CHAPTER 9

Capacity Planning and Facility Location

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

1. Globalization, Chapter 1, p. 18.
2. Differences between strategic and tactical decisions, Chapter 1, p. 9.
3. Break-even analysis, Chapter 3, pp. 59–60.
4. Qualitative forecasting methods, Chapter 8, pp. 268–270.

LEARNING OBJECTIVES

After studying this chapter you should be able to

1. Define capacity planning.
2. Define location analysis.
3. Describe the relationship between capacity planning and location and their importance to the organization.
4. Explain the steps involved in capacity planning and location analysis.
5. Describe the decision support tools used in capacity planning.
6. Identify key factors in location analysis.
7. Describe the decision support tools used in location analysis.

CHAPTER OUTLINE

WHAT'S IN OM FOR ME?

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Have you ever signed up for a course at your college or university only to find out that it is closed? Have you ever attended a class that was held in a remote location and found that the room was overcrowded? Most of us have had these experiences as students. These examples illustrate problems of poor capacity planning and location—problems that can greatly affect the success of a business. Students have been known to drop out of a course that is uncomfortable to sit in, difficult to get to, or even to leave a program in which courses are frequently closed. Similarly, businesses can lose customers by not being able to produce enough goods or by being in an inconvenient location.

Matching the capacity of a business with customer demand can be a challenge. Having too much capacity is just as problematic as not having enough capacity. The first leads to excess cost from having idle facilities, workers, and equipment. The second leads to lost sales as the company cannot satisfy customer demands.

After the terrorist attacks of September 11, 2001, many firms in the hospitality industry found themselves with excess capacity. This included such businesses as hotels, airlines, cruise ships, and amusement parks. Many of these companies, such as the Marriott Corporation, Walt Disney Company, and Carnival Cruises, offered promotional incentives to increase customer demand. Similarly, after the SARS epidemic in 2003 many international airlines offered large discounts on fares as they found themselves with excess capacity in the form of idle aircraft.

Capacity planning and location analysis are actually two separate decisions. Capacity planning deals with the maximum output rate that a facility can have, determined by the size of facilities and equipment. Location analysis, on the other hand, deals with the best location for a facility. You can probably see why these two decisions are usually made simultaneously. When a company decides to open a new facility, it must also decide on both the size of the facility and its location. The size of the facility may also be affected by the location.

In this chapter we will learn about both capacity planning and location analysis. We will see how companies make both kinds of decisions. We will also see how both of these issues can affect not only the success of a company but your everyday life as well.

CAPACITY PLANNING

Capacity
The maximum output rate that can be achieved by a facility.

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Capacity can be defined as the maximum output rate that can be achieved by a facility. The facility may be an entire organization, a division, or only one machine. Planning for capacity in a company is usually performed at two levels, each corresponding to either strategic or tactical decisions, as discussed in Chapter 1. The first level of capacity decisions is strategic and long-term in nature. This is where a company decides what investments in new facilities and equipment it should make. Because these decisions are strategic in nature, the company will have to live with them for a long time. Also, they require large capital expenditures and will have a great impact on the company's ability to conduct business. The second level of capacity decisions is more tactical in nature, focusing on short-term issues that include planning of workforce, inventories, and day-to-day use of machines. In this chapter we focus on long-term, strategic capacity decisions. Short-term capacity decisions are discussed in Chapter 14.

Why Is Capacity Planning Important?

Capacity planning
The process of establishing the output rate that can be achieved by a facility.

Capacity planning is the process of establishing the output rate that can be achieved by a facility. If a company does not plan its capacity correctly, it may find that it either does not have enough output capability to meet customer demands or has too much capacity sitting idle. In our university example, that would mean either not being able to offer enough courses to accommodate all students or having too few students in the classrooms. Both cases are costly to the university. Another example is a bakery. Not having enough capacity would mean not being able to produce enough baked goods to meet sales. The bakery would often run out of stock, and customers might start going somewhere else. Also, the bakery would not be able to take advantage of the true demand available. On the other hand, if there is too much capacity, the bakery would incur the cost of an unnecessarily large facility that is not being used, as well as much higher operating costs than necessary.

LINKS TO PRACTICE

Capacity Planning in the ER


Masterfile

A hospital emergency room (ER) exemplifies the challenges of capacity planning. The problems of over- or undercapacity we just discussed also occur in the ER, only with potentially dire consequences. A number of factors contribute to the capacity of the ER. One is the number of beds and the amount of space available. If there are not enough beds, patients may have to wait long periods of time to be examined. Too many empty beds, on the other hand, result in wasted space.

Another factor affecting the ER's capacity is the number of nurses and doctors scheduled to work on a shift. If not enough staff is available, patients may not have anyone to treat them. The consequences of not having enough capacity can be grave. However, scheduling more staff than needed results in excess capacity in the form of highly paid professionals not having anything to do.

Capacity planning problems are notorious in the ER, partly due to high fluctuations in demand and the high costs of insufficient capacity. In fact, the American College of Emergency Physicians estimates that 62 percent of U.S. emergency rooms are at or above capacity. Particularly troubling are long patient waiting times that average over 47 minutes before a doctor is seen but can be as long as many hours. Many ERs are looking at ways to address this problem. One alternative being implemented is to immediately screen patients and identify those with minor ailments. These patients are then put into a "fast-track" category to be quickly treated and released. This technique serves to free up capacity for those patients that need it.

Planning for capacity is important if a company wants to grow and take full advantage of demand. At the same time, capacity decisions are complicated because they require long-term commitments of expensive resources, such as large facilities. Once these commitments have been made, it is costly to change them. Think about a business that purchases a larger facility in anticipation of an increase in demand, only to find that the demand increase does not occur. It is then left with a huge expense, no return on its investment, and the need to decide how to use a partially empty facility. Recall from Chapter 8 that forecasting future demands entails a great deal of uncertainty and risk; this makes long-term facility purchases inherently risky.

Another issue that complicates capacity planning is the fact that capacity is usually purchased in "chunks" rather than in smooth increments. Facilities, such as buildings and equipment, are acquired in large sizes, and it is virtually impossible to achieve an exact match between current needs and needs based on future demand. You can see this in the classroom example. If a university anticipates a large demand for a particular course, it may offer multiple sections. Each additional section adds capacity in chunks equal to one class size. If one class can hold a maximum of 45 students, opening up another class means adding capacity for up to an additional 45 students. The university must consider its forecast of the additional demand for the course. If the forecast for additional demand is only 4 additional students, the university will probably not open up another section. The reason is that the cost for each section takes the form of chunks that include the room, the instructor, and utilities. This cost is the same whether 1 student or 45 students attend.

Because of the uncertainty of future demand, the overriding capacity planning decision becomes one of whether to purchase a larger facility in anticipation of greater demand or to expand in slightly smaller but less efficient increments. Each strategy has its advantages and disadvantages. Think about a young married couple who want to purchase a home. They can purchase a very small home that would be more affordable, knowing that if they have children they eventually will need to face the disruption and cost of moving. On the other hand, if they purchase a larger home now they will be better prepared for the future but will be paying for additional space that they currently do not need.

Measuring Capacity

Although our definition of capacity seems simple, there is no one way to measure it. Different people have different interpretations of what capacity means, and the units of measurement are often very different. Table 9-1 shows some examples of how capacity might be measured by different organizations.

TABLE 9-1

Examples of Different Capacity Measures

Type of Business	Input Measures of Capacity	Output Measures of Capacity
Car manufacturer	Labor hours	Cars per shift
Hospital	Available beds per month	Number of patients per month
Pizza parlor	Worker hours per day	Number of pizzas per day
Ice-cream manufacturer	Operational hours per day	Gallons of ice cream per day
Retail store	Floor space in square feet	Revenues per day

Note that each business can measure capacity in different ways and that capacity can be measured using either inputs or outputs. Output measures, such as the number of cars per shift, are easier to understand. However, they do not work well when a company produces many different kinds of products. For example, if we operate a bakery that bakes only pumpkin pies, then a measure such as pies per day would work well. However, if we made many different kinds of pies and varied the combination from one day to the next, then simply using pies per day as our measure would not work as well, especially if some pies took longer to make than others. Suppose that pecan pies take twice as long to make as pumpkin pies. If one day we made 20 pumpkin pies and the next day we made 10 pecan pies, using *pies per day* as our measure would make it seem as if our capacity was underutilized on the second day, even though it was equally utilized on both days. When a company produces many different kinds of products, input measures work better.

When discussing the capacity of a facility, we need two types of information. The first is the *amount of available capacity*, which will help us understand how much capacity our facility has. The second is *effectiveness of capacity use*, which will tell us how effectively we are using our available capacity. Next we look at how to quantify and interpret this information.

E. Dygas/Taxi/Getty Images, Inc.

Overcrowding is a sign of insufficient capacity.

Measuring Available Capacity Let's return to our bakery example for a moment. Suppose that on the average we can make 20 pies per day. However, if we are really pushed, such as during holidays, maybe we can make 30 pies per day. Which of these is our true capacity? We can make 30 pies per day at a maximum, but we cannot keep up that pace for long. Saying that 30 per day is our capacity would be misleading. On the other hand, saying that 20 pies per day is our capacity does not reflect the fact that we can, if necessary, push our production to 30 pies.

Through this example you can see that different measures of capacity are useful because they provide different kinds of information. Following are two of the most common measures of capacity:

▶ **Design capacity** The maximum output rate that can be achieved by a facility under ideal conditions.

Design capacity is the maximum output rate that can be achieved by a facility under ideal conditions. In our example, this is 30 pies per day. Design capacity can be sustained only for a relatively short period of time. A company achieves this output rate by using many temporary measures, such as overtime, overstaffing, maximum use of equipment, and subcontracting.

Effective capacity is the maximum output rate that can be sustained under normal conditions. These conditions include realistic work schedules and breaks, regular staff levels, scheduled machine maintenance, and none of the temporary measures that are used to achieve design capacity. Note that effective capacity is usually lower than design capacity. In our example, effective capacity is 20 pies per day.

▶ **Effective capacity** The maximum output rate that can be sustained under normal conditions.

Measuring Effectiveness of Capacity Use Regardless of how much capacity we have, we also need to measure how well we are utilizing it. **Capacity utilization** simply tells us how much of our capacity we are actually using. Certainly there would be a big difference if we were using 50 percent of our capacity, meaning our facilities, space, labor, and equipment, rather than 90 percent. Capacity utilization can simply be computed as the ratio of actual output over capacity:

▶ **Capacity utilization** Percentage measure of how well available capacity is being used.

$$\text{Utilization} = \frac{\text{actual output rate}}{\text{capacity}}(100\%)$$

However, since we have two capacity measures, we can measure utilization relative to either design or effective capacity:

$$\text{Utilization}_{\text{effective}} = \frac{\text{actual output}}{\text{effective capacity}}(100\%)$$

$$\text{Utilization}_{\text{design}} = \frac{\text{actual output}}{\text{design capacity}}(100\%)$$

EXAMPLE 9.1

Computing Capacity Utilization

In the bakery example, we have established that design capacity is 30 pies per day and effective capacity is 20 pies per day. Currently, the bakery is producing 27 pies per day. What is the bakery's capacity utilization relative to both design and effective capacity?

- **Before You Begin:** To compute capacity utilization, you need to calculate the ratio of actual output (27 pies per day) over capacity. The difference between the two capacity measures is that one uses effective capacity (20 pies per day) and the other uses design capacity (30 pies per day).
- **Solution:**

$$\text{Utilization}_{\text{effective}} = \frac{\text{actual output}}{\text{effective capacity}}(100\%) = \frac{27}{20}(100\%) = 135\%$$

$$\text{Utilization}_{\text{design}} = \frac{\text{actual output}}{\text{design capacity}}(100\%) = \frac{27}{30}(100\%) = 90\%$$

The utilization rates show that the bakery's current output is only slightly below its design capacity and output is considerably higher than its effective capacity. The bakery can probably operate at this level for only a short time.

Capacity Considerations

We have seen that changing capacity is not as simple as acquiring the right amount of capacity to exactly match our needs. The reason is that capacity is purchased in discrete chunks. Also, capacity decisions are long term and strategic in nature. Acquiring

anticipated capacity ahead of time can save cost and disruption in the long run. Later, when demand increases, output can be increased without incurring additional fixed cost. Extra capacity can also serve to intimidate and preempt competitors from entering the market. Important implications of capacity that a company needs to consider when changing its capacity are discussed in this section.

Best operating level The volume of output that results in the lowest average unit cost.

Economies of scale A condition in which the average cost of a unit produced is reduced as the amount of output is increased.

Economies of Scale Every production facility has a volume of output that results in the lowest average unit cost. This is called the facility's **best operating level**. Figure 9-1 illustrates how the average unit cost of output is affected by the volume produced. You can see that as the number of units produced is increased, the average cost per unit drops. The reason is that when a large amount of goods is produced, the costs of production are spread over that large volume. These costs include the fixed costs of buildings and facilities, the costs of materials, and processing costs. The more units are produced, the larger the number of units over which costs can be spread—that is, the greater the **economies of scale**. The concept of economies of scale is very well known. It basically states that the average cost of a unit produced is reduced when the amount of output is increased.

