Chapter 14

Production and Operations Management

Learning Goals

1. Outline the roles of specialization, mechanization, and standardization in mass production.

2. Explain the contributions and problems associated with the use of assembly lines, automation, and robots in producing products and services.

3. Discuss the three components of production and operations management.

4. Identify the major factors involved in deciding plant locations.

5. Discuss the alternative designs for production facilities.

6. Explain the steps involved in the purchasing process.

7. Discuss the advantages and disadvantages of maintaining large amounts of inventory.

8. Outline the steps in the production control process.

9. Identify the contributions of quality circles in improving quality control.

14

Chapter Overview

Firms will continue to do business as long as they meet consumer demands. By producing and selling goods and services that satisfy consumer needs businesses will compete in the marketplace. What firms create for the marketplace, economists call **utility**—the want-satisfying power of a good or service. Economists have defined four types of utility: time, place, ownership, and form. Time, place, and ownership utility exist through marketing and distribution — having goods and services available for consumers at locations convenient for them and that facilitate title transfer at the time of purchase.

utility
Want-satisfying power of a product or service.

form utility
Utility created through the conversion of raw materials and other inputs into finished goods and services.

Form utility is created when raw materials are converted into finished goods or services. A chair is the sum of wood, design, manufacture and assembly. Cotton is harvested from fields, processed into thread, woven into fabric, and then by cutting, shaping, sewing, adding zippers and belt loops are made into Wrangler jeans. A firms production function is responsible for the creation of form utility.

production
Use of people and machinery to convert materials into finished products or services.

Production is the process of using people and machinery to convert materials into finished goods and services. Although the term production is sometimes used interchangeably with manufacturing, production is a broader term and includes a number of non-manufacturing processes. For example, production encompasses such extractive industries as fishing, lumber, and mining. Production also applies to the creation of services. Services are intangible outputs of the production system. They include outputs as diverse as trash hauling, education, haircuts, tax accounting, health delivery systems, mail services, transportation, and lodging. Table 14.1 lists five examples of production systems for a variety of goods and services.

Whether production results in a tangible good or an intangible service, both are created by the conversion of inputs into outputs. The conversion process may involve major changes in raw materials or a simple combining of finished parts. The butcher performs a production function by cutting up a side of beef into ground beef, steaks, chuck roasts, and other cuts of meat. General Motors combines tires, spark plugs, a battery, and thousands of other components to complete a new Saturn. These processes result in the creation of form utility.

This chapter describes the process of producing goods and services. We begin by explaining how production techniques, technology, and the concept of quality increase productivity. Then we identify the tasks of the production and operations manager in planning for production, implementing the plan, and controlling the production process. Finally, we discuss the impact of production on the environment.

Mass Production and the Assembly Line

The United States began as a colonial supplier of raw materials to Europe and grew into an industrial giant. A major factor in this remarkable change has been the application of the concept of mass production. **Mass production** is the manufacture of products in large amounts through the effective combination of three factors: specialized labor, mechanization, and standardization. The result of mass production is the availability of large quantities of products produced efficiently and sold at substantially lower prices than if such products were individually crafted.

mass production
Manufacture of products in large quantities as a result of standardization, specialized labor, and mechanization.

Specialization

specialization
Dividing work into its simplest components to permit concentration in performing each task.

A key factor in making mass production possible is **specialization**, the dividing of work into its simplest components so workers can concentrate on performing each task. The father of this approach was Frederick W. Taylor, whose efforts in the late nineteenth and early twentieth centuries were devoted to achieving industrial efficiency by reducing and simplifying jobs.

Taylor's contemporary, Frank B. Gilbreth, carried this reduction of tasks to the ultimate. Gilbreth called the smallest possible time-and-motion unit for a given task

Table 14.1 Some Typical Production Systems

Example	Primary Inputs	Transformation	Outputs
Animal feed factory (Primary Producer)	Grain, water, fish meal, personnel, tools, machines, paper bags, cans, buildings, utilities	Converts raw materials into finished goods	Pet food products
Trucking firm (Facilitator-transportation)	Trucks, personnel, buildings, fuel, goods to be shipped, packaging supplies, truck parts, utilities	Packages and transports goods from sources to destinations	Delivered goods
Retail store (Tertiary Producer)	Buildings, displays, shopping carts, machines, stock goods, personnel, supplies, utilities	Attracts customers, stores goods, sells products	Marketed goods
Automobile body shop (Secondary Producer)	Damaged autos, paints, supplies, machines, tools, buildings, personnel, utilities	Transforms damaged auto bodies into facsimiles of the originals	Repaired automobile bodies
County sheriff's department (Facilitator-safety)	Supplies, personnel, equipment, automobiles, office furniture, buildings, utilities	Detects crimes, brings criminals to justice, keeps the peace	Acceptable crime rates and peaceful communities

a *therblig*, a term that comes from reversing the letters in his last name. He applied many of his production concepts to operating his household and became famous to later generations in the book and film *Cheaper by the Dozen*, written by 2 of his 12 children.

Firms conduct time-and-motion studies to increase worker productivity. The studies help determine the rate at which a job should be done and the most efficient sequence and number of motions needed to accomplish a specific task. The industrial engineers at United Parcel Service used time-and-motion studies to improve the sorting and delivery of packages.[1]

Mechanization

Once jobs were separated into smaller tasks, managers could consider the possibility of **mechanization**, the use of machines to perform work previously performed by people. Before the Industrial Revolution, work was performed primarily by people and animals. In 1850's, the typical American worker spent 70 hours per week on the job and produced an average of 25 cents worth of goods per hour. The average American farmer produced enough food for himself and five others. Today, the average American working a 40-hour week and, with machines, produces goods having 39 times the value of their counterpart of the mid-nineteenth century; and the todays farmer produces enough food for themselves and 92 others.

mechanization
Use of machines to perform work previously performed by humans.

Standardization

The third component of a mass production system—**standardization**— involves the production of uniform, interchangeable goods and parts. Although production of virtually identical products is taken for granted today, this was not always the case.

standardization
Production of uniform and interchangeable goods and parts.

Before 1798 each part of an army rifle was manufactured by hand. The result was that each part fit only one gun. That year Eli Whitney, inventor or the cotton gin, introduced a new method of forging and stamping out "standard" interchangeable parts for muskets. These parts were produced in quantity and then assembled into finished rifles at a later stage of production. Also, with a little filing each part could be used in other muskets when the parts were worn out or damaged. Availability of standardized parts makes possible the replacement of defective and worn-out components. Repairs of such products as automobiles are facilitated by the simple purchase of replacement parts at a local auto supply store. Without such standardization, each needed replacement would involve special machining at unacceptable expense.

Assembly Lines

assembly line
Manufacturing technique wherein the product passes through several workstations, each with a specific task.

Because of worker specialization, mechanization, and standardization, Henry Ford revolutionized the factory by using what he called the **assembly line** to assemble his automobiles. This manufacturing technique involved placing the product upon a conveyor system that travels past numerous workstations where workers perform specialized tasks such as welding, painting, installing a part, or tightening a nut. Before adding the assembly line, Ford's Model Ts were assembled at the rate of one for each 12-hour workday. The assembly-line technique cut the number of work hours required to 1.5. Not surprisingly, dozens of other industries whose production consisted of assembling complex products quickly adopted the assembly-line technique.

Although the assembly line continues to be a fixture in many manufacturing operations, the trend toward worker specialization and repetitive performance of minute tasks has been reversed. As Harvard University professor Richard Walton points out, "[The Industrial Revolution] taught that jobs should be fragmented and de-skilled and that mental functions, like planning, should be separated from physical work. Now, after six decades, we are unraveling that logic."[2] This opinion

This small team of employees is one of 24 craft stations that assemble General Motors' Buick Reatta. GM's goal of using this approach to assembly-line production is to create a work atmosphere that provides all GM workers the opportunity to make a worthwhile contribution in producing a top-quality product.

is shared by Donald F. Ephlin, vice-president of the United Automobile Workers: "We overdid the old principle that work should be broken down into the smallest operations on the basis that the workers are stupid. Thank goodness, we are beginning to reverse that."[3]

General Motors changed its attitude toward assembly-line workers. GM is creating a work environment that considers the dignity and worth of each worker. With the help of its employees, GM developed a new assembly-line approach—the craft station concept—to assemble the Buick Reatta. The car moves down the assembly line to 24 separate craft stations, where a small team of workers performs tasks at its own pace. Each team must be satisfied with the quality of its tasks before it moves the vehicle to the next craft station.[4]

Classifying Production Processes

Methods used in producing goods and services are classified by the means and the time used to create them. Goods or services result from the use of either an analytic or a synthetic system under a continuing or an intermittent process.

An **analytic system** is one in which a raw material is reduced to its elemental parts so that one or more products are produced. In petroleum refining, crude oil is broken down and gasoline, wax, fuel oil, kerosene, tar, and other products are obtained. A meat-packing plant slaughters cattle and produces various cuts of meat, glue from the horns and hooves, and leather from the hides.

analytic system
System of reducing raw materials into component parts.

A **synthetic system** is the reverse of an analytic system. It combines raw materials or parts into a finished product. On the assembly line, an automobile is produced from the combination of thousands of individual parts. Pharmaceuticals and chemicals are produced by a synthetic system, as is stainless steel.

synthetic system
System that combines raw materials or parts into a finished product or changes them into completely different products.

