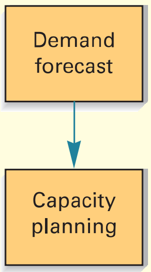

Capacity planning is a key strategic component in designing the system. It encompasses many basic decisions with long-term consequences for the organization. In this chapter, you will learn about the importance of capacity decisions, the measurement of capacity, how capacity requirements are determined, and the development and evaluation of capacity alternatives. Note that decisions made in the product or service design stage have major implications for capacity planning. Designs have processing requirements related to volume and degree of customization that affect capacity planning.

5.1 INTRODUCTION

Hospitals that not too long ago had what could be described as "facility oversupply" are now experiencing what can be described as a "capacity crisis" in some areas. The way hospitals plan for capacity will be critical to their future success. And the same applies to all sorts of organizations, and at all levels of these organizations. **Capacity** refers to an upper limit or ceiling on the load that an operating unit can handle. The load might be in terms of the number of physical units produced (e.g., bicycles assembled per hour) or the number of services performed (e.g., computers upgraded per hour). The operating unit might be a plant, department, machine, store, or worker. Capacity needs include equipment, space, and employee skills.

Capacity The upper limit or ceiling on the load that an operating unit can handle.

The goal of strategic capacity planning is to achieve a match between the long-term supply capabilities of an organization and the predicted level of long-term demand. Organizations become involved in capacity planning for various reasons. Among the chief reasons are changes in demand, changes in technology, changes in the environment, and perceived threats or opportunities. A gap between current and desired capacity will result in capacity that is out of balance. Overcapacity causes operating costs that are too high, while undercapacity causes strained resources and possible loss of customers.

Excess Capacity Can Be Bad News!

READING

Today, huge gaps between supply and demand have many companies struggling. Excess capacity abounds in such major industries as telecom, airline, and auto manufacturing. The bad news is that some companies are losing millions of dollars a year because of this. In the telecom industry, the increasing reach of cellular technology and other kinds of wireless access is continuing to create more and more supply, requiring telecom companies to cut prices and offer incentives to increase demand.

In the airline industry, air travel is way down, leaving airline companies awash in capacity. And even much of the currently mothballed aircraft are only in storage. Companies have eliminated flights to save money and cut prices to the bone trying to lure passengers.

The auto producers don't have it quite so bad, but for years they've been offering their customers incentives and interest-free financing—in order to keep their excess plants running.

LO5.1 Name the three key questions in capacity planning

The key questions in capacity planning are the following:

1. What kind of capacity is needed?
2. How much is needed to match demand?
3. When is it needed?

The question of what kind of capacity is needed depends on the products and services that management intends to produce or provide. Hence, in a very real sense, capacity planning is governed by those choices.

Forecasts are key inputs used to answer the questions of how much capacity is needed and when is it needed.

Related questions include:

1. How much will it cost, how will it be funded, and what is the expected return?
2. What are the potential benefits and risks? These involve the degree of uncertainty related to forecasts of the amount of demand and the rate of change in demand, as well as costs, profits, and the time to implement capacity changes. The degree of accuracy that can be attached to forecasts is an important consideration. The likelihood and impact of wrong decisions also need to be assessed.
3. Are there sustainability issues that need to be addressed?
4. Should capacity be changed all at once, or through several (or more) small changes?
5. Can the supply chain handle the necessary changes? Before an organization commits to ramping up its input, it is essential to confirm that its *supply chain* will be able to handle related requirements.

Because of uncertainties, some organizations prefer to delay capacity investment until demand materializes. However, such strategies often inhibit growth because adding capacity takes time and customers won't usually wait. Conversely, organizations that add capacity in anticipation of growth often discover that the new capacity actually attracts growth. Some organizations "hedge their bets" by making a series of small changes and then evaluating the results before committing to the next change.

In some instances, capacity choices are made very infrequently; in others, they are made regularly, as part of an ongoing process. Generally, the factors that influence this frequency are the stability of demand, the rate of technological change in equipment and product design, and competitive factors. Other factors relate to the type of product or service and whether style changes are important (e.g., automobiles and clothing). In any case, management must review product and service choices periodically to ensure that the company makes capacity changes when they are needed for cost, competitive effectiveness, or other reasons.

5.2 CAPACITY DECISIONS ARE STRATEGIC

LO5.2 Explain the importance of capacity planning.

For a number of reasons, capacity decisions are among the most fundamental of all the design decisions that managers must make. In fact, capacity decisions can be *critical* for an organization:

1. Capacity decisions have a real impact on the ability of the organization to meet future demands for products and services; capacity essentially limits the rate of output possible. Having capacity to satisfy demand can often allow a company to take advantage of tremendous benefits. When Microsoft introduced its new Xbox in late 2005, there were insufficient supplies, resulting in lost sales and unhappy customers. And shortages of flu vaccine in some years due to production problems affected capacity, limiting the availability of the vaccine.
2. Capacity decisions affect operating costs. Ideally, capacity and demand requirements will be matched, which will tend to minimize operating costs. In practice, this is not always achieved because actual demand either differs from expected demand or tends to vary (e.g., cyclically). In such cases, a decision might be made to attempt to balance the costs of over- and undercapacity.
3. Capacity is usually a major determinant of initial cost. Typically, the greater the capacity of a productive unit, the greater its cost. This does not necessarily imply a one-for-one relationship; larger units tend to cost *proportionately* less than smaller units.
4. Capacity decisions often involve long-term commitment of resources and the fact that, once they are implemented, those decisions may be difficult or impossible to modify without incurring major costs.
5. Capacity decisions can affect competitiveness. If a firm has excess capacity, or can quickly add capacity, that fact may serve as a barrier to entry by other firms. Then too, capacity can affect *delivery speed,* which can be a competitive advantage.
6. Capacity affects the ease of management; having appropriate capacity makes management easier than when capacity is mismatched.
7. Globalization has increased the importance and the complexity of capacity decisions. Far-flung supply chains and distant markets add to the uncertainty about capacity needs.
8. Because capacity decisions often involve substantial financial and other resources, it is necessary to plan for them far in advance. For example, it may take years for a new power-generating plant to be constructed and become operational. However, this increases the risk that the designated amount of capacity will not match actual demand when the capacity becomes available.

5.3 DEFINING AND MEASURING CAPACITY

LO5.3 Describe ways of defining and measuring capacity.

Capacity often refers to an upper limit on the *rate* of output. Even though this seems simple enough, there are subtle difficulties in actually measuring capacity in certain cases. These difficulties arise because of different interpretations of the term *capacity* and problems with identifying suitable measures for a specific situation.

In selecting a measure of capacity, it is important to choose one that does not require updating. For example, dollar amounts are often a poor measure of capacity (e.g., capacity of $30 million a year) because price changes necessitate updating of that measure.

Where only one product or service is involved, the capacity of the productive unit may be expressed in terms of that item. However, when multiple products or services are involved, as is often the case, using a simple measure of capacity based on units of output can be misleading. An appliance manufacturer may produce both refrigerators and freezers. If the output rates for these two products are different, it would not make sense to simply state capacity in units without reference to either refrigerators or freezers. The problem is compounded if the firm has other products. One possible solution is to state capacities in terms of each product. Thus, the firm may be able to produce 100 refrigerators per day *or* 80 freezers per day. Sometimes this approach is helpful, sometimes not. For instance, if an organization has many different products or services, it may not be practical to list all of the relevant capacities. This is especially true if there are frequent changes in the mix of output, because this would necessitate a frequently changing composite index of capacity. The preferred alternative in such cases is to use a measure of capacity that refers to *availability of inputs*. Thus, a hospital has a certain number of beds, a factory has a certain number of machine hours available, and a bus has a certain number of seats and a certain amount of standing room.

No single measure of capacity will be appropriate in every situation. Rather, the measure of capacity must be tailored to the situation. Table 5.1 provides some examples of commonly used measures of capacity.

Up to this point, we have been using a general definition of capacity. Although it is functional, it can be refined into two useful definitions of capacity:

Design capacity The maximum designed service capacity or output rate.

Effective capacity Design capacity minus allowances such as personal time, equipment maintenance, delays due to scheduling problems, and changing the mix of products.

