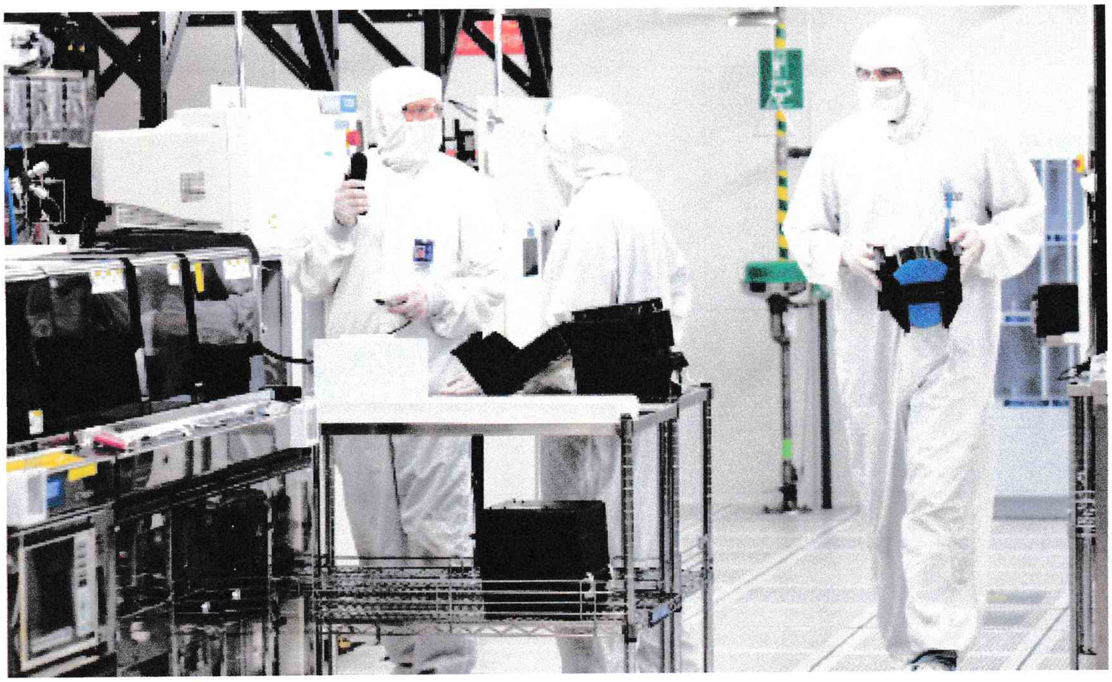
Processes and Technology



Bloomberg/Getty Images, Inc.

LEARNING OBJECTIVES

After reading this chapter, you will be able to:

- Evaluate strategic options in process planning, including whether or not to outsource.
- Differentiate among different types of production processes.
- Understand the effect of volume and standardization on process selection.
- Appreciate the difficulties in translating a design to a process.
- Use simple flowcharting tools to improve everyday processes.
- Investigate the use of technology in manufacturing and service processes.

From Sand to Silicon to Smartphone

The semiconductor industry makes the chips that are the brains of smartphones. The process of making a chip is long and involved, over 300 steps in all, and takes place in the highly automated clean room environment of a foundry or *fab* (i.e., fabricator), as shown in the photo above. It begins with silicone (e.g., sand), which is purified, melted, and cooled into a solid crystallized ingot, commonly with a diameter of 300 mm. The ingot is sliced into discs called wafers, each about one mm thick. The wafers are polished and packaged for shipment to the next process or to an outside manufacturer. Photolithography then imprints a specific pattern on the wafer, deposits a liquid called photo resist, and exposes it to ultraviolet light. Many more steps are performed and repeated depending on the complexity of the chip; material and ions are added, diffused, etched, cleaned, and doped in precise sequences layer after layer. Transistors control the electrical current in the chip and are added layer by layer as well. The wafers are tested and then sliced into individual pieces and packaged into what we know as a chip. Depending on the size of each chip, its quality, and its intended use, one wafer can produce tens of thousands of chips.

The entire process is complex in both design and execution, *and* it is microscopic. With today's technology, over 30 million transistors can fit across the width of a single human hair. Smaller sizes mean more powerful chips and a faster and more powerful processor for your smartphone.

In this chapter, we'll talk about different types of processes and technologies, from highly automated advanced manufacturing to low-tech manual assembly operations. We'll examine how to select the right process, how to plan it out, and how to improve it.

Source: ITA, "Semiconductors and Semiconductor Manufacturing Equipment Top Markets Report," Washington, DC: International Trade Administration, July 2015; S. Gibbs, "Moore's law wins: new chips have circuits 10,000 times thinner than hairs," *The Guardian*, (July 9, 2015); "How Intel Makes Chips: Transistors to Transformations," Intel, Corporate brochure, 2015.

A **process** is a group of related tasks with specific inputs and outputs. Processes exist to create value for the customer, the shareholder, or society. *Process design* defines what tasks need to be done and how they are to be coordinated among functions, people, and organizations. Planning, analyzing, and improving processes is the essence of operations management. Processes are planned, analyzed, and redesigned as required by changes in strategy and emerging technology.

Process A group of related tasks with specific inputs and outputs.

Process strategy is an organization's overall approach for physically producing goods and providing services. Process decisions should reflect how the firm has chosen to compete in the marketplace, reinforce product decisions, and facilitate the achievement of corporate goals. A firm's process strategy defines its:

Process strategy An organization's overall approach for physically producing goods and services.

- ***Vertical integration:*** The extent to which the firm will produce the inputs and control the outputs of each stage of the production process.
- ***Capital intensity:*** The mix of capital (i.e., equipment, automation) and labor resources used in the production process.
- ***Process flexibility:*** The ease with which resources can be adjusted in response to changes in demand, technology, products or services, and resource availability.
- ***Customer involvement:*** The role of the customer in the production process.

In this chapter we examine the planning, analysis, and innovation of processes, as well as technology decisions related to those processes.

Process Planning

Process planning determines *how* a product will be produced or a service provided. It decides which components will be made in-house and which will be purchased from a supplier, selects processes, and develops and documents the specifications for manufacture and delivery. In this section, we discuss outsourcing decisions, process selection, and process plans.

Process planning Converts designs into workable instructions for manufacture or delivery.

Outsourcing

A firm that sells the product, assembles the product, makes all the parts, and extracts the raw material is completely **vertically integrated**. But most companies cannot or will not make all of the parts that go into a product. A major strategic decision, then, is how much of the work should be done outside the firm. The decision involves questions of dependence, competency-building, and proprietary knowledge, as well as cost.

Vertical integration The degree to which a firm produces the parts that go into its products.

On what basis should particular items be made in-house? When should items be outsourced? How should suppliers be selected? What type of relationship should be maintained with suppliers—arm's length, controlling, partnership, alliance? What is expected from the suppliers? How many suppliers should be used? How can the quality and dependability of suppliers be ensured? How can suppliers be encouraged to collaborate?

For process planning, we need to decide which items will be purchased from an outside supplier and which items will be produced in our own factories. More advanced sourcing decisions and a discussion of the questions posed above are covered in Chapter 10.

The basic outsourcing decision rests on an evaluation of the following factors:

1. ***Cost.*** Would it be cheaper to make the item or buy it? To perform the service in-house or outsource it? The cost of *buying* the item from a supplier includes the purchase price, transportation costs, and various tariffs, taxes, and fees (referred to as landed cost in Chapter 10). The cost of coordinating production over long distances and increased inventory levels to cover demand during a lengthy lead time can also run high. The cost of *making* the item includes labor, material, and overhead. Existing overhead does not disappear when some products are outsourced. Spreading overhead over fewer products can actually increase unit costs.

In some situations a company may decide to buy an item rather than make it (or vice versa) when, from a cost standpoint, it would be cheaper to do otherwise. The remaining factors in this list represent noneconomic factors that can influence or dominate the economic considerations.

2. ***Capacity.*** Companies that are operating at less than full capacity may elect to make components rather than buy them, especially if maintaining a level workforce or capability to produce is important. Sometimes the available capacity is not sufficient to make all the components, so choices have to be made. Typically, it is better to produce more customized or volatile products in-house, and to outsource steady products with high volume/high standardization.
3. ***Quality.*** The capability to provide quality parts consistently is an important consideration in the outsourcing decision. It is easier to control the quality of items produced in your own factory. However, standardization of parts, supplier certification, and supplier involvement in design can improve the quality of supplied parts. In the event that quality becomes a problem, increased monitoring of the supplier can significantly increase costs.
4. ***Speed.*** The savings from purchasing an item from a far-off vendor can be eaten up by the lengthy transit time of offshore shipments. At other times, a smaller supplier can be more flexible, and can adapt more quickly to design and technology changes. Of course, speed is useful only if it is reliable.

Internet Exercises

5. ***Reliability.*** Suppliers need to be reliable in both the quality and the timing of what they supply. Unexpected delays in shipments or partially filled orders because of quality rejects can wreak havoc with the manufacturing system. Many companies today are requiring that their suppliers meet certain quality and delivery standards to be certified as an approved supplier. As discussed in Chapter 2, the most common quality certification is ISO 9000. Other companies assess huge penalties for unreliable supply. Some automakers, for example, fine their suppliers $30,000 for each *hour* an order is late.
6. ***Expertise.*** Companies that are especially good at making or designing certain items may want to keep control over their production. Coca-Cola would not want to release its formula to a supplier, even if there were guarantees of secrecy. Although automakers might outsource many of their component parts, they need proprietary control over major components such as engines, transmissions, and electronic guidance systems. Japanese, Taiwanese, and Korean firms are currently learning U.S. expertise in aircraft design and manufacture by serving as suppliers of component parts. Chinese markets are often flooded with cheap knockoffs of goods manufactured by suppliers in that country. The protection of intellectual property is a major concern in extended supply chains.

The outsourcing decision can be made along a continuum from a single purchasing decision to a joint venture, as shown in **Figure 6.1**. Single contracts are used if the outsourcing decision is temporary, or the products are standardized (like commodities) and suppliers are chosen based on lowest cost. Strategic -alliances signify that the supplier is an important long-term partner, and the cost or consequences of switching suppliers would be significant. Companies share more information with strategic suppliers and work with them to solve problems or improve processes. Joint ventures are used when entering a foreign country for the first time, or as a condition for operating in another country. Risks, resources, and rewards are shared among equity partners of a joint venture.

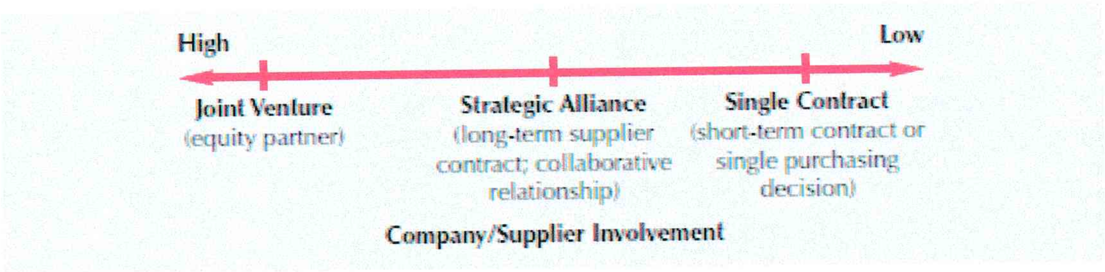


FIGURE 6.1 **The Sourcing Continuum**

Process Selection

The next step in process planning is to select a production process for those items we will produce in-house. Production processes can be classified into projects, batch production, mass production, and continuous production.

Projects take a long time to complete, involve a large investment of funds and resources, and produce one item at a time to consumer order. Examples include construction projects, shipbuilding, new-product development, and aircraft manufacturing.

Projects One-at-a-time production of a product to customer order.

Batch production processes many different jobs through the production system at the same time in groups or batches. Products are typically made to customer order, volume (in terms of customer order size) is low, and demand fluctuates. Examples of batch production include printers, bakeries, machine shops, education, and furniture making.

Batch production Processing many different jobs at the same time in groups (or batches).

Mass production produces large volumes of a standard product for a mass market. Product demand is stable, and product volume is high. Goods that are mass produced include automobiles, televisions, personal computers, fast food, and most consumer goods.

Mass production Producing large volumes of a standard product for a mass market.

Continuous production is used for *very* high-volume commodity products that are *very* standardized. The system is *highly* automated and is typically in operation continuously 24 hours a day (as seen in the photo). Refined oil, treated water, paints, chemicals, steel and foodstuffs are produced by continuous production.

Continuous production Producing very high-volume commodity products.

The process chosen to create the product or service must be consistent with product and service characteristics. The most important product characteristics (in terms of process choice) are degree of *standardization* and *demand volume*. Figure 6.2 shows a product-process matrix that matches product characteristics with process choice.

