Chapter One

Strategy and Competition

Chapter Overview

Purpose

The purpose of this chapter is to introduce the student to a variety of strategic issues that arise in the manufacturing function of the firm.

Key Points

1. *Manufacturing matters.* This writer contends that the loss of the manufacturing base in the U.S. economy is not healthy and will eventually lead to an overall loss in the standard of living and quality of life in this country. It counters the argument that our evolution into a service economy is a natural and healthy thing.
2. *Strategic dimensions.* Along with cost and/or product differentiation, other dimensions along which firms distinguish themselves include (a) quality, (b) delivery speed, (c) delivery reliability, and (d) flexibility.
3. *Classical view.* The classical literature on manufacturing strategy indicates that strategy should be viewed in relation to one or more of the following issues: (a) time horizon, (b) focus, (c) evaluation, and (d) consistency.
4. *Global competition.* How do we measure our success and economic health on a global scale? One way is to examine classical measures of relative economic strength, which include (a) balance of trade, (b) share of world exports, (c) creation of jobs, and (d) cost of labor. However, such macro measures do not adequately explain why certain countries dominate certain industries. National competitive advantage is a consequence of several factors (factor conditions, demand conditions, related and supporting industries, firm strategy structure, and rivalry), although productivity also plays an important role.
5. *Strategic initiatives.* We discuss several strategic initiatives that have allowed many companies to shine in their respective arenas. These include (a) business process reengineering, (b) just-in-time manufacturing and purchasing systems, (c) time-based competition, and (d) competing on quality.
6. *Product and process life cycles.* Most of us understand that products have natural life cycles: start-up, rapid growth, maturation, stabilization, or decline. However, it is rarely recognized that processes too have life cycles. Initially, new manufacturing processes have the characteristics of a job shop. As the process matures, automation is introduced. In the mature phases of a manufacturing

process, most major operations are automated. A firm needs to match the phases of product and process life cycles to be the most successful in its arena.

7. *Learning and experience curves.* These are helpful in forecasting the decline in unit cost of a manufacturing process as one gains experience with the process. Learning curves are more appropriate when modeling the learning of an individual worker, and experience curves are more appropriate when considering an entire industry.
8. *Capacity growth planning.* Another important strategic issue in operations is determining the timing and sizing of new capacity additions. Simple models (make or buy problem) and more complex exponential growth models are explored in Section 1.11. In addition, some of the factors that determine appropriate location of new facilities is explored.

According to Wikipedia (the online encyclopedia), "*strategy* is a long-term plan of action designed to achieve a particular goal, most often 'winning.'" Its root is from the Greek *stratēgos,* which referred to a "military commander" during the age of Athenian Democracy. Strategy was originally conceived in the military context. Two famous books dealing with military strategy are *The Prince* by Machiavelli and *The Art of War* by Sun Tzu.

Hence, we can see that business strategy relates closely to military strategy. Companies fight on an economic battlefield, and long-term strategies determine winners and losers. Business strategy is the highest level of corporate activity that bundles together the disparate functional area strategies. Business strategy sets the terms and goals for a company to follow.

Perhaps the reason that chief executive officers (CEOs) are compensated so highly in the United States is the realization that the strategic vision of the CEO is often the difference between the success and failure of a company. The strategic visions of industry giants such as Henry Ford, Jack Welch, and Bill Gates were central to the success of their companies that have, at one time or another, dominated their competition.

Rarely do large corporations make significant changes in their fundamental business strategies, but it does happen. One of the most dramatic examples in recent years was Apple's launch of the iPod in early 2002. The case is described in the Snapshot Application.

Success requires a vision, and visions must be articulated so all of the firm's employees can share in that vision. The formal articulation of the vision is known as the company mission statement. A good mission statement should provide a clear description of the goals of the firm and is the first step toward formulating a coherent business strategy. Poor mission statements tend to be wordy and full of generalities. Good mission statements are direct, clear, and concise. In their book, Jones and Kahaner (1995) list the 50 corporate mission statements that they perceive as the best. One example is the Gillette Corporation. Their mission statement is: "Our Mission is to achieve or enhance clear leadership, worldwide, in the existing or new core consumer product categories in which we choose to compete." They then go on to list exactly which areas they perceive as their core competencies. Intel defines their mission as: "Do a great job for our customers, employees, and stockholders by being the preeminent building block supplier to the computing industry." The statement then provides details on "Values and Objectives." In many cases, their objectives are quite specific (e.g., "Lead in LAN products and Smart Network Services"). Certainly, the award for conciseness has to go to the General Electric Corporation, whose mission statement is three words: "Boundaryless . . . Speed . . . Stretch." The commentary

Snapshot Application

APPLE ADOPTS A NEW BUSINESS STRATEGY AND SHIFTS ITS CORE COMPETENCY FROM COMPUTERS TO PORTABLE MUSIC

Every company must decide where its core competency lies and how best to leverage that competency for success in the marketplace. Apple Computer was founded in the late 1970s by Steven Jobs and Steven Wozniak, whose vision for a mass-market personal computer literally changed our lives. Apple was enormously successful in the early years, but the nature of the personal computer market changed dramatically when IBM entered the fray. IBM introduced an open architecture model in 1981 that was easily cloned, thus leading to low-cost competition. As software developers devoted their efforts to Microsoft's DOS and Windows operating systems, it appeared at the turn of the century that Apple Computer might not survive.

What Apple did at that point is a fascinating bit of business history and one of the few examples of a firm successfully undergoing a fundamental shift in business strategy. Apple took the vision of one man and created a product different from any it had previously produced. As the story goes, an independent contractor and hardware expert named Tony Fadell dreamed up the idea of an MP3 player linked to a music sales service.

Fadell shopped his concept around to many companies, none of whom were interested—except for Apple. Apple hired Fadell in early 2001 and assigned him to a team of about 30 people, including designers, programmers, and hardware engineers.

Apple subcontracted much of the development and design work to PortalPlayer. Portal dropped its other customers and devoted all of its resources (200 employees in the United States and 80 in India) to the new product. At the time, Fadell was quoted as saying "This is the product that's going to remold Apple and 10 years from now, it's going to be a music business, not a computer business." Visionaries, such as Fadell, see the possibilities of innovation long before the rest of us. As of this writing in early 2007, Tony Fadell is senior vice president of the iPod division of Apple.

Apple's on-and-off head, Steve Jobs, was intimately involved with the development, design, and look and feel of the new product. The ease with which one can locate songs, playlists, and so forth, was largely due to the demands of the company president.

The rest, as they say, is history. In April of 2007 the number of iPods sold worldwide passed the 100 million mark. The product has become the gold standard of portable digital music (and now video) players and has been responsible for a huge turnaround in the success of the company.

Source: Kahney, Leander, "Inside Look at the Birth of the iPod." July 2004, http://www.wired.com (accessed July 21, 2004).

following the statement provides an explanation of exactly what these words mean in the context of the corporation.

Once having articulated a vision, the next step is to plan a strategy for achieving that vision. This is the firm's business strategy. The overall business strategy includes defining

1. The market in which the enterprise competes.
2. The level of investment.
3. The means of allocating resources to and the integrating of separate business units.
4. Functional area strategies, including
    - The marketing strategy
    - The financial strategy
    - The operations strategy

Broadly defined, the operations strategy is the means by which the firm deploys its resources to achieve its competitive goals. For manufacturing firms, it is the sum total of all decisions concerning the production, storage, and distribution of goods. Important operations strategy decisions include where to locate new manufacturing facilities, how large these facilities should be, what processes to use for manufacturing and moving goods through the system, and what workers to employ. Service firms also require an operations strategy. The United States continues to be a leader in financial services, which must be supported by effective and reliable operations departments in order to remain competitive. The Disney theme park's continuing record of success is due in part to its careful attention to detail in every phase of its operations.

Does the American culture place too much emphasis on marketing (selling the product) and finance (leveraged buyouts, mergers, stock prices) and too little on operations (making and delivering the product)? Years ago, this was certainly the case. However, we are quick learners. The enormous success of the Japanese auto industry, for example, provided strong motivation for the American big three to close their inefficient plants and change the way things were done. The dramatic differences that were brought to light by Womack, Jones, and Roos (1990) have largely been eliminated. Today, the best American auto plants rival their Japanese counterparts for quality and efficiency.

Still, a coherent operations strategy is essential. When the Apple Macintosh was introduced, the product was extremely successful. However, the company was plagued with backorders and failed to keep up with consumer demand. According to Debbi Coleman, Apple's former director of worldwide manufacturing:

> Manufacturing lacked an overall strategy which created problems that took nine months to solve . . . we had extremely poor forecasting. Incoming materials weren't inspected for defects and we didn't have a mechanism for telling suppliers what was wrong, except angry phone calls. Forty percent of Mac materials were coming from overseas and no one from Apple was inspecting them before they were shipped. . . . One of the biggest tasks that high-tech manufacturers face is designing a manufacturing strategy that allows a company to be flexible so it can ride with the highs and lows of consumer and business buying cycles. (Fallon, 1985)

Although it is easy to be critical of American management style, we must be aware of the factors motivating American managers and those motivating managers from other cultures. For example, the Japanese have not achieved their dramatic successes without cost. Sixteen-hour work days and a high rate of nervous breakdowns among management are common in Japan.

Measuring a firm's success by the performance of its share price can result in shortsighted management practices. Boards of directors are more concerned with the next quarterly report than with funding major long-term projects. In fact, Hayes and Wheelwright (1984) make a compelling argument that such factors led to a myopic management style in the United States, characterized by the following:

1. Managers' performance is measured on the basis of **return on investment** (ROI), which is simply the ratio of the profit realized by a particular operation or project over the investment made in that operation or project.
2. Performance is measured over short time horizons. There is little motivation for a manager to invest in a project that is not likely to bear fruit until after he or she has moved on to another position.

In order to improve ROI, a manager must either increase the numerator (profits) or decrease the denominator (investment). In the short term, decreasing the denominator by cutting back on the investment in new technologies or new facilities is easier than trying to increase profits by improving efficiency, the quality of the product, or the productivity of the operating unit. The long-term effects of decreasing investment are devastating. At some point, the capital costs required to modernize old factories become more than the firm can bear, and the firm loses its competitive position in the marketplace.

It would be encouraging if the problems of U.S. industries arising from overemphasis on short-term financial performance were decreasing, but sadly, they appear to be worsening. Because of gross mismanagement and questionable auditing practices, two giants of American industry were brought down in 2001: Enron and Arthur Andersen. "Enron went from the No. 7 company on the Fortune 500 to a penny stock in a stunning three weeks because it apparently lied on its financial statements," said Representative John D. Dingell, one-time member of the House Energy Committee. While other parts of the world have experienced spectacular problems as well (such as the Asian financial crisis that hit in the late 1990s), few Americans can understand how a company that had recently expanded and profited from the energy crisis, and an American icon such as Arthur Andersen, could both be brought down so quickly and completely. It is our continual focus on short-term performance and the incentive system we have built up around this objective that led to these crises.

Measuring individual performance over the short term is a philosophy that seems to pervade American life. Politicians are elected for two-, four-, or six-year terms. There is a strong incentive for them to show results in time for the next election. Even university professors are evaluated yearly on their professional performance in many institutions, even though most serious academic projects extend over many years.

1.1 MANUFACTURING MATTERS

A question that is being debated and has been debated by economists for several decades is the importance of a strong manufacturing base. The decline of manufacturing domestically has led to a shift in jobs from the manufacturing sector to the service sector. Because there are major disparities in labor costs in different parts of the world, there are strong incentives for American firms to locate volume manufacturing facilities overseas to reduce labor costs. Is a strong manufacturing base important for the health of the economy?

There is little debate that manufacturing jobs have been steadily declining in the United States. The growth of manufacturing overseas, and in China in particular, is well documented. If we compare the proportion of nonagriculture jobs in the United States in service versus manufacturing in 1950 versus 2002, the change is quite dramatic. In 1950, manufacturing jobs accounted for 34 percent of nonagriculture labor and service jobs accounted for 59 percent. In 2002, however, manufacturing jobs only accounted for 13 percent of nonagriculture jobs, while service jobs soared to 82 percent of the total (Hagenbaugh, 2002).

One mitigating factor in the loss of manufacturing was the dramatic rise in manufacturing productivity during this same period. Average annual manufacturing productivity growth was 2.57 percent annually during the 1980s and 3.51 percent annually during the 1990s (Faux, 2003). This dramatic rise in manufacturing productivity has had the effect of offsetting the loss of high-paying manufacturing jobs at home, thus partially accounting for the success of the U.S. economy in the latter part of the first decade of the century.

An argument put forth by several scholars (e.g., Daniel Bell, 1976) is that we are simply evolving from an industrial to a service economy. In this view, the three stages of economic evolution are (1) agrarian, (2) industrial, and (3) service. In the early years of our country, we were primarily an agrarian economy. With the industrial revolution, a large portion of the labor force shifted from agriculture to manufacturing. In recent years it seems that there is less interest in manufacturing. These scholars would argue that we are merely entering the third stage of the evolutionary process: moving from an industrial economy to a service economy.

It is comforting to think that the American economy is healthy and simply evolving from an industrial to a service economy. One might even argue that manufacturing is not important for economic well-being. According to economist Gary S. Becker (1986), "Strong modern economies do not seem to require a dominant manufacturing sector."

It is far from clear, however, that we evolved from an agrarian economy to an industrial economy. Although fewer American workers are employed in the agricultural sector of the economy, agricultural production has *not* declined. Based on U.S. Department of Commerce data, Cohen and Zysman (1987) state that "agriculture has sustained, over the long term, the highest rate of productivity increase of any sector." By utilizing new technologies, agriculture has been able to sustain growth while consuming fewer labor hours. Hence, the figures simply do not bear out the argument that our economy has shifted from an agricultural one to an industrial one.

The argument that the economy is undergoing natural stages of evolution is simply not borne out by the facts. I believe that all sectors of the economy—agricultural, manufacturing, and service—are important and that domestic economic well-being depends upon properly linking the activities of these sectors.

The return on innovations will be lost if new products are abandoned after development. The payoff for research and development (R&D) can come only when the product is produced and sold. If manufacturing is taken offshore, then the "rent on innovation" cannot be recaptured. Furthermore, manufacturing naturally leads to innovation. It will be difficult for the United States to retain its position as a leader in innovation if it loses its position as a leader in manufacturing.

That manufacturing naturally leads to innovation is perhaps best illustrated by the Japanese experience in the video market. After Japan had captured the lion's share of the world market for televisions, the next major innovation in consumer video technology, the videocassette recorder (VCR), (at least, the inexpensive consumer version) was developed in Japan, not the United States. Virtually all VCRs sold were manufactured in Asia.

It is difficult to support the argument that we can shift easily from an industrial economy to a service economy. Many services exist to support manufacturing. If manufacturing activities shift to foreign soil, it is likely that the services that complement manufacturing will suffer. According to Cohen and Zysman (1987):

> Were America to lose mastery and control of manufacturing, vast numbers of service jobs would be relocated after a few short rounds of product and process innovation, largely to destinations outside the United States, and real wages in all service activities would fall, impoverishing the nation.

Manufacturing Jobs Outlook

The U.S. Bureau of Labor Statistics (a subsidiary of the Department of Labor) provides up-to-date information on the prospects for jobs in the manufacturing sector by industry. According to the *Occupational Outlook Handbook* (OOH), 2006–2007 Edition (http://www.bls.gov/oco/), even though manufacturing jobs are expected to decline overall, there are some areas of growth and opportunity. Consider the individual sectors:

1. *Aerospace products and parts*. This sector is projected to grow, but more slowly than the economy in general. Earnings are higher here than in most other manufacturing industries, as workers must be highly skilled. However, the sector is unstable and workers are subject to frequent layoffs.

2. *Chemical (except pharmaceuticals and medicines)*. Manufacturing is expected to decline in this sector.
3. *Computer and electronic products*. Employment is expected to decline 7 percent in the decade from 2004–2014 due primarily to higher productivity and the movement of some jobs to lower-wage countries.
4. *Food*. Although needs are projected to be stable, this industry has one of the highest incidences of injury and illness.
5. *Machinery*. Small declines in the total numbers of jobs in this sector are anticipated due to productivity gains, but openings will result from having to replace retiring workers. These jobs are highly skilled, requiring specialized training beyond high school, but are among the highest-paying manufacturing jobs.
6. *Motor vehicles and parts*. At the present time, 22 percent of these jobs are located in the Detroit area, but it is expected that many of these jobs will be relocated in coming years. Earnings tend to be much higher than other industries, but domestic automobile production is on the decline. More growth is expected in the manufacture of automobile parts than in complete vehicles.
7. *Pharmaceuticals and medicine*. This is one of the few fast-growth areas. Earnings are much higher here than in other industries, but workers tend to be highly skilled and educated. More than 6 out of 10 workers have college, professional, or graduate degrees.
8. *Printing*. It is expected that job opportunities will continue their steady decline in the face of increasing computerization.
9. *Steel*. Domestically, this continues to be a declining industry, but opportunities will exist for engineers, computer scientists, business majors, and skilled production workers.
10. *Textiles, textile products, and apparel*. A large proportion of these jobs are located in North Carolina, South Carolina, and Georgia. Employment is expected to decline due to technological advances and increasing imports of apparel and textiles.

