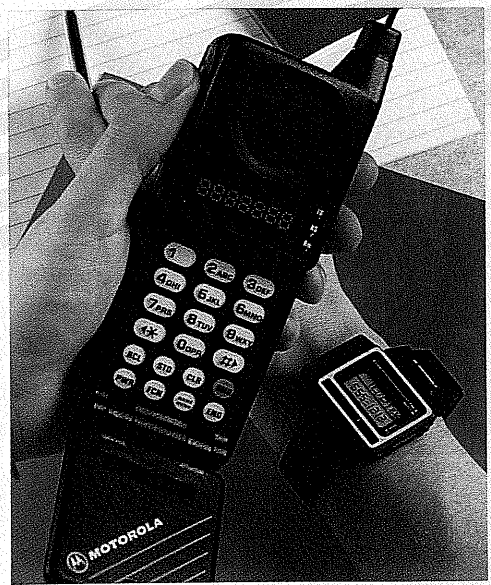


Motorola's cellular phones and wristwatch-sized pagers utilize cutting-edge technology and are manufactured to the world's most exacting standards.

In the mid-1980s, Motorola was in trouble.[1] Japanese companies such as NEC, Toshiba, and Hitachi were gobbling up the company's markets in pagers, cellular phones, and semiconductor chips. Something had to be done, and fast. Motorola's management responded with a bold plan that included rapid product development, sharply upgraded quality, and a focused determination to reduce costs through fine-tuning manufacturing processes. A key element in this plan is a statistical way of measuring quality called "Six Sigma."

Launched in 1987, Motorola's Six Sigma (99.99966% perfect) program seeks to slash defects down to 3.4 per million components. To put that in perspective, in 1986 Motorola's components had 6,000 defects per million! By 1991, the company had improved 150-fold—to an impressive 40 per million. Yet when your goal is perfection, which it now is at Motorola, 40 defects per million is deemed to be still unacceptable.

Today, Motorola is number one in semiconductor chip sales in the United States, number three in Southeast Asia, and number four worldwide. Its pocket-size cellular phone, MicroTac, has become the industry's top seller. And the company has achieved impressive improvements in production efficiency. It has cut the time it takes two-way radios to go from order to shipment from thirty days to three. Cellular phone development—from design to start of production—was slashed from three years to fifteen months. The assembly time for portable cellular phones has gone from forty hours to two!

How did Motorola's management do it? There are no simple explanations. The company reassessed and reworked dozens of its operating practices. For example, it launched an education drive to reach all of its 105,000 employees. Motorola is now spending more than $60 million a year to teach its employees about global competition, risk taking, statistical process control, and techniques for reducing product cycle times. The company's CEO and all top executives began a series of regular visits to key customers in order to learn, first hand, how customers were reacting to Motorola's products. And structurally, Motorola has expanded spans of control, flattened the organization, integrated departments to break down artificial functional barriers, redesigned work around teams, and made quality the key component of performance reviews, compensation, and reward programs.

This chapter focuses on the importance of efficiency, productivity, and controls in the operations side of the organization. Managers who thoughtfully develop well-designed operating systems and tight controls—as Motorola's management has done—will be the survivors in the increasingly competitive global economy. They'll be able to produce higher-quality products and services at prices that meet or beat those of their rivals.

Operations Management and the Transformation Process

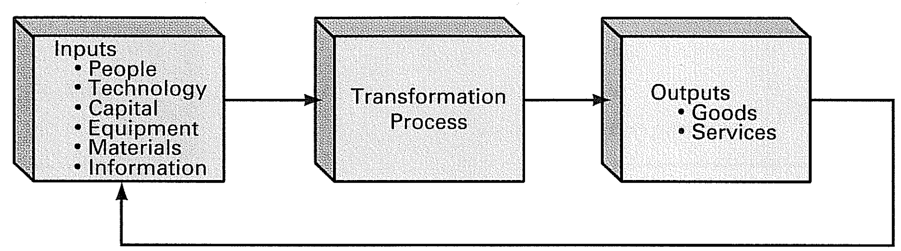
operations management
The design, operation, and control of the transformation process that converts resources into finished goods and services.

Operations management refers to the design, operation, and control of the transformation process that converts such resources as labor and raw materials into finished goods and services. Remember that every organization produces something. Unfortunately, however, this is often overlooked except in obvious cases such as in the manufacturing of telephones or automobiles. But hospitals produce medical services, airlines produce a transportation service that moves people from one location to another, the armed forces produce defense capabilities, and the list goes on. Take a university as a specific illustration. University administrators bring together instructors, books, academic journals, audio-visual material, and similar resources to transform "unenlightened" students into educated and skilled individuals.

Figure 21–1 portrays, in a very simplified fashion, the fact that every organization has an operations system that creates value by transforming inputs into outputs. The system takes inputs—people, capital, equipment, materials—and transforms them into desired finished goods and services. Thus the transformation process is as relevant to service organizations as to those in manufacturing.

Just as every organization produces something, every unit in an organization also produces something. Marketing, finance, research and development, personnel, and accounting convert inputs into outputs such as sales, increased market shares, high rates of return on capital, new and innovative products, productive and satisfied employees, and accounting reports. As a manager, you need to be familiar with operations management concepts—regardless of the area in which you manage—in order to achieve your objectives more efficiently.

FIGURE 21–1
The Operations System



Managing Productivity

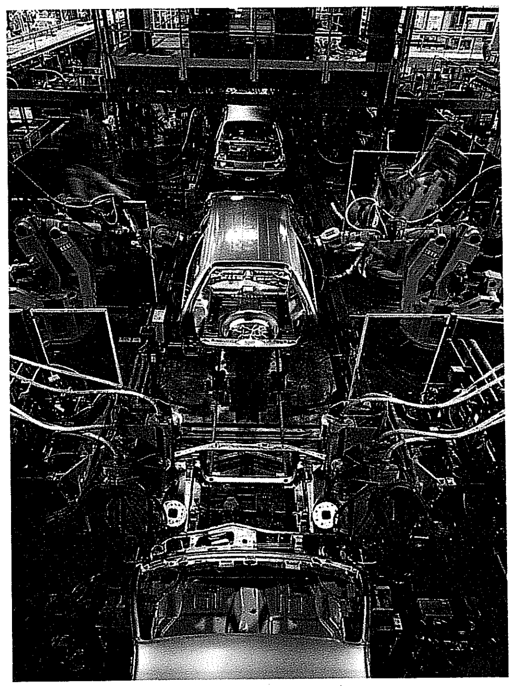
productivity
The overall output of goods and services produced, divided by the inputs needed to generate that output.

Improving productivity has become a major goal in virtually every organization. By **productivity,** we mean the overall output of goods or services produced, divided by the inputs needed to generate that output. For countries, higher productivity generates "costless growth."[2] Employees can receive higher wages and company profits can increase without causing inflation. For individual organizations, increased productivity means a more competitive cost structure and the ability to offer more competitive prices.

Increasing productivity is the key to global competitiveness. For instance, a great deal of Japan's prosperity in the 1980s can be explained in terms of its growth in manufacturing productivity. Between 1979 and 1986, Japan's productivity increased at an annual rate of 5.5. percent. During the same period, U.S. productivity gained only 2.8 percent annually.[3] But U.S. firms have responded in the last half-dozen years by making dramatic improvements to increase their efficiency. Xerox, for example, has halved the cost of producing a copier since the mid-1980s. Cummins Engine Co., the largest American manufacturer of heavy-duty diesel truck engines, has doubled its output per worker since 1985 and used this new efficiency to gain market share by cutting its engine prices by nearly a third.[4]

Contrary to what many American politicians claim, U.S. workers are now among the most productive in the world. They're an impressive 23 percent more productive than Japanese workers, for instance, and 25 percent more productive than British workers.[5] Where the Japanese are strongest in productivity is in automobile production and consumer electronics. Yet Japanese productivity in general merchandise retailing is 44 percent that of American workers, and Japanese factory workers overall produce 80 percent as much as Americans on an hourly basis.[6] Of course, this is not a static game. Managers in all countries are striving to improve the productivity of their

Ford's Taurus plant in Atlanta, Georgia, can match the best the Japanese have to offer in terms of both efficiency and quality. It takes 17.6 labor-hours to build a Taurus in this plant. That compares with 27 hours at a typical General Motors plant and 21 hours at a typical Japanese plant in the United States.



employees and organizations. In this competitive climate, organizations have no choice but to look for ways to significantly improve productivity.

How can organizations improve their productivity? Productivity is a composite of people and operations variables. To improve productivity, management needs to focus on both.

On the people side, techniques discussed in previous chapters should be considered. Participative decision making, management by objectives, team-based work groups, and equitable pay systems are examples of people-oriented approaches toward productivity improvement. Management consultant and quality expert W. Edwards Deming, who teaches that managers, not workers, are the primary source of increased productivity, outlined fourteen point for improving management's productivity. They are listed in Table 21–1.

A close look at Table 21–1 reveals Deming's understanding of the interplay between people and operations. High productivity cannot come solely from good "people management." The truly effective organization will maximize productivity by successfully integrating people into the overall operations system. This can explain, for instance, why in one recent year alone, U.S. companies spent $17 billion on computers and new process-control equipment.[7] Increased capital investment will make facilities more modern and efficient. It also explains why so many organizations have laid off employees and shrunk in size in recent years. These organizations aspire to get more output per labor hour—that is, to increase their productivity.

In this chapter, we'll demonstrate that factors such as size and layout of operating facilities, capacity utilization, inventory usage, and maintenance controls are important determinants of an organization's overall productivity performance.

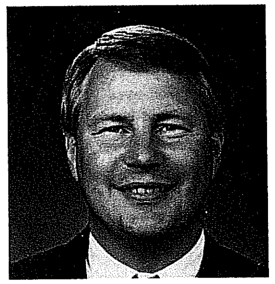
TABLE 21–1 Deming's Fourteen Points for Improving Management's Productivity

1. Plan for the long-term future, not for next month or next year.
2. Never be complacent concerning the quality of your product.
3. Establish statistical control over your production processes and require your suppliers to do so as well.
4. Deal with the fewest number of suppliers—the best ones, of course.
5. Find out whether your problems are confined to particular parts of the production process or stem from the overall process itself.
6. Train workers for the job that you are asking them to perform.
7. Raise the quality of your line supervisors.
8. Drive out fear.
9. Encourage departments to work closely together rather than to concentrate on departmental or divisional distinctions.
10. Do not be sucked into adopting strictly numerical goals, including the widely popular formula of "zero defect."
11. Require your workers to do quality work, not just to be at their stations from 9 to 5.
12. Train your employees to understand statistical methods.
13. Train your employees in new skills as the need arises.
14. Make top managers responsible for implementing these principles.

Source: W. Edwards Deming, "Improvement of Quality and Productivity Through Action by Management," *National Productivity Review,* Winter 1981–82, pp. 12–22. With permission. Copyright 1981 by Executive Enterprises, Inc., 22 West 21st St., New York, NY 10010-6904. All rights reserved.

MANAGERS WHO MADE A DIFFERENCE

Herman Moore at Reynolds Metals Co.