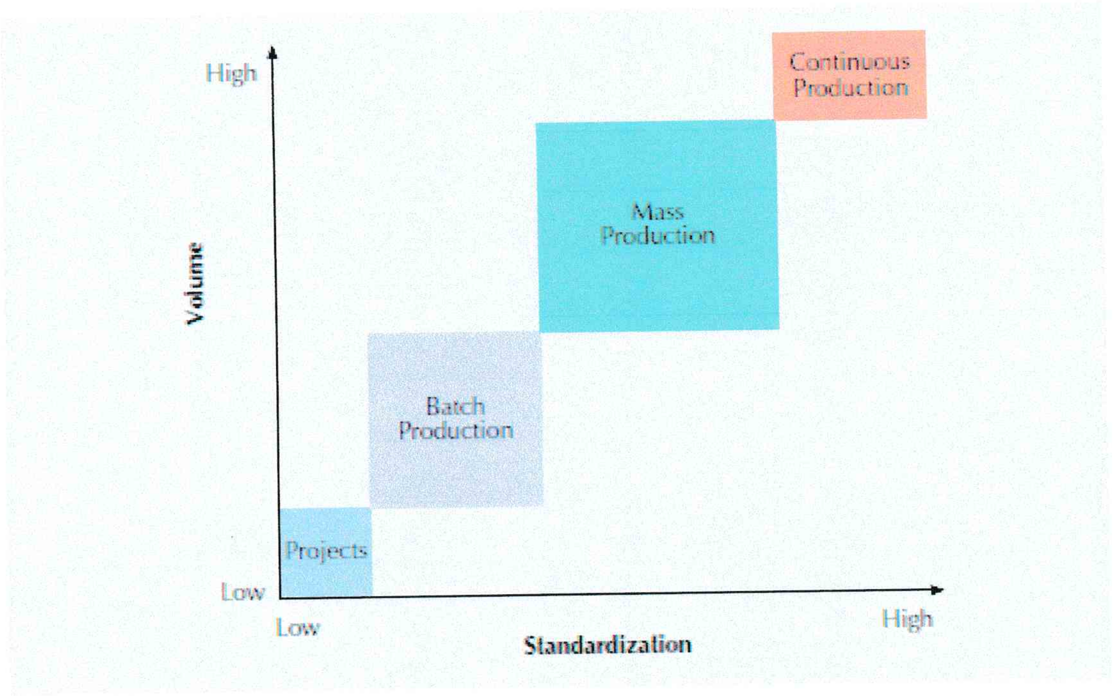


FIGURE 6.2 **The Product-Process Matrix**

Source: Adapted from Robert Hayes and Steven Wheelwright, *Restoring the Competitive Edge: Competing Through Manufacturing* (New York, John Wiley & Sons, 1984), p. 209.

The best process strategy is found on the diagonal of the matrix. Companies or products that are off the diagonal have either made poor process choices or have found a means to execute a competitive advantage. For example, technological advancements in flexible automation allow Motorola to mass produce customized pagers. Volvo and Rolls Royce occupy a special market niche by producing cars in a crafted, customized fashion. Examples of poor process choice include Texas Instruments' attempt to produce consumer products for mass markets by the same process that had been successful in the production of scientific products for specialized markets, and Corning's production of low-volume consumer items, such as range covers, with the same continuous process used for other items formed from glass.

Table 6.1 summarizes the characteristics of each type of process. Examples of each type of process are shown in the photos that follow. As we move from projects to continuous production, demand volume increases; products become more standardized; systems become more capital-intensive, more automated, and less flexible; and customers become less involved.

TABLE 6.1 Types of Processes

	PROJECT	BATCH PRODUCTION	MASS PRODUCTION	CONTINUOUS PRODUCTION
Type of product	Unique	Made-to-order (customized)	Made-to-stock (standardized)	Commodity
Type of customer	One-at-a-time	Few individual customers	Mass market	Mass market
Product demand	Infrequent	Fluctuates	Stable	Very stable
Demand volume	Very low	Low to medium	High	Very high
No. of different products	Infinite variety	Many, varied	Few	Very few
Production system	Long-term project	Discrete, job shops	Repetitive, assembly lines	Continuous, process industries
Equipment	Varied	General-purpose	Special-purpose	Highly automated
Primary type of work	Specialized contracts	Fabrication	Assembly	Mixing, treating, refining
Worker skills	Experts, craftspersons	Wide range of skills	Limited range of skills	Equipment monitors
Advantages	Custom work, latest technology	Flexibility, quality	Efficiency, speed, low cost	Highly efficient, large capacity, ease of control
Disadvantages	Nonrepetitive, small customer base, expensive	Costly, slow, difficult to manage	Capital investment, lack of responsiveness	Difficult to change, far-reaching errors, limited variety
Examples	Construction, shipbuilding, spacecraft	Machine shops, print shops, bakeries, education	Automobiles, televisions, computers, fast food	Paint, chemicals, foodstuffs

Process Selection With Breakeven Analysis

Several quantitative techniques are available for selecting a process. One that bases its decision on the cost tradeoffs associated with demand volume is **breakeven analysis**. The components of breakeven analysis are volume, cost, revenue, and profit.

Breakeven analysis Examines the cost trade-offs associated with demand volume.

Volume is the level of production, usually expressed as the number of units produced and sold. We assume that the number of units produced can be sold.

Cost is divided into two categories: fixed and variable. *Fixed costs* remain constant regardless of the number of units produced, such as plant and equipment and other elements of overhead. *Variable costs* vary with the volume of units produced, such as labor and material. The total cost of a process is the sum of its fixed cost and its total variable cost (defined as volume times per unit variable cost).

Revenue on a per-unit basis is simply the price at which an item is sold. *Total revenue* is price times volume sold. *Profit* is the difference between total revenue and total cost. These components can be expressed mathematically as follows:

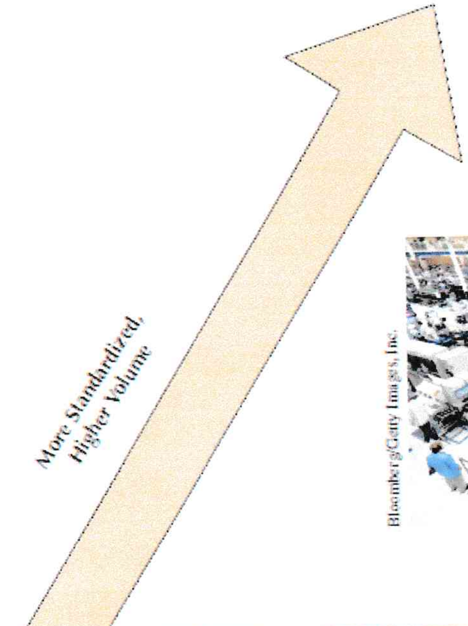
$$\begin{aligned}
\text{Total cost} &= \text{fixed cost} + \text{total variable cost} \\
\text{TC} &= c_f + vc_v \\
\text{Total revenue} &= \text{volume} \times \text{price} \\
\text{TR} &= vp \\
\text{Profit} &= \text{total revenue} - \text{total cost} \\
Z &= \text{TR} - \text{TC} \\
&= vp - (c_f + vc_v)
\end{aligned}$$

where

$$\begin{aligned}
c_f &= \text{fixed cost} \\
v &= \text{volume (i.e., number of units produced and sold)} \\
c_v &= \text{variable cost per unit} \\
p &= \text{price per unit}
\end{aligned}$$

Continuous Production. *A paper manufacturer produces a continuous sheet of paper from wood pulp surry, which is mixed, pressed, dried, and wound onto reels. Later winders will cut the paper into customer size rolls for wrapping and labeling. Production per day exceeds 1700 tons or the equivalent of 680,000 reams of paper.*

Philip Gould/Getty Images, Inc.



Bloomberg/Getty Images, Inc.

Mass Production. *At this Flextronics factory in Fort Worth, Texas, workers assemble more than 100,000 MotoZ cellphones per week. Work is arranged in a line with assembly tasks performed in sequence. Each task takes less than a minute to complete.*

Matt Rourke/AP Images

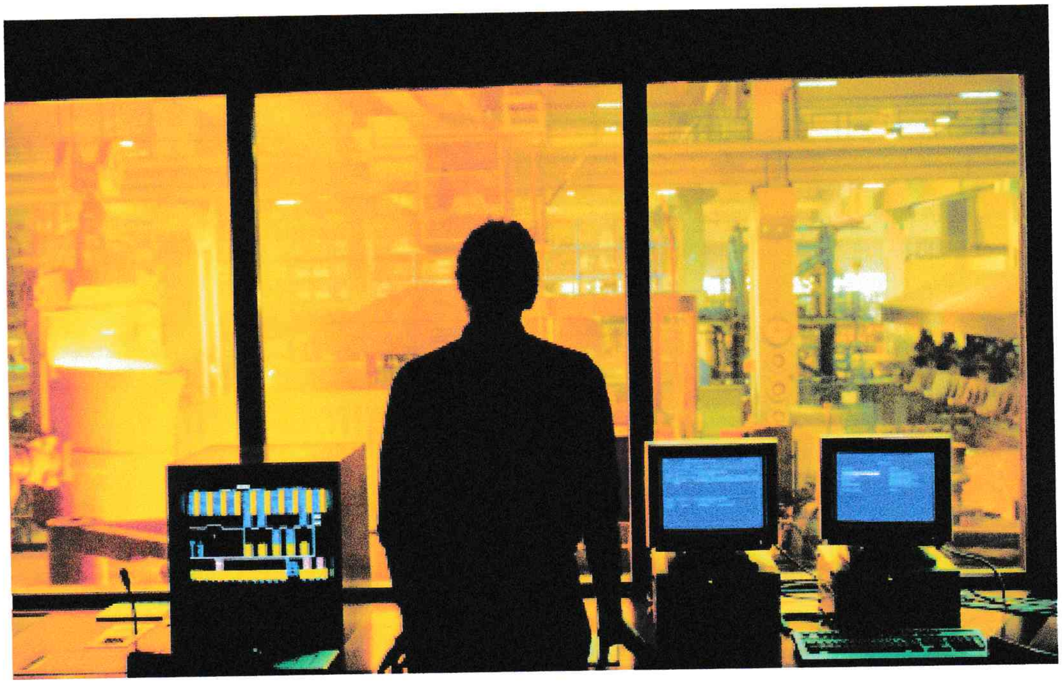
Batch Production. *At Martin Guitar, skilled craftsmen and women carefully construct and assemble the numerous parts of a guitar. Except for rough cutting and sanding, most of the 150 steps required to make an acoustic guitar are performed by hand. One of the most crucial steps for quality sound is fitting the neck to the body. While some manufacturers use computer-aided manufacturing (CAM) for this, at Martin, a master neck setter fits, shaves and refits the joint by hand for superior quality. Even with such careful attention to detail, the factory can produce approximately 200 guitars a day.*

JUNG YEON-JE/Getty Images, Inc.

Project. *The construction of an aircraft carrier is an enormous project. The USS Nimitz, shown here, took more than four years to build at a cost of $4.5 billion. The carrier accommodates a crew of more than 6000 people and a full-load displacement of 100,000 tons. The carrier also houses two nuclear reactors, enabling it to operate for 13 years without refueling. Modular construction, in which a ship is built in sections or modules, has cut the production time of carriers and other ships in half. This is accomplished by outfitting several modules at one time and then adding them to the hull. Extensive use of CAD/CAM, precise tolerances, and careful quality control ensure that the modules fit together perfectly.*

In selecting a process, it is useful to know at what volume of sales and production we can expect to earn a profit. We want to make sure that the cost of producing a product does not exceed the revenue we will receive from the sale of the product. By equating total revenue with total cost and solving for v, we can find the volume at which profit is zero. This is called the **breakeven point**. At any volume above the breakeven point, we will make a profit. A mathematical formula for the breakeven point can be determined as follows:

$$\begin{aligned} \mathrm{TR} &= \mathrm{TC} \\ vp &= c_f + vc_v \\ vp - vc_v &= c_f \\ v\,(p - c_v) &= c_f \\ v &= \tfrac{c_f}{p - c_v} \end{aligned}$$



The Image Bank/Getty Images, Inc.

Continuous processes are used for very-high-volume, commodity products whose output is measured rather than counted. The production system is capital-intensive and highly automated (with workers who monitor the equipment rather than perform the work) and is typically operated 24 hours a day. Here a worker monitors steel production from a control center at ThyssenKrupp AG in Germany.

