CHAPTER 3

Product Design and Process Selection

Before studying this chapter you should know or, if necessary, review

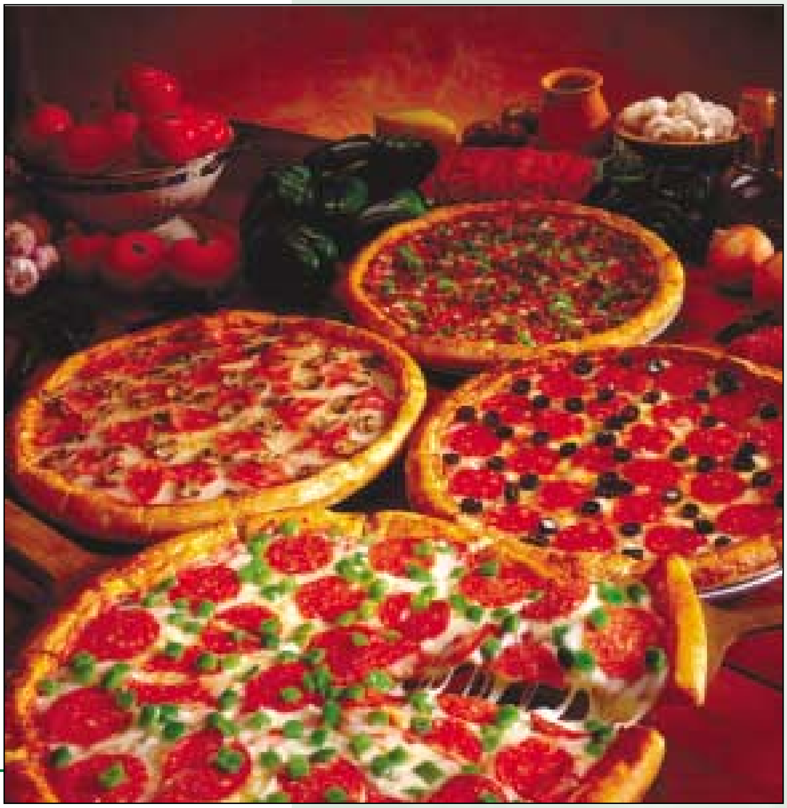
1. Differences between manufacturing and service organizations, Chapter 1, pp. 5–7.
2. Differences between strategic and tactical decisions, Chapter 1, pp. 00–00.
3. Competitive priorities, Chapter 2, pp. 36–39.

LEARNING OBJECTIVES

After completing this chapter you should be able to

1. Define product design and explain its strategic impact on the organization.
2. Describe the steps used to develop a product design.
3. Use break-even analysis as a tool in deciding between alternative products.
4. Identify different types of processes and explain their characteristics.
5. Understand how to use a process flowchart.
6. Understand how to use process performance metrics.
7. Understand current technological advancements and how they impact process and product design.
8. Understand issues of designing service operations.

CHAPTER OUTLINE



Have you ever been with a group of friends and decided to order pizzas? One person wants pizza from Pizza Hut because he likes the taste of stuffed-crust pizza made with cheese in the crust. Someone else wants Donatos pizza because she likes the unique crispy-thin crust. A third wants pizza from Spagio's because of the wood-grilled oven taste. Even a simple product like a pizza can have different features unique to its producer. Different customers have different tastes, preferences, and product needs. The variety of product designs on the market appeal to the preferences of a particular customer group. Also, the different product designs have different processing requirements. This is what product design and process selection are all about.

We can all relate to the product design of a pizza just from everyday life. Now consider the complexities involved in designing more sophisticated products. For example, Palm, Inc. (www.palm.com) is a leading provider of handheld computers whose slogan is "different people, different needs, different handhelds." The company designs different products with differing capabilities, such as personal information management, wireless Internet access, and games, intended for different types of customers. The company also has to decide on the best process to produce the different types of handhelds.

The challenge of product design can also be illustrated by an example of the Alza Corporation. Alza is a leader in designing new ways that pharmaceutical drugs can be administered to different types of patients. One of their product designs is an under the skin implant for pharmaceutical drugs that previously could only be administered by injection. The product design had to include time release of the drug, as well as the best material and shape of the implant. In addition to the product design, a process had to be designed to produce the unique product.

These examples illustrate that a product design that meets customer needs, although challenging, can have a large impact on a company's success. In fact, product design is so important that leading edge companies routinely invest in product designs well into the future. For example, Daimler Chrysler has been conducting research to design intelligent technologies for their vehicles that would have pedestrian and street sign recognition systems. This type of innovative product design can give a company a significant competitive advantage.

In this chapter we will learn about *product design*, which is the process of deciding on the unique characteristics and features of the company's product. We will also learn about *process selection*, which is the development of the process necessary to produce the designed product. Product design and process selection decisions are typically made together. A company can have a highly innovative design for its product, but if it has not determined how to make the product in a cost effective way, the product will stay a design forever.

Product design and process selection affect product quality, product cost, and customer satisfaction. If the product is not well designed or if the manufacturing process is not true to the product design, the quality of the product may suffer. Further, the product has to be manufactured using materials, equipment, and labor skills that are efficient and affordable; otherwise, its cost will be too high for the market. We call this the product's **manufacturability**—the ease with which the product can be made. Finally, if a product is to achieve customer satisfaction, it must have the combined characteristics of good design, competitive pricing, and the ability to fill a market need. This is true whether the product is pizzas or cars.

