What information is necessary for random stocking to work?
17. Explain the concept of cross-docking.
18. What is a heuristic? Name several that can be used in assembly-line balancing.

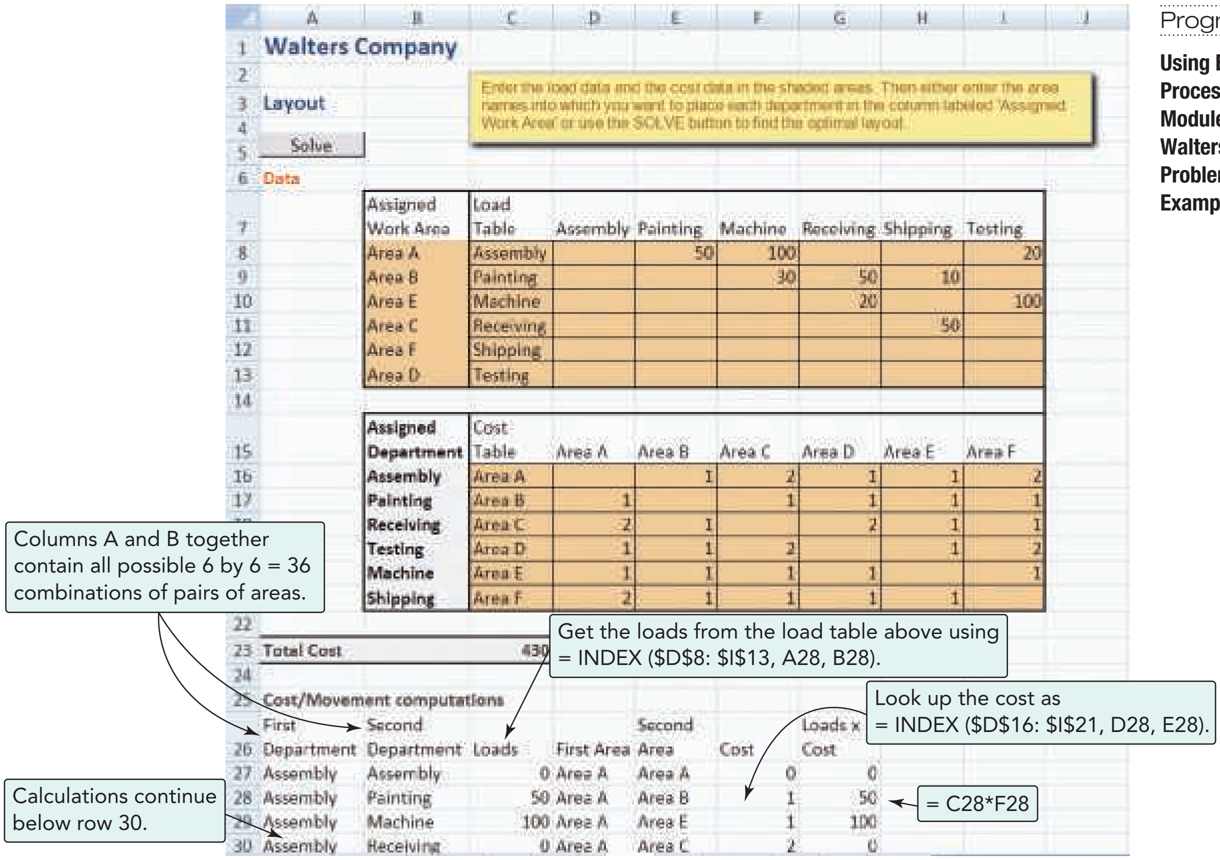
Using Software to Solve Layout Problems

In addition to the many commercial software packages available for addressing layout problems, Excel OM and POM for Windows, both of which accompany this text, contain modules for the process problem and the assembly-line-balancing problem.

USING EXCEL OM

Excel OM can assist in evaluating a series of department work assignments like the one we saw for the Walters Company in Example 1. The layout module can generate an optimal solution by enumeration or by computing the "total movement" cost for each layout you wish to examine. As such, it provides a speedy calculator for each flow–distance pairing.

Program 9.1 illustrates our inputs in the top two tables. We first enter department flows, then provide distances between work areas. Entering area assignments on a trial-and-error basis in the upper left of the top table generates movement computations at the bottom of the screen. Total movement is recalculated each time we try a new area assignment. It turns out that the assignment shown is optimal at 430 feet of movement.



Program 9.1
Using Excel OM's Process Layout Module to Solve the Walters Company Problem in Example 1

USING POM FOR WINDOWS

The POM for Windows facility layout module can be used to place up to 10 departments in 10 rooms to minimize the total distance traveled as a function of the distances between the rooms and the flow between departments. The program exchanges departments until no exchange will reduce the total amount of movement, meaning an optimal solution has been reached.

The POM for Windows and Excel OM modules for line balancing can handle a line with up to 99 tasks, each with up to six immediate predecessors. In this program, cycle time can be entered as either (1) *given*, if known, or (2) the *demand* rate can be entered with time available as shown. All five "heuristic rules" are used: (1) longest operation (task) time, (2) most following tasks, (3) ranked positional weight, (4) shortest operation (task) time, and (5) least number of following tasks. No one rule can guarantee an optimal solution, but POM for Windows displays the number of stations needed for each rule.

Appendix IV discusses further details regarding POM for Windows.

Solved Problems

Virtual Office Hours help is available in MyOMLab.

SOLVED PROBLEM 9.1

Aero Maintenance is a small aircraft engine maintenance facility located in Wichita, Kansas. Its new administrator, Ann Daniel, decides to improve material flow in the facility, using the process layout method she studied at Wichita State University. The current layout of Aero Maintenance's eight departments is shown in Figure 9.14.

The only physical restriction perceived by Daniel is the need to keep the entrance in its current location. All other departments can be moved to a different work area (each 10 feet square) if layout analysis indicates a move would be beneficial.

First, Daniel analyzes records to determine the number of material movements among departments in an average month. These data are shown in Figure 9.15. Her objective, Daniel decides, is to lay out the departments so as to minimize the total movement (distance traveled) of material in the facility. She writes her objective as:

$$\text{Minimize material movement} = \sum_{i=1}^{8}\sum_{j=1}^{8} X_{ij}C_{ij}$$

where X_{ij} = number of material movements per month (loads or trips) moving from department i to department j

C_{ij} = distance in feet between departments i and j (which, in this case, is the equivalent of cost per load to move between departments)

Note that this is only a slight modification of the cost-objective equation shown earlier in the chapter.

Daniel assumes that adjacent departments, such as entrance (now in work area A) and receiving (now in work area B), have a walking distance of 10 feet. Diagonal departments are also considered adjacent and assigned a distance of 10 feet. Nonadjacent departments, such as the entrance and parts (now in area C) or the entrance and inspection (area G) are 20 feet apart, and nonadjacent rooms, such as entrance and metallurgy (area D), are 30 feet apart. (Hence, 10 feet is considered 10 units of cost, 20 feet is 20 units of cost, and 30 feet is 30 units of cost.)