Production by **continuous process** describes a manufacturing operation in which long production runs turn out finished products over a period of days, months, or even years. The steel industry provides a classic example; its blast furnaces never completely shut down unless a malfunction occurs. Petroleum refineries, chemical plants, and nuclear power plants also represent continuous process production. A shutdown can ruin equipment and prove extremely costly. The shutdown of a nuclear power plant, for example, can cost the utility an estimated $500,000 a day to replace the lost electricity.[5]

continuous process
Manufacturing operation with long production runs lasting months or years.

Production by **intermittent process** describes a manufacturing operation in which the production run is short and machines are shut down frequently or changed in order to produce different products. When intermittent production occurs in response to a specific customer order, it is called *job-order production*. When it is used for inventory, it is called *lot-order production*.

intermittent process
Manufacturing operation with short production runs allowing machines to be shut down or changed to make different products.

Most services use an intermittent production system. Standardization of services provided by accountants, plumbers, electricians, and dentists has traditionally been considered unworkable because the problems each service provider confronts are different and each of them requires a different approach or production system. This thinking has been challenged in recent years, however, as service providers seek to enhance productivity. The move to industrialize the service sector in a fashion similar to what occurred in the production of tangible goods is illustrated by Jiffy Lube auto service, giant vision retailers like Lens Crafters, Midas's specialized muffler service, Terminix pest control services, home cleaning providers such as The Maids, and the growing number of dental chains located in regional shopping centers. Movement in the direction of the continuous-flow production system, once thought impossible for services, is revolutionizing the service sector.

Automating the Production Process

Continuous-process production systems are typically highly mechanized and frequently utilize assembly lines. A logical extension of mechanization is *automation*—the replacement of people with machines that perform production processes with little or no help from humans.

Once jobs are divided into specific tasks, it is often possible to design machines to perform such tasks, eliminating humans from the repetitive, boring work that characterizes many production operations. In an automated factory, people design the systems and occasionally monitor their operations and inspect the final outputs, but the actual work is performed by machines. At Unisys Corporation, for example, workers feed electronic parts to a robot. The robot inserts electronic chips into circuit boards. Workers then check the robot's work. Human inspection is important because the circuit boards are the core of the computer terminals and workstations that Unisys manufactures. At the end of the production process, other workers pack the finished products into corrugated cartons.[6]

The following sections describe production technologies that American businesses are using to achieve higher productivity.

Robots

To increase factory productivity and free people from routine assembly-line tasks and potentially dangerous assignments, such as handling hazardous materials, many production managers are replacing assembly-line wokers with robots. A **robot** is a programmable machine capable of performing a variety of tasks requiring ordered manipulations of materials and tools.[7]

robot
Reprogrammable machine capable of performing numerous programmed tasks by manipulating materials and tools.

Today's industrial robots look nothing like the androids in the *Star Wars* movie, and they vary considerably in complexity and versatility. A pick-and-place robot is the simplest version; its freedom of movement is usually limited to two or three directions as it picks up an item from one spot and places it in another. The most common industrial robot is the servo robot. The name comes from the servomechanisms that permit the arm and gripper to alter direction in midair without having to trip a mechanical switch. It can be taught a sequence of arm-and-gripper movements, which are repeated indefinitely. A computerized servo robot can be taught new tasks through instructions transmitted electronically. In addition, some computerized robots have one or more artificial senses, typically sight or touch.

The advantages of robots in the factory has been demonstrated. Robots don't take coffee breaks, call in sick, or experience lowered productivity as a result of fatigue or attitude. As technology has reduced their cost and increased their flexibility, robots have become increasingly common in American industry. Initially used primarily in the automotive and electronics industries, robots are moving into other fields. For example, a class-ring manufacturer uses a robot to position and hold the rings while they are engraved by a laser. A robot at a novelties maker stretches balloons flat so they can be printed with slogans. A custom upholstering firm uses a robot to cut carpeting for vans.[8]

Advances in robotic technology in such areas as vision, sensing, and mobility are making robots especially useful in many service industries. In health care, robots that drill precisely into the skull assist surgeons in performing delicate brain operations. Some hospitals use robots to deliver meal trays to patients; others use voice-controlled robots with versatile hand movements to feed, shave, and brush the teeth of paralyzed patients. Businesses are installing surveillance robots rather than hiring human guards. With microwave vision, the robots can outperform humans by seeing through walls, in the dark, and at distances up to 130 feet.

Service robots, like their industrial counterparts, are well suited to perform jobs that are dangerous to humans. Maintenance and repair work at nuclear power plants requires hundreds of employees working in short relays to minimize their exposure to radiation. Robots can do the same work faster without suffering the risk of radiation exposure. Offshore oil and gas firms are replacing deep-sea divers—more than 50 of whom have lost their lives in the North Sea in the past two decades—with robots to build and maintain drilling rigs. The U.S. Navy is using robots instead of divers to cut the mooring cables of stationary mines. Service robots designed to fly are used to inspect high-tension electric wires and spot forest fires.[9]

Futuristic applications for robots in production will expand as technology improves. Engineers are adapting the technology of microelectronics in developing very small motors and gears for a new generation of robots dubbed gnat robots, so called because they will be no larger than the size of a gnat. Researchers envision numerous applications for these microrobots. Surgeons, for example, could use microrobots to perform "closed-heart" surgery. A microrobot on a catheter could be inserted into a patient's blood vessel, travel through the vascular system to the heart where, by remote control, a surgeon could direct the tiny machine to correct a heart defect.[10]

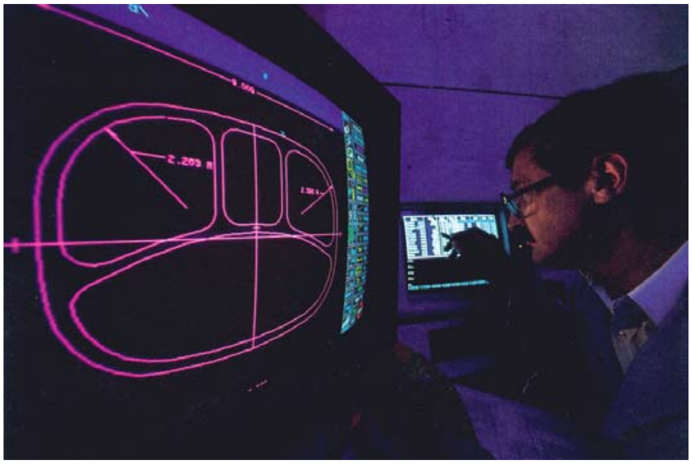
Computers

The growing importance of robots and automation in the modern factory has been accompanied by the integration of new computer technologies. U.S. companies gain the edge they need to compete effectively with foreign manufacturers using computer-aided design (CAD), computer-aided manufacturing (CAM), flexible manufacturing systems (FMS), and computer simulations which have revolutionized the way American industry designs and manufactures products.

computer-aided design (CAD)
Interaction between a designer and a computer resulting in a product, building, or part that meets predetermined specifications.

Computer-Aided Design. A process called **computer-aided design (CAD)** enables engineers to design parts and buildings on computer screens faster and with fewer mistakes than on paper. Using a special electronic pen, engineers can sketch three-dimensional designs on a tablet connected to the computer. Some systems allow the design to be sketched directly on the computer screen. The computer is then used to make any design changes. When engineers are satisfied with their sketches, they instruct the computer to analyze the design for certain characteristics or problems.

Engineer in aerospace using computer aided design on jet engines to develop a better engine with more thrust and a longer life.



Engineers at Campbell Soup Company use the technology of computer-aided design to develop food packaging that gives consumers such benefits as added convenience and portion control. In this photo, an engineer uses CAD in designing a new

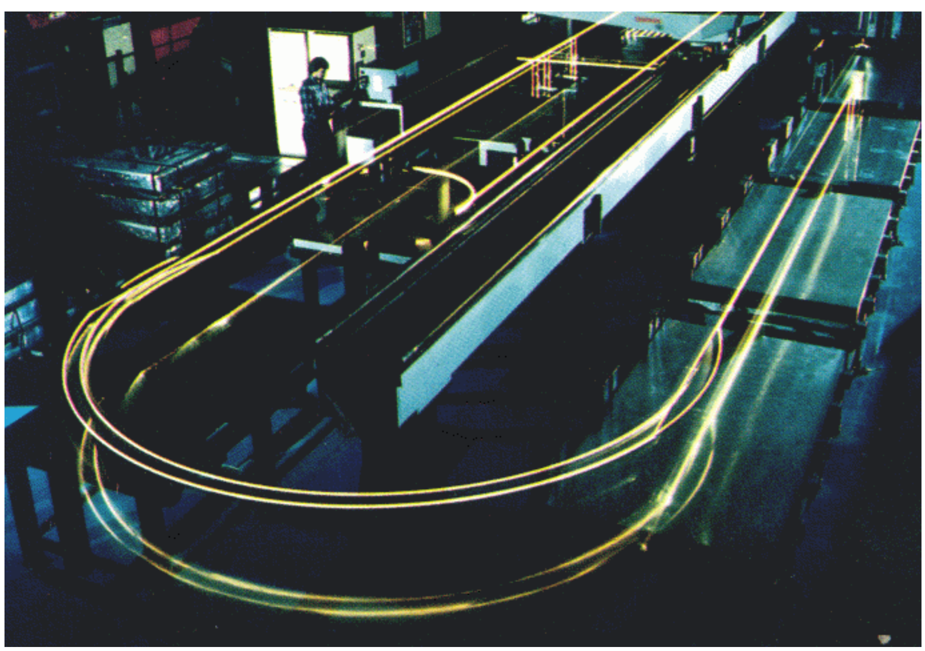
Tractor designers use the computer to put the structural components of a new tractor design through the paces of a simulated field test. If, for instance, they find a problem with weight distribution they make the necessary changes on their computer terminal. Only when they are satisfied with all the structural characteristics of their design will they manufacture an actual tractor model. In a similar manner, automobile and aircraft designers can analyze the shape and strength of a proposed automobile body or aircraft fuselage and wings under various conditions.