1. **Design capacity**: The maximum output rate or service capacity an operation, process, or facility is designed for.
2. **Effective capacity**: Design capacity minus allowances such as personal time, and maintenance.

Design capacity is the maximum rate of output achieved under ideal conditions. Effective capacity is always less than design capacity owing to realities of changing product mix, the need for periodic maintenance of equipment, lunch breaks, coffee breaks, problems in scheduling and balancing operations, and similar circumstances. *Actual output* cannot exceed effective capacity and is often less because of machine breakdowns, absenteeism, shortages of materials, and quality problems, as well as factors that are outside the control of the operations managers.

TABLE 5.1
Measures of capacity

Business	Inputs	Outputs
Auto manufacturing	Labor hours, machine hours	Number of cars per shift
Steel mill	Furnace size	Tons of steel per day
Oil refinery	Refinery size	Gallons of fuel per day
Farming	Number of acres, number of cows	Bushels of grain per acre per year, gallons of milk per day
Restaurant	Number of tables, seating capacity	Number of meals served per day
Theater	Number of seats	Number of tickets sold per performance
Retail sales	Square feet of floor space	Revenue generated per day

These different measures of capacity are useful in defining two measures of system effectiveness: efficiency and utilization. *Efficiency* is the ratio of actual output to effective capacity. *Capacity utilization* is the ratio of actual output to design capacity.

$$\text{Efficiency} = \frac{\text{Actual output}}{\text{Effective capacity}} \times 100\% \tag{5–1}$$

$$\text{Utilization} = \frac{\text{Actual output}}{\text{Design capacity}} \times 100\% \tag{5–2}$$

Both measures are expressed as percentages.

It is not unusual for managers to focus exclusively on efficiency, but in many instances this emphasis can be misleading. This happens when effective capacity is low compared to design capacity. In those cases, high efficiency would seem to indicate effective use of resources when it does not. The following example illustrates this point.

EXAMPLE 1

excel

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Given the following information, compute the efficiency and the utilization of the vehicle repair department:

Design capacity = 50 trucks per day
Effective capacity = 40 trucks per day
Actual output = 36 trucks per day

SOLUTION

$$\text{Efficiency} = \frac{\text{Actual output}}{\text{Effective capacity}} \times 100\% = \frac{36 \text{ trucks per day}}{40 \text{ trucks per day}} \times 100\% = 90\%$$

$$\text{Utilization} = \frac{\text{Actual output}}{\text{Design capacity}} \times 100\% = \frac{36 \text{ trucks per day}}{50 \text{ trucks per day}} \times 100\% = 72\%$$

Compared to the effective capacity of 40 units per day, 36 units per day looks pretty good. However, compared to the design capacity of 50 units per day, 36 units per day is much less impressive although probably more meaningful.

Because effective capacity acts as a lid on actual output, the real key to improving capacity utilization is to increase effective capacity by correcting quality problems, maintaining equipment in good operating condition, fully training employees, and fully utilizing bottleneck equipment.

Hence, increasing utilization depends on being able to increase effective capacity, and this requires a knowledge of what is constraining effective capacity.

The following section explores some of the main determinants of effective capacity. It is important to recognize that the benefits of high utilization are realized only in instances where there is demand for the output. When demand is not there, focusing exclusively on utilization can be counterproductive, because the excess output not only results in additional variable costs but also generates the costs of having to carry the output as inventory. Another disadvantage of high utilization is that operating costs may increase because of increasing waiting time due to bottleneck conditions.

5.4 DETERMINANTS OF EFFECTIVE CAPACITY

Many decisions about system design have an impact on capacity. The same is true for many operating decisions. This section briefly describes some of these factors, which are then elaborated on elsewhere in the book. The main factors relate to facilities, products or services, processes, human considerations, operational factors, the supply chain, and external forces.

LO5.4 Name several determinants of effective capacity.

Facilities. The design of facilities, including size and provision for expansion, is key. Locational factors, such as transportation costs, distance to market, labor supply, energy sources, and room for expansion, are also important. Likewise, layout of the work area often determines how smoothly work can be performed, and environmental factors such as heating, lighting, and ventilation also play a significant role in determining whether personnel can perform effectively or whether they must struggle to overcome poor design characteristics.

Product and Service Factors. Product or service design can have a tremendous influence on capacity. For example, when items are similar, the ability of the system to produce those items is generally much greater than when successive items differ. Thus, a restaurant that offers a limited menu can usually prepare and serve meals at a faster rate than a restaurant with an extensive menu. Generally speaking, the more uniform the output, the more opportunities there are for standardization of methods and materials, which leads to greater capacity. The particular mix of products or services rendered also must be considered since different items will have different rates of output.

In only 48 hours Solectron in San Jose, California, can build to order, ship, and install a complex computer system. Suppliers hold inventory until it is pulled, thereby increasing manufacturing flexibility.

Making a violin requires precision and skill from an artisan. Capacity is highly limited when items are specialized and produced one at a time.

Process Factors. The quantity capability of a process is an obvious determinant of capacity. A more subtle determinant is the influence of output *quality.* For instance, if quality of output does not meet standards, the rate of output will be slowed by the need for inspection and rework activities. Productivity also affects capacity. Process improvements that increase quality and productivity can result in increased capacity. Also, if multiple products or multiple services are processed in batches, the time to change over equipment settings must be taken into account.

Human Factors. The tasks that make up a job, the variety of activities involved, and the training, skill, and experience required to perform a job all have an impact on the potential and actual output. In addition, employee motivation has a very basic relationship to capacity, as do absenteeism and labor turnover.

TABLE 5.2
Factors that determine effective capacity

A. Facilities
   1. Design
   2. Location
   3. Layout
   4. Environment
B. Product/service
   1. Design
   2. Product or service mix
C. Process
   1. Quantity capabilities
   2. Quality capabilities
D. Human factors
   1. Job content
   2. Job design
   3. Training and experience
   4. Motivation
   5. Compensation
   6. Learning rates
   7. Absenteeism and labor turnover
E. Policy
F. Operational
   1. Scheduling
   2. Materials management
   3. Quality assurance
   4. Maintenance policies
   5. Equipment breakdowns
G. Supply chain
H. External factors
   1. Product standards
   2. Safety regulations
   3. Unions
   4. Pollution control standards

Policy Factors. Management policy can affect capacity by allowing or not allowing capacity options such as overtime or second or third shifts.

Operational Factors. Scheduling problems may occur when an organization has differences in equipment capabilities among alternative pieces of equipment or differences in job requirements. Inventory stocking decisions, late deliveries, purchasing requirements, acceptability of purchased materials and parts, and quality inspection and control procedures also can have an impact on effective capacity.

Inventory shortages of even one component of an assembled item (e.g., computers, refrigerators, automobiles) can cause a temporary halt to assembly operations until the components become available. This can have a major impact on effective capacity. Thus, insufficient capacity in one area can affect overall capacity.

Supply Chain Factors. Supply chain factors must be taken into account in capacity planning if substantial capacity changes are involved. Key questions include: What impact will the changes have on suppliers, warehousing, transportation, and distributors? If capacity will be increased, will these elements of the supply chain be able to handle the increase? Conversely, if capacity is to be decreased, what impact will the loss of business have on these elements of the supply chain?

External Factors. Product standards, especially minimum quality and performance standards, can restrict management's options for increasing and using capacity. Thus, pollution standards on products and equipment often reduce effective capacity, as does paperwork required by government regulatory agencies by engaging employees in nonproductive activities. A similar effect occurs when a union contract limits the number of hours and type of work an employee may do.

Table 5.2 summarizes these factors. In addition, *inadequate planning* can be a major limiting determinant of effective capacity.

5.5 STRATEGY FORMULATION

The three primary strategies are leading, following, and tracking. A leading capacity strategy builds capacity in anticipation of future demand increases. If capacity increases involve a long lead time, this strategy may be the best option. A following strategy builds capacity when demand exceeds current capacity. A tracking strategy is similar to a following strategy, but it adds capacity in relatively small increments to keep pace with increasing demand.

An organization typically bases its capacity strategy on assumptions and predictions about long-term demand patterns, technological changes, and the behavior of its competitors. These typically involve (1) the growth rate and variability of demand, (2) the costs of building and operating facilities of various sizes, (3) the rate and direction of technological innovation, (4) the likely behavior of competitors, and (5) availability of capital and other inputs.

