STEM Applications

1. **ENGINEERING** Design and make a hydroponics unit for a location that needs attractive plants without continuous maintenance. Document your design and include it in your portfolio.
2. **TECHNOLOGY** Find a recipe for making applesauce from apples. With your parent or guardian's permission, follow the recipe. Record the technology you used in the course of preparing the applesauce. Brainstorm technological improvements that might make the process easier, faster, or more fun.
3. **SCIENCE** Research the construction of a greenhouse. Individually or as a class, design and make a greenhouse that will allow you to grow a type of plant that does not ordinarily grow in your location. Test the greenhouse by using it to grow the specified plants from seeds. Document your design and record the results of your growing efforts. Did the plants sprout? Did they flourish? What kind of care did they require? At the end of the growing season, publish your results in a scientific reporting format.

CHAPTER 15

Manufacturing and Production

Better by Design

Metaphase Design Group develops user-centered designs

Work gloves provide important protection, but often they make handling objects more difficult. At Metaphase Design Group, a team of designers explored how work gloves are used. They then designed a range of gloves for specific tasks. Constructors' gloves have a small magnet in one finger. The magnet is strong enough to pick up one nail, but weak enough to prevent picking up more than one. People who work in shipping, receiving, and delivery need bare fingertips to use their electronic tracking devices. Their gloves have fingertip "hats" that can be flipped back and held with Velcro®. The wedge-like thumb design slides easily under boxes for handling.

A small magnet in the index fingers of these gloves allows carpenters to pick up one nail at a time.

The tips of these gloves can be folded back and secured by Velcro when employees are working with electronic equipment.

"The best way to find out what a product should do is by watching people use it in the real world."

Reading Target

Summarizing Information

A *summary* is a short paragraph that describes the main idea of a selection of text. Making a summary can help you remember what you read. As you read each section of this chapter, think about the main ideas presented. Then use the Reading Target graphic organizer at the end of the chapter to summarize the chapter content.

Key Terms

artisan
assembly line
automation
computer numerical control (CNC) machine tool
continuous improvement
degree of freedom
division of labor
durable
efficiency
factory
flexible manufacturing system
interchangeable parts
just-in-time delivery
lean manufacturing
manufacturing
mass production
nondurable
production technology
rectangle
subassemblies
sustainable manufacturing
tolerance
work cell
zero defects

Objectives

After reading this chapter, you will be able to:

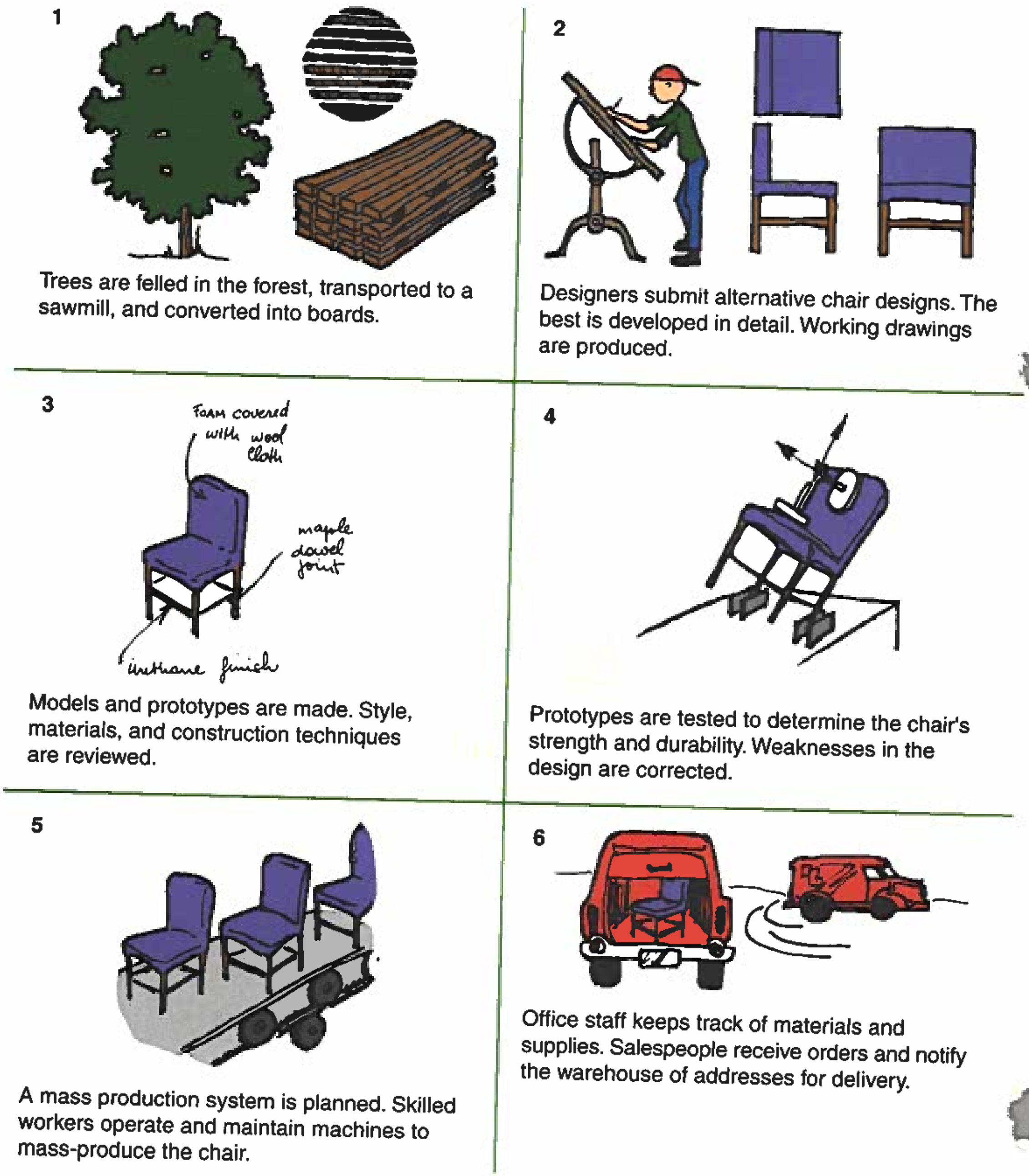
- List the two main steps in producing a manufactured product.
- Describe the development of manufacturing processes in the last 200 years.
- State the purpose of automation and identify its advantages and disadvantages.
- Explain the differences between traditional and modern management systems.
- Describe the elements of a production system.
- Explain how sustainable manufacturing is different from traditional manufacturing.

Useful Web sites:
www.metaphase.com/
www.chi-athenaeum.org/gdesign/index.html

Manufacturing is the process of using raw materials to create products. Some of the products we produce are *durable*. They are meant to last for a long time. A bicycle is an example of a durable product. Other products, such as paper plates, are meant to be used once and then discarded. These items are *nondurable*. Durable and nondurable products are manufactured using similar manufacturing and production processes.

The wood used to build the chairs in your home came from a tree growing in a forest. What is involved in creating a chair from a tree? From **Figure 15-1**, you can see that the steps in producing any product are:

- Obtaining and processing raw materials
- Changing raw and processed materials into a product we can use



1 Trees are felled in the forest, transported to a sawmill, and converted into boards.

2 Designers submit alternative chair designs. The best is developed in detail. Working drawings are produced.

3 Models and prototypes are made. Style, materials, and construction techniques are reviewed.

4 Prototypes are tested to determine the chair's strength and durability. Weaknesses in the design are corrected.

5 A mass production system is planned. Skilled workers operate and maintain machines to mass-produce the chair.

6 Office staff keeps track of materials and supplies. Salespeople receive orders and notify the warehouse of addresses for delivery.

Figure 15-1. Making a chair from a tree takes much planning and work.