In recent years, many firms have installed CAD systems as part of their cost-control programs. CAD is used extensively by designers at Johnson & Johnson in an effort to shorten the development cycle, improve the efficiency, and reduce the cost of surgical staplers and other wound closure products. CAD has helped reduce the total product cost of Gillette Company's Braun coffee makers. Computer-aided design also benefits service firms. CAD is a key tool used by engineers at Browning-Ferris Industries, a waste-disposal services firm, in the design and analysis of landfill sites.

computer-aided manufacturing (CAM) Computer analysis of a CAD to determine steps in producing the design, and electronic transmission of instructions to production equipment used in producing the part or product.

Computer-Aided Manufacturing. The process of **computer-aided manufacturing (CAM)** picks up where CAD leaves off. It enables manufacturers to use specially-designed computers to analyze the necessary steps that a machine must make to produce a needed product or part. Electronic signals are then transmitted to the production processing equipment instructing it to perform the appropriate production steps in the correct order.

The Vanity Fair division of VF Corporation uses a CAD/CAM system in designing and manufacturing women's intimate apparel. Computers are used to design new styles and then transform them into patterns for different sizes. The dimensions of the garments are recorded, and patterns are laid out to minimize fabric waste. This design data is then transferred to computers on the factory floor that direct the fabric-cutting machines. The process involves several weeks of labor when performed manually, but with CAD/CAM, the process now takes only several days. By adopting the new computer technology, apparel makers such as VF are becoming more competitive with Asian firms with lower wage for labor.[11]



This flexible manufacturing system at the Westinghouse plant in Sumter, South Carolina, produces sheet metal components for panelboard and switchboard enclosures. The system dramatically reduced work-in-process, storeroom inventories, and production cycle time for these parts. The FMS was developed by Westinghouse's Productivity and Quality Center and its automation division.

Flexible Manufacturing Systems. The state of the art in industry is a **flexible manufacturing system (FMS)** that can be modified quickly to manufacture different products. The typical system consists of computer-controlled machining centers to produce metal parts, robots to handle the parts, and remote-controlled carts to deliver materials. All components are linked by electronic controls that dictate what will happen at each stage of the manufacturing sequence, even automatically replacing broken or worn-out drill bits and other implements.

flexible manufacturing system (FMS)
State-of-the-art facility that allows production methods to be modified quickly when different products are manufactured.

Flexible manufacturing systems also enable manufacturers to produce different versions of a product in small batches at mass-production speeds. An FMS at one General Electric plant can be programmed to produce 2,000 variations of 40 basic models of electric motors. Such flexibility allows GE, Lockheed, Caterpillar, and other firms using FMS technology to adapt quickly to changing market needs.[12]

Computer Simulation. As automation and robots increase the complexity of the production process, more and more production managers use computer simulations to analyze the efficiency of their operations. By constructing a computer model of the production process, which is graphically displayed on a computer screen, managers can determine the best way to produce their products from the input to output stages. Some firms use computer simulations to schedule the delivery and handling of component parts. Others use it for production-line planning. Ingersoll-Rand, for example, developed a production system for making ball bearings that would utilize 77 machine tools that performed 16 functions. A computer simulation of the plan indicated it could be improved and run more efficiently by eliminating four of the machine tools, thus saving the company $750,000 in equipment costs.[13]

The Tasks of Production Managers

Obviously, the process of converting inputs into finished goods and services must be managed. This is the task of **production and operations management**—to manage the use of people and machinery in converting materials and resources into finished goods and services.

production and operations management
Managing people and machinery used in converting materials and resources into finished products and services.

Managers of the production function are responsible for three major activities. First, production managers must make plans for production inputs. This involves determining the inputs required in the firm's operations and includes such decisions as product planning, plant location, and provision for adequate supplies of raw materials, labor, power, and machinery. These plans must be completed before the conversion process from raw material to finished product or service can begin.

Second, production managers must make decisions about the installation of the necessary inputs. These include the actual plant design, the best types of machines to be used, the arrangement of the production machinery, and determinating the most efficient flow of work in the plant.

Third, production managers must coordinate the production processes: the routing material to the right places, the developing work schedules, and the assigning work to specific employees. The objective is to promote efficiency.

Planning the Production Process

When Richard Dauch joined Chrysler Corporation as executive vice-president of manufacturing, he faced a formidable challenge. At the time, Chrysler had the highest production costs and lowest-quality products in the automobile industry. Dauch's job was to devise a production plan that would improve product quality, lower production costs and improve product quality to make the firm more competitive with domestic and foreign car makers. The plan he developed extended from product design to relationships with suppliers and workers to assembly-line layout.

Dauch's first planning step was aimed at satisfying customers who had complained that Chrysler cars rattled and squeaked and had uneven paint jobs.

Facility location is an important element in McDonald's growth strategy. It started with restaurants in suburban locations but has broadened its business base by opening restaurants in urban areas, airports, commercial buildings, zoos, shopping malls, train stations, casinos, hospitals, and military bases. McDonald's targets the trucker and long distance traveler market by locating restaurants near interstate highways, such as the one in this photo in Litchfield, Illinois.

Dauch planned to correct these problems by automating production plants. Robots would build cars according to precise specifications, and computers would control the robots and inspect their work. New paint shops, complete with ostrich feathers that removed dust from car bodies, and the application of a clear top coating would result in better paint jobs. A new assembly-line setup would eliminate costly and inefficient repair work. Regular meetings and open communications would heighten workers' consciousness to build quality products. Suppliers would have to meet strict specifications for quality, costs, and delivery. A new product-design procedure would take manufacturing problems into account during the product planning stage. Simpler car designs and fewer options would further reduce product costs.

Dauch's production plan worked. In six years, Chrysler was building 8,000 vehicles a day, compared to 4,500 per day. Today, it takes 102 worker-hours to build a vehicle, compared to 175. Defects per 100 vehicles have decreased 42 percent. Production planning is an ongoing process.

Product Planning

A firm's total planning process begins with the choice of goods and services it wants to offer its customers. Plant location, machinery purchases, pricing decisions, and selection of retail outlets are all based on product planning. In a sense, the sole economic justification for the firm's existence is the production and marketing of want-satisfying products.

Because a product must be designed to satisfy consumer needs, marketing research studies are used to obtain consumer reactions to proposed products, to test prototypes of new products, and to estimate the potential sales and profitability of new products. The production department is primarily concerned with (1) converting the original product concept into the final product and (2) designing production facilities to produce this new product as efficiently as possible. The new product must not only be accepted by consumers, it must also be produced economically to assure an acceptable return on company funds invested in the project.

Traditionally, product planning was the joint responsibility of the production and marketing departments. But today, innovative firms such as Xerox, Procter & Gamble, Polaroid, and Corning Glass Works involve other company personnel in product design and development. For example, Xerox included manufacturing experts, marketers, product planners, systems engineers, customers, and potential suppliers in planning a new line of copier machines.[14]

The team approach to planning helps firms shorten the product development cycle, enabling them to bring products to market faster. Xerox, whose world market share dropped from 82 percent to 41 percent in six years, adopted the team approach after learning that its Japanese competitors developed new copier models in two years, while it took Xerox four to five years. Now Xerox can produce copiers in two years.[15]

Facility Location

One of the major production decisions is the choice of plant location. This decision requires careful planning and typically represents a long-term commitment and a substantial investment. A poor location poses severe problems for a firm attempting to compete with better-located competitors.

Consider the case of Lionel Trains. The firm's management based a location decision primarily on low-cost labor. In the early 1980s, Lionel executives decided to manufacture toy trains, tracks, and collector trains in Tijuana, Mexico, to take advantage of 55-cent-per-hour wages. Lionel closed its plant in Chesterfield Township, Michigan, and fired all but 5 of its 350 employees. Inadequate planning almost brought Lionel to financial ruin. Soon after the move, it encountered unanticipated communications, supply, and labor problems. The Tijuana telephone company could give Lionel only two telephone lines, not nearly the number the firm needed to conduct business. Lionel managers also realized there were no Mexican firms to do plating work, and they were forced to send parts to contractors in California. They also assumed they could hire and train local Mexican managers, but, unable to find managerial talent they needed in Tijuana, they had to bring engineers from Michigan to Mexico, which cost the firm thousands of dollars in airfare and housing. Because of these and other problems, the company was able to fill only one-third of its orders, resulting in complaints from dealers and customers. Lionel products lost shelf space in retail stores and market share to competitors. After three years in Tijuana, Lionel moved back to Michigan, leased the plant it had sold, rehired many former workers, and started recovering its financial losses.[16]

What Constitutes a Good Location?

Choosing a location typically involves two decisions: (1) selecting a community in which the facility will be located and (2) choosing a specific site within the community. The choice of a location should be made after considering such factors as proximity to raw materials and markets; availability of labor, transportation, and energy; state and local taxes; and community living conditions.