1.2 A FRAMEWORK FOR OPERATIONS STRATEGY

Classical literature on competitiveness claims that firms position themselves strategically in the marketplace along one of two dimensions: lower cost or product differentiation (Porter, 1990).

Often new entrants to a market position themselves as the low-cost providers. Firms that have adopted this approach include the Korean automakers (Hyundai, Daewoo, Kia), discount outlets such as Costco, and retailers such as Wal-Mart. While being the low-cost provider can be successful over the near term, it is a risky strategy. Consumers ultimately will abandon products that they perceive as poor quality regardless of cost. For example, many manufacturers of low-cost PC clones popular in the 1980s are long gone.

Most firms that have a long record of success in the marketplace have differentiated themselves from their competitors. By providing uniqueness to buyers, they are able to sustain high profit margins over time. One example is BMW, one of the most profitable auto firms in the world. BMW continues to produce high-performance, well-made cars that are often substantially more expensive than those of competitors in their class. Product differentiation within a firm has also been a successful strategy. Consider the success of General Motors in the early years compared to Ford. GM was able to successfully capture different market segments at the same time by forming five distinct divisions, while Henry Ford's insistence on providing only a single model almost led the company to bankruptcy (Womack et al., 1990).

Strategic Dimensions

However, cost and product differentiation are not the only two dimensions along which firms distinguish themselves. The following additional factors relate directly to the operations function:

- Quality
- Delivery speed
- Delivery reliability
- Flexibility

What does *quality* mean? It is a word often bandied about, but one that means different things in different contexts. Consider the following hypothetical remarks.

1. "That hairdryer was a real disappointment. It really didn't dry my hair as well as I expected."
2. "I was thrilled with my last car. I sold it with 150,000 miles and hardly had any repairs."
3. "I love buying from that catalogue. I always get what I order within two days."
4. "The refrigerator works fine, but I think the shelves could have been laid out better."
5. "That park had great rides, but the lines were a mess."
6. "Our quality is great. We've got less than six defectives per one million parts produced."

In each case, the speaker is referring to a different aspect of quality. In the first case, the product simply didn't perform the task it was designed to do. That is, its function was substandard. The repair record of an automobile is really an issue of reliability rather than quality, per se. In the third case, it is delivery speed that translates to quality service for that customer. The fourth case refers to a product that does what it is supposed to do, but the consumer is disappointed with the product design. The product quality (the rides) at the amusement park were fine, but the logistics of the park management were a disappointment. The final case refers to the statistical aspects of quality control.

Hence the word *quality* means different things in different contexts. A Geo Prism is a quality product and so is a Ferrari Testarosa. Consumers buying these products are both looking for quality cars but have fundamentally different objectives. The fact is that *everyone* competes on quality. For this reason, Terry Hill (1993) would classify quality as an order qualifier rather than an order winner. An option is immediately eliminated from consideration if it does not meet minimum quality standards. It is the particular aspect of quality on which one chooses to focus that determines the nature of the competitive strategy and the positioning of the firm.

Delivery speed can be an important competitive weapon in some contexts. Some firms base their primary competitive position on delivery speed, such as UPS and Federal Express. Mail-order and Web-based retailers also must be able to deliver products reliably and quickly to remain competitive. Building contractors that complete projects on time will have an edge.

Delivery reliability means being able to deliver products or services when promised. Online brokerages that execute trades reliably and quickly will retain customers. Contract manufacturers are measured on several dimensions, one being whether they can deliver on time. As third-party sourcing of manufacturing continues to grow, the successful contract manufacturers will be the ones that put customers first and maintain a record of delivering high-quality products in a reliable fashion.

Flexibility means offering a wide range of products and being able to adjust to unexpected changes in the demand of the product mix offered. Successful manufacturers in the 21st century will be those that can respond the fastest to unpredictable changes in customer tastes. This writer was fortunate enough to tour Toyota's Motomachi Plant located in Toyoda City, Japan. What was particularly impressive was the ability to produce several different models in the same plant. In fact, each successive car on the assembly line was a different model. A right-hand drive Crown sedan, for the domestic market, was followed by a left-hand drive Lexus coupe, designated for shipment to the United States. Each car carried unique sets of instructions that could be read by both robot welders and human assemblers. This flexibility allowed Toyota to adjust the product mix on a real-time basis and to embark on a system in which customers could order custom-configured cars directly from terminals located in dealer showrooms (Port, 1999).

Hence, one way to think of operations strategy is the strategic positioning the firm chooses along one of the dimensions of cost, quality, delivery speed, delivery reliability, and flexibility. Operations management is concerned with implementing the strategy to achieve leadership along one of these dimensions.

1.3 THE CLASSICAL VIEW OF OPERATIONS STRATEGY

The traditional view of manufacturing strategy was put forward by Wickham Skinner of the Harvard Business School and enhanced by several researchers, mostly from Harvard as well. The traditional view treats most strategic issues in the context of a single plant rather than the entire firm. The broad issues discussed in Section 1.2 relate to operations strategy on the firm level. While the classical view might be considered a bit old-fashioned, the issues are still important and relevant. Classical operations strategy thinking relates to the following issues:

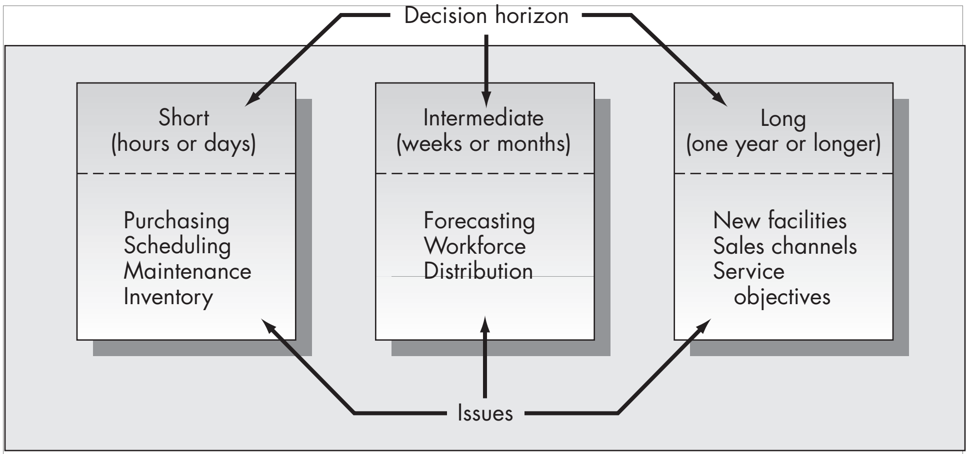
1. Time horizon
2. Focus
3. Evaluation
4. Consistency

Time Horizon

Time horizon refers to the length of time required for the strategy to have an effect. A natural classification here is to separate strategy decisions into short-, medium-, and long-range decisions. Short-term operations decisions may have an impact that can be measured in days or even hours. These include decisions regarding purchasing, production and personnel scheduling, policies for control of quality and maintenance functions, short-term inventory control issues, production schedules, and so forth. It is short-term decisions of this type that concern the operations manager, and they are the primary focus of this text.

Medium-range operations decisions are those whose impact can be measured in terms of weeks and months. They include demand and requirements forecasting, employment-planning decisions including determining the workforce size and mix, decisions concerning the distribution of goods in existing distribution channels, and setting of company targets for inventory and service levels. Changing the levels that

FIGURE 1–1
Decision horizons of manufacturing strategy



signal an out-of-control situation for a control chart is a short-term quality decision, whereas restructuring the production line and seeking more reliable vendors are issues that would affect product quality farther into the future.

Strategy is generally associated with long-term decisions. Choosing the timing, the location, and the scale of construction of new manufacturing facilities are typical long-term manufacturing and operations strategy decisions. Making these decisions requires information about the forecast for new and existing products, the changing characteristics of the marketplace, and the changes in the costs and availability of resources. Manufacturing strategy must address the groundwork for building the proper channels for sales and distribution as well as facilities design and development. Figure 1–1 shows a breakdown of the production and operations decisions in terms of the timing of the consequences of these decisions.

Time horizons affect the impact of decisions, the uncertainties surrounding those decisions, and the penalty for wrong decisions. Short time horizons involve many decisions, each of whose impact may be small, but cumulatively can make a difference. For example, managers at The Gap stores restock shelves every day. The manager phones orders into the distribution center (DC) that generally are delivered the following day (assuming the DC is in stock on requested items). The manager relies on sales data and personal judgment to select the mix of items to reorder. Mistakes mean that items may go out of stock, resulting in lost sales and irate customers, or not sell, resulting in wasted shelf space.

Buyers in the San Francisco headquarters of the firm decide on what lines of clothes to stock for the coming season. These may be considered intermediate-term decisions. The buyers have less information available to make their decisions than does the store manager, and the decisions they make have greater impact. The buyers have to judge fashion trends and color preferences. A line that doesn't sell must be marked down and sold at a loss.

Top management must make the long-term decisions. For The Gap, some long-term decisions might include (1) the number, location, and size of distribution centers; (2) terms and conditions of long-term contracts with suppliers; (3) arrangements for firmwide supply chain logistics (in-house versus outsourced); and (4) selection of management personnel. There is more uncertainty involved with these decisions. Demographics change, which could make prior decisions on the location and sizing for DCs wrong. A long-term contract with a plant overseas, for example, in China, could backfire. Quotas can be imposed by the U.S. government, or tariffs could be imposed by the Chinese government. The importance and sensitivity of long-term decisions are probably among the reasons top management personnel are paid so well in the United States.

Focus

The notion of **focus** in manufacturing strategy was first considered by Skinner (1974). He defined the five key characteristics of the focused factory as follows:

1. *Process technologies.* A natural means of focusing the operations of one plant or factory is by the process employed. Management should limit new unproven process technologies to one per factory and keep the number of different mature process technologies to a level that the plant manager can oversee efficiently.

2. *Market demands.* The marketplace often determines the focus of a product or line of products produced at a factory. Typical areas in which the market dictates plant focus are

- *Price.* There is evidence that the American consumer is more price conscious than many overseas consumers. Price has always been a key product differentiation factor in the United States.
- *Lead time.* Products not protected by patents must be produced and distributed quickly in order to reach the marketplace before those of competitors.
- *Reliability.* Reliability specifications differ by market segment, often for identical products. As an example, consider a company producing a line of integrated circuits that are sold to a variety of different customers. One uses them in refrigerators and another in heart–lung machines. The reliability specifications are likely to be far greater for the heart–lung machine.

3. *Product volumes.* The production volumes within a single plant should be similar so that plant tooling, materials-handling systems, and production lines are neither under- nor overutilized.

4. *Quality level.* The level of quality of products produced in a single plant should be similar so that the firm can establish a consistent quality control standard. Quality standards are the result of several factors: the statistical control techniques used, the monitoring procedures, and the workers' training, procedures, and attitudes.

5. *Manufacturing tasks.* The productivity of a plant producing a broad line of different products will suffer from disruptions that result from frequent setups and restructuring of the production lines. When management limits the number of distinct manufacturing tasks at one location, workers can concentrate on perfecting existing processes.

There is evidence that focused companies are more successful. Hayes and Wheelwright (1984) relate the operating profit margin for 11 companies to the number of major product types these companies produce. Based on these data, they show that firms that produce fewer products tend to be more profitable. It is interesting to note that for the 11 firms surveyed, focus, as measured in this fashion, was a better predictor of profitability than size of sales.

It should be noted that many firms successfully serve several diverse markets simultaneously. One example (and there are certainly many others in both the United States and Japan) is Yamaha. Yamaha has established itself as a high-quality manufacturer of products as diverse as stereo equipment, musical instruments (including band instruments, pianos, and digital synthesizers), and sports equipment. However, focused factories are certainly preferred even for firms that have a broad product line.

Evaluation

There are several dimensions along which one can evaluate production/operations strategy. Here are the most significant:

1. *Cost.* Where pricing is a key to market differentiation and competitiveness, a major means of strategy evaluation is the cost of products delivered to the customer. Direct costs of production include costs of materials, equipment, and labor. Costs of distribution involve inventory carrying costs, particularly inventory in the pipeline, transportation, and distribution costs. Cost of plant and process overhead also must be factored into the cost calculation. Overhead costs of new processes may be the most difficult to evaluate because of the uncertainties of both the process reliability and the useful lifetime.

2. *Quality.* In markets where product quality is a major determinant of product success in the marketplace, or high reliability is required to meet product specifications, strategy should be evaluated along the quality dimension. For example, product quality is the primary means of evaluating manufacturing performance in Japan.

3. *Profitability.* Ultimately, it is the profitability of a product line that determines the success of the strategy undertaken to produce and to sell it. However, as noted above, short-term profit maximization could be a poor strategy for the firm if it entails reductions in the investment in new capacity and technology. If the time horizon associated with the evaluation of any particular strategy is not correct, top management could be making poor decisions. Strategies that achieve short-term profitability may not necessarily be in the best interests of the firm in the long term.

4. *Customer satisfaction.* Successful firms have come to realize that ultimate success is achieved only by maintaining a satisfied and loyal customer base. This means that the customer must not only be satisfied with a product when purchased, but must have confidence that the firm will stand behind its guarantees by supplying efficient and cost-effective service after a sale is made. *Market-driven quality* is a term we often hear these days. Its recent emphasis shows that companies are becoming more aware that customer service must be made an explicit part of the product delivery process.

Consistency

It is often the case that rather than having a single consistent strategy for manufacturing, the "strategy" is simply the composite of all company policies that affect manufacturing. Personnel and wage policies should be designed to encourage efficiency and improve productivity. Inventory control, scheduling, and production plans are geared toward minimizing production costs and improving measures such as worker idle time, work-in-process inventory, and production lead times. Process design is geared toward producing high-quality products. The problem is that each of these individual goals may be optimizing a different objective. The result is a complex plant structure in which management and labor assume adversarial positions.

Skinner (1974) cites a number of causes for the common inconsistencies that are observed in most firms. These include the following:

1. *Professionalism in the plant.* The number of different job titles and job functions has increased while the scope of many of these jobs has narrowed. Professionals in

different areas have a stake in making themselves look good, and hence seek to maximize their personal contributions. Unfortunately, these professionals are not necessarily working toward the same goals. Some are attempting to minimize costs, others to improve the quality of the work environment, and others to optimize the cash flow within the firm.

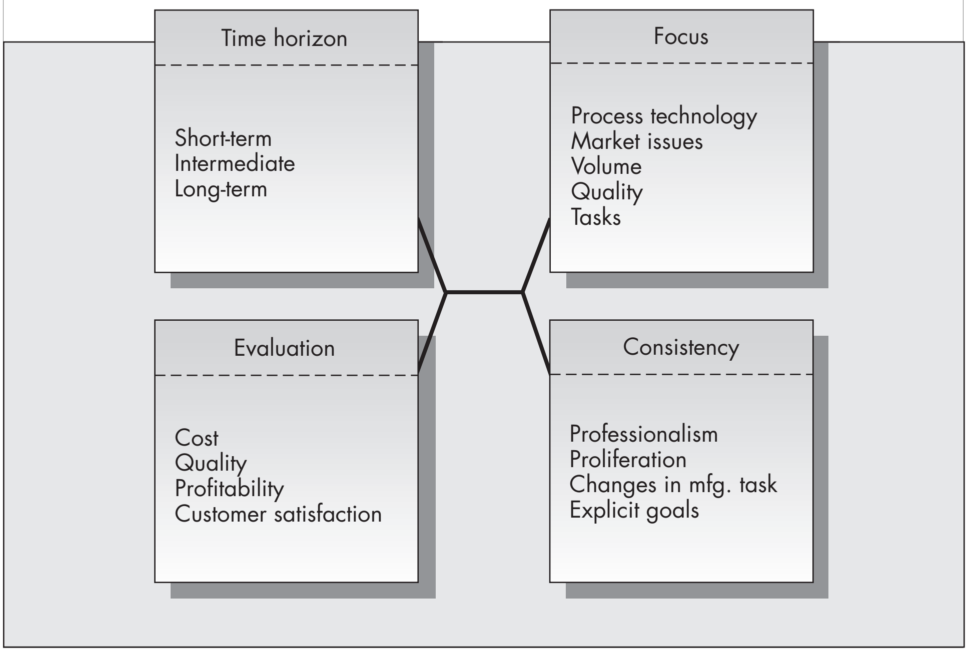
2. *Product proliferation.* As noted above, those firms that produce a smaller number of products tend to be more profitable. As the number of distinct products grows, retaining a consistent set of goals within the plant is more difficult. Why do firms increase the size of the product line produced at one plant? Recall the discussion in the first part of this chapter concerning the consequences of measuring performance based on the return on investment. One sure way of decreasing the investment in new capacity is simply to produce new products in old plants. From management's point of view, this is a means of reducing overhead, but it could also result in poor product quality and inefficient production control.

3. *Changes in the manufacturing task.* Management decides to add productive capacity in response to the needs dictated by the marketplace. Markets change, however, and as a result the function of the plant may change as well. The goals and the means for evaluating those goals may not change along with the demands placed upon the plant. It may happen that the objectives that made sense when the plant was constructed no longer make sense after the plant's function has changed.