Capacity cushion Extra capacity used to offset demand uncertainty.

In some instances a decision may be made to incorporate a **capacity cushion**, which is an amount of capacity in excess of expected demand when there is some uncertainty about demand. Capacity cushion = capacity − expected demand. Typically, the greater the degree of demand uncertainty, the greater the amount of cushion used. Organizations that have standard products or services generally have smaller capacity cushions. Cost and competitive priorities are also key factors.

Steps in the Capacity Planning Process

1. Estimate future capacity requirements.
2. Evaluate existing capacity and facilities and identify gaps.
3. Identify alternatives for meeting requirements.
4. Conduct financial analyses of each alternative.
5. Assess key qualitative issues for each alternative.
6. Select the alternative to pursue that will be best in the long term.
7. Implement the selected alternative.
8. Monitor results.

Capacity planning can be difficult at times due to the complex influence of market forces and technology.

5.6 FORECASTING CAPACITY REQUIREMENTS

Capacity planning decisions involve both long-term and short-term considerations. Long-term considerations relate to overall *level* of capacity, such as facility size; short-term considerations relate to probable *variations* in capacity requirements created by such things as seasonal, random, and irregular fluctuations in demand. Because the time intervals covered by each of these categories can vary significantly from industry to industry, it would be misleading to put times on the intervals. However, the distinction will serve as a framework within which to discuss capacity planning.

Long-term capacity needs require forecasting demand over a time horizon and then converting those forecasts into capacity requirements. Figure 5.1 illustrates some basic demand patterns that might be identified by a forecast. In addition to basic patterns there are more complex patterns, such as a combination of cycles and trends.

When trends are identified, the fundamental issues are (1) how long the trend might persist, because few things last forever, and (2) the slope of the trend. If cycles are identified, interest focuses on (1) the approximate length of the cycles and (2) the amplitude of the cycles (i.e., deviation from average).

Short-term capacity needs are less concerned with cycles or trends than with seasonal variations and other variations from average. These deviations are particularly important because they can place a severe strain on a system's ability to satisfy demand at some times and yet result in idle capacity at other times.

An organization can identify seasonal patterns using standard forecasting techniques. Although commonly thought of as annual fluctuations, seasonal variations are also reflected in monthly, weekly, and even daily capacity requirements. Table 5.3 provides some examples of items that tend to exhibit seasonal demand patterns.

When time intervals are too short to have seasonal variations in demand, the analysis can often describe the variations by probability distributions such as a normal, uniform, or Poisson

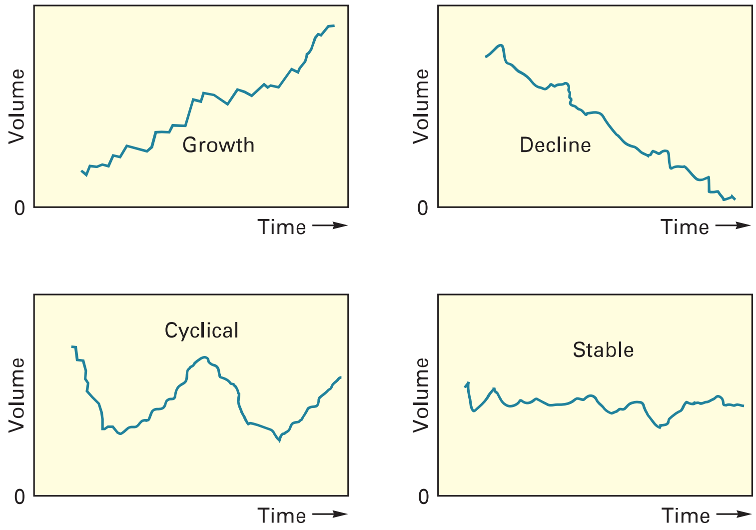

FIGURE 5.1
Common demand patterns

TABLE 5.3
Examples of seasonal demand patterns

Period	Items
Year	Beer sales, toy sales, airline traffic, clothing, vacations, tourism, power usage, gasoline consumption, sports and recreation, education
Month	Welfare and social security checks, bank transactions
Week	Retail sales, restaurant meals, automobile traffic, automotive rentals, hotel registrations
Day	Telephone calls, power usage, automobile traffic, public transportation, classroom utilization, retail sales, restaurant meals

distribution. For example, we might describe the amount of coffee served during the midday meal at a luncheonette by a normal distribution with a certain mean and standard deviation. The number of customers who enter a bank branch on Monday mornings might be described by a Poisson distribution with a certain mean. It does not follow, however, that *every* instance of random variability will lend itself to description by a standard statistical distribution. Service systems in particular may experience a considerable amount of variability in capacity requirements unless requests for service can be scheduled. Manufacturing systems, because of their typical isolation from customers and the more uniform nature of production, are likely to experience fewer variations. Waiting-line models and simulation models can be useful when analyzing service systems. These models are described in Chapter 18.

Irregular variations are perhaps the most troublesome: They are difficult or impossible to predict. They are created by such diverse forces as major equipment breakdowns, freak storms that disrupt normal routines, foreign political turmoil that causes oil shortages, discovery of health hazards (nuclear accidents, unsafe chemical dumping grounds, carcinogens in food and drink), and so on.

The link between marketing and operations is crucial to realistic determination of capacity requirements. Through customer contracts, demographic analyses, and forecasts, marketing can supply vital information to operations for ascertaining capacity needs for both the long term and the short term.

Calculating Processing Requirements

A necessary piece of information is the capacity requirements of products that will be processed. To get this information, one must have reasonably accurate demand forecasts for each product and know the standard processing time per unit for each product, the number of workdays per year, and the number of shifts that will be used.

EXAMPLE 2

eXcel

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A department works one 8-hour shift, 250 days a year, and has these figures for usage of a machine that is currently being considered:

Product	Annual Demand	Standard Processing Time per Unit (hr)	Processing Time Needed (hr)
1	400	5.0	2,000
2	300	8.0	2,400
3	700	2.0	1,400
			5,800

$$\text{Units of capacity needed} = \frac{\text{Processing time needed}}{\text{Processing time capacity per unit}} \tag{5–3}$$

Working one 8-hour shift 250 days a year provides an annual capacity of $8 \times 250 = 2{,}000$ hours per year. Consequently, three of these machines would be needed to handle the required volume:

$$\frac{5{,}800 \text{ hours}}{2{,}000 \text{ hours/machine}} = 2.90 \text{ machines}$$

The task of determining capacity requirements should not be taken lightly. Substantial losses can occur when there are misjudgments on capacity needs. One key reason for those misjudgments can be overly optimistic projections of demand and growth. Marketing personnel are generally optimistic in their outlook, which isn't necessarily a bad thing. But care must be taken so that that optimism doesn't lead to overcapacity, because the resulting underutilized capacity will create an additional cost burden. Another key reason for misjudgments may be focusing exclusively on sales and revenue potential, and not taking into account the *product mix* that will be needed to generate those sales and revenues. To avoid that, marketing and operations personnel must work closely to determine the optimal product mix needed and the resulting cost and profit.

A reasonable approach to determining capacity requirements is to obtain a forecast of future demand, translate demand into both the *quantity and the timing* of capacity requirements, and then decide what capacity changes (increased, decreased, or no changes) are needed.

Long-term capacity alternatives include expansion or contraction of an existing facility, opening or closing branch facilities, and relocation of existing operations. At this point, a decision must be made on whether to make or buy a good, or provide or buy a service.

5.7 ADDITIONAL CHALLENGES OF PLANNING SERVICE CAPACITY

While the foregoing discussion relates generally to capacity planning for both goods and services, it is important to note that capacity planning for services can present special challenges due to the nature of services. Three very important factors in planning service capacity are (1) there may be a need to be near customers, (2) the inability to store services, and (3) the degree of volatility of demand.

Convenience for customers is often an important aspect of service. Generally, a service must be located near customers. For example, hotel rooms must be where customers want to stay; having a vacant room in another city won't help. Thus, capacity and location are closely tied.