You use the concept of economies of scale in your daily life, whether or not you are aware of it. Suppose you decide to make cookies in your kitchen. Think about the cost per cookie if you make only five cookies. There would be a great deal of effort—getting the ingredients, mixing the dough, shaping the cookies—all for only five cookies. If you had everything set up, making five additional cookies would not cost much more. Perhaps making even ten more cookies would cost only slightly more because you had already set up all the materials. This lower cost is due to economies of scale.

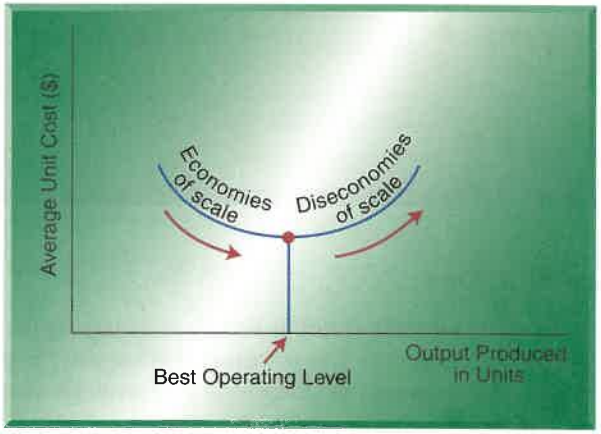
Diseconomies of scale A condition in which the cost of each additional unit made increases.

Diseconomies of Scale What if you continued to increase the number of cookies you chose to produce? For a while, making a few more cookies would not require much additional effort. However, after a certain point there would be so much material that the kitchen would become congested. You might have to get someone to help because there was more work than one person could handle. You might have to make cookies longer than expected, and the cleanup job might be much more difficult. You would be experiencing **diseconomies of scale**. Diseconomies of scale occur at a point beyond the best operating level, when the cost of each additional unit made increases. Diseconomies of scale are also illustrated in Figure 9-1.

Operating a facility close to its best operating level is clearly important because of the impact on costs. However, we have to keep in mind that different facility sizes have different best operating levels. In our cookie example, we can see that the number of

FIGURE 9-1

Different operating levels of a facility



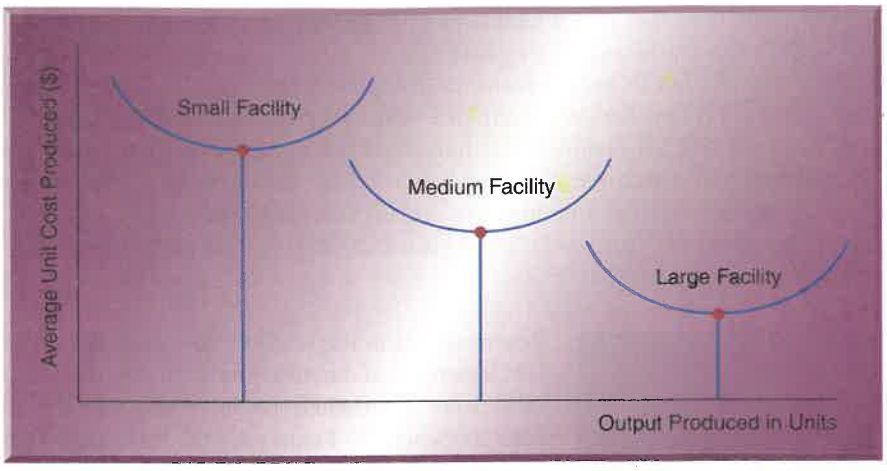


FIGURE 9-2

Best operating levels as functions of facility size

cookies comfortably produced by one person in a small kitchen would be much lower than the number produced by three friends in a large kitchen. Figure 9-2 shows how best operating level varies between facilities of different sizes.

You can see that each facility experiences both economies and diseconomies of scale. However, their best operating levels are different. This is a very important consideration when changing capacity levels. The capacity of a business can be changed by either expanding or reducing the amount of capacity. Although both decisions are important, expansion is typically a costlier and more critical event.

When expanding capacity, management has to choose between one of the following two alternatives:

Alternative 1: Purchase one large facility, requiring one large initial investment.
Alternative 2: Add capacity incrementally in smaller chunks as needed.

The first alternative means that we would have a large amount of excess capacity in the beginning and that our initial costs would be high. We would also run the risk that demand might not materialize and we would be left with unused overcapacity. On the other hand, this alternative allows us to be prepared for higher demand in the future. Our best operating level is much higher with this alternative, enabling us to operate more efficiently when meeting higher demand. Our costs would be lower in the long run, since one large construction project typically costs more than many smaller construction projects due to startup costs. Thus, alternative 1 provides greater rewards but is more risky. Alternative 2 is less risky but does not offer the same opportunities and flexibility. It is up to management to weigh the risks versus the rewards in selecting an alternative.

Focused Factories Facilities can respond more efficiently to demand if they are small, specialized, and focused on a narrow set of objectives; this concept is referred to as **focused factories**. We encountered this concept in Chapter 7 when we studied just-in-time (JIT) systems. Focused factories are only one of many factors that contribute to the success of JIT, but the concept is applicable to any facility.

▶ **Focused factories** Facilities that are small, specialized, and focused on a narrow set of objectives.

The idea that large facilities are necessary for success because they bring economies of scale is rather dated. Today's facilities must succeed in a business environment that has short product and technology life cycles and in which flexibility is more important than ever before. Large facilities tend to be less flexible because they generally contain larger machines or process technology that is costly to change in order to make other goods and services. Many companies have realized that to be more agile they need to

be focused. A smaller, specialized facility can be more efficient because it can focus on a smaller number of tasks and fewer goals.

Even a large facility can benefit from the concept of the focused factory by creating what is known as a *plant within a plant*, or PWP. A PWP is a large facility divided into smaller, more specialized facilities that have separate operations, competitive priorities, technology, and workforce. They can be physically separated with a wall or barrier and kept independent from one another. In this manner, unnecessary layers of bureaucracy are eliminated, and each "plant" is free to focus on its own objectives. PWP was discussed in detail in Chapter 3.

LINKS TO PRACTICE

Focus in the Retail Industry

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Recent trends in the retail industry provide an excellent example of factory focus. In the 1980s, retail sales were dominated by large department stores such as Sears, JC Penney's, and Federated Department Stores. However, in the 1990s, gains in sales were made by specialty stores such as the Gap, The Limited, and Ann Taylor, while large department stores faltered. The reason is that consumer preferences change very rapidly, and each small specialty store can focus precisely on the needs of its customer group. Specialty stores are able to focus on a specific set of customers and respond to their unique needs. The Limited and the Gap are excellent examples of factory focus, with specialty stores such as Limited Too, Baby Gap, and Gap Kids.

Subcontractor Networks Another alternative to having a large production facility is to develop a large network of subcontractors and suppliers who perform a number of tasks. This is one of the fastest-growing trends today. Companies are realizing that to be successful in today's market, they need to focus on their core capabilities—for example, by hiring third parties or subcontractors to take over tasks that the company does not need to perform itself. Companies such as American Airlines and Procter & Gamble have hired outside firms to manage noncritical inventories. Also, many companies are contracting with suppliers to perform tasks that they used to perform themselves. A good example is in the area of quality management. Historically, companies performed quality checks on goods received from suppliers. Today, suppliers and manufacturers work together to achieve the same quality standards, and much of the quality checking of incoming materials is performed at the supplier's site. Another example can be seen in the auto industry, where manufacturers are placing more responsibility on suppliers to perform tasks such as design of packaging and transportation of goods. By placing more responsibility on subcontractors and suppliers, a manufacturer can focus on tasks that are critical to its success, such as product development and design.

MAKING CAPACITY PLANNING DECISIONS

The three-step procedure for making capacity planning decisions is as follows:

Step 1 Identify Capacity Requirements The first step is to identify the levels of capacity needed by the company now, as well as in the future. A company cannot decide whether to purchase a new facility without knowing exactly how much capacity it will need in the future. It also needs to identify the gap between available capacity and future requirements.

Step 2 Develop Capacity Alternatives Once capacity requirements have been identified, the company needs to develop a set of alternatives that would enable it to meet future capacity needs.

Step 3 Evaluate Capacity Alternatives The last step in the procedure is to evaluate the capacity alternatives and select the one alternative that will best meet the company's requirements.

Let's look at these steps in a little more detail.

Identify Capacity Requirements

Long-term capacity requirements are identified on the basis of forecasts of future demand. Certainly, companies look for long-term patterns such as trends when making forecasts. However, long-term patterns are not enough at this stage. Planning, building, and starting up a new facility can take well over five years. Much can happen during that time. When the facilities are operational, they are expected to be utilized for many years into the future. During this time frame numerous changes can occur in the economy, consumer base, competition, technology, and demographic factors, as well as in government regulation and political events.

Forecasting Capacity Capacity requirements are identified on the basis of forecasts of future demand. Forecasting at this level is performed using qualitative forecasting methods, some of which are discussed in Chapter 8. Qualitative forecasting methods, such as *executive opinion* and the *Delphi method*, use subjective opinions of experts. These experts may consider inputs from quantitative forecasting models that can numerically compute patterns such as trends. However, because so many variables can influence demand at this level, the experts use their judgment to validate the quantitative forecast or modify it based on their own knowledge.

One way to proceed with long-range demand forecasting at this stage is to first forecast overall market demand. For example, experts might forecast the total market for overnight delivery to be $30 billion in five years. Then the company can estimate its market share as a percentage of the total. For example, our market share may be 15 percent. From that we can compute an estimate of demand for our company in five years by multiplying the overall market demand with the percentage held by our company (0.15 × $30 billion = $4.5 billion). That forecast of demand can then be translated into specific facility requirements.

Capacity Cushions Companies often add **capacity cushions** to their regular capacity requirements. A capacity cushion is an amount of capacity added to the needed capacity in order to provide greater flexibility. Capacity cushions can be helpful if demand is greater than expected. Also, cushions can help the ability of a business to respond to customer needs for different products or different volumes. Finally, businesses that operate too close to their maximum capacity experience many costs due to diseconomies of scale and may also experience deteriorating quality.

▶ **Capacity cushion** Additional capacity added to regular capacity requirements to provide greater flexibility.

Strategic Implications Finally, a company needs to consider how much capacity its competitors are likely to have. Capacity is a strategic decision, and the position of a company in the market relative to its competitors is very much determined by its capacity. At the same time, plans by all major competitors to increase capacity may signal the potential for overcapacity in the industry. Therefore, the decision as to how much capacity to add should be made carefully.

Large expansion alternatives often involve construction of new facilities.

Richard Braine/Stone/Getty Images

Develop Capacity Alternatives

Once a company has identified its capacity requirements for the future, the next step is to develop alternative ways to modify its capacity. One alternative is to do nothing and reevaluate the situation in the future. With this alternative, the company would not be able to meet any demands that exceed current capacity levels. Choosing this alternative and the time to reevaluate the company's needs is a strategic decision. The other alternatives require deciding whether to purchase one large facility now or add capacity incrementally, as discussed earlier in the chapter.

Capacity Alternatives:
1. Do nothing
2. Expand large now
3. Expand small now, with option to add later

Evaluate Capacity Alternatives

There are a number of tools that we can use to evaluate our capacity alternatives. Recall that these tools are only decision-support aids. Ultimately, managers have to use many different inputs, as well as their judgment, in making the final decision. One of the most popular of these tools is the decision tree. In the next section we look more closely at how decision trees can be helpful to managers at this stage.

DECISION TREES

Decision trees are useful whenever we have to evaluate interdependent decisions that must be made in sequence and when there is uncertainty about events. For that reason, they are especially useful for evaluating capacity expansion alternatives given that future demand is uncertain. Remember that our main decision is whether to purchase a large facility or a small one with the possibility of expansion later. You can see that the decision to expand later is dependent on choosing a small facility now. Which

alternative ends up being best will depend on whether demand turns out to be high or low. Unfortunately, we can only forecast future demand and have to incur some risks.

A **decision tree** is a diagram that models the alternatives being considered and the possible outcomes. Decision trees help by giving structure to a series of decisions and providing an objective way of evaluating alternatives. Decision trees contain the following information:

Decision tree Modeling tool used to evaluate independent decisions that must be made in sequence.

- *Decision points.* These are the points in time when decisions, such as whether or not to expand, are made. They are represented by squares, called "nodes."
- *Decision alternatives.* Buying a large facility and buying a small facility are two decision alternatives. They are represented by "branches" or arrows leaving a decision point.
- *Chance events.* These are events that could affect the value of a decision. For example, demand could be high or low. Each chance event has a probability or likelihood of occurring. For example, there may be a 60 percent chance of high demand and a 40 percent chance of low demand. Remember that the sum of the probabilities of all chances must add up to 100 percent. Chance events are "branches" or arrows leaving circular nodes.
- *Outcomes.* For each possible alternative an outcome is listed. In our example, that may be expected profit for each alternative (expand now or later) given each chance event (high demand or low demand).