4. *The manufacturing task was never made explicit.* Management must understand how the goals of manufacturing fit in with the overall corporate strategy in order for a consistent policy to emerge. If there is no clear corporate strategy, there is little hope that the functional areas of the firm—finance, marketing, and production—can develop a meaningful and consistent strategy independently.

The essential elements of the discussion of this section are summarized in Figure 1–2.

FIGURE 1–2
The elements of production and operations strategy



1.4 COMPETING IN THE GLOBAL MARKETPLACE

International competitiveness has become a national obsession. Americans are concerned that their standard of living is eroding while it seems to improve elsewhere. Evidence exists that there is some truth to this perception. Our balance of trade with Japan has been in the red for decades, with no evidence of a reversal. American firms once held a dominant position worldwide in industries that have nearly disappeared domestically. Consumer electronics, steel, and machine tools are some examples. All the news is not bad, however. The American economy is strong and continues to grow. American firms still have the lion's share of the world market in many industries.

In his excellent study of international competitiveness, Porter (1990) poses the following question: Why does one country become the home base for successful international competitors in an industry? That certain industries flourish in certain countries cannot be disputed. Some examples are

1. Germany: printing presses, luxury cars, chemicals.
2. Switzerland: pharmaceuticals, chocolate.
3. Sweden: heavy trucks, mining equipment.
4. United States: personal computers, software, films.
5. Japan: automobiles, consumer electronics, robotics.

What accounts for this phenomenon? One can offer several compelling explanations, but most have counterexamples. Here are a few:

1. *Historical.* Some industries are historically strong in some countries and are not easily displaced. *Counterexample:* The demise of the steel industry in the United States is one of many counterexamples.
2. *Tax structure.* Some countries, such as Germany, have no capital gains tax, thus providing a more fertile environment for industry. *Counterexample:* However, there is no reason that favorable tax treatment should favor certain industries over others.
3. *National character.* Many believe that workers from other countries, particularly from Pacific Rim countries, are better trained and more dedicated than American workers. *Counterexample:* If this is true, why then do American firms dominate in some industry segments? How does one explain the enormous success Japanese-based corporations have had running plants in the United States with an American workforce?
4. *Natural resources.* There is no question that some industries are highly resource dependent and these industries have a distinct advantage in some countries. One example is the forest products industry in the United States and Canada. *Counterexample:* Many industry sectors are essentially resource independent but still seem to flourish in certain countries.
5. *Government policies.* Some governments provide direct assistance to fledgling industries, such as MITI in Japan. The role of the U.S. government is primarily regulatory. For example, environmental standards in the United States are probably more stringent than almost anywhere else. *Counterexample:* This does not explain why some industries dominate in countries with strict environmental and regulatory standards.
6. *Advantageous macroeconomic factors.* Exchange rates, interest rates, and government debt are some of the macroeconomic factors that provide nations with competitive advantage. For example, in the 1980s when interest rates were much higher in the United States than they were in Japan, it was much easier for Japanese firms to borrow for new projects. *Counterexample:* These factors do not explain why

many nations have a rising standard of living despite rising deficits (Japan, Italy, and Korea are some examples).

7. *Cheap, abundant labor.* Although cheap labor can attract new industry, most countries with cheap labor are very poor. On the other hand, many countries (Germany, Switzerland, and Sweden are examples) have a high standard of living, high wage rates, and shortages of qualified labor.
8. *Management practices.* There is evidence that Japanese management practices are more effective in general than Western-style practices. Counterexample: If American management practices are so ineffective, why do we continue to dominate certain industries, such as personal computers, software development, and pharmaceuticals?

Talking about competitiveness is easier than measuring it. What are the appropriate ways to measure one country's success over another? Some possibilities are

- Balance of trade.
- Share of world exports.
- Creation of jobs.
- Low labor costs.

Arguments can be made against every one of these as a measure of international competitiveness. Switzerland and Italy have trade deficits, and at the same time have experienced rising standards of living. Similar arguments can be made for countries that import more than they export. The number of jobs created by an economy is a poor gauge of the health of that economy. More important is the quality of the jobs created. Finally, low labor costs correlate with a low standard of living. These counterexamples show that it is no easy task to develop an effective measure of international competitiveness.

Porter (1990) argues that the appropriate measure to compare national performance is the rate of productivity growth. Productivity is the value of output per unit of input of labor or capital. Porter argues that productivity growth in some industries appears to be stronger in certain countries, and that there are reasons for this. In some cases we can find the reasons in domestic factor advantages. The factor theory says all countries have access to the same technology (an assumption that is not strictly true) and that national advantages accrue from endowments of production factors such as land, labor, natural resources, and capital.

There are some excellent examples of factor theory. Korea has relatively low labor costs, so it exports labor-intensive goods such as apparel and electronic assemblies. Sweden's iron ore is low in impurities, which contributes to a strong Swedish steel industry. As compelling as it is, there are counterexamples to the factor endowment theory as well. For example, after the Korean War, South Korea developed and excelled in several highly capital-intensive industries such as steel and shipbuilding even though the country was cash poor. Also, many countries have similar factor endowments, but some seem to excel in certain industries, nonetheless. These examples suggest that factor endowments do not explain all cases of nations with dominant industry segments.

Porter (1990) suggests the following four determinants of national advantage:

1. *Factor conditions* (previously discussed).
2. *Demand conditions.* If domestic consumers are sophisticated and demanding, they apply pressure on local industry to innovate faster, which gives firms an edge internationally. Consumers of electronics in Japan are very demanding, thus positioning this industry competitively in the international marketplace.

3. *Related and supporting industries.* Having world-class suppliers nearby is a strong advantage. For example, the Italian footwear industry is supported by a strong leather industry and a strong design industry.
4. *Firm strategy, structure, and rivalry.* The manner in which firms are organized and managed contributes to their international competitiveness. Japanese management style is distinctly different from American. In Germany, many senior executives possess a technical background, producing a strong inclination to product and process improvement. In Italy, there are many small family-owned companies, which encourages individualism.

Even though Porter makes a very convincing argument for national competitive advantage in some industries, there is a debate among economists as to whether the notion of international competitiveness makes any sense at all. Companies compete, not countries. This is the point of view taken by Paul Krugman (1994). According to Krugman, the United States and Japan are simply not competitors in the same way that Ford and Toyota are. The standard of living in a country depends on its own domestic economic performance and not on how it performs relative to other countries.

Krugman argues that too much emphasis on international competitiveness can lead to misguided strategies. Trade wars are much more likely in this case. This was the case in mid-1995 when the Clinton administration was planning to impose high tariffs on makers of Japanese luxury cars. Most economists agree that trade wars and their consequences, such as tariffs, benefit no one in the long run. Another problem that arises from national competitive pride is it can lead to poorly conceived government expenditures. France has spent billions propping up its failing computer industry. (Certainly, not all government investments in domestic industry can be considered a mistake. The Japanese government, for example, played a major role in nurturing the flat-panel display industry. Japanese-based firms now dominate this multibillion dollar industry.)

Another point supporting Krugman's position is that the lion's share of U.S. gross domestic product (GDP) is consumed in the United States, thus making a firm's success in our domestic market more important than its success in the world market. Krugman agrees that productivity growth is a valid concern. He argues, however, that we should be more productive in order to produce more, not to better our international competitors.

The debate over competitive advantage will continue. Policy makers need to be aware of all points of view and weigh each carefully in formulating policy. Although Krugman makes several telling points, there is no question that globalization is a trend that shows no sign of reversing. We cannot stick our heads in the sand and say that foreign markets are not important to us. Economic borders are coming down all across the globe.

Problems for Sections 1.1–1.4

1. Why is it undesirable for the United States to evolve into a service economy?
2. What disadvantages do you see if the chief executive officer (CEO) is primarily concerned with short-term ROI?
3. Can you think of companies that have gone out of business because they focused only on cost and were not able to achieve a minimum quality standard?
4. What are the different quality standards referred to in the example comparing the Geo and the Ferrari?
5. List the four elements of operations strategy and discuss the role of each in strategic planning.

Snapshot Application

GLOBAL MANUFACTURING STRATEGIES IN THE AUTOMOBILE INDUSTRY

Consider the following four foreign automobile manufacturers: Honda, Toyota, BMW, and Mercedes Benz. As everyone knows, Honda and Toyota are Japanese companies and BMW and Mercedes are German companies. The four account for the lion's share of foreign nameplates sold in the U.S. auto market. However, many assume that these cars are manufactured in their home countries. In fact, depending on the model, it could be more likely that a consumer buying a Honda, Toyota, BMW, or Mercedes is buying a car manufactured in the United States.

Honda was the first of the foreign automakers to commit to a significant investment in U.S.-based manufacturing facilities. Honda's first U.S. facility was its Marysville Motorcycle plant, which started production in 1979. Honda must have been pleased with the Ohio-based facility, since an automobile plant followed shortly. Automobile production in Marysville began in 1982. Today, Honda operates four plants in west-central Ohio, producing the Accord sedan and coupe, the Acura TL sedan, the Honda Civic line, and the Honda Element, with the capacity to produce a whopping 440,000 vehicles annually.

Next to make a significant commitment in U.S. production facilities was Toyota. Toyota's plant in Georgetown, Kentucky, has been producing automobiles since 1986 and accounts for all of the Camry's sold in the domestic market. It is interesting to note that the Honda Accord and the Toyota Camry are two of the biggest-selling models in the United States, and are also produced here. They also top almost all reliability surveys.

The two German automakers were slower to commit to U.S.-based manufacturing facilities. BMW launched its Spartenburg, South Carolina, plant in March of 1995. BMW produces both the Z series sports cars and its SUV line in this plant. It is interesting to note that BMW's big sellers, its 3, 5, and 7 series sedans, are still manufactured in Germany.

Mercedes was the last of these four to make a significant commitment to production facilities here. The facility in Tuscaloosa, Alabama, is dedicated to producing the line of Mercedes SUVs. As with BMW, the more popular C, E, and S class sedans are still manufactured in Germany.

(One might ask why Volkswagen is not on this list. In fact, Volkswagen has 45 separate manufacturing facilities located in 18 countries around the world, but no significant manufacturing presence in the mainland United States.)

Sources: Honda's Web site (http://www.ohio.honda.com/), Toyota's Web site (http://www.toyota.com), Autointell's Web site (http://www.autointell-news.com/european_companies/BMW/bmw3.htm), Mercedes Benz's Web site (http://www.mbusi.com/).

6. What are the advantages and disadvantages of producing new products in existing facilities?
7. Consider the following fictitious industrial scenarios. In each case, identify the possible errors in strategy.
   a. A manufacturer of Winchester disk drives located in northern California is expanding the product line to include optical disks. Both products will be manufactured at the same facility even though the optical disks require a different process technology.
   b. A conflict has developed between the head of quality control and the vice president for operations at a tool and die manufacturer in the Midwest. The quality control manager has requested new die-casting equipment costing $400,000 that has an excellent reliability record, while the operations vice president has decided to purchase a similar product that is less reliable from another manufacturer for $300,000.
   c. The chief financial officer of a firm has established the policy of no new investments in facilities for the next year in order to improve the firm's current profitability profile.
   d. A microprocessor designed in the United States and produced in a plant in Mexico is used to monitor the pressure of fluids. It is sold both to an automobile manufacturer and to a maker of life-sustaining equipment.

8. What are the four determinants of national advantage suggested by Porter? Give examples of companies that have thrived as a result of each of these factors.
9. What factor advantage favors the aluminum industry in the United States over Japan and makes aluminum much cheaper to produce here? (Hint: Aluminum production is very energy intensive. In what part of the country is an inexpensive energy source available?)
10. Paul Krugman argues that because most of our domestic product is consumed domestically, we should not dwell on international competition. What industries in the United States have been hardest hit by foreign competition? What are the potential threats to the United States if these industries fail altogether?
11. Krugman points out some misguided government programs that have resulted from too much emphasis on international competitiveness. What risks are there from too little emphasis on international competitiveness?
12. Consider the Snapshot Application in this section concerning foreign automakers locating manufacturing facilities in the United States. Discuss the advantages and disadvantages of the strategy of locating manufacturing facilities where the product is consumed rather than where the company is located.

1.5 STRATEGIC INITIATIVES: REENGINEERING THE BUSINESS PROCESS

Seemingly on schedule, every few years a hot new production control method or management technique comes along, almost always described by a three-letter acronym. While it is easy to be skeptical, by and large, the methods are sound and can have substantial value to corporations when implemented intelligently. *Business process reengineering* (BPR) caught on after the publication of the book by Hammer and Champy (1993). BPR is not a specific technique, such as materials requirements planning or a production-planning concept like just-in-time. Rather, it is the idea that entrenched business processes can be changed and can be improved. The process is one of questioning why things are done a certain way, and not accepting the answer, "because that's the way we do it."

Hammer and Champy, who define BPR as "starting over," provide several examples of successful reengineering efforts. The first is the IBM Credit Corporation, a wholly owned subsidiary of IBM, that, if independent, would rank among the *Fortune* 100 service companies. This arm of IBM is responsible for advancing credit to new customers purchasing IBM equipment. The traditional credit approval process followed five steps:

1. An IBM salesperson would call in with a request for financing and the request would be logged on a piece of paper.
2. Someone carried the paper upstairs to the credit department, where someone else would enter the information into a computer system and check the potential borrower's credit rating. The specialist wrote the results of the credit check on a piece of paper, which was sent off to the business practices department.
3. A third person, in the business practices department, modified the standard loan document in response to the customer request. These modifications, which were done on yet another computer system, were then attached to the original request form and the credit department specialist's report.

4. Next the request went to a pricer, who keyed the information into a spreadsheet to determine the appropriate interest rate to charge the customer. The pricer's recommendation was written on a piece of paper and delivered (with the other papers) to the clerical group.
5. The information was turned into a quote letter that would be delivered to the field salesperson by Federal Express.

This process required an average of six days and sometimes as long as two weeks. Sales reps logged endless complaints about this delay: during this time, the customer could find other financing or another vendor. In an effort to see if this process could be streamlined, two senior managers decided to walk a new request through all five steps, asking personnel to put aside what they were doing and process it as they normally would. They found that the entire five-step process required an average of only 90 minutes of work! The rest of the time, requests were either in transit from one department to another or queueing up on somebody's desk waiting to be processed. Clearly the problem did not lie with the efficiency of the personnel but with the design of the credit approval process itself.

The solution was simple: the four specialists handling each loan request were replaced by a single loan generalist who handled each request from beginning to end. Up-to-date software was designed to support the generalist, who had no trouble dealing with most requests. The credit approval process was designed assuming that each request was sufficiently complex to require someone with special knowledge in each area. In truth, most requests were routine, and specialists generally did little more than a simple table lookup to determine the appropriate figure.

What was the result of this change? The six-day turnaround for loan requests was slashed to only four hours! And this was accomplished with fewer personnel and with a hundredfold increase in the number of deals handled.

While each reengineering effort requires careful thought and no two solutions will be exactly alike, Hammer and Champy (1993) suggest that reengineering efforts utilize the following general principles:

1. *Several jobs are combined into one.* Few examples of BPR are as dramatic as that of IBM Credit, but there are other success stories in the literature as well. Many of the successful cases have a common thread: the reduction of a complex process requiring many steps to a simpler one requiring fewer steps. In the case of IBM Credit, a five-step process was reduced to only a single step. This suggests a general principle. The IBM Credit process was a natural evolution of the concept of division of labor. The economist Adam Smith espoused this principle as far back as the 18th century (see the quote from *The Wealth of Nations* at the beginning of Section 1.10 of this chapter). However, a good thing can be carried too far. If one divides a process into too many steps, one eventually reaches the point of diminishing returns. BPR's most dramatic successes have come from complex processes that were simplified by reducing the number of steps required.

2. *Workers make decisions.* One goal is to reduce the number of levels of reporting by allowing workers to make decisions that were previously reserved for management. In the case of IBM Credit, most decisions once reserved for specialists are now done by a single generalist. Giving workers greater decision-making power may pose a threat to management, who might see such a step as encroaching on their prerogatives.

3. *The steps in the process are performed in a natural order*. Process steps should not be performed necessarily in rigid linear sequence, but in an order that makes sense in the context of the problem being solved. In particular, in many cases, some tasks can be

done simultaneously rather than in sequence. (These ideas, of course, are well known and form the basis for the concepts of project management in Chapter 8.)

4. *Processes should have multiple versions.* One should allow for contingencies, not by designing multiple independent processes, but by designing one flexible process that can react to different circumstances. In the case of IBM Credit, for example, the final credit issuance process had three versions: one for straightforward cases (handled by computer), one for cases of medium difficulty (handled by the deal structurer), and one for difficult cases (performed by the deal structurer with help from specialist advisers).

5. *Work is performed where it makes the most sense.* One of the basic principles of reengineering is not to carry the idea of division of labor too far. Another is not to carry the idea of centralization too far. For example, in most companies, purchasing is done centrally. This means that every purchase request is subject to the same minimum overhead in time and paperwork. A consequence might be that the cost of processing a request exceeds the cost of the item being purchased! A great deal can be saved in this case by allowing individual departments to handle their own purchasing for low-cost items. (Hammer and Champy discuss such a case.)