Given the above information, redesign Aero Maintenance's layout to improve its material flow efficiency.

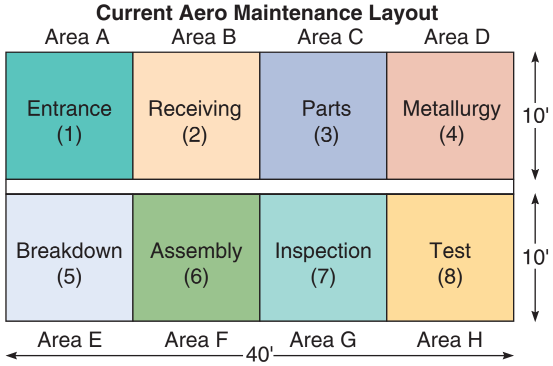


Figure **9.14**

Aero Maintenance Layout

Figure **9.15**

Number of Material Movements (Loads) Between Departments in 1 Month

Department	Entrance (1)	Receiving (2)	Parts (3)	Metallurgy (4)	Breakdown (5)	Assembly (6)	Inspection (7)	Test (8)
Entrance (1)		100	100	0	0	0	0	0
Receiving (2)			0	50	20	0	0	0
Parts (3)				30	30	0	0	0
Metallurgy (4)					20	0	0	20
Breakdown (5)						20	0	10
Assembly (6)							30	0
Inspection (7)								0
Test (8)								

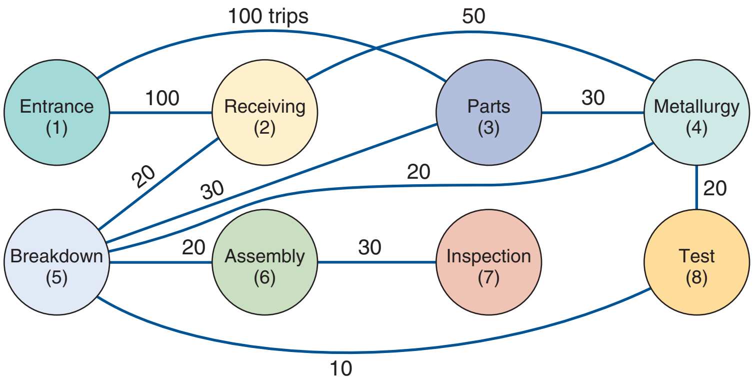
SOLUTION

First, establish Aero Maintenance's current layout, as shown in Figure 9.16. Then, by analyzing the current layout, compute material movement:

$$\begin{aligned}\text{Total movement} &= \underbrace{(100 \times 10')}_{1\text{ to }2} + \underbrace{(100 \times 20')}_{1\text{ to }3} + \underbrace{(50 \times 20')}_{2\text{ to }4} + \underbrace{(20 \times 10')}_{2\text{ to }5} \\ &\quad + \underbrace{(30 \times 10')}_{3\text{ to }4} + \underbrace{(30 \times 20')}_{3\text{ to }5} + \underbrace{(20 \times 30')}_{4\text{ to }5} + \underbrace{(20 \times 10')}_{4\text{ to }8} \\ &\quad + \underbrace{(20 \times 10')}_{5\text{ to }6} + \underbrace{(10 \times 30')}_{5\text{ to }8} + \underbrace{(30 \times 10')}_{5\text{ to }7} \\ &= 1{,}000 + 2{,}000 + 1{,}000 + 200 + 300 + 600 + 600 \\ &\quad + 200 + 200 + 300 + 300 \\ &= 6{,}700 \text{ feet}\end{aligned}$$

Figure **9.16**

Current Material Flow



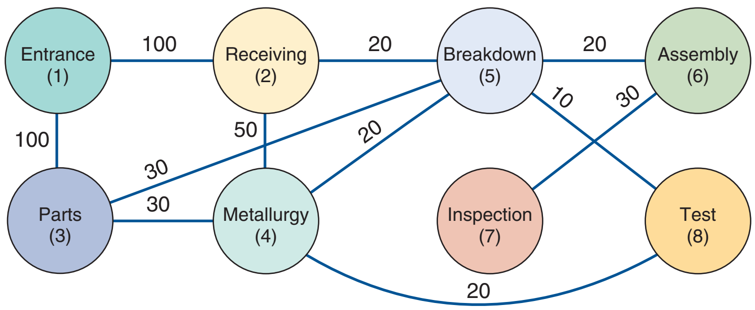
Propose a new layout that will reduce the current figure of 6,700 feet. Two useful changes, for example, are to switch departments 3 and 5 and to interchange departments 4 and 6. This change would result in the schematic shown in Figure 9.17:

$$\begin{aligned}\text{Total movement} &= \underbrace{(100 \times 10')}_{1\text{ to }2} + \underbrace{(100 \times 10')}_{1\text{ to }3} + \underbrace{(50 \times 10')}_{2\text{ to }4} + \underbrace{(20 \times 10')}_{2\text{ to }5} \\ &\quad + \underbrace{(30 \times 10')}_{3\text{ to }4} + \underbrace{(30 \times 20')}_{3\text{ to }5} + \underbrace{(20 \times 10')}_{4\text{ to }5} + \underbrace{(20 \times 20')}_{4\text{ to }8} \\ &\quad + \underbrace{(20 \times 10')}_{5\text{ to }6} + \underbrace{(10 \times 10')}_{5\text{ to }8} + \underbrace{(30 \times 10')}_{6\text{ to }7} \\ &= 1{,}000 + 1{,}000 + 500 + 200 + 300 + 600 + 200 \\ &\quad + 400 + 200 + 100 + 300 \\ &= 4{,}800 \text{ feet}\end{aligned}$$

Do you see any room for further improvement?

Figure **9.17**

Improved Layout



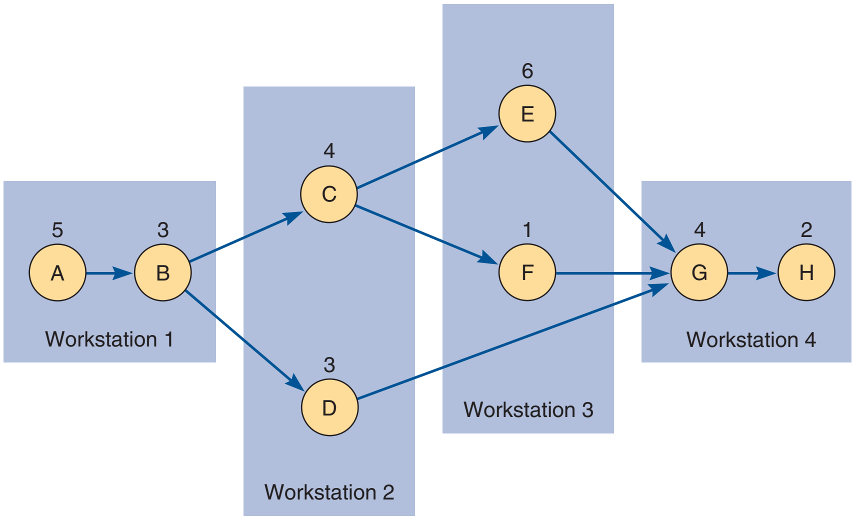
SOLVED PROBLEM 9.2

The assembly line whose activities are shown in Figure 9.18 has an 8-minute cycle time. Draw the precedence graph, and find the minimum possible number of one-person workstations. Then arrange the work activities into workstations so as to balance the line. What is the efficiency of your line balance?