Processing Raw Materials

All materials for products come from nature in one form or another. Some materials are renewable and can be reproduced continually. Others are nonrenewable; once used, they cannot be replaced.

Renewable Materials

Renewable raw materials come from plants or animals. Some are found in a wild state, and others are produced on farms. For instance, forests and tree farms provide wood for the lumber industry. See **Figure 15-2**. The fishing industry harvests fish and other marine life from oceans, lakes, and waterways, as shown in **Figure 15-3**. Wild animals are hunted and trapped for their furs, hides, and meat.

Nonrenewable Raw Materials

Nonrenewable raw materials include fossil fuels, nonmetallic minerals, and metallic minerals. Fossil fuels include coal, peat, petroleum, and natural gas. Refer to Chapter 10 for more information about fossil fuels.

Nonmetallic minerals include construction materials such as sand, gravel, and building stone. They also include abrasive materials, such as corundum. Among the metallic minerals are those from which iron, copper, and aluminum are extracted.

Figure 15-2. Lumberjacks harvest trees, a renewable raw material. Environmentally sound harvesting practices help preserve the forests and ensure that trees remain a renewable raw material in the future.

Figure 15-3. Commercial fisheries harvest fish and other seafood.

Manufacturing Products

The second step in production is to change raw and processed materials into useful products. Today's manufactured products include computers, jet planes, glues, lasers, plastics, medications, photocopying machines, and bubble gum. Construction products include structures that people use for living, working, traveling, and playing. Among these structures are houses, office towers, and sports stadiums. Also included is the construction of road tunnels, bridges, towers, and dams.

Manufacturing has changed in the last 200 years. It has evolved through three stages:

- The individual artisan
- Mechanization and mass production
- Automation

The Individual Artisan

Before the eighteenth century, the production of articles was entirely in the hands of individuals. One person, an *artisan*, made products. Artisans used hand methods. Each product evolved by trial and error. One generation passed on acquired skills to the next through an apprenticeship system. The artisan was responsible for every step in the process. He or she did everything from obtaining the raw materials to completing the finished product. For instance, **Figure 15-4** illustrates the work of a chair maker. This artisan, working alone, produced Windsor chairs.

Mechanization and Mass Production

In the second stage in the evolution of manufacturing, the production process was divided into specialized steps. Machinery replaced handwork. This was done to reduce the unit cost of the product. For the first time, products could be made in large quantities. This change, which occurred first in England, was known as the Industrial Revolution.

Early steam-powered machines replaced the muscle power of workers and animals. See **Figure 15-5**. Burning coal produced the steam. Watt's steam engine was the first machine to convert the chemical energy of coal into steam and then into mechanical energy. The mechanical energy powered the machinery.

As a result of the increased use of steam-powered machinery, production had to be located in larger buildings called *factories*. Towns and cities developed rapidly as people moved to live near these factories.

At first, factories had to be near the coalfields. Moving the coal long distances was too costly. After the mid-nineteenth century, however, transportation became cheaper. Coal could be more readily transported. Factories could be built almost anywhere.

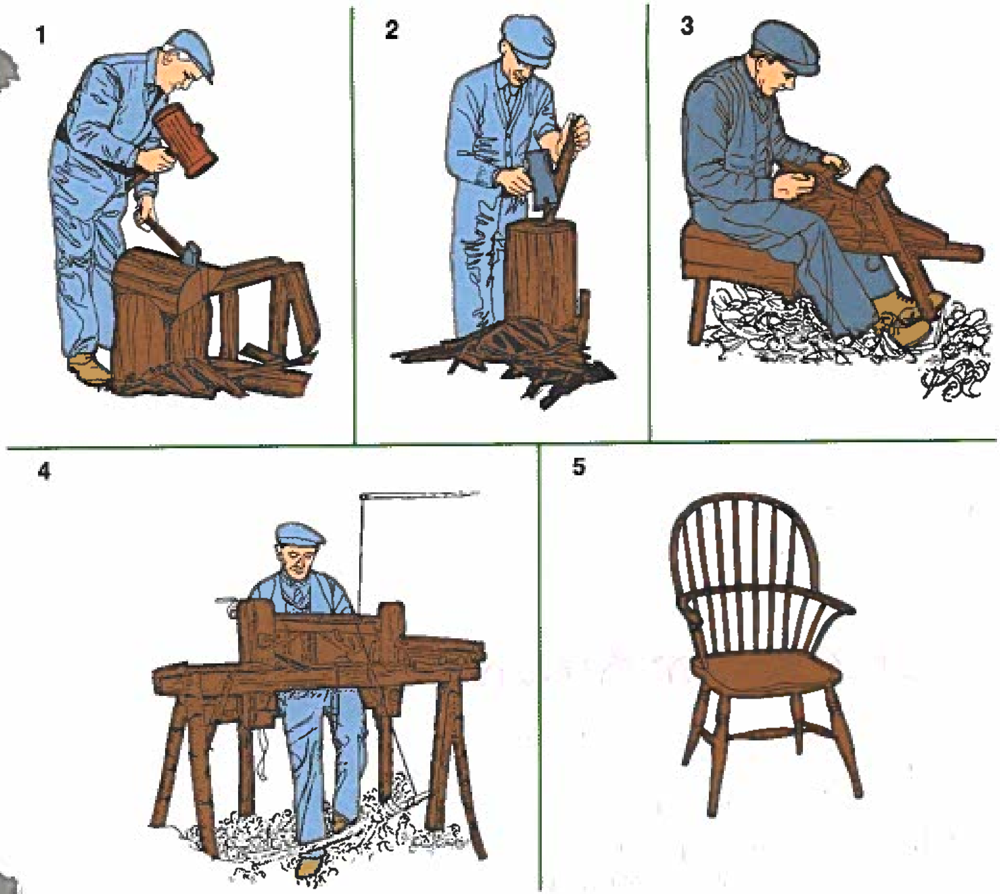


Figure 15-4. Steps in making the legs and spindles for a Windsor chair. A single artisan working alone made the entire chair.

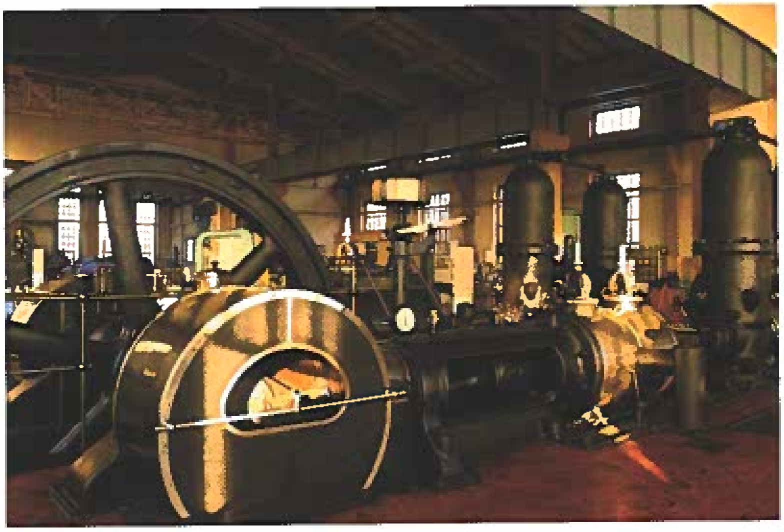


Figure 15-5. Machinery in early factories was powered by steam.

The factory system expanded because it was efficient. *Efficiency* means that good use is made of energy, time, and materials. Efficiency was further achieved through the use of new methods of production. These included:

- Division of labor
- Use of specialized machinery to build parts
- Use of interchangeable parts
- Assembly lines and mass production

Division of labor means each person is assigned one specific task in the making of a product. Through constant repetition, the worker becomes skilled in that task. As the worker becomes skilled, he or she can perform the task at a more rapid rate.