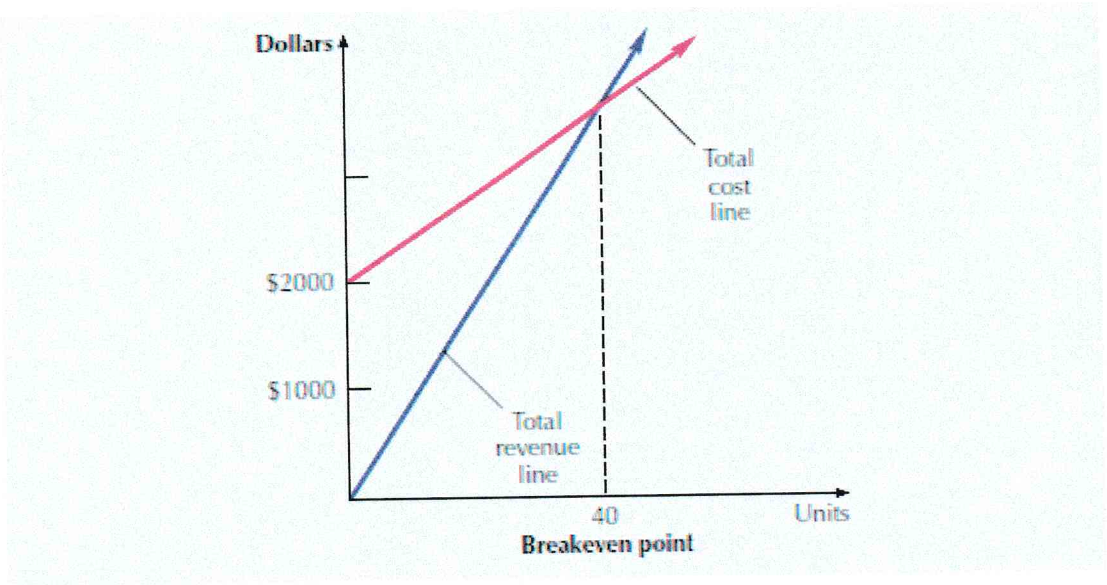
EXAMPLE 6.1 | Breakeven Analysis

Travis and Jeff own Up Right Paddlers, a new startup company with the goal of designing, making, and marketing stand-up paddle boards for streams and rivers. A new fitness craze, stand-up paddle boards are similar to surfboards in appearance, but are used by individuals to navigate down rivers in an upright position with a single long pole (or paddle), instead of sitting in tubes or rafts and floating down. River boards are constructed from heavy-duty raft material that is inflatable, rather than fiberglass used in ocean boards. Unlike ocean boards that market for $500 to $1000 each, paddle boards are typically sold for between $100 and $400. Since Travis and Jeff are just starting out and the demand for paddle boards on the East Coast has not been firmly established, they anticipate selling their product for $100 each. Travis estimates the fixed cost for equipment and space will be $2000, and the material and labor costs will run $50 per unit. What volume of demand will be necessary for Travis and Jeff to break even on their new venture?

Solution:

$$\begin{aligned}
\text{Fixed cost} &= c_f = \$2{,}000 \\
\text{Variable cost} &= c_v = \$50 \text{ per board} \\
\text{Price} &= p = \$100 \text{ per board} \\
v &= \frac{c_f}{p - c_v} = \frac{2000}{100-50} = 40 \text{ units}
\end{aligned}$$

The solution is shown graphically in the following figure. The *x*-axis represents production or demand volume, and the *y*-axis represents dollars of revenue, cost, or profit. The total revenue line extends from the origin, with a slope equal to the unit price of a board. The total cost line intersects the *y*-axis at a level corresponding to the fixed cost of the process and has a slope equal to the per-unit variable cost. The intersection of these two lines is the breakeven point. If demand is less than the breakeven point, the company will operate at a loss. But if demand exceeds the breakeven point, the company will be profitable. The company needs to sell more than 40 paddle boards to make a profit.



Breakeven analysis is especially useful when evaluating different degrees of automation. More automated processes have higher fixed costs but lower variable costs. The "best" process depends on the anticipated volume of demand for the product and the tradeoffs between fixed and variable costs. Example 6.2 shows how breakeven analysis can guide the selection of a process among two alternatives. The example uses this procedure:

1. Formulate a total cost equation for each process considered.
2. Calculate the ***point of indifference*** between two alternative processes (i.e., the volume at which the total cost of manufacturing is the same for the two processes) by setting their total cost equations equal to each other and solving for v, demand volume.
3. Above the point of indifference, choose the alternative with the lowest variable cost.
4. Below the point of indifference, choose the alternative with the lowest fixed cost.

For an example of choosing the best process among three alternatives, see the Solved Problem at the end of the chapter.

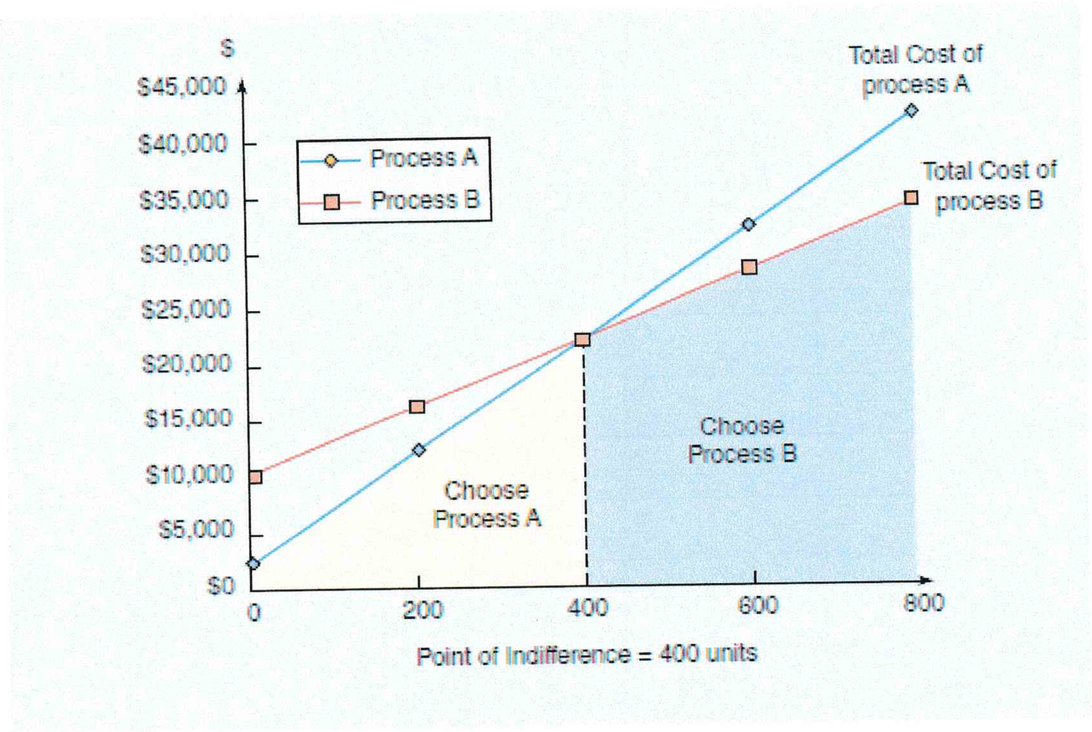
EXAMPLE 6.2 | Process Selection

Jeff, the more optimistic of the two owners of UpRight Paddlers, believes that demand for paddle boards will exceed the breakeven point of 40 units calculated in Example 6.1. He proposes spending $10,000 in fixed costs to buy more automated equipment that would reduce the materials and labor cost to $30 per board. The boards would sell for $100, regardless of which manufacturing process is chosen. Compare the two processes and determine for what level of demand each process would be preferred. Label Travis's proposal as Process A and Jeff's proposal as Process B.

Solution:

$$\begin{aligned} \textit{Process A} \qquad & \qquad \textit{Process B} \\ \$2{,}000 + \$50v &= \$10{,}000 + \$30v \\ \$20v &= \$8{,}000 \\ v &= 400 \text{ units} \end{aligned}$$

If demand is less than or equal to 400 boards, the alternative with the lowest fixed cost, *process A*, should be chosen. If demand is greater than or equal to 400 boards, the alternative with the lowest variable cost, *process B*, is preferred. Our decision can be confirmed by examining the next graph. (Because the boards will be sold for $100 apiece regardless of which process is used to manufacture them, no revenue line is needed.)



Process Plans

Process plans are a set of documents that detail manufacturing and service delivery specifications. They begin with detailed drawings of product design (usually from a CAD system) and include **assembly charts** or bills of material (showing the parts and materials needed and how they are to be assembled together), *operations sheets* or routing sheets (listing the operations to be performed with details on equipment, tools, skills, etc.), and *quality-control checksheets* (specifying quality standards and quality data to be recorded).

Process plans A set of documents that detail manufacturing and service delivery specifications.

Assembly charts A schematic diagram of a product that shows the relationship of component parts to parent assemblies.

Process plans are used in both manufacturing and service settings. A hospital, for example, has a set of process plans (often called protocols) for different types of medical procedures and service plans for each particular patient. Similarly, in manufacturing, some process plans are standard, and others are created for each customer order. Figure 6.3 shows an assembly chart for a Big Mac. Figure 6.4 shows an operations sheet for a plastic molded vacuum cleaner attachment.

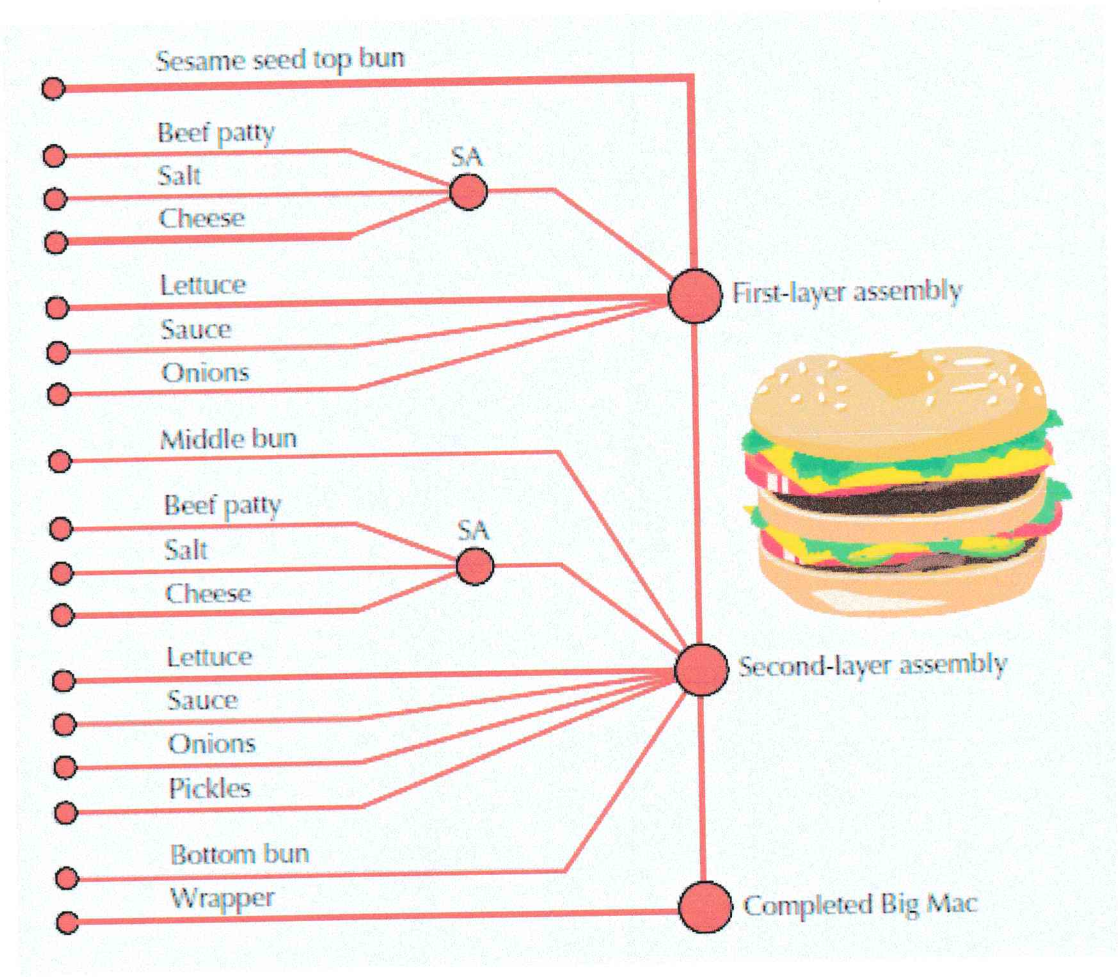
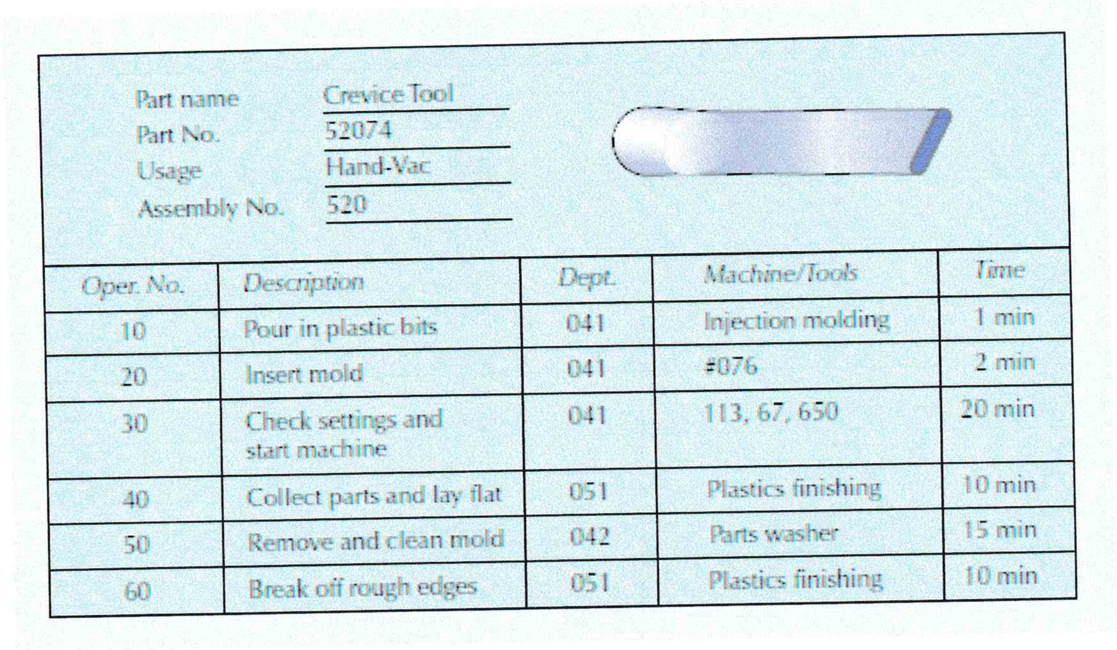