TASK	PERFORMANCE TIME (MINUTES)	TASK MUST FOLLOW THIS TASK
A	5	—
B	3	A
C	4	B
D	3	B
E	6	C
F	1	C
G	4	D, E, F
H	2	G
	28	

Figure **9.18**

Four-Station Solution to the Line-Balancing Problem



SOLUTION

The theoretical minimum number of workstations is:

$$\frac{\Sigma t_i}{\text{Cycle time}} = \frac{28 \text{ minutes}}{8 \text{ minutes}} = 3.5, \text{ or } 4 \text{ stations}$$

The precedence graph and one good layout are shown in Figure 9.18:

$$\text{Efficiency} = \frac{\text{Total task time}}{(\text{Actual number of workstations}) \times (\text{Largest assigned cycle time})} = \frac{28}{(4)(8)} = 87.5\%$$

Problems

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

Problems 9.1–9.10 relate to Process-Oriented Layout

•• **9.1** Gordon Miller's job shop has four work areas, A, B, C, and D. Distances in feet between centers of the work areas are:

	A	B	C	D
A	—	4	9	7
B	—	—	6	8
C	—	—	—	10
D	—	—	—	—

Workpieces moved, in hundreds of workpieces per week, between pairs of work areas, are:

	A	B	C	D
A	—	8	7	4
B	—	—	3	2
C	—	—	—	6
D	—	—	—	—

It costs Gordon $1 to move 1 work piece 1 foot. What is the weekly total material handling cost of the layout? PX

•• **9.2** A Missouri job shop has four departments—machining (M), dipping in a chemical bath (D), finishing (F), and plating (P)—assigned to four work areas. The operations manager, Mary Marrs, has gathered the following data for this job shop as it is currently laid out (Plan A).

100s of Workpieces Moved Between Work Areas Each Year Plan A

	M	D	F	P
M	—	6	18	2
D	—	—	4	2
F	—	—	—	18
P	—	—	—	—

Distances Between Work Areas (Departments) in Feet

	M	D	F	P
M	—	20	12	8
D	—	—	6	10
F	—	—	—	4
P	—	—	—	—

It costs $0.50 to move 1 workpiece 1 foot in the job shop. Marrs's goal is to find a layout that has the lowest material handling cost.

a) Determine cost of the current layout, Plan A, from the data above.
b) One alternative is to switch those departments with the high loads, namely, finishing (F) and plating (P), which alters the distance between them and machining (M) and dipping (D), as follows:

Distances Between Work Areas (Departments) in Feet Plan B

	M	D	F	P
M	—	20	8	12
D	—	—	10	6
F	—	—	—	4
P	—	—	—	—

What is the cost of *this* layout?

c) Marrs now wants you to evaluate Plan C, which also switches milling (M) and drilling (D), below.

Distance Between Work Areas (Departments) in Feet Plan C

	M	D	F	P
M	—	20	10	6
D	—	—	8	12
F	—	—	—	4
P	—	—	—	—

What is the cost of *this* layout?

d) Which layout is best from a cost perspective?

• **9.3** Three departments—milling (M), drilling (D), and sawing (S)—are assigned to three work areas in Victor Berardis's machine shop in Vent, Ohio. The number of workpieces moved per day and the distances between the centers of the work areas, in feet, follow.

Pieces Moved Between Work Areas Each Day

	M	D	S
M	—	23	32
D	—	—	20
S	—	—	—

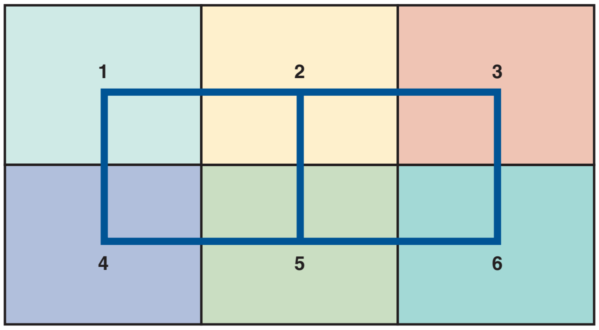
Distances Between Centers of Work Areas (Departments) in Feet

	M	D	S
M	—	10	5
D	—	—	8
S	—	—	—

It costs $2 to move 1 workpiece 1 foot.
What is the cost?

•• **9.4** Roy Creasey Enterprises, a machine shop, is planning to move to a new, larger location. The new building will be 60 feet long by 40 feet wide. Creasey envisions the building as having six distinct production areas, roughly equal in size. He feels strongly about safety and intends to have marked pathways throughout the building to facilitate the movement of people and materials. See the following building schematic.

Building Schematic (with work areas 1–6)



His foreman has completed a month-long study of the number of loads of material that have moved from one process to another in the current building. This information is contained in the following flow matrix.

Flow Matrix Between Production Processes

FROM \ TO	MATERIALS	WELDING	DRILLS	LATHES	GRINDERS	BENDERS
Materials	0	100	50	0	0	50
Welding	25	0	0	50	0	0
Drills	25	0	0	0	50	0
Lathes	0	25	0	0	20	0
Grinders	50	0	100	0	0	0
Benders	10	0	20	0	0	0

Finally, Creasey has developed the following matrix to indicate distances between the work areas shown in the building schematic.

Distance Between Work Areas

	1	2	3	4	5	6
1		20	40	20	40	60
2			20	40	20	40
3				60	40	20
4					20	40
5						20
6						

What is the appropriate layout of the new building?

•• **9.5** Adam Munson Manufacturing, in Gainesville, Florida, wants to arrange its four work centers so as to minimize interdepartmental parts handling costs. The flows and existing facility layout are shown in Figure 9.19. For example, to move a part from Work Center A to Work Center C is a 60-foot movement distance. It is 90 feet from A to D.