These diagrams are called decision trees because the diagram of the decisions resembles a tree. Simple decision trees are not hard to understand. Next we look at an example to see how a decision tree might be used to solve a capacity alternative problem.

EXAMPLE 9.2

Using Decision Trees

Anna, the owner of Anna's Greek Restaurant, has determined that she needs to expand her facility. The decision is whether to expand now with a large facility, incurring additional costs and taking the risk that demand will not materialize, or expand now on a smaller scale, knowing that she will have to consider expanding again in three years. She has estimated the following chances for demand:

- The likelihood of demand being high is 0.70.
- The likelihood of demand being low is 0.30.

She has also estimated profits for each alternative:

- Large expansion has an estimated profitability of either $300,000 or $50,000, depending on whether demand turns out to be high or low.
- Small expansion has a profitability of $80,000, assuming that demand is low.
- Small expansion with an occurrence of high demand would require considering whether to expand further. If she expands at that point, her profitability is expected to be $200,000. If she does not expand further, profitability is expected to be $150,000.

Next we develop a decision tree to solve Anna's problem.

- **Before You Begin:** Remember that before you begin a decision tree problem, you should first draw a decision tree diagram. Then add the given information to the diagram and proceed to evaluate it.

- **Solution:**

To solve this problem we first need to draw the decision tree. Table 9-2 shows steps in drawing a decision tree.

TABLE 9-2

Procedure for Drawing a Decision Tree

1. Draw a decision tree from left to right. Use squares to indicate decisions and circles to indicate chance events.
2. Write the probability of each chance event in parentheses.
3. Write out the outcome for each alternative in the right margin.

A decision tree is shown in Figure 9-3. We read the diagram from left to right, with node 1 representing the first decision point. The two alternatives at that decision point are presented as branches. They are labeled with the two alternatives "Expand Small" and "Expand Large." Regardless of which alternative is followed, some chance events will take place. In our example the chance events are the occurrence of either high or low demand. The circular node represents the chance events, with the branches providing the label and the probability of the event. For example, the chance of high demand is 0.70 and the chance of low demand is 0.30.

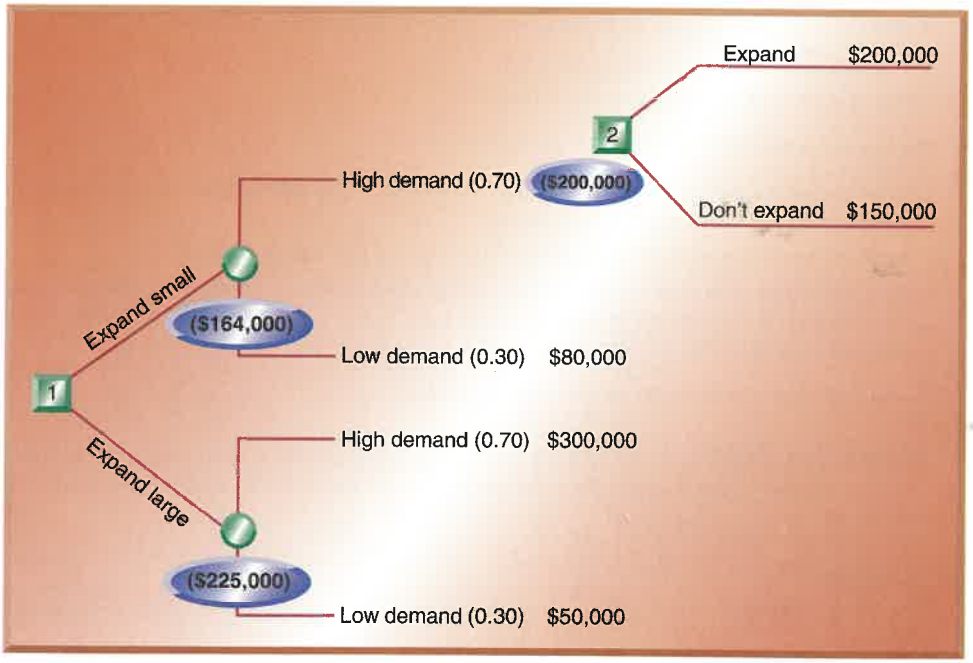
If we start with a small expansion and high demand occurs, we will have to decide whether or not to expand further. This second decision point is represented by node 2. The dollar amounts at the end of each alternative are the estimated profits. Now that we have drawn the decision tree, let's see how we can solve it. The procedure for solving a decision tree is outlined in Table 9-3.

Expected value (*EV*)
A weighted average of chance events, where each chance event is given a probability of occurrence.

We drew the decision tree from left to right. To evaluate it, we work backward, from right to left, to determine the expected value. The **expected value (*EV*)** is a weighted average of the chance events, where each chance event is given a probability of occurrence. We start with the profitability of each alternative, working backward and selecting the most profitable alternative. For example, at node 2 we should decide to expand further, because the profits from that decision are higher ($200,000 versus $150,000). If we come to that point, that is the decision we should make. The expected value (*EV*)

FIGURE 9-3

Decision tree for Anna's restaurant



1. To solve a decision tree, work from right to left. At each circle representing chance events, compute the expected value (*EV*).
2. Write the *EV*s below each circle.
3. Select the alternative with the highest *EV*.

TABLE 9-3

Procedure for Solving a Decision Tree

of profits at that point is written below node 2. This is the expected value if we decide on a small expansion and high demand occurs.

To compute the expected value (*EV*) of the small expansion, we evaluate it as a weighted average of estimated profits given the probability of occurrence of each chance event:

$$EV_{\text{small expansion}} = 0.30(\$80{,}000) + 0.70(\$200{,}000) = \$164{,}000$$

$$EV_{\text{large expansion}} = 0.30(\$50{,}000) + 0.70(\$300{,}000) = \$225{,}000$$

The large expansion gives the higher expected value. This means that Anna should pursue a large expansion now.

Before You Go On

Up to this point we have focused exclusively on capacity planning. By now you should understand that capacity is the maximum output rate of a facility. Capacity is defined in different ways, depending on the nature of the business. You should understand the basic trade-off made in choosing between capacity planning alternatives and the procedure used to evaluate alternatives. Finally, make sure you understand the relationship between capacity planning and location analysis. In the next section we discuss location analysis, which is another decision area for operations managers. Note, however, that location analysis is usually made in conjunction with capacity planning. Because the size of a facility is typically tied to its location, these decisions are made together. Make sure you understand the relationship between these decisions and their strategic implications for the firm.

LOCATION ANALYSIS

Location analysis Techniques for determining location decisions.

You might have heard the old real estate adage: the three most important factors in the value of a property are location, location, location. Have you ever left a service provider that you liked—say, a doctor, barber, or tailor—because they were in a location that was difficult to get to or too far away? Look at the business locations in your own neighborhood. We have all seen facilities in certain locations that have a high turnover of businesses and owners. The types of businesses and owners may be completely different, yet something about the location does not make it successful. Why do most fast-food restaurants locate near one another? In order to draw customers to one location. Why are the large automakers centered in Michigan? To draw suppliers to one area. Why do many medical facilities locate near hospitals? To be accessible to patients. Why do retail stores typically locate near each other? To attract a higher volume of customers.

These examples illustrate the strategic importance of location decisions. All other aspects of a business can be designed efficiently, but if the location is selected poorly, the business will have a harder time being successful. Different types of businesses emphasize different factors when making location decisions. Service organizations such as

restaurants, movie theaters, and banks focus on locating near their customers. Manufacturing organizations seek to be close to sources of transportation, suppliers, and abundant resources such as labor. However, many other factors need to be considered.

What Is Facility Location?

Facility location is determining the best geographic location for a company's facility. Facility location decisions are particularly important for two reasons. First, they require long-term commitments in buildings and facilities, which means that mistakes can be difficult to correct. Second, these decisions require sizable financial investment and can have a large impact on operating costs and revenues. Poor location can result in high transportation costs, inadequate supplies of raw materials and labor, loss of competitive advantage, and financial loss. Businesses therefore have to think long and hard about where to locate a new facility.

In most cases, there is no one best location for a facility. Rather, there are a number of acceptable locations. One location may satisfy some factors whereas another location may be better for others. If a new location is being considered in order to provide more capacity, the company needs to consider options such as expanding the current facility if the current location is satisfactory. Another option might be to add a new facility but also keep the current one. As you can see, there is a lot to consider.

Factors Affecting Location Decisions

Many factors can affect location decisions, including proximity to customers, transportation, source of labor, community attitude, proximity to suppliers, and many other factors. The nature of the firm's business will determine which factors should dominate the location decision. As already mentioned, service and manufacturing firms will focus on different factors. Profit-making and nonprofit organizations will also focus on different factors. Profit-making firms tend to locate near the markets they serve, whereas nonprofit organizations generally focus on other criteria.

It is important to identify factors that have a critical impact on the company's strategic goals. For example, even though proximity to customers is typically a critical factor for service firms, if the firm provides an in-home service (say, carpet cleaning), this may not be a critical issue. Also, while profit-making firms might locate near the markets they serve, nonprofit firms might choose to be near their major benefactors. Managers should also eliminate factors that are satisfied by every location alternative. Next we look more closely at some factors that affect location decisions.

Proximity to Sources of Supply Many firms need to locate close to sources of supply. The reasons for this can vary. In some cases, the firm has no choice, such as in farming, forestry, or mining operations, where proximity to natural resources is necessary. In other cases, the location may be determined by the perishable nature of goods, such as in preparing and processing perishable food items. Dole Pineapple has its pineapple farm and plant in Hawaii for both these purposes. Similarly, Tropicana has its processing plant in Florida, near the orange-growing orchards.

Another reason to locate close to sources of supply is to avoid high transportation costs—for example, if a firm's raw materials are much bulkier and costlier to move than the finished product. Transporting the finished product outbound is less costly than transporting the raw materials inbound, and the firm should locate closer to the source of supply. A paper mill is an example. Transporting lumber would be much more costly than transporting the paper produced.

LINKS TO PRACTICE

Locating in Silicon Valley

©AP/Wide World Photos

The importance of location decisions can be seen in the case of Internet companies during the boom of the dot-coms. Locating in Silicon Valley or San Francisco had become a major priority in the 1990s, for close proximity to highly skilled talent. Dot-coms were seeking over 4 million square feet of space in San Francisco, where only 1 million square feet was available. Consequently, the cost of locating there, including rent and leasing requirements, had become increasingly expensive. Tenants were paying $60 per square foot, an increase from the $40 per square foot paid just six months earlier. Landlords had also become picky about their tenants, and some were making unusual demands. Many were requiring as much as two years rent in advance. Others were even asking for equity in the company.

Then came the fall of the dot-coms. Space became abundant as many companies went out of business, and the cost of space dropped. Other companies, in an effort to remain financially viable, sought less costly locations. Almost overnight the importance of locating in Silicon Valley diminished.

Proximity to Customers Locating near the market they serve is often critical for many organizations, particularly service firms. To capture their share of the business, service firms need to be accessible to their customers. For this reason, service firms typically locate in high-population areas that offer convenient access. Examples include retail stores, fast-food restaurants, gas stations, grocery stores, dry cleaners, and flower shops. Large retail firms often locate in a central area of the market they serve. Smaller service firms usually follow the larger retailers because of the large number of the customers they attract. The smaller firms can usually count on getting some of the business.

Other reasons for locating close to customers may include the perishable nature of the company's products or high costs of transportation to the customer site. Food items such as groceries and baked goods, fresh flowers, and medications are perishable and need to be offered close to the market. Also, items such as heavy metal sheets, pipes, and cement need to be produced close to the market because the costs of transporting these materials are high.

Proximity to Source of Labor Proximity to an ample supply of qualified labor is important in many businesses, especially those that are labor intensive. The company needs to consider the availability of a particular type of labor and whether special skills are required. Some companies, such as those looking for assembly-line workers, want to be near a supply of blue-collar labor. Other companies may be looking for computer or technical skills and should consider locating in areas with a concentration of those types of workers.

Other factors that should be considered are local wage rates, the presence of local unions, and attitudes of local workers. Work ethics and attitudes toward work can vary greatly in different parts of the country and between urban and rural workers. Attitudes toward factors such as absenteeism, tardiness, and turnover can greatly affect a company's productivity.

Community Considerations The success of a company at a particular location can be affected by the extent to which it is accepted by the local community. Many communities welcome new businesses, viewing them as providing sources of tax revenues and opportunities for jobs, and as contributing to the overall well-being of the community. However, communities do not want businesses that bring pollution, noise, and traffic and that lower the quality of life. Extreme examples are a nuclear facility, a trash dump site, and an airport. Less extreme examples are companies like Wal-Mart, which often are not accepted by smaller communities, which may view such large merchants as a threat to their way of life and thus actively work to discourage them from locating there.