FIGURE 6.3 **An Assembly Chart for a Big Mac**



Part name Crevice Tool
Part No. 52074
Usage Hand-Vac
Assembly No. 520

Oper. No.	*Description*	*Dept.*	*Machine/Tools*	*Time*
10	Pour in plastic bits	041	Injection molding	1 min
20	Insert mold	041	#076	2 min
30	Check settings and start machine	041	113, 67, 650	20 min
40	Collect parts and lay flat	051	Plastics finishing	10 min
50	Remove and clean mold	042	Parts washer	15 min
60	Break off rough edges	051	Plastics finishing	10 min

FIGURE 6.4 **An Operations Sheet for a Plastic Part**

Process Analysis

Process analysis is the systematic examination of all aspects of a process to improve its operation—to make it faster, more efficient, less costly, or more responsive to the customer. The basic tools of process analysis are process flowcharts, diagrams, and maps.

Exhibit 6.1 shows the various flowcharts available in Microsoft Visio to map out business processes.

EXHIBIT 6.1 | Flowcharts Available in Microsoft Visio

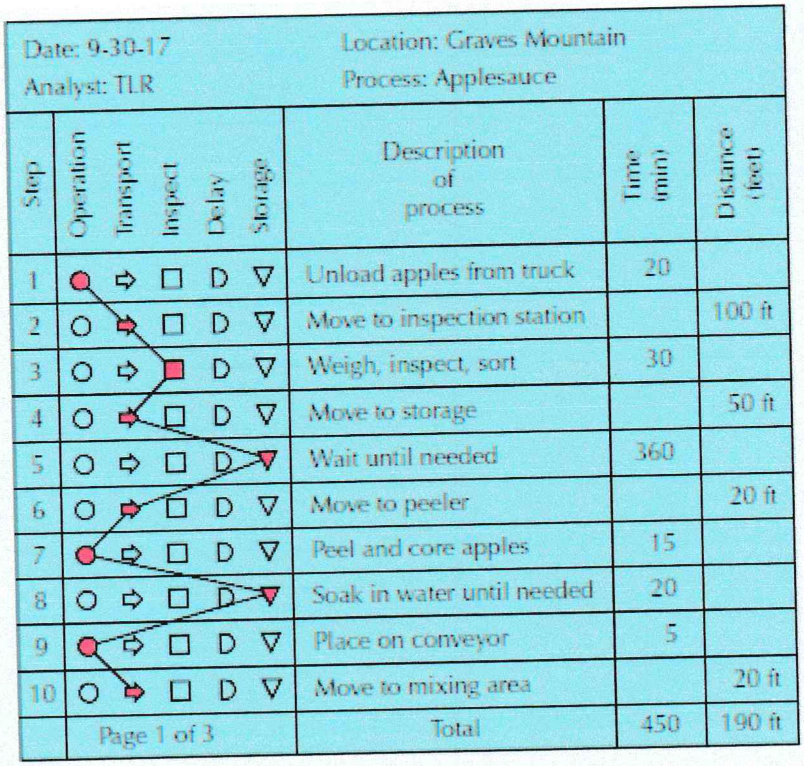
These flowcharts come in many different sizes, shapes, and forms; several are depicted in this chapter. While the format and symbols used may vary, the "process" of building a flowchart follows these steps:

1. Determine objectives.
2. Define process boundaries.
3. Define units of flow (i.e., patients, products, data).
4. Choose type of chart.
5. Observe process and collect data.
6. Map out process.
7. Validate chart (with user, expert, or observation).

Process FlowCharts

The classic **process flowchart** looks at the manufacture of a product or delivery of a service from a broad perspective. The chart uses five standard symbols, shown in Figure 6.5, to describe a process: ○ for operations, □ for inspections, ⇒ for transportation, D for delay, and ▽ for storage. The details of each process are not necessary for this chart; however, the time required to perform each process and the distance between processes are often included. By incorporating nonproductive activities (*inspection, transportation, delay, storage*), as well as productive activities (*operations*), process flowcharts may be used to analyze the efficiency of a series of processes and to suggest improvements. They also provide a standardized method for documenting the steps in a process and can be used as a training tool. Automated versions of these charts are available that will superimpose the charts on floor plans of facilities. In this fashion, bottlenecks can be identified and layouts can be adjusted. Process flowcharts are used in both manufacturing and service operations. They are a basic tool for process innovation, as well as for job design.

Process flowchart A document that uses standardized symbols to chart the productive and nonproductive flow of activities involved in a process.



Date: 9-30-17
Analyst: TLR
Location: Graves Mountain
Process: Applesauce

Step	Operation	Transport	Inspect	Delay	Storage	Description of process	Time (min)	Distance (feet)
1	●	⇨	□	D	▽	Unload apples from truck	20	
2	○	➡	□	D	▽	Move to inspection station		100 ft
3	○	⇨	■	D	▽	Weigh, inspect, sort	30	
4	○	➡	□	D	▽	Move to storage		50 ft
5	○	⇨	□	D	▼	Wait until needed	360	
6	○	➡	□	D	▽	Move to peeler		20 ft
7	●	⇨	□	D	▽	Peel and core apples	15	
8	○	⇨	□	D	▼	Soak in water until needed	20	
9	●	⇨	□	D	▽	Place on conveyor	5	
10	○	➡	□	D	▽	Move to mixing area		20 ft
	Page 1 of 3					Total	450	190 ft

FIGURE 6.5 **A Process Flowchart of Apple Processing**

Excel File

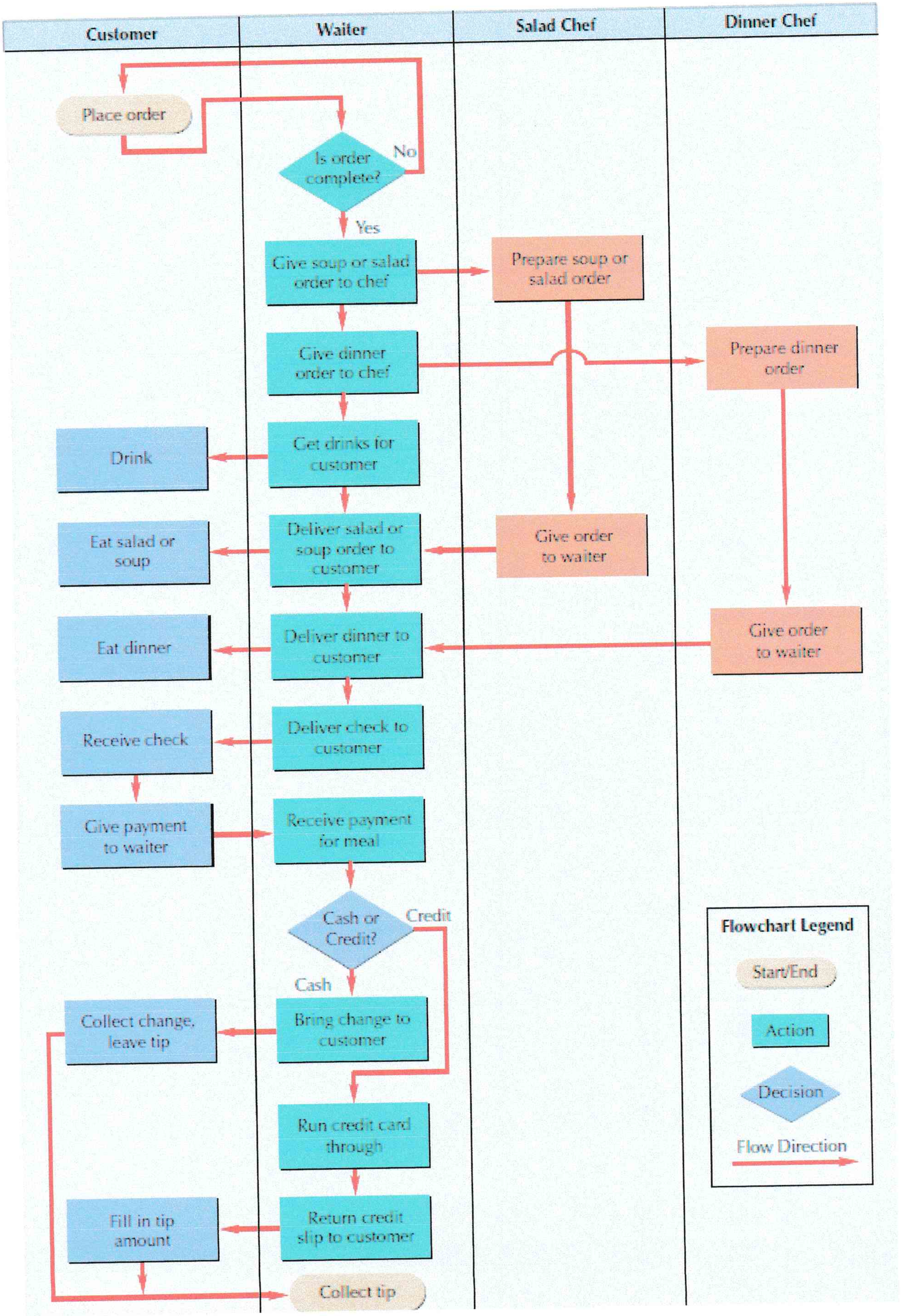
Process improvement teams are likely to make a first pass at diagramming a process, with adhesive notes plastered on large sheets of paper connected with hand-drawn arrows. As documentation of the process becomes more complete, departments or companies may prefer particular symbols to represent inputs, outputs, decisions, activities, and resources.

Flowcharts can take many forms, from freehand drawings to animated simulations. Flowcharting tools are available from Microsoft Visio, SmartDraw (www.smartdraw.com), iGrafx (www.igrafx.com), and others. You may be able to download free trial copies of the software for limited periods of time.

Figure 6.6 shows a *process map*, or swimlane chart, so called because it maps out the activities performed by various people in the process. Often process maps will include a time scale as well. **Figure 6.7** shows a simple value chain flowchart from supplier to customer.

➜ Internet Exercises

➜ Excel File


Customer
Waiter
Salad Chef
Dinner Chef
Place order
Is order complete?
No
Yes
Give soup or salad order to chef
Prepare soup or salad order
Give dinner order to chef
Prepare dinner order
Drink
Get drinks for customer
Eat salad or soup
Deliver salad or soup order to customer
Give order to waiter
Eat dinner
Deliver dinner to customer
Give order to waiter
Receive check
Deliver check to customer
Give payment to waiter
Receive payment for meal
Cash or Credit?
Credit
Cash
Collect change, leave tip
Bring change to customer
Run credit card through
Fill in tip amount
Return credit slip to customer
Collect tip
Flowchart Legend
Start/End
Action
Decision
Flow Direction

Along the Supply Chain

Fat Tire Ale's Carbon Footprint

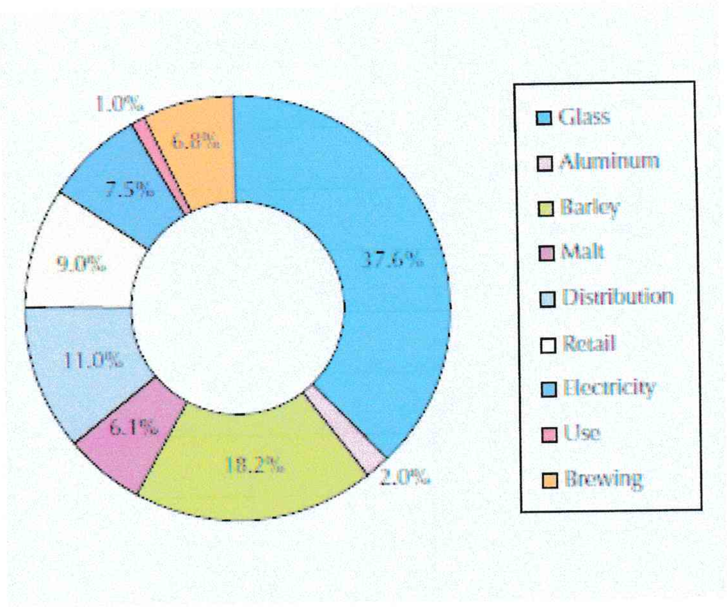
Fat Tire Ale is a product of the New Belgium Brewing Company, located in Fort Collins, Colorado. The company is a certified B Corp, meaning its purpose is to benefit society as well as to make a profit. For New Belgium, that benefit is expressed in employee ownership and concern for the environment.