Parts Moved Between Work Centers

	A	B	C	D
A	—	450	550	50
B	350	—	200	0
C	0	0	—	750
D	0	0	0	—

Existing Layout

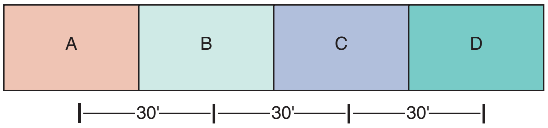


Figure **9.19**

Munson Manufacturing

a) What is the "load × distance," or "movement cost," of the layout shown?
b) Provide an improved layout and compute its movement cost. Px

••• **9.6** You have just been hired as the director of operations for Reid Chocolates, a purveyor of exceptionally fine candies. Reid Chocolates has two kitchen layouts under consideration for its recipe making and testing department. The strategy is to provide the best kitchen layout possible so that food scientists can devote their time and energy to product improvement, not wasted effort in the kitchen. You have been asked to evaluate these two kitchen layouts and to prepare a recommendation for your boss, Mr. Reid, so that he can proceed to place the contract for building the kitchens. [See Figure 9.20(a), and Figure 9.20(b).] Px

Number of trips between work centers:

From: \ To:		Refrigerator 1	Counter 2	Sink 3	Storage 4	Stove 5
Refrig.	1	0	8	13	0	0
Counter	2	5	0	3	3	8
Sink	3	3	12	0	4	0
Storage	4	3	0	0	0	5
Stove	5	0	8	4	10	0

Figure **9.20(a)**

Layout Options

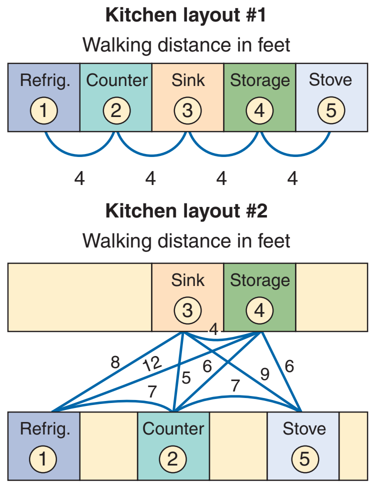
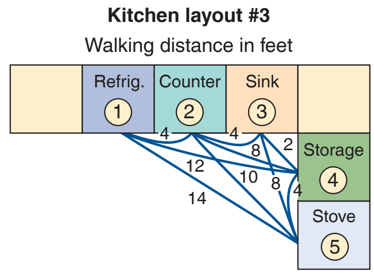
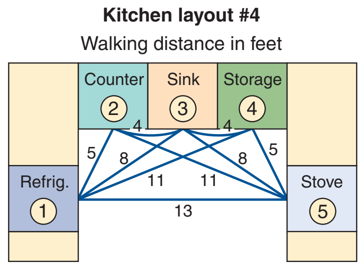


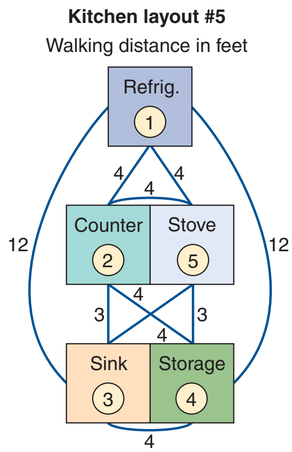
Figure **9.20(b)**

••• **9.7** Reid Chocolates (see Problem 9.6) is considering a third layout, as shown below. Evaluate its effectiveness in trip-distance feet. Px



••• **9.8** Reid Chocolates (see Problems 9.6 and 9.7) has yet two more layouts to consider.
a) Layout 4 is shown below. What is the total trip distance?
b) Layout 5, which also follows, has what total trip distance?





•• **9.9** Six processes are to be laid out in six areas along a long corridor at Rita Gibson Accounting Services in Daytona Beach. The distance between adjacent work centers is 40 feet. The number of trips between work centers is given in the following table:

	TRIPS BETWEEN PROCESSES					
	TO					
FROM	A	B	C	D	E	F
A		18	25	73	12	54
B			96	23	31	45
C				41	22	20
D					19	57
E						48
F						

a) Assign the processes to the work areas in a way that minimizes the total flow, using a method that places processes with highest flow adjacent to each other.
b) What assignment minimizes the total traffic flow? PX

Additional problem **9.10** *is available in* MyOMLab.

Problem 9.11 relates to Work Cells

•• **9.11** After an extensive product analysis using group technology, Leon Bazil has identified a product he believes should be pulled out of his process facility and handled in a work cell. Leon has identified the following operations as necessary for the work cell. The customer expects delivery of 250 units per day, and the workday is 420 minutes.
a) What is the takt time?
b) How many employees should be cross-trained for the cell?
c) Which operations may warrant special consideration?

OPERATION	STANDARD TIME (min)
Shear	1.1
Bend	1.1
Weld	1.7
Clean	3.1
Paint	1.0

Problems 9.12–9.27 relate to Repetitive and Product-Oriented Layout

•• **9.12** Stanford Rosenberg Computing wants to establish an assembly line for producing a new product, the Personal Digital Assistant (PDA). The tasks, task times, and immediate predecessors for the tasks are as follows:

TASK	TIME (sec)	IMMEDIATE PREDECESSORS
A	12	—
B	15	A
C	8	A
D	5	B, C
E	20	D

Rosenberg's goal is to produce 180 PDAs per hour.
a) What is the cycle time?
b) What is the theoretical minimum for the number of workstations that Rosenberg can achieve in this assembly line?
c) Can the theoretical minimum actually be reached when workstations are assigned? PX

••• **9.13** Illinois Furniture, Inc., produces all types of office furniture. The "Executive Secretary" is a chair that has been designed using ergonomics to provide comfort during long work hours. The chair sells for $130. There are 480 minutes available during the day, and the average daily demand has been 50 chairs. There are eight tasks:

TASK	PERFORMANCE TIME (min)	TASK MUST FOLLOW TASK LISTED BELOW
A	4	—
B	7	—
C	6	A, B
D	5	C
E	6	D
F	7	E
G	8	E
H	6	F, G

a) Draw a precedence diagram of this operation.
b) What is the cycle time for this operation?
c) What is the *theoretical* minimum number of workstations?
d) Assign tasks to workstations.
e) What is the idle time per cycle?
f) How much total idle time is present in an 8-hour shift?
g) What is the efficiency of the assembly line, given your answer in (d)? PX

•• **9.14** Sue Helms Appliances wants to establish an assembly line to manufacture its new product, the Micro Popcorn Popper. The goal is to produce five poppers per hour. The tasks, task times, and immediate predecessors for producing one Micro Popcorn Popper are as follows:

TASK	TIME (min)	IMMEDIATE PREDECESSORS
A	10	—
B	12	A
C	8	A, B
D	6	B, C
E	6	C
F	6	D, E

a) What is the *theoretical* minimum for the smallest number of workstations that Helms can achieve in this assembly line?
b) Graph the assembly line, and assign workers to workstations. Can you assign them with the theoretical minimum?
c) What is the efficiency of *your* assignment? PX

•• **9.15** The Action Toy Company has decided to manufacture a new train set, the production of which is broken into six steps. The demand for the train is 4,800 units per 40-hour workweek:

TASK	PERFORMANCE TIME (sec)	PREDECESSORS
A	20	None
B	30	A
C	15	A
D	15	A
E	10	B, C
F	30	D, E

a) Draw a precedence diagram of this operation.
b) Given the demand, what is the cycle time for this operation?
c) What is the *theoretical* minimum number of workstations?
d) Assign tasks to workstations.

e) How much total idle time is present each cycle?
f) What is the efficiency of the assembly line with five stations? With six stations?