Unlike many of his business-school classmates who chose careers in marketing or finance, Herman Moore has chosen to make his mark by making things.[8]

After graduating from the University of Dayton with a degree in industrial engineering, Herman Moore joined Reynolds Metals Co.'s management training program. After completing the program, he took a staff job with Reynolds at their Richmond, Virginia, headquarters. While there, he attended night classes at the University of Richmond and earned his M.B.A. in 1982. In 1985, Moore became superintendent at a Reynold's reclamation plant in Muscle Shoals, Alabama. He quickly realized that he had a talent for the manufacturing arena. The plant's scrap rate and its overall costs improved under Moore, and, after a year, he won a promotion to become manager of a newly opened plant that recycled cans.

In his new job, Moore found himself overseeing a plant that was operating at only 40 percent of capacity and with costs considerably higher than the competition. Moore lured top engineers from other company plants. He developed teams to cut costs and improve quality and safety. He upgraded equipment. Within two years, the plant was at 100 percent of capacity, and efficiency had been increased by 35 percent. The plant won a company award in 1989 in recognition of its setting records for productivity, shipments, energy conservation, and profits.

In 1990, Moore was promoted to his current job as plant superintendent at Reynold's Alloy Plant in Muscle Shoals. There he's second in command at the company's largest plant, where 2100 employees make aluminum sheets for cans, siding, and appliances. As in his prior job, Moore is making an impact at Alloys. He's overseeing a $430 million capital improvement project that will raise capacity by 30 percent, while cutting costs by 39 percent. Under Moore, the plant has also automated its process controls, which has helped to cut defects by almost two-thirds.

Herman Moore represents the new breed of operations manager. "Before, a manufacturing manager was responsible for getting a pound out the door," he says. "Now you have to get the pound out the door in a safe, quality, cost-effective, and environmental manner." And Moore seems to be thoroughly enjoying the challenges he faces. As he puts it, "I can't save American manufacturing, but at least I'm doing my part to make it possible."

Operations Management Includes Both Manufacturing and Services

manufacturing organizations
Organizations that produce physical goods such as steel, automobiles, textiles, and farm machinery.

For the first half of this century, **manufacturing organizations**—that is, organizations that produce physical goods such as steel, automobiles, textiles, and farm machinery—dominated most advanced industrialized nations. Today, in the United States, Canada, Australia, and Western Europe, **service organizations** dominate. They produce nonphysical outputs such as educational, medical, and transportation services that are intangible, can't be stored in inventory, and incorporate the customer or client in the actual production process.

service organizations
Organizations that produce nonphysical outputs such as educational, medical, and transportation services that are intangible, can't be stored in inventory, and incorporate the customer or client in the actual production process.

deindustrialization
The conversion of an economy from dominance by manufacturing to dominance by service-oriented businesses.

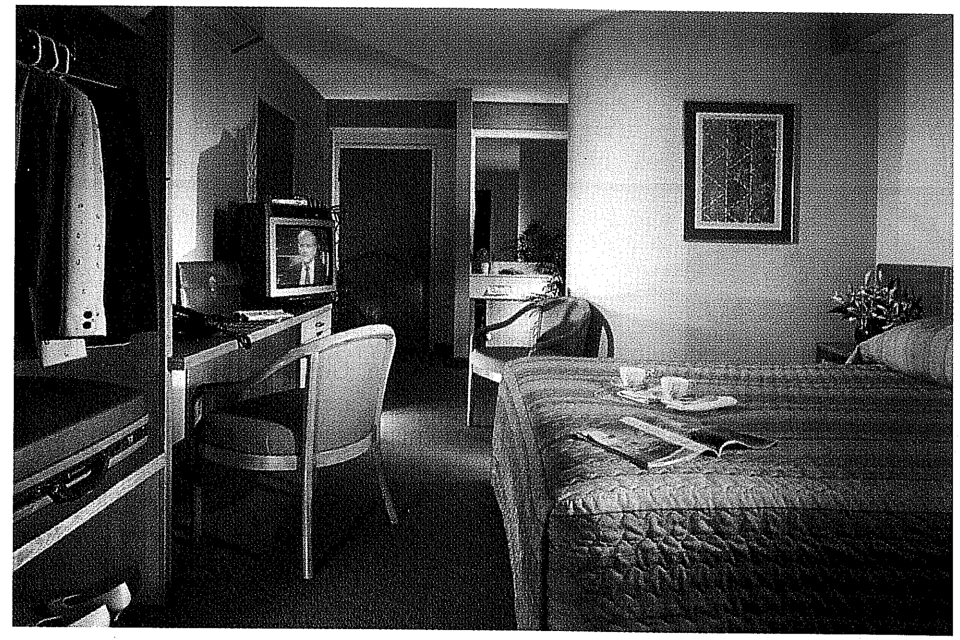
Deindustrialization is taking place among advanced economies. Blue-collar jobs in manufacturing are being replaced by jobs in the service sector. The manufacturing firms that survive are becoming smaller and leaner. The bulk of new jobs are being created in services—from janitors to fast-food servers to computer repairers and programmers to accountants and physicians.

A major challenge for management in a deindustrialized society will be increasing productivity in the service sectors. Many managers and administrators in colleges, hospitals, airlines, government agencies, and similar service-sector organizations are responding to the challenge by transferring concepts and techniques that worked in manufacturing to services.

For example, state and local governments are increasingly using operations management techniques.[9] The city of Madison, Wisconsin, has used statistical process control and worker empowerment to improve the efficiency of its garbage collection operations. The Arkansas Department of Human Services cut the error rate on its nightly computer runs by 68 percent after a quality team figured out which programs were causing problems and why. Phoenix, Arizona, used quality teams and operations management techniques to cut the costs of the city's emergency ambulance service by 25 percent while, at the same time, cutting average response time from nineteen to just five minutes.

Strategic Operations Management

Modern manufacturing was born three-quarters of a century ago in the United States, primarily in Detroit's automobile factories. The success U.S. manufacturers experienced during World War II led executives of manufacturing firms to believe that the troublesome problems of production had been conquered. These executives directed their attention to other areas such as finance and marketing. From the late 1940s through the mid-1970s, manufacturing activities were slighted. With only the occasional exception (such as the aerospace industry), top management gave manufactur-



Sleep Inn is proving that significant productivity gains can be achieved in service firms. It employs 13 percent fewer people than comparably sized no-frills hotels. It was designed with the mind set of an industrial engineer laying out an assembly line. Among some of its features: the laundry room is almost completely automated; closets have no doors for maids to open and shut; and the shower stalls are round, eliminating corners that collect dust.

MANAGING FROM A GLOBAL PERSPECTIVE

Global Operations Strategy

Japanese firms such as Sony and Panasonic could never produce the quality electronic products they do at the prices at which they sell them if they sold their products only in Japan. Why? Because the Japanese home market is very small. These companies are able to justify the investments they make in research, technology, and quality design only because they enjoy the economies of selling their products worldwide.

In the global marketplace, the place where goods are manufactured, the amount to be produced, and similar production and operations decisions must consider international comparative advantages.[10] Because of rapidly rising labor costs in Japan, Sony has moved some of its low-skill, labor-intensive manufacturing operations to Taiwan. The need for creative design skills encouraged Mazda executives to locate a design center in Southern California. The rise of the yen in relation to the dollar motivated Honda to set up manufacturing plants in Ohio. Low-interest loans by the Irish government led California-based semiconductor equipment manufacturer Western Digital Corporation to open a new plant in Ireland.

Global organizations no longer produce their goods in one country and then ship them around the world. Such companies as Ford, Procter & Gamble, and Royal Dutch Shell have manufacturing operations in countries throughout the world. They design products for world markets and use worldwide production and distribution systems, as well as vertical integration, to gain economies of scale. But many other benefits can accrue from pursuing a global operations strategy. Take, as examples, the ability to prolong life cycles and the benefits that can result from exploiting the volatility of economic factors. Companies can prolong product life cycles by manufacturing in developing nations. A tire retread manufacturer may face a declining market in the United States or Canada but a rapidly growing market in Latin American countries. Global firms can experience fluctuations of exchange rates, inflation rates, and similar volatile factors that provide advantages precisely because they do fluctuate, if the firms know how to benefit from the ups and downs. Firms that can accurately forecast economic fluctuations and adjust their manufacturing decisions accordingly, can outperform nonglobal organizations as well as global firms that forecast poorly or operate under the assumption of economic stability.

ing little attention, managers "on the way up" avoided it, and market leadership dwindled.

Meanwhile, with U.S. executives neglecting the production side of their business, managers in Japan, Germany, and other countries took the opportunity to develop modern, computer-assisted facilities that fully integrated manufacturing operations into strategic planning decisions. The competition's success realigned world manufacturing leadership. For example, U.S. manufacturers found that foreign goods were being made not only less expensively but also better. By the late 1970s, U.S. manufacturers were facing a true crisis, and a good percentage of them responded.[11] They invested heavily in improving manufacturing technology, increased the authority of

manufacturing executives, and began incorporating existing and future production requirements into the organization's overall strategic plan. Today, successful manufacturers are taking a top-down approach to operations and implementing comprehensive manufacturing planning systems.[12]

Harvard University professor Wickham Skinner has been urging a "manufacturing focus" to strategy for a number of years.[13] He argues that too many important production decisions have been relegated to lower-level managers. Production needs to be managed from the top down rather than from the bottom up. According to Skinner, the organization's overall strategy should directly reflect its manufacturing capabilities and limitations and should include operations objectives and strategies. He points out, for example, that each organization's operations strategy needs to be unique and reflect the inherent trade-offs in any production process. Cost reduction and quality enhancement often work against each other. So, too, do short delivery times and limited inventory levels. Because there is no single "most efficient way" to produce things, top management needs to identify and emphasize its competitive advantage in operations. Some organizations are competing on the more traditional basis of low prices achieved through cost reduction. Others are competing on the basis of quality, reliable delivery, warranties, short lead times, customer service, rapid product introduction, or flexible capacity.

As we noted, Skinner's appeals have been heeded. The manufacturing organizations that expect to compete successfully in world markets are incorporating operations decisions in their strategic plans and returning manufacturing executives to a place of prominence in the organization's power structure.[14]

Planning Operations

As we've noted in several places throughout this book, planning must precede control. Therefore, before we can introduce operations-management control techniques, we need to review a few of the more important decisions related to planning operations.

Four key decisions—capacity, location, process, and layout—provide the long-term strategic direction for operations planning. They determine the proper size of an operating system, where the physical facilities should be located, the best methods for transforming inputs into outputs, and the most efficient layout of equipment and work stations. Once these decisions have been made, three short-term decisions—the aggregate plan, the master schedule, and a material requirements plan—need to be established. These provide the tactical plans for the operating system. In this section, we'll review each of these seven types of planning decisions. (See Figure 21–2.)

Capacity Planning

capacity planning
Assessing an operating system's ability to produce a desired number of output units for each type of product during a given time period.