Breweries use a lot of water; in fact, more than four glasses of water are used to create one glass of beer. New Belgium wants to reduce that amount to 3.5 glasses of water by 2017 and to continue to reduce it after that. Breweries use electricity to cool the beer for fermentation and maturation, and natural gas to boil water and malt to extract sugars and create wort for fermentation.

Reducing energy consumption is one of the first steps to sustainability. New Belgium does so through conservation, energy-efficient equipment, and heat exchangers. The company has also found a way to generate energy from wastewater treatment. As wastewater from the brewing process gets treated, it generates methane gas, which powers a generator that is used to fill 15% of the brewery's energy needs. Solar power now supplies electricity to the company's Packaging Hall, accounting for 3% of its energy use. A Smart Grid installed between the company and the city's utility allows excess energy to be transferred to the city's grid.

New Belgium is an employee-owned company. When an environmental audit showed that the largest contributor to the company's carbon footprint came from coal-powered electricity, the employees voted unanimously to use their bonus checks to subscribe to the City of Fort Collins' Wind Program, which bought wind power from Medicine Bow, Wyoming. Thus, New Belgium Brewing became the country's first brewery to generate 100% of its electricity through wind power.

New Belgium keeps track of its carbon footprint with greenhouse gas (GHG) accounting. The most recent report shows that almost 38% of its carbon footprint is accounted for by the glass bottle. The environmental impact of glass versus aluminum cans is an ongoing discussion at the brewery. In the meantime, the thickness of the glass in the container has been reduced to save GHG emissions. Barley has the second largest footprint at 18%, mainly due to fertilizers and irrigation. New Belgium is working with its barley farmers and maltsters to reduce their impact, and has considered organic farming as an alternative source of supply. Distribution (i.e., trucking the beer all over the country) accounted for 11% of the carbon footprint, a number consistent with other carbon footprint studies across industries. University of Michigan's Center for Sustainable Systems estimates the carbon footprint of a six-pack of Fat Tire Amber Ale at 7 pounds, compared to 7.2 pounds for a gallon of milk, 31 pounds for half a gallon of laundry detergent, 66 pounds for a jacket, 121 pounds for leather boots, and 97,000 pounds for an automobile.



Finally, New Belgium reuses or recycles 99.8% of its waste. There are no dumpsters outside its plants, just a variety of recycling containers.

1. Explore the environmental impact of packaging beer in glass bottles versus aluminum cans. List pros and cons and make a recommendation to New Belgium.
2. Read about New Belgium's new brewery site in Asheville, NC. What factors impacted the location decision? What is a brownfield site?
3. As a consumer, does it matter to you whether a company values sustainability? Why or why not?

Sources: 2015 New Belgium Sustainabiity Report, www.newbelgium.com/sustainability, accessed February 10, 2016, Jeffrey Ball, "Six Products, Six Carbon Footprints," *The Wall Street Journal* (October 6, 2008).

Process innovation is most successful in organizations that can view their system as a set of processes providing value to the customer, instead of functional areas vying for limited resources. **Figure 6.9** shows this change from a functional to a process orientation. In an environment of rapid change, the ability to learn faster, reconfigure processes faster, and execute processes faster is a competitive advantage.

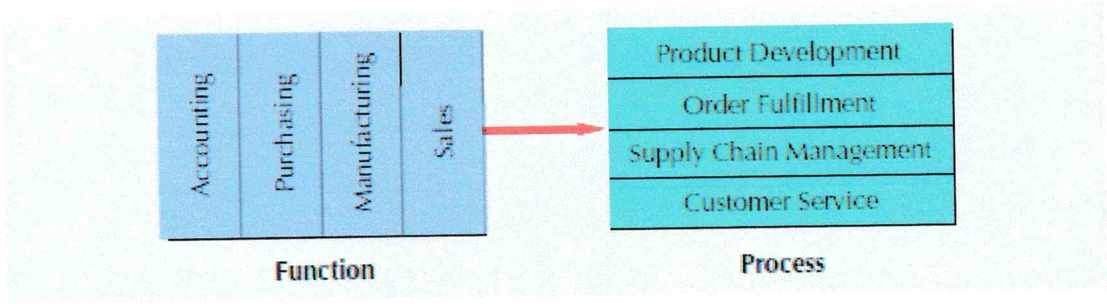


FIGURE 6.9 **From Function to Process**

Steps in Process Innovation

Figure 6.10 outlines the innovation process. Let's review the process step by step. The initial step establishes the goals for process performance. Data from the existing process are used as a baseline to which benchmarking data on best industry practices, customer requirements data, and strategic directives are compared.[2]

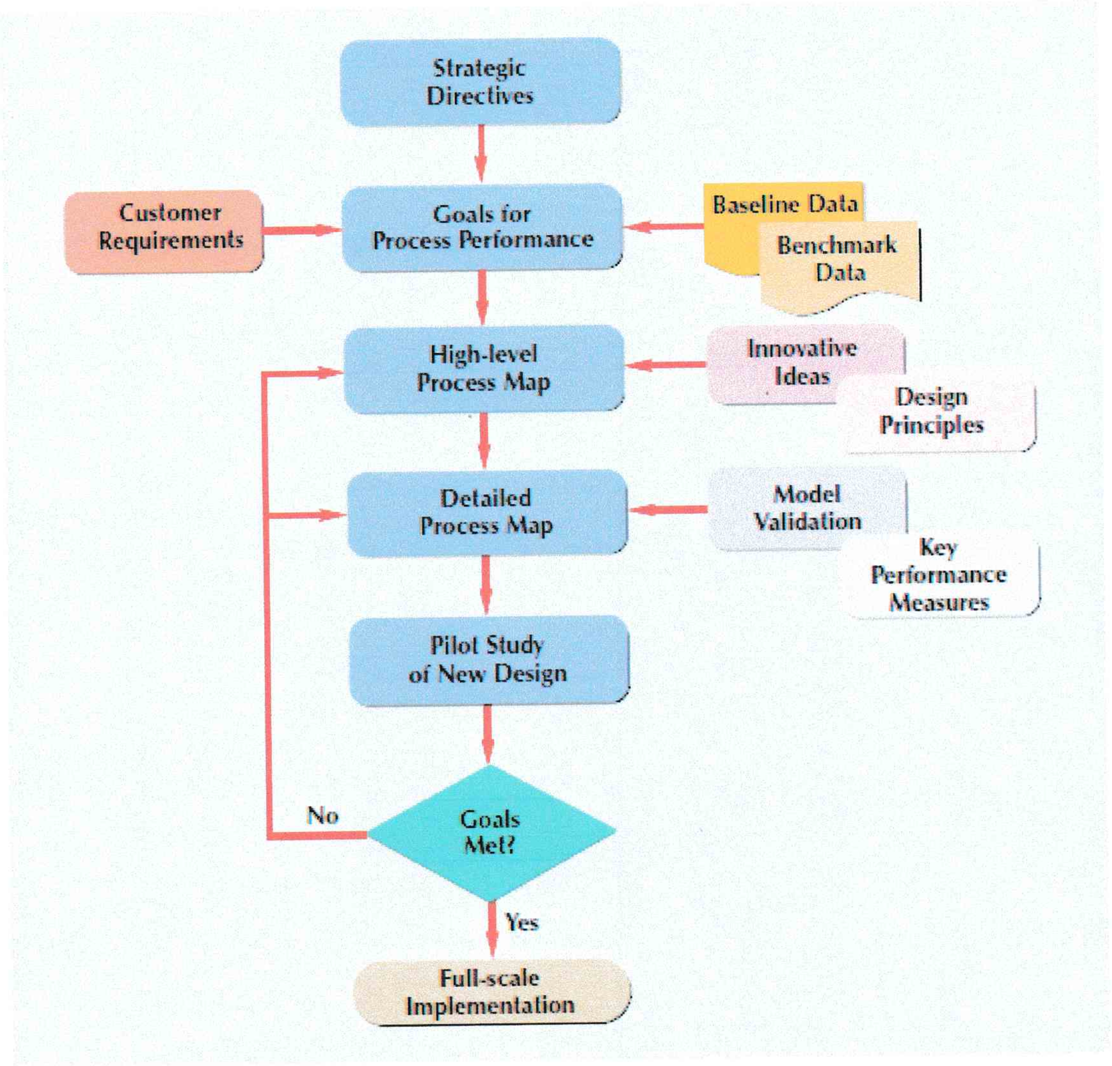


FIGURE 6.10 **Process Innovation**

A useful tool in beginning the redesign of a process is a *high-level process map*. Pared to its simplest form, a high-level map contains only the essential building blocks of a process. As shown in Figure 6.11, it is prepared by focusing on the performance goal—stated in customer terms—and working backward through the desired output, subprocesses, and

Along the Supply Chain

Fat Tire Ale's Carbon Footprint

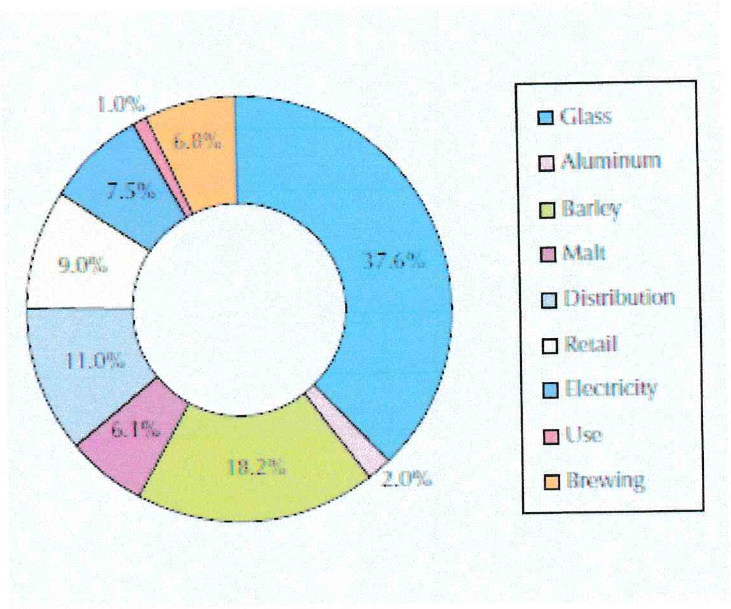
Fat Tire Ale is a product of the New Belgium Brewing Company, located in Fort Collins, Colorado. The company is a certified B Corp, meaning its purpose is to benefit society as well as to make a profit. For New Belgium, that benefit is expressed in employee ownership and concern for the environment.

Breweries use a lot of water; in fact, more than four glasses of water are used to create one glass of beer. New Belgium wants to reduce that amount to 3.5 glasses of water by 2017 and to continue to reduce it after that. Breweries use electricity to cool the beer for fermentation and maturation, and natural gas to boil water and malt to extract sugars and create wort for fermentation.

Reducing energy consumption is one of the first steps to sustainability. New Belgium does so through conservation, energy-efficient equipment, and heat exchangers. The company has also found a way to generate energy from wastewater treatment. As wastewater from the brewing process gets treated, it generates methane gas, which powers a generator that is used to fill 15% of the brewery's energy needs. Solar power now supplies electricity to the company's Packaging Hall, accounting for 3% of its energy use. A Smart Grid installed between the company and the city's utility allows excess energy to be transferred to the city's grid.

New Belgium is an employee-owned company. When an environmental audit showed that the largest contributor to the company's carbon footprint came from coal-powered electricity, the employees voted unanimously to use their bonus checks to subscribe to the City of Fort Collins' Wind Program, which bought wind power from Medicine Bow, Wyoming. Thus, New Belgium Brewing became the country's first brewery to generate 100% of its electricity through wind power.