The authors list several other basic principles, involving minimizing checks and reconciliations, having a single point of contact, and being able to employ hybrid centralized/decentralized operations.

It is easier to list the steps one might consider in a reengineering effort than to actually implement one. In the real world, political realities cannot be ignored. For many of the success stories in the literature, not only are the processes simplified, but the headcount of personnel is reduced as well. It is certainly understandable for employees to see BPR as a thinly veiled excuse for downsizing (euphemistically called "right-sizing"). This was exactly the case in one financial services company. When word got out that management was planning a reengineering effort, most assumed that there would be major layoffs. Some even thought the company was on the verge of bankruptcy. In another instance, union leadership saw reengineering as a means for management to throw away the job categories and work rules they had won in hard-fought negotiations over the years, and persuaded the members to strike. In a third case, a senior manager was unhappy with the potential loss of authority that might accompany a reengineering effort. He resigned to start his own company. (These examples are related in a follow-up book by Hammer and Stanton, 1995.)

These stories show that starting a reengineering effort is not without risks. Rarely is the process as simple as IBM's. Reengineering has been described by Ronald Compton, the CEO of Aetna Life and Casualty, as "agonizingly, heartbreakingly, tough." There needs to be some cost–benefit analysis done up front to be sure the potential gains compensate for the risks.

Process optimization is not new. In its early years, the field of industrial engineering dealt with optimal design of processes, setting standards using time and motion studies, and flowcharting for understanding the sequence of events and flow of material in a factory. Why is BPR different? For one, BPR is concerned with business process flows rather than manufacturing process flows. Second, the concept is not one of optimizing an existing process, but one of rethinking how things should be done from scratch. As such, it is more revolutionary than evolutionary. It is likely to be more disruptive but could have larger payoffs. To make BPR work, employees at every level have to buy into the approach, and top management must champion it. Otherwise, the reengineering effort could be a costly failure.

1.6 STRATEGIC INITIATIVES: JUST-IN-TIME

Just-in-time (JIT) is a manufacturing process on one hand and a broad-based operations strategy on the other. The process elements of JIT will be discussed in detail in Chapter 7 as part of a complete analysis of push and pull inventory systems. However, JIT (or lean production, as it is also known) is a philosophy that includes treatment of inventory in the plant, relationships with suppliers, and distribution strategies. The core of the philosophy is to eliminate waste. This is accomplished by efficient scheduling of incoming orders, work-in-process inventories, and finished goods inventories.

JIT is an outgrowth of the **kanban system** introduced by Toyota. Kanban is a Japanese word meaning card or ticket. Originally, kanban cards were the only means of implementing JIT. The kanban system was introduced by Toyota to reduce excess work-in-process (WIP) inventories. Today, JIT is more ambitious. Both quality control systems and relationships with suppliers are part of an integrated JIT system. JIT systems can be implemented in ways other than using kanban cards. Integrating JIT philosophies with sophisticated information systems makes information transfer faster. The speed with which information can be transferred from one part of the firm to another is an important factor in the success of the JIT system.

JIT is a philosophy of operating a company that includes establishing understandings and working relationships with suppliers, providing for careful monitoring of quality and work flow, and ensuring that products are produced only as they are needed. Although JIT can be used simply as it was originally designed by Toyota, namely as a means of moving work-in-process (WIP) from one work center to another, proponents of the method recommend much more. They would have a firm integrate the JIT philosophy into its overall business strategy.

Inventory and material flow systems are classified as either **push** or **pull systems.** A push system is one in which decisions concerning how material will flow through the system are made centrally. Based on these decisions, material is produced and "pushed" to the next level of the system. A typical push system is materials requirements planning (MRP), which is discussed in detail in Chapter 7. In MRP, appropriate production amounts for all levels of the production hierarchy are computed all at once based on forecasts of end-product demand and the relationship between components and end items. In JIT, production is initiated at one level as a result of a request from a higher level. Units are then "pulled" through the system.

JIT has many advantages over conventional systems. Eliminating WIP inventories results in reduced holding costs. Less inventory means less money tied up in inventory. JIT also allows quick detection of quality problems. Since units are produced only as they are needed, the situation in which large amounts of defective WIP inventory are produced before a quality problem is detected should never occur in a properly running JIT system. JIT also means that relationships with suppliers must be tightened up. Suppliers must be willing to absorb some uncertainty and adjust delivery quantities and the timing of deliveries to match the rates of product flows.

Part of what made the kanban system so effective for Toyota was its success in reducing setup times for critical operations. The most dramatic example of setup time reduction is the so-called SMED, or single-minute exchange of dies. Each time a major change in body style is initiated, it is necessary to change the dies used in the process.

The die-changing operation typically took from four to six hours. During the die-changing operation the production line was closed down. Toyota management heard that Mercedes Benz was able to reduce its die-changing operation to less than one hour. Realizing that even more dramatic reductions were possible, Toyota set about focusing on the reduction of the time required for die changing. In a series of dramatic improvements, Toyota eventually reduced this critical operation to only several minutes. The essential idea behind SMED is to make as many changes as possible off-line, while the production process continues.

An important part of JIT is forming relationships with suppliers. What separates JIT purchasing from conventional purchasing practices? Freeland (1991) gives a list of characteristics contrasting the conventional and JIT purchasing behavior. Some of these include

Conventional Purchasing	JIT Purchasing
1. Large, infrequent deliveries.	1. Small, frequent deliveries.
2. Multiple suppliers for each part.	2. Few suppliers; single sourcing.
3. Short-term purchasing agreements.	3. Long-term agreements.
4. Minimal exchange of information.	4. Frequent information exchange.
5. Prices established by suppliers.	5. Prices negotiated.
6. Geographical proximity unimportant.	6. Geographical proximity important.

In his study, Freeland notes that the industries that seemed to benefit most from JIT purchasing were those that typically had large inventories. Companies without JIT purchasing tended to be more job-shop oriented or make-to-order oriented. Vendors that entered into JIT purchasing agreements tended to carry more safety stock, suggesting manufacturers are reducing inventories at the expense of the vendors. The JIT deliveries were somewhat more frequent, but the differences were not as large as one might expect. Geographical separation of vendors and purchasers was a serious impediment to successful implementation of JIT purchasing. The automotive industry was one that reported substantial benefit from JIT purchasing arrangements. In other industries, such as computers, the responses were mixed; some companies reported substantial benefits and some reported few benefits.

Although reducing excess work-in-process inventory can have many benefits, JIT is not necessarily the answer for all manufacturing situations. According to Stasey and McNair (1990),

> Inventory in a typical plant is like insurance, insurance that a problem in one area of a plant won't affect work performed in another. When problems creating the need for insurance are solved, then inventories disappear from the plant floor.

The implication is that we merely eliminate all sources of uncertainty in the plant and the need for inventories disappears. The problem is that there are some sources of variation that can never be eliminated. One is variation in consumer demand. JIT is effective only if final demand is regular. Another may be sources of variation inherent in the production process or in the equipment. Can one simply legislate away all sources of uncertainty in the manufacturing environment? Of course not. Hence, although the underlying principles of JIT are sound, it is not a cure-all and will not necessarily be the right method for every production situation.

1.7 STRATEGIC INITIATIVES: TIME-BASED COMPETITION

Professor Terry Hill of the London School of Business has proposed an interesting way to look at competitive factors. He classifies them into two types: "qualifiers" and "order winners." A product not possessing a qualifying factor is eliminated from consideration. The order winner is the factor that determines who gets the sale among the field of qualifiers.

Two factors about which we hear a great deal are quality and **time to market.** In the past decade, the Japanese and Germans gained a loyal following among U.S. consumers by producing quality products. American firms are catching up on the quality dimension. From the discussion in Section 1.6, we see that successful U.S.–based companies have been able to produce products that match the defect rates of foreign competitors. If this trend continues, product quality will be assumed by the consumer. Quality may become an order qualifier rather than an order winner.

If that is the case, what factors will determine order winners in years to come? Japanese automobile companies provided and continue to provide high-quality automobiles. In recent years, however, the major automobile producers in Japan have begun to focus on aesthetics and consumer tastes. They have branched out from the stolid small cars of the 1970s and 1980s to new markets with cars such as the Toyota-made Lexus luxury line and Mazda's innovative and successful Miata.

The timely introduction of new features and innovative design will determine the order winners in the automobile industry. In the computer industry, Compaq built its reputation partly on its ability to be the first to market with new technology. Time-based competition is a term that we will hear more and more frequently in coming years.

What is **time-based competition?** It is not the time and motion studies popular in the 1930s that formed the basis of the industrial engineering discipline. Rather, according to Blackburn (1991),

> Time-based competitors focus on the bigger picture, on the entire value-delivery system. They attempt to transform an entire organization into one focused on the total time required to deliver a product or service. Their goal is not to devise the best way to perform a task, but to either eliminate the task altogether or perform it in parallel with other tasks so that over-all system response time is reduced. Becoming a time-based competitor requires making revolutionary changes in the ways that processes are organized.

Successful retailers understand time-based competition. The success of the fashion chains The Gap and The Limited is due largely to their ability to deliver the latest fashions to the customer in a timely manner. Part of the success of the enormously successful Wal-Mart chain is its time-management strategy. Each stock item in a Wal-Mart store is replenished twice a week, while the industry average is once every two weeks. This allows Wal-Mart to achieve better inventory turnover rates than its competition and respond more quickly to changes in customer demand. Wal-Mart's strategies have enabled it to become the industry leader, with a growth rate three times the industry average and profits two times the industry average (Blackburn, 1991, Chapter 3).

Time-based management is a more complex issue for manufacturers, and in some industries it is clearly the key factor leading to success or failure. The industry leaders in the dynamic random access memory (DRAM) industry changed four times between 1978 and 1987. In each case, the firm that was first to market with the next-generation

DRAM dominated that market. The DRAM experience is summarized in the following table (Davis, 1989):

Product	Firm	Year Introduced	First Year of Volume Production	Market Leaders in First Year of Volume Production
16 K	Mostek	1976	1978	Mostek (25%) NEC (20%)
64 K	Hitachi	1979	1982	Hitachi (19%) NEC (15%)
256 K	NEC	1982	1984	NEC (27%) Hitachi (24%)
1 MB	Toshiba	1985	1987	Toshiba (47%) Mitsubishi (16%)

I am aware of no other example that shows so clearly and so predictably the value of getting to the market first.

1.8 STRATEGIC INITIATIVES: COMPETING ON QUALITY

What competitive factors do American managers believe will be important in the next decade? Based on a survey of 217 industry participants, the following factors were deemed as the most important for gaining a competitive edge in the coming years; they are listed in the order of importance.

1. Conformance quality
2. On-time delivery performance
3. Quality
4. Product flexibility
5. After-sale service
6. Price
7. Broad line (features)
8. Distribution
9. Volume flexibility
10. Promotion

In this list we see some important themes. **Quality** and **time management** emerge as leading factors. Quality control has been given was brought to public attention with the establishment of the prestigious Malcolm Baldrige Award (modeled after the Japanese Deming Prize, which has been around a lot longer). Quality means different things in different contexts, so it is important to understand how it is used in the context of manufactured goods. A high-quality product is one that performs as it was designed to perform. Products will perform as they are designed to perform if there is little variation in the manufacturing process. With this definition of quality, it is possible for a product with a poor design to be of high quality, just as it is possible for a well-designed product to be of poor quality. Even granting this somewhat narrow definition of quality, what is the best measure? Defect rates are a typical barometer. However, a more appropriate measure might be reliability of the product after manufacture. This measure is typically used to monitor quality of products such as automobiles and consumer electronics.

There has been an enormous groundswell of interest in the quality issue in the United States in recent years. With the onslaught of Japanese competition, many American industries are fighting for their lives. The business of selling quality is at an all-time high. Consulting companies that specialize in providing quality programs to industry, such as the Juran Institute and Philip Crosby Associates, are doing a booming business. The question is whether American firms are merely paying lip service to quality or are seriously trying to change the way they do business. There is evidence that, in some cases at least, the latter is true.

For example, in a comparison of American and Japanese auto companies, quality as measured by defects reported in the first three months of ownership declined significantly from 1987 to 1990 for U.S. companies, narrowing the gap with Japan significantly. The Buick Division of General Motors, a winner of the Baldrige Award, has made dramatic improvements along these lines. Between 1987 and 1990 Buick decreased this defect rate by about 70 percent, equaling the rate for Hondas in 1990 (*Business Week,* October 22, 1990).

There are many success stories in U.S. manufacturing. Ford Motors achieved dramatic success with the Taurus. Ford improved both quality and innovation, providing buyers with reliable and technologically advanced cars. In 1980, James Harbour reported that Japanese automakers could produce a car for $1,500 less than their American counterparts. That gap has been narrowed by Ford to within a few hundred dollars. Part of Ford's success lies in former CEO Donald Petersen's decision not to invest billions in new plants incorporating the latest technology as GM did in the mid-1980s. This is only part of the story, however. According to Faye Wills (1990),

> If you are looking for surprise answers to Ford's ascendancy, for hidden secrets, forget it. Good solid everyday management has turned the trick—textbook planning and execution, common-sense plant layouts and procedures, intelligent designs that not only sell cars, but also cut costs and bolster profit margins. It's that simple.

We can learn from our successes. The machine tool industry was one in which the Japanese made dramatic inroads in the 1980s. Many American firms fell to the onslaught of Asian competition, but not the Stanley Works of New Britain, Connecticut. In 1982, the firm's president was considering whether Stanley should remain in the hardware business as Asian firms flooded the U.S. market with low-priced hammers, screwdrivers, and other tools. Stanley decided to fight back. It modernized its plants and introduced new quality control systems. Between 1982 and 1988 scrap rates dropped from 15 percent to only 3 percent at New Britain. Stanley not only met the competition head-on here at home, but also competed successfully in Asia. Stanley now runs a profitable operation selling its distinctive yellow tape measures in Asia.

Where are most PC clones made? Taiwan? Korea? Guess again. The answer may surprise you: Texas. Two Texas firms have been extremely successful in this marketplace. One is Compaq Computer (now part of HP), which entered the market in the early 1980s with the first portable PC. It continued to build well-designed and high-quality products, and rose to command 20 percent of the world's PC market. Compaq established itself as a market leader. The other successful PC maker, Dell Computer, is also from Texas. The sudden rise of Dell is an interesting story. Michael Dell, a former University of Texas student, started reselling IBM PCs in the early 1980s. He later formed PC's Limited, which marketed one of the first mail-order PC clones. Dell is now a market leader in the PC marketplace, offering a combination of state-of-the-art designs, high-quality products, and excellent service.

Another American firm that has made a serious commitment to quality is Motorola. Motorola, winner of the Baldrige Award in 1987, has been steadily driving down the rate of defects in its manufactured products. Defects were reported to be near 40 parts per million at the end of 1991, down from 6,000 parts per million in 1986. Motorola has announced that its goal is to reach six-sigma (meaning six standard deviations away from the mean of a normal distribution), which translates to 3.4 parts per million. Motorola feels that the process of applying for the Baldrige Award was so valuable that it now requires all its suppliers to apply for the award as well.

Success stories like these show that the United States can compete successfully with Japan and other overseas rivals on the quality dimension. However, total quality management must become ingrained into our culture if we are going to be truly world class. The fundamentals must be there. The systems must be in place to monitor the traditional quality measures: conformance to specifications and defect-free products. However, quality management must expand beyond statistical measures. Quality must pervade the way we do business, from quality in design, quality in manufacture, and quality in building working systems with vendors, to quality in customer service and satisfaction.

Problems for Sections 1.5–1.8

13. What is an operational definition of quality? Is it possible for a 13-inch TV selling for $100 to be of superior quality to a 35-inch console selling for $1,800?
14. Studies have shown that the defect rates for many Japanese products are much lower than for their American-made counterparts. Speculate on the reasons for these differences.
15. What does "time-based competition" mean? Give an example of a product that you purchased that was introduced to the marketplace ahead of its competitors.
16. Consider the old maxim, "Build a better mousetrap and the world will beat a path to your door." Discuss the meaning of this phrase in the context of time-based competition. In particular, is getting to the market first the only factor in a product's eventual success?
17. What general features would you look for in a business process that would make that process a candidate for reengineering? Discuss a situation from your own experience in which it was clear that the business process could have been improved.
18. In what ways might the following techniques be useful as part of a reengineering effort?
    - Computer-based simulation
    - Flowcharting
    - Project management techniques
    - Mathematical modeling
    - Cross-functional teams
19. What problems can you foresee arising in the following situations?
    a. Top management is interested in reengineering to cut costs, but the employees are skeptical.
    b. Line workers would like to see a reengineering effort undertaken to give them more say-so in what goes on, but management is uninterested.
20. Just-in-time has been characterized as a system whose primary goal is to eliminate waste. Discuss how waste can be introduced in (*a*) relationships with vendors,

(*b*) receipt of material into the plant, and (*c*) movement of material through the plant. How do JIT methods cut down on these forms of waste?