Capacity also must be matched with the *timing* of demand. Unlike goods, services cannot be produced in one period and stored for use in a later period. Thus, an unsold seat on an airplane, train, or bus cannot be stored for use on a later trip. Similarly, inventories of goods allow customers to immediately satisfy wants, whereas a customer who wants a service may have to wait. This can result in a variety of negatives for an organization that provides the service. Thus, speed of delivery, or customer waiting time, becomes a major concern in service capacity planning. For example, deciding on the number of police officers and fire trucks to have on duty at any given time affects the speed of response and brings into issue the *cost* of maintaining that capacity. Some of these issues are addressed in the chapter on waiting lines.

Demand volatility presents problems for capacity planners. Demand volatility tends to be higher for services than for goods, not only in timing of demand, but also in the amount of time required to service individual customers. For example, banks tend to experience higher volumes of demand on certain days of the week, and the number and nature of transactions tend to vary substantially for different individuals. Then, too, a wide range of social, cultural, and even weather factors can cause major peaks and valleys in demand. The fact that services can't be stored means service systems cannot turn to inventory to smooth demand requirements on the system the way goods-producing systems are able to. Instead, service planners have to devise other methods of coping with demand volatility and cyclical demand. For example, to cope with peak demand periods, planners might consider hiring extra workers, hiring temporary workers, outsourcing some or all of a service, or using pricing and promotion to shift some demand to slower periods.

In some instances, *demand management strategies* can be used to offset capacity limitations. Pricing, promotions, discounts, and similar tactics can help to shift some demand away from peak periods and into slow periods, allowing organizations to achieve a closer match in supply and demand.

5.8 DO IT IN-HOUSE OR OUTSOURCE IT?

LO5.5 Discuss factors to consider when deciding whether to operate in-house or outsource.

Once capacity requirements have been determined, the organization must decide whether to produce a good or provide a service itself, or to outsource from another organization. Many organizations buy parts or contract out services, for a variety of reasons. Among those factors are

1. **Available capacity.** If an organization has available the equipment, necessary skills, and *time,* it often makes sense to produce an item or perform a service in-house. The additional costs would be relatively small compared with those required to buy items or subcontract services. On the other hand, outsourcing can increase capacity and flexibility.
2. **Expertise.** If a firm lacks the expertise to do a job satisfactorily, buying might be a reasonable alternative.
3. **Quality considerations.** Firms that specialize can usually offer higher quality than an organization can attain itself. Conversely, unique quality requirements or the desire to closely monitor quality may cause an organization to perform a job itself.
4. **The nature of demand.** When demand for an item is high and steady, the organization is often better off doing the work itself. However, wide fluctuations in demand or small orders are usually better handled by specialists who are able to combine orders from multiple sources, which results in higher volume and tends to offset individual buyer fluctuations.
5. **Cost.** Any cost savings achieved from buying or making must be weighed against the preceding factors. Cost savings might come from the item itself or from transportation cost savings. If there are fixed costs associated with making an item that cannot be reallocated if the service or product is outsourced, that has to be recognized in the analysis. Conversely, outsourcing may help a firm avoid incurring fixed costs.
6. **Risks.** Buying goods or services may entail considerable risks. Loss of direct control over operations, knowledge sharing, and the possible need to disclose proprietary information are three risks. And liability can be a tremendous risk if the products or services of other companies cause harm to customers or the environment, as well as damage to an organization's reputation. Reputation can also be damaged if the public discovers that a supplier operates with substandard working conditions.

In some cases, a firm might choose to perform part of the work itself and let others handle the rest in order to maintain flexibility and to hedge against loss of a subcontractor. If part or all of the work will be done in-house, capacity alternatives will need to be developed.

Outsourcing brings with it a host of supply chain considerations. These are described in Chapter 15.

The following reading describes outsourcing that might surprise you.

My Compliments to the Chef, er, Buyer

READING

Ever wonder how some sit-down restaurants are able to offer a huge variety of menu items, and how they are able to serve everything on that menu quickly? Could they have humongous kitchens and a battery of chefs scurrying around? Or maybe a few amazing chefs whose hands are almost quicker than the eye? Maybe, and maybe not. In fact, that great-tasting restaurant entrée or dessert you are served might have been prepared in a distant kitchen, where it was partially cooked, then flash-frozen or vacuum-packed, and shipped to your restaurant, awaiting your order. Then the entrée was finished cooking, perhaps in a microwave oven, and soon it was served to you—fresh made, so to speak. Surprised? Don't be. Many restaurants, from chains like Fuddruckers and Perkins, to top-quality restaurants, are going the outsourcing route. And companies such as Sara Lee, Land O' Lakes, and Stockpot Soup Company of Redwood, Washington, are only too happy to oblige them. Advertisements in restaurant trade magazines abound, with taglines such as "Hours versus ours" and "Just heat and serve."

Not exactly like mother used to make, but then mother never had to contend with labor costs that run about 30 percent of revenue, or worry about keeping up with the competition.

Questions

1. Explain the meaning of the phrase "Hours versus ours."
2. What advantages are there when restaurants outsource?
3. What are some important disadvantages or limitations of outsourcing for restaurants?
4. Do you consider restaurant outsourcing to be dishonest? Unethical? Explain.
5. Does restaurant outsourcing increase capacity? Explain.

5.9 DEVELOPING CAPACITY STRATEGIES

LO5.6 Discuss the major considerations related to developing capacity alternatives.

There are a number of ways to enhance development of capacity strategies:

1. **Design flexibility into systems.** The long-term nature of many capacity decisions and the risks inherent in long-term forecasts suggest potential benefits from designing flexible systems. For example, provision for future expansion in the original design of a structure frequently can be obtained at a small price compared to what it would cost to remodel an existing structure that did not have such a provision. Hence, if future expansion of a restaurant seems likely, water lines, power hookups, and waste disposal lines can be put in place initially so that if expansion becomes a reality, modification to the existing structure can be minimized. Similarly, a new golf course may start as a 9-hole operation, but if provision is made for future expansion by obtaining options on adjacent land, it may progress to a larger (18-hole) course. Other considerations in flexible design involve layout of equipment, location, equipment selection, production planning, scheduling, and inventory policies, which will be discussed in later chapters.

2. **Take stage of life cycle into account.** Capacity requirements are often closely linked to the stage of the life cycle that a product or service is in. At the *introduction phase,* it can be difficult to determine both the size of the market and the organization's eventual share of that market. Therefore, organizations should be cautious in making large and/or inflexible capacity investments.

In the *growth phase,* the overall market may experience rapid growth. However, the real issue is the rate at which the *organization's* market share grows, which may be more or less than the market rate, depending on the success of the organization's strategies. Organizations generally regard growth as a good thing. They want growth in the overall market for their products or services, and in their share of the market, because they see this as a way of increasing volume, and thus, increasing profits. However, there can also be a downside to this because increasing output levels will require increasing capacity, and that means increasing investment and increasing complexity. In addition, decision makers should take into account possible similar moves by competitors, which would increase the risk of overcapacity in the market, and result in higher unit costs of the output. Another strategy would be to compete on some nonprice attribute of the product by investing in technology and process improvements to make differentiation a competitive advantage.

In the *maturity phase,* the size of the market levels off, and organizations tend to have stable market shares. Organizations may still be able to increase profitability by reducing costs and making full use of capacity. However, some organizations may still try to increase profitability by increasing capacity if they believe this stage will be fairly long, or the cost to increase capacity is relatively small.

In the *decline phase,* an organization is faced with underutilization of capacity due to declining demand. Organizations may eliminate the excess capacity by selling it, or by introducing new products or services. An option that is sometimes used in manufacturing is to transfer capacity to a location that has lower labor costs, which allows the organization to continue to make a profit on the product for a while longer.

3. **Take a "big-picture" (i.e., systems) approach to capacity changes.** When developing capacity alternatives, it is important to consider how parts of the system interrelate. For example, when making a decision to increase the number of rooms in a motel, one should also take into account probable increased demands for parking, entertainment and food, and housekeeping. Also, will suppliers be able to handle the increased volume?

Capacity changes inevitably affect an organization's supply chain. Suppliers may need time to adjust to their capacity, so collaborating with supply chain partners on plans for capacity increases is essential. That includes not only suppliers, but also distributors and transporters.