With specialized machinery, the same part could be made again and again with little variation in size or shape. Because more products could be produced in the same amount of time, the cost for producing each item dropped. This meant the item could be sold for less, too.

Interchangeable parts are parts that are the same shape and size. They are made within *tolerances* (specifications for size and shape) to ensure that a new part can be substituted for one that is worn or broken. Each new part fits just like the old one.

An *assembly line* allows assembly of parts in a planned sequence. This is possible only when parts are manufactured to uniform standards. Use of assembly lines made factories more efficient. A continuous assembly line could quickly produce a large number of identical items. Assembly begins with one major part. Other parts are added as the product moves to other stations along the line.

Making a large number of products on an assembly line is called *mass production*. Henry Ford first used it in 1914. Ford's assemblers worked side by side in long lines. See **Figure 15-6**. The parts were brought to them. Each worker had only one assigned task as the Model T cars moved slowly by on the assembly line. As a result, the time needed to produce a car dropped from 12 hours 30 minutes to 1 hour 33 minutes.

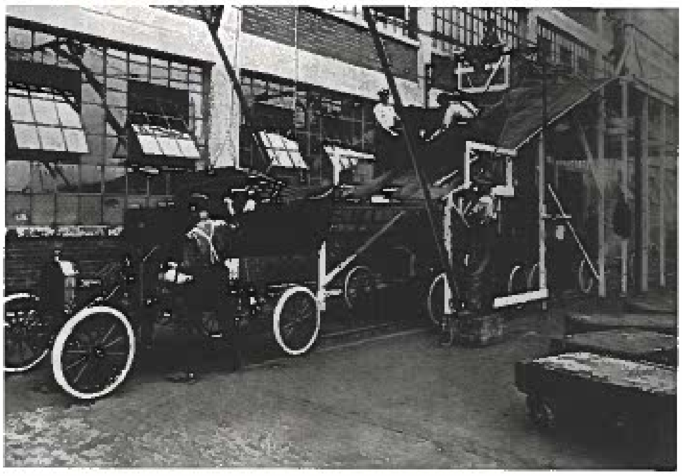


Figure 15-6. Henry Ford perfected the first assembly line to produce his Model T car.

Modern automobile plants are huge assembly points. See **Figure 15-7**. Each plant contains a number of small assembly lines that produce *subassemblies*. These are components having a number of parts. Engines, gearboxes, and suspensions are examples. Subassemblies are later assembled into complete automobiles.

Automation

While the assembly-line techniques pioneered by Ford increased the rate at which products could be produced, they were still limited. Humans could work only so fast. To produce products faster, automated assembly lines were developed.

Today, instead of making products, workers build, monitor, and maintain the machines that make products. *Automation* is the use of computers or other machines control machine operations. Machines have been developed that perform many different operations. They can receive a number of parts and assemble them at high speed in the correct sequence.

For example, the machinery shown in **Figure 15-8** is used to package macaroni. The display packages have to be opened, filled, sealed, weighed, and boxed. Almost all of the operations are automated. Even on final inspection, machines check each package for the correct amount of macaroni.

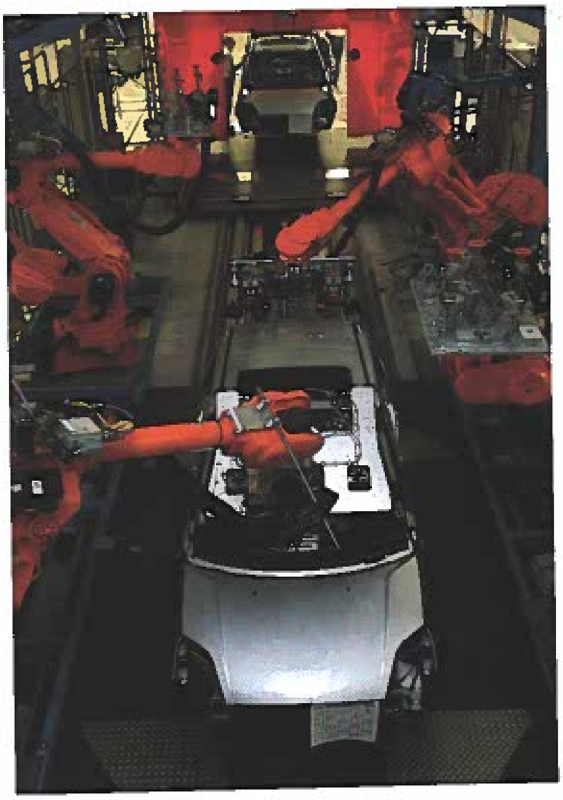


Figure 15-7. Modern automobile assembly lines are automated to improve speed and precision.

Math Application

Calculating Material Needed

The steel used to make food cans is rolled into huge coils and then shipped to a tinplate mill. There it is given a fine coating of either tin or chromium oxide. This coating protects the steel from rust. The rolls are then delivered to can-making factories.

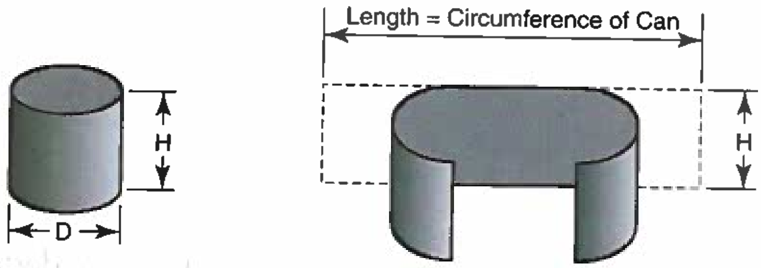
To manufacture cans efficiently, the manufacturer needs to know how much coated steel to order for each batch. When unrolled, a can has the shape of a long rectangle. A ***rectangle*** is a four-sided shape in which the opposite sides are parallel and the adjacent sides are at right angles to each other.

The length of the rectangle is equal to the circumference of the can. If you know the diameter of the can, you can calculate the circumference using the formula $\pi \times D$. D equals the diameter of the can, and π, or pi, equals approximately 3.1416. For example, a small can of soup measures 4″ high and has a diameter of 2.5″. The circumference of the can equals 3.1416 × 2.5″ = 7.8535″.

You can now calculate the area of the rectangle that makes up the sides of the soup can. Multiply length (which equals the circumference of the can) × the height of the can: 7.8535″ × 4″ = 31.414 square inches.

Math Activity

1. Find the surface area of the sides of a can of soup that measures 4.5″ high and has a diameter of 4″.
2. How many square feet of sheet metal would be required to produce the rectangles for 1,000 soup cans? (*Hint:* To convert square inches to square feet, divide by 144.)