21. In what ways can JIT systems improve product quality?

1.9 MATCHING PROCESS AND PRODUCT LIFE CYCLES

The Product Life Cycle

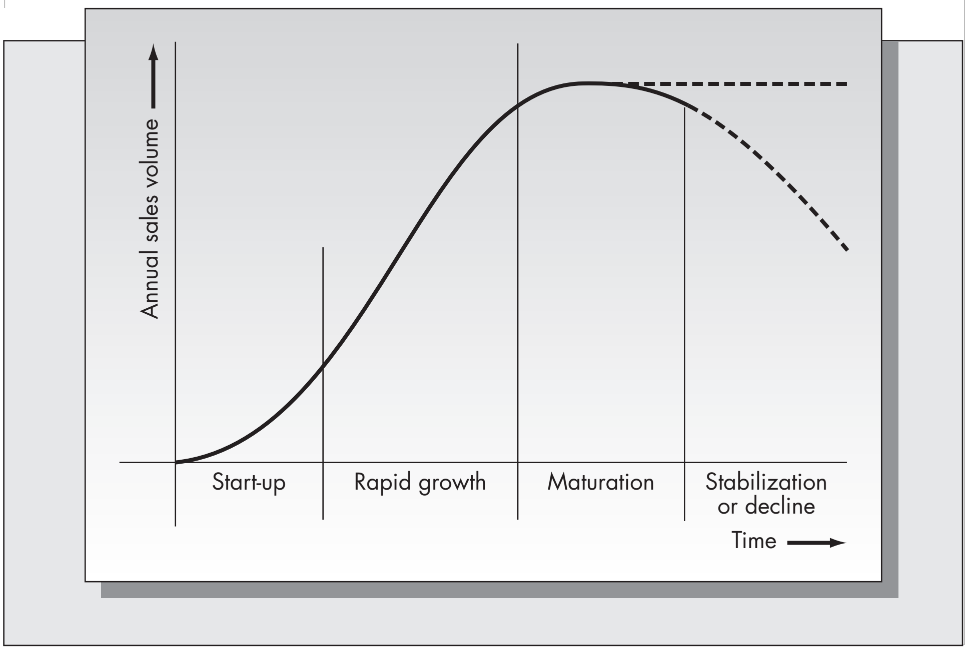
The demand for new products typically undergoes cycles that can be identified and mapped over time. Understanding the nature of this evolution helps to identify appropriate strategies for production and operations at the various stages of the product cycle. A typical **product life cycle** is pictured in Figure 1–3. The product life cycle consists of four major segments:

1. Start-up
2. Rapid growth
3. Maturation
4. Stabilization or decline

During the start-up phase, the market for the product is developing, production and distribution costs are high, and competition is generally not a problem. During this phase the primary strategy concern is to apply the experiences of the marketplace and of manufacturing to improve the production and marketing functions. At this time, serious design flaws should be revealed and corrected.

The period of rapid growth sees the beginning of competition. The primary strategic goal during this period is to establish the product as firmly as possible in the marketplace. To do this, management should consider alternative pricing patterns that

FIGURE 1–3
The product life-cycle curve



suit the various customer classes and should reinforce brand preference among suppliers and customers. The manufacturing process should be undergoing improvements and standardization as product volume increases. Flexibility and modularization of the manufacturing function are highly desirable at this stage.

During the maturation phase of the product life cycle, the objective should be to maintain and improve the brand loyalty that the firm cultivated in the growth phase. Management should seek to increase market share through competitive pricing. Cost savings should be realized through improved production control and product distribution. During this phase the firm must listen to the messages of the marketplace. Most problems with product design and quality should have been corrected during the start-up and growth phases, but additional improvements should also be considered during this phase.

The appropriate shape of the life-cycle curve in the final stage depends on the nature of the product. Many products will continue to sell, with the potential for annual growth continuing almost indefinitely. Examples of such products are commodities such as household goods, processed food, and automobiles. For such products the company's primary goals in this phase would be essentially the same as those described previously for the maturation phase. Other products will experience a natural decline in sales volume as the market for the product becomes saturated or as the product becomes obsolete. If this is the case, the company should adopt a strategy of squeezing out the most from the product or product line while minimizing investment in new manufacturing technology and media advertising.

Although a useful concept, the product life-cycle curve is not accurate in all circumstances. Marketing departments that base their strategies on the life-cycle curve may make poor decisions. Dhalla and Yuspeh (1976) report an example of a firm that shifted advertising dollars from a successful stable product to a new product. The assumption was that the new product was entering the growth phase of its life cycle and the stable product was entering the declining phase of its life cycle. However, the new product never gained consumer acceptance, and because of a drop in the advertising budget, the sales of the stable product went into a decline and never recovered. They suggest that in some circumstances it is more effective to build a model that is consistent with the product's history and with consumer behavior than to blindly assume that all products follow the same pattern of growth and decline. Although we believe that the life-cycle concept is a useful way of looking at customer demand patterns in general, a carefully constructed model for each product will ultimately be a far more effective planning tool.

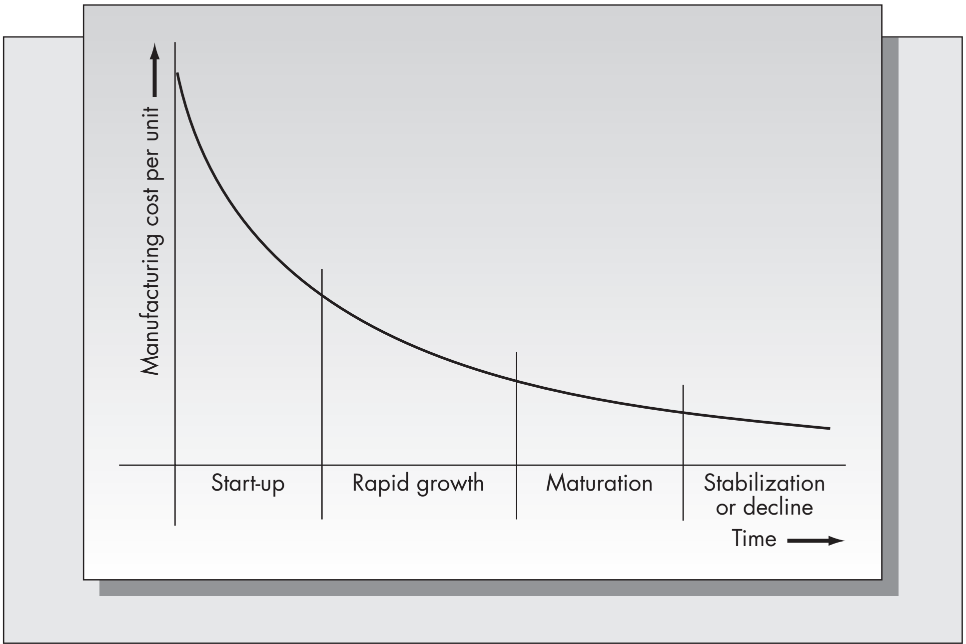
The Process Life Cycle

Abernathy and Townsend (1975) have classified three major stages of the **manufacturing process life cycle:** early, middle, and mature. These phases do not necessarily coincide exactly with the stages of the product life cycle, but they do provide a conceptual framework for planning improvements in the manufacturing process as the product matures.

In the first phase of the process life cycle, the manufacturing function has the characteristics of a job shop. It must cope with a varied mix of relatively low-volume orders and be responsive to changes in the product design. The types and quality of the inputs may vary considerably, and the firm has little control over suppliers.

In the middle phase of the process life cycle, automation begins to play a greater role. The firm should be able to exert more control over suppliers as the volume of production

FIGURE 1–4
The process life cycle and the experience curve



increases. Unit production costs decline as a result of learning effects. The production process may involve batch processing and some transfer lines (assembly lines).

In the last phase of the process life cycle, most of the major operations are automated, the production process is standardized, and few manufacturing innovations are introduced. The production process may assume the characteristics of a continuous flow operation.

This particular evolutionary scenario is not appropriate for all new manufacturing ventures. Companies that thrive on small one-of-a-kind orders will maintain the characteristics of a job shop, for example. The process life-cycle concept applies to new products that eventually mature into high-volume items. The issue of matching the characteristics of the product with the characteristics of the process is discussed subsequently.

Experience curves show that unit production costs decline as the cumulative number of units produced increases. One may think of the experience curve in terms of the process life cycle shown in Figure 1–4. An accurate understanding of the relationship between the experience curve and the process life cycle can be very valuable. By matching the decline in unit cost with the various stages of the process life cycle, management can gain insight into the consequences of moving from one phase of the process life cycle into another. This insight will assist management in determining the proper timing of improvements in the manufacturing process.

The Product–Process Matrix

Hayes and Wheelwright (1979) consider linking the product and process life cycles using the **product–process matrix** pictured in Figure 1–5. The matrix is based on four phases in the evolution of the manufacturing process: (1) jumbled flow, (2) disconnected line flow, (3) connected line flow, and (4) continuous flow. This matrix may be viewed in two ways. One is to match the appropriate industry in its mature phase with

FIGURE 1–5
The product–process matrix

Source: Robert H. Hayes and Steven C. Wheelwright, "Link Manufacturing Process and Product Life Cycles" in the *Harvard Business Review* (January–February 1979). © 1979 by the President and Fellows of Harvard College; all rights reserved. Reprinted by permission.

Process structure Process life-cycle stage	I Low volume, low standardization, one of a kind	II Multiple products, low volume	III Few major products, higher volume	IV High volume, high standardization, commodity products
I Jumbled flow (job shop)	Commercial printer			Void
II Disconnected line flow (batch)		Heavy equipment		
III Connected line flow (assembly line)			Auto assembly	
IV Continuous flow	Void			Sugar refinery

the appropriate process. This point of view recognizes that not all industries necessarily follow the process evolution described in the previous section on the process life cycle. Certain companies or certain products could remain in an early phase of the process life cycle indefinitely. However, even firms that do not evolve to a position in the lower right-hand corner of the matrix should, in most cases, be located somewhere on the diagonal of the matrix.

Located in the upper left-hand corner of this matrix are companies that specialize in "one of a kind" jobs in which the manufacturing function has the characteristics of a jumbled flow shop. A commercial printer is an example of a jumbled flow shop. Production is in relatively small lots, and the shop is organized for maximum flexibility.

Farther down the diagonal are firms that still require a great deal of flexibility but produce a limited line of standardized items. Manufacturers of heavy equipment would fall into this category because they would produce in somewhat higher volumes. A disconnected line would provide enough flexibility to meet custom orders while still retaining economies of limited standardization.

The third category down the diagonal includes firms that produce a line of standard products for a large-volume market. Typical examples are producers of home appliances or electronic equipment, and automobile manufacturers. The assembly line or transfer line would be an appropriate process technology in this case.

Finally, the lower right-hand portion of the matrix would be appropriate for products involving continuous flow. Chemical processing, gasoline and oil refining, and sugar refining are examples. Such processes are characterized by low unit costs, standardization of the product, high sales volume, and extreme inflexibility of the production process.

What is the point of this particular classification scheme? It provides a means of assessing whether a firm is operating in the proper portion of the matrix; that is, if the process is properly matched with the product structure. Firms choosing to operate off the diagonal should have a clear understanding of the reasons for doing so. One example of a successful firm that operates off the diagonal is Rolls-Royce. Another is a company producing handmade furniture. The manufacturing process in these cases would have the characteristics of a jumbled flow shop, but competitors might typically be located in the second or third position on the diagonal.

There is another way to look at the product–process matrix. It can be used to identify the proper match of the production process with the phases of the product life cycle. In the start-up phase of product development, the firm would typically be positioned in the upper left-hand corner of the matrix. As the market for the product matures, the firm would move down the diagonal to achieve economies of scale. Finally, the firm would settle at the position on the matrix that would be appropriate based on the characteristics of the product.

Problems for Section 1.9

22. *a.* What are the four phases of the manufacturing process that appear in the product–process matrix?
    b. Discuss the disadvantages of operating off the diagonal of the matrix.
23. Give an example of a product that has undergone the four phases of the product life cycle and has achieved stability.
24. Discuss the following: "All firms should evolve along the diagonal of the product–process matrix."
25. Locate the following operations in the appropriate position on the product–process matrix.
    a. A small shop that repairs musical instruments.
    b. An oil refinery.
    c. A manufacturer of office furniture.
    d. A manufacturer of major household appliances such as washers, dryers, and refrigerators.
    e. A manufacturing firm in the start-up phase.

1.10 LEARNING AND EXPERIENCE CURVES

As experience is gained with the production of a particular product, either by a single worker or by an industry as a whole, the production process becomes more efficient. As noted by the economist Adam Smith as far back as the 18th century in his landmark work, *The Wealth of Nations:*

> The division of labor, by reducing every man's business to some one simple operation, and by making this operation the sole employment of his life, necessarily increases very much the dexterity of the worker.

By quantifying the relationship that describes the gain in efficiency as the cumulative number of units produced increases, management can accurately predict the eventual capacity of existing facilities and the unit costs of production. Today we recognize that many other factors besides the improving skill of the individual worker contribute to this effect. Some of these factors include the following:

- Improvements in production methods.
- Improvements in the reliability and efficiency of the tools and machines used.
- Better product design.
- Improved production scheduling and inventory control.
- Better organization of the workplace.

Studies of the aircraft industry undertaken during the 1920s showed that the direct-labor hours required to produce a unit of output declined as the cumulative number of units produced increased. The term **learning curve** was adopted to explain this phenomenon. Similarly, it has been observed in many industries that marginal production costs also decline as the cumulative number of units produced increases. The term **experience curve** has been used to describe this second phenomenon.

Learning Curves

As workers gain more experience with the requirements of a particular process, or as the process is improved over time, the number of hours required to produce an additional unit declines. The learning curve, which models this relationship, is also a means of describing dynamic economies of scale. Experience has shown that these curves are accurately represented by an exponential relationship. Let $Y(u)$ be the number of labor hours required to produce the uth unit. Then the learning curve is of the form

$$Y(u) = au^{-b},$$

where a is the number of hours required to produce the first unit and b measures the rate at which the marginal production hours decline as the cumulative number of units produced increases. Traditionally, learning curves are described by the percentage decline of the labor hours required to produce item $2n$ compared to the labor hours required to produce item n, and it is assumed that this percentage is independent of n. That is, an 80 percent learning curve means that the time required to produce unit $2n$ is 80 percent of the time required to produce unit n for any value of n. For an 80 percent learning curve

$$\frac{Y(2u)}{Y(u)} = \frac{a(2u)^{-b}}{au^{-b}} = 2^{-b} = .80.$$

It follows that

$$-b \ln(2) = \ln(.8)$$

$$\text{or } b = -\ln(.8)/\ln(2) = .3219. \text{ (ln is the natural logarithm.)}$$

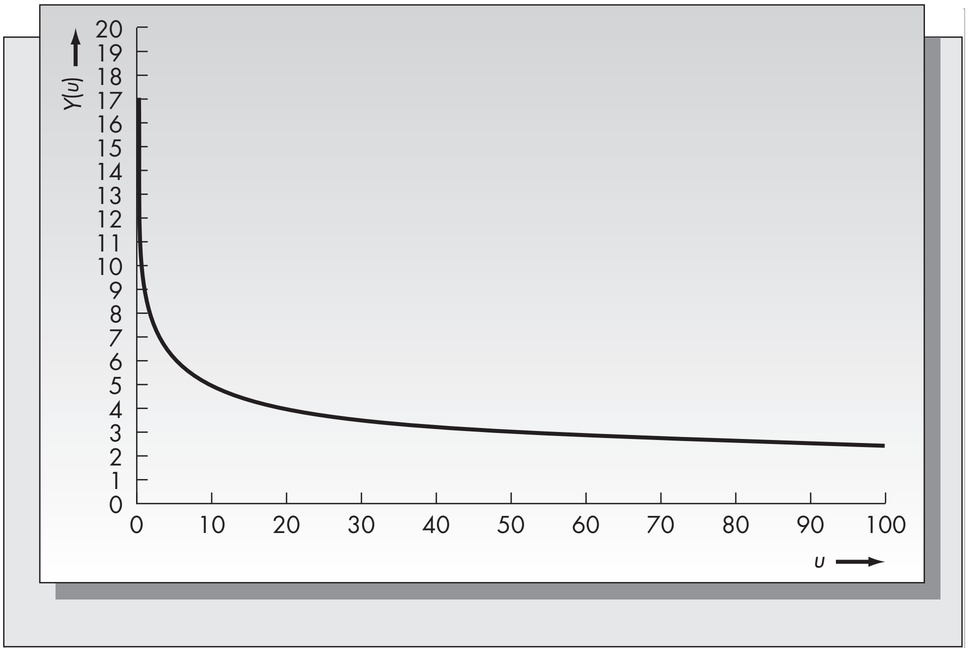
More generally, if the learning curve is a $100L$ percent learning curve, then

$$b = -\ln(L)/\ln(2).$$

Figure 1–6 shows an 80 percent learning curve. When graphed on double-log paper, the learning curve should be a straight line if the exponential relationship we have assumed is accurate. If logarithms of both sides of the expression for $Y(u)$ are taken, a linear relationship results, since

$$\ln(Y(u)) = \ln(a) - b \ln(u).$$

FIGURE 1–6
An 80 percent learning curve



Linear regression is used to fit the values of a and b to actual data after the logarithm transformation has been made. (General equations for finding least squares estimators in linear regression appear in Appendix 2–B.)