The risk in not taking a big-picture approach is that the system will be unbalanced. Evidence of an unbalanced system is the existence of a *bottleneck operation.* A **bottleneck operation** is an operation in a sequence of operations whose capacity is lower than the capacities of other operations in the sequence. As a consequence, the capacity of the bottleneck operation limits the system capacity; the capacity of the system is reduced to the capacity of the bottleneck operation. Figure 5.2 illustrates this concept: Four operations generate work that must then be processed by a fifth operation. The four different operations each have a capacity of 10 units per hour, for a total capacity of 40 units per hour. However, the fifth operation can only process 30 units per hour. Consequently, the output of the system will only be 30 units per hour. If the other operations operate at capacity, a line of units waiting to be processed by the bottleneck operation will build up at the rate of 10 per hour.

Bottleneck operation An operation in a sequence of operations whose capacity is lower than that of the other operations.

Here is another example. The following diagram illustrates a three-step process, with capacities of each step shown. However, the middle process, because its capacity is lower than that of the others, constrains the system to its capacity of 10 units per hour. Hence it is a bottleneck. In order to increase the capacity of the entire process, it would be necessary to increase the capacity of this bottleneck operation. Note, though, that the potential for increasing the capacity of the process is only 5 units, to 15 units per hour. Beyond that, operation 3's capacity would limit process capacity to 15 units per hour.

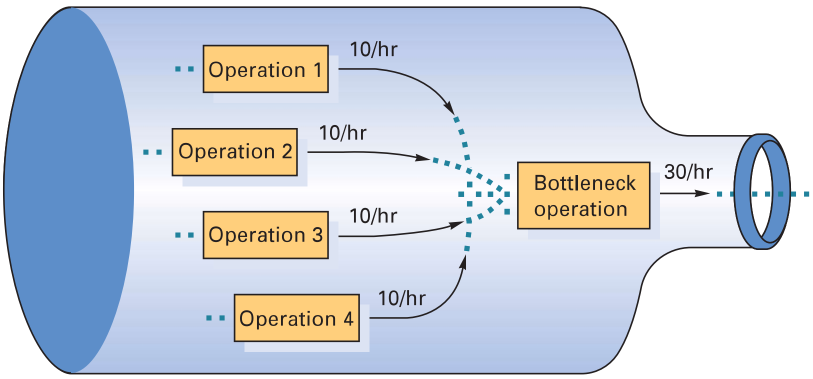
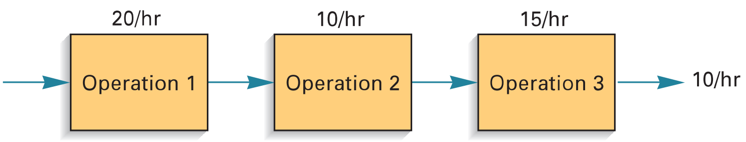


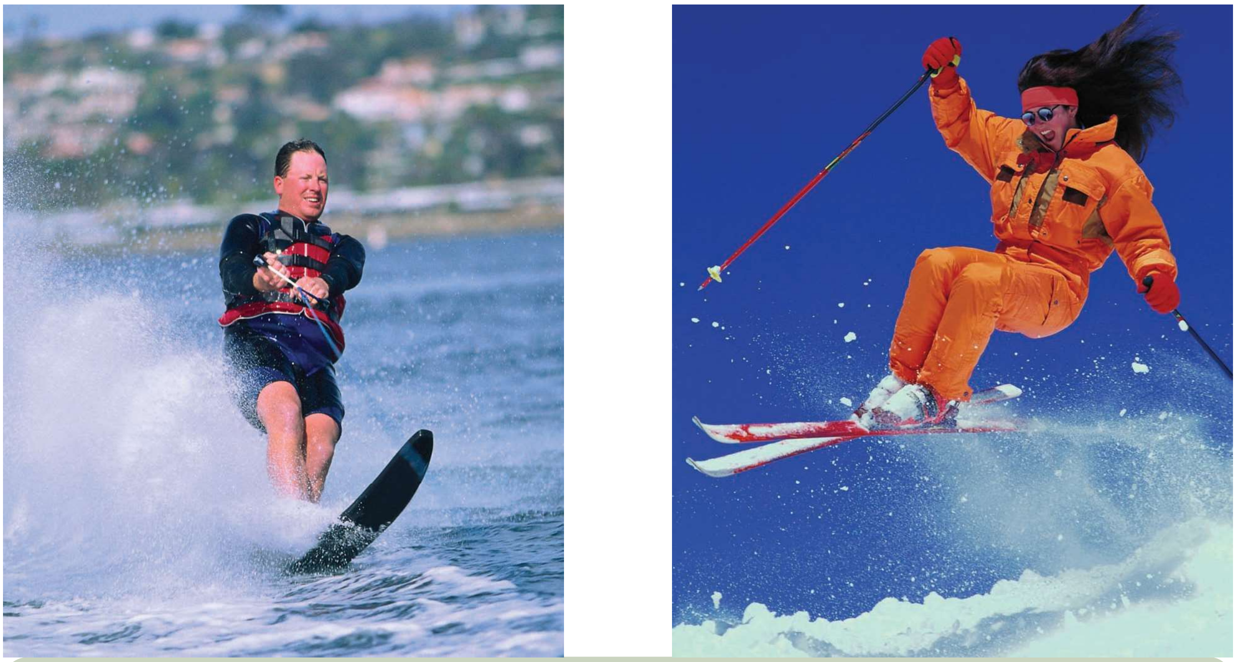
FIGURE 5.2
Bottleneck operation



4. **Prepare to deal with capacity "chunks."** Capacity increases are often acquired in fairly large chunks rather than smooth increments, making it difficult to achieve a match between desired capacity and feasible capacity. For instance, the desired capacity of a certain operation may be 55 units per hour, but suppose that machines used for this operation are able to produce 40 units per hour each. One machine by itself would cause capacity to be 15 units per hour short of what is needed, but two machines would result in an excess capacity of 25 units per hour. The illustration becomes even more extreme if we shift the topic—to open-hearth furnaces or to the number of airplanes needed to provide a desired level of capacity.

5. **Attempt to smooth out capacity requirements.** Unevenness in capacity requirements also can create certain problems. For instance, during periods of inclement weather, public transportation ridership tends to increase substantially relative to periods of pleasant weather. Consequently, the system tends to alternate between underutilization and overutilization. Increasing the number of buses or subway cars will reduce the burden during periods of heavy demand, but this will aggravate the problem of overcapacity at other times and certainly add to the cost of operating the system.

We can trace the unevenness in demand for products and services to a variety of sources. The bus ridership problem is weather related to a certain extent, but demand could be considered to be partly random (i.e., varying because of chance factors). Still another source of varying demand is seasonality. Seasonal variations are generally easier to cope with than random variations because they are *predictable*. Consequently, management can make allowances in planning and scheduling activities and inventories. However, seasonal variations can still pose problems because of their uneven demands on the system: At certain times the system



Capacity requirements are affected by seasonal variations. One approach is to identify products that offset each other such as demand for water skis and demand for snow skis.

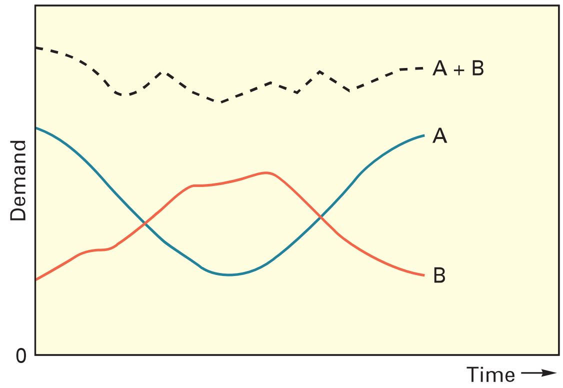


FIGURE 5.3
A and B have complementary demand patterns

will tend to be overloaded, while at other times it will tend to be underloaded. One possible approach to this problem is to identify products or services that have complementary demand patterns, that is, patterns that tend to offset each other. For instance, demand for snow skis and demand for water skis might complement each other: Demand for water skis is greater in the spring and summer months, and demand for snow skis is greater in the fall and winter months. The same might apply to heating and air-conditioning equipment. The ideal case is one in which products or services with complementary demand patterns involve the use of the same resources but at different times, so that overall capacity requirements remain fairly stable and inventory levels are minimized. Figure 5.3 illustrates complementary demand patterns.