D = Diameter
H = Height

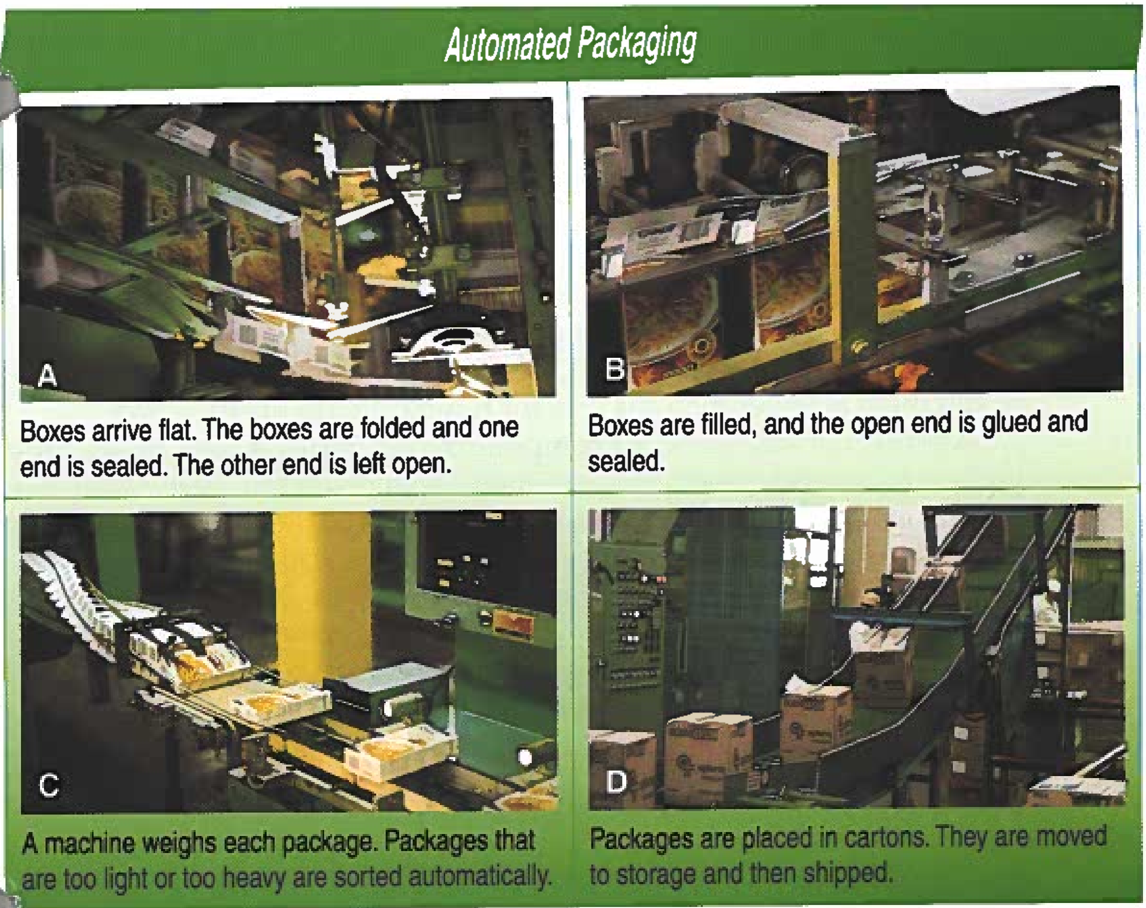


Figure 15-8. An automated packaging line.

Robots

The 1980s brought further development in automated manufacturing. Industrial robots revolutionized production lines. Computer-controlled robots can be programmed to perform various functions, including:

- Handling—loading and unloading parts and assemblies on machines
- Processing—machining, drilling, painting, and coating
- Assembling parts and subassemblies
- Breaking down an object into its component parts
- Fixing objects permanently in place by welding or soldering
- Performing dangerous tasks and operations
- Transporting materials and parts or delivering mail

To understand the operation of an industrial robot, imagine that you have been blindfolded and tied to a chair. You are able only to move one arm and to rotate at the waist. Your one arm has joints at the shoulder, elbow, and wrist. Robots also have joints much like a waist, shoulder, elbow, and wrist that can move in two or three directions. Each joint, or direction of movement, in a robot arm is called a *degree of freedom*. Most robots have five or six degrees of freedom. See **Figure 15-9**.

Some robots can be programmed to perform an operation by leading them through the sequence of moves they have to follow. This is like taking someone by the hand to guide him or her through a strange place. As the robot arm is moved, it is possible to record the positions into computer memory by pushing a button or trigger on the robot arm.

In many factories, computers control the machinery. Once its program of instructions has been written, a ***computer numerical control (CNC) machine tool*** can do the same job again and again. It can work day and night, seven days a week. However, such machines are expensive to purchase and use. The use of robots and CNC machines is effective only if the cost to run them is lower than the cost for humans to do the same jobs.

Another consideration for computerized factories is cleanliness. Most high-tech factories need to be extremely clean. Even tiny particles of dust may cause the machines to malfunction. This is particularly important in the manufacture of computer chips. See **Figure 15-10**.

Robots have several advantages over humans. They work better in hot, noisy, or dangerous situations. Robots do not take coffee breaks, go home ill, or sleep. They continue working 24 hours a day and operate for thousands of hours before they require maintenance. See **Figure 15-11**.

Advantages of Automation

Automation, including robotics, has certain advantages for industry. First, it improves work quality. A machine set up to produce one product to a high standard will continue to produce parts to the same standard. Also, automation results in increased production. Each worker can produce more products in the same amount of time. Thus, the cost to produce each item is reduced.

Figure 15-9. This industrial robot has five degrees of freedom.

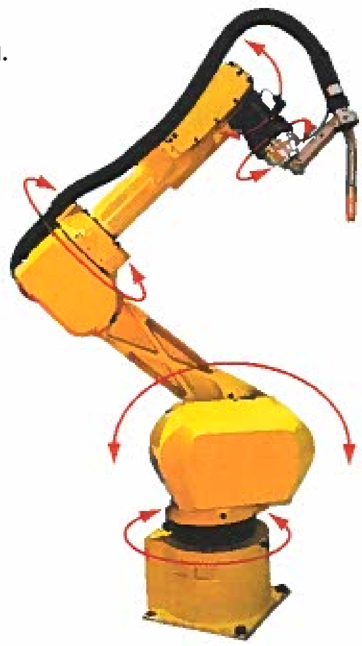


Figure 15-10. The enclosed workspaces contain special filters to keep dust and other particles out. Even outside the filtered areas, workers wear head coverings and "booties" to prevent contamination in this "clean room."

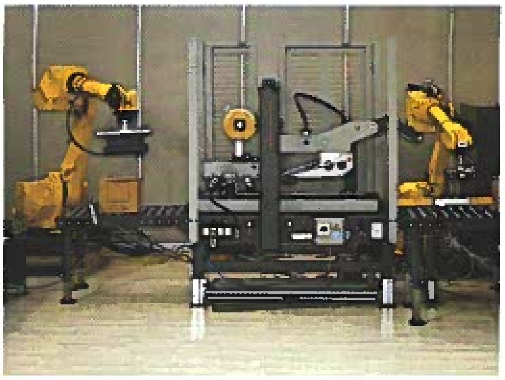


Figure 15-11. These robots automate the final packing and shipping of manufactured items.

Disadvantages of Automation

In spite of its advantages, automation also has some disadvantages. Machines sometimes malfunction. If a machine has been set up incorrectly, all of the products it produces are inaccurate or substandard. Such mistakes, if not detected early, can be very costly. Thousands of defective items may have been produced.

Another concern is the loss of jobs as machines and robots take over tasks in the workplace. The prospect of being replaced by machines frightens or angers many people. They are concerned about being unemployed or having to retrain for another type of job.

This is not a new issue. Until 1880, more than half of all workers in advanced nations worked on farms. At that time, tractors and other machines were developed. Farm mechanization displaced more than two thirds of the farmhands. These machines enabled one person to produce what ten or more had done previously. In the last 100 years about 90% of the farm jobs have disappeared.

Many of the workers leaving the farms went to work in factories, but there, too, machines were replacing people. Ford's mass production caused fears that the assembly line would result in loss of jobs. However, mass production created mass markets. Most people could now buy goods once affordable only to the rich. Products began to sell in the millions.