Site Considerations Site considerations for a particular location include factors such as utility costs, taxes, zoning restrictions, soil conditions, and even climate. These factors are not too different from those one would consider when purchasing a home or a lot to build on. Just as most homeowners consider their purchase to be an investment, so does a business. Inspectors should be hired to perform a thorough evaluation of the grounds, such as checking for adequate drainage. Site-related factors can also limit access roads for trucks and make it difficult for customers to reach the site.

Quality-of-Life Issues Another important factor in location decisions is the quality of life a particular location offers the company's employees. This factor can also become important in the future when the business is recruiting high-caliber employees. Quality of life includes factors such as climate, a desirable lifestyle, good schools, and a low crime rate. Certainly, quality of life would not be considered the most critical factor in selecting a location. However, when other factors do not differ much from one location to another, quality of life can be the decisive factor.

Other Considerations In addition to the factors discussed so far, there are others that companies need to consider. They include room for customer parking, visibility, customer and transportation access, as well as room for expansion. Room for expansion may be particularly important if the company has decided to expand now and possibly expand further at a later date. Other factors include construction costs, insurance, local competition, local traffic and road congestion, and local ordinances.

Globalization

▶ **Globalization**
The process of locating facilities around the world.

In addition to considering the specific factors affecting site location in the United States, companies need to consider how they will be affected by a major trend in business today: globalization. **Globalization** is the process of locating facilities around the world. Over the past decade it has become not only a trend but a matter-of-fact way of conducting business. Technology such as faxes, e-mails, video conferencing, and overnight delivery have made distance less relevant than ever before. Markets and competition are increasingly global. To compete effectively based on cost, many companies have had to expand their operations to include global sources of supply. Factors other than mere distance have become critical in selecting a geographic location.

Deciding to expand an operation globally is not a simple decision. There are many things to consider, and the problems must be weighed along with the benefits. In this section we look at both advantages and disadvantages of global operations. We also look at some additional implications of global operations that managers need to consider.

Advantages of Globalization There are many reasons why companies choose to expand their operations globally. The main one, however, is to take advantage of foreign markets. The demand for imported goods has grown tremendously, and these markets offer a new arena for competition. Also, locating production facilities in foreign countries reduces the stigma associated with buying imports. This concept works not only for U.S. companies abroad but for foreign companies in the United States as well. For example, Japanese automobile manufacturers have located in the United States and employed American workers, which has gone a long way toward eliminating negative attitudes about buying Japanese cars. Being in the United States has also reduced their exposure to currency variations between the dollar and yen.

Another advantage of global locations is reduction of trade barriers. By producing goods in the country where customers are located, a company can avoid import quotas. Trade barriers have also been reduced through the creation of trading blocs such as the European Union and trade agreements such as NAFTA (North American Free Trade Agreement). We discussed the contribution of these agreements to globalization in Chapter 1.

Cheap labor in countries such as Korea, Taiwan, and China has also attracted firms to locate there. Often it is cheaper to send raw materials to these countries for fabrication and assembly and then ship them elsewhere for final consumption than it is to keep the process in this country. The cost of labor can be so low that it more than offsets the additional transportation costs.

An area that has further encouraged globalization is the growth of just-in-time manufacturing, which encourages suppliers and manufacturers to be in close proximity to one another. Many suppliers have moved closer to the manufacturers they supply, and some manufacturers have moved closer to their suppliers.

Disadvantages of Globalization Although there are advantages to globalization, there are also a number of disadvantages that companies should consider. Political risks can be large, particularly in countries with unstable governments. For example, during a period of political unrest a company may have its technology confiscated. Foreign governments may also impose restrictions, tariffs on particular industries, and local ordinances that must be obeyed.

Using offshore suppliers might mean that a company may need to share some of its proprietary technology. Today's age of total quality management encourages the sharing of this type of information between manufacturers and suppliers to the advantage of both parties. A manufacturer may want to think carefully before sharing, however.

Another issue is whether to use local employees. Companies are often attracted to cheap foreign labor. However, the company might find that worker attitudes toward tardiness and absenteeism are different. Also, worker skills and productivity may be considerably lower, offsetting the benefits of lower wages.

The local infrastructure is another important issue. Many foreign countries do not have the developed infrastructure necessary for companies to operate in the manner that they do in their home country. Infrastructure includes everything from roads to utilities as well as other support services.

Issues to Consider in Locating Globally Firms are attracted to foreign locations in order to take advantage of foreign markets; cheaper suppliers or labor; and natural resources such as copper, aluminum, and timber. However, there are many issues to

consider when locating globally. One such issue is the effect of a *different culture*. Each culture has a different set of values, norms, ethics, and standards. For example, in France it is considered polite to be slightly late for an appointment, and such lateness is quite customary. The British, on the other hand, consider punctuality highly important and tardiness very rude. You can see how misunderstandings can develop even through simple differences like this one.

Language barriers are another potential problem. Employees need to be able to communicate easily in their work environment. Engaging in discussions, following instructions, and understanding exactly what is being said can become difficult when employees speak different languages. Even when one language is translated into another, the translation may have lost very essential parts of the meaning, resulting in damaging misunderstanding.

Different laws and regulations—including everything from pollution regulations to labor laws—may require changes in business practices. Also, what is acceptable in one culture may be completely unacceptable or even illegal in another. For example, in some countries offering a bribe may be an acceptable part of doing business, whereas in others it may land a person in jail.

Although it is important to know the factors affecting facility location, it is not enough for making good location decisions. In the next section we look at specific tools that can help managers with facility location decisions.

MAKING LOCATION DECISIONS

Procedure for Making Location Decisions

As with capacity planning, managers need to follow a three-step procedure when making facility location decisions. These steps are as follows:

Step 1 Identify Dominant Location Factors. In this step managers identify the location factors that are dominant for the business. This requires managerial judgment and knowledge.

Step 2 Develop Location Alternatives. Once managers know what factors are dominant, they can identify location alternatives that satisfy the selected factors.

Step 3 Evaluate Location Alternatives. After a set of location alternatives have been identified, managers evaluate them and make a final selection. This is not easy because one location may be preferred based on one set of factors, whereas another may be better based on a second set of factors.

Procedures for Evaluating Location Alternatives

A number of procedures can help in evaluating location alternatives. These are decision-support tools that help structure the decision-making process. Some of them help with qualitative factors that are subjective, such as quality of life. Others help with quantitative factors that can be measured, such as distance. A manager may choose to use multiple procedures to evaluate alternatives and come up with a final decision. Remember that the location decision is one that a company will have to live with for a long time. It is highly important that managers make the right decision.

Factor Rating You have seen by now that many of the factors that managers need to consider when evaluating location alternatives are qualitative in nature. Their importance is also highly subjective, based on the opinion of who is evaluating them. An

excellent procedure that can be used to give structure to this process is called factor rating. **Factor rating** can be used to evaluate multiple alternatives based on a number of selected factors. It is valuable because it helps decision makers structure their opinions relative to the factors identified as important. The following steps are used to develop a factor rating:

▶ **Factor rating**
A procedure that can be used to evaluate multiple alternative locations based on a number of selected factors.

Step 1 Identify dominant factors (e.g., proximity to market, access, competition, quality of life).

Step 2 Assign weights to factors reflecting the importance of each factor relative to the other factors. The sum of these weights must be 100.

Step 3 Select a scale by which to evaluate each location relative to each factor. A commonly used scale is a five-point scale, with 1 being poor and 5 excellent.

Step 4 Evaluate each alternative relative to each factor, using the scale selected in Step 3. For example, if you chose to use a five-point scale, a location that was excellent based on quality of life might get a 5 for that factor.

Step 5 For each factor and each location, multiply the weight of the factor by the score for that factor and sum the results for each alternative. This will give you a score for each alternative based on how you have rated the factors and how you have weighted each of the factors at each location.

Step 6 Select the alternative with the highest score.

Let's look at an example to see how this procedure is used.

Using Factor Rating — EXAMPLE 9.3

Antonio is evaluating three different locations for his new Italian restaurant. Costs are comparable at all three locations. He has identified seven factors that he considers important and has decided to use factor rating to evaluate his three location alternatives based on a five-point scale, with 1 being poor and 5 excellent. Table 9-4 shows Antonio's factors, the weights he has assigned to each factor, as well as the factor score for each factor at each location.

Table 9-4 Factor Rating for Antonio's Italian Restaurant

					Weighted Score for Each Location (Factor Weight × Factor Score)		
	Factor	Factor Score at Each Location					
Factor	Weight	Location 1	Location 2	Location 3	Location 1	Location 2	Location 3
Appearance	20	5	3	2	100	60	40
Ease of expansion	10	4	4	2	40	40	20
Proximity to market	20	2	3	5	40	60	100
Customer parking	15	5	3	3	75	45	45
Access	15	5	2	3	75	30	45
Competition	10	2	4	5	20	40	50
Labor supply	10	3	3	4	30	30	40
Total	**100**				**380**	**305**	**340**

From Table 9-4 it is clear that Antonio considers facility appearance and proximity to market the two most important factors, because he has rated each of these with a 20. Other factors are slightly less important. Note that Antonio selected the factors first. Then he decided to weight them based on his perception of their importance. He then computed a factor score for each factor at each location. Looking at the factor scores he selected, it appears that location 1 is excellent based on appearance, parking, and access, but poor based on closeness to the market. Location 3 is just the opposite, being excellent based on closeness to the market but poor based on facility

appearance. Location 2 appears to be somewhere in the middle. To evaluate which location alternative is best, Antonio needed to multiply the factor weight by the factor score for each factor at each location and then sum them. The best location alternative is that with the highest factor rating score. In Antonio's case, it is location 1. This problem can also be solved with a spreadsheet as shown:

	A	B	C	D	E	F	G
1							
2	**Factor Rating for Antonio's Italian Restaurant**						
3							
4		**Factor Scores (1-5 scale)**					
5	**Factor**	**Location 1**	**Location 2**	**Location 3**	**Factor Weight**		
6	Appearance	5	3	2	20		
7	Ease of expansion	4	4	2	10		
8	Proximity to market	2	3	5	20		
9	Customer parking	5	3	3	15		
10	Access	5	2	3	15		
11	Competition	2	4	5	10		
12	Labor supply	3	3	4	10		
13				Total	100		
14							
15	**Compute Weighted Factor Scores and Overall Scores for Each Location**						
16		**Weighted Factor Scores**					
17	**Factor**	**Location 1**	**Location 2**	**Location 3**			
18	Appearance	100	60	40			
19	Ease of expansion	40	40	20			
20	Proximity to market	40	60	100			
21	Customer parking	75	45	45			
22	Access	75	30	45			
23	Competition	20	40	50			
24	Labor supply	30	30	40			
25	Totals	380	305	340			
26							
27	Best Total Score	380					
28	Best Location	Location 1					

E13: =SUM(E6:E12)

B18: =B6*$E6 (copied to B18:D24)

B25: =SUM(B18:B24) (copied right)

B27: =MAX(B25:D25)

B28: =INDEX(B17:D17,MATCH(B27,B25:D25,0))

Load–distance model A procedure for evaluating location alternatives based on distance.

The Load–Distance Model The **load–distance model** is a procedure for evaluating location alternatives based on distance. The distance to be measured could be proximity to markets, proximity to suppliers or other resources, or proximity to any other facility that is considered important. The objective of the model is to select a location that minimizes the total amount of loads moved weighted by the distance traveled. What is a load? A load represents the goods moved in or out of a facility or the number of movements between facilities. For example, if 200 boxes of Kellogg's cereal are shipped between the local warehouse and a grocery store, that is the load between the warehouse and grocery store. The idea is to reduce the amount of distance between facilities that have a high load between them.

The model is shown in Table 9-5. Relative locations are compared by computing the load–distance, or *ld*, score for each location. The *ld* score for a particular location

ld score for a location $= \Sigma\, l_{ij}d_{ij}$
where l_{ij} = load between locations i and j
d_{ij} = distance between locations i and j

TABLE 9-5

The Load–Distance Model

is obtained by multiplying the load (denoted by l) for each location by the distance traveled (denoted by d) and then summing over all the locations. This score is a surrogate measure for movement of goods, material handling, or even communication. Our goal is to make the ld score as low as possible by reducing the distance the large loads have to travel.

Next we look at the steps in developing the load–distance model.

Step 1 Identify Distances. The first step is to identify the distances between location sites. It is certainly possible to use the actual mileage between locations. However, it is much quicker, and just as effective, to use simpler measures of distance. A frequently used measure of distance is **rectilinear distance**, the shortest distance between two points measured by using only north–south and east–west movements. To measure rectilinear distance, we place grid coordinates on a map and use them to measure the distance between two locations. Figure 9-4 presents an example of how the distance between locations A and B could be measured using rectilinear distance.