Assume that you have decided to go into the boat-building business. On the basis of your analysis of the market and other environmental factors (see Chapter 8), you believe there is a market for a premium-quality 28-foot sailboat. You know *what* you want to produce. What's the next step? You need to determine *how many* boats you expect to build. This, in turn, will determine the proper size of your plant and other facility-planning issues. When managers assess their operating system's capabilities for producing a desired number of output units for each type of product anticipated during a given time period, they are engaged in **capacity planning.**

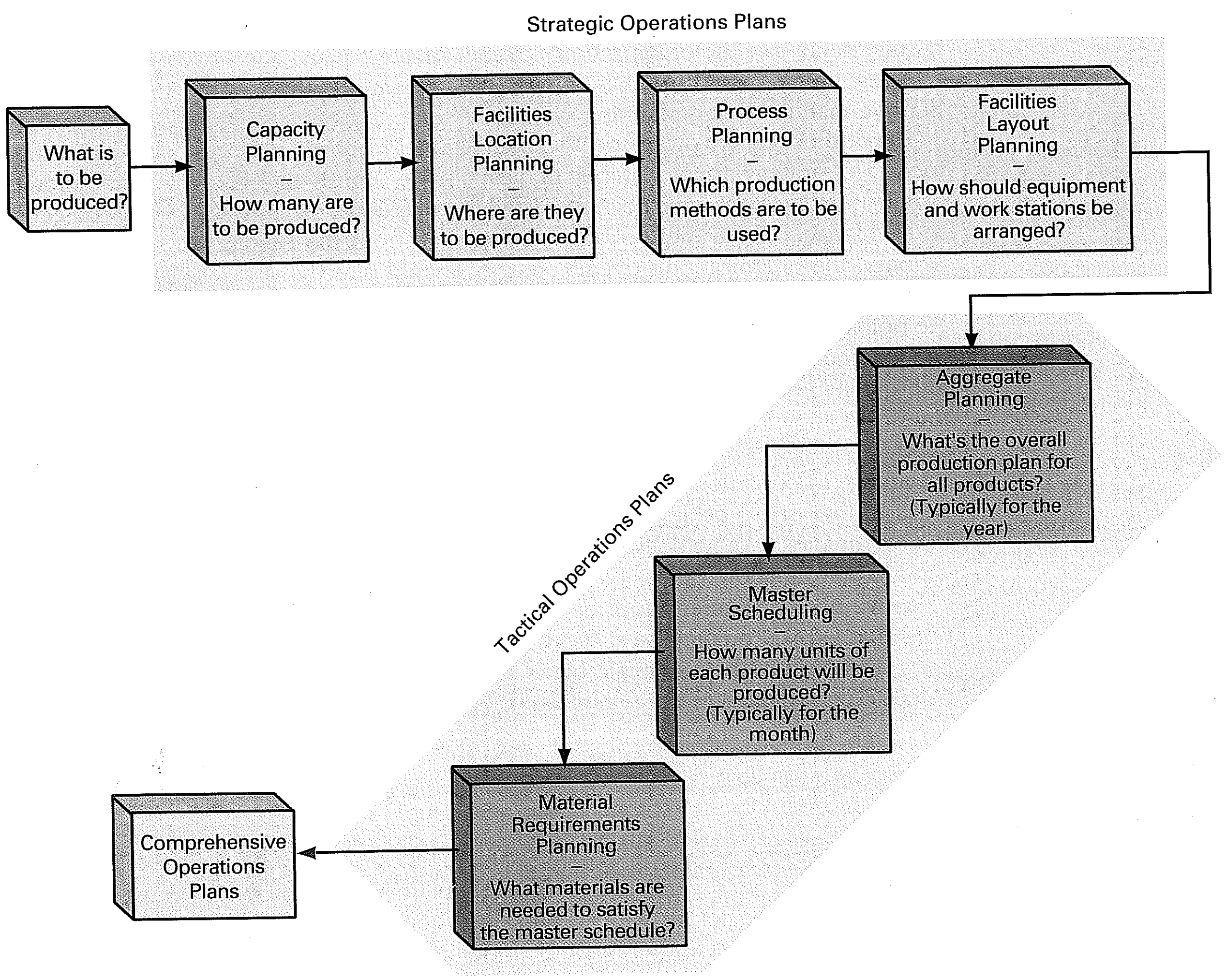


FIGURE 21–2
Planning Operations

Capacity planning begins by taking the forecasts of sales demand (see Chapter 9) and converting them into capacity requirements. If you produce only one type of boat, plan to sell the boats for an average of $50,000 each, and anticipate generating sales of $2.5 million during the first year, your physical capacity requirements need to handle fifty boats. This calculation is obviously much more complex if you're producing dozens of different products.

If your organization is already established, you compare this forecast against your existing production capacity. Then you can determine whether you'll need to add to or subtract from your existing capacity. Keep in mind that you don't have to be in a manufacturing business to use capacity planning. The following steps are just as relevant for determining the number of beds needed in a hospital or the maximum number of sandwiches that a Burger King can serve.

Once you have converted the forecast into physical capacity requirements, you will be able to develop a set of alternative capacity plans that will meet the requirements. You will often have to make some modifications—that is, you will have to expand or reduce capacity. In the long term, you can alter the size of your operation significantly and permanently by buying new equipment or selling off existing facilities. In the short term, however, you're forced to make more temporary modifications. You can add an extra shift, increase overtime, or reduce work hours; temporarily shut down operations; or subcontract work out to other organizations. If you manufacture a product that can be stored (like sailboats), you can build inventories during slack periods to be used when demand exceeds capacity.

Facilities Location Planning

facilities location planning The design and location of an operations facility.

When you determine the need for additional capacity, you must design and choose a facility. This process is called **facilities location planning.** Where you choose to locate will depend on which factors have the greatest impact on total production and distribution costs. These include availability of labor skills, labor costs, energy costs, proximity to suppliers or customers, and the like. Rarely are all these factors of equal importance. The kind of business you're in typically dictates your critical contingencies, which then dictate—to a large degree—the optimum location.

The need for skilled technical specialists has led an increasing number of high-tech firms to locate in the Boston area. The area's high concentration of colleges and universities makes it easier for firms who require employees with computer, engineering, and research skills to find and hold onto such people. Similarly, it's not by chance that many manufacturers whose conversion processes are labor intensive have moved their manufacturing facilities overseas to places such as Taiwan and South Korea. When labor costs are a critical contingency, organizations will locate their facilities where wage rates are low. Tire manufacturers chose their original locations in northern Ohio in order to be close to their major customers, the automobile manufacturers in Detroit. When customer convenience is critical, as it is for many retail outlets, the location decision is often dictated by concerns such as proximity to a highway or pedestrian traffic.

What contingencies are going to be critical in your sailboat business? You'll need employees with boat-building skills, and they're most likely to be plentiful in coastal areas such as New England, Florida, and southern California. Shipping costs of the final product are likely to be a major expenditure, thus, to keep your prices competitive you might want to locate close to your customers. That again suggests the east, west, or Gulf coasts, or possibly the Great Lakes. Weather might be a further factor. It

The building of this Reynolds Metals plant in Washington State is a clear response to low energy costs. Aluminum reduction mills require a great deal of energy, and Washington has cheap hydroelectric power.

might be less expensive to build boats outside in warm-weather climates than indoors during winter in the northeast. If labor availability, shipping costs, and weather are your critical contingencies, you still have a great deal of latitude in your location decision. After you choose a region, you still must select a community and a specific site.

Process Planning

process planning
Determining how a product or service will be produced.

In **process planning,** management determines how a product or service will be produced. Process planning encompasses evaluating the available production methods and selecting the set that will best achieve the operating objectives.

For any given production process, whether in manufacturing or the service sector, there are always alternative conversion methods. Designing a restaurant, for instance, allows for a number of process choices: to-inventory fast food (as served at McDonald's), limited-option fast food (as served at Burger King or Wendy's), cafeteria-style delivery, drive-in take out, a no-option fixed menu, and complex meals prepared to order. Key questions that ultimately determine how an organization's products or services will be produced include: Will the technology be routine or nonroutine? What degree of automation will be utilized? Should the system be developed to maximize efficiency or flexibility? How should the product or service flow through the operations system?[15]

In our sailboat-manufacturing example, the boats could be made by an assembly-line process. If you decide to keep them highly standardized, you will find a routine transformation process to be most cost efficient. But if you want each boat to be made to order, you will require a different technology and a different set of production methods.

Process planning is complex. Deciding on the best combinations of processes in terms of costs, quality, labor efficiency, and similar considerations is difficult because the decisions are intertwined. A change in one element of the production process often has spillover effects on a number of other elements. As a result, the detailed planning is usually left to production and industrial engineers under the overall guidance of top management.

Facilities Layout Planning

facilities layout planning
Assessing and selecting among alternative layout options for equipment and work stations.

process layout
Arranging manufacturing components together according to similarity of function.

product layout
Arranging manufacturing components according to the progressive steps by which a product is made.

fixed-position layout
A manufacturing layout in which the product stays in place while tools, equipment, and human skills are brought to it.

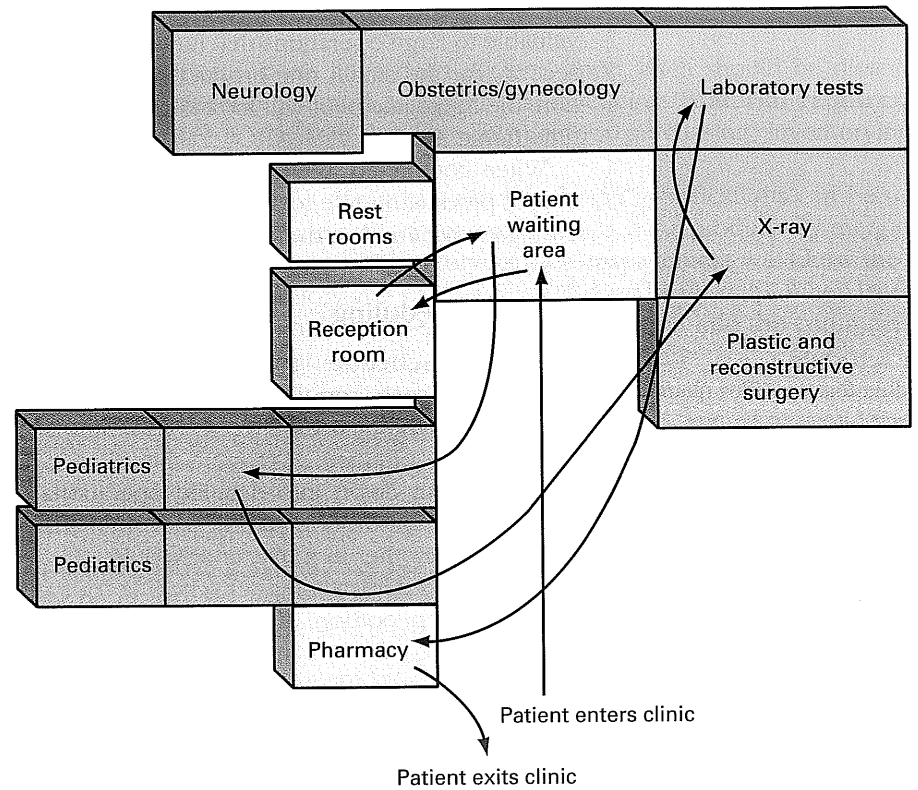
The final strategic decision in operations planning is to assess and select among alternative layout options for equipment and work stations. This is called **facilities layout planning.** The objective of layout planning is to find a physical arrangement that will best facilitate production efficiency and that is also appealing to employees.