Example *1.1*

XYZ has kept careful records of the average number of labor hours required to produce one of its new products, a pressure transducer used in automobile fuel systems. These records are represented in the following table.

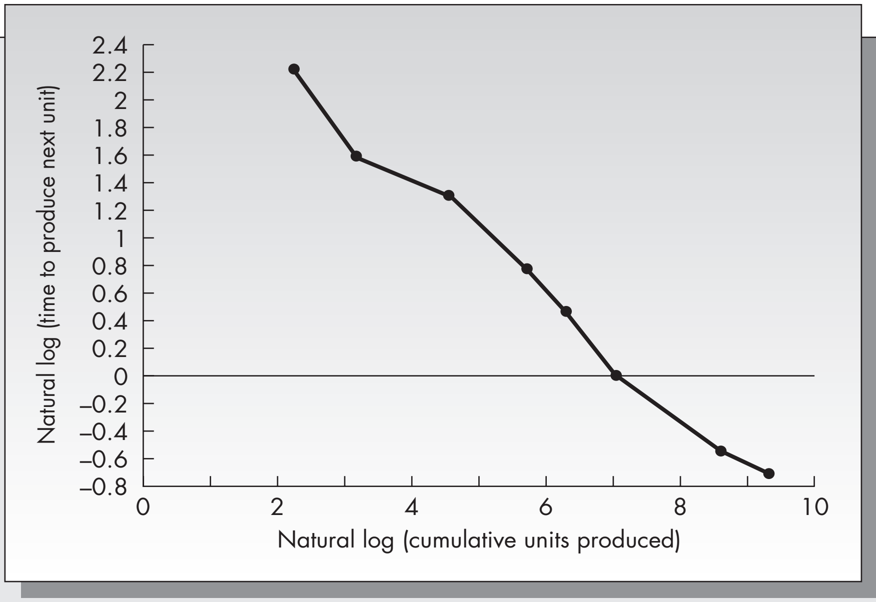
Cumulative Number of Units Produced (A)	Ln (Column A)	Hours Required for Next Unit (B)	Ln (Column B)
10.00	2.30	9.22	2.22
25.00	3.22	4.85	1.58
100.00	4.61	3.80	1.34
250.00	5.52	2.44	0.89
500.00	6.21	1.70	0.53
1,000.00	6.91	1.03	0.53
5,000.00	8.52	0.60	−0.51
10,000.00	9.21	0.50	−0.69

According to the theory, there should be a straight-line relationship between the logarithm of the cumulative number of units produced and the logarithm of the hours required for the last unit of production. The graph of the logarithms of these quantities for the data above appears in Figure 1–7. The figure suggests that the exponential learning curve is fairly accurate in this case. Using the methods outlined in Appendix 2–B, we have obtained estimators for the slope and the intercept of the least squares fit of the data in Figure 1–7. The values of the least squares estimators are

$$\text{Intercept} = 3.1301,$$
$$\text{Slope} = -.42276.$$

Since the intercept is ln(a), the value of a is exp(3.1301) = 22.88. Hence, it should have taken about 23 hours to produce the first unit. The slope term is the constant $-b$. From the

FIGURE 1–7
Log–log plot of XYZ data



equation for b on page 000 we have that

$$\ln(L) = -b \ln(2) = (-.42276)(.6931) = -.293.$$

It follows that $L = \exp(-.293) = .746$.

Hence, these data show that the learning effect for the production of the transducers can be accurately described by a 75 percent learning curve. This curve can be used to predict the number of labor hours that will be required for continued production of these particular transducers. For example, substituting $u = 50{,}000$ into the relationship

$$Y(u) = 22.88u^{-.42276}$$

gives a value of $Y(50{,}000) = .236$ hour. One must interpret such results with caution, however. A learning curve relationship may not be valid indefinitely. Eventually the product will reach the end of its natural life cycle, which could occur before 50,000 units have been produced in this example. Alternatively, there could be some absolute limit on the number of labor hours required to produce one unit that, because of the nature of the manufacturing process, can never be improved. Even with these limitations in mind, learning curves can be a valuable planning tool when properly used.

Experience Curves

Learning curves are a means of calibrating the decline in marginal labor hours as workers become more familiar with a particular task or as greater efficiency is introduced into the production process. Experience curves measure the effect that accumulated experience with production of a product or family of products has on overall cost and price. Experience curves are most valuable in industries that are undergoing major changes, such as the microelectronics industry, rather than very mature industries in which most radical changes have already been made, such as the automobile industry. The steady decline in the prices of integrated circuits (ICs) is a classic example of an experience curve. Figure 1–8 (Noyce, 1977) shows the average price per unit as a function of the industry's accumulated experience, in millions of units of production, during the period 1964 to 1972. This graph is shown on log–log scale and the points fall very close to a straight line. This case represents a 72 percent experience curve. That

FIGURE 1–8
Prices of integrated circuits during the period 1964–1972

Source: Robert N. Noyce, "Microelectronics," in *Scientific American,* September 1977. Reprinted with permission of the publisher.

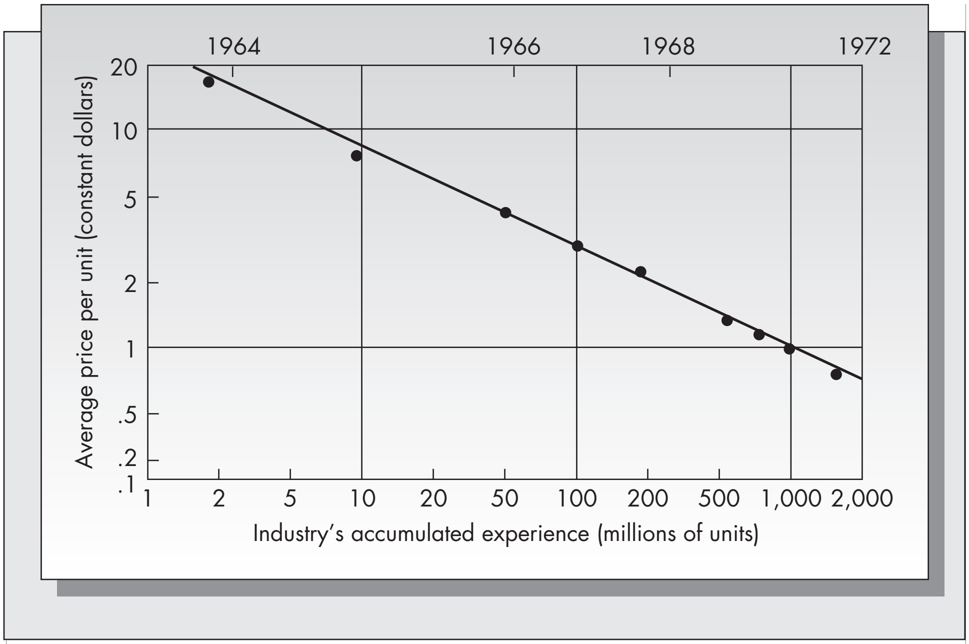
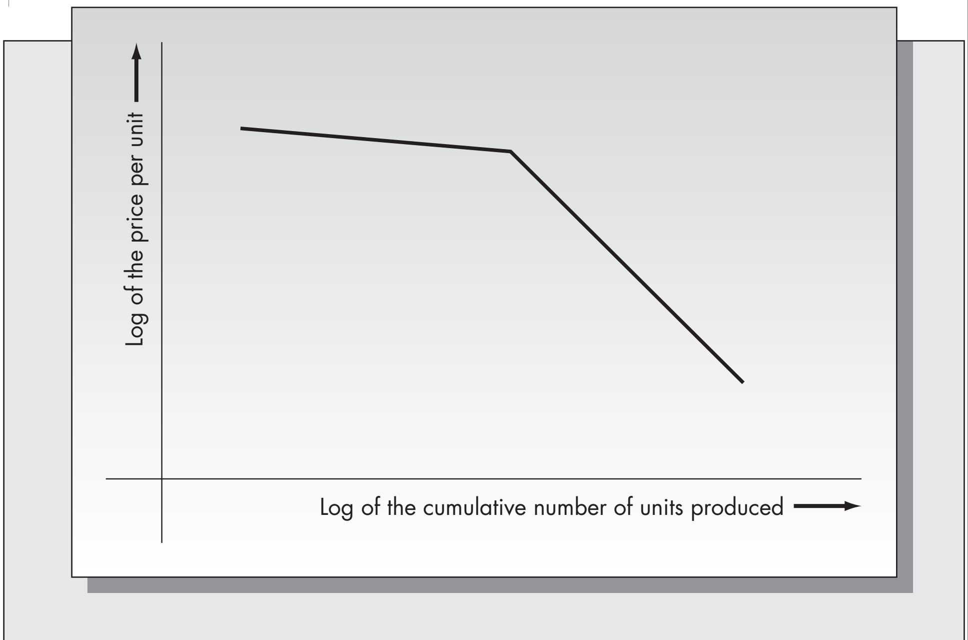


FIGURE 1–9
"Kinked" experience curve due to umbrella pricing



is, the average price per unit declines to about 72 percent of its previous value for each doubling of the cumulative production of ICs throughout the industry.

Experience curves are generally measured in terms of cost per unit of production. In most circumstances, the price of a product or family of products closely tracks the cost of production. However, in some cases umbrella pricing occurs. That is, prices remain fairly stable during a period in which production costs decline. Later, as competitive pressures of the marketplace take hold, prices decline more rapidly than costs until they catch up. This can cause a kink in the experience curve when price rather than cost is measured against cumulative volume. This type of phenomenon is pictured in Figure 1–9. Hayes and Wheelwright (1984, p. 243) give two examples of umbrella pricing and its effect on the experience curve. The experience curves for the pricing of free-standing gas ranges and polyvinyl chloride are examples of this phenomenon.

Learning curves have been the subject of criticism in the literature recently on a number of grounds: (*a*) they lack theoretical justification; (*b*) they confuse the effects of learning, economies of scale, and other technological improvements; and (*c*) they focus on cost rather than profit (Devinney, 1987). However, it is clear that such curves are accurate descriptors of the way that marginal labor hours and costs decline as a function of the cumulative experience gained by the firm or industry.

Learning and Experience Curves and Manufacturing Strategy

We define a **learning curve strategy** as one in which the primary goal is to reduce costs of production along the lines predicted by the learning curve. Ford Motors adopted a learning curve strategy in seeking cost reductions in the Model T during the period 1909 to 1923. Abernathy and Wayne (1974) showed that the selling price of the Model T during this period closely followed an 85 percent experience curve. Ford's strategy during this time was clearly aimed at cost cutting; the firm acquired or built new facilities including blast furnaces, logging operations and saw mills, a railroad, weaving mills, coke ovens, a paper mill, a glass plant, and a cement plant. This allowed Ford to vertically integrate operations, resulting in reduced throughput time and inventory levels—a strategy similar in spirit to the just-in-time philosophy discussed earlier in this chapter.

A learning curve strategy may not necessarily be the best choice over long planning horizons. Abernathy and Wayne (1974) make the argument that when manufacturing strategy is based on cost reduction, innovation is stifled. As consumer tastes changed in the 1920s, Ford's attention to cost cutting and standardization of the Model T manufacturing process resulted in its being slow to adapt to changing patterns of customer preferences. Ford's loss was General Motors's gain. GM was quick to respond to customer needs, recognizing that the open car design of the Model T would soon become obsolete. Ford thus found itself fighting for survival in the 1930s after having enjoyed almost complete domination of the market. Survival meant a break from the earlier rigid learning curve strategy to one based on innovation.

Another example of a firm that suffered from a learning curve strategy is Douglas Aircraft. The learning curve concept was deeply rooted in the airframe industry. Douglas made several commitments in the 1960s for delivery of jet aircraft based on extrapolation of costs down the learning curve. However, because of unforeseen changes in the product design, the costs were higher than anticipated, and commitments for delivery times could not be met. Douglas was forced into a merger with McDonnell Company as a result of the financial problems it experienced.

We are not implying by these examples that a learning curve strategy is wrong. Standardization and cost reduction based on volume production have been the keys to success for many companies. Failure to achieve quick time-to-volume can spell disaster in a highly competitive marketplace. What we are saying is that the learning curve strategy must be balanced with sufficient flexibility to respond to changes in the marketplace. Standardization must not stifle innovation and flexibility.

Problems for Section 1.10

26. What are the factors that contribute to the learning curve/experience curve phenomenon?
27. What is a "learning curve strategy"? Describe how this strategy led to Ford's success up until the mid-1920s and Ford's problems after that time.

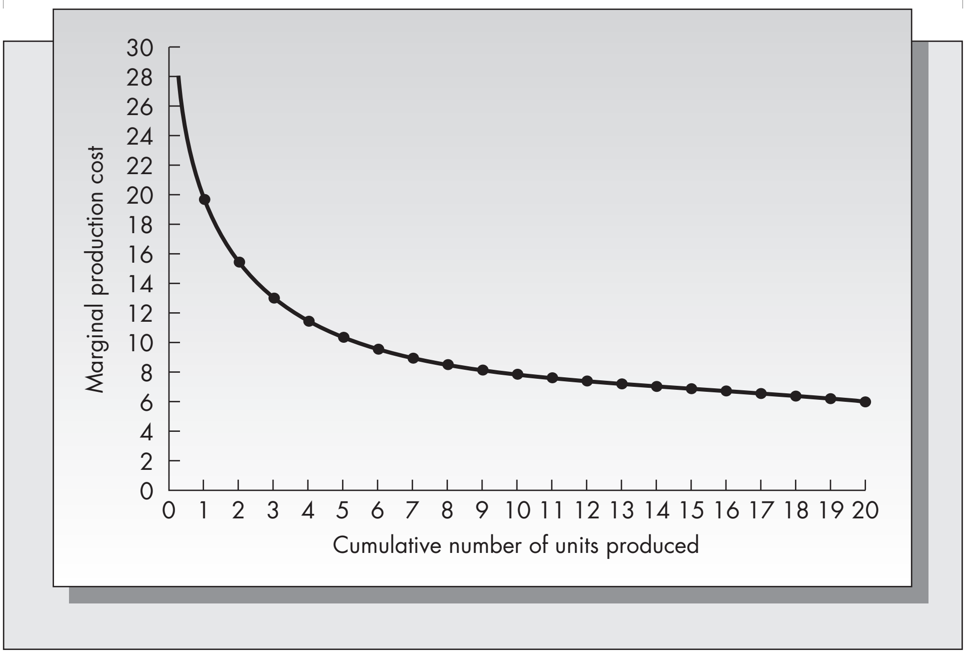
28. What are some of the pitfalls that can occur when using learning curves and experience curves to predict costs? Refer to the experience of Douglas Aircraft.
29. Consider the example of XYZ Corporation presented in this section. If the learning curve remains accurate, how long will it take to produce the 100,000th unit?
30. A start-up firm has kept careful records of the time required to manufacture its product, a shutoff valve used in gasoline pipelines.

Cumulative Number of Units Produced	Number of Hours Required for Next Unit
50	3.3
100	2.2
400	1.0
600	0.8
1,000	0.5
10,000	0.2

a. Compute the logarithms of the numbers in each column. (Use natural logs.)
b. Graph the ln(hours) against the ln(cumulative units) and eyeball a straight-line fit of the data. Using your approximate fit, estimate a and b.
c. Using the results of part (*b*), estimate the time required to produce the first unit and the appropriate percentage learning curve that fits these data.
d. Repeat parts (*b*) and (*c*), but use an exact least squares fit of the logarithms computed in part (*a*).

31. Consider the learning curve derived in Problem 30. How much time will be required to produce the 100,000th unit, assuming the learning curve remains accurate?
32. Consider the experience curve plotted in Figure 1–10. What percentage experience curve does this represent?

FIGURE 1–10
(for Problem 32)



33. Discuss the limitations of learning and experience curves.
34. An analyst predicts that an 80 percent experience curve should be an accurate predictor of the cost of producing a new product. Suppose that the cost of the first unit is $1,000. What would the analyst predict is the cost of producing the
    a. 100th unit?
    b. 10,000th unit?

1.11 CAPACITY GROWTH PLANNING: A LONG-TERM STRATEGIC PROBLEM

The capacity of a plant is the number of units that the plant can produce in a given time. Capacity policy plays a key role in determining the firm's competitive position in the marketplace. A capacity strategy must take into account a variety of factors, including

- Predicted patterns of demand.
- Costs of constructing and operating new facilities.
- New process technology.
- Competitors' strategy.

Capacity planning is an extremely complex issue. Each time a company considers expanding existing productive capacity, it must sift through a myriad of possibilities. First, the decision must be made whether to increase capacity by modifying existing facilities. From an overhead point of view, this is an attractive alternative. It is cheaper to effect major changes in existing processes and plants than to construct new facilities. However, such a strategy ultimately could be penny wise and pound foolish. There is substantial evidence that plants that have focus are the most productive. Diminishing returns quickly set in if the firm tries to push the productive capacity of a single location beyond its optimal value.

Given the decision to go ahead with construction of a new plant, many issues remain to be resolved. These include

1. *When.* The timing of construction of new facilities is an important consideration. Lead times for construction and changing patterns of demand are two factors that affect timing.