▶ **Rectilinear distance** The shortest distance between two points measured by using only north–south and east–west movements.

The rectilinear distance between two locations, A and B, is computed by summing the absolute differences between the x coordinates and the absolute differences between the y coordinates. The equation is as follows:

$$d_{AB} = |x_A - x_B| + |y_A - y_B|$$

In our example, the coordinates for location A are (30, 40). The coordinates for location B are (10, 15). Therefore, the rectilinear distance between these two points is

$$d_{AB} = |30 - 10| + |40 - 15| = 45 \text{ miles}$$

Step 2 Identify Loads. The next step is to identify the loads between different locations. The notation l_{ij} is used to indicate the load between locations i and j.

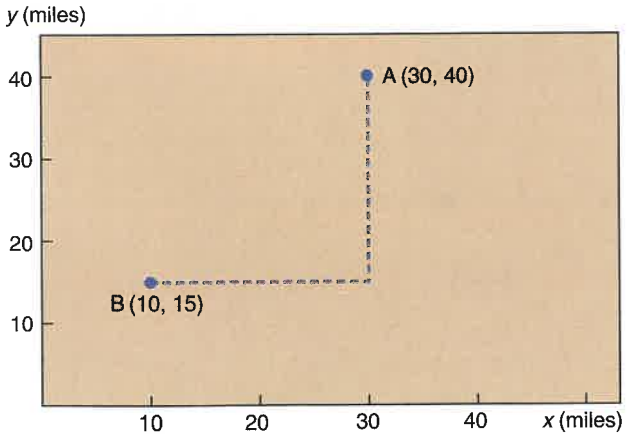


FIGURE 9-4

Rectilinear distance between points A and B

Step 3 Calculate the Load–Distance Score for Each Location. Next we calculate the load–distance score for each location by multiplying the load, l_{ij}, by the distance, d_{ij}. We compute the sum of $l_{ij}d_{ij}$ to get the ld score. Finally, we select the site with the lowest load–distance score.

Next we look at an example to see how to use the model.

EXAMPLE 9.4

Using the Load–Distance Model

Matrix Manufacturing Corporation is considering where to locate its warehouse in order to service its four stores located in four Ohio cities: Cleveland, Columbus, Cincinnati, and Dayton. Two possible sites for the warehouse are being considered. One is in Mansfield, Ohio, and the other is in Springfield, Ohio. Let's follow the steps of the load–distance model to select the best location for the warehouse.

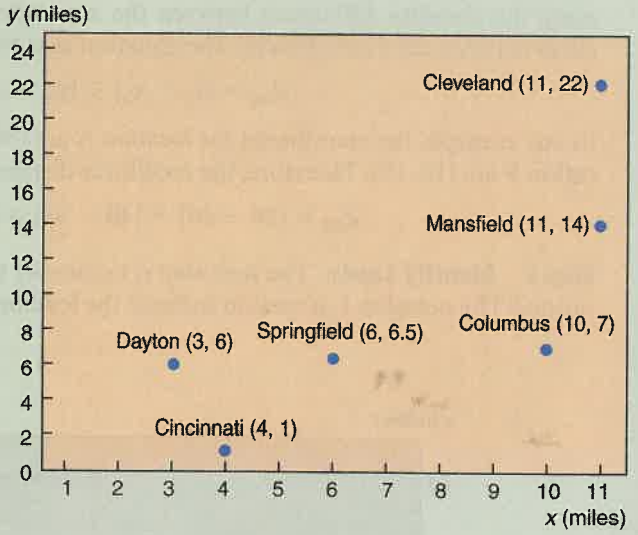
- **Before You Begin:** To solve this problem, follow the three steps given in the text for selecting a location with the load–distance model.

- **Solution:**

Step 1 Identify Distances. The distances between the locations can be seen in Figure 9-5, which shows a map of the cities with grid coordinates. The coordinates allow us to compute the distances between the cities. To compute the specific distances, we use the rectilinear distance measure.

FIGURE 9-5

Location map for Matrix Manufacturing



From Figure 9-5 we can compute the distances between the four cities and the Springfield site as follows:

City	Distance to Springfield
Cleveland	$\|11 - 6\| + \|22 - 6.5\| = 20.5$
Columbus	$\|10 - 6\| + \|7 - 6.5\| = 4.5$
Cincinnati	$\|4 - 6\| + \|1 - 6.5\| = 7.5$
Dayton	$\|3 - 6\| + \|6 - 6.5\| = 3.5$

Similarly, we can compute the distance between the four cities and the Mansfield site as follows:

City	Distance to Mansfield
Cleveland	$\|11 - 11\| + \|22 - 14\| = 8$
Columbus	$\|10 - 11\| + \|7 - 14\| = 8$
Cincinnati	$\|4 - 11\| + \|1 - 14\| = 20$
Dayton	$\|3 - 11\| + \|6 - 14\| = 16$

Step 2 Identify Loads. The next step is to identify the loads between the four cities and the warehouse. Remember that these loads will be the same regardless of where the warehouse is located. For this reason, we want to locate the warehouse at a place that will minimize the amount of distance large loads will have to travel.

City	Load between City and Warehouse
Cleveland	15
Columbus	10
Cincinnati	12
Dayton	4

Step 3 Calculate the Load–Distance Score for Each Location. The final step is to calculate the load–distance score for each location. The computation for Springfield is shown in Table 9-6.

Table 9-6 Computing the Load–Distance Score for Springfield

City	Load (l_{ij})	Distance (d_{ij})	$l_{ij}d_{ij}$
Cleveland	15	20.5	307.5
Columbus	10	4.5	45
Cincinnati	12	7.5	90
Dayton	4	3.5	14
Total	**Load–Distance Score: (456.5)**		

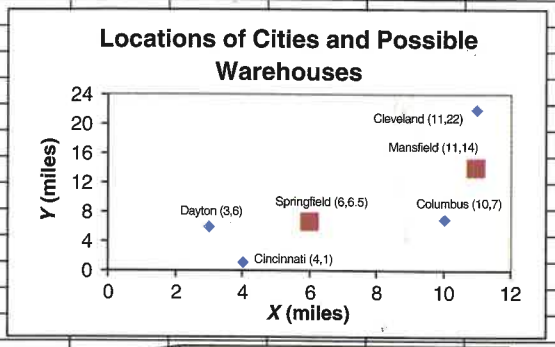
The load–distance score computed for Springfield does not tell us very much by itself. This number is useful only when comparing relative locations—that is, when we compare it to another load–distance score. The load–distance score for Mansfield is shown in Table 9-7.

Table 9-7 Computing the Load–Distance Score for Mansfield

City	Load (l_{ij})	Distance (d_{ij})	$l_{ij}d_{ij}$
Cleveland	15	8	120
Columbus	10	8	80
Cincinnati	12	20	240
Dayton	4	16	64
Total	**Load–Distance Score: (504)**		

The load–distance score for Mansfield is higher than the score for Springfield. Therefore, Matrix Manufacturing should locate its warehouse in Springfield. Note in the computation for the load–distance score for Mansfield that the load between the city and the warehouse did not change. What changed was the distance. Through the load–distance model we select a location that will minimize the distance large loads travel. This can also be computed using a spreadsheet, as shown.

	A	B	C	D	E	F	G	H	I
1									
2	**Load-Distance Model for Matrix Manufacturing**								
3									
4	**Coordinates of Stores (miles)**								
5		X	Y						
6	Cincinnati	4	1						
7	Cleveland	11	22						
8	Columbus	10	7						
9	Dayton	3	6						
10									
11	**Coordinates of Warehouses (miles)**								
12	Mansfield	11	14						
13	Springfield	6	6.5						
14									
15									
16	**Distances (rectilinear, in miles)**								
17		Cincinnati	Cleveland	Columbus	Dayton				
18	Mansfield	20	8	8	16				
19	Springfield	7.5	20.5	4.5	3.5				
20									
21	**Load between Warehouse and Store**								
22		Cincinnati	Cleveland	Columbus	Dayton				
23	Load	12	15	10	4				
24									
25	**Load-Distance Calculations**								
26		Cincinnati	Cleveland	Columbus	Dayton	Total			
27	Mansfield	240	120	80	64	**504**			
28	Springfield	90	307.5	45	14	**456.5**			
29									
30	Minimum Load-Di		**456.5**						
31	Best Location:		**Springfield**						



B18: =ABS($B12-$B$6)+ABS($C12-C6) (copied to B18:E19)

B27: =B$23*B18 (copied down and right)

F27: =SUM(B27:E27) (copied down)

C30: =MIN(F27:F28)

C31: =INDEX(A27:A28,MATCH(C30,F27:F28,0))

The Center of Gravity Approach When we used the load–distance model, we compared only two location alternatives. The load–distance was lower for Springfield than for Mansfield. However, we can also use the model to find other locations that may give an even lower load–distance score than Springfield. An easy way to do this is to start by testing the location at the center of gravity of the target area. The X and Y coordinates that give us the center of gravity for a particular area are computed in the following way:

$$X_{\text{c.g.}} = \frac{\Sigma\, l_i x_i}{\Sigma\, l_i}$$

$$Y_{\text{c.g.}} = \frac{\Sigma\, l_i y_i}{\Sigma\, l_i}$$

$$\text{c.g.} = \text{center of gravity}$$

The X coordinate for the center of gravity is computed by taking the X coordinate for each point and multiplying it by its load. These are then summed and divided by the sum of the loads. The same procedure is used to compute the Y coordinate.

The location identified with the center of gravity puts a larger penalty on long distances. This can have practical value given that longer distances impose more costs on the organization. However, the location identified may not be a feasible site because of geographic restrictions. For example, the center of gravity might turn out to be in the middle of Lake Michigan. However, the center of gravity provides an excellent starting point. We can use it to test the load–distance score of other locations in the area.

EXAMPLE 9.5

Computing the Center of Gravity

Find the center of gravity for the Matrix Manufacturing problem.

- **Before You Begin:** To solve this problem, use the center of gravity equations. Remember that you need to find both the X and Y coordinates.
- **Solution:**

Location	Coordinates (X, Y)	Load (l_i)	$l_i x_i$	$l_i y_i$
Cleveland	(11, 22)	15	165	330
Columbus	(10, 7)	10	100	70
Cincinnati	(4, 1)	12	48	12
Dayton	(3, 6)	4	12	24
Total		**41**	**325**	**436**

Now we need to find the coordinates for the center of gravity:

$$X_{c.g.} = \frac{\Sigma l_i x_i}{\Sigma l_i} = \frac{325}{41} = 7.9$$

$$Y_{c.g.} = \frac{\Sigma l_i y_i}{\Sigma l_i} = \frac{436}{41} = 10.6$$

Break-Even Analysis **Break-even analysis** is a technique used to compute the amount of goods that must be sold just to cover costs. The break-even point is precisely the quantity of goods a company needs to sell to break even. Whatever is sold above that point will bring a profit. Below that point the company will incur a loss. We discussed break-even analysis in Chapter 3 as a technique for evaluating the success of different products. In this chapter we use break-even analysis to evaluate different location alternatives. Remember that break-even analysis works with costs, such as fixed and variable costs. It can be an excellent technique when the factors under consideration can be expressed in terms of costs. Let's briefly review the basic break-even equations:

▶ **Break-even analysis** Technique used to compute the amount of goods that must be sold just to cover costs.

$$\text{Total cost} = F + cQ$$

$$\text{Total revenue} = pQ$$

where F = fixed cost
c = variable cost per unit
Q = number of units sold
p = price per unit

At the break-even point, total cost and total revenue are equal. We can use those equations to solve for Q, which is the break-even quantity:

$$Q = \frac{F}{p - c}$$

As we saw in Chapter 3, these quantities can be obtained graphically. Now let's look at the basic steps in using break-even analysis for location selection.

Step 1: For Each Location, Determine Fixed and Variable Costs. Recall from Chapter 3 that fixed costs are incurred regardless of how many units are produced and include items such as overhead, taxes, and insurance. Variable costs are costs that vary directly with the number of units produced and include items such as materials and labor. Total cost is the sum of fixed and variable costs.

Step 2: Plot the Total Costs for Each Location on One Graph. To plot any straight line we need two points. One point is $Q = 0$, which is the y intercept. Another point can be selected arbitrarily, but it is best to use the expected volume of sales in the future.

Step 3: Identify Ranges of Output for Which Each Location Has the Lowest Total Cost.

Step 4: Solve Algebraically for the Break-Even Points over the Identified Ranges. Select the location that gives the lowest cost for the range of output required by the new facility.

EXAMPLE 9.6 Using Break-Even Analysis

Clean-Clothes Cleaners is a dry cleaning business that is considering four possible sites for its new operation. The annual fixed and variable costs for each site have been estimated as follows:

Location	Fixed Costs	Variable Costs
A	$350,000	$ 5/unit
B	$170,000	$25/unit
C	$100,000	$40/unit
D	$250,000	$20/unit

(a) Plot the total cost curves for each location on the same graph and identify the range of output for which each location provides the lowest total cost.
(b) If demand is expected to be 10,000 units per year, which is the best location?