Layout planning begins by assessing space needs. Space has to be provided for work areas, tools and equipment, storage, maintenance facilities, rest rooms, offices, lunch areas and cafeterias, waiting rooms, and even parking lots. Then, based on previous process plans, various layout configurations can be evaluated to determine how efficient each is for handling the work flow. To help make these decisions, a number of layout-planning devices are available, ranging from simple, scaled-to-size paper cutouts to sophisticated computer software programs that can manipulate hundreds of variables and print out alternative layout designs.[16]

There are basically three work-flow layouts.[17] The **process layout** arranges components (such as work centers, equipment, or departments) together according to similarity of function. Figure 21–3 illustrates the process layout at a medical clinic. In **product layout,** the components are arranged according to the progressive steps by which the product is made. Figure 21–4 illustrates a product layout in a plant that manufactures aluminum tubing. The third approach, the **fixed-position layout,** is used when, because of its size or bulk, the product remains at one location. The

FIGURE 21–3
A Process Layout at a Medical Clinic

Source: From Everett E. Adam, Jr. and Ronald J. Ebert, *Production and Operations Management: Concepts, Models, and Behavior,* 5th ed. (Englewood Cliffs, NJ: Prentice Hall, 1992), p. 254. With permission.



product stays in place, and tools, equipment, and human skills are brought to it. Sound stages on a movie lot or the manufacturing of airplanes illustrates the fixed-position layout. The building of your 28-foot sailboats is likely to use either a product or fixed-position layout.

Aggregate Planning

aggregate planning
Planning overall production activities and their associated operating resources.

Once the strategic design decisions have been made, we move to the tactical operations decisions. The first of these deals with planning the overall production activities and their associated operating resources. This is called **aggregate planning** and often deals with a time frame of up to a year.

The aggregate plan provides a "big picture." On the basis of the demand forecast and capacity plan, the aggregate plan sets inventory levels and production rates and estimates the size of the total operation's labor force on a monthly basis for approximately the next twelve months. The focus is on *generalities,* not specifics. Families of items are considered, not individual items. A paint company's aggregate plan would look at the total number of gallons of house paint to be manufactured but avoid

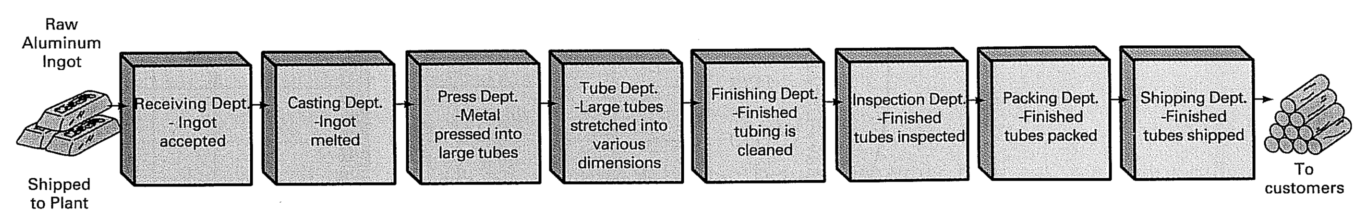


FIGURE 21–4
A Product Layout in an Aluminum Tubing Plant

decisions about color or size of container. As such, the aggregate plan is particularly valuable to large operations that have a varied product line. As you'll see in the next section, for the small, one-product firm, such as the sailboat-manufacturing operation, the aggregate plan will look like the master schedule, only it will cover a longer time frame.

When completed, the aggregate plan often yields two basic decisions: the best overall production rate to adopt and the overall number of workers to be employed during each period in the planning horizon.[18]

Master Scheduling

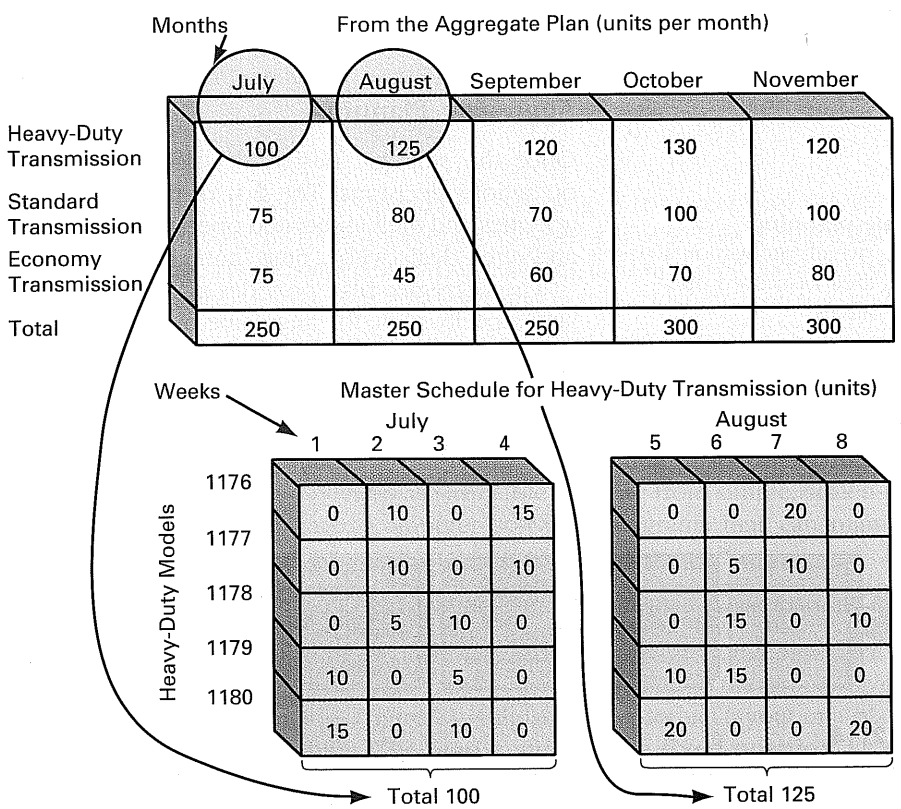
master schedule
A schedule that specifies quantity and type of items to be produced; how, when, and where they should be produced; labor force levels; and inventory.

The **master schedule** is derived from the aggregate plan. It specifies the quantity and type of each item to be produced; how, when, and where they should be produced for the next day, week, or month; labor force levels; and inventory.

The first requirement of master scheduling is *disaggregation*—that is, breaking the aggregate plan down into detailed operational plans for each of the products or services the organization produces.[19] After that, these plans need to be scheduled against one another in a master schedule.

Figure 21–5 depicts a master schedule for a manufacturer of automobile transmissions. The top portion of the figure informs lower-level managers (through the aggregate plan) that top management has authorized the capacity, inventory, and people to produce 100 heavy-duty transmissions in July, 125 in August, and so forth. The lower part of the figure illustrates a master schedule. For example, it shows how lower-level managers consider the July production for 100 heavy-duty transmissions and determine which models to make. Not only do they determine what specific models to make each week, they also state how many. During the first week of July, for instance, ten units of Model 1179 and fifteen units of Model 1180 will be assembled.

FIGURE 21–5
Developing a Master Schedule from an Aggregate Plan



Material Requirements Planning

material requirements planning (MRP)
A system that dissects products into the materials and parts necessary for purchasing, inventorying, and priority-planning purposes.

After the specific products have been decided upon, each should be dissected to determine the precise materials and parts that it requires. **Material requirements planning (MRP)** is a system that uses this data for purchasing, inventorying, and priority-planning purposes.

With the assistance of a computer, product design specifications can be used to identify all the materials and parts necessary to produce the product. By merging this information with computerized inventory records, management will know the quantities of each part in inventory and when each is likely to be used up. When lead times and safety stock requirements are established and entered into the computer, MRP ensures that the right materials are available when needed.

Controlling Operations

Once the operating system has been designed and implemented, its key elements must be monitored. The following discussion offers guidance for controlling costs, purchasing, maintenance, and quality.

Cost Control

An automobile industry analyst has compared the U.S. and Japanese approaches to cost control: "The Japanese regard cost control as something you wake up every morning and do. Americans have always thought of it as a project. You cut costs 20 percent and say: 'Whew! That's over.' We can't afford to think that way anymore."[20]

U.S. managers have often treated cost control as an occasional crusade that is initiated and controlled by the accounting staff. Accountants establish cost standards per unit, and if deviations occur, management looks for the cause. Have material prices increased? Is labor being used efficiently? Do employees need additional training? However, as the previous annotation implies, cost control needs to play a central part in the design of an operating system, and it needs to be a continuing concern of every manager.

cost center
A unit in which managers are held responsible for all associated costs.

direct costs
Costs incurred in proportion to the output of a particular good or service.

indirect costs
Costs that are largely unaffected by changes in output.

Many organizations have adopted the cost-center approach to controlling costs. Work areas, departments, or plants are identified as distinct **cost centers,** and their managers are held responsible for the cost performance of these units. Any unit's total costs are made up of two types of costs: direct and indirect. **Direct costs** are costs incurred in proportion to the output of a particular good or service. Labor and materials typically fall into this category. On the other hand, **indirect costs** are largely unaffected by changes in output. Insurance expenses and the salaries of staff personnel are examples of typical indirect costs. This direct–indirect distinction is important. While cost-center managers are held responsible for all direct costs in their units, indirect costs are not necessarily within their control. However, because all costs are controllable at some level in the organization, top managers should identify where the control lies and hold lower managers accountable for costs under their control.[21]

Purchasing Control

It has been said that human beings *are* what they eat. Metaphorically, the same applies to organizations. Their processes and outputs depend on the inputs they "eat." It's difficult to make quality products out of inferior inputs. Highly skilled leather workers need quality cowhides if they are going to produce high-quality wallets. Gas station operators depend on a regular and dependable inflow of certain octane-rated gasolines from their suppliers in order to meet their customer's demands. If the gas isn't there, they can't sell it. If the gasoline is below the specified octane rating, customers may be dissatisifed and take their business somewhere else. Management must therefore monitor the delivery, performance, quality, quantity, and price of inputs from suppliers. Purchasing control seeks to ensure availablilty, acceptable quality, continued reliable sources, and, at the same time, reduced costs.

What can managers do to facilitate control of inputs? They need to gather information on the dates and conditions in which supplies arrive. They need to gather data about the quality of supplies and the compatibility of those supplies with operations processes. Finally, they need to obtain data on supplier price performance. Are the prices of the delivered goods the same as those quoted when the order was placed?

This information can be used to rate suppliers, identify problem suppliers, and guide management in choosing future suppliers. Trends can be detected. Suppliers can be evaluated, for instance, on responsiveness, service, reliability, and competitiveness.

Building Close Links with Suppliers A rapidly growing trend in manufacturing is turning suppliers into partners.[22] Instead of using ten or twelve vendors and forcing them to compete against each other to gain the firm's business, manufacturers are using only two or three vendors and working closely with them to improve efficiency and quality.