Variability in demand can pose a problem for managers. Simply adding capacity by increasing the size of the operation (e.g., increasing the size of the facility, the workforce, or the amount of processing equipment) is not always the best approach, because that reduces flexibility and adds to fixed costs. Consequently, managers often choose to respond to higher than normal demand in other ways. One way is through the use of overtime work. Another way is to subcontract some of the work. A third way is to draw down finished goods inventories during periods of high demand and replenish them during periods of slow demand. These options and others are discussed in detail in the chapter on aggregate planning.

6. **Identify the optimal operating level.** Production units typically have an ideal or optimal level of operation in terms of unit cost of output. At the ideal level, cost per unit is the lowest for that production unit. If the output rate is less than the optimal level, increasing the output rate will result in decreasing average unit costs. This is known as **economies of scale**. However, if output is increased beyond the optimal level, average unit costs will become increasingly larger. This is known as **diseconomies of scale**. Figure 5.4 illustrates these concepts.

Economies of scale If the output rate is less than the optimal level, increasing the output rate results in decreasing average unit costs.

Diseconomies of scale If the output rate is more than the optimal level, increasing the output rate results in increasing average unit costs.

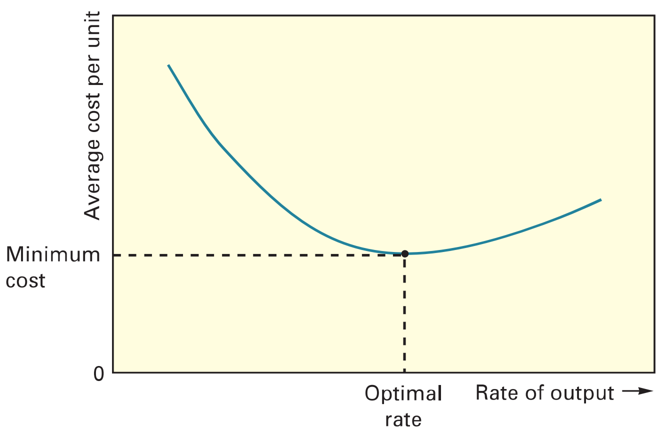


FIGURE 5.4
Production units have an optimal rate of output for minimum cost

Reasons for economies of scale include the following:

a. Fixed costs are spread over more units, reducing the fixed cost per unit.

b. Construction costs increase at a decreasing rate with respect to the size of the facility to be built.

c. Processing costs decrease as output rates increase because operations become more standardized, which reduces unit costs.

Reasons for diseconomies of scale include the following:

a. Distribution costs increase due to traffic congestion and shipping from one large centralized facility instead of several smaller, decentralized facilities.

b. Complexity increases costs; control and communication become more problematic.

c. Inflexibility can be an issue.

d. Additional levels of bureaucracy exist, slowing decision making and approvals for changes.

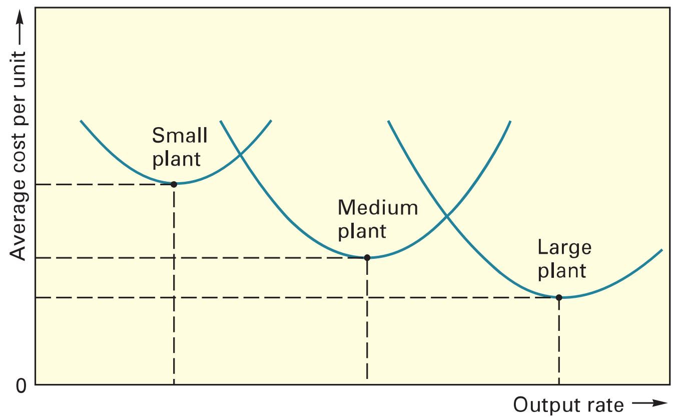
The explanation for the shape of the cost curve is that at low levels of output, the costs of facilities and equipment must be absorbed (paid for) by very few units. Hence, the cost per unit is high. As output is increased, there are more units to absorb the "fixed" cost of facilities and equipment, so unit costs decrease. However, beyond a certain point, unit costs will start to rise. To be sure, the fixed costs are spread over even more units, so that does not account for the increase, but other factors now become important: worker fatigue; equipment breakdowns; the loss of flexibility, which leaves less of a margin for error; and, generally, greater difficulty in coordinating operations.

Both optimal operating rate and the amount of the minimum cost tend to be a function of the general capacity of the operating unit. For example, as the general capacity of a plant increases, the optimal output rate increases and the minimum cost for the optimal rate decreases. Thus, larger plants tend to have higher optimal output rates and lower minimum costs than smaller plants. Figure 5.5 illustrates these points.

In choosing the capacity of an operating unit, management must take these relationships into account along with the availability of financial and other resources and forecasts of expected demand. To do this, it is necessary to determine enough points for each size facility to be able to make a comparison among different sizes. In some instances, facility sizes are givens, whereas in others, facility size is a continuous variable (i.e., any size can be selected). In the latter case, an ideal facility size can be selected. Usually, management must make a choice from given sizes, and none may have a minimum at the desired rate of output.

7. **Choose a strategy if expansion is involved.** Consider whether incremental expansion or single step is more appropriate. Factors include competitive pressures, market opportunities, costs and availability of funds, disruption of operations, and training requirements. Also, decide whether to lead or follow competitors. Leading is more risky, but it may have greater potential for rewards.

FIGURE 5.5
Minimum cost and optimal operating rate are functions of size of a production unit



5.10 CONSTRAINT MANAGEMENT

Constraint Something that limits the performance of a process or system in achieving its goals.

A **constraint** is something that limits the performance of a process or system in achieving its goals. Constraint management is often based on the work of Eli Goldratt (*The Theory of Constraints*), and Eli Schragenheim and H. William Dettmer (*Manufacturing at Warp Speed*). There are seven categories of constraints:

Market: Insufficient demand.

Resource: Too little of one or more resources (e.g., workers, equipment, and space), as illustrated in Figure 5.2.

Material: Too little of one or more materials.

Financial: Insufficient funds.

Supplier: Unreliable, long lead time, substandard quality.

Knowledge or competency: Needed knowledge or skills missing or incomplete.

Policy: Laws or regulations interfere.

There may only be a few constraints, or there may be more than a few. Constraint issues can be resolved by using the following five steps:[1]

LO5.7 Describe the steps that are used to resolve constraint issues.

1. Identify the most pressing constraint. If it can easily be overcome, do so, and return to Step 1 for the next constraint. Otherwise, proceed to Step 2.
2. Change the operation to achieve the maximum benefit, given the constraint. This may be a short-term solution.
3. Make sure other portions of the process are supportive of the constraint (e.g., bottleneck operation).
4. Explore and evaluate ways to overcome the constraint. This will depend on the type of constraint. For example, if demand is too low, advertising or price change may be an option. If capacity is the issue, working overtime, purchasing new equipment, and outsourcing are possible options. If additional funds are needed, working to improve cash flow, borrowing, and issuing stocks or bonds may be options. If suppliers are a problem, work with them, find more desirable suppliers, or insource. If knowledge or skills are needed, seek training or consultants, or outsource. If laws or regulations are the issue, working with lawmakers or regulators may be an option.
5. Repeat the process until the level of constraints is acceptable.

5.11 EVALUATING ALTERNATIVES

LO5.8 Briefly describe approaches that are useful for evaluating capacity alternatives.

An organization needs to examine alternatives for future capacity from a number of different perspectives. Most obvious are economic considerations: Will an alternative be economically feasible? How much will it cost? How soon can we have it? What will operating and maintenance costs be? What will its useful life be? Will it be compatible with present personnel and present operations?

Less obvious, but nonetheless important, is possible negative public opinion. For instance, the decision to build a new power plant is almost sure to stir up reaction, whether the plant is coal-fired, hydroelectric, or nuclear. Any option that could disrupt lives and property is bound to generate hostile reactions. Construction of new facilities may necessitate moving personnel to a new location. Embracing a new technology may mean retraining some people and terminating some jobs. Relocation can cause unfavorable reactions, particularly if a town is about to lose a major employer. Conversely, community pressure in a new location may arise if the presence of the company is viewed unfavorably (noise, traffic, pollution).