Math Application

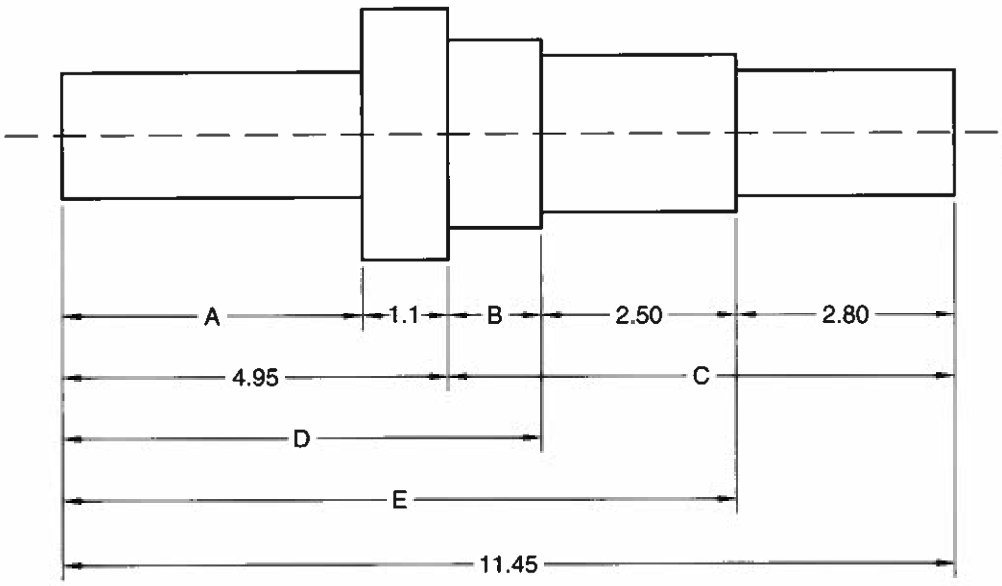
Mathematics and Machining

A hundred years ago, machine operators used lathes to produce machined parts like the one shown here. Today, most production lathes are computer-controlled. They work by reading thousands of bits of information stored in the computer's memory. To place this information in the machine's memory, the programmer creates a series of instructions that the machine can understand.

All of the information needed to make a product must be present in the machine programming. Otherwise, the numerically controlled machine cannot complete its task.

Math Activity

The drawing shown below is missing some horizontal measurements. Calculate the measurements for A, B, C, D, and E. Start by noting the given dimensions. Then add or subtract as necessary to obtain each value. (For this exercise, you may ignore the vertical measurements.)



Production and Management Systems

Production technology consists of the systems and processes that are used to manufacture products. Factory management and production systems have evolved slowly over the years. New ideas and better technology have improved efficiency and working conditions. In some cases, they have also lowered the costs to make products.

Traditional Management Systems

The traditional management system for a mass production factory is shown in Figure 15-12. Each person is given responsibility for a specific job. However, this system has some drawbacks.

For example, in this management system, any problems that occur must be sent up the chain of command for a solution. The problem is passed along from a machine operator to a supervisor to a department head to a manager, and even higher in some cases. Meanwhile, the machine operator waits for a solution.

Another limitation of the traditional system of management is that workers look after only one machine. They are not skilled in the operation of other machines. If the machine a worker uses is not needed, the worker cannot go to work on a different machine, resulting in "down-time."

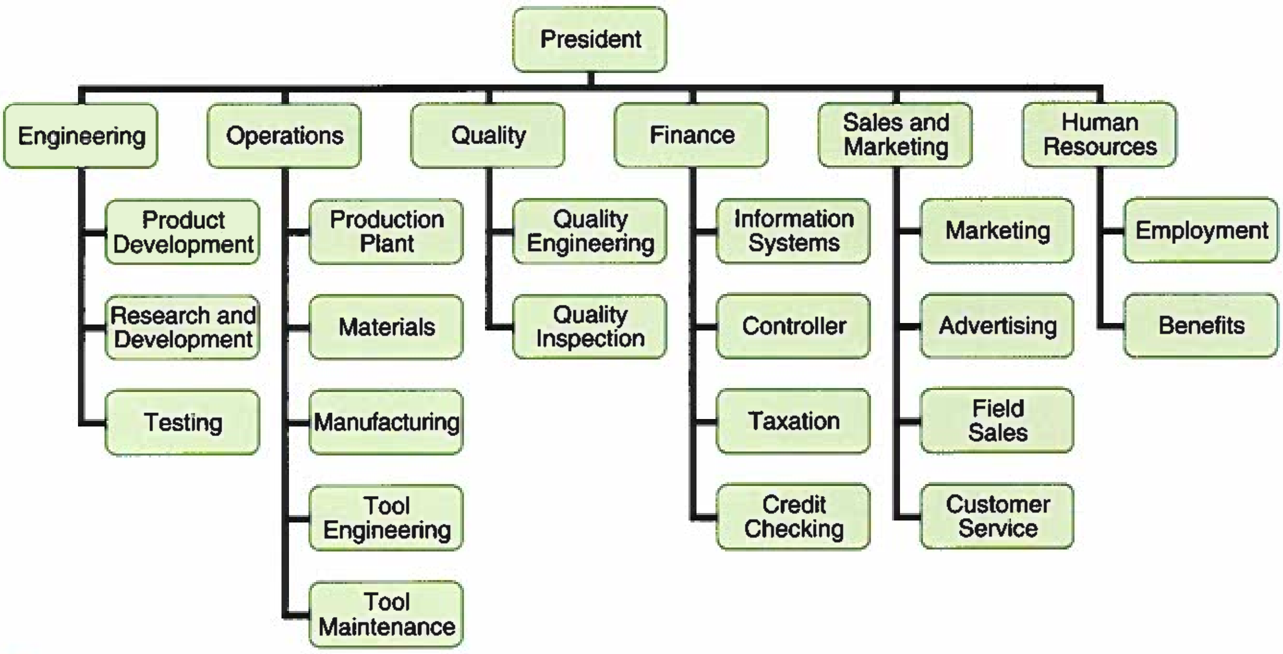


Figure 15-12. Typical organization of a traditional factory.

Lean Manufacturing

Many factories have changed to a new organization called *lean manufacturing*. The purpose of lean manufacturing is to make products more efficiently. It is more cost-effective because fewer resources are needed. It focuses on eliminating waste, ensuring quality, and maximizing employee involvement in the manufacturing process.

In this system, employees work in small, product-oriented teams. See **Figure 15-13**. They work in *work cells* that consist of all the equipment and processes used to make a specific part. All of the equipment is located in the same small area. Team members are cross-trained to use all of the equipment in their work cells. They become skilled in the operation of many different machines. Because anyone on the team can use any piece of equipment, down-time is rare.

Leadership comes from the workers. Individual teams and team members are encouraged to look for better solutions to manufacturing issues. Solutions to problems are sought by the workers, rather than by top-level management, as was the case with the old organization. The entire team is involved in problem solving, making changes, and even the design of new products.

Continuous improvement is the theory that all products and processes can and should be improved on a continual basis. This is an important part of lean manufacturing, for both the product and the manufacturing process. To encourage continuous improvement, lean manufacturing systems reward employees for suggesting improvements to the production process.