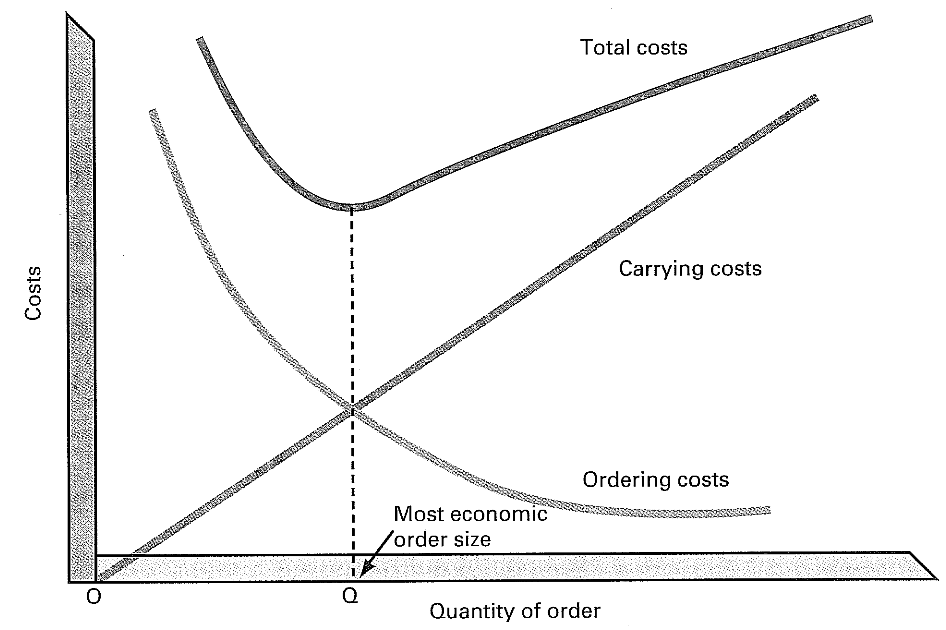
Motorola, for instance, sends its design-and-manufacturing engineers to suppliers to help with any problem.[23] Other firms now routinely send inspection teams to rate suppliers' operations. They're assessing these suppliers' manufacturing and delivery techniques, statistical process controls that identify causes of defects, and ability to handle data electronically. Companies in the United States and around the world are doing what has long been a tradition in Japan—that is, they are developing long-term relationships with suppliers. As collaborators and partners, rather than adversaries, firms are finding that they can achieve better quality of inputs, fewer defects, and lower costs. Furthermore, when problems arise with suppliers, open communication channels facilitate quick resolutions.

economic order quantity model (EOQ)
A technique for balancing purchase, ordering, carrying, and stockout costs to derive the optimum quantity for a purchase order.

Economic Order Quantity Model One of the best-known techniques for mathematically deriving the optimum quantity for a purchase order is the **economic order quantity model (EOQ).** The EOQ model seeks to balance four costs involved in ordering and carrying inventory: the *purchase costs* (purchase price plus delivery charges less discounts); the *ordering costs* (paperwork, follow-up, inspection when the item arrives, and other processing costs); *carrying costs* (money tied up in inventory, storage, insurance, taxes, and so forth); and *stockout costs* (profits forgone from orders lost, the cost of reestablishing goodwill, and additional expenses incurred to expedite late shipments).

The objective of the EOQ model, as shown in Figure 21–6, is to minimize the total costs of two of these four costs—carrying costs and ordering costs. As the amount ordered gets larger and larger, average inventory increases and so do carrying costs. But placing larger orders means fewer orders and thus lowers ordering costs. For example, if annual demand for an inventory item is 26,000 units, and we order 500 each time, we will place 52 (26,000/500) orders per year. This gives us an average inventory of 250 (500/2) units. However, if the order quantity is increased to 2,000 units, there will be fewer orders placed, 13 (26,000/2,000), but the average inventory on hand will increase to 1,000 (2,000/2) units. Thus as holding costs go up, ordering costs go down, and vice versa. As depicted in Figure 21–6, the lowest total cost—and thus the most economic order quantity—is reached at the lowest point on the total

FIGURE 21–6
Determining the Most Economic Order Quantity



cost curve. That is the point at which ordering cost equals carrying cost. It is called the *economic order quantity*.

To compute this optimal order quantity, you need the following data: forecasted demand for the item during the period (*D*), the cost of placing each order (*OC*), the value or purchase price of the item (*V*), and the carrying cost of maintaining the total inventory expressed as a percentage (*CC*),, We can now present the standard EOQ formula and demonstrate its use:

$$\text{EOQ} = \sqrt{\frac{2 \times D \times OC}{V \times CC}}$$

As an example, Playback Electronics, a retailer of high-quality sound and video equipment, is trying to ascertain its economic order quantities. The item in question is a Yamaha compact sound system. The company forecasts sales of 4,000 units a year. Purchasing believes that the cost of each system will be $500. The accountants estimate the cost of placing an order for the sound system at $75 per order and annual insurance, taxes, and other carrying costs at 20 percent of the system's worth. Using the EOQ formula and the information above, we find

$$\begin{aligned} \text{EOQ} &= \sqrt{\frac{2 \times 4{,}000 \times 75}{500 \times 0.20}} \\ &= \sqrt{6{,}000} \\ &= 77.45 \text{ units} \cong 78 \text{ units} \end{aligned}$$

The inventory model suggests to Playback's management that it is most economic to order in quantities or lots of approximately 78 units; stated differently, they should order about 52 (4,000/78) times a year.

What would happen if Yamaha offered Playback a 5 percent discount on purchases if Playback buys in minimum quantitites of 120 units? Should Playback's management now purchase in quantities of 78 or 120? Without the discount, and therefore ordering 78 each time, Playback's annual costs for this sound system would be as follows:

Purchase cost: $500 × 4,000			=	$2,000,000
Carrying cost: $\frac{78}{2}$ × $500 × 0.20			=	3,900
(average inventory units) × (value of item) × (percentage)				
Ordering cost: 52	×	75	=	3,900
(Number of orders)	×	(cost to place order)		
Total cost:				$2,007,800

With the 5 percent discount for ordering 120 units, the item cost would be $475. The annual inventory costs would be as follows:

Purchase cost:	$475 × 4,000	=	$1,900,000
Carrying cost:	$\frac{120}{2}$ × 475 × 0.20	=	5,700
Ordering cost:	$\frac{4{,}000}{120}$ × 75	=	2,500
Total cost:			$1,908,200

These computations suggest to Playback's management that it should take the 5 percent discount. Even though it has to stock larger quantities, the savings are almost $100,000 a year.

A word of caution should be added. The EOQ model assumes that demand and lead time are known and constant. If these conditions cannot be met, the model should not be used. For example, it generally should not be used for manufactured component inventory, because the components are taken out of stock all at once or in lumps or in lots rather than at a constant rate. Does this mean that the EOQ model is useless when demand is variable? No. The model can still be of some use in demonstrating trade-offs in costs and the need to control lot sizes. However, there are more sophisticated lot-sizing models for handling lumpy demand and special situations.

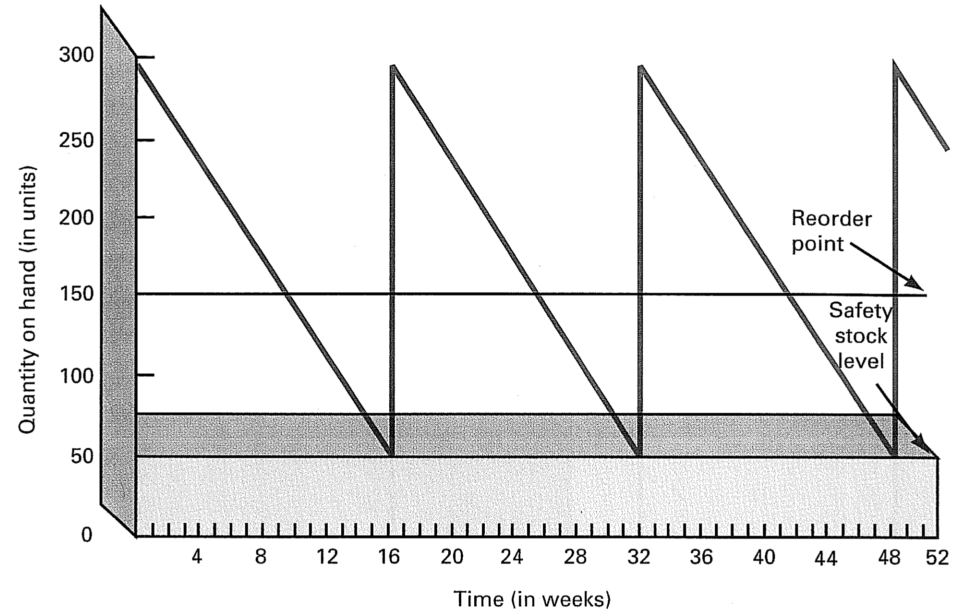
fixed-point reordering system
A system that "flags" the fact that inventory needs to be replenished when it reaches a certain level.

Inventory Ordering Systems In many checkbooks, after you use up about 95 percent of the checks, you find a reorder form included among the few that remain; it reminds you that it's time to reorder. This is an example of a **fixed-point reordering system.** At some preestablished point in the operations process, the system is designed to "flag" the fact that the inventory needs to be replenished. The flag is triggered when the inventory reaches a certain point or level.

The goal of a fixed-point reordering system is to minimize inventory carrying costs and to ensure a reasonable level of customer service (limiting the probability of an item running out—a *stockout*). Therefore the reorder point should be established to equate the time remaining before a stockout and the lead time to receive delivery of the reordered quantity. In such cases, the newly ordered items would arrive at the same time as the last item in inventory was used up. More realistically, management does not usually allow the inventory to fall below some safety stock level. (See Figure 21–7). By using certain statistical procedures, one can set a reorder point at a level that gives an organization enough inventory to get through the lead-time period and some reasonable insurance against a stockout. This buffer, or safety stock, gives protection against greater usage than expected during the lead time or an unexpected delay in receiving new stock.

As a simple example, to determine a check reorder point let's assume that the lead time averages three weeks and that we write about twenty checks a week. We would need sixty checks to get us through a "normal" reordering lead time. If we feel, on the basis of history, that a one-week safety stock would be sufficient to get us through most lead-time periods, the order should be placed when there are 80 (60 + 20) checks left. This is the reorder point. Another word of caution: The more safety stock,

FIGURE 21–7
Inventory Cycle with Safety Stock



the less the risk of stockout. But the additional inventory will add to the carrying costs. Thus we again face a cost-benefit decision. At times it may be prudent (costwise) to run out of stock.

One of the most primitive but certainly effective uses of the fixed-point reordering system is to keep the item—for example, pens and duplicating paper in an office or boxes of shoes in a retail shoe store—in two separate containers. Inventory is drawn from one until it is empty. At that point, a reorder is placed, and items are drawn from the second container. If demand for an item has been estimated properly, the replacement order to replenish the stock should arrive before the second container is used up.