2. *Where.* Locating new facilities is a complex issue. Consideration of the logistics of material flows suggests that new facilities be located near suppliers of raw materials and market outlets. If labor costs were the key issue, overseas locations might be preferred. Tax incentives are sometimes given by states and municipalities trying to attract new industry. Cost of living and geographical desirability are factors that would affect the company's ability to hire and keep qualified employees.

3. *How much.* Once management has decided when and where to add new capacity, it must decide on the size of the new facility. Adding too much capacity means that the capacity will be underutilized. This is an especially serious problem when capital is scarce. On the other hand, adding too little capacity means that the firm will soon be faced with the problem of increasing capacity again.

Economies of Scale and Economies of Scope

Economies of scale are generally considered the primary advantages of expanding existing capacity. Panzer and Willig (1981) introduced the concept of **economies of scope,** which they defined as the cost savings realized from combining the production of two or more product lines at a single location. The idea is that the manufacturing processes for these product lines may share some of the same equipment and personnel so that the cost of production at one location could be less than at two or more different locations.

The notion of economies of scope extends beyond the direct cost savings that the firm can realize by combining the production of two or more products at a single location. It is often necessary to duplicate a variety of support functions at different locations. These functions include information storage and retrieval systems and clerical and support staff. Such activities are easier to coordinate if they reside at the same location. The firm also can realize economies of scope by locating different facilities in the same geographic region. In this way employees can, if necessary, call upon the talents of key personnel at a nearby location.

Goldhar and Jelinek (1983) argue that considerations of economies of scope support investment in new manufacturing technology. Flexible manufacturing systems and computer-integrated manufacturing result in "efficiencies wrought by variety, not volume." These types of systems, argue the authors, allow the firm to produce multiple products in small lot sizes more cheaply using the same multipurpose equipment. (Flexible manufacturing systems are discussed in greater detail in Chapter 10.)

Management must weigh the benefits that the firm might realize by combining product lines at a single location against the disadvantages of lack of focus discussed previously. Too many product lines produced at the same facility could cause the various manufacturing operations to interfere with each other. The proper sizing and diversity of the functions of a single plant must be balanced so that the firm can realize economies of scope without allowing the plant to lose its essential focus.

Make or Buy: A Prototype Capacity Expansion Problem

A classic problem faced by the firm is known as the **make-or-buy decision.** The firm can purchase the product from an outside source for c_1 per unit, but can produce it internally for a lower unit price, $c_2 < c_1$. However, in order to produce the product internally, the company must invest $\$K$ to expand production capacity. Which strategy should the firm adopt?

The make-or-buy problem contains many of the elements of the general capacity expansion problem. It clarifies the essential trade-off of investment and economies of scale. The total cost of the firm to produce x units is $K + c_2x$. This is equivalent to $K/x + c_2$ per unit. As x increases, the cost per unit of production decreases, since K/x is a decreasing function of x. The cost to purchase outside is c_1 per unit, independent of the quantity ordered. By graphing the total costs of both internal production and external purchasing, we can find the point at which the costs are equal. This is known as the break-even quantity. The break-even curves are pictured in Figure 1–11.

The break-even quantity solves

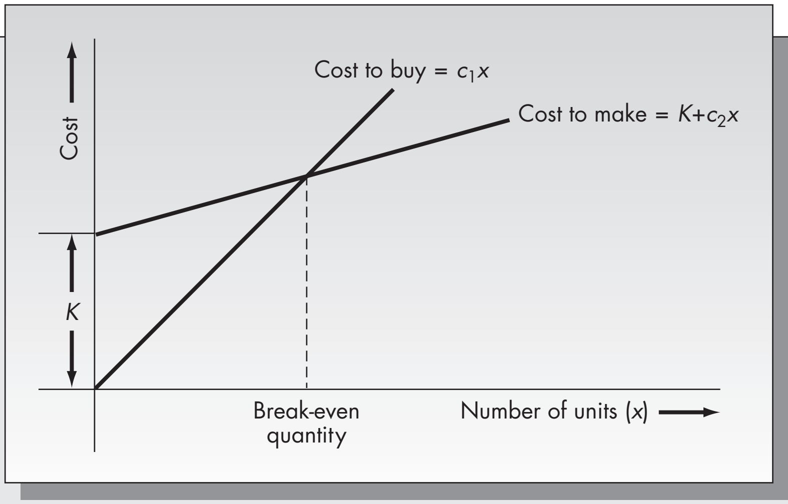
$$K + c_2x = c_1x,$$

giving $x = K/(c_1 - c_2)$.

Example *1.2*

A large international computer manufacturer is designing a new model of personal computer and must decide whether to produce the keyboards internally or to purchase them from an outside supplier. The supplier is willing to sell the keyboards for \$50 each, but the manufacturer estimates that the firm can produce the keyboards for \$35 each. Management estimates that expanding the current plant and purchasing the necessary equipment to make the keyboards would cost \$8 million. Should they undertake the expansion?

FIGURE 1–11
Break-even curves



The break-even quantity is

$$x = 8{,}000{,}000/(50 - 35) = 533{,}333.$$

Hence, the firm would have to sell at least 533,333 keyboards in order to justify the $8 million investment required for the expansion.

Break-even curves such as this are useful for getting a quick ballpark estimate of the desirability of a capacity addition. Their primary limitation is that they are static. They do not consider the dynamic aspects of the capacity problem, which cannot be ignored in most cases. These include changes in the anticipated pattern of demand and considerations of the time value of money. Even as static models, break-even curves are only rough approximations. They ignore the learning effects of production; that is, the marginal production cost should decrease as the number of units produced increases. (Learning curves are discussed in detail in Section 1.10.) Depending on the structure of the production function, it may be economical to produce some units internally and purchase some units outside. Manne (1967) discusses the implications of some of these issues.

Dynamic Capacity Expansion Policy

Capacity decisions must be made in a dynamic environment. In particular, the dynamics of the changing demand pattern determine when the firm should invest in new capacity. Two competing objectives in capacity planning are

1. Maximizing market share
2. Maximizing capacity utilization

A firm that bases its long-term strategy on maximization of capacity utilization runs the risk of incurring shortages in periods of higher-than-anticipated demand. An alternative strategy to increasing productive capacity is to produce to inventory and let the inventory absorb demand fluctuations. However, this can be very risky. Inventories can become obsolete, and holding costs can become a financial burden.

Alternatively, a firm may assume the strategy of maintaining a "capacity cushion." This capacity cushion is excess capacity that the firm can use to respond to sudden demand surges; it puts the firm in a position to capture a larger portion of the marketplace if the opportunity arises.

Consider the case where the demand exhibits an increasing linear trend. Two policies, (*a*) and (*b*), are represented in Figure 1–12. In both cases the firm is acquiring new capacity at equally spaced intervals x, $2x$, $3x$, . . . , and increasing the capacity by the same amount at each of these times. However, in case (*a*) capacity leads demand, meaning that the firm maintains excess capacity at all times; whereas in case (*b*), the capacity lags the demand, meaning that the existing capacity is fully utilized at all times. Following policy (*a*) or (*b*) results in the time path of excess capacity (or capacity shortfall, if appropriate) given in Figure 1–13.

FIGURE 1–12
Capacity planning strategies

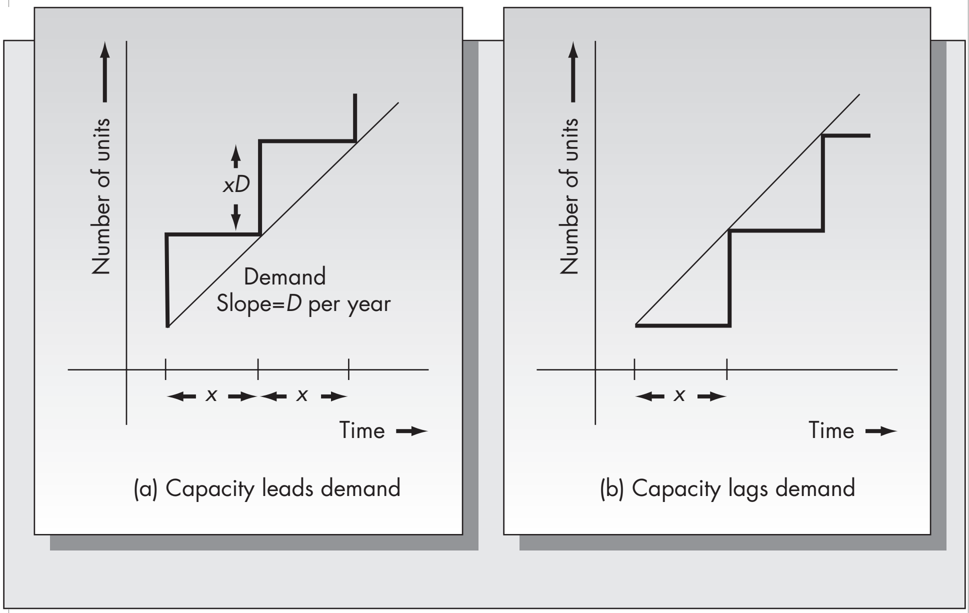
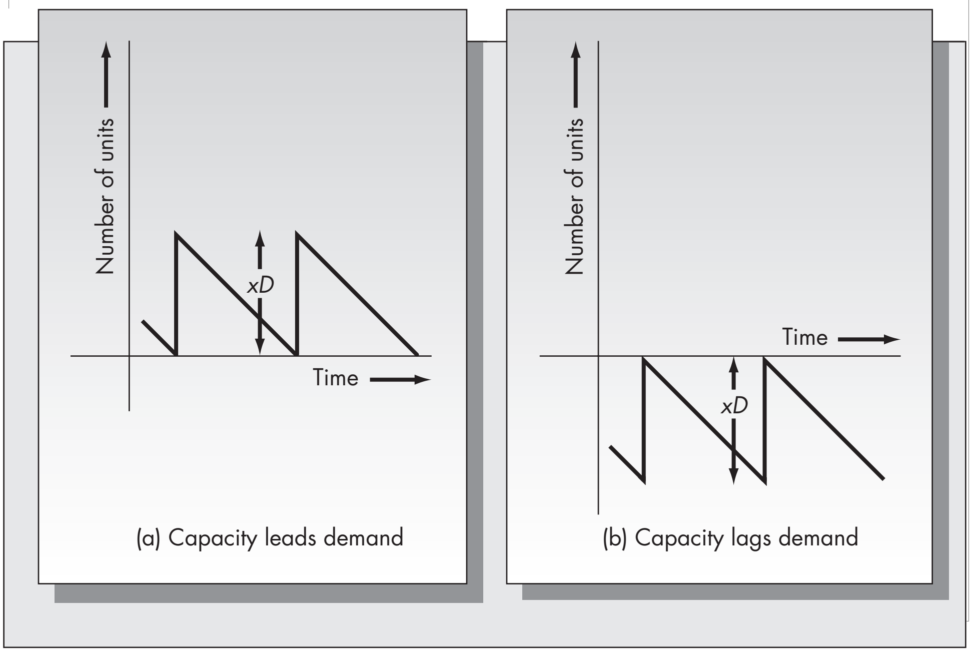


FIGURE 1–13
Time path of excess or deficient capacity



Consider the following specific model that appears in Manne (1967). Define

D = Annual increase in demand.
x = Time interval between introduction of successive plants.
r = Annual discount rate, compounded continuously.
$f(y)$ = Cost of opening a plant of capacity y.

From Figure 1–12*a* (which is the strategy assumed in the model), we see that if the time interval for plant replacement is x, it must be true that the plant size at each replacement is xD. Furthermore, the present value of a cost of \$1 incurred t years into the future is given by e^{-rt}. (A discussion of discounting and the time value of money appears in Appendix 1–A.)

Define $C(x)$ as the sum of discounted costs for an infinite horizon given a plant opening at time zero. It follows that

$$\begin{aligned} C(x) &= f(xD) + e^{-rx}f(xD) + e^{-2rx}f(xD) + \cdots \\ &= f(xD)[1 + e^{-rx} + (e^{-rx})^2 + (e^{-rx})^3 + \cdots] \\ &= \frac{f(xD)}{1 - e^{-rx}}. \end{aligned}$$

Experience has shown that a representation of $f(y)$ that explains the economies of scale for plants in a variety of industries is

$$f(y) = ky^a,$$

where k is a constant of proportionality. The exponent a measures the ratio of the incremental to the average costs of a unit of plant capacity. A value of 0.6 seems to be common (known as the six-tenths rule). As long as $a < 1$, there are economies of scale in plant construction, since a doubling of the plant size will result in less than a doubling of the construction costs. To see this, consider the ratio

$$\frac{f(2y)}{f(y)} = \frac{k(2y)^a}{k(y)^a} = 2^a.$$

Substituting $a = 0.6$, we obtain $2^a = 1.516$. This means that if $a = 0.6$ is accurate, the plant capacity can be doubled by increasing the dollar investment by about 52 percent. Henceforth, we assume that $0 < a < 1$ so that there are economies of scale in the plant sizing.

Given a specific form for $f(y)$, we can solve for the optimal timing of plant additions and hence the optimal sizing of new plants. If $f(y) = ky^a$, then

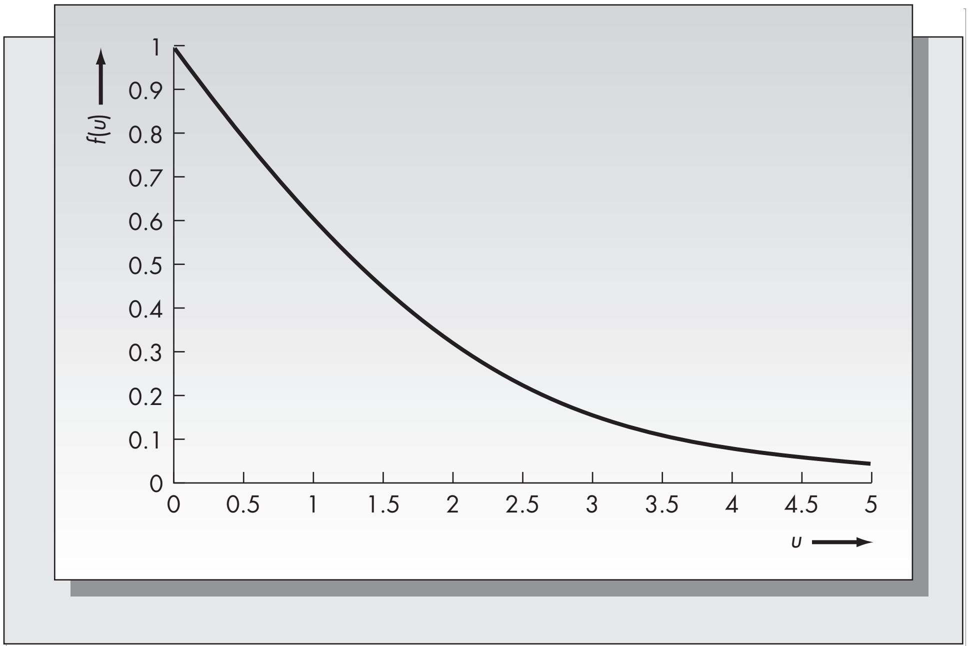
$$C(x) = \frac{k(xD)^a}{1 - e^{-rx}}.$$

Consider the logarithm of $C(x)$:

$$\begin{aligned} \log[C(x)] &= \log[k(xD)^a] - \log[1 - e^{-rx}] \\ &= \log(k) + a\log(xD) - \log[1 - e^{-rx}]. \end{aligned}$$

It can be shown that the cost function $C(x)$ has a unique minimum with respect to x and furthermore that the value of x for which the derivative of $\log[C(x)]$ is zero is the

FIGURE 1–14
The function $u/(e^u - 1)$



value of x that minimizes $C(x)$. It is easy to show[1] that the optimal solution satisfies

$$\frac{rx}{e^{rx} - 1} = a.$$

The function $f(u) = u/(e^u - 1)$ appears in Figure 1–14, where $u = rx$. By locating the value of a on the ordinate axis, one can find the optimal value of u on the abscissa axis.

Example ***1.3***

A chemicals firm is planning for an increase of production capacity. The firm has estimated that the cost of adding new capacity obeys the law

$$f(y) = .0107y^{.62},$$

where cost is measured in millions of dollars and capacity is measured in tons per year. For example, substituting $y = 20{,}000$ tons gives $f(y) = \$4.97$ million plant cost. Furthermore, suppose that the demand is growing at a constant rate of 5,000 tons per year and future costs are discounted using a 16 percent interest rate. From Figure 1–14 we see that, if $a = .62$, the value of u is approximately 0.9. Solving for x, we obtain the optimal timing of new plant openings:

$$x = u/r = .9/.16 = 5.625 \text{ years}.$$

The optimal value of the plant capacity should be $xD = (5.625)(5{,}000) = 28{,}125$ tons. Substituting $y = 28{,}125$ into the equation for $f(y)$ gives the cost of each plant at the optimal solution as \$6.135 million.