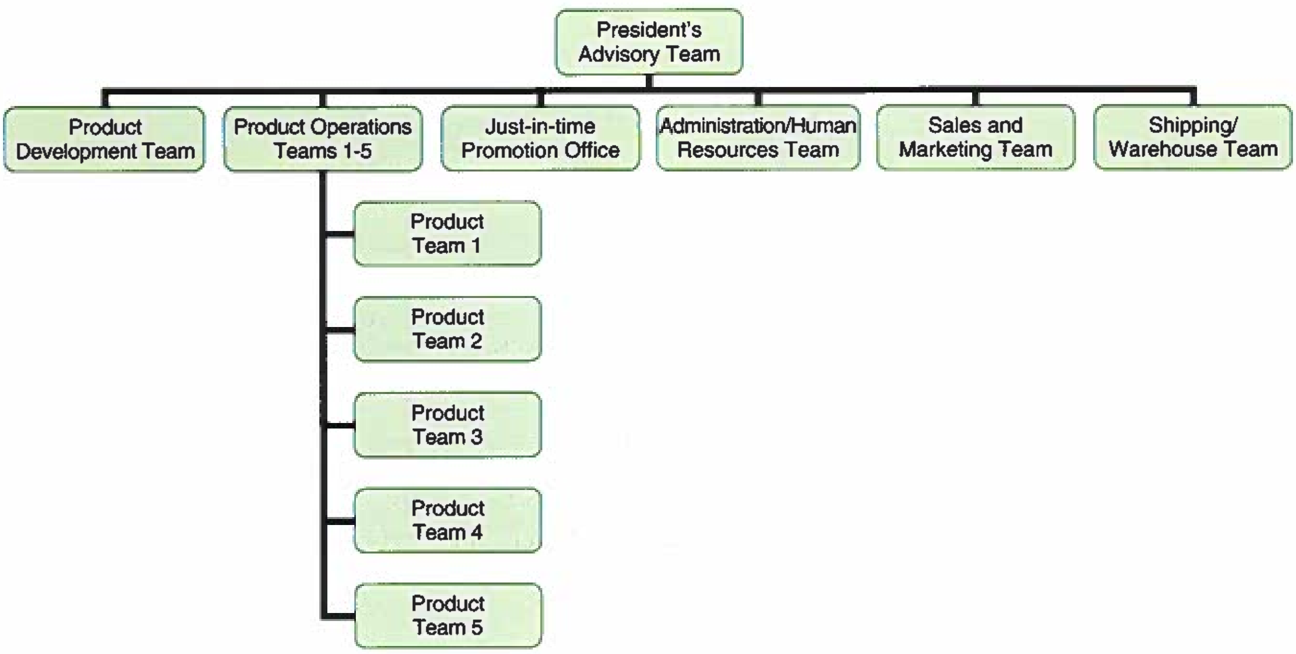


Figure 15-13. In lean manufacturing, workers are grouped into small, product-oriented teams. Each team is encouraged to make improvements to manufacturing processes.

Lean manufacturing works best when it incorporates three features:

- Just-in-time delivery
- Zero defects
- Flexible manufacturing system

Together, these three changes result in a reduction in product development time, a reduction in production time, and elimination of waste.

Just-in-Time Delivery

In the traditional method, known as "batch and queue," parts were created in advance. Then they were stockpiled, or stored near the equipment, to await future use at an undetermined time. This method resulted in higher inventory costs. Also, more factory space was needed to store the inventory.

In *just-in-time delivery*, parts are not stockpiled. Only the parts that are actually needed for the current day's production are made. Those that must be ordered are ordered daily. Each order consists of just enough parts to fill the daily need. This reduces the floor space needed and lowers the cost of producing the final product.

Zero Defects

Defective parts are expensive. They cannot be sold, so the time and materials used to make them is wasted. Automatic machines or an assembly line may have to be stopped if a defective part is noticed, resulting in a further waste of time.

The concept of *zero defects* was first introduced by Philip Crosby in 1979. He defined zero defects as "doing things right the first time." If parts are made correctly the first time, no defective parts are passed forward. Assembly lines do not have to be stopped, and there is less need for troubleshooting. In addition, customer satisfaction is improved because the product works. All of these things result in better efficiency and increased profit.

Flexible Manufacturing Systems

Manufacturing systems that are designed to handle changes easily are known as *flexible manufacturing systems*. See **Figure 15-14.** A work cell in a flexible manufacturing system may consist of a number of automated machines that make parts or assemble products. The equipment can be changed quickly to produce a different type of product.

Reduction in setup time is important because it helps to reduce the total time from the beginning to the end of making a product. This is called the total cycle time. When the total cycle time is reduced, a company can meet changing customer needs more quickly.

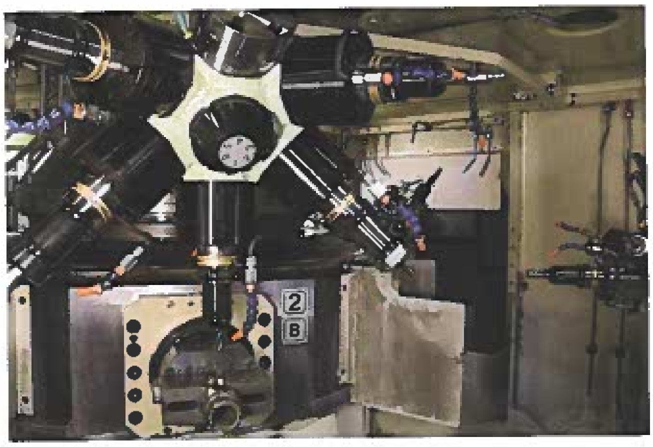


Figure 15-14. Programmable tools like this CNC milling machine can be reprogrammed and retooled quickly. This helps manufacturers meet changing needs without a loss of productivity.

Production Systems

All production systems involve five basic operations.

- Designing
- Planning—organizing a system in which personnel, materials, and equipment work together
- Tooling up—acquiring and setting up tools and machines for production
- Controlling production—using machines to make the product
- Packaging and distribution—packaging, storing, and transporting the products to wholesalers and retailers

Designing

Designing involves making the original plans and drawings of products that satisfy consumer demands. Before starting to design a product, a manufacturer determines what buyers want. This involves market research. The product will not be made if the potential sales are not large enough to make a profit after costs are paid.

Designing is the responsibility of industrial designers. The designers work with engineers, market researchers, and sales personnel. First, they learn the needs of potential customers. Relying on research, they generate ideas and make preliminary sketches of the product. Next, they rework these sketches and make detailed drawings. See **Figure 15-15**.

Designers consult with the engineering staff to determine what production methods and processes to use. When a basic design has been approved, drafters produce scaled or full-size drawings. A three-dimensional model may also be made.

The information gained from the sketches, drawings, and models is then used to make working drawings and specifications. These drawings show the exact size and shape of each part. Specifications include information about:

- The materials to be used
- The number of parts to be made

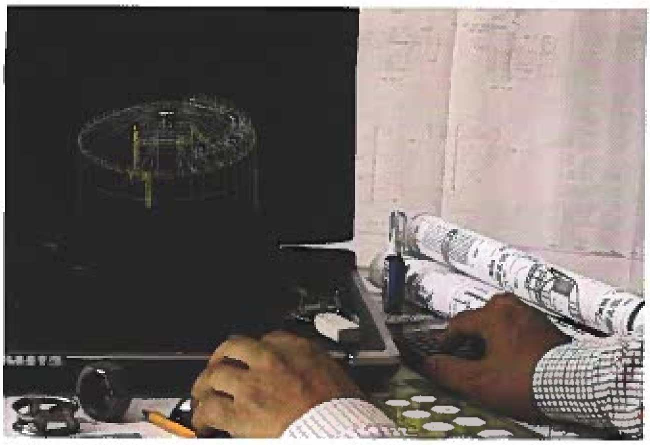


Figure 15-15. Many designers create sketches and refine drawings using computer-aided design (CAD) software.

- The operations needed to produce the part
- The level of accuracy required

Full-scale working models and prototypes are sometimes made. Physical prototypes are often used, but many products can also be tested using a digital 3D prototype and computer testing software. See Figure 15-16. These prototypes help identify weaknesses or errors in the design.

Planning

Production must be planned. Personnel, materials, and equipment must be specified carefully to ensure a smooth operation. This planning includes:

- Selecting and ordering equipment, machines, and processes
- Finding the best way for people to work together
- Determining how long each manufacturing operation will take
- Gathering information on production costs

An engineer or production planner considers a variety of ways to complete each operation. See Figure 15-17. He or she selects the most efficient one. The decision is based on the time involved, cost, and the quality and quantity of the product.