• • 9.16 The following table details the tasks required for Indiana-based Frank Pianki Industries to manufacture a fully portable industrial vacuum cleaner. The times in the table are in minutes. Demand forecasts indicate a need to operate with a cycle time of 10 minutes.

ACTIVITY	ACTIVITY DESCRIPTION	IMMEDIATE PREDECESSORS	TIME
A	Attach wheels to tub	—	5
B	Attach motor to lid	—	1.5
C	Attach battery pack	B	3
D	Attach safety cutoff	C	4
E	Attach filters	B	3
F	Attach lid to tub	A, E	2
G	Assemble attachments	—	3
H	Function test	D, F, G	3.5
I	Final inspection	H	2
J	Packing	I	2

a) Draw the appropriate precedence diagram for this production line.
b) Assign tasks to workstations and determine how much idle time is present each cycle.
c) Discuss how this balance could be improved to 100%.
d) What is the *theoretical* minimum number of workstations?

• • 9.17 Tailwind, Inc., produces high-quality but expensive training shoes for runners. The Tailwind shoe, which sells for $210, contains both gas- and liquid-filled compartments to provide more stability and better protection against knee, foot, and back injuries. Manufacturing the shoes requires 10 separate tasks. There are 400 minutes available for manufacturing the shoes in the plant each day. Daily demand is 60. The information for the tasks is as follows:

TASK	PERFORMANCE TIME (min)	TASK MUST FOLLOW TASK LISTED BELOW
A	1	—
B	3	A
C	2	B
D	4	B
E	1	C, D
F	3	A
G	2	F
H	5	G
I	1	E, H
J	3	I

a) Draw the precedence diagram.
b) Assign tasks to the minimum feasible number of workstations according to the "ranked positioned weight" decision rule.
c) What is the efficiency of the process you completed in (b)?
d) What is the idle time per cycle?

• • 9.18 The Mach 10 is a one-person sailboat manufactured by Creative Leisure. The final assembly plant is in Cupertino, California. The assembly area is available for production of the Mach 10 for 200 minutes per day. (The rest of the time it is busy making other products.) The daily demand is 60 boats. Given the information in the table,
a) Draw the precedence diagram and assign tasks using five workstations.
b) What is the efficiency of the assembly line, using your answer to (a)?
c) What is the *theoretical* minimum number of workstations?
d) What is the idle time per boat produced?

TASK	PERFORMANCE TIME (min)	TASK MUST FOLLOW TASK LISTED BELOW
A	1	—
B	1	A
C	2	A
D	1	C
E	3	C
F	1	C
G	1	D, E, F
H	2	B
I	1	G, H


Ivan Smuk/Shutterstock

• • 9.19 Because of the expected high demand for Mach 10, Creative Leisure has decided to increase manufacturing time available to produce the Mach 10 (see Problem 9.18).
a) If demand remained the same but 300 minutes were available each day on the assembly line, how many workstations would be needed?
b) What would be the efficiency of the new system, using the actual number of workstations from (a)?
c) What would be the impact on the system if 400 minutes were available?

• • • 9.20 Dr. Lori Baker, operations manager at Nesa Electronics, prides herself on excellent assembly-line balancing. She has been told that the firm needs to complete 96 instruments per 24-hour day. The assembly-line activities are:

TASK	TIME (min)	PREDECESSORS
A	3	—
B	6	—
C	7	A
D	5	A, B
E	2	B
F	4	C
G	5	F
H	7	D, E
I	1	H
J	6	E
K	4	G, I, J
	50	

a) Draw the precedence diagram.
b) If the daily (24-hour) production rate is 96 units, what is the highest allowable cycle time?
c) If the cycle time after allowances is given as 10 minutes, what is the daily (24-hour) production rate?
d) With a 10-minute cycle time, what is the theoretical minimum number of stations with which the line can be balanced?
e) With a 10-minute cycle time and six workstations, what is the efficiency?
f) What is the total idle time per cycle with a 10-minute cycle time and six workstations?
g) What is the best workstation assignment you can make without exceeding a 10-minute cycle time, and what is its efficiency? PX

• • **9.21** Suppose production requirements in Solved Problem 9.2 (see page 396) increase and require a reduction in cycle time from 8 minutes to 7 minutes. Balance the line once again, using the new cycle time. Note that it is not possible to combine task times so as to group tasks into the minimum number of workstations. This condition occurs in actual balancing problems fairly often. PX

• • **9.22** The preinduction physical examination given by the U.S. Army involves the following seven activities:

ACTIVITY	AVERAGE TIME (min)
Medical history	10
Blood tests	8
Eye examination	5
Measurements (e.g., weight, height, blood pressure)	7
Medical examination	16
Psychological interview	12
Exit medical evaluation	10

These activities can be performed in any order, with two exceptions: Medical history must be taken first, and Exit medical evaluation is last. At present, there are three paramedics and two physicians on duty during each shift. Only physicians can perform exit evaluations and conduct psychological interviews. Other activities can be carried out by either physicians or paramedics.

a) Develop a layout and balance the line.
b) How many people can be processed per hour?
c) Which activity accounts for the current bottleneck?
d) What is the total idle time per cycle?
e) If one more physician and one more paramedic can be placed on duty, how would you redraw the layout? What is the new throughput?

• • • **9.23** Samuel Smith's company wants to establish an assembly line to manufacture its new product, the iStar phone. Samuel's goal is to produce 60 iStars per hour. Tasks, task times, and immediate predecessors are as follows:

TASK	TIME (sec)	IMMEDIATE PREDECESSORS	TASK	TIME (sec)	IMMEDIATE PREDECESSORS
A	40	—	F	25	C
B	30	A	G	15	C
C	50	A	H	20	D, E
D	40	B	I	18	F, G
E	6	B	J	30	H, I

a) What is the theoretical minimum for the number of workstations that Samuel can achieve in this assembly line?
b) Use the *most following tasks* heuristic to balance an assembly line for the iStar phone.
c) How many workstations are in your answer to (b)?
d) What is the efficiency of your answer to (b)? PX

• • • • **9.24** As the Cottrell Bicycle Co. of St. Louis completes plans for its new assembly line, it identifies 25 different tasks in the production process. VP of Operations Jonathan Cottrell now faces the job of balancing the line. He lists precedences and provides time estimates for each step based on work-sampling techniques. His goal is to produce 1,000 bicycles per standard 40-hour workweek.

TASK	TIME (sec)	PRECEDENCE TASKS	TASK	TIME (sec)	PRECEDENCE TASKS
K3	60	—	E3	109	F3
K4	24	K3	D6	53	F4
K9	27	K3	D7	72	F9, E2, E3
J1	66	K3	D8	78	E3, D6
J2	22	K3	D9	37	D6
J3	3	—	C1	78	F7
G4	79	K4, K9	B3	72	D7, D8, D9, C1
G5	29	K9, J1	B5	108	C1
F3	32	J2	B7	18	B3
F4	92	J2	A1	52	B5
F7	21	J3	A2	72	B5
F9	126	G4	A3	114	B7, A1, A2
E2	18	G5, F3			

a) Balance this operation, using various heuristics. Which is best and why?
b) What happens if the firm can change to a 41-hour workweek? PX

Additional problems **9.25–9.27** *are available in* MyOMLab.