New Belgium keeps track of its carbon footprint with greenhouse gas (GHG) accounting. The most recent report shows that almost 38% of its carbon footprint is accounted for by the glass bottle. The environmental impact of glass versus aluminum cans is an ongoing discussion at the brewery. In the meantime, the thickness of the glass in the container has been reduced to save GHG emissions. Barley has the second largest footprint at 18%, mainly due to fertilizers and irrigation. New Belgium is working with its barley farmers and maltsters to reduce their impact, and has considered organic farming as an alternative source of supply. Distribution (i.e., trucking the beer all over the country) accounted for 11% of the carbon footprint, a number consistent with other carbon footprint studies across industries. University of Michigan's Center for Sustainable Systems estimates the carbon footprint of a six-pack of Fat Tire Amber Ale at 7 pounds, compared to 7.2 pounds for a gallon of milk, 31 pounds for half a gallon of laundry detergent, 66 pounds for a jacket, 121 pounds for leather boots, and 97,000 pounds for an automobile.



Finally, New Belgium reuses or recycles 99.8% of its waste. There are no dumpsters outside its plants, just a variety of recycling containers.

1. Explore the environmental impact of packaging beer in glass bottles versus aluminum cans. List pros and cons and make a recommendation to New Belgium.
2. Read about New Belgium's new brewery site in Asheville, NC. What factors impacted the location decision? What is a brownfield site?
3. As a consumer, does it matter to you whether a company values sustainability? Why or why not?

Sources: 2015 New Belgium Sustainabiity Report, www.newbelgium.com/sustainability, accessed February 10, 2016, Jeffrey Ball, "Six Products, Six Carbon Footprints," *The Wall Street Journal* (October 6, 2008).

Process innovation is most successful in organizations that can view their system as a set of processes providing value to the customer, instead of functional areas vying for limited resources. **Figure 6.9** shows this change from a functional to a process orientation. In an environment of rapid change, the ability to learn faster, reconfigure processes faster, and execute processes faster is a competitive advantage.

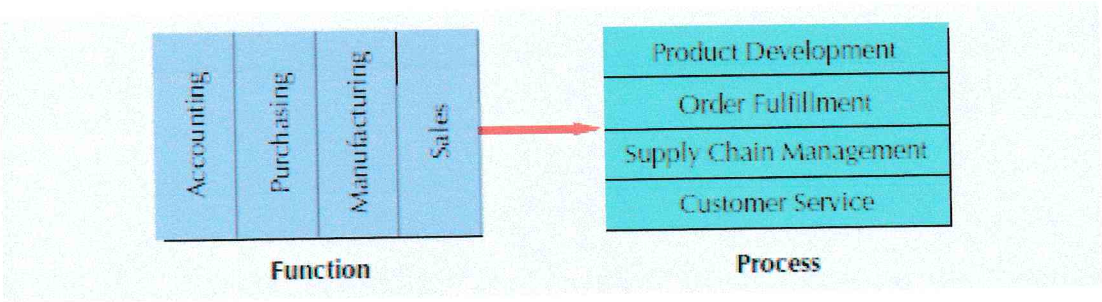


FIGURE 6.9 **From Function to Process**

Steps in Process Innovation

Figure 6.10 outlines the innovation process. Let's review the process step by step. The initial step establishes the goals for process performance. Data from the existing process are used as a baseline to which benchmarking data on best industry practices, customer requirements data, and strategic directives are compared.[2]

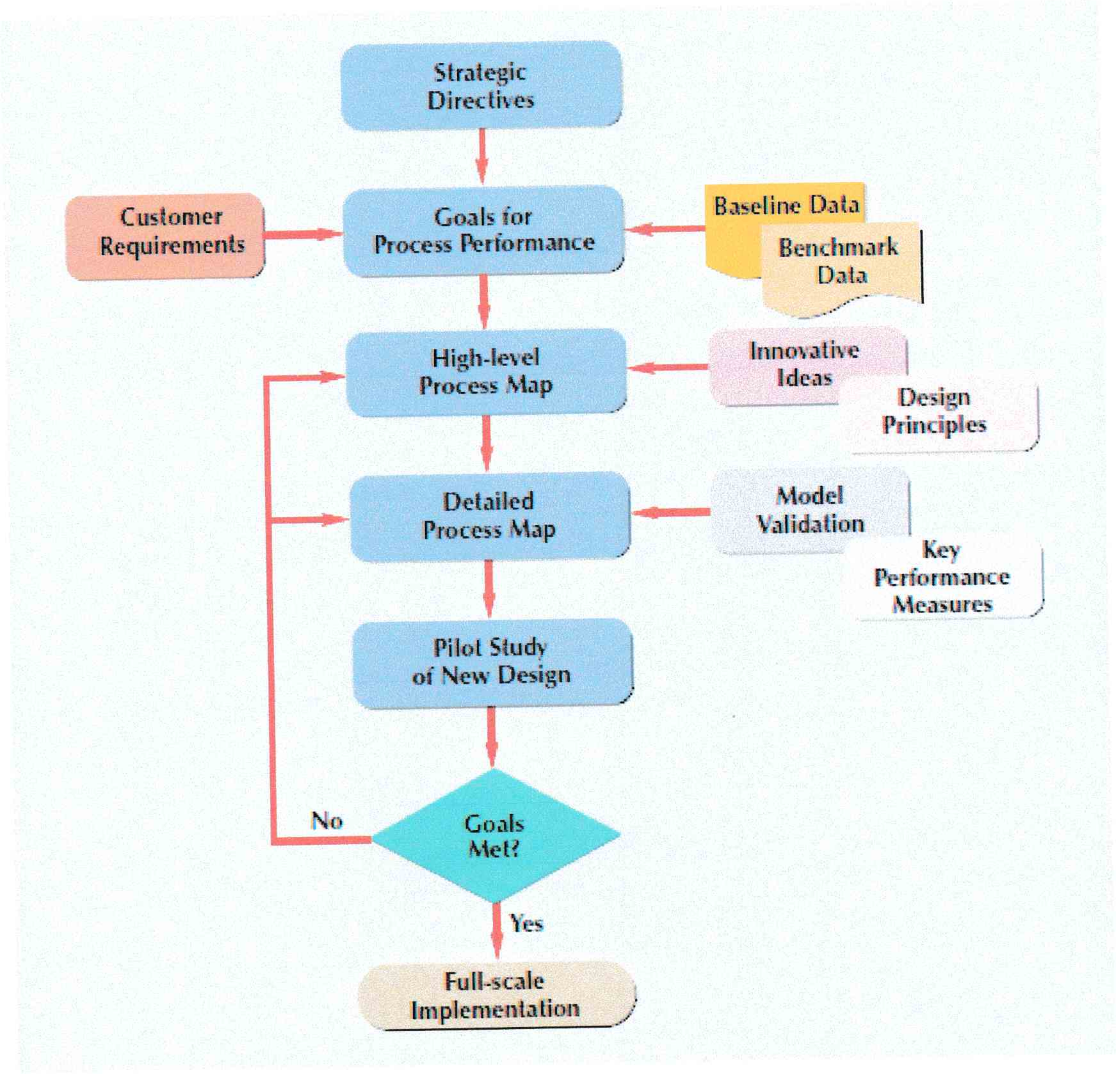


FIGURE 6.10 **Process Innovation**

A useful tool in beginning the redesign of a process is a *high-level process map*. Pared to its simplest form, a high-level map contains only the essential building blocks of a process. As shown in Figure 6.11, it is prepared by focusing on the performance goal—stated in customer terms—and working backward through the desired output, subprocesses, and

Senior Business Process Manager for a Public Sector Healthcare Company

Roberta Russell

I'm a process manager for the public sector division of one of the largest and best performing healthcare corporations in the United States. My region is the Northeast where the processes I oversee are responsible for the healthcare of over 400,000 lives.

I began my work auditing claims processing, and then became interested in how a claim works its way through the system. I noticed all sorts of inefficiencies. For example, high-dollar claims were manually handled with 10 different touch points. The Claims Processor would identify high-dollar claims and then forward it to the Special Matters Expert, who would work with the Claims Liaison, who would need approval from the Executive Director of the plan, who would consult the Claims Analyst, who would ask Contracting to get back to them so that they could inform the Executive Director, who would make a decision and send it to the Liaison, who would notify the Special Matters Expert, who would lastly pass along the decision to the Claims Processor, who would pay the claim. After redesign, the approval goes from Claims Processor to Special Matters Expert to Executive Director, period. The process flows more efficiently using fewer resources, and the providers are happier because they receive their payments more quickly, which ultimately ensures that members get access to the best care possible.

Like a lot of manufacturing firms, we have more data than we can process efficiently, and it seems that people are always looking for the same information. I remember one situation in particular with case management of high-risk pregnancies. There was a two-month backlog, which meant that by the time the case manager got around to contacting the patient, the pregnancy was too far along for treatment to make much of a difference. I analyzed the process and found that if we developed a shared database between the applicants, the case managers, and the nurses, we could eliminate the manual data entry of cases. That one change reduced the backlog to zero, saved the company millions, and most importantly reduced the number of detained babies (those that need to stay in the hospital after the mother had been released) by 50%. In this job, you can make a real difference. You can save lives.

I was amazed when I took the operations management class at NYU that there's a field of study for what I do. I live by flowcharts and Pareto analysis. We're always configuring and reconfiguring systems. If it doesn't work, we try something else. It's important to take a step back and look at the broader picture. Then you have to take risks and make decisions, and always look for ways of improving the process.

The concept of process innovation emerged in response to rapid changes in technology that rendered existing processes obsolete. In the next section, we discuss the impact of technology decisions and provide resources for a more in-depth study of technology.

Technology Decisions

Technology decisions involve large sums of money and can have a tremendous impact on the cost, speed, quality, and flexibility of operations. More importantly, they define the future capabilities of a firm and set the stage for competitive interactions. Thus, it is dangerous to delegate technology decisions to technical experts or financial analysts. A manager's ability to ask questions and understand the basic thrust of proposed technology is invaluable in making wise technology choices.

In this section we discuss the financial justification of new technology, followed by a brief technology primer. One technology that is changing the way we think about the economics of production is 3D printing, described in the Along the Suppy Chain box that follows

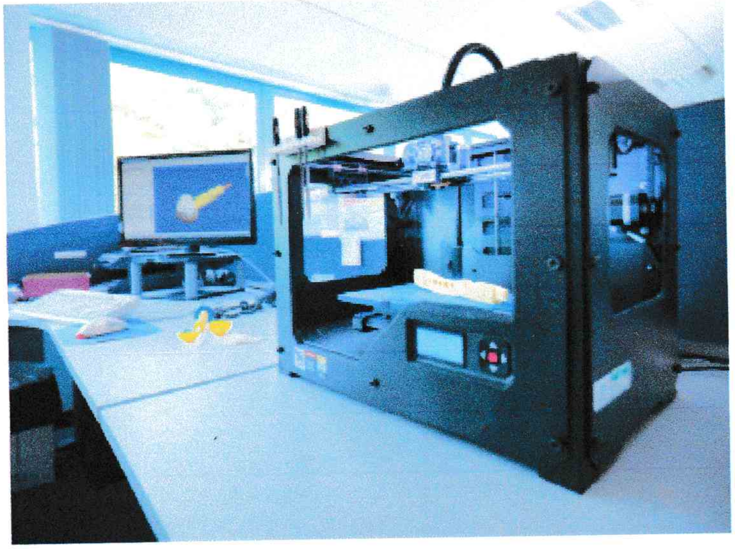
Financial Justification of Technology

After it is decided that a part will be produced or service provided in-house, specific technology decisions can be made. Alternatives include using, replacing, or upgrading existing equipment, adding additional capacity, or purchasing new equipment. Any alternative that involves an outlay of funds is considered a *capital investment*. Capital investments involve the commitment of funds in the present with an expectation of returns over some future time period. The expenditures are usually large and can have a significant effect on the future profitability of a firm. These decisions are analyzed carefully and typically require top management approval.

Along the Supply Chain

3D Printing and Other Advances in Additive Manufacturing

Traditional manufacturing works by subtraction—that is, carving out a part or product from a solid block of metal or wood, often resulting in 90% of the material being cut away. Additive manufacturing builds up a part or product by spraying layers of material back and forth across a build platform as directed by a special CAD model. It converts a digital model into a 3D product, and since the process resembles how a dot-matrix printer operates, it's called 3D printing (see photo). Similar to those desktop printers, a 3D printer can be purchased and operated on your desktop to produce a vast variety of shapes, parts, and products. Right now, the time required to "print" those parts can be lengthy—two to three hours, or overnight—and precision is limited, but there are some interesting possibilities that make this technology revolutionary.



Monty Rakuse /Getty Images, Inc.

Additive manufacturing technology has actually been available for some time and has been used to prepare prototypes before building working products. It went by the name *rapid prototyping* and used patented processes such as *stereolithography* in which parts are formed by successively layering thin amounts of liquid resin. Advances in the technology now allow fully functional products to be built by this method out of a variety of materials beyond plastics. Metals are used in powder form and are either mixed with a binding agent or fused with a laser beam as they are deposited on the platform or build tray. After each layer is complete, the build tray is lowered by a fraction of a millimeter and the next layer is added. The layers are defined by software that takes a series of digital slices through a CAD design (see Chapter 4) and sends those descriptions to the 3D printer. Materials can also be mixed, such as lightweight composites, one layer at a time. 3D printing is especially useful for aerospace, as weight is critical in making aircraft. A reduction of 1 kg in the weight of an airliner, for example, will save around $3000 worth of fuel a year and significantly cut carbon-dioxide emissions.