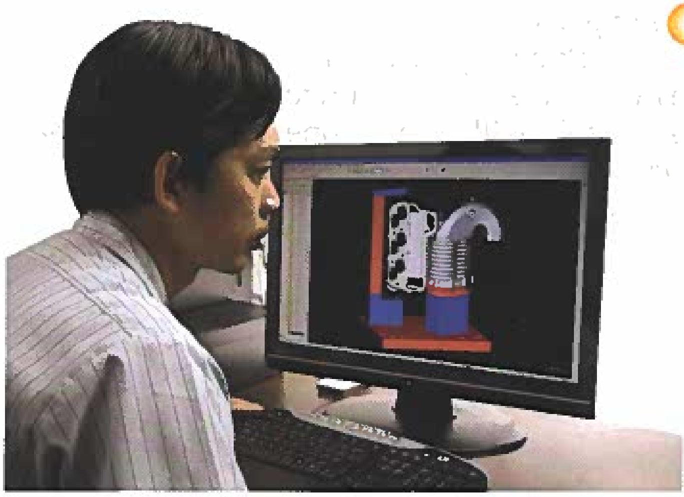


Figure 15-16. Testing 3D digital prototypes saves the cost of building a physical prototype. In most cases, building and testing a digital prototype is also faster, decreasing total development time.

Figure 15-17. Production planners calculate the most efficient and cost-effective methods for making a new product.

Tooling Up

Tooling up is the process of gathering or making the tools and equipment needed to manufacture a new product. Some of the tools and machines may be purchased. Tool-and-die makers design and create others especially for the product. The machines are installed according to the plan created by the engineer or production planner. See **Figure 15-18**. Then a trial production run is conducted to test the setup.

Controlling Production

The production process is organized so that materials and parts move efficiently from one operation to the next with as little waste as possible. This sequence begins in the receiving area, where raw materials are kept. The inventory manager's job is to control the flow of all materials and products. He or she prevents the purchase of unnecessary raw materials, as well as the production and storage of unnecessary products. Materials or parts arrive only a day, or even hours, before they are needed.

Figure 15-18. During the tooling-up stage, engineers check machine setups to make certain parts will be machined accurately.

From receiving, materials move through various stages of processing and assembling. The focus is on avoiding waste of materials, resources and personnel. All unproductive actions and motions are minimized. For example, time is saved when parts are stored closer to the place where they are used. Processes are fine-tuned to minimize the wasted time that occurs when workers or machines have nothing to do.

Throughout the production process, a variety of inspection tools are used. See **Figure 15-19**. Gauges are used to check the sizes of parts. X-rays check the internal structure of metal parts. The amount of inspection varies. In the manufacture of aircraft, it is important to check every part before it is installed in the aircraft. However, for most consumer products, it is enough to check a small number of items from a large batch.

Packaging and Distribution

Various forms of packaging are used to protect products during shipping. Bubble packaging, boxes, cartons, and crates are used to protect the product. They provide insulation and protection against moisture, weather, and rough handling. Packaged products must also be labeled so that the consumer can recognize the contents. Labels and other kinds of markings show the product, the name of the manufacturer, quantity, and directions for use and care. They also provide other special information.

Packaged and labeled products are usually stored in a warehouse to await shipment. See **Figure 15-20**. They are organized in quantities that are convenient for handling, sorting, and counting. The machinery for handling bulk shipments includes conveyor belts, forklift trucks, and pallets. Pallets are wooden platforms on which the packaged products

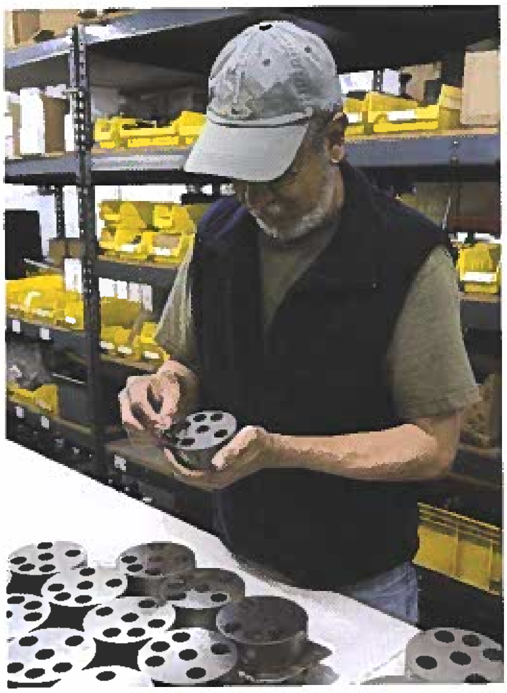


Figure 15-19. Quality is checked throughout the manufacturing process. In addition, a quality control inspector checks a certain number of parts from each batch produced.

Figure 15-20. In many warehouses, inventory is tracked using a bar code attached to each storage box or container. The boxes are stacked on pallets and placed on racks until they are needed.

are placed. A forklift then picks up the loaded pallet and moves it to and from its storage location. When they are sold, products are loaded onto trucks, railroad cars, and ships. These vehicles transport the products to wholesalers and retailers.

Sustainable Manufacturing

Economic growth all over the world has meant an increasing demand for products. This, in turn, has led to an increased demand for raw materials. The result has been an almost intolerable burden on our planet's resources. Can we continue to take from the Earth without eventually running out of raw materials? The answer is no. We must change the way we make our products.

Sustainable manufacturing is the use of processes designed not only to reduce waste, but also to conserve resources such as electrical energy and water. The processes result in little or no pollution. In addition, considerable thought is given to reusing the product after it is no longer useful. Figure 15-21 compares sustainable manufacturing with traditional manufacturing practices.

The cradle-to-cradle (C2C) design philosophy challenges designers to create products with a positive footprint. This means that not only should every component of the items be biodegradable, nontoxic, and fully recyclable, but their waste should be reusable, too. In nature, a tree grows leaves and later sheds them. The leaves decompose, fertilizing the ground on which they fall. In cradle-to-cradle design, manufactured products are designed to be used in this kind of perpetual, closed loop.

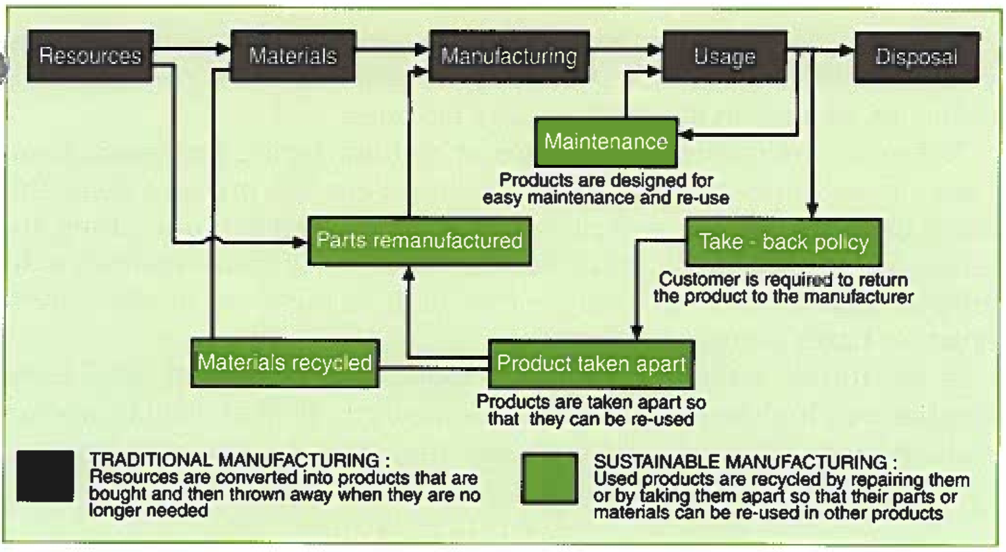


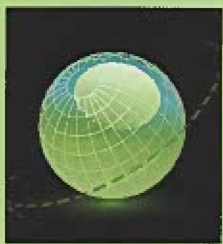
Figure 15-21. Comparison of traditional and sustainable manufacturing.