• **Before You Begin:** To solve this problem, follow the four steps given in the text for using break-even analysis in location selection.

• **Solution:**

(a) Step 1 in the break-even procedure has already been completed; that is, we have identified the fixed and variable costs. The next step is to plot the total costs of each location on a graph. For each line that we have to plot, we need two points. The first point can be $Q = 0$. We can compute the second point using expected demand, which is $Q = 10{,}000$ units. For $Q = 10{,}000$ units we compute the following total costs for each location:

Location	Fixed Cost	Variable Cost	Total Cost
A	$350,000	$ 5 (10,000)	$400,000
B	$170,000	$25 (10,000)	$420,000
C	$100,000	$40 (10,000)	$500,000
D	$250,000	$20 (10,000)	$450,000

The plots of these graphs are shown in Figure 9-6. You can see that depending on the range of output, locations C, B, and A are best. Location D is never a best option.

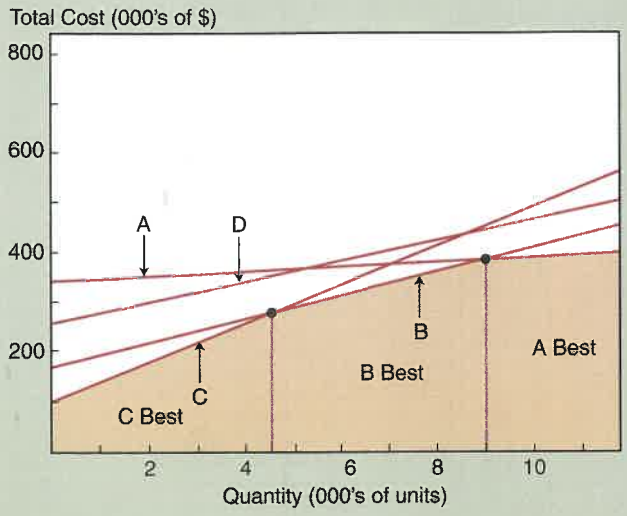


FIGURE 9-6

Break-even graph for Clean-Clothes Cleaners

(b) We can see the approximate ranges for each location in Figure 9-6. We can compute the exact ranges for each output location by finding the exact output level for which locations C and B are equal and for which locations B and A are equal. We can do this by computing the output levels at which the total cost equations for these locations are equal:

$$\text{Total cost equation for C} = \text{Total cost equation for B}$$

$$100{,}000 + \$40\,Q = 170{,}000 + \$25\,Q$$

$$Q = 4666.7 \text{ units}$$

Thus, the point between C and B is 4666.7, or roughly 4667 units.

$$\text{Total cost equation for B} = \text{Total cost equation for A}$$

$$170{,}000 + \$25\,Q = 350{,}000 + \$5\,Q$$

$$Q = 9000 \text{ units}$$

The breaking point between B and A is 9000 units, which means that location A would provide the lowest cost if we produce 9000 units or more. If we plan to meet a demand of 10,000 units, we should select location A. This problem can also be solved using a spreadsheet, as shown.

Break-Even Point Analysis for Clean Clothes Cleaners

Location	Fixed Cost	Variable Cost
A	$350,000	$5
B	$170,000	$25
C	$100,000	$40
D	$250,000	$20

Calculation of Exact Break-Even Point:

	Quantity
Between B and C	4,666.67
Between A and B	9,000.00

B12: =(B6-B7)/(C7-C6)
B13: =(B5-B6)/(C6-C5)

Enter any quantity

The Total Costs are computed, showing the best location for that quantity.

Quantity	4000
Minimum Cost	$260,000
Best Location	C

B18: =MIN(E18:E21)
B19: =INDEX(A5:A8,MATCH(B18,E18:E21,0))

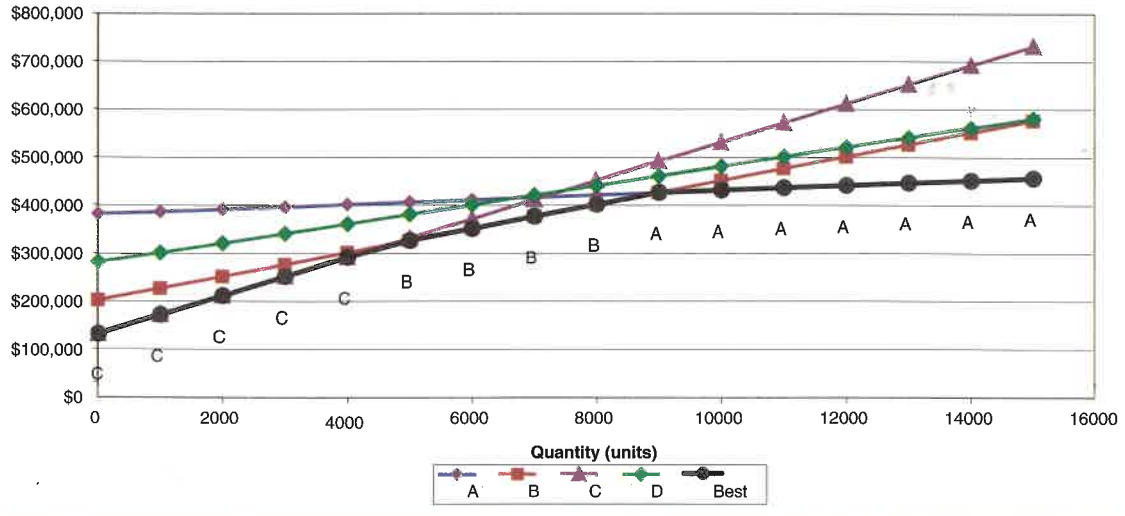
Location	0
A	$370,000
B	$270,000
C	$260,000
D	$330,000

E18: =B5+C5*B$17 (copied down)

Data Table to Compare Locations (highlighting shows best choice for each quantity)

Quantity	A	B	C	D	Best	Best Loc
	$370,000	$270,000	$260,000	$330,000	$260,000	C
0	$350,000	$170,000	$100,000	$250,000	$100,000	C
1000	$355,000	$195,000	$140,000	$270,000	$140,000	C
2000	$360,000	$220,000	$180,000	$290,000	$180,000	C
3000	$365,000	$245,000	$220,000	$310,000	$220,000	C
4000	$370,000	$270,000	$260,000	$330,000	$260,000	C
5000	$375,000	$295,000	$300,000	$350,000	$295,000	B
6000	$380,000	$320,000	$340,000	$370,000	$320,000	B
7000	$385,000	$345,000	$380,000	$390,000	$345,000	B
8000	$390,000	$370,000	$420,000	$410,000	$370,000	B
9000	$395,000	$395,000	$460,000	$430,000	$395,000	A
10000	$400,000	$420,000	$500,000	$450,000	$400,000	A
11000	$405,000	$445,000	$540,000	$470,000	$405,000	A
12000	$410,000	$470,000	$580,000	$490,000	$410,000	A
13000	$415,000	$495,000	$620,000	$510,000	$415,000	A
14000	$420,000	$520,000	$660,000	$530,000	$420,000	A
15000	$425,000	$545,000	$700,000	$550,000	$425,000	A

Example 9.6
Break-Even Analysis for Alternate Locations (black line shows best cost and location)



The Transportation Method The transportation method of linear programming is a useful technique for solving specific location problems; it is discussed in detail in the supplement for this text. The method relies on a specific algorithm to evaluate the cost impact of adding potential location sites to the network of existing facilities. For example, an existing network of facilities may consist of multiple sending and receiving sites. Our task might be to evaluate adding a new location site to this network, either a receiving site or a sending site. We might also wish to evaluate adding multiple new sites or completely redesigning the network. The transportation method can efficiently analyze all these situations and provide the lowest cost for each configuration considered.

CAPACITY PLANNING AND FACILITY LOCATION WITHIN OM: HOW IT ALL FITS TOGETHER

Decisions about capacity and location are highly dependent on forecasts of demand (Chapter 8). Forecasts determine the size of current and future capacity needs. Incorrect forecasts, where capacity is either over- or underestimated, can have a devastating effect on the capacity decision. Capacity is also affected by operations strategy (Chapter 2), as size of capacity is a key element of organizational structure. For example, the decision whether to expand now or later can be an important strategic choice. The former can preempt competition by enabling the company to be ready to meet demand. The latter can provide flexibility. Other operations decisions that are affected by capacity and location are issues of job design and labor skills (Chapter 11), choice on the mix of labor and technology, as well as choices on technology and automation (Chapter 3).

CAPACITY PLANNING AND FACILITY LOCATION ACROSS THE ORGANIZATION

By now it should be clear how capacity planning and location analysis affect operations management. However, these decisions are also important to many other functions in the company. In particular, finance and marketing have a great stake in capacity planning and location decisions.

Finance must be actively involved in the organization's capacity planning decisions. At the same time, operations managers need input from finance in order to finalize their capacity decisions. The reason should be clear. Capacity planning requires large financial expenditures. Building a large facility now would mean that funds would be tied up in excess capacity from which no financial return would be obtained for several years. At the same time, expanding capacity in increments could prove to be a greater financial drain due to poor planning. Location analysis, which is tied to the capacity planning decision, is basically a financial investment. Certain locations may be cheaper but may prove to be a poorer business investment. Finance needs to be an active participant in both the capacity planning and location analysis decisions.

Marketing is another function that is highly affected by capacity planning and location decisions. The amount of current and future capacity restricts the ability to meet demand. Building a large facility that enables the company to capture future demand and position itself in the marketplace could be advantageous from a marketing perspective. On the other hand, given future demands and competition this may not be a critical issue. Marketing is the function that has this information. Also, locating near customers can be critical for certain businesses, particularly service organizations. Marketing managers are in the best position to understand which location factors are most important to customers.

Capacity planning and location analysis are excellent examples of decisions that must be made by operations, finance, and marketing working together. As you can see, each of these functional areas has its domain of expertise and provides information that the others do not have. Together, they must arrive at capacity and location decisions that are best for the company in the long run.

THE SUPPLY CHAIN LINK

Think of a supply chain as a pipeline that supplies a certain level of customer demand. In order for the pipeline to satisfy this demand, the pipeline must flow smoothly without disruption. This can only happen if capacity is uniform throughout the entire supply chain and is matched between entities. For example, a manufacturer must make sure that the capacity of its suppliers is sufficient to meet its own capacity needs and that there is no gap in product delivery.

The link to supply chains also ties to the location decision. Many firms locate close to their source of supply or require their suppliers to locate in close proximity to them. Recall that Dell requires its suppliers to be located within a 15-minute radius of its production facility. Without close proximity and a match in capacity between supply chain entities, smooth flow throughout the supply chain would not be possible.

Chapter Highlights

1. Capacity planning is deciding on the maximum output rate of a facility.
2. Location analysis is deciding on the best location for a facility.
3. Capacity planning and location analysis decisions are often made simultaneously because the location of a facility is usually related to its capacity. When a business decides to expand, it usually also addresses the issue of where to locate. These decisions are very important because they require long-term investments in buildings and facilities, as well as a sizable financial outlay. Also, if capacity planning and location analysis are not done properly, a business will not be able to meet customer demands or may find that it is losing customers due to lack of proximity to the market.
4. In both capacity planning and location analysis, managers must follow a three-step process to make a good decision. The steps are assessing needs, developing alternatives, and evaluating alternatives.
5. To choose between capacity planning alternatives managers may use decision trees, which are a modeling tool for evaluating independent decisions that must be made in sequence.
6. Key factors in location analysis include proximity to customers, transportation, source of labor, community attitude, and proximity to supplies. Service and manufacturing firms focus on different factors. Profit-making and nonprofit organizations also focus on different factors.
7. Several tools can be used to facilitate location analysis. Factor rating is a tool that helps managers evaluate qualitative factors. The load–distance model and center of gravity approach evaluate the location decision based on distance. Break-even analysis is used to evaluate location decisions based on cost values. The transportation method is an excellent tool for evaluating the cost impact of adding sites to the network of current facilities.

Key Terms

capacity 316
capacity planning 316
design capacity 318
effective capacity 319
capacity utilization 319
best operating level 320
economies of scale 320
diseconomies of scale 320
focused factories 321
capacity cushion 323
decision tree 325
expected value (*EV*) 326
location analysis 327
globalization 330
factor rating 333
load–distance model 334
rectilinear distance 335
break-even analysis 339

Formula Review

1. $ld = \Sigma\, l_{ij} d_{ij}$

2. $\text{Utilization}_{\text{effective}} = \dfrac{\text{actual output}}{\text{effective capacity}}(100\%)$

3. $\text{Utilization}_{\text{design}} = \dfrac{\text{actual output}}{\text{design capacity}}(100\%)$

4. $X_{\text{c.g.}} = \dfrac{\Sigma\, l_i x_i}{\Sigma\, l_i}$

   $Y_{\text{c.g.}} = \dfrac{\Sigma\, l_i y_i}{\Sigma\, l_i}$

5. $Q = \dfrac{F}{p - c}$

Solved Problems

(See student companion site for Excel template.)