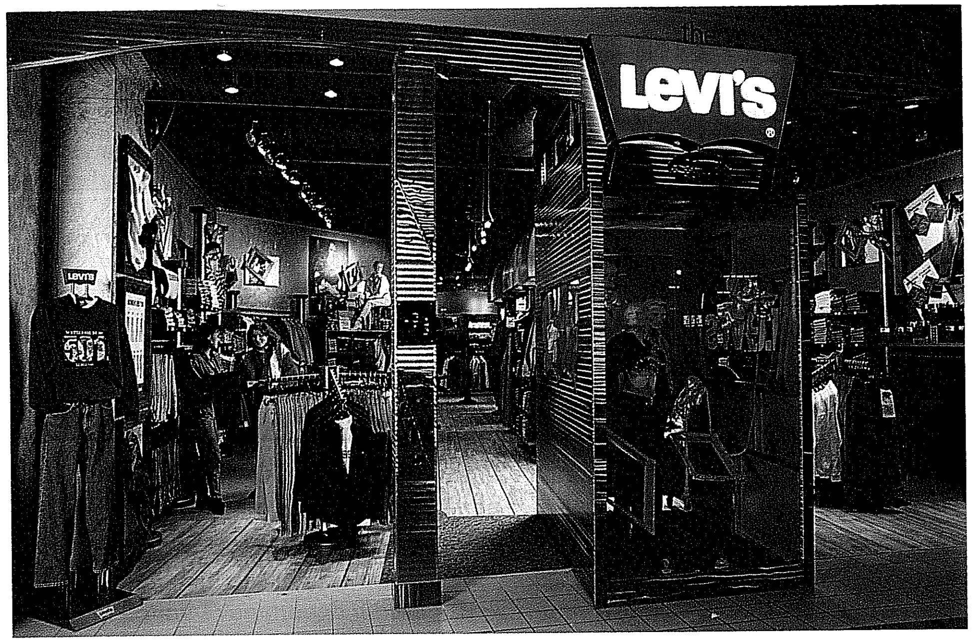
Another, more recent, version of the fixed-point reorder system relies on computer control. Sales are automatically recorded by a central computer that has been programmed to initiate a purchase order for an item when its inventory reaches some critical fixed point. A number of retail stores have such systems. The cash registers are actually computers, and each sale automatically adjusts the store's inventory record. When the inventory of an item hits the critical point, the computer tells management to reorder or, in some systems, actually prints out the purchase order requisition.

fixed-interval reordering system
A system that uses time as the determining factor for reviewing and reordering inventory items.

Another common inventory system is the **fixed-interval reordering system.** The fixed-interval system uses time as the determining factor for inventory control. At a predetermined time—say, once a week or every ninety days—the inventory is counted, and an order is placed for the number of items necessary to bring the inventory back to the desired level. The desired level is established so that if demand and ordering lead time are average, consumption will draw the inventory down to zero (or some safety lead time can be added) just as the next order arrives. This system may have some transportation economies and quantity discount economies over the fixed-point system. For example, it may allow us to consolidate orders from one supplier if we review all the items we purchase from this source at the same time. This is not possible in the other system.

In the 1800s, economist Vilfredo Pareto found that 80 percent of the wealth was controlled by only 20 percent of the population. College instructors typically find that a few students cause most of their problems, and students have probably similarly found that a few instructors cause most of their problems. This concept, the vital few and the trivial many, can be applied to inventory control.

It might take a men's store three weeks to get an order for Levis 501 jeans filled by the manufacturer. If the store typically sells ten pairs of size 30-30 jeans a week, the store manager could set up two containers, keep thirty pairs of jeans in the second container, and initiate reorders whenever the first container is empty. This would be an application of the fixed-point reordering system.



It is not unusual for a company to have thousands of items in inventory. However, evidence indicates that roughly 10 percent of the items in most organizations' inventory account for 50 percent of the annual dollar inventory value. Another 20 percent of the items account for 30 percent of the value. The remaining 70 percent of the items appear to account for only 20 percent of the value. These have been labeled as A, B, and C categories, respectively. Thus we have the name **ABC system.** (See Figure 21–8.)

ABC system
A priority system for monitoring inventory items.

Cost-benefit analysis would justify that A items receive the tightest control, B items moderate control, and C items the least control. This can be accomplished because there are so few A items and they represent a large dollar investment. Similarly, there are so many C items, but so little dollar investment, that tight control would not be justified. A items, for example, might be monitored weekly, B items monthly, and C items quarterly because they account for so little dollar value. Or C items might be controlled by using a simple form of order point.

Maintenance Control

Delivering goods or services in an efficient and effective manner requires operating systems with high equipment utilization and a minimum amount of downtime. Therefore managers need to be concerned with maintenance control. The importance of maintenance control, however, depends on the process technology used. For example, if a standardized assembly-line process breaks down, it can affect hundreds of employees. On an automobile or dishwasher assembly line, it's not unusual for a serious breakdown on one machine to bring an entire plant to a halt. In contrast, most systems using more general-purpose and redundant processes have less interdependency between activities, therefore a machine breakdown is likely to have less of an impact. Nevertheless, an equipment breakdown—like an inventory stockout—may mean higher costs, delayed deliveries, or lost sales.

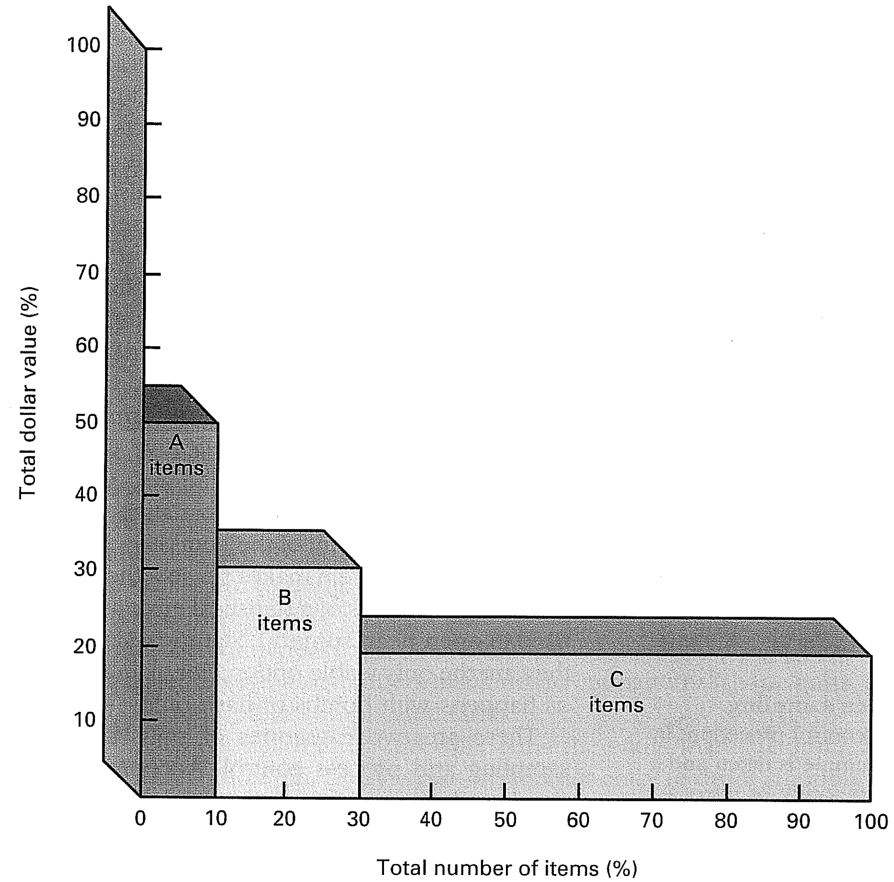
There are three approaches to maintenance control.[24] **Preventive maintenance** is performed before a breakdown occurs. **Remedial maintenance** is a complete overhaul, replacement, or repair of the equipment when it breaks down. **Conditional maintenance** refers to overhaul or repair in response to an inspection and

preventive maintenance
Maintenance performed before a breakdown occurs.

remedial maintenance
Maintenance that calls for the overhaul, replacement, or repair of equipment when it breaks down.

conditional maintenance
Maintenance that calls for an overhaul or repair in response to an inspection.

FIGURE 21–8
Example of an ABC Inventory System



measurement of the equipment's state. When American Airlines tears down its planes' engines every 1,000 hours, it is engaging in preventive maintenance. When it inspects the planes' tires every twenty-four hours and changes them when conditions warrant it, it is performing conditional maintenance. Finally, if American Airlines' operations policy is to repair lavatory equipment on board its planes only after the equipment breaks down, then it is using remedial maintenance practices.

The American Airlines example points out that the type of maintenance control depends on the costs of a breakdown. The greater the cost in terms of money, time, liability, and goodwill, the greater the benefits from preventive maintenance. That is, the benefits can justify the costs.

Maintenance control should also be considered in the design of equipment. If downtime is highly inconvenient or costly, reliability can be increased by designing redundancy into the equipment. Nuclear power plants, for example, have elaborate backup systems built in. Similarly, equipment can be designed to facilitate fast or low-cost maintenance. Equipment that has fewer parts has fewer things to go wrong. High-failure items can also be placed in locations that are easily accessible or in independent modular units that can be quickly removed and replaced. Cable television operators follow these guidelines. Breakdowns infuriate customers, so when they occur management wants to be able to correct them quickly. Speed is facilitated by centralizing equipment in easy-access locations and making extensive use of modular units. If a piece of equipment fails, the whole module of which it is a part can be pulled or replaced in just a few minutes. Television service is resumed rapidly, and the pulled modular unit can be taken to the shop and repaired without time pressures.

Quality Control

We've discussed Total Quality Management throughout this book. We've described it as a comprehensive, customer-focused program to continuously improve the quality of the organization's processes, products, and services. In this section, we present the more limited and traditional approach to quality by focusing on its control. While TQM emphasizes actions to prevent mistakes, quality control emphasizes identifying mistakes that may have already occurred.

So what do we mean by *quality control?* It refers to monitoring quality—weight, strength, consistency, color, taste, reliability, finish, or any one of a myriad of characteristics—to ensure that it meets some preestablished standard. Quality control will probably be needed at one or more points beginning with the receipt of inputs. It will continue with work in process and all steps up to the final product. Assessments at intermediate stages of the transformation process typically are part of quality control. Early detection of a defective part or process can save the cost of further work on the item.

In imposing quality control, managers should begin by asking whether they expect to examine 100 percent of the items or whether a sample can be used. The inspection of each and every item makes sense if the cost of continuous evaluation is very low or if the consequences of a statistical error are very high (as in the manufacture of a drug used in open-heart surgery). Statistical samples are usually less costly, and sometimes they are the only viable option. For example, if the quality test destroys the product—as happens with bombs or flash bulbs—then sampling has to be utilized.

acceptance sampling
A quality control procedure in which a sample is taken and a decision to accept or reject a whole lot is based on a calculation of sample risk error.

process control
A quality control procedure in which sampling is done during the transformation process to determine whether the process itself is under control.