Ideally, in order to preserve resources for future generations, products should be designed to be:

- Energy-efficient
- Easily and affordably maintained so they last longer
- Easily disassembled into component parts
- Recycled for other uses or reused after repair or updating
- Packaged and returned to the manufacturer when they are no longer needed

Think **Green**

Aluminum: A Sustainable Material



Recycling aluminum cans is nothing new. People have been doing it for many years now. What you may not know is that aluminum recycling is a perfect example of sustainable manufacturing. Aluminum is 100% recyclable, and it can be recycled again and again.

The aluminum recycling process is not complex. It consists of removing contaminants, such as paint, and then melting the aluminum. It can then be molded into storage shapes such as ingots (bars) or rolls. These products are supplied to the manufacturers for use in new products.

Recycling aluminum also saves energy. The recycling process requires only 5% of the energy needed to mine aluminum from bauxite ore. In addition to helping the environment, this lowers the cost of producing aluminum products.

Many communities also accept other types of aluminum for recycling. Accepted items may range from aluminum foil to used lawn furniture. This is important, because although aluminum is easily recycled, it decomposes very slowly. If it ends up in a landfill, it may take 400 years or more to break down. Check with the recyclers in your community. What aluminum items are accepted?

End Note

Industrial manufacturing arose from advances made during the Industrial Revolution. Interchangeable parts made mass production possible. Mass production resulted in the need for large factories.

Today, we are taking another look at manufacturing processes. Many of our current processes pollute the environment. We produce items that we use once, then throw away. Concepts such as lean manufacturing and sustainable manufacturing may help us move away from wasteful older methods. Cradle-to-cradle designs may help us meet our needs without depleting Earth's natural resources.

In the future, we will continue to look for new methods and ideas. Factories may look much different as we incorporate ideas to manufacture products more efficiently and with less impact on the environment.

Summary

- The first step in producing a product is to process renewable or nonrenewable raw materials.
- The second step in producing a product is to change processed raw materials into useful products.
- Automation of assembly lines and other manufacturing processes has resulted in higher productivity and better accuracy.
- Traditional production and manufacturing systems are being replaced by more efficient lean manufacturing methods.
- Sustainable manufacturing incorporates many of the concepts of lean manufacturing, but emphasizes lowering pollution levels and designing products to be reused or recycled rather than thrown away.

Reading Target

Summarizing Information

Copy the following graphic organizer onto a separate sheet of paper. For each chapter section (topic) listed in the left column, write a short, one-paragraph summary of the topic in the right column. Do not write in this book.

Chapter Section (Topic)	Summary
Processing Raw Materials	
Manufacturing Products	
Automation	
Production and Management Systems	
Sustainable Manufacturing	

Test Your Knowledge

Write your answers to these review questions on a separate sheet of paper.

1. What are the two main steps in producing a product from raw materials?
2. List the three stages through which the manufacturing process has evolved.
3. What is the advantage of products made with interchangeable parts?
4. Describe the difference between a traditional mass production assembly line and an automated assembly line.
5. List five jobs that robots can perform in the manufacture of a product.
6. List the advantages and disadvantages of automation.
7. How is lean manufacturing different from traditional manufacturing?
8. What three features are often incorporated into lean manufacturing systems?
9. List the five basic steps in a production system.
10. How is sustainable manufacturing different from traditional manufacturing?

Critical Thinking

1. This chapter briefly discusses the potential loss of jobs caused by automation. However, other factors also cause job loss in manufacturing. Research and explain the role of the global economy on jobs in the manufacturing sector.
2. Analyze the following statement: "Sustainable manufacturing will further reduce jobs in manufacturing because products will be reused indefinitely." Is the statement true? Explain your answer.

Apply Your Knowledge

1. Select a raw material to research. Find out:
   A. Where is it found?
   B. In what form is it found in its natural state?
   C. How is it extracted, harvested, or farmed?
   D. How is it transported?
   E. How is it processed or refined?
2. Create a chart comparing robots to human workers. Design the chart to show advantages and disadvantages of using humans and robots in each stage of the production process.
3. Imagine that in your working life, you started as an artisan. You then moved to a factory and worked on a mass production line. Your last job was in a fully automated factory in which robots did the work. Describe the advantages, disadvantages, and working conditions in each of your three jobs.
4. Research how new technologies have replaced, outdated, or created new jobs in your community.
5. Give one example of leading-edge products in each of the following areas. Find examples that are *not* described in the textbook. Where and by what company is each product manufactured?
   A. Computers and electronics
   B. Telecommunications and networking
   C. Media and entertainment
   D. Nanotechnology and materials
   E. Energy and the environment
   F. Biotechnology and health care
   G. Transportation and cities
   H. Privacy, security, and defense
6. From a science-fiction book, comic, TV show, or movie in which events occur in the future, identify three technical objects or systems that do not exist today. Describe how each one operates.
7. The following list shows how change took place from the beginning to the end of the twentieth century. Find or draw a picture that illustrates each of the changes. For example, for part A, you could have a picture of a steam train and another of an electric train.
   A. Steam to electric
   B. Rural to urban
   C. Cottage industries to factories
   D. Cart tracks to railroads
   E. Personal contact to telephone
   F. Horse to car and airplane
   G. Brick and stone to steel and aluminum
   H. General store to department store
   I. Natural materials to synthetic materials
8. Research one career related to the information you have studied in this chapter. Create a report that states the following:
   - The occupation you selected
   - The education requirements to enter this occupation
   - The possibilities for promotion to a higher level
   - What someone with this career does on a daily basis
   - The earning potential for someone with this career

   You might find this information on the Internet or in your library. If possible, interview a person who already works in this field to answer the five points. Finally, state why you might or might not be interested in pursuing this occupation when you finish school.

STEM Applications

1. **TECHNOLOGY** Design a plant stand that has no more than four or five pieces. The plant stand should be made of commonly available, inexpensive materials. Plan a production system to mass-produce the plant stand. Create a graph or chart to show all of the steps in the production process. If the materials are available, ask classmates to help you test your production plan by producing a batch of plant stands.
2. **ENGINEERING** Identify a product you use every day that is manufactured using traditional methods. Plan a sustainable manufacturing system in which the product could be manufactured. Your plan should minimize waste and account for what happens to the product after its useful life is over. Present your plan to the class.
3. **ENGINEERING** Using the cradle-to-cradle design philosophy, design and make a cabinet that will hold up to 40 CDs or DVDs. Create a sustainable manufacturing plan to produce the cabinet. Document your plan in a report, using charts and graphs to show the various steps of production. Make a poster showing the planned life cycle of the cabinet.
4. **TECHNOLOGY** Research to find a manufacturing company that has switched from traditional to lean manufacturing. Assess the products output before and after the switch. Write a report explaining what is different in the new system. State whether the company's goal of reducing waste was achieved. List the overall positive and negative effects of the change.

CHAPTER 16

Technology and the Environment

Better by Design

The LifeStraw Personal contains filters that make polluted water safe to drink.

Mikkel Vestergaard Frandsen and the LifeStraw® Personal

Safe drinking water is hard to find in many Third World countries. Many people in undeveloped areas suffer from diseases they catch by drinking polluted water, and many of them even die. Mikkel Vestergaard Frandsen developed a straw called LifeStraw Personal that makes polluted water safe to drink. Contaminated water is drawn in through the lower end. The straw kills 99.999% of water-borne bacteria and viruses. By the time the water reaches the person's mouth, it is safe to drink. The filters in the straw can process about 185 gallons (700 liters) of water. This is enough to provide drinking water for one person for about a year. It is inexpensive, light, and portable and can be carried on a string around the neck. This makes it perfect for people in Third World countries who need a reliable source of drinking water.

LifeStraw Personal does not require batteries and can be used anywhere.

"We must use our innovative skills to save the lives of millions of people who are dying needlessly."