Much of the research into the capacity expansion problem consists of extensions of models of this type. This particular model could be helpful in some circumstances

[1] $$\frac{d\log[C(x)]}{dx} = \frac{aD}{xD} - \frac{(-e^{-rx})(-r)}{1 - e^{-rx}} = \frac{a}{x} - \frac{r}{e^{rx} - 1} = 0,$$

which gives $\frac{rx}{e^{rx} - 1} = a.$

but ignores a number of fundamental features one would expect to find in the real world:

1. *Finite plant lifetime.* The assumption of the model is that, once constructed, a plant has an infinite lifetime. However, companies close plants for a variety of reasons: Equipment becomes obsolete or unreliable and cannot be replaced easily. Labor costs or requirements may dictate moving either to less expensive locations domestically or to overseas locations. Major changes in the process technology may not be easily adaptable to existing facilities.

2. *Demand patterns.* We have assumed that demand grows at a constant rate per year. Models have been proposed to account for more complex growth patterns of demand. In truth, demand uncertainty is a key factor. In many industries, foreign competition has made significant inroads into established markets, thus forcing rethinking of earlier strategies.

3. *Technological developments.* The model assumes that the capacity of all new plants constructed remains constant and that the cost of building a plant of given size remains constant as well. This is obviously unreasonable. Major changes in process technology occur on a regular basis, changing both the maximum size of new plants and the costs associated with a fixed plant size.

4. *Government regulation.* Environmental and safety restrictions may limit choices of plant location and scale.

5. *Overhead costs.* Most capacity expansion and location models do not explicitly account for the costs of overhead. During the energy crunch in the late 1970s, costs of energy overhead soared, wreaking havoc with plant overhead budgets.

6. *Tax incentives.* The financial implications of the sizing and location of new facilities must be considered in the context of tax planning. Tax incentives are offered by local or state municipalities to major corporations considering sites for the construction of new facilities.

An interesting question is whether models of this type really capture the way that companies have made capacity expansion decisions in the past. There is some preliminary evidence that they do not. Lieberman (1987) attempted to assess the factors that motivated firms to construct new chemical plants during the period 1957 to 1982. He found that the size of new plants increased by about 8 percent per year independent of market conditions. In periods of high demand, firms constructed more plants. This preliminary study indicates that the rational thinking that leads to models such as the one developed in this section does not accurately reflect the way that companies make plant-sizing decisions. His results suggest that firms build the largest plants possible with the existing technology. (Given sufficient economies of scale, however, this policy may theoretically be optimal.)

Issues in Plant Location

This section has been concerned with capacity expansion decisions, specifically, determining the amount and timing of new capacity additions. A related issue is the **location of the new facility.** Deciding where to locate a plant is a complex problem. Many factors must be carefully considered by management before making the final choice.

The following information about the plant itself is relevant to the location decision:

1. *Size of the plant.* This includes the required acreage, the number of square feet of space needed for the building structure, and constraints that might arise as a result of special needs.

2. *Product lines to be produced.*
3. *Process technology to be used.*
4. *Labor force requirements.* These include both the number of workers required and the specification of the particular skills needed.
5. *Transportation needs.* Depending on the nature of the product produced and the requirements for raw materials, the plant may have to be located near major interstate highways or rail lines.
6. *Utilities requirements.* These include special needs for power, water, sewage, or fossil fuels such as natural gas. Plants that have unusual power needs should be located in areas where energy is less expensive or near sources of hydroelectric power.
7. *Environmental issues.* Because of government regulations, there will be few allowable locations if the plant produces significant waste products.
8. *Interaction with other plants.* If the plant is a satellite of existing facilities, it is likely that management would want to locate the new plant near the others.
9. *International considerations.* Whether to locate a new facility domestically or overseas is a very sensitive issue. Although labor costs may be lower in some locations, such as the Far East, tariffs, import quotas, inventory pipeline costs, and market responsiveness also must be considered.
10. *Tax treatment.* Tax consideration is an important variable in the location decision. Favorable tax treatment is given by some countries, such as Ireland, to encourage new industry. There are also significant differences in state tax laws designed to attract domestic manufacturers.

Mathematical models are useful for assisting with many operational decisions. However, they generally are of only limited value for determining a suitable location for a new plant. Because so many factors and constraints enter into the decision process, such decisions are generally made based on the inputs of one or more of the company's divisions, and the decision process can span several years. (Mathematical techniques for making location decisions will be explored in Chapter 9, on facilities layout and location.) Schmenner (1982) has examined the decision process at a number of the *Fortune* 500 companies. His results showed that in most firms, the decision of where to locate a new facility was made either by the corporate staff or by the CEO, even though the request for new facilities might have originated at the division level. The degree of decision-making autonomy enjoyed at the division level depended on the firm's management style.

Based on a sample survey, Schmenner reported that the major factors that influenced new facilities location decisions were the following:

1. *Labor costs.* This was a primary concern for industries such as apparel, leather, furniture, and consumer electronics. It was less of a concern for capital-intensive industries.
2. *Unionization.* A motivating factor for a firm considering expanding an existing facility, as opposed to one considering building a new facility, is the potential for eliminating union influence in the new facility. A fresh labor force may be more difficult to organize.
3. *Proximity to markets.* When transportation costs account for a major portion of the cost of goods sold, locating new plants near existing markets is essential.
4. *Proximity to supplies and resources.* The decision about where to locate plants in certain industries is based on the location of resources. For example, firms producing wood or paper products must be located near forests and firms producing processed food, near farms.

5. *Proximity to other facilities.* Many companies tend to place manufacturing divisions and corporate facilities in the same geographic area. For example, IBM originated in Westchester County in New York, and located many of its divisions in that state. By locating key personnel near each other, the firm has been able to realize economies of scope.
6. *Quality of life in the region.* When other issues do not dictate the choice of a location, choosing a site that will be attractive to employees may help in recruiting key personnel. This is especially true in high-tech industries that must compete for workers with particular skills.

Problems for Section 1.11

35. A start-up company, Macrotech, plans to produce a device to translate Morse code to a written message on a home computer and to send written messages in Morse code over the airwaves. The device is primarily of interest to ham radio enthusiasts. The president, Ron Lodel, estimates that it would require a $30,000 initial investment. Each unit costs him $20 to produce and each sells for $85.
    a. How many units must be sold in order for the firm to recover its initial investment?
    b. What is the total revenue at the break-even volume?
    c. If the price were increased to $100 each, find the break-even volume.
36. For Problem 35, suppose that sales are expected to be 100 units in the first year and increase at a rate of 40 percent per year. How many years will it take to recoup the $30,000 initial investment? Assume that each unit sells for $85.
37. A domestic producer of baby carriages, Pramble, buys the wheels from a company in the north of England. Currently the wheels cost $4 each, but for a number of reasons the price will double. In order to produce the wheels themselves, Pramble would have to add to existing facilities at a cost of $800,000. It estimates that its unit cost of production would be $3.50. At the current time, the company sells 10,000 carriages annually. (Assume that there are four wheels per carriage.)
    a. At the current sales rate, how long would it take to pay back the investment required for the expansion?
    b. If sales are expected to increase at a rate of 15 percent per year, how long will it take to pay back the expansion?
38. Based on past experience, a chemicals firm estimates that the cost of new capacity additions obeys the law

$$f(y) = .0205y^{.58}$$

    where y is measured in tons per year and $f(y)$ in millions of dollars. Demand is growing at the rate of 3,000 tons per year, and the accounting department recommends a rate of 12 percent per year for discounting future costs.
    a. Determine the optimal timing of plant additions and the optimal size of each addition.
    b. What is the cost of each addition?
    c. What is the present value of the cost of the next four additions? Assume an addition has just been made for the purposes of your calculation. (Refer to Appendix 1–A for a discussion of cost discounting.)

39. A major oil company is considering the optimal timing for the construction of new refineries. From past experience, each doubling of the size of a refinery at a single location results in an increase in the construction costs of about 68 percent. Furthermore, a plant size of 10,000 barrels per day costs \$6 million. Assume that the demand for the oil is increasing at a constant rate of two million barrels yearly and the discount rate for future costs is 15 percent.
    a. Find the values of k and a assuming a relationship of the form $f(y) = ky^a$. Assume that y is in units of barrels per day.
    b. Determine the optimal timing of plant additions and the optimal size of each plant.
    c. Suppose that the largest single refinery that can be built with current technology is 15,000 barrels per day. Determine the optimal timing of plant additions and the optimal size of each plant in this case. (Assume 365 days per year for your calculations.)

1.12 Summary

This chapter discussed the importance of **operations strategy** and its relationship to the overall business strategy of the firm. Operations continues to grow in importance in the firm. While a larger portion of direct manufacturing continues to move off-shore, the importance of the manufacturing function should not be underestimated. The success of the operations strategy can be measured along several dimensions. These include the obvious measures of cost and product characteristics, but also include quality, delivery speed, delivery reliability, and flexibility.

The classical view of manufacturing strategy, due primarily to Wickham Skinner, considers the following four dimensions of strategy: **time horizon, focus, evaluation,** and **consistency.** Different types of decisions relate to different time frames. A plant should be designed with a specific focus in mind, whether it be to minimize unit cost or to maximize product quality. Several evaluation criteria may be applied to analyze the effectiveness of a strategy.

We hear more and more frequently that we are part of a global community. When buying products today, we are less concerned with the country of origin than with the characteristics of the product. How many consumers of cell phones are even aware that Nokia is headquartered in Finland, Ericsson in Sweden, and Motorola in the United States? An interesting question explored by Michael Porter is: Why do some industries seem to thrive in some countries? While the answer is complex, Porter suggests that the following four factors are most important: *factor conditions; demand conditions; related and supporting industries;* and *firm strategy, structure, and rivalry.*

Changing the way that one does things can be difficult. Even more difficult is changing the way that a company does things. For that reason, **business process engineering (BPR)** is a painful process, even when it works. The most dramatic successes of BPR have come in service functions, but the concept can be applied to any environment. It is the process of rethinking how and why things are done in a certain way. Intelligently done, BPR can lead to dramatic improvements. However, it can also be a time-consuming and costly process.

Just-in-time (JIT) is a philosophy that grew from the kanban system developed by Toyota. At the heart of the approach is the elimination of waste. Systems are put in place to reduce material flows to small batches to avoid large buildups of work-in-process inventories. While JIT developed on the factory floor, it is a concept that has been applied to the purchasing function as well. Successful application of JIT purchasing requires the development of long-term relationships, and usually requires close proximity to suppliers. The mechanics of JIT are discussed in more detail in Chapter 7.

Being able to get to the market quickly with products that people want in the volumes that the marketplace requires is crucial if one wants to be a market leader. **Time-based competition** means that the time from product conception to its appearance in the marketplace must be reduced. To do so, one performs as many tasks concurrently as possible. In many instances, time to market is less important than time to volume. Being the first to the market may not mean much if one cannot meet product demand.

The dramatic successes of the Japanese during the 1970s and 1980s were to a large extent due to the outstanding **quality** of their manufactured products. Two Americans, Deming and Juran, visited Japan in the early 1950s and played an important role in making the Japanese aware of the importance of producing quality products. The quality movement in the United States has resulted in a much greater awareness of the importance of quality, recognition for outstanding achievement in this arena via the Malcolm Baldrige Award, and initiation of important programs such as quality circles and the six-sigma program at Motorola. (Both the statistical and the organizational issues concerning quality are discussed in detail in Chapter 11.)

It is important to understand both **product and process life cycles.** Both go through the four cycles of start-up, rapid growth, maturation, and stabilization or decline. It is also important to understand which types of processes are appropriate for which types of products and industries. To this end, Hayes and Wheelwright have developed the concept of the product–process matrix.

Learning and experience curves are useful in modeling the decline in labor hours or the decline in product costs as experience is gained in the production of an item or family of items. These curves have been shown to obey an exponential law, and can be useful predictors of the cost or time required for production. (Moore's Law, due to Gordon Moore, a founder of Intel, predicted the doubling of chip performance every 18 months. This is an example of an experience curve, and the prediction has continued to be accurate to the present day.)

We discussed two methods for assisting with **capacity expansion** decisions. Break-even curves provide a means of determining the sales volume necessary to justify investing in new or existing facilities. A simple model for a dynamic expansion policy is presented that gives the optimal timing and sizing of new facilities assuming constant demand growth and discounting of future costs. We also discussed issues that arise in trying to decide where to locate new facilities. This problem is very complex in that there are many factors that relate to the decision of where to locate production, design, and management facilities.

Additional Problems for Chapter 1

40. What is a production and operations strategy? Discuss the elements in common with marketing and financial strategies and the elements that are different.
41. What is the difference between the product life cycle and the process life cycle? In what way are these concepts related?
42. Suppose that the Mendenhall Corporation, a producer of women's handbags, has determined that a 73 percent experience curve accurately describes the evolution of its production costs for a new line. If the first unit costs $100 to produce, what should the 10,000th unit cost based on the experience curve?
43. Delon's Department Store sells several of its own brands of clothes and several well-known designer brands as well. Delon's is considering building a plant in

Malaysia to produce silk ties. The plant will cost the firm $5.5 million. The plant will be able to produce the ties for $1.20 each. On the other hand, Delon's can subcontract to have the ties produced and pay $3.00 each. How many ties will Delon's have to sell worldwide to break even on its investment in the new plant?

44. A Japanese steel manufacturer is considering expanding operations. From experience, it estimates that new capacity additions obey the law

$$f(y) = .00345y^{.51},$$

where the cost $f(y)$ is measured in millions of dollars and y is measured in tons of steel produced. If the demand for steel is assumed to grow at the constant rate of 8,000 tons per year and future costs are discounted using a 10 percent discount rate, what is the optimal number of years between new plant openings?

The following problems are designed to be solved by spreadsheet.

45. Consider the following break-even problem: the cost of producing Q units, $c(Q)$, is described by the curve

$$c(Q) = 48Q[1 - \exp(-.08Q)],$$

where Q is in hundreds of units of items produced and $c(Q)$ is in thousands of dollars.

a. Graph the function $c(Q)$. What is its shape? What economic phenomenon gives rise to a cumulative cost curve of this shape?

b. At what production level does the cumulative production cost equal $1,000,000?

c. Suppose that these units can be purchased from an outside supplier at a cost of $800 each, but the firm must invest $850,000 to build a facility that would be able to produce these units at a cost $c(Q)$. At what cumulative volume of production does it make sense to invest in the facility?

46. Maintenance costs for a new facility are expected to be $112,000 for the first year of operation. It is anticipated that these costs will increase at a rate of 8 percent per year. Assuming a rate of return of 10 percent, what is the present value of the stream of maintenance costs over the next 30 years?

47. Suppose the supplier of keyboards described in Example 1.2 is willing to offer the following incremental quantity discount schedule:

Cost per Keyboard	Order Quantity
$50	$Q \leq 100{,}000$
$45	$100{,}000 < Q \leq 500{,}000$
$40	$500{,}000 < Q$

Determine the cost to the firm for order quantities in increments of 20,000 for $Q = 200{,}000$ to $Q = 1{,}000{,}000$, and compare that to the cost to the firm of pro-ducing internally for these same values of Q. What is the break-even order quantity?

Appendix 1–A

PRESENT WORTH CALCULATIONS

Including the time value of money in the decision process is common when considering alternative investment strategies. The idea is that a dollar received today has greater value than one received a year from now. For example, if a dollar were placed in a simple passbook account paying 5 percent, it would be worth \$1.05 in one year. More generally, if it were invested at a rate of return of r (expressed as a decimal), it would be worth $1 + r$ in a year, $(1 + r)^2$ in two years, and so on.

In the same way, a cost of \$1 incurred in a year has a present value of less than \$1 today. For example, at 5 percent interest, how much would one need to place in an account today so that the total principal plus interest would equal \$1 in a year? The answer is $1/(1.05) = 0.9524$. Similarly, the present value of a \$1 cost incurred in two years at 5 percent is $1/(1.05)^2 = 0.9070$. In general, the present value of a cost of \$1 incurred in t years assuming a rate of return r is $(1 + r)^{-t}$.

These calculations assume that there is no compounding. Compounding means that one earns interest on the interest, so to speak. For example, 5 percent compounded semiannually means that one earns 2.5 percent on \$1 after six months and 2.5 percent on the original \$1 plus interest earned in the first six months. Hence, the total return is

$$(1.025)(1.025) = \$1.050625$$

after one year, or slightly more than 5 percent. If the interest were compounded quarterly, the dollar would be worth

$$(1 + .05/4)^4 = 1.0509453$$

at the end of the year. The logical extension of this idea is continuous compounding. One dollar invested at 5 percent compounded continuously would be worth

$$\begin{aligned}\lim_{n\to\infty} (1 + .05/n)^n &= e^{.05}\\ &= 1.05127\end{aligned}$$

at the end of a year. The number $e = 2.7172818\ldots$ is defined as

$$e = \lim_{n\to\infty} (1 + 1/n)^n.$$

Notice that continuous compounding only increases the effective simple interest rate from 5 percent to 5.127 percent.

More generally, C invested at a rate of r for t years compounded continuously is worth Ce^{rt} at the end of t years.

Reversing the argument, the present value of a cost of C incurred in t years assuming continuous compounding at a discount rate r is Ce^{-rt}. A stream of costs $C_1, C_2, \ldots, C_n$ incurred at times $t_1, t_2, \ldots, t_n$ has present value

$$\sum_{i=1}^{n} C_i e^{-rt_i}.$$

A comprehensive treatment of discounting and its relationship to the capacity expansion problem can be found in Freidenfelds (1981).

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