There are two categories of statistical quality control procedures: acceptance sampling and process control. **Acceptance sampling** refers to the evaluation of purchased or manufactured materials or products that already exist. A sample is taken, then the decision to accept or reject the whole lot is based on a calculation of sample risk error. **Process control** refers to sampling items during the transformation process to see whether the transformation process itself is under control. For example, a process control procedure at Coca-Cola would be able to detect if a bottling machine was out of adjustment because it was filling twenty-six ounce bottles with only twenty-three ounces of soda. Managers could then stop the process and readjust the machine.

attribute sampling
A quality control technique that classifies items as acceptable or unacceptable on the basis of a comparison to a standard.

variable sampling
A quality control technique in which a measurement is taken to determine how much an item varies from the standard.

A final consideration in quality control relates to whether the test is done by examining attributes or variables. The inspection and classification of items as acceptable or unacceptable is called **attribute sampling.** This is the way paint color and potato chips are evaluated. An inspector compares the items against some standard and rates their quality as acceptable or not acceptable. In contrast, **variable sampling** involves taking a measurement to determine how much an item varies from the standard. It involves a range rather than a dichotomy. Management typically identifies the standard and an acceptable deviation. Any sample that measures within the range is accepted, and those outside are rejected. Inland Steel might test some steel bar to see whether the average breaking strength is between 120 and 140 pounds per square inch. If it is not, the cause is investigated, and corrective action is initiated.

Current Issues in Operations Management

Capitalizing on new technology! Successfully implementing TQM! Reducing inventories! Utilizing flexibility and speed as competitive advantages! These issues currently top management's list for improving operations productivity. Because managers consider them to be essential for making products and services competitive in world markets, we review each of them in this section.

Technology and Product Development

Today's competitive marketplace has put tremendous pressure on manufacturers to deliver products with high quality and low cost and to significantly reduce time to market. Even if you have the proverbial "better mousetrap," customers won't be beating a path to your door if your competitor develops a mousetrap that is almost as good but is in stores a year or two ahead of yours. Two key ingredients to successfully accelerating the product-development process are organizational commitment to improving the development cycle and investment in the technology to make it happen.

computer-integrated manufacturing (CIM)
Combines the organization's strategic business plan and manufacturing plan with state-of-the-art computer applications.

One of the most effective tools that manufacturers have in meeting the time-to-market challenge is **computer-integrated manufacturing (CIM).** This brings together the organization's stratgic business plan and manufacturing plan with state-of-the-art computer applications.[25] The technologies of computer-aided design (CAD) and computer-aided manufacturing (CAM) typically are the basis for CIM.

CAD essentially has made manual drafting obsolete. Using computers to visually display graphics, CAD enables engineers to develop new product designs in about half the time required for manual drafting. Eagle Engine Manufacturing, for instance, used its CAD system to design a new race-car engine in nine months instead of the traditional two-plus years.[26]

CAM relies on computers to guide and control the manufacturing process. Numerically controlled programs can direct machines to cut patterns, shape parts, assemble units, and perform other complicated tasks.

In the not-too-distant future, CIM will permit the entire manufacturing process to be viewed as a continuum. Every step—from order entry to order shipping—will be expressed as data and computerized. It will allow management to respond rapidly to changing markets. It will give firms the ability to test hundreds of design changes in hours rather than months and then provide the flexibility to produce multiple variations of products efficiently in lot sizes as small as one or two. When manufacturing is computer-integrated, for example, it is no longer necessary to stop the assembly line and spend valuable time changing dies and equipment in order to produce a new or nonstandard product. A single change in the computer program—which can be done in seconds—immediately realigns the manufacturing process.

In the textile industry, computer-aided design (CAD) allows manufacturers to create and view cloth patterns in a fraction of the time it would have taken to prepare a preproduction sample for customer inspection.

THE CHANGING FACE OF MANAGEMENT PRACTICE

Small is Beautiful

"Bigger is better" was the rallying cry of management in the 1970s and 1980s. In the 1990s, that has been replaced by "small is beautiful."[27]

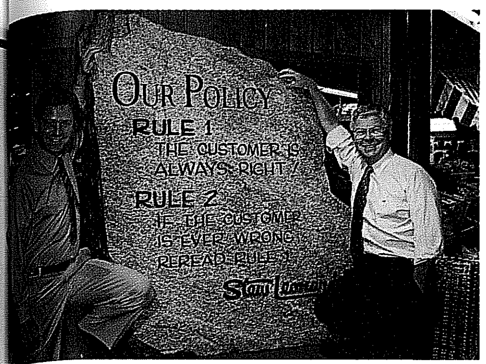
Managers long assumed that increases in size led to lower costs. This is what economists call "economies of scale." Larger size, the theory states, allows for an organization to distribute its fixed costs over more units of production, hence larger organizations have lower average costs. This belief led to the creation of large banks, huge steel mills, one-stop-shopping retail stores, and even mega-universities. But in recent years, something seemed to go wrong with the economies-of-scale argument. Big banks such as Citicorp and BankAmerica have been outperformed by smaller regional banks. Mini steel mills, run by companies such as Nucor and Chaparral, have become more efficient than the big ones operated by Bethlehem and U.S. Steel. Small niche retailers are grabbing market share from Sears and J.C. Penneys. And taxpayers are increasingly questioning whether small state colleges aren't doing a better job teaching students than the large research universities.

Why are smaller organizations increasingly able to outperform their larger rivals? They're flatter and often have less overhead. Smaller organizations are often more responsive and can react more quickly to changes in the market. Because they target narrower market segments, they can gain economies through specialization. Most importantly, however, technology now allows the little guys to do what only the big guys could do before. For an investment of less than $25,000, small firms can do computer-aided design. Similarly, use of computer-linked networks allows small companies to instantaneously coordinate with outside suppliers who provide the small firm with design, manufacturing, and sales services.

Implementing TQM Successfully

The list of organizations that have implemented TQM is long and impressive. It includes firms such as Motorola, Federal Express, Xerox, and IBM. In addition, public-sector organizations have recently gotten the message. Beginning with the class of '94, each high school graduate of the Los Angeles Unified School District will come with a written warranty assuring companies that he or she has the basic skills needed to enter the work force.[28] If an employer is not satisfied, the school district will provide remedial training at the district's expense. The governor of Ohio has created a statewide quality council to put TQM concepts to work throughout all state agencies.[29] Even the U.S. federal government is beginning to implement TQM.[30] A recent General Accounting Office study reports that 68 percent of the government's 2800 installations now use TQM.

Unfortunately, not all TQM efforts have been successful. A study of 584 companies in the United States, Canada, Germany, and Japan provides some important insights into factors that may hinder TQM effectiveness.[31] Consistent with the contingency approach to management, the survey found that the successful application of certain TQM concepts—including teams, benchmarking, training efforts, and empowering employees—depends on the company's current performance. The following suggestions highlight the study's recommendations for lower-, medium-, and higher-performing firms:[32]



The Stew Leonards, Jr. and Sr., understand that quality begins and ends with satisfying the customer. This five-ton piece of granite, with the company's motto, stands outside their monstrous Norwalk, Connecticut, food store. By listening to the customer, the Leonards have sales of $115 million a year and employ 650 people at this one store alone.

For Lower-Performing Firms Increase training of all types. Emphasize teams across and within departments. The formation of teams to help identify and solve small problems can help lower-performing companies as they begin their quality-improvement efforts. But teams lose their value and can distract from broader strategic issues once corporate performance improves. Don't use benchmarking because it tends to create unreasonable goals and thus can frustrate quality efforts. And don't empower employees yet because they usually don't have the training to make empowerment work.

For Medium-Performing Firms Simplify corporate processes such as design and focus training on problem solving.

For Higher-Performing Firms Use benchmarking to identify new processes, product, and services. Encourage companywide quality meetings. Actively disburse decision-making power by empowering employees. Don't increase departmental teams because this tends to inhibit cooperation across functions.

While the above contingency suggestions provide important limitations for the implementation of TQM, the survey also found some practices that tended to be universally effective. These included explaining the organization's strategy to all employees, customers, and suppliers; improving and simplifying operations and development processes; and shortening the time it takes from the design to the delivery of a product.

Reducing Inventories

A major portion of many companies' assets is tied up in inventories. For instance, General Electric recently reported its inventory assets at $7.4 billion and Boeing's inventory exceeds $13 billion.[33] Firms that can significantly cut their inventories of raw materials and of in-process and finished goods can reduce costs and improve their efficiency.

This fact has not been lost on management. In recent years, U.S. managers have been seeking ways to manage inventories better. On the output side, managers have been improving the information link between internal manufacturing schedules and forecasted customer demand. Marketing personnel are being increasingly relied on to provide accurate, up-to-date information on future sales. This is then being coordinated with operating systems data to get a better match between what is produced and what the customers want. Manufacturing resource planning systems are particularly well suited to this function. On the input side, they have been experimenting with another technique widely used in Japan: **just-in-time (JIT) inventory systems.**[34] This is a system in which inventory items arrive when they are needed in the production process instead of being stored in stock.

just-in-time (JIT) inventory system
A system in which inventory items arrive when they are needed in the production process instead of being stored in stock.

kanban
The Japanese name for a just-in-time inventory system.

In Japan, JIT systems are called **kanban.** The derivation of the word gets to the essence of the just-in-time concept. *Kanban* is Japanese for "card" or "sign." Japanese suppliers ship parts to manufacturers in containers. Each container has a card, or kanban, slipped into a side pocket. When a production worker opens a container, he or she takes out the card and sends it back to the supplier. That initiates the shipping of a second container of parts that, ideally, reaches the production worker just as the last part in the first container is being used up. The ultimate goal of a JIT inventory system is to eliminate raw material inventories by coordinating production and supply deliveries precisely. When the system works as designed, it results in a number of positive benefits for a manufacturer: reduced inventories, reduced setup time, better work flow, shorter manufacturing time, less space consumption, and even higher quality. Of course, suppliers who can be depended on to deliver quality

ETHICAL DILEMMAS IN MANAGEMENT

JIT: Cost-Savings for Whom?

Just-in-time inventory systems reduce costs and increase efficiency for organizations that apply them. But what about the effect of these systems on suppliers? If Firestone builds a tire plant in the Detroit area to serve Chrysler better and to permit just-in-time deliveries to Chrysler, does Firestone benefit? Not if it has to stockpile an extensive tire inventory to meet Chrysler's needs.

An often overlooked side-effect of a JIT system is the burden it can place on suppliers. At the extreme, it can be argued that a JIT system is a self-serving device that merely pushes the costs and inefficiencies of carrying inventory back onto suppliers. If Chrysler's management demands that, to keep Chrysler as a customer, Firestone must be able to make daily deliveries of precisely the number and type of tires that Chrysler needs for each day's production, what options does Firestone have? It can impose JIT requirements on its own suppliers or it can manufacture for inventory and draw on those inventories, as needed, to meet Chrysler's demands.

One way out of this conundrum is for all firms in the supply chain to practice JIT. But that's unusual. In practice, companies that use JIT merely load their inventory problems onto the backs of their suppliers. Is that ethical? Are large companies that practice JIT abusing their power by exploiting suppliers who want and need their business? What do *you* think?

materials on time must be found. Because there are no inventories, there is no slack in the system to absorb defective materials or delays in shipment.