• Problem 1

A manufacturer of ballet shoes has determined that its production facility has a design capacity of 300 shoes per week. The effective capacity, however, is 230 shoes per week. What is the manufacturer's capacity utilization relative to both design and effective capacity if output is 200 shoes per week?

• *Before You Begin:*

Remember that utilization is computed as the ratio of actual output over capacity. The difference between the two capacity measures is that one uses effective capacity and the other uses design capacity.

• *Solution*

$$\text{Utilization}_{\text{effective}} = \frac{\text{actual output}}{\text{effective capacity}}(100\%)$$

$$= \frac{200}{230}(100\%) = 86.9\%$$

$$\text{Utilization}_{\text{design}} = \frac{\text{actual output}}{\text{design capacity}}(100\%)$$

$$= \frac{200}{300}(100\%) = 66.7\%$$

The utilization rates computed show that the facility's current output is comfortably below its design capacity. It is also slightly below effective utilization, which means that the manufacturer is not using capacity to its fullest extent.

• Problem 2

EKG Software Development Corporation has determined that it needs to expand its current capacity. The decision has come down to whether to expand now with a large facility, incurring additional costs and taking the risk that the demand will not materialize, or to undertake a small expansion, knowing that the decision will have to be reconsidered in five years. Management has estimated the following chances for demand:

- The likelihood of demand being high is 0.60.
- The likelihood of demand being low is 0.40.

Profits for each alternative have been estimated:

- Large expansion has an estimated profitability of either $1,000,000 or $600,000, depending on whether demand turns out to be high or low.
- Small expansion has a profitability of $500,000, assuming that demand is low.
- Small expansion with an occurrence of high demand would require considering whether to expand further. If the company expands at that point, the profitability is expected to be $700,000. If it does not expand further, the profitability is expected to be $500,000.

• *Before You Begin:*

Always begin a decision tree problem by drawing a decision tree diagram and adding the information that you are given. Then you can proceed to evaluate it.

• *Solution*

To solve this problem we need to draw the decision tree and evaluate it. A decision tree for this problem is shown in Figure 9-7. We read the diagram from left to right, with node 1 representing the first decision point: expanding with a large facility or expanding small. Following each decision are chance events, which are the occurrence of either high or low demand. The probabilities for each event are shown on each branch. Notice that decision point 2 is where we may have to make our second decision, but only if we expand small now and demand turns out to be high. Then in five years we would decide whether to expand further. The estimated profits are shown in the right margins. We can see that at node 2 we should decide to expand further because the profits from that decision are higher ($700,000 versus $500,000). The expected value (*EV*) of profits at that point is written below node 2. The dollar amounts at the end of each alternative are the estimated profits.

Now that we have drawn the decision tree, let's see how we can solve it. We do this by computing the expected value (EV) of the small and large expansions:

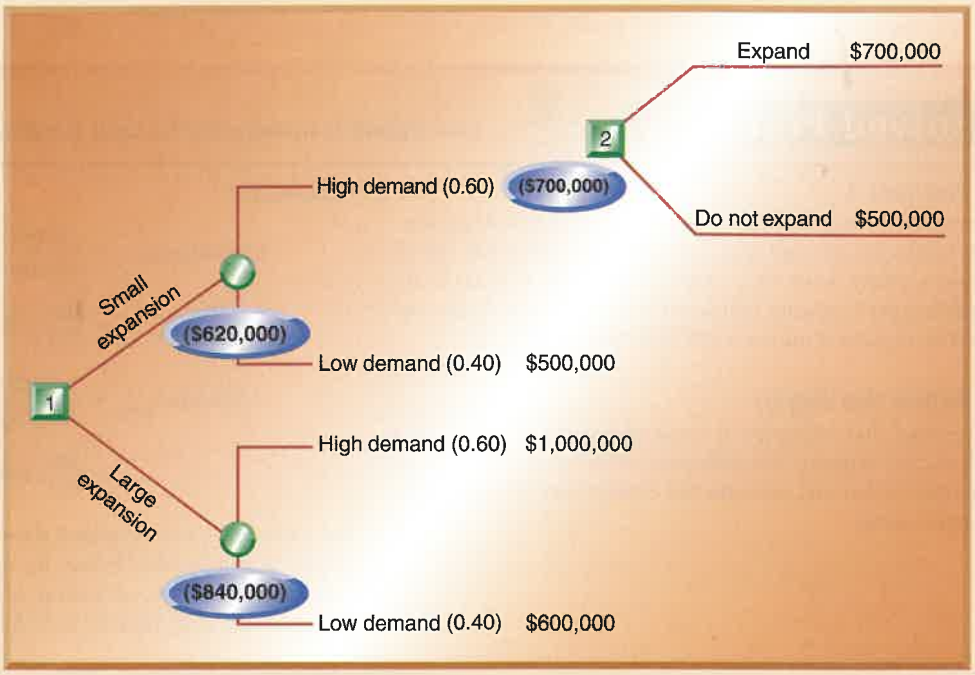
$$EV_{\text{small expansion}} = 0.60\ (\$700{,}000) + 0.40\ (\$500{,}000)$$
$$= \$620{,}000$$

$$EV_{\text{large expansion}} = 0.60\ (\$1{,}000{,}000) + 0.40\ (\$600{,}000)$$
$$= \$840{,}000$$

A large expansion now gives us a higher expected value.

FIGURE 9-7

Decision tree for EKG Corporation



• Problem 3

As a recent business school graduate, you are considering two job opportunities that both require relocation. The two jobs are identical and have the same career potential. Therefore, your decision will be based on an evaluation of the two locations. You have decided to use factor rating to make your decision and have identified the most important factors. You have also placed a weight on each factor that reflects its importance and have developed a factor score for each location based on a five-point scale. This information is shown in the table. Using the procedure for factor rating, complete the table.

• *Before You Begin:*

To solve this problem, for each location multiply the weight of the factor by the score for that factor and sum the results for each alternative. Then select the alternative with the highest score.

• *Solution*

The completed factor rating spreadsheet is shown on the next page.

		Factor Score at Each Location	
Factor	Factor Weight	Location 1	Location 2
Cost of living	10	5	2
Proximity to family	20	4	2
Climate	30	2	5
Transportation system	10	5	3
Quality of life	30	3	5

	A	B	C	D	E	F
1						
2	**Job Opportunity Location Analysis**					
3						
4		**Factor Scores (1-5 scale)**				
5	**Factor**	**Location 1**	**Location 2**	**Factor Weight**		
6	Cost of Living	5	2	10		
7	Proximity to Family	4	2	20		
8	Climate	2	5	30		
9	Transportation System	5	3	10		
10	Quality of Life	3	5	30	D11: =SUM(D6:D10)	
11			Total	100		
12						
13	**Compute Weighted Factor Scores and Overall Scores for Each Location**					
14		**Weighted Factor Scores**				
15	**Factor**	**Location 1**	**Location 2**			
16	Cost of Living	50	20			
17	Proximity to Family	80	40			
18	Climate	60	150			
19	Transportation System	50	30			
20	Quality of Life	90	150			
21	Totals	**330**	**390**			
22						
23	Best Total Score	**390**				
24	Best Location	**Location 2**				

B16: =B6*$D6 (copied to B16:C20)

B21: =SUM(B16:B20) (copy right)

B23: =MAX(B21:C21)

B24: =INDEX(B15:C15,MATCH(B23,B21:C21,0))

Based on these results, you should move to location 2.

• Problem 4

Shoeless Joe is a specialty retailer that is deciding where to locate its new facility. The annual fixed and variable costs for each site under consideration have been estimated as follows:

Location	Fixed Costs	Variable Costs
A	$70,000	$1/unit
B	$34,000	$5/unit
C	$20,000	$8/unit
D	$50,000	$4/unit

If demand is expected to be 2000 units, which location is best?

• *Before You Begin:*

To solve this problem, you must first determine fixed and variable costs and add them to compute total cost. Then select the location with the lowest total cost.

• *Solution*

For $Q = 2000$ units, we compute the following total costs for each location:

Location	Fixed Cost	Variable Cost	Total Cost
A	$70,000	$1 (2000)	$72,000
B	$34,000	$5 (2000)	$44,000
C	$20,000	$8 (2000)	$36,000
D	$50,000	$4 (2000)	$58,000

Shoeless Joe should locate at location C because it provides the lowest total cost for the expected demand of 2000 units.

Discussion Questions

1. Explain why capacity planning is important to a business.
2. Explain the differences between design capacity and effective capacity.
3. How is capacity utilization computed, and what does it tell us?
4. What are the steps in capacity planning?
5. What are decision trees, and how do they help us make better decisions?
6. Find and discuss business examples of overcapacity and undercapacity.
7. Explain the consequences of poor location decisions for a business.
8. Find examples of good and bad location decisions.
9. Describe three advantages and three disadvantages of globalization.
10. Describe the steps used to make location decisions.
11. Describe five factors that should be considered in the location decision.
12. Explain the differences among factor rating, the load–distance model, and break-even analysis. What criteria does each method use to make the location decision?

Problems

1. Joe's Tasty Burger has determined that its production facility has a design capacity of 400 hamburgers per day. The effective capacity, however, is 250 hamburgers per day. Lately Joe has noticed that output has been 300 hamburgers per day. Compute both design and effective capacity utilization measures. What can you conclude?

2. A manufacturer of printed circuit boards has a design capacity of 1000 boards per day. The effective capacity, however, is 700 boards per day. Recently, the production facility has been producing 950 boards per day. Compute the design and effective capacity utilization measures. What do they tell you?

3. Beth's Bakery can comfortably produce 60 brownies in one day. If Beth takes some unusual measures, such as hiring her two aunts to help in the kitchen and work overtime, she can produce up to 100 brownies in one day.
   (a) What are the design and effective capacities for Beth's Bakery?
   (b) If Beth is currently producing 64 brownies, compute the capacity utilization for both measures. What can you conclude?

4. The town barber shop can accommodate 35 customers per day. The manager has determined that if two additional barbers are hired, the shop can accommodate 80 customers per day. What are the design and effective capacities for the barber shop?

5. The design and effective capacities for a local paper manufacturer are 1000 and 600 pounds of paper per day, respectively. At present, the manufacturer is producing 500 pounds per day. Compute capacity utilization for both measures. What can you conclude?

6. The design and effective capacities for a local emergency facility are 300 and 260 patients per day, respectively. Currently, the emergency room processes 250 patients per day. What can you conclude from these figures?

7. The Steiner-Wallace Corporation has determined that it needs to expand in order to accommodate growing demand for its laptop computers. The decision has come down to either expanding now with a large facility, incurring additional costs and taking the risk that the demand will not materialize, or expanding small, knowing that in three years management will need to reconsider the question.

   Management has estimated the following chances for demand:

   - The likelihood of demand being high is 0.60.
   - The likelihood of demand being low is 0.40.

   Profits for each alternative have been estimated as follows:

   - Large expansion has an estimated profitability of either $100,000 or $60,000, depending on whether demand turns out to be high or low.
   - Small expansion has a profitability of $50,000, assuming that demand is low.
   - Small expansion with an occurrence of high demand would require considering whether to expand further. If the company expands at that point, the profitability is expected to be $70,000. If it does not expand further, the profitability is expected to be $45,000.

   (a) Draw a decision tree showing the decisions, chance events, and their probabilities, as well as the profitability of outcomes.
   (b) Solve the decision tree and decide what Steiner-Wallace should do.

8. The owners of Sweet-Tooth Bakery have determined that they need to expand their facility in order to meet their increased demand for baked goods. The decision is whether to expand now with a large facility or expand small with the possibility of having to expand again in five years.

   The owners have estimated the following chances for demand:

   - The likelihood of demand being high is 0.70.
   - The likelihood of demand being low is 0.30.

Profits for each alternative have been estimated as follows:

- Large expansion has an estimated profitability of either $80,000 or $50,000, depending on whether demand turns out to be high or low.
- Small expansion has a profitability of $40,000, assuming demand is low.
- Small expansion with an occurrence of high demand would require considering whether to expand further. If the bakery expands at this point, the profitability is to be $50,000.

(a) Draw a decision tree showing the decisions, chance events, and their probabilities, as well as the profitability of outcomes.
(b) Solve the decision tree and decide what the bakery should do.

9. Demand has grown at Dairy May Farms, and it is considering expanding. One option is to expand by purchasing a very large farm that will be able to meet expected future demand. Another option is to expand the current facility by a small amount now and take a wait-and-see attitude, with the possibility of a larger expansion in two years.

Management has estimated the following chances for demand:

- The likelihood of demand being high is 0.70.
- The likelihood of demand being low is 0.30.