Proximity to Raw Materials. When raw materials are large and heavy, manufacturing firms often locate their plants near their input source. Production facilities for sheetrock are usually close to where gypsum, the major ingredient, mined. (Mined gypsum must be dehydrated immediately in order to avoid transporting the water in it.) Trees are processed into wood products near forests, eliminating the cost of transporting those parts of the log that become waste materials. Because 32,000 gallons of water are required to produce one ton of paper, paper mills also must be located in areas where large quantities of clean, low-cost water are available.

Proximity to Markets. If transportation costs for raw materials are not a significant part of total production costs, the plant is likely to be located near markets where the final products will be sold. A nearby location allows the manufacturer to provide fast, convenient service for customers. Many manufacturers of automobile components are located in the metropolitan Detroit area so as to provide quick service for auto assembly plants.

Some foreign firms with large U.S. markets set up production and service facilities in the United States. They include the Industrial Bank of Japan (New York), Mitsubishi (Bloomington, Illinois), Nissan (Smyrna, Tennessee), Honda (Columbus, Ohio), and Volvo (Norfolk, Virginia).

Facilities that provide services, such as dry cleaners, laundromats, banks, hotels, local government offices, and hospitals, must be located near the largest concentrations of their target customers. If a dry cleaner were located too far from where people live, no one would patronize the business.

Table 14.2 Factors in the Facility Location Decision

Location Factor	Examples of Affected Businesses
Transportation	
Proximity to markets	Baking companies or manufacturers of other perishable products, dry cleaners and hotels or other services for profit
Proximity to raw materials	Mining companies
Availability of transportation alternatives	Brick manufacturers, retail stores
Human Factors	
Labor supply	Auto manufacturers, hotels
Local regulations	Explosives manufacturers, welding shops
Community living conditions	All businesses
Physical Factors	
Water supply	Paper mills
Energy	Aluminum, chemical, and fertilizer manufacturers

Availability of Personnel. A third consideration in the location of production or service facilities is the availability of a qualified labor force. One early problem faced by the developers of a giant shipbuilding complex in the little Gulf Coast town of Pascagoula, Mississippi, was the lack of sufficient numbers of skilled workers. Many electronics firms are located in the San Jose, California, and Boston areas, which have high concentrations of skilled technicians. The same is true for Hartford (insurance), Pittsburgh (steel), and Seattle (aircraft).

When unskilled workers can be used, the manufacturer can choose from a much greater number of alternative locations. Many manufacturing plants employing unskilled labor have located in the South, where wage rates have historically been below those in the North. In the worldwide search for inexpensive labor, a number of electrical equipment manufacturers have begun to manufacture parts in the United States, ship them in unassembled form to Taiwan, for assembly there by inexpensive labor, and then ship them back to the United States for inclusion in a finished product.

Transportation. Most manufacturing plants use transportation facilities to ship raw materials to the plant and finished products to customers. At most locations, the producer chooses among several alternatives such as trucks, railroads, ships, and airplanes. Availability of numerous alternatives results in increased competition and lower rates for transportation users.

Service facilities also must consider available transportation. Customers must be able to get to them by either public transportation or private automobile. If cars are the primary method of transportation, then adequate parking must be provided.

Energy. While all production facilities are affected by both the availability of adequate energy resources and their costs, factories producing goods tend to be more affected than service industries.

The aluminum industry began in the Tennessee Valley because the manufacture of aluminum requires great amounts of electrical power. The cheap electricity provided by the Tennessee Valley Authority allows aluminum manufacturers to produce their product at lower costs than they could in Baltimore or Philadelphia, where electricity rates are substantially higher. The availability of inexpensive power supplies is a major consideration in plant location for certain industries.

Taxes. Another factor to consider in facility location is tax structure for the local and state governements. Local and state governments typically impose real estate taxes on factories, equipment, and inventories. Sales taxes and income taxes may also be imposed. These taxes, which vary considerably from state to state and city to city, should be considered in making the location decision. Some states and cities attempt to entice manufacturers or service businesses into their areas by granting low taxes or temporary exemptions from taxation. However, low taxes may also mean inadequate municipal services. Taxes must be considered together with the availability and quality of needed city services.

Some governments attempt to influence a firm's location decision by offering other incentives in addition to low taxes. Kentucky, for example, agreed to pay half the cost of preparing the plant site and installing sewers and utilities for Toyota Motor Corporation's new auto-assembly plant near Georgetown. The state also funded construction of new local highways, built an employee training center where 3,000 American employees learn Toyota's techniques of producing vehicles, and agreed to provide English-language classes for Toyota's Japanese employees and their families for ten years.[17]

Environmental Impact. An increasingly common requirement for firms desiring to locate a production facility in a particular area is an **environmental impact study**. It analyzes the impact of a proposed plant on the quality of life in an area. Regulatory agencies typically require the study to cover such topics as impact on transportation facilities; energy requirements; water and sewage treatment needs; effect on natural plant life and wildlife; and polution to water quality, air quality, and noise pollution.

environmental impact study
Analysis of the impact of a proposed plant location on the quality of life in a specific area.

14

Both community and state pressure in Maine and New Hampshire prevented construction of oil refineries in New England. Construction of a Miami jetport located in part on the edge of the Everglades was blocked by environmentalists. The Delaware Coastal Zone Act prevents heavy manufacturing industry from locating within two miles of the state's 115-mile coastline. State and community attitudes, thus, often play a role in the facility location decision.

Community Living Conditions. A final consideration in choosing a location is the quality of the community, as measured by its school system, colleges, cultural programs, fire and police protection, climate, income levels of its residents, and community attitudes toward the new facility.

Factors affecting the decision on plant location are summarized in Table 14.2. The final decision is likely to result from careful evaluation of all the factors. Since no one location is likely to be superior in every factor, the ultimate choice is likely to involve trade-offs.

Choosing a Site

Once a community has been selected, a specific site is to be chosen. Before this can be done, a number of factors are considered: zoning regulations; availability of sufficient land; cost of the land; existence of shipping facilities, such as railroad sidings, roads, and dock facilities; and construction costs.

industrial park
Planned commercial site that provides necessary zoning, land, shipping facilities, and waste disposal outlets.

Most cities have at least one **industrial park**, a planned site location that provides necessary zoning, land, shipping facilities, and waste disposal outlets. These sites are created to entice manufacturers to locate new plants in the area by providing maximum cooperation between the firm and the local governing bodies.

Proximity to customers or clients is often the determining factor in the location of service facilities. Such service-oriented organizations as government services, health and emergency services, retailers, and profit-seeking service firms attempt to locate near their customers or clients. Locating near population concentrations allows such facilities as hospitals, fire stations, and ambulance services to provide fast service and minimize loss of life and loss of property.

Layout of Production Facilities

process layout
Manufacturing facility design suited to the production of a variety of nonstandard products in relatively small batches.

product layout
Manufacturing facility design that accommodates a few products in relatively large quantities.

fixed-position layout
Manufacturing facility design that locates the product in a fixed position, with workers, materials, and machines transported to and from it.

customer-oriented layout
Service facility design that promotes interaction between the organization's services and the customers.

An efficient production facility is the result of careful consideration of all phases of production and the necessary inputs at each step of the process. As Figure 14.1 indicates, a number of alternatives are available in selecting the most appropriate layout. The first three designs are common in manufacturing facilities, and the last layout is often used in service facilities.

A **process layout** is designed to accommodate a variety of nonstandard products in relatively small batches. In this layout, workers and equipment performing the same activity, or process, are grouped in one department or location. Custom machine shops are typically organized in this fashion.

When a firm produces large quantities of the same or similar products, an efficient design is a **product layout**. This layout accommodates only a few product variations. Product layouts are frequently used in assembly-line operations, such as those in the automobile industry.

In a **fixed-position layout**, the product stays in one place and workers, materials, and machines are transported to and from that position. This approach is common in such operations as missile assembly, ship construction, large aircraft assembly, and bridge construction, where the product is very bulky, large, heavy, or fragile.

A **customer-oriented layout** is common in service facilities where the facility must be arranged to enhance the interactions of customers and the organization's services.

Implementing the Production Plan

Once the product or service decisions have been made, the production facilities developed, the necessary machinery purchased, and the most efficient facility layout determined, management must implement the production plan. Raw materials, component parts, and all other goods and services that will serve as production ingredients must be purchased, from paper clips to steel bars and computers. Inventory levels must be determined and controlled, and production schedules must be put into operation. Each of these activities has to be performed efficiently if the production plan is to succeed.

The Make, Buy, or Lease Decision

One of the fundamental issues facing every producer is the **make, buy, or lease decision:** whether to manufacture a needed product or component, to purchase it from an outside supplier, or to lease it. Rolls-Royce provides the engines for the Boeing 757 plane, while Boeing's Wichita plant builds the nose, and another outside supplier, Vought, manufactures the tail section. Like other auto companies, Ford Motor Company depends upon hundreds of suppliers to produce over half of the 12,000 parts used in a typical Ford. By contrast, brewers such as Anheuser-Busch and Coors manufacture their own cans at company-owned subsidiaries. Many commercial airlines, however, lease their aircraft rather than producing or purchasing them.

make, buy, or lease decision Whether to manufacture, purchase, or lease a needed product, component, or material.