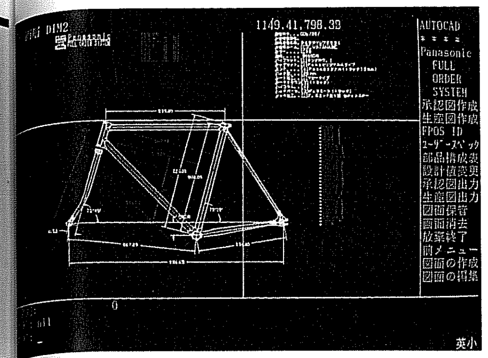
An illustration of JIT's benefits can be seen at Walgreen Laboratories, a manufacturer of health and beauty products for the Walgreen drugstore chain.[35] The firm calculated the cost of carrying and managing its inventory at about 25 percent of its total inventory costs. By introducing JIT, it cut its inventory levels by about $8 million. Of course, these benefits required additional work on the part of Walgreen's management. For instance, to allow its suppliers to plan their own production schedules, Walgreen had to project its supply needs six months in advance and commit itself to firm delivery dates weeks ahead of time.

A JIT system isn't for every manufacturer.[36] It requires that suppliers be located in close proximity to the manufacturer's production facility and that suppliers be capable of providing consistently defect-free materials. Such a system also requires reliable transportation links between suppliers and manufacturer; efficient receiving, handling, and distribution of materials; and precisely tuned production planning. Where these conditions can be met, JIT can help management to reduce inventory costs.

Flexibility as a Competitive Advantage

In today's changing world of business, firms that can't adjust rapidly won't survive. This is putting a premium on developing manufacturing flexibility.[37] As a result, many organizations are developing flexible manufacturing systems.[38]

They look like something out of a science-fiction movie in which remote-controlled carts deliver a basic casting to a computerized machining center. With



Using computer-aided design, Panasonic is able to produce separate blueprints for each bicycle it manufactures.

flexible manufacturing systems
Systems in which custom-made products can be mass produced by means of computer-aided design, engineering, and manufacturing.

robots positioning and repositioning the casting, the machining center calls upon its hundreds of tools to perform varying operations that turn the casting into a finished part. Completed parts, each a bit different from the others, are finished at a rate of one every ninety seconds. Neither skilled machinists nor conventional machine tools are used. Nor are there any costly delays for changing dies or tools in this factory. A single machine can make dozens or even hundreds of different parts in any order management wants.

The unique characteristic of **flexible manufacturing systems** is that by integrating computer-aided design, engineering, and manufacturing, they can produce low-volume, custom products at a cost comparable to what had been possible only through mass production. Flexible manufacturing systems are repealing the laws of economies of scale. Management no longer has to mass produce thousands of identical products to achieve low per-unit production costs. With a flexible manufacturing system, when management wants to produce a new part, it doesn't change machines—it just changes the computer program.

Some automated plants can build a wide variety of flawless products and switch from one product to another on cue from a central computer. John Deere, for instance, has a $1.5 billion automated factory that can turn out ten basic tractor models with as many as 3,000 options without plant shutdowns for retooling. These new flexible-factories are also proving to be cost effective. IBM's automated plant in Austin, Texas, can produce a laptop computer in less than two minutes without the help of a single worker. IBM's management has found the automated plant to be 75 percent more efficient than a conventional system.[39] National Bicycle Industrial Co., which sells its bikes under the Panasonic brand, uses flexible manufacturing to produce any of 11,231,862 variations on eighteen models of racing, road, and mountain bikes in 199 color patterns and an almost unlimited number of sizes.[40]

Speed as a Competitive Advantage

For years we have heard that on the highway, speed kills. Managers are now learning that the same principle works in business: Speed kills, only this time it's the competition's speed.[41] By quickly developing, making, and distributing products and services, organizations can gain a competitive advantage. Just as customers may select one organization over another because its products or services are less expensive, uniquely designed, or of superior quality, customers also choose organizations because they can get the product or service they want fast. In essence, Domino's has created a billion-dollar business by using speed as a competitive advantage, guaranteeing delivery of its pizzas in thirty minutes or less.

A number of companies have made incredible improvements in the time it takes them to design and produce their products.[42] AT&T used to need two years to design a new phone. Now it does the job in one year. General Electric used to take three weeks after an order to deliver a custom-made industrial circuit-breaker box. They've cut that down to three *days*. Kingston Technology Corp., founded in 1987, has become one of the fastest-growing companies in America by capitalizing on speed. The firm designs and manufactures memory upgrades for computers. In a market where customers want their upgrades yesterday, Kingston has achieved a remarkable 45 percent market share by being able to fill orders the same day they are received while its competitors continue to take four to six weeks. These firms and many others are cutting red tape; flattening their organization structures; adding cross-functional teams; redesigning their distribution chains; and using JIT, CIM, and flexible manufacturing systems to speed up their operations and put increased pressure on their competitors.

Summary

This summary is organized by the chapter-opening learning objectives found on page 625.

1. The transformation process is the essence of operations management. Operations management takes inputs, including people and materials, and then acts on them by transforming them into finished goods and services. This applies in service organizations as well as in manufacturing firms.
2. United States managers are increasingly concerned with improving productivity. How people are integrated into the overall operations system determines how productive an organization will be. Factors such as the size and layout of operating facilities, capacity utilization, inventory usage, and maintenance controls are operations management concepts that have a critical bearing on overall productivity.
3. A manufacturing focus to strategy pushes important production decisions to the top of the organization. It recognizes that an organization's overall strategy should directly reflect its manufacturing capabilities and limitations and should include operations objectives and strategies.
4. Four key decisions—capacity, location, process, and layout—provide the long-term strategic direction for operations planning. They determine the proper size of an operating system, the location of physical facilities, the best methods for transforming inputs into outputs, and the most efficient layout of equipment and work stations.
5. The three decisions that make up the tactical operations plans are the aggregate plan, the master schedule, and the material requirements plan. The aggregate plan determines the overall production plan, the master schedule determines how many units of each product will be produced, and the material requirements plan determines what materials are needed to satisfy the master schedule.
6. The economic order quantity model balances the costs of ordering and carrying inventory. To calculate the optimal order quantity, you need to know the forecasted demand for an item during a specific period, the cost of placing each order, the value or purchase price of the item, and the carrying cost of maintaining the total inventory.
7. The three types of maintenance control are preventive, remedial, and conditional. Preventive maintenance is performed before a breakdown occurs. Remedial maintenance is performed when the equipment breaks down. Conditional maintenance is a response to an inspection.
8. Evidence demonstrates that the application of certain TQM concepts should reflect whether the organization is a low, medium, or high performer. Low-performing firms, for instance, should emphasize team creation and downplay benchmarking and empowerment. High-performing firms, on the other hand, should encourage benchmarking and empowerment and deemphasize departmental teams.
9. Just-in-time inventory systems seek to reduce inventories, reduce setup time, improve work flow, cut manufacturing time, reduce space consumption, and raise the quality of production by coordinating the arrival of inventory items to their demand in the production process. However, they require precise coordination; if this is lacking, they can threaten the smooth, continuous operation of a production system.
10. A flexible manufacturing system can give an organization a competitive advantage by allowing it to produce a wider variety of products, at a lower cost, and in considerably less time than the competition.

Review Questions

1. What is the operations system?
2. What does W. Edwards Deming have to say about increasing productivity?
3. What is the role of critical contingencies in facilities location planning?
4. Contrast process, product, and fixed-position layouts.
5. How is cost control transferred from accountants to managers?
6. Contrast acceptance sampling and process control.
7. What is the ABC system? Why is it a contingency approach to inventory control?
8. How do CAD and CAM speed the product-development process?
9. Explain why benchmarking is inappropriate in low-performing firms.
10. What TQM practices are universally effective despite contingencies?

Discussion Questions

1. How might operations management apply to other managerial functions besides control? Discuss.
2. Demonstrate how capacity, facilities location, process, and facilities layout planning concepts can apply to a service organization.
3. Would you see any potential problems with implementing both CIM and TQM in the same organization? Discuss.
4. We have seen that increasing productivity is a concern of service organizations, but what about individuals? In what ways could you improve your own productivity?

SELF-ASSESSMENT EXERCISE

How's Your Knowledge of Japanese Manufacturing?

The following questions test your awareness of Japanese business and manufacturing practices:

1. In the typical large Japanese company, how many employee suggestions for improvement of operations would there be in a year?
   a. 1000
   b. 10,000
   c. 100,000
   d. a million
   e. 10 million
2. Compared to the United States, Japan has ______ as many industrial robots in operation.
   a. half
   b. the same number
   c. twice
   d. five times
   e. ten times

3. The term *kaizen* refers to:
   a. an inventory control system
   b. continuous improvement
   c. highest quality
   d. a decision-making process
   e. ethnocentric policies
4. The term *kanban* refers to:
   a. an inventory control system
   b. continuous improvement
   c. highest quality
   d. a decision-making process
   e. ethnocentric policies
5. Which group is discriminated against in Japanese companies?
   a. Younger workers
   b. All workers with children
   c. Elderly workers
   d. Women
   e. None of the above
6. A fishbone diagram most directly addresses:
   a. causes of problems
   b. cost controls
   c. scrap reduction planning
   d. process planning
   e. facilities layout planning
7. The typical career path in a Japanese manufacturing company emphasizes:
   a. finance experience
   b. manufacturing experience
   c. sales experience
   d. any specialization
   e. generalization
8. A new hiree in a Japanese company would typically expect to receive his or her first promotion in:
   a. six months
   b. one year
   c. two years
   d. five years
   e. ten years
9. Which one of the following *best* describes Japanese decision making?
   a. the manager makes the decision and tells his subordinates
   b. the manager makes the decision and then gets input from all employees affected by the decision before implementing it
   c. the manager asks for input from all affected employees before making a decision
   d. the manager and his employees share in making the decision equally
   e. the manager delegates the decision completely to his or her employees
10. Which of the following statements is true about the Japanese government's role in business:
   a. it pursues a laissez faire policy
   b. it owns most of the major industries
   c. it provides subsidies and incentives to certain firms
   d. the key executives in most Japanese corporations are political appointees
   e. it regularly appropriates the assets of companies that make too much profit

Turn to page SK-8 for scoring directions and key.

FOR YOUR IMMEDIATE ACTION

WESTWOOD TRAVEL SERVICES

To: Ron Crawford, Director of Operations
From: Anne Mendales, President
Subject: Applying TQM to our travel business

I just finished reading a fascinating book, *Total Quality Management in the Department of Defense* (by Jack Strickland and Peter Angiola; U.S. Government Printing Office, 1989). It made me realize that everything we read about TQM in manufacturing industries such as autos and computers should be applicable to service businesses like ours.

As you know, we've gone from one small agency to five offices and nearly forty employees by responding to the needs of the business traveler. However, in the last six months, we've lost several valuable clients to more aggressive competitors. Our competition, especially Chapman Travel and the American Express agency, are doing a better job at meeting customers' needs.

TQM might be able to help us. I'd like you to think about how we might be able to implement TQM in our travel agencies. Please prepare an analysis describing how we could apply the concepts of continuous process improvement, customer focus, benchmarking, training, teamwork, and empowerment to our travel business to make us more competitive.

This is a fictionalized account of a potentially real management issue. It is meant for academic purposes only and is not meant to reflect either positively or negatively on Westwood Travel Services or any of its employees.