[1]Adapted from Eli Schragenheim and H. William Dettmer, *Manufacturing at Warp Speed* (Boca Raton: St. Lucie Press, 2000).

TABLE 5.4
Cost–volume symbols

FC =	Fixed cost
VC =	Total variable cost
v =	Variable cost per unit
TC =	Total cost
TR =	Total revenue
R =	Revenue per unit
Q =	Quantity or volume of output
Q_{BEP} =	Break-even quantity
P =	Profit

A number of techniques are useful for evaluating capacity alternatives from an economic standpoint. Some of the more common are cost–volume analysis, financial analysis, decision theory, and waiting-line analysis. Cost–volume analysis is described in this section. Financial analysis is mentioned briefly, decision analysis is described in the chapter supplement, and waiting-line analysis is described in Chapter 18.

Cost–Volume Analysis

Cost–volume analysis focuses on relationships between cost, revenue, and volume of output. The purpose of cost–volume analysis is to estimate the income of an organization under different operating conditions. It is particularly useful as a tool for comparing capacity alternatives.

Use of the technique requires identification of all costs related to the production of a given product. These costs are then designated as fixed costs or variable costs. *Fixed costs* tend to remain constant regardless of volume of output. Examples include rental costs, property taxes, equipment costs, heating and cooling expenses, and certain administrative costs. *Variable costs* vary directly with volume of output. The major components of variable costs are generally materials and labor costs. We will assume that variable cost per unit remains the same regardless of volume of output, and that all output can be sold.

Table 5.4 summarizes the symbols used in the cost–volume formulas.

The total cost associated with a given volume of output is equal to the sum of the fixed cost and the variable cost per unit times volume:

$$\text{TC} = \text{FC} + \text{VC} \tag{5–4}$$

$$\text{VC} = Q \times v \tag{5–5}$$

where v = variable cost per unit. Figure 5.6A shows the relationship between volume of output and fixed costs, total variable costs, and total (fixed plus variable) costs.

Revenue per unit, like variable cost per unit, is assumed to be the same regardless of quantity of output. Total revenue will have a linear relationship to output, as illustrated in Figure 5.6B. The total revenue associated with a given quantity of output, Q, is

$$\text{TR} = R \times Q \tag{5–6}$$

Figure 5.6C describes the relationship between profit—which is the difference between total revenue and total (i.e., fixed plus variable) cost—and volume of output. The volume at which total cost and total revenue are equal is referred to as the **break-even point (BEP)**. When volume is less than the break-even point, there is a loss; when volume is greater than the break-even point, there is a profit. The greater the deviation from this point, the greater the profit or loss. Figure 5.6D shows total profit or loss relative to the break-even point. Figure 5.6D can be obtained from Figure 5.6C by drawing a horizontal line through the point where the total cost and total revenue lines intersect. Total profit can be computed using the formula

Break-even point (BEP) The volume of output at which total cost and total revenue are equal.

$$P = \text{TR} - \text{TC} = R \times Q - (\text{FC} + v \times Q)$$

Rearranging terms, we have

$$P = Q(R - v) - \text{FC} \tag{5–7}$$

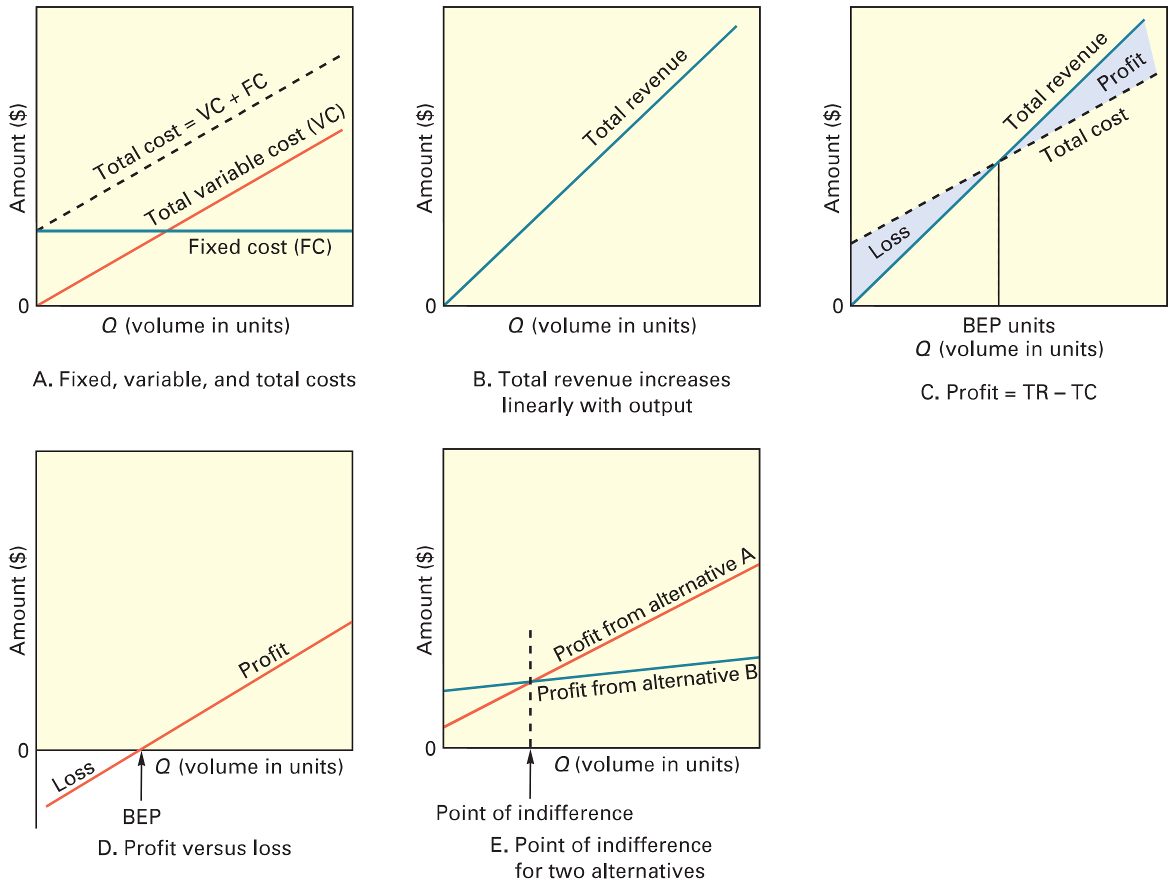
The difference between revenue per unit and variable cost per unit, $R - v$, is known as the *contribution margin.*

The required volume, Q, needed to generate a specified profit is

$$Q = \frac{P + \text{FC}}{R - v} \tag{5–8}$$

A special case of this is the volume of output needed for total revenue to equal total cost. This is the break-even point, computed using the formula

FIGURE 5.6
Cost–volume relationships



$$Q_{BEP} = \frac{FC}{R - v} \qquad (5\text{–}9)$$

Different alternatives can be compared by plotting the profit lines for the alternatives, as shown in Figure 5.6E.

Figure 5.6E illustrates the concept of an **indifference point**: the quantity at which a decision maker would be indifferent between two competing alternatives. In this illustration, a quantity less than the point of indifference would favor choosing alternative B because its profit is higher in that range, while a quantity greater than the point of indifference would favor choosing alternative A.

Indifference point The quantity that would make two alternatives equivalent.

EXAMPLE 3

eXcel

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The owner of Old-Fashioned Berry Pies, S. Simon, is contemplating adding a new line of pies, which will require leasing new equipment for a monthly payment of $6,000. Variable costs would be $2 per pie, and pies would retail for $7 each.

a. How many pies must be sold in order to break even?
b. What would the profit (loss) be if 1,000 pies are made and sold in a month?
c. How many pies must be sold to realize a profit of $4,000?
d. If 2,000 can be sold, and a profit target is $5,000, what price should be charged per pie?