Factors affecting the make, buy, or lease decision include the costs of leasing or purchasing parts from outside suppliers as compared with the cost of producing them in-house; the availability of outside suppliers and dependability of their shipments in the quality and quantity needed; the need for confidentiality; and whether the need for the commodity in question is short or long term. Because airlines often experience equipment shortages, they arrange for short-term leases of engines and other aircraft components required for immediate operating needs.

Even when the decision is made to purchase from outside suppliers, managers should maintain more than one supply source. An alternative supplier assures the availability of needed materials in the event of strikes, quality assurance problems, or other situations preventing a supplier from meeting its delivery commitments.

Purchasing Decisions

The objective of purchasing is to buy the right materials in the right amounts at the right time for the right price. To achieve this goal, the purchasing department must (1) precisely determine the correct materials to purchase, (2) select the best supplier, and (3) develop an efficient ordering system.

Selecting the Right Supplier

The choice of a supplier is usually made by comparing the quality, prices, availability, and services offered among competing companies. In many cases, quality and price are virtually identical among suppliers, and the choice is based on factors such as the firm's previous experience with each supplier, speed of delivery, warranties on purchases, and other services.

For major purchases, negotiations between the purchaser and potential suppliers may take several weeks or even months, and the buying decision may rest with a number of persons in the firm. The choice of a supplier for industrial drill presses, for example, may be made jointly by the production, engineering, and maintenance departments as well as by the purchasing agent. These departments have different views that must be reconciled before purchasing decisions are made.

Raw materials and component parts are often purchased on a long-term contractual basis. If a manufacturer requires a continuous supply of materials, a one- or two-year contract with a supplier ensures they will be available as needed.

Improving Buyer-Seller Relationships. Emphasis on quality improvement in recent years has affected the buyer-supplier relationship. Many firms are drastically reducing their number of suppliers, keeping only those that deliver defect-free parts on time. Xerox, for example, purchased parts and components from 5,000 suppliers in 1980. Today, it buys from 400 suppliers and plans to reduce that number to 250 by the late-1990s. Xerox now receives 99 percent of its parts defect-free, compared to 92 percent in the early 1980s.[18]

Firms are also building better and longer-term relationships with their suppliers. Boeing sponsors seminars to teach its suppliers about quality improvement techniques. Harley-Davidson offers its suppliers courses in statistical process control and assists them in improving their product design. General Motors rewards suppliers by giving them long-term contracts.

Suppliers, in turn, are improving their relationships with their customers. AMP, a manufacturer of electrical and electronic connectors and terminals, guarantees the quality of its parts so customers do not have to inspect them. AMP engineers become involved in the early design stages of customers' new-product development. Walter Raab, AMP's chairman and CEO, says such involvement "allows us to enhance our customers' products, not only in terms of performance, but in making the final product easier to manufacture."[19] Some suppliers are offering to produce parts-making systems or do parts-assembly work rather than supply individual components. A division of Dana Corporation now supplies Ford with subassemblies of an entire power system (axles, drive shafts, and transfer cases); in the past, it simply supplied Ford with axles. To serve its customers better, Johnson Controls has located ten automobile seating and trim plants near its major customers, including Ford, Honda, General Motors, Toyota, and Chrysler.

Inventory Control

inventory control
Balancing costs of holding raw materials, work in progress, and inventory with costs involved in ordering them.

Inventory control balances the need to have inventory on hand to meet demand with the costs involved in carrying the inventory. The financial costs of carrying inventory are the funds tied up in it that cannot be used in other activities of the business. Among the expenses involved in storing inventory are warehousing, taxes, insurance, and maintenance. Too much inventory represents wasted expenditures.

But a shortage of raw materials, parts, goods, or sales often means lost production—and delays in production mean unhappy customers if the delays result in late delivery of promised merchandise. Firms lose business when they are consistently unable to meet promised delivery dates or when their shelves are empty. These two costs must be balanced to produce acceptable inventory levels.

perpetual inventory
Continuously updated listing of items in inventory.

A commonly used technique for monitoring the amount and location of inventory is the maintenance of a **perpetual inventory**. This inventory control system continuously updates all major inventory systems. The system is typically computerized and frequently will automatically determine orders to be made and print purchase orders at the appropriate times. The scanning devices used in many supermarkets are typically linked to perpetual inventory systems used in reordering merchandise. As a shopper's purchase is recorded, each item is subtracted from the inventory data stored in the computer. Once inventory on hand drops to a predetermined level, the merchandise is automatically reordered.

just-in-time (JIT) inventory system
System designed to minimize inventory at production facilities.

Just-in-Time Inventory System. Just ten years ago, you could walk into a typical American factory and see several weeks' worth of parts and supplies piled high throughout the plant. Walk into a similar factory in Japan and you would have noticed no such inventory backlog. The Japanese plant then and now may have only enough supplies on hand to keep it going for a day. This shortage is hardly accidental. It is an essential ingredient of the **just-in-time (JIT) inventory system** used by major Japanese corporations for years and gaining acceptance in American firms.

The JIT system does what its name implies: It supplies needed parts to the production line on a last-minute basis. As a result, factory inventory levels are as low as possible and production costs are held down. Just-in-time delivery makes it easy to spot and expose production problems before they are built into the system, and it shifts responsibility for the problems from the consumer to the suppliers. If a part is defective, the assembly line shuts down and the supplier risks losing the firm's business. Often, when a slightly defective part is found in a U.S. plant, it is made to fit rather than shipped back to the supplier. With weeks of inventory on hand, companies are forced into this decision to avoid a production slowdown.

The just-in-time system also enables firms to respond rapidly to changes in the market, maintain high standards, and to remove all non-essential personnel from the production system. It forces them to keep their machinery in perfect running order at all times—a practice that has saved firms considerable time and money. Just-in-time production at an AT&T plant cut the production time for some products from three-and-one-half weeks to two-and-one-half days.

The advantages of JIT are helping many U.S. corporations, both large and small, become more competitive. By switching to a JIT system, Fireplace Manufacturers Inc., a California firm that makes prefabricated metal fireplaces, reduced its inventory of raw materials and work in progress from $1.1 million to $750,000. Just-in-time helped Huffy Corporation become the most productive bicycle maker in the world. Huffy executives measure the results of the changeover to JIT in terms of the number of tubs the firm uses to store and move parts. Before JIT, parts filled 3,000 tubs, but now only 700 are needed.[20]

Materials Requirement Planning

In order to implement the production plan, an adequate amount of the raw materials, components, and operating supplies must be available when needed. For relatively simple products with few components provided by numerous suppliers in the immediate vicinity, this is a relatively simple process. A telephone call may be sufficient to secure overnight delivery of needed materials, and management enjoys the luxury of minimal investments in inventory and little risk of production downtime resulting from lack of needed materials.

This process of ensuring adequate amounts of materials and parts in the right amounts at the right times becomes much more complicated when complex products are involved. For a firm such as Ford Motor Company, determining the efficient sequencing of precisely the exact amounts of materials at exactly the right times can be a nightmare. If the components are received too early, they must be stored until needed. If they arrive late, production is disrupted until they are available. In his book *American Made*, Harold Livesay describes a group of Chrysler Corporation workers using acetylene torches to cut holes in a locked railway car filled with bolts. Stopping the production line while assembly-line workers waited for the car to be unlocked would have cost Chrysler $40,000 per hour, so the plant manager instead opted to pay for the damaged rail car.[21]

Materials requirement planning (MRP) is a production planning system designed to ensure that a firm has the parts and materials needed to produce its products and services at the right time and place and in the right amounts. Production managers use special computer programs to create schedules that identify the specific parts and materials required to produce an item, the exact quantities required of each, and the dates when orders should be released to suppliers and should be received for best timing within the production cycle.[22]

materials requirement planning (MRP) Computer-based production planning system for ensuring needed parts and materials are available at the right time and place in the correct amounts.

MRP is invaluable in systems involving complex products assembled with parts and materials secured from outside suppliers. It is even more important in major products such as the B-2 bomber, where entire subassemblies of the plane are produced by dozens of firms scattered throughout the nation (in every state except Alaska and Hawaii). MRP's computer program coordinates the deadlines for each subassembly in addition to deadlines for the overall assembly.

To ensure the short delivery times required by its just-in-time inventory system, Colgate-Palmolive Company formed partner-like relationships with its valued suppliers. Here, Colgate's JIT coordinator works with employees from a Venezuelan packaging supplier to reduce changeover and make-ready time on the production line for Banner soap, a family deodorant bar similar to Irish Spring. Such meetings are held regularly between managers and workers from both companies to improve package design, increase production efficiencies, solve problems, and better understand each others' operations.

Manufacturing Resource Planning

manufacturing resource planning (MRP II) Integration of planning data from individual departments resulting in a master business plan.

While MRP is used to control inventory, a more advanced computer-based system is designed to control all of a firm's resources. Called **MRP II**, for **manufacturing resource planning**, the system integrates planning data from individual departments—marketing, production, engineering, and finance—and produces a master business plan for the entire organization. MRP II then translates the business plan into marketing forecasts; requirements for inventory, materials handling, and personnel; and production schedules. All managers have access to this information. With MRP II, a change in a marketing forecast will automatically produce an adjustment in production scheduling. Some MRP II software programs can even give managers advice on ways to solve manufacturing and other production problems.

Control of the Production Process

production control Well-defined set of procedures for coordinating people, materials, and machinery to provide maximum production efficiency.