From a business perspective, additive manufacturing lowers the cost of entry into an industry, shortens the time-to-market of new designs, allows mass customization, eliminates the need for costly inventory or the supply chain to provide it, saves resources (materials, energy, labor, tooling, etc.), and is better for the environment. Re-placement parts, for example, can be printed instead of ordered; no need for stocking thousands of parts in -inventory, or making them in advance of need. Think about how much weight could be jettisoned from aircraft carriers or spacecraft with no need for those extra parts; or how your local Advanced Auto store would house a printer or two, instead of shelves of inventory. Some stores or repair centers may cease to exist because individuals would have their own "printers."

3D printing can also create more intricate designs (and more rounded shapes) than is possible from conventional manufacturing, and it can make production profitable at lower volumes (nixing economies of scale). For example, since each item is created separately rather than from a mold, a build tray could hold 100 items that are different in design, and produce them at the same cost as 100 items of the same design. Invisalign currently uses 3D printing in this way to produce customized retainers for its large suite of patients who need new ones every two weeks as part of the orthodontic procedure. It's also used to produce custom orthotics, hearing aids, and dental crowns faster and at a much reduced cost than traditional means.

Silver inks are now available to print circuit boards (Xerox); stainless steel powders are used to print repair parts (Shapeways); gold "dust" prints customized jewelry (Concept Laser); concrete fixtures are printed for building structures (Loughborough University), and organic polymers build customized cartilage and joint replacements (BioRap). Bioprinters are now producing functional human tissue for medical research and regenerative therapies, such as lung tissue, blood vessels, heart valves, and kidney cells. The U.S. military is considering the use of in situ bioprinting to help treat wounds on the battlefield. One day in the future, we may even be able to design and print human organs for transplants from layering human tissue.

1. For what types of products and markets is 3D printing currently best suited? What future possibilities do you see for technology such as 3D printing?
2. How might additive manufacturing change the way companies provide products and customers purchase products? What are the social, commercial, and legal ramifications of this new approach to manufacture?

Sources: Based on Johnny Ryan, "Manufacturing 2.0," *Fortune* (May 23, 2011); "The Printed World," *The Economist* (February 10, 2011); "The Third Industrial Revolution," *The Economist* (April 21, 2012); "Solid Print," *The Economist* (April 21,2012); "Additive Manufacturing: Pursuing the Promise," U.S. Department of Energy, Advanced

Manufacturing Office, DOE/EE-0776 (August 2012); Robert Hotz, “Printing Evolves: An Inkjet for Living Tissue,” *The Wall Street Journal* (September 18, 2012), D1.

The most effective quantitative techniques for capital investment consider the time value of money as well as the risks associated with benefits that will not accrue until the future. These techniques, known collectively as *capital budgeting* techniques, include payback period, net present value, and internal rate of return. Detailed descriptions can be found in any basic finance text. Although capital budgeting techniques are beyond the scope of this text, we do need to comment on several factors that are often overlooked in the financial analysis of technology.

PURCHASE COST The initial investment in equipment consists of more than its basic purchase price. The cost of special tools and fixtures, installation, training, maintenance, and engineering or programming adjustments can represent a significant additional investment. Operating costs are often underestimated as well.

OPERATING COSTS To assess more accurately the requirements of the new technology, it is useful to consider, step by step, how the equipment will be operated, started, stopped, loaded, unloaded, changed over, upgraded, networked, maintained, repaired, cleaned up, speeded up, and slowed down.

ANNUAL SAVINGS Most new technology is justified based on direct labor savings. However, other savings can actually be more important. For example, a more efficient process may be able to use less material and require less machine time or fewer repairs, so that downtime is reduced. A process that produces a better-quality product can result in fewer inspections and less scrap and rework. New processes (especially those that are automated) may significantly reduce safety costs, in terms of compliance with required regulations, as well as fines or compensation for safety violations.

REVENUE ENHANCEMENT Increases in revenue due to technology upgrades or new-equipment purchases are often ignored in financial analysis because they are difficult to predict. Improvements in product quality, price reductions due to decreased costs, and more rapid or dependable delivery can increase market share and, thus, revenue. Flexibility of equipment can also be important in adapting to the changing needs of the customer.

REPLACEMENT ANALYSIS As existing equipment ages, it may become slower, less reliable, and obsolete. The decision to replace old equipment with state-of-the-art equipment depends in large measure on the competitive environment. If a major competitor upgrades to a newer technology that improves quality, cost, or flexibility and you do not, your ability to compete will be severely damaged. In some industries, technology changes so rapidly that a replacement decision also involves determining whether this generation of equipment should be purchased or if it would be better to wait for the next generation. Replacement analysis maps out different schedules for equipment purchases over a two-to five-year period and selects a replacement cycle that will minimize cost.

RISK AND UNCERTAINTY Investment in new technology can be risky. Estimates of equipment capabilities, length of life, and operating cost may be uncertain.

Because of the risk involved, financial analysts tend to assign higher hurdle rates (i.e., required rates of return) to technology investments, making it difficult to gain approval for them.

Piecemeal analysis Investment in equipment and new technology is also expensive. Rarely can a company afford to automate an entire facility all at once. This has led to the proposal and evaluation of equipment purchases in a piecemeal fashion, resulting in pieces of technology that don't fit into the existing system and fail to deliver the expected returns.

A Technology Primer

Technology is important in both manufacturing and service operations. Cars now have hundreds of embedded systems performing thousands of computerized functions. Pacemakers, vending machines, Xerox copiers, and store shelves notify the manufacturer when repairs or restocking are needed. Wearable technology measures vital statistics and notifies a physician or recommends changes in medication regimes. Refrigerators can pre-order ingredients to match weekly menus or order milk when the supply is low. We discuss many of the information technology advances that support these systems in more detail in Chapter 10 and 15. In this section, we present a brief overview of technology advances in manufacturing systems.

Technology in manufacturing includes computer-aided design, robots, automated guided vehicles, computer numerically controlled machines, automated storage and retrieval systems, and flexible manufacturing systems. Automated manufacturing systems integrated through computer technology have aptly been called computer-integrated manufacturing (CIM). While that term is still used, a new era in automated manufacturing has emerged that is more digital, networked, and collaborative.

The digital revolution we spoke about in Chapter 1 has made its way to manufacturing. Digital or smart manufacturing technologies are changing how products are designed and made, how processes are controlled, how suppliers are monitored, and how value is delivered to the customer. More than automation, it is the connectivity and intelligence of these devices that is driving the new "digital" industrial revolution. Countries are preparing their industries to compete in this new era of manufacturing as evidenced by the U.S. National Network for Manufacturing Innovation, Germany's Industry 4.0 initiative, and China's Made in China 2025.

Digital manufacturing uses advanced digital technologies to integrate product, process, manufacture, and information technology over the life of the product. Sensors embedded in a product can record status and conditions of use, determine when the product needs repair or replacement, and send updates or begin working on a replacement part before the customer places an order. Products can be made to exact customer specifications, and settings to improve operation can be modified in real-time. Machines, cells, and factories can be controlled remotely and adjusted on-demand to reflect changing needs, resources, or preferences. Operations managers can monitor production in supplier plants down to the settings on machines and break times for workers. Vision systems can perform 100% inspection and trigger rework when needed. Repair shops (or customers, for that matter) can make their own replacement parts through 3D printing technology. In order to facilitate this meshing of product, process, and technology, protocols for communication must be established and ICT infrastructure and security measures must be in place.

Digital manufacturing Also called smart manufacturing; using digital technologies to design, manufacture, and control production, even remotely.

Sensors used to control automated equipment and communicate information to remote locations are referred to collectively as the industrial internet of things or **IIoT**. Figure 6.12

summarizes the technologies needed for a digital transformation in four essential areas: product, process, manufacture, and information. Table 6.4 serves as a technology primer, briefly defining the terms listed in the figure. Together, these resources provide a good starting point for investigating the advanced digital technologies that are becoming an integral part of lives.

IIOT (Industrial Internet of Things) Sensors to collect information and control processes; enables digital manufacture.

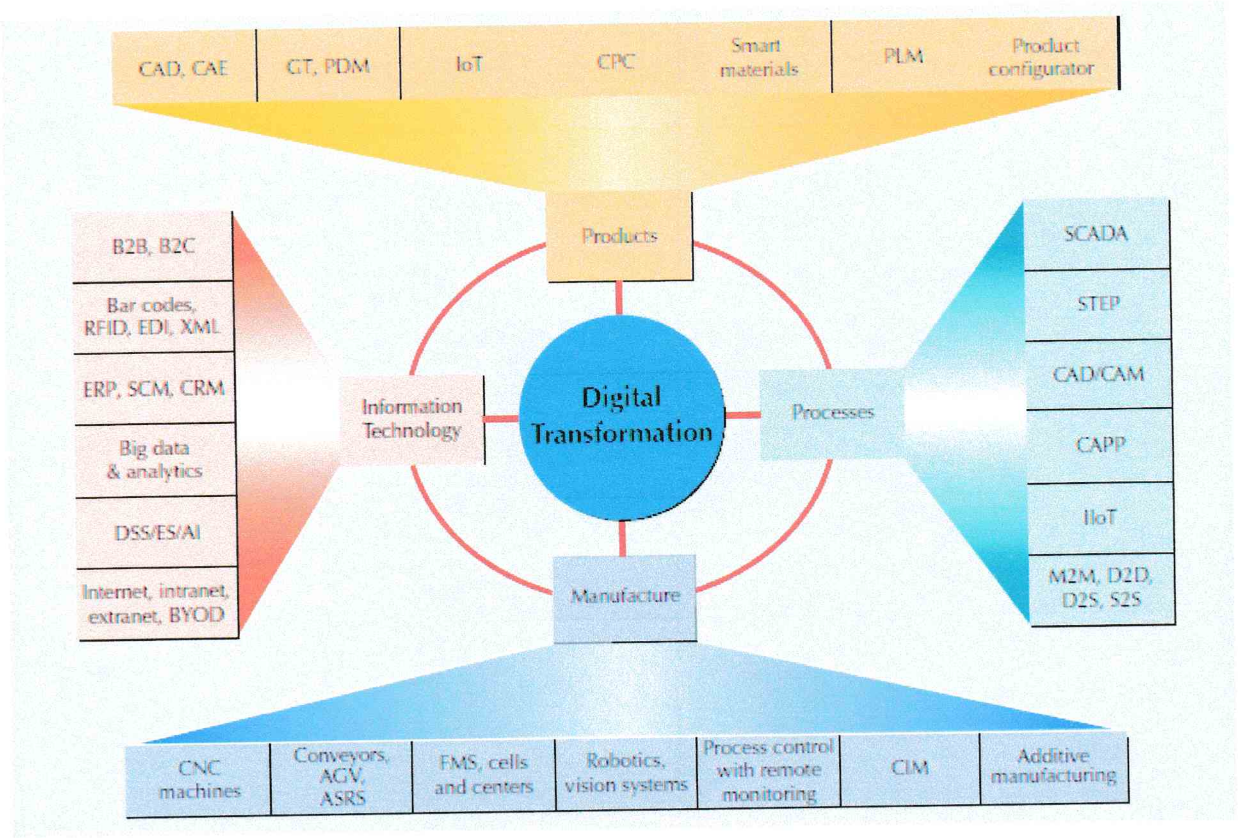


FIGURE 6.12 **Components of a Digital Transformation**

TABLE 6.4 A Technology Primer

PRODUCT TECHNOLOGY		
CAD, CAE	Computer-aided design, computeraided engineering	Creates, communicates, and tests product designs electronically
GT, PDM	Group technology; Product data management	Classifies designs into families for easy retrieval and modification; keeps track of design specs and revisions for the life of the product
CPC	Collaborative product commerce	Facilitates electronic communication and exchange of information among designers and suppliers
PLM	Product lifecycle management	Integrates the decisions of those involved in product development, manufacturing, sales, customer service, recycling, and disposal
Product configurator		Defines products “configured” by customers who have selected among various options, usually from a website
Smart materials	Materials with properties that react to changes in the environment	Examples: self-healing, shape-memory, conduction, etc.
IoT	Internet of Things	Embedded sensors that detect & relay information
PROCESS TECHNOLOGY		
STEP	Standard for exchange of product model data (ISO 10303)	Sets standards for communication among different CAD vendors; translates CAD data into requirements for automated inspection and manufacture
CAD/CAM	Computer-aided design and manufacture	The electronic link between automated design (CAD) and automated manufacture (CAM)
CAPP		