SOLUTION

$FC = \$6{,}000, \quad VC = \$2 \text{ per pie}, \quad R = \$7 \text{ per pie}$

a. $Q_{BEP} = \dfrac{FC}{R - VC} = \dfrac{\$6{,}000}{\$7 - \$2} = 1{,}200 \text{ pies/month}$

b. For $Q = 1{,}000$, $P = Q(R - v) - FC = 1{,}000(\$7 - \$2) - \$6{,}000 = -\$1{,}000$

c. $P = \$4{,}000$; solve for Q using Formula 5–8:

$$Q = \frac{\$4{,}000 + \$6{,}000}{\$7 - \$2} = 2{,}000 \text{ pies}$$

d. $\text{Profit} = Q(R - v) - FC$

$$\$5{,}000 = 2{,}000(R - \$2) - \$6{,}000$$

$$R = \$7.50$$

Capacity alternatives may involve *step costs,* which are costs that increase stepwise as potential volume increases. For example, a firm may have the option of purchasing one, two, or three machines, with each additional machine increasing the fixed cost, although perhaps not linearly. (See Figure 5.7A.) Then fixed costs and potential volume would depend on the number of machines purchased. The implication is that *multiple break-even quantities* may occur, possibly one for each range. Note, however, that the total revenue line might not intersect the fixed-cost line in a particular range, meaning that there would be no break-even point in that range. This possibility is illustrated in Figure 5.7B, where there is no break-even point in the first range. In order to decide how many machines to purchase, a manager must consider projected annual demand (volume) relative to the multiple break-even points and choose the most appropriate number of machines, as Example 4 shows.

EXAMPLE 4

eXcel

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A manager has the option of purchasing one, two, or three machines. Fixed costs and potential volumes are as follows:

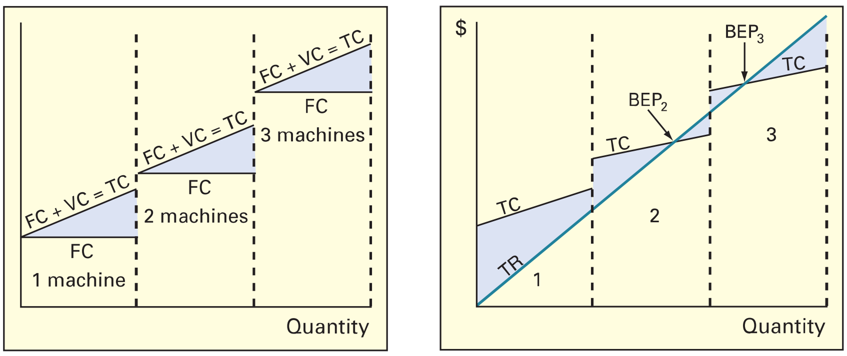
Number of Machines	Total Annual Fixed Costs	Corresponding Range of Output
1	$ 9,600	0 to 300
2	15,000	301 to 600
3	20,000	601 to 900

Variable cost is $10 per unit, and revenue is $40 per unit.

a. Determine the break-even point for each range.

b. If projected annual demand is between 580 and 660 units, how many machines should the manager purchase?

FIGURE 5.7
Break-even problem with step fixed costs



A. Step fixed costs and variable costs   B. Multiple break-even points

SOLUTION

a. Compute the break-even point for each range using the formula $Q_{BEP} = FC/(R - v)$.

For one machine: $$Q_{BEP} = \frac{\$9{,}600}{\$40/\text{unit} - \$10/\text{unit}} = 320 \text{ units [not in range, so there is no BEP]}$$

For two machines: $$Q_{BEP} = \frac{\$15{,}000}{\$40/\text{unit} - \$10/\text{unit}} = 500 \text{ units}$$

For three machines: $$Q_{BEP} = \frac{\$20{,}000}{\$40/\text{unit} - \$10/\text{unit}} = 666.67 \text{ units}$$

b. Comparing the projected range of demand to the two ranges for which a break-even point occurs (see Figure 5.7B), you can see that the break-even point is 500, which is in the range 301 to 600. This means that even if demand is at the low end of the range, it would be above the break-even point and thus yield a profit. That is not true of range 601 to 900. At the top end of projected demand, the volume would still be less than the break-even point for that range, so there would be no profit. Hence, the manager should choose two machines.

Cost–volume analysis can be a valuable tool for comparing capacity alternatives if certain assumptions are satisfied:

1. One product is involved.
2. Everything produced can be sold.
3. The variable cost per unit is the same regardless of the volume.
4. Fixed costs do not change with volume changes, or they are step changes.
5. The revenue per unit is the same regardless of volume.
6. Revenue per unit exceeds variable cost per unit.

As with any quantitative tool, it is important to verify that the assumptions on which the technique is based are reasonably satisfied for a particular situation. For example, revenue per unit or variable cost per unit is not always constant. In addition, fixed costs may not be constant over the range of possible output. If demand is subject to random variations, one must take that into account in the analysis. Also, cost–volume analysis requires that fixed and variable costs can be separated, and this is sometimes exceedingly difficult to accomplish. Cost–volume analysis works best with one product or a few products that have the same cost characteristics.

A notable benefit of cost–volume considerations is the conceptual framework it provides for integrating cost, revenue, and profit estimates into capacity decisions. If a proposal looks attractive using cost–volume analysis, the next step would be to develop cash flow models to see how it fares with the addition of time and more flexible cost functions.

Financial Analysis

Operations personnel need to have the ability to do *financial analysis.* A problem that is universally encountered by managers is how to allocate scarce funds. A common approach is to use financial analysis to rank investment proposals, taking into account the *time value of money.*

Two important terms in financial analysis are *cash flow* and *present value:*

Cash flow refers to the difference between the cash received from sales (of goods or services) and other sources (e.g., sale of old equipment) and the cash outflow for labor, materials, overhead, and taxes.

Present value expresses in current value the sum of all future cash flows of an investment proposal.

The three most commonly used methods of financial analysis are payback, present value, and internal rate of return.

Cash flow The difference between cash received from sales and other sources, and cash outflow for labor, material, overhead, and taxes.

Present value The sum, in current value, of all future cash flows of an investment proposal.

Payback is a crude but widely used method that focuses on the length of time it will take for an investment to return its original cost. For example, an investment with an original cost of $6,000 and a monthly net cash flow of $1,000 has a payback period of six months. Payback ignores the *time value of money*. Its use is easier to rationalize for short-term than for long-term projects.

EXAMPLE 5

A new machine will cost $2,000, but it will result in savings of $500 per year. What is the payback time in years?

SOLUTION

Initial cost = $2,000 Annual savings = $500

The payback time is initial cost divided by annual savings. Thus, the payback time is

$$\text{Payback time} = \frac{\text{Initial cost}}{\text{Annual Saving}} = \frac{\$2{,}000}{\$500/\text{yr}} = 4 \text{ years}$$

The *present value (PV)* method summarizes the initial cost of an investment, its estimated annual cash flows, and any expected salvage value in a single value called the *equivalent current value,* taking into account the time value of money (i.e., interest rates).

The *internal rate of return (IRR)* summarizes the initial cost, expected annual cash flows, and estimated future salvage value of an investment proposal in an *equivalent interest rate*. In other words, this method identifies the rate of return that equates the estimated future returns and the initial cost.

These techniques are appropriate when there is a high degree of *certainty* associated with estimates of future cash flows. In many instances, however, operations managers and other managers must deal with situations better described as risky or uncertain. When conditions of risk or uncertainty are present, decision theory is often applied.

Decision Theory

Decision theory is a helpful tool for financial comparison of alternatives under conditions of risk or uncertainty. It is suited to capacity decisions and to a wide range of other decisions managers must make. It involves identifying a set of possible future conditions that could influence results, listing alternative courses of action, and developing a financial outcome for each alternative–future condition combination. Decision theory is described in the supplement to this chapter.

Waiting-Line Analysis

Analysis of lines is often useful for designing or modifying service systems. Waiting lines have a tendency to form in a wide variety of service systems (e.g., airport ticket counters, telephone calls to a cable television company, hospital emergency rooms). The lines are symptoms of bottleneck operations. Analysis is useful in helping managers choose a capacity level that will be cost-effective through balancing the cost of having customers wait with the cost of providing additional capacity. It can aid in the determination of expected costs for various levels of service capacity.

This topic is described in Chapter 18.

Simulation

Simulation can be a useful tool in evaluating what-if scenarios. Simulation is described on the book's Web site.