Throughout this chapter, production has been viewed as a process of converting inputs into finished products and services. First, plans are made for production inputs—the goods to be produced, the location of facilities, and the sources of raw materials, consumers, labor, energy, and machinery. Next, the production plans are implemented through the purchase of materials and equipment and the employment of a trained work force to convert the inputs into salable products and services. The final step in the production process is control. **Production control** is a well-defined set of procedures for coordinating people, materials, and machinery to provide maximum production efficiency.

Suppose a food processing plant has been assigned the production of 800,000 TV dinners during October. Production control executives break this down into a daily production assignment of 40,000 for each of 20 working days. The next step is to determine the number of workers, raw materials, parts, and machines needed to meet this production schedule.

Similarly, in a service business such as a restaurant it is necessary to estimate

Table 14.3 Information Needed to Construct a PERT Diagram

Activity Number	Activity Completed	Time Required (in months)
1	Build exterior brick walls	2.0
2	Build roof supports	1.5
3	Insulate ceiling	0.5
4	Install roofing	1.0
5	Build room partitions	3.5
6	Install insulation in walls	1.5
7	Install electrical wiring	2.0
8	Install plasterboard	3.0
9	Install air conditioning	0.5
10	Paint interior and exterior	3.0
11	Final cleanup	0.5

how many meals will be served each day and then determine the number of people needed to prepare and serve the food, as well as how much food must be purchased and how often. For example, meat, fish, and fresh vegetables might have to be bought every day or every other day to ensure freshness, while canned and frozen foods might be bought less often, depending on storage space.

The Five Steps in Production Control

Production control can be thought of as a five-step sequence: planning, routing, scheduling, dispatching, and follow-up.

Production Planning. The phase of production control called **production planning** determines the amount of resources (including raw materials and other components) needed to produce a certain amount of goods or services. During the production planning process, a **bill of materials** is developed, listing all parts and materials needed to produce a good or service. Comparison of the needed parts and materials with the firm's perpetual inventory allows the purchasing department to determine the additional purchases required to ensure availability of needed amounts. The MRP system establishes delivery schedules so the needed parts and materials will arrive at regular intervals as required during the production process. Similar determinations are made to ensure that the necessary machines and workers are available when needed. Although material inputs contribute to service-producing systems, such systems tend to depend more on personnel than on materials.

production planning
Phase of production control that determines the amount of resources needed to produce a certain amount of goods or services.

bill of materials
Detailed listing of all parts and materials needed to produce a product or service.

Routing. The phase of production control that determines the sequence of work throughout the facility is called **routing**. It specifies where and by whom each aspect of production will be performed. Routing is determined by two factors: the nature of the good or service and the facility layouts discussed earlier—product, process, fixed-position, and customer-oriented.

routing
Phase of production control that determines the sequence of work throughout the facility.

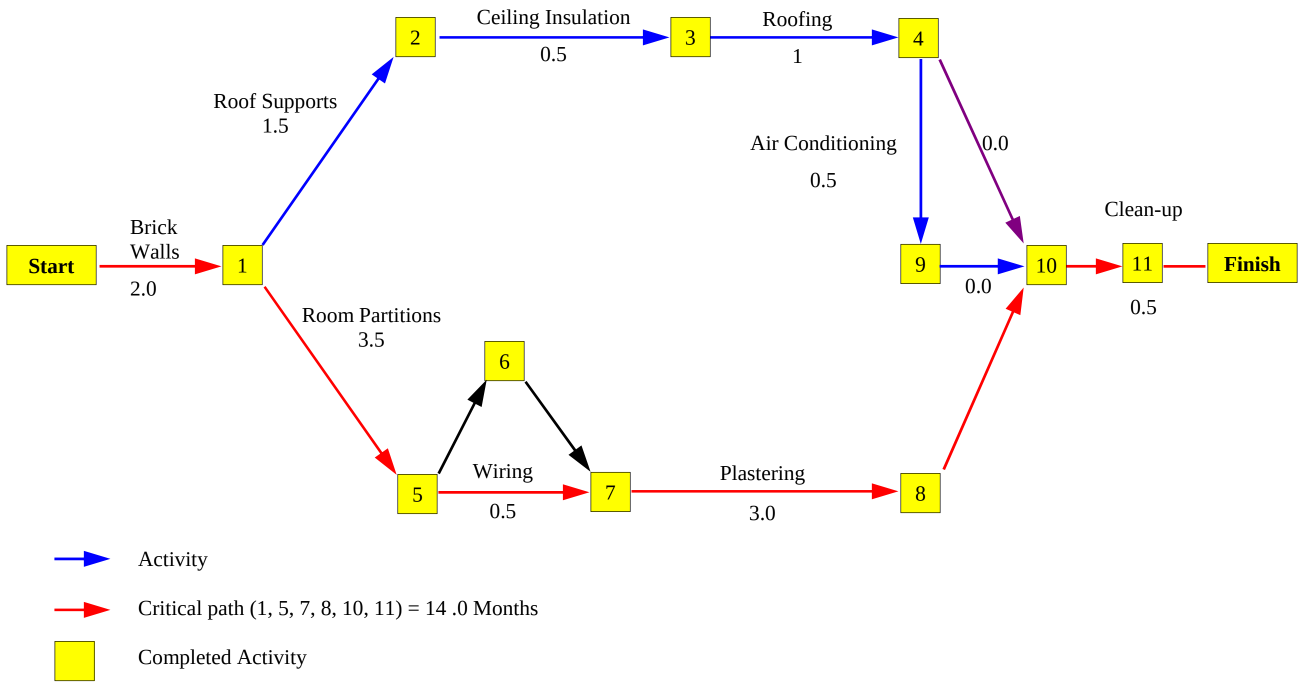
Scheduling. Another phase of production control, **scheduling**, involves developing timetables that specify how long each operation in the production process takes and when it should be performed. Efficient scheduling ensures that delivery schedules are met and productive resources are efficiently used.

Scheduling is extremely important for manufacturers of complex products with large numbers of parts or production stages. A watch contains dozens of component parts, and each of them must be available in the right place, at the right time, and in the right amounts if the production process is to function smoothly.

Scheduling practices vary considerably in service-related organizations. Small

scheduling
Phase of production control that develops timetables specifying how long each operation in the production process takes.

Figure 14.1 PERT Diagram for Building an Industrial Warehouse



PERT (Program Evaluation and Review Technique) Scheduling technique for minimizing production delays by coordinating all aspects of the process.

critical path Sequence of operations in PERT diagram requiring the longest time for completion.

dispatching Phase of production control that instructs each department on what work is to be done and the time allowed for its completion.

services such as local trucking companies or doctors' offices may use relatively unsophisticated scheduling systems and resort to such devices as "first come, first served" rules, appointment schedules, or take-a-number systems. Part-time workers and standby equipment may be used in handling demand fluctuations. On the other hand, hospitals typically use sophisticated scheduling systems similar to those used by manufacturers.

A number of methods have been devised for effective scheduling of complex products. A commonly used scheduling technique for such complex products as ships and new airplane designs is **PERT (Program Evaluation and Review Technique)**. First developed for the military, PERT was used to produce guided missiles for the Polaris nuclear submarine before being modified for use by industry.

PERT is designed to minimize production delays by coordinating all aspects of the production task. Consider, for example, the construction of an industrial warehouse. Table 14.3 shows the various activities involved and an estimate of the time required for the completion of each activity.

Figure 14.1 shows a simplified PERT diagram. The red line indicates the **critical path**—the sequence of operations that requires the longest time for completion. The operations that can be completed before they are needed by operations on the critical path have some slack time and are therefore not critical. These operations can be performed earlier or delayed until later in the production process. Some workers and machinery can be assigned to critical path tasks early in the process, then reassigned to noncritical operations as they are needed.

In practice, a PERT network may consist of thousands of events and cover months of time. Complex computer programs are used in developing the network and in finding the critical path among the maze of events and activities.

Dispatching. The phase of production control that instructs each department on what work is to be done and the time allowed for its completion is called **dispatching**. The dispatcher authorizes performance, provides instructions, and lists priorities for each job.

Computers that monitor preset quality control parameters are part of Engelhard Corporation's statistical process quality control system. The system enables Engelhard to produce coating pigments and additives that consistently match the exact specifications and standards of its customers in the paper, paint, plastics, and other industries. Engelhard employs statistical methods to control quality throughout the entire manufacturing process, including the consistency of raw materials.

Follow-up. Because even the best plans sometimes go awry, some means must be available to keep management aware of problems as they arise. **Follow-up** is the phase of production control that spots problems in the production process and informs management of needed adjustments. Problems come in many forms. Machinery malfunctions, delays in shipment of vital materials or in arrival of goods or supplies, and employee absenteeism can all result in production delays. These delays must be reported to production control so adjustments in production schedules can be made. A delay in the delivery of a particular component may require new assignments to be made by the dispatcher to work areas affected by this delay.

follow-up
Phase of production control that spots production problems and informs management of needed adjustments.

The Quest for Quality

Quality begins with product and service design. Performance standards are necessary prerequisites for the development of quality controls. Once these standards are set, various types of inspections can be made to provide quality assurance.

Quality control involves measuring products and services against established quality standards. Such checks are necessary to spot defective products and to see that they are not shipped to customers. Devices for monitoring quality levels of the firm's output include visual inspection, electronic sensors, and X-rays. Robots are particularly suited for many types of inspections since fatigue and inattention do not present problems. A high rate of rejected products can lead to changes in equipment or raw materials or to additional training for workers.

quality control
Measurement of products and services against established quality standards.