CASE STUDIES

State Automobile License Renewals

Henry Coupe, the manager of a metropolitan branch office of the state department of motor vehicles, attempted to analyze the driver's license-renewal operations. He had to perform several steps. After examining the license-renewal process, he identified those steps and associated times required to perform each step, as shown in the following table:

State Automobile License Renewal Process Times

STEP	AVERAGE TIME TO PERFORM (sec)
1. Review renewal application for correctness	15
2. Process and record payment	30
3. Check file for violations and restrictions	60
4. Conduct eye test	40
5. Photograph applicant	20
6. Issue temporary license	30

Coupe found that each step was assigned to a different person. Each application was a separate process in the sequence shown. He determined that his office should be prepared to accommodate a maximum demand of processing 120 renewal applicants per hour.

He observed that work was unevenly divided among clerks and that the clerk responsible for checking violations tended to shortcut her task to keep up with the others. Long lines built up during the maximum-demand periods.

Coupe also found that Steps 1 to 4 were handled by general clerks who were each paid $12 per hour. Step 5 was performed by a photographer paid $16 per hour. (Branch offices were charged $10 per hour for each camera to perform photography.) Step 6, issuing temporary licenses, was required by state policy to be handled by uniformed motor vehicle officers. Officers were paid $18 per hour but could be assigned to any job except photography.

A review of the jobs indicated that Step 1, reviewing applications for correctness, had to be performed before any other step could be taken. Similarly, Step 6, issuing temporary licenses, could not be performed until all the other steps were completed.

Henry Coupe was under severe pressure to increase productivity and reduce costs, but he was also told by the regional director that he must accommodate the demand for renewals. Otherwise, "heads would roll."

Discussion Questions

1. What is the maximum number of applications per hour that can be handled by the present configuration of the process?
2. How many applications can be processed per hour if a second clerk is added to check for violations?
3. If the second clerk could be added *anywhere* you choose (and not necessarily to check for violations, as in Question 2), what is the maximum number of applications the process can handle? What is the new configuration?
4. How would you suggest modifying the process to accommodate 120 applications per hour? What is the cost per application of this new configuration?

Source: Modified from a case by W. Earl Sasser, Paul R. Olson, and D. Daryl Wyckoff, *Management of Services Operations: Text, Cases, and Readings* (Boston: Allyn & Bacon).

Laying Out Arnold Palmer Hospital's New Facility

Video Case

When Orlando's Arnold Palmer Hospital began plans to create a new 273-bed, 11-story hospital across the street from its existing facility, which was bursting at the seams in terms of capacity, a massive planning process began. The $100 million building, opened in 2006, was long overdue, according to Executive Director Kathy Swanson: "We started Arnold Palmer Hospital in 1989, with a mission to provide quality services for children and women in a comforting, family-friendly environment. Since then we have served well over 1.5 million women and children and now deliver more than 12,000 babies a year. By 2001, we simply ran out of room, and it was time for us to grow."

The new hospital's unique, circular pod design provides a maximally efficient layout in all areas of the hospital, creating a patient-centered environment. *Servicescape* design features include a serene environment created through the use of warm colors, private rooms with pull-down Murphy beds for family members, 14-foot ceilings, and natural lighting with oversized windows in patient rooms. But these radical new features did not come easily. "This pod concept with a central nursing area and pie-shaped rooms resulted from over 1,000 planning meetings of 35 user groups, extensive motion and time studies, and computer simulations of the daily movements of nurses," says Swanson.

In a traditional linear hospital layout, called the *racetrack* design, patient rooms line long hallways, and a nurse might walk 2.7 miles per day serving patient needs at Arnold Palmer. "Some nurses spent 30% of their time simply walking. With the nursing shortage and the high cost of health care professionals, efficiency is a major concern," added Swanson. With the nursing station in the center of 10- or 12-bed circular pods, no patient room is more than 14 feet from a station. The time savings are in the 20% range. Swanson pointed to Figures 9.21 and 9.22 as examples of the old and new walking and trip distances.*

"We have also totally redesigned our neonatal rooms," says Swanson. "In the old system, there were 16 neonatal beds in a large and often noisy rectangular room. The new building features semiprivate rooms for these tiny babies. The rooms are much improved, with added privacy and a quiet, simulated night atmosphere, in addition to pull-down beds for parents to use. Our research shows that babies improve and develop much more quickly with this layout design. Layout and environment indeed impact patient care!"

*Layout and walking distances, including some of the numbers in Figures 9.21 and 9.22, have been simplified for purposes of this case.

Figure **9.21**

Traditional Hospital Layout

Patient rooms are on two linear hallways with exterior windows. Supply rooms are on interior corridors. This layout is called a "racetrack" design.

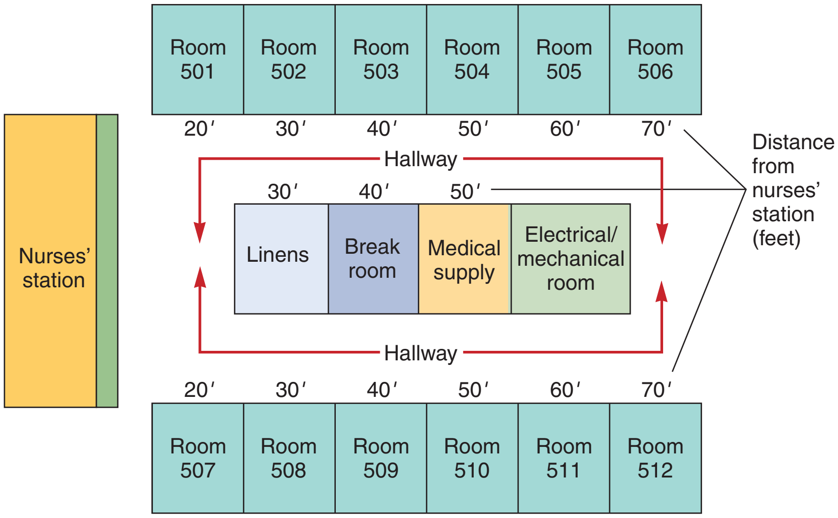
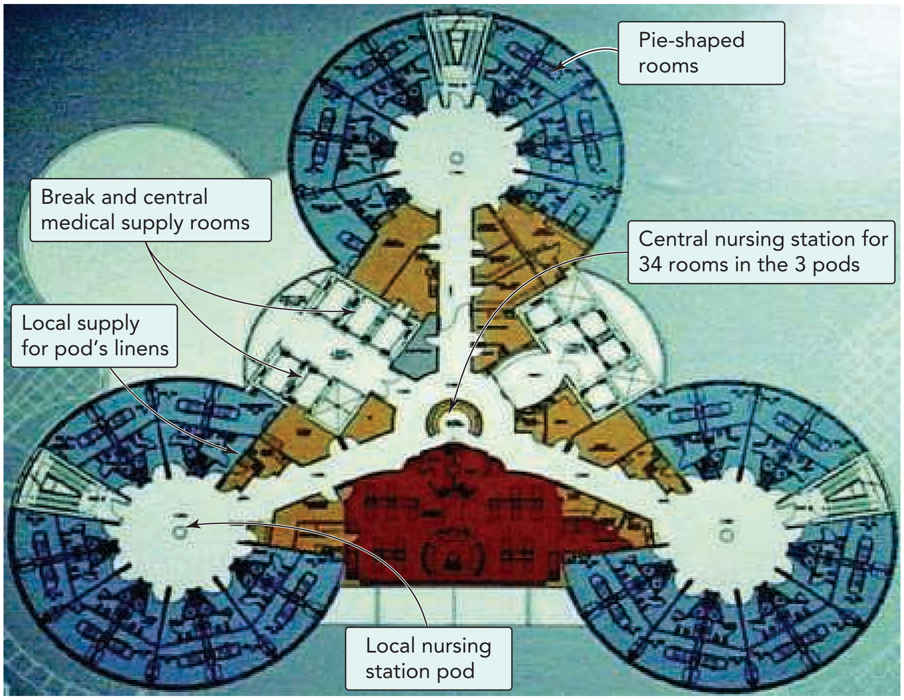