Profits for each alternative have been estimated as follows:

- Large expansion has an estimated profitability of either $40,000 or $20,000, depending on whether demand turns out to be high or low.
- Small expansion has a profitability of $15,000, assuming that demand is low.
- Small expansion with an occurrence of high demand would require considering whether to expand further. If the company expands at that point, the profitability is expected to be $35,000. If it does not expand further, the profitability is expected to be $12,000.

(a) Draw a decision tree diagram for Dairy May Farms.
(b) Solve the decision tree you developed. What should Dairy May Farms do?

10. Spectrum Hair Salon is considering expanding its business, as it is experiencing a large growth. The question is whether it should expand with a bigger facility than needed, hoping that demand will catch up, or with a small facility, knowing that it will need to reconsider expanding in three years.

The management at Spectrum has estimated the following chances for demand:

- The likelihood of demand being high is 0.70.
- The likelihood of demand being low is 0.30.

Estimated profits for each alternative are as follows:

- Large expansion has an estimated profitability of either $100,000 or $70,000, depending on whether demand turns out to be high or low.
- Small expansion has a profitability of $50,000, assuming that demand is low.
- Small expansion with an occurrence of high demand would require considering whether to expand further. If the business expands at this point, the profitability is expected to be $90,000. If it does not expand further, the profitability is expected to be $60,000.

Draw a decision tree and solve the problem. What should Spectrum do?

11. Jody of Jody's Custom Tailoring is considering expanding her growing business. The question is whether to expand with a bigger facility than she needs or with a small facility, knowing that she will have to reconsider expanding in three years.

Jody has estimated the following chances for demand:

- The likelihood of demand being high is 0.50.
- The likelihood of demand being low is 0.50.

She has also estimated profits for each alternative:

- Large expansion has an estimated profitability of either $200,000 or $100,000, depending on whether demand turns out to be high or low.
- Small expansion has a profitability of $80,000, assuming that demand is low.
- Small expansion with an occurrence of high demand would require considering whether to expand further. If the business expands at that point, the profitability is expected to be $120,000. If it does not expand further, the profitability is expected to be $70,000.

Draw a decision tree and solve it. What should Jody's Custom Tailoring do?

12. The owners of Speedy Logistics, a company that provides overnight delivery of documents, are considering where to locate their new facility in the Midwest. They have narrowed their search down to two locations and have decided to use factor rating to make their decision. They have listed the factors they consider important and assigned a factor score to each location based on a five-point scale. The information is shown here. Using the procedure for factor rating, decide on the better location.

		Factor Score at Each Location	
Factor	Factor Weight	Location 1	Location 2
Proximity to airport	40	5	3
Proximity to road access	30	4	1
Proximity to labor source	10	3	5
Size of facility	20	2	4

13. Sue and Joe are a young married couple who are considering purchasing a new home. Their search has been reduced to two homes that they both like, at different locations. They have decided to use factor rating to help them make their decision. They have listed the factors they consider important and assigned a factor score to each location based on a five-point scale. The information is shown here. Using the procedure for factor rating, complete the table and help Sue and Joe make their decision.

		Factor Score at Each Location	
Factor	Factor Weight	Location 1	Location 2
Proximity to work	10	5	2
Proximity to family	20	4	2
Size of home	30	2	5
Transportation system	10	5	3
Neighborhood	30	3	5

14. The Bakers Dozen Restaurant is considering opening a new location. It has considered many factors and identified the ones that are most important. Two locations are being evaluated based on these factors, using factor rating. Each location has been evaluated relative to the factors on a five-point scale. These numbers are shown here. Use factor rating to help the restaurant decide on the better location.

		Factor Score at Each Location	
Factor	Factor Weight	Location 1	Location 2
Proximity to customers	30	5	2
Proximity to competition	10	4	2
Proximity to labor supply	30	2	5
Transportation system	20	5	3
Quality of life	10	3	5

15. Joe's Sports Supplies Corporation is considering where to locate its warehouse in order to service its four stores in four towns: A, B, C, and D. Two possible sites for the warehouse are being considered, one in Jasper and the other in Longboat. The following table shows the distances between the two locations being considered and the four store locations. Also shown are the loads between the warehouse and the four stores. Use the load–distance model to determine whether the warehouse should be located in Jasper or in Longboat.

Town	Distance to Jasper	Distance to Longboat	Load between City and Warehouse
A	30	12	15
B	6	12	10
C	10.5	30	12
D	4.5	24	8

16. Given here are the coordinates for each of the four towns to be serviced by the warehouse in Problem 15. Use the information from Problem 15 and the center of gravity method to determine coordinates for the warehouse.

Town	Coordinates (*X*, *Y*)
A	(4, 18)
B	(12, 2)
C	(10, 8)
D	(8, 15)

17. Shoeless Joe is a specialty retailer that is deciding where to locate a new facility. The annual fixed and variable costs for each possible site have been estimated as follows:

Location	Fixed Costs	Variable Costs
A	$70,000	$1/unit
B	$34,000	$5/unit
C	$20,000	$8/unit
D	$50,000	$4/unit

If demand is expected to be 2000 units, which location is best?

18. The Quick Copy center for document copying is deciding where to locate a new facility. The annual fixed and variable costs for each site it is considering have been estimated as follows:

Location	Fixed Costs	Variable Costs
A	$85,000	$2/unit
B	$49,000	$7/unit
C	$35,000	$10/unit
D	$65,000	$6/unit

If demand is expected to be 3000 units, which location is best?

CASE: Data Tech, Inc.

Data Tech, Inc. is a small but growing company started by Jeff Styles. Data Tech is a business that transfers hard copies of documents, such as invoices, bills, or mailing lists, onto CDs. As more companies move to a paperless environment, placing data on CDs is the wave of the future. Jeff had started the company in his two-car garage three years earlier by purchasing the necessary software and signing two large corporations as his first customers. Now he was about to sign on two additional corporate customers. Suddenly what was a small garage operation was turning into a major business.

The Business

The operations function of Data Tech seems deceptively simple. Every day Data Tech receives packages of mail from corporate customers containing documents they want transferred to disc. Data Tech usually receives anywhere from 10,000 to 30,000 pieces of mail per day that need to be processed. The first step requires workers to unpack and sort the mail received. Next, workers scan each item through one of two scanning machines that transfer content to disc. An accuracy check is then made to ensure that information was transferred correctly. This stage is particularly important as many of the documents contain important private information. Finally, the discs and the documents are packaged and sent back to the customer, with Data Tech keeping a backup disc for its records.

The Need for Capacity and Relocation

Running a full-time business out of his two-car garage is a challenge for Jeff Styles. Jeff has spent a great deal of time ensuring that the operation of Data Tech runs smoothly without any bottlenecks. He has been successful, and his two original customers have just signed long-term contracts with him. In addition, he has acquired two additional customers. This means that Data Tech needs to move to a larger facility that could accommodate the larger size of the business.

Jeff has narrowed his search to three potential locations. He has identified the factors that are important to him and rated each location considering a number of criteria. Some factors are especially important, such as proximity to the postal service that delivers the daily packages. Another is closeness to the airport, as Jeff frequently travels to customer locations.

A factor that is particularly troubling for Jeff is the issue of capacity. Two of the locations he is considering are larger than he currently needs and offer excess growth capacity. The third location would meet current capacity needs but would not offer ample room for expansion. He doesn't know which is a better strategy. In his list of factor weights Jeff has made spaces for both capacity options, giving himself some time to think about the issues.

The information that Jeff has compiled is shown in the table.

Factor	Factor Weight	Factor Score at Each Location		
		#1	#2	#3
Proximity to airport	20	3	4	4
Proximity to postal service	30	4	2	5
Facility with excess capacity	?	4	5	0
Facility with potential for expansion	?	0	1	5
Close to business community	10	5	4	4
Pleasant environment	10	3	4	4

To Expand Large or Small

Jeff is not sure how to evaluate whether he should focus on moving into a larger facility now or moving into a smaller facility with potential for expansion. He has estimated the following chances for demand:

- The likelihood of demand being high is 0.70.
- The likelihood of demand being low is 0.30.

He also estimated profitability for each alternative:

- Moving into a large facility has a profitability of either $1,000,000 or $600,000, depending on whether demand turns out to be high or low.
- Moving into a small facility has a profitability of $500,000, assuming that demand is low.
- Moving into a small facility would require considering expanding if demand turned high. If Data Tech decided to expand at that point, profitability would be $800,000. If it did not expand further, the profitability would be $500,000.

Case Questions

1. Help Jeff decide whether he should give greater priority to a smaller facility with possibility for expansion or move into a larger facility immediately. Decide on which is the best alternative and choose weights for the two capacity factors based on your findings.
2. Once you have selected the factors for the two capacity alternatives, use factor rating to select a new location for Data Tech.
3. How would your factor analysis be different if you had selected a different capacity alternative?

CASE: The Emergency Room (ER) at Northwest General (B)

Jenn Kostich, director of emergency services at Northwest General Hospital, is faced with a decision on how to respond to a recent memo. Her response could affect the entire ER operation, and she wants to make sure it is prepared correctly.

The Problem

Jenn has just learned that the board of Northwest General has approved plans for a large remodeling and expansion project. All department directors of the hospital have been asked to provide an assessment of their capacity needs if they were requesting an increase in their departmental space. The directors were told to specify the amount of increase they required and provide justification for the request. They were also directed to base their requests on the average of their departments' demand requirements.

The ER desperately needs more space, and Jenn is easily able to provide the needed documentation. However, she is not sure whether it is reasonable to base capacity requirements for the ER on average demand.

Background

Northwest General is the only major hospital in the area between Seattle and Vancouver. Its ER is always busy, since it is the only hospital servicing the local population and visitors during the long tourist season.

The area has been stable in population growth over the past 10 years. The area is also a significant tourist destination for campers, hikers, and nature lovers. During the tourist season—consisting of summer months (June, July, and August), winter holidays (December), and spring break (March and April)—the population swells by as much as 30 percent.

The ER has been able to meet demand adequately during the nontourist season. However, it does not have sufficient capacity to meet demand when tourists arrive. These peak periods, amounting to 6 out of 12 months, have been extremely difficult for the ER staff. The ER does not have enough space capacity for the large number of patients during these periods. Frequently, they have to resort to using hallways and closets for patient space. The staff feel that this is unacceptable, not to mention unsafe.

The capacity problems occur only during the busy tourist season. Computing the average of the capacity requirements does not reveal this problem, as the peak demands are averaged with the lower demands during the nontourist season.

Case Questions

1. Discuss the pros and cons of using average demand to assess capacity requirements. Is this a reasonable approach for the ER?
2. Make a recommendation for Jenn as to what she should do and the information that she should provide in her request.

INTERACTIVE CASE Virtual Company

www.wiley.com/college/reid

On-line Case: Cruise International, Inc.

Assignment: *Capacity Analysis at Cruise International, Inc.*

Bob Bristol just called to congratulate you on your excellent work on the various assignments at CII. He now wants you to do some capacity analysis for Meghan Willoughby, the Chief Purser. Meghan is concerned about the capacity needed for the embarkation process. If there is too much capacity, it is an unnecessary expense. However, if there is insufficient capacity, passengers are forced to wait in line for too long and their vacation starts with a negative experience. The amount of capacity is flexible as Meghan negotiates arrangements with the owners of the pier used, in terms of both square footage and the amount of time. This assignment will enhance your knowledge of the material in Chapter 9 of your textbook while preparing you for future assignments.

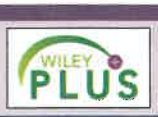
To access the Web site:

- Go to **www.wiley.com/college/reid**
- Click **Student Companion Site**
- Click **Virtual Company**
- Click **Consulting Assignments**
- Click **Capacity Analysis at CII**

INTERNET CHALLENGE EDS Office Supplies, Inc.

EDS is a national distributor of office supplies that delivers goods to department and specialty stores. It is planning to build a large distribution center in your state and is analyzing different location sites. You have been assigned the task of selecting the major city in your state that you think should be the site of the new distribution center. Here are some facts to consider. At present EDS has no other distribution center in your state. The goal is to locate in a major city that has easy access to major roadways; this will enable EDS to reach other destinations in the state. Although your decision will be subjective, be prepared to justify it. Go to the Internet to find a map of your state. Analyze roadways, distances, and access to other locations. Then use the Internet to get other information, such as traffic patterns, populations, and other geographic factors. Decide on the best location for the EDS distribution center and explain your decision.

On-line Resources



Companion Website www.wiley.com/college/reid

- Take interactive *practice quizzes* to assess your knowledge and help you study in a dynamic way
- Review *PowerPoint slides* or print slides for notetaking
- Download *Excel Templates* to use for problem solving
- Access the *Virtual Company: Cruise International, Inc.*
- Find links to *Company Tours* for this chapter
  Northeast Knitting Mills
  Coppley Apparel Group
- Find links for *Additional Web Resources* for this chapter
  The Association for Manufacturing Excellence, *www.ame.org*
  APICS—The Educational Society of Resource Management, *www.apics.org*

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