Table 14.4 Ten Commandments of Quality

1. There is no such thing as acceptable quality. It can always get better.
2. From the corner office to the shop floor, quality is everybody's business.
3. Keep your ears open. Some of the best ideas will come from the most unexpected sources.
4. Develop a detailed implementation plan. Talking about quality isn't enough.
5. Help departments work together. The territorial is your biggest obstacle.
6. Analyze jobs to identify their elements and set quality standards for each step.
7. Take control of your process: You must know why something goes wrong.
8. Be patient. Don't expect gains to show up next quarter.
9. Make extraordinary efforts in unusual situations. Customers will remember those best.
10. Think beyond cutting costs. The benefits of improved quality should reach every part of the organization.

Source: Joel Dreyfuss, "Victories in the Quality Crusade," Fortune (October 10,1988), p. 82.

Few subjects have been more popular among U.S. organizations in recent years than that of quality. American firms have long held a reputation for making products of outstanding quality. Examples include Boeing's 747 family of jet aircraft, A. T. Cross ballpoint pens, Reynolds Metals aluminum foil, General Electric dishwashers, Levi Strauss 501 jeans, Honeywell heating controls, Polaroid instant camera films, Du Pont fibers, 3M tape, and Deere tractors.

But at the same time U.S. factories were improving quality, their Japanese counterparts were leapfrogging ahead by applying concepts developed in the United States. The success of their efforts in developing a reputation for outstanding quality is evident by the inroads Japanese products have made in U.S. and world markets. Japan now holds the lead in worldwide sales of steel, automobiles, machine tools, textiles, and consumer electronics; industries once dominated by U.S. manufacturers.

Japan's most coveted industrial award is the Deming Prize, given to the company and the individual who achieve the most significant gains in quality. The annual award is broadcast on national television in Japan. The prize is named in honor of W. Edwards Deming, an American statistician whose lectures on quality control were largely ignored by American managers during the competition-free, post-World War II years but were listened to by Japanese managers.

Deming suggests that building quality into the entire production process leads to improved productivity. Rather than inspect products for flaws after they are made, he emphasizes making products correctly the first time to avoid wasting time and money in rework. To accomplish this, Deming taught Japanese managers and employees how to implement **statistical process control (SPC)**, a process of gathering, plotting, and analyzing data to pinpoint problem areas. SPC allows firms to spot quality problems, whether they are caused by poor employee work, poor supervision, or faulty machinery, and then install controls to ensure the problems are corrected.

statistical process control (SPC)
Process of gathering, plotting, and analyzing data to pinpoint problem areas.

Deming stresses that the commitment to quality must be a companywide philosophy and a continuous process. Top managers must be totally committed to the quality concept and serve as flexible advisors and coaches. Employees must be trained and involved as partners in the drive to produce on-time, error-free products.

Many U.S. firms, eager to restore their long-held images as producers of high-quality products, have embraced Deming's quality methods during the 1980s. Several years ago, Monsanto Company began a companywide "Total Quality"

Photo source: Courtesy of the Stanley Works

Gary Schuler (center), president and general manager of Stanley-Bostitch, a division of The Stanley Works, listens as three quality circle members (at right) explain reductions in set-up time they recommend for computer-controlled machining operations that produce components for the division's products. Richard Cotoia, foreman, and Deborah Pannulo, director of productivity improvements, evaluate all QC suggestions and look for applications to other manufacturing processes. Management has approved about 50 cost-reduction and over 35 quality-improvement projects recommended by QCs in the past few years. A poll revealed that over 90 percent of company employees find the QC concept meaningful and valuable.

process that was saving the firm an estimated $50 million to $60 million. Ford Motor Company hired Deming as a consultant in 1981, and his influence has helped Ford become the most profitable domestic automobile manufacturer. Rember the Ford moto, "Quality is Job One."

Deming's quality principles also apply to service firms. When P.I.E., a trucking company, discovered 60 percent of its shipping contracts had errors, it used SPC and employee suggestions to locate the cause of the problem. P.I.E. learned that 56 percent of the errors resulted from the misidentification of crates and boxes used to ship products. The problem was corrected within 30 days, resulting in cost savings of $250,000 a year.[23]

In 1988, the U.S. government began awarding its own version of the Deming Prize. The Malcolm Baldrige National Quality Award is a prestigious national award to communicate to the nation and the world the importance of quality in U.S. production efforts. Malcom Baldrige was the Secretary of the U.S. Department of Commerce and administered the National Bureau of Standards during the Ronald Reagan Presidential administration. The first three recipients of the award were two giant U.S. corporations—Motorola Inc. and Westinghouse Electric—and Globe Metallurgical of Beverly, Ohio, a 210-employee firm that makes alloys and metals for use in such products as autos, farm equipment, and silicon chips. Prize-winning companies such as these are likely to be adhering to the ten commandments of quality listed in Table 14.4.

Quality Circles

Researchers seeking to compare U.S. and Japanese firms discovered a widely used Japanese concept based upon the philosophy that the firm's work force is often the group most qualified to identify and solve work-related problems. A survey of 1,566 Japanese firms revealed that 91 percent used quality circles. A **quality circle** is a group of employees from the same work area who define, analyze, and solve quality and related problems in their area. Groups usually number seven to ten people. They meet voluntarily and on a regular basis, typically once a week. A first-line supervisor or one of the workers usually serves as team leader to facilitate

quality circle
Group of employees from the same work area who meet regularly to define, analyze, and solve quality and related problems in their area.

discussions and to keep management informed of the issues being addressed and the group's progress.

Because the quality-circle concept represents a means of increasing productivity, raising quality levels, reducing costs, and improving the quality of work life through employee participation, many U.S. firms have implemented the concept. Among the first U.S. corporations to establish quality circles were Lockheed Aircraft and Honeywell. Thousands of these voluntary groups have since been formed in the auto, aircraft, electronics, steel, and other industries. Their use has also expanded to the government sector. A quality circle operating in the Hayward, California, police department modified the police headquarters' layout to create a private area for use by police detectives in conducting interviews. A streamlined method for reviewing job applications was devised by a ten-member quality circle made up of Michigan state civil service employees.

The problems tackled by quality circles vary considerably in scope. They may include methods for reducing defects, scrap, rejected products, and equipment downtime. At a Corning Glass Works plant, a quality circle composed of machine operators, mechanics, technicians, and electricians figured out a way to reduce the changeover time on their machinery by replacing threaded couplings with easy-to-use snap-on couplings, a procedure that is saving the firm $106,000 each year.[24] In other instances, quality circles may focus on employee training, working conditions, and morale problems. Another Corning Glass quality circle noticed production-line crew performance dropped when new employees joined the crew because they lacked proper training. The employees designed a training program, complete with an instruction book, video, on-the-job training, and certification test.

Sometimes the quality circle produces spectacular results. At Northrop Corporation's Aircraft Division near Los Angeles, 55 separate blue- and white-collar quality circles helped reduce the cost of producing Boeing 747 parts by 50 percent in two years, even though the size of the work force quadrupled. Worker recommendations included a redesigned, break-resistant drill bit that saved the company $28,000 a year, a metal stretcher used to prevent loud popping sounds in a 747's belly at high altitudes, and special stools that enable workers to roll from one workstation to another.

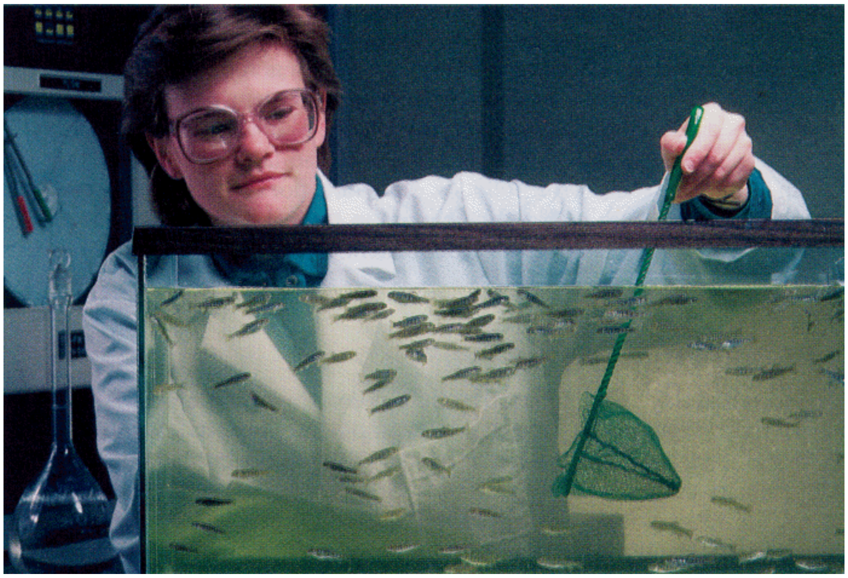
At one of Chrysler's X-car plants, a quality circle discovered car-door leaks could be prevented by heating rubber gaskets before installing them on the doors—a process that made the gaskets more malleable and easier to install.