Figure **9.22**

New Pod Design for Hospital Layout

Note that each room is 14 feet from the pod's *local* nursing station. The *break rooms* and the *central medical station* are each about 60 feet from the local nursing pod. Pod *linen supply* rooms are also 14 feet from the local nursing station.



Courtesy Arnold Palmer Medical Center

Discussion Questions*

1. Identify the many variables that a hospital needs to consider in layout design.
2. What are the advantages of the circular pod design over the traditional linear hallway layout found in most hospitals?
3. Figure 9.21 illustrates a sample linear hallway layout. During a period of random observation, nurse Thomas Smith's day includes 6 trips from the nursing station to each of the 12 patient rooms (back and forth), 20 trips to the medical supply room, 5 trips to the break room, and 12 trips to the linen supply room. What is his total distance traveled in miles?
4. Figure 9.22 illustrates an architect's drawing of Arnold Palmer Hospital's new circular pod system. If nurse Susan Jones's day includes 7 trips from the nursing pod to each of the 12 rooms (back and forth), 20 trips to central medical supply, 6 trips to the break room, and 12 trips to the pod linen supply, how many miles does she walk during her shift? What are the differences in the travel times between the two nurses for this random day?
5. The concept of *servicescapes* is discussed in this chapter. Describe why this is so important at Arnold Palmer Hospital, and give examples of its use in layout design.

6. As technology and costs change, hospitals continue to innovate. The reduced cost of computers means some hospitals have moved from a central computer at the nurse's station to computers in the room or on carts (see photo). What changes in overall hospital layout would these innovations suggest?

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

Rubbermaid Healthcare.

Facility Layout at Wheeled Coach

Video Case

When President Bob Collins began his career at Wheeled Coach, the world's largest manufacturer of ambulances, there were only a handful of employees. Now the firm's Florida plant has a workforce of 350. The physical plant has also expanded, with offices, R&D, final assembly, and wiring, cabinetry, and upholstery work cells in one large building. Growth has forced the painting work cell into a separate building, aluminum fabrication and body installation into another, inspection and shipping into a fourth, and warehousing into yet another.

Like many other growing companies, Wheeled Coach was not able to design its facility from scratch. And although management realizes that material handling costs are a little higher than an ideal layout would provide, Collins is pleased with the way the facility has evolved and employees have adapted. The aluminum cutting work cell lies adjacent to body fabrication, which, in turn, is located next to the body-installation work cell. And while the vehicle must be driven across a street to one building for painting and then to another for final assembly, at least the ambulance is on wheels. Collins is also satisfied with the flexibility shown in the design of the work cells. Cell construction is flexible and can accommodate changes in product mix and volume. In addition, work cells are typically small and movable, with many work benches and staging racks borne on wheels so that they can be easily rearranged and products transported to the assembly line.

Assembly-line balancing is one key problem facing Wheeled Coach and every other repetitive manufacturer. Produced on a schedule calling for four 10-hour work days per week, once an ambulance is on one of the six final assembly lines, it *must* move forward each day to the next workstation. Balancing just enough workers and tasks at each of the seven workstations is a never-ending challenge. Too many workers end up running into each other; too few can't finish an ambulance in seven days. Constant shifting of design and mix and improved analysis has led to frequent changes.

Discussion Questions*

1. What analytical techniques are available to help a company like Wheeled Coach deal with layout problems?
2. What suggestions would you make to Bob Collins about his layout?
3. How would you measure the "efficiency" of this layout?

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

- **Additional Case Study:** Visit MyOMLab for this free case study:
  Microfix, Inc.: This company needs to balance its PC manufacturing assembly line and deal with sensitivity analysis of time estimates.

Endnotes

1. Fayurd, A. L., and J. Weeks. "Who Moved My Cube?" *Harvard Business Review* (July–August, 2011): 102.
2. *Takt* is German for "time," "measure," or "beat" and is used in this context as the rate at which completed units must be produced to satisfy customer demand.
3. *Cycle time* is the maximum time allowed to accomplish a task or process step. Several process steps may be necessary to complete the product. *Takt time*, discussed earlier, is determined by the customer and is the speed at which completed units must be produced to satisfy customer demand.