	Computer-aided process planning	Generates process plans based on a database of similar requirements
SCADA	Supervisory Control and Data Acquisition	An industrial automation control system for remote monitoring; used for critical infrastructure
M2M	Machine-to-machine communication	Sensors on one machine can direct other machines to turn on/off, adjust, etc.
D2D	Device-to-device communication	Integrates intelligent machines or devices; real-time applications
S2S	Server-to-server communication	For web services and business apps
D2S	Device-to-server communication	For data collection and remote monitoring
MANUFACTURING TECHNOLOGY		
CNC	Computer numerically controlled	Machines controlled by software code to perform a variety of operations with the help of automated tool changers; also collects processing information and quality data
FMS	Flexible manufacturing system	A collection of CNC machines connected by an automated material handling system to produce a wide variety of parts
Robots	Pick-and-place, articulated; Smart robots	Manipulators that can be programmed to perform repetitive tasks at varying levels of difficulty. Smart robots can detect, act, and learn.
Conveyors		Fixed-path material handling; moves items along a belt or overhead chain; "reads" packages via bar code or RFID tag and diverts them to different directions; can be very fast
AGV	Automatic guided vechicle	A driverless truck that moves material along a specified path; directed by wire or tape embedded in the floor or by radio frequencies; very flexible

ASRS	Automated storage and retrieval system	An automated warehouse—some 26 stories high—in which items are placed in a carousel-type storage system and retrieved by fast-moving stacker cranes; controlled by computer
Process Control		Continuous monitoring of automated equipment; makes real-time decisions on ongoing operation, maintenance, and quality; can be employed remotely
CIM	Computer-integrated manufacturing	Automated manufacturing systems integrated through computer technology; a precursor to digital manufacturing
3D printing	Additive manufacturing	Building up a product layer by layer from digital instructions
INFORMATION TECHNOLOGY		
B2B, B2C	Business-to-business; Business-to-consumer	Electronic transactions between businesses, or between businesses and the consumer, usually over the Internet
Internet, Intranet, Extranet		A global information system of computer networks. Intranets are communication networks internal to an organization. Extranets give suppliers, customers, and trading partners access to select portions of a company's intranet through secure portals.
Bar codes		A series of vertical lines printed on most packages that identifies the item and other information when read by a scanner
RFID	Radio frequency identification tags	An integrated circuit embedded in a tag that can send and receive information; a 21st-century bar code with read/write capabilities
EDI	Electronic data interchange	A computer-to-computer exchange of business documents over a proprietary network; very expensive and inflexible
XML	Extensible markup language	

		A programming language that enables computer-to-computer communication over the internet by tagging data before it is sent
ERP, SCM, CRM	Enterprise resource planning, Supply chain management, Customer relationship management	A suite of software products for managing the business processes of an enterprise (see Chapter 15); SCM software manages suppliers and supply chain networks; CRM manages customer and sales data.
Big data & analytics	Big data is characterized by its volume, variety (structured and unstructured data), and velocity	Anaytics uses techniques such as statistics, math programming, data mining, and text mining to find patterns in data and make inferences
DSS	Decision support systems	An information system that helps managers make decisions; includes a quantitative modeling component and an interactive component for what-if? analysis
ES	Expert systems	A computer system that uses an expert knowledge base to diagnose or solve a problem
AI	Artificial intelligence	A field of study that attempts to replicate elements of human thought in computer processes; includes expert systems, genetic algorithms, neural networks, and fuzzy logic (see Chapter 17)

Summary

Important issues in process design are types of processes, process planning, analysis and innovation, and technology decisions. The type of production process selected depends primarily on demand volume and degree of product standardization. *Projects* are produced one at a time to customer order. *Batch production* is used to process a variety of low-volume jobs. *Mass production* produces large volumes of a standard product for a mass market. *Continuous production* is used for very-high-volume commodity products.

Process planning consists of converting product designs into workable instructions for manufacture. They often take the form of assembly charts, process flowcharts, operations sheets, and manufacturing or delivery specifications. On a broader scale, process planning involves process selection, technology decisions, and decisions on outsourcing. Process analysis drives the continuous improvement of operations; process innovation drives breakthrough improvements. Digital manufacturing has been called the next industrial revolution due to the dramatic changes in production possibilities that it brings to factories, entities, and workers worldwide.

Key Terms

assembly chart A schematic diagram of a product that shows the relationship of component parts to parent assemblies, the groupings of parts that make up a subassembly, and the overall sequence of assembly.

batch production The low-volume production of customized products.

breakeven analysis A technique that determines the volume of demand needed to be profitable; it takes into account the trade-off between fixed and variable costs.

continuous production The production of a very-high-volume commodity product with highly automated equipment.

digital manufacturing Also called smart manufacturing; using digital technologies to design, manufacture, and control production, even remotely.

IIoT Industrial Internet of Things; sensors to collect information and control processes; enables digital manufacture

mass production The high-volume production of a standard product for a mass market.

process A group of related tasks with specific inputs and outputs.

process flowchart A document that uses standardized symbols to chart the productive and nonproductive flow of activities involved in a process; it may be used to document current processes or as a vehicle for process improvement.

process innovation The total redesign of a process.

process planning The conversion of designs into workable instructions for manufacture, along with associated decisions on component purchase or fabrication, and process and equipment selection.

process plans A set of documents that detail manufacturing or service delivery specifications.

process strategy An organization's overall approach for physically producing goods and services.

project The one-of-a-kind production of a product to customer order that requires a long time to complete and a large investment of funds and resources.

vertical integration The degree to which a firm produces the parts that go into its products

Key Formulas

Breakeven point

$$v = \frac{c_f}{p - c_v}$$

Point of indifference

$$\left| \frac{c_{f2} - c_{f1}}{c_{v1} - c_{v2}} \right|$$

Solved Problems

Texloy Manufacturing Company must select a process for its new product, TX2, from among three different alternatives. The following cost data have been gathered:

	PROCESS A	PROCESS B	PROCESS C
Fixed cost	$10,000	$40,000	$70,000
Variable cost	$5/unit	$2/unit	$1/unit

For what volume of demand would each process be desirable?

Solution

If v represents the number of TX2s demanded (and, we assume, produced), then

$$\begin{aligned}\text{Total cost for process A} &= \$10{,}000 + \$5v \\ \text{Total cost for process B} &= \$40{,}000 + \$2v \\ \text{Total cost for process C} &= \$70{,}000 + \$1v\end{aligned}$$

Next, we calculate the points of indifference between each pair of processes by equating their total costs and solving for demand volume, *v*. Always begin with the process that has the lowest fixed cost and compare it to the process with the next lowest fixed cost, and so on. For this example that means we'll compare process A to process B and process B to process C.

Comparison 1: Process A versus Process B

$$\begin{aligned} \textit{Process A} &\qquad \textit{Process B} \\ \$10{,}000 + \$5v &= \$40{,}000 + \$2v \\ v &= 10{,}000 \text{ units} \end{aligned}$$

If demand is less than or equal to 10,000, we should choose the alternative with the lowest fixed cost, process A. Conversely, if demand is greater than 10,000, we should choose the alternative with the lowest variable cost, process B. At 10,000 units we can actually choose either A or B.

Comparison 2: Process B versus Process C

$$\begin{aligned} \textit{Process B} &\qquad \textit{Process C} \\ \$40{,}000 + \$2v &= \$70{,}000 + \$1v \\ v &= 30{,}000 \text{ units} \end{aligned}$$

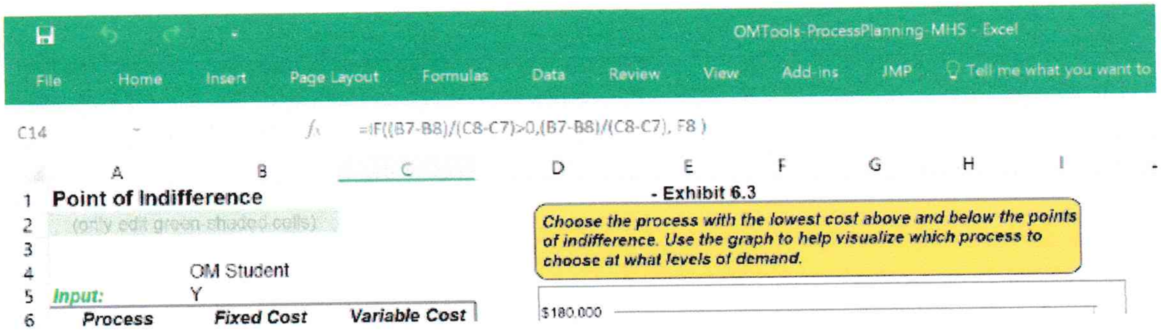
If demand is greater than 30,000 units, we should choose process C. If demand is less than 30,000 but greater than 10,000 (see comparison 1), we should choose process B. At 30,000, we can choose either B or C.

The Excel solution to this problem is shown in Exhibit 6.2.

To summarize, from the graph in Exhibit 6.2 and our decision rules, we can recommend the following process selection:

- Below 10,000 units, choose process A.
- Between 10,000 and 30,000 units, choose process B.
- Above 30,000 units, choose process C.

EXHIBIT 6.2 | Using Excel for the Point of Indifference



=IF((B7-B8)/(C8-C7)>0,(B7-B8)/(C8-C7), F8)

Point of Indifference

(only edit green-shaded cells)

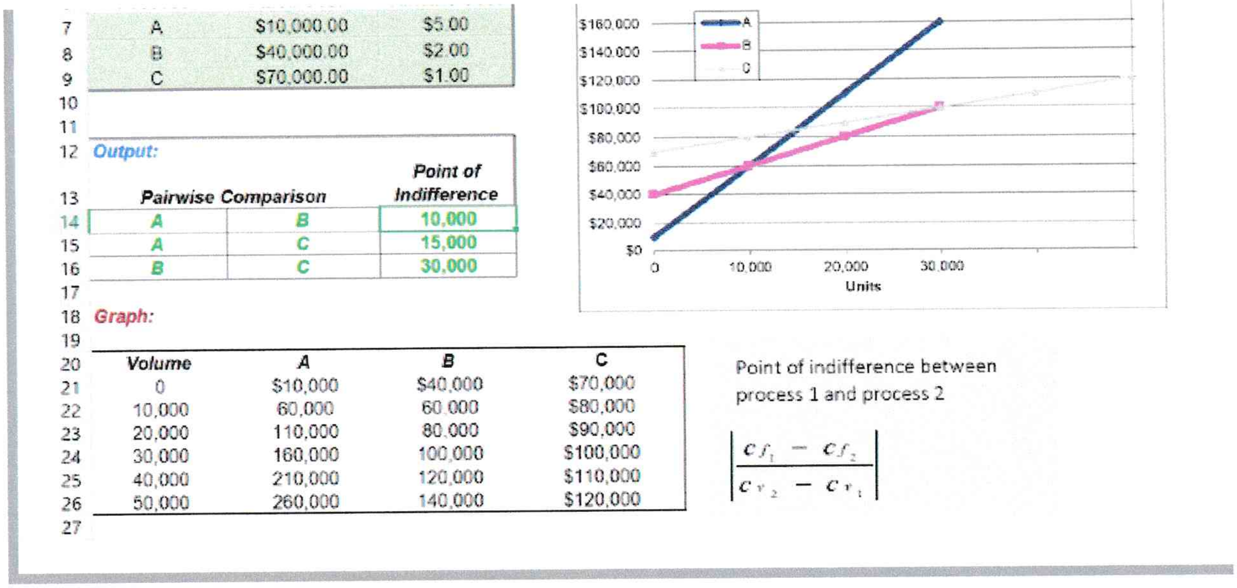
OM Student

Input: Y

Process	Fixed Cost	Variable Cost

- Exhibit 6.3

Choose the process with the lowest cost above and below the points of indifference. Use the graph to help visualize which process to choose at what levels of demand.



7	A	$10,000.00	$5.00
8	B	$40,000.00	$2.00
9	C	$70,000.00	$1.00

12 **Output:**

	Pairwise Comparison		Point of Indifference
13			
14	A	B	10,000
15	A	C	15,000
16	B	C	30,000

18 **Graph:**

	Volume	A	B	C
20	Volume	A	B	C
21	0	$10,000	$40,000	$70,000
22	10,000	60,000	60,000	$80,000
23	20,000	110,000	80,000	$90,000
24	30,000	160,000	100,000	$100,000
25	40,000	210,000	120,000	$110,000
26	50,000	260,000	140,000	$120,000

Point of indifference between process 1 and process 2

$$\left| \frac{cf_1 - cf_2}{cv_2 - cv_1} \right|$$

Questions

Internet Exercises

Weblinks

6.1 Discuss the types of decisions that are involved in creating a process strategy. Apply the four elements of process strategy to the process of completing a project or paper for one of your classes. Does the process differ from class to class?

6.2 List and explain six factors that affect the decision to outsource. Explain the sourcing continuum.

6.3 Describe the four basic types of production processes. What are the advantages and disadvantages of each? When should each be used?