A study of organizations with quality-circle programs concluded circles have the potential to increase worker self-respect, improve capabilities of individual workers, and develop workers' supervisory potential. A major problem on the part of some managers is expecting too much too soon from these voluntary, cooperative efforts. "You have to allow time for people to adjust to new relationships," points out Gene Kofke, director of work relationships at AT&T. The problem's "worst enemy . . . is the impatience for quick and finite results. You measure the success of these things in years."[25]

Production and Pollution

An undesirable output of many production processes is pollution, which takes many forms, including air pollution, water pollution, and noise pollution. Activities such as strip mining have produced extensive damage in Illinois, Kentucky, West Virginia, and other ore-producing states. Major oil spills along the Pacific and Gulf coasts have killed thousands of fish and birds and damaged beaches. Discharges from chemical plants have closed recreational areas and killed fish. Atmospheric discharges by lead smelters have endangered the health of nearby residents. Acid rain has become an international problem, involving the United States, Canada, and many European countries. An estimated 165 tons of air borne pollutants are produced each year by American factories.

In its most extreme form, pollution can—and does—kill people. The 1984 gas leak at Union Carbide's pesticide plant in Bhopal, India, killed more than 2,000 people and caused serious, permanent disabilities to many times that number.



Chevron built a laboratory at its Richmond refinery to monitor the quality of the effluent released into San Francisco Bay. In this photo, a lab technician uses environmentally sensitive trout to test the algae-tinged effluents' compliance with regulations. Going a step beyond complying with regulations, Chevron also launched a voluntary program to reduce industrial waste generation by more than 60 percent.

Antipollution Regulations

These undesirable outputs have resulted in enactment of numerous state and federal laws designed to protect the environment. Since its establishment in 1970, the Environmental Protection Agency (EPA) has been the federal agency with primary authority for dealing with various types of pollution. During the 1980s, the EPA's power was strengthened by the Resource Conservation and Recovery Act. Manufacturers are now required to adopt programs to reduce the volume and toxicity of hazardous materials. Moreover, the regulations also limit the use of landfills, traditionally the least expensive disposal solution. A recent law mandates that firms inform the communities in which they operate about the types and amounts of hazardous chemicals at their facilities and the amounts of chemicals they release into the environment.

Waste-Reduction Methods

Efforts by manufacturers to stop pollution have resulted in the investment of billions of dollars in equipment. Over $24 billion is being spent each year to control air pollution. Buyers of new cars currently pay from $250 to $450 for air pollution abatement devices. Waste-reduction programs are tailored to fit a specific industry or plant. Most companies concentrate on four areas: raw materials, processes, equipment, and reuse.

By pursuing all these alternatives, USX Corporation estimates it reduced its hazardous waste generation by almost 50 percent in four years and slashed its use of landfill sites by 80 percent in five years. For example, the steel company substituted nonleaded greases and oils for leaded lubricants in its rolling mills. In its coke plants, heavy sludge residues that were discarded are now mixed with tars and converted into fuel.

One sure way to minimize waste is to squeeze more finished products from less raw material. Minnesota Mining and Manufacturing (3M) credits a savings of $845,000 a year to a process change in its sandpaper manufacturing operation. Previously, abrasive resins used to coat sandpaper were dumped into large kettles at the beginning of the manufacturing process. The leftover resins were flushed out of the vats, creating a resin-waste stream. 3M redesigned its equipment to feed resins continuously into the process in the precise amount needed. The reduction in resin wastes: 400 tons a year.

Some firms are reducing waste by developing reuse methods. The Goodyear Tire & Rubber Company is building facilities that shred scrap tires to produce a high-energy supplemental fuel used by paper, cement, and lime manufacturers.

Consolidated Papers Inc. spent $13.8 million in 1988 on environmental improvements, mostly on air emission control equipment at a plant that produces chemical pulp for its four paper mills. Chevron spent $45 million on a project at its Richmond, California, refinery to improve the treatment of the effluent it discharges into San Francisco Bay.

A strong commitment to protection of the environment, coupled with investments in pollution control, will be an increasingly important component of production decisions during the remaining years of the twentieth century.

Summary of Learning Goals

1. **Outline the roles of specialization, mechanization, and standardization in mass production.** Mass production in manufacturing is accomplished by effectively combining (1) specialization, the division of work into its simplest components; (2) mechanization, the use of machines to perform work; and (3) standardization, the production of uniform, interchangeable goods and parts.

2. **Explain the contributions and problems associated with the use of assembly lines, automation, and robots in producing products and services.** The use of assembly lines in manufacturing increases the speed of production as employees utilize the concepts of specialization, mechanization, and standardization. A logical extension of mechanization is automation, including the use of robots. Technological developments reduced the costs of automated equipment. Robots can be assigned to perform boring, routine, repetitive, and sometimes dangerous work, thereby freeing humans for more challenging assignments. However, automation often results in unemployment, making retraining of displaced workers necessary.

3. **Discuss the three components of production and operations management.** Production and operations management is responsible for (1) developing plans for production inputs, (2) installing necessary production inputs and implementing production plans, and (3) coordinating and controlling the production process.

4. **Identify the major factors involved in deciding plant locations.** Among the factors to be considered in selecting a plant location are proximity to raw materials and to markets; availability of labor, transportation, and energy; local regulation; and community living conditions. Regulatory authorities may require an environmental impact study to assess the impact on the quality of life of locating the plant in a particular area.

5. **Discuss the alternative designs for production facilities.** Process layouts are used for nonstandard products produced in relatively small batches. Product layout facilitates production of a few designs in relatively large quantities. A fixed-position layout is common when production involves very large, heavy, or fragile products. A customer-oriented layout is typically used for service facilities where interaction between the customer and the service facility are important factors.

6. **Explain the steps involved in the purchasing process.** The make, buy, or lease decision results in the determination of whether needed inputs will be manufactured in-house, purchased, or leased from an outside supplier. Those responsible for purchasing determine the correct materials to purchase, select appropriate suppliers, and develop an efficient ordering system, with the objective being to buy the right materials in the right amounts at the right time

for the right place.

7. **Discuss the advantages and disadvantages of maintaining large amounts of inventory.** The task of inventory control is to balance the need to maintain adequate supplies and the need to minimize funds invested in inventory. Excessive inventory results in increased expenditures for warehousing, taxes, insurance, and maintenance. Inadequate inventory may mean production delays, lost sales, and inefficient operations.

8. **Outline the steps in the production control process.** The production control process consists of five steps: planning, routing, scheduling, dispatching, and follow-up, as well as quality control. Coordination of each of these phases should result in improved production efficiency and lower production costs.

9. **Identify the contributions of quality circles in improving quality control.** Quality control involves the measurement of products and services against quality standards through devices ranging from visual inspections to electronic sensors and X rays. One technique is the use of quality circles, groups of seven to ten people from the same work area who regularly meet to define, analyze, and solve various problems in that area. In addition to developing methods of reducing waste and improving quality, such groups have the potential to increase worker self-respect, improve individual capabilities, and develop supervisory personnel.

Questions for Review and Discussion

1. Give two examples of production facilities in your city or region that use each of the following manufacturing methods:
   a. Analytic process
   b. Synthetic process
   c. Continuous process
   d. Intermittent process

2. Suggest types of form utility that the following firms might produce:
   a. Delivery service
   b. Sugar refinery
   c. Commercial airline
   d. Family counseling center

3. Explain how specialization, mechanization, standardization, and assembly lines have contributed to the development of mass production systems and how they continue to influence the work environment.

4. Relate computer-aided design to computer-aided manufacturing.

5. Explain the concept of a flexible manufacturing system.

6. Assign a facility layout to each of the businesses listed and explain the reasons behind your selection.

_____ Automotive service center	a. Process layout
_____ Surgical operating room	b. Production layout
_____ Theater or stage production	c. Fixed-position layout
_____ One-hour eyeglass store	d. Customer-oriented layout
_____ Retail florist	
_____ Winery or brewery	

14

7. Discuss the concepts behind materials requirement planning (MRP) and manufacturing resource planning (MRP II).

8. What factors are likely to be most important in the make, buy, or lease decision? List instances when make, buy, or lease decisions might be made for the following firms:

a. Lawn and garden center
b. Asphalt company
c. Party supply house
d. Upholstery shop

9. Relate the three components of production and operations management to each of the following. Give specific examples of each component.
a. Major league sports facility
b. Convenience food store
c. Fish processing facility
d. Color television assembly plant

14. What are the chief methods of ensuring quality control? Suggest appropriate quality control techniques for use in the following firms:
a. Local bank
b. City hospital
c. Amusement park
d. Furniture factory
e. Bottling plant

11. Evaluate your city or county as a prospective industrial site and suggest organizations that would be well suited to the location.

12. Name five factories and five service firms located in your community or a nearby city. Identify the factors likely to have led to the location of each. Explain your choices.

13. A successful production plan provides sufficient materials (manufactured, purchased, or leased), efficient production schedules, and a controlled inventory. Draw up a proposed production plan, including make, buy, or lease decisions, for a small business in your area.

14. Assess the effect on inventory control resulting from the various inventory systems discussed in the chapter.

15. Draw a PERT diagram for the product described below. Make any necessary assumptions.

In order to become a Vlasic fresh-packed pickle, the cucumber undergoes a series of operations. Once the cucumbers arrive at the plant, they are sized, sorted, washed, sliced, and packed into jars. Specially prepared brine containing spices is added to the sliced product, and the jars are closed. The pickles next undergo a pasteurizing process, after which labels are affixed to the jars. The individual jars are then packaged into protective cases. The cases are finally combined on shipping pallets and moved to a warehouse to await shipment to customers.

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