Chapter 9 *Rapid Review*

Main Heading	Review Material	MyOMLab
THE STRATEGIC IMPORTANCE OF LAYOUT DECISIONS (p. 370)	Layout has numerous strategic implications because it establishes an organization's competitive priorities in regard to capacity, processes, flexibility, and cost, as well as quality of work life, customer contact, and image. *The objective of layout strategy is to develop an effective and efficient layout that will meet the firm's competitive requirements.*	Concept Questions: 1.1–1.4
TYPES OF LAYOUT (pp. 370–371)	Types of layout and examples of their typical objectives include: 1. *Office layout*: Locate workers requiring frequent contact close to one another. 2. *Retail layout*: Expose customers to high-margin items. 3. *Warehouse layout*: Balance low-cost storage with low-cost material handling. 4. *Fixed-position layout*: Move material to the limited storage areas around the site. 5. *Process-oriented layout*: Manage varied material flow for each product. 6. *Work-cell layout*: Identify a product family, build teams, and cross-train team members. 7. *Product-oriented layout*: Equalize the task time at each workstation.	Concept Questions: 2.1–2.4
OFFICE LAYOUT (pp. 371–372)	■ **Office layout**—The grouping of workers, their equipment, and spaces/offices to provide for comfort, safety, and movement of information. A *relationship chart* displays a "closeness value" between each pair of people and/or departments that need to be placed in the office layout.	Concept Questions: 3.1–3.4
RETAIL LAYOUT (pp. 372–375)	■ **Retail layout**—An approach that addresses flow, allocates space, and responds to customer behavior. Retail layouts are based on the idea that sales and profitability vary directly with customer exposure to products. The main *objective of retail layout is to maximize profitability per square foot of floor space* (or, in some stores, per linear foot of shelf space). ■ **Slotting fees**—Fees manufacturers pay to get shelf space for their products. ■ **Servicescape**—The physical surroundings in which a service takes place and how they affect customers and employees.	Concept Questions: 4.1–4.4
WAREHOUSE AND STORAGE LAYOUTS (pp. 375–377)	■ **Warehouse layout**—A design that attempts to minimize total cost by addressing trade-offs between space and material handling. The variety of items stored and the number of items "picked" has direct bearing on the optimal layout. Modern warehouse management is often an automated procedure using *automated storage and retrieval systems* (ASRSs). ■ **Cross-docking**—Avoiding the placement of materials or supplies in storage by processing them as they are received for shipment. Cross-docking requires both tight scheduling and accurate inbound product identification. ■ **Random stocking**—Used in warehousing to locate stock wherever there is an open location. ■ **Customizing**—Using warehousing to add value to a product through component modification, repair, labeling, and packaging.	Concept Questions: 5.1–5.4
FIXED-POSITION LAYOUT (pp. 377–378)	■ **Fixed-position layout**—A system that addresses the layout requirements of stationary projects. Fixed-position layouts involve three complications: (1) there is limited space at virtually all sites, (2) different materials are needed at different stages of a project, and (3) the volume of materials needed is dynamic.	Concept Questions: 6.1–6.4
PROCESS-ORIENTED LAYOUT (pp. 378–383)	■ **Process-oriented layout**—A layout that deals with low-volume, high-variety production in which like machines and equipment are grouped together. ■ **Job lots**—Groups or batches of parts processed together. $$\text{Minimize cost} = \sum_{i=1}^{n}\sum_{j=1}^{n} X_{ij}C_{ij} \quad (9\text{-}1)$$	Concept Questions: 7.1–7.4 Problems: 9.1–9.10 Virtual Office Hours for Solved Problem: 9.1 **VIDEO 9.1** Laying Out Arnold Palmer Hospital's New Facility **ACTIVE MODEL 9.1**

Chapter 9 *Rapid Review* continued

Main Heading	Review Material	MyOMLab
WORK CELLS (pp. 383–386)	■ **Work cell**—An arrangement of machines and personnel that focuses on making a single product or family of related products. ■ **Takt time**—Pace of production to meet customer demands. Takt time = Total work time available/ Units required to satisfy customer demand (9-2) Workers required = Total operation time required/Takt time (9-3) ■ **Focused work center**—A permanent or semipermanent product-oriented arrangement of machines and personnel. ■ **Focused factory**—A facility designed to produce similar products or components.	Concept Questions: 8.1–8.4 Problem: 9.11
REPETITIVE AND PRODUCT-ORIENTED LAYOUT (pp. 386–391)	■ **Fabrication line**—A machine-paced, product-oriented facility for building components. ■ **Assembly line**—An approach that puts fabricated parts together at a series of workstations; a repetitive process. ■ **Assembly-line balancing**—Obtaining output at each workstation on a production line in order to minimize delay. ■ **Cycle time**—The maximum time that a product is allowed at each workstation. Cycle time = Production time available per day ÷ Units required per day (9-4) $\text{Minimum number of workstations} = \sum_{i=1}^{n} \text{Time for task } i/(\text{Cycle time})$ (9-5) ■ **Heuristic**—Problem solving using procedures and rules rather than mathematical optimization. Line-balancing heuristics include *longest task (operation) time, most following tasks, ranked positional weight, shortest task (operation) time,* and *least number of following tasks.* $\text{Efficiency} = \dfrac{\sum \text{Task times}}{(\textit{Actual}\text{ number of workstations}) \times (\text{Largest assigned cycle time})}$ (9-6) Idle time = (Actual number of workstations × Largest assigned cycle time) − ∑Task times (9-7)	Concept Questions: 9.1–9.4 Problems: 9.12–9.27 **VIDEO 9.2** Facility Layout at Wheeled Coach Ambulances Virtual Office Hours for Solved Problem: 9.2

Self Test

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

LO 9.1 Which of the statements below best describes *office layout*?
- **a)** Groups workers, their equipment, and spaces/offices to provide for movement of information.
- **b)** Addresses the layout requirements of large, bulky projects such as ships and buildings.
- **c)** Seeks the best personnel and machine utilization in repetitive or continuous production.
- **d)** Allocates shelf space and responds to customer behavior.
- **e)** Deals with low-volume, high-variety production.

LO 9.2 Which of the following does *not* support the retail layout objective of maximizing customer exposure to products?
- **a)** Locate high-draw items around the periphery of the store.
- **b)** Use prominent locations for high-impulse and high-margin items.
- **c)** Maximize exposure to expensive items.
- **d)** Use end-aisle locations.
- **e)** Convey the store's mission with the careful positioning of the lead-off department.

LO 9.3 The major problem addressed by the warehouse layout strategy is:
- **a)** minimizing difficulties caused by material flow varying with each product.
- **b)** requiring frequent contact close to one another.
- **c)** addressing trade-offs between space and material handling.
- **c)** balancing product flow from one workstation to the next.
- **d)** none of the above.

LO 9.4 A fixed-position layout:
- **a)** groups workers to provide for movement of information.
- **b)** addresses the layout requirements of large, bulky projects such as ships and buildings.
- **c)** seeks the best machine utilization in continuous production.
- **d)** allocates shelf space based on customer behavior.
- **e)** deals with low-volume, high-variety production.

LO 9.5 A process-oriented layout:
- **a)** groups workers to provide for movement of information.
- **b)** addresses the layout requirements of large, bulky projects such as ships and buildings.
- **c)** seeks the best machine utilization in continuous production.
- **d)** allocates shelf space based on customer behavior.
- **e)** deals with low-volume, high-variety production.

LO 9.6 For a focused work center or focused factory to be appropriate, the following three factors are required:
- **a)** ____________
- **b)** ____________
- **c)** ____________

LO 9.7 Before considering a product-oriented layout, it is important to be certain of:
- **a)** ____________
- **b)** ____________
- **c)** ____________
- **d)** ____________

LO 9.8 An assembly line is to be designed for a product whose completion requires 21 minutes of work. The factory works 400 minutes per day. Can a production line with five workstations make 100 units per day?
- **a)** Yes, with exactly 100 minutes to spare.
- **b)** No, but four workstations would be sufficient.
- **c)** No, it will fall short even with a perfectly balanced line.
- **d)** Yes, but the line's efficiency is very low.
- **e)** Cannot be determined from the information given.

Answers: LO 9.1. a; LO 9.2. c; LO 9.3. c; LO 9.4. b; LO 9.5. e; LO 9.6. family of products, stable forecast (demand), volume; LO 9.7. adequate volume, stable demand, standardized product, adequate/quality supplies; LO 9.8. c.