► **Manufacturability**
The ease with which a product can be made.

PRODUCT DESIGN

Marketing, Finance

Most of us might think that the design of a product is not that interesting. After all, it probably involves materials, measurements, dimensions, and blueprints. When we think of design we usually think of car design or computer design and envision engineers working on diagrams. However product design is much more than that. Product design brings together marketing analysts, art directors, sales forecasters, engineers, finance experts, and other members of a company to think and plan strategically. It is exciting and creative, and it can spell success or disaster for a company.

Product design is the process of defining all the features and characteristics of just about anything you can think of, from Starbuck's cafe latte or Jimmy Dean's sausage to GM's Saturn or HP's DeskJet printer. Product design also includes the design of services, such as those provided by Salazar's Beauty Salon, La Petite Academy Day Care Center, or FedEx. Consumers respond to a product's appearance, color, texture, performance. All of its features, summed up, are the product's design. Someone came up with the idea of what this product will look like, taste like, or feel like so that it will appeal to you. This is the purpose of product design. **Product design** defines a product's characteristics, such as its appearance, the materials it is made of, its dimensions and tolerances, and its performance standards.

► **Product design**
The process of defining all of the product's characteristics.

The Sony Clié is one of the latest product designs in handheld computer devices that combine portability, power, and features.

Design of Services Versus Goods

The design elements discussed are typical of industries such as manufacturing and retail in which the product is tangible. For service industries, where the product is intangible, the design elements are equally important, but they have an added dimension.

Service design is unique in that we are designing both the service and the entire *service concept*. As with a tangible product, the service concept is based on meeting customer needs. The service design, however, adds the esthetic and psychological benefits of the product. These are the service elements of the operation, such as promptness and friendliness. They also include the ambiance, image, and "feel-good" elements of the service. Consider the differences in service design of a company like Canyon Ranch, which provides a pampering retreat for health-conscious but overworked professionals, versus Gold's Gym, which caters to young athletes. As with a tangible product, the preference for a service is based on its product design. **Service design** defines the characteristics of a service, such as its physical elements, and the esthetic and psychological benefits it provides.

▶ **Service design** The process of establishing all the characteristics of the service, including physical, sensual, and psychological benefits.

THE PRODUCT DESIGN PROCESS

Certain steps are common in the development of most product designs. They are idea generation, product screening, preliminary design and testing, and final design. These steps are shown in Figure 3-1. Notice that the arrows show a circular process. Product designs are never finished, but are always updated with new ideas. Let's look at these steps in more detail.

Idea Development

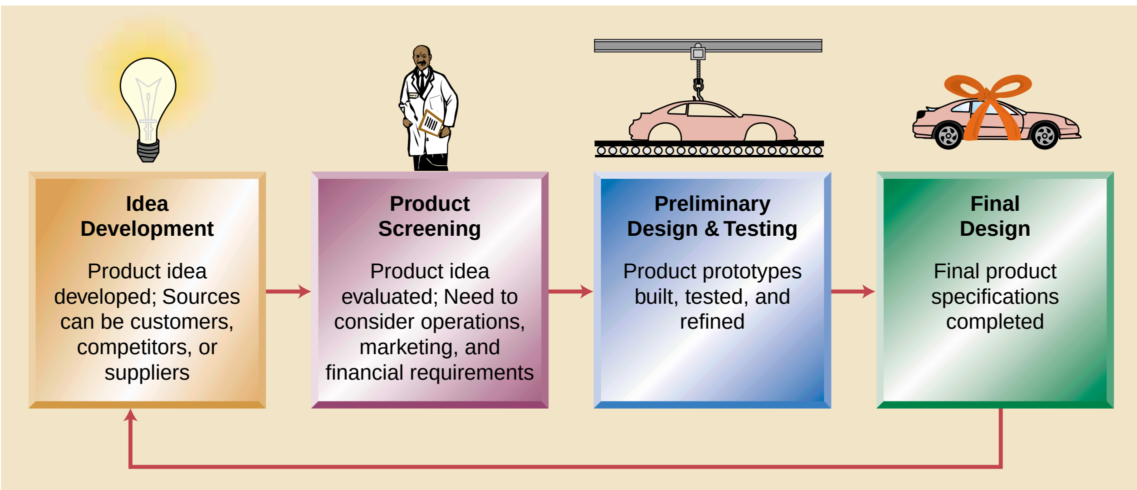
All product designs begin with an idea. The idea might come from a product manager who spends time with customers and has a sense of what customers want, from an engineer with a flare for inventions, or from anyone else in the company. To remain competitive, companies must be innovative and bring out new products regularly. In some industries, the cycle of new product development is predictable. We see this in the auto industry, where new car models come out every year, or the retail industry, where new fashion is designed for every season.

In other industries, new product releases are less predictable but just as important. The Body Shop, retailer of plant-based skin care products, periodically comes up with new ideas for its product lines. The timing often has to do with the market for a product, and whether sales are declining or continuing to grow.

Ideas from Customers, Competitors, and Suppliers The first source of ideas are customers, the driving force in the design of goods and services. Marketing is a vital

FIGURE 3-1

Steps in the product design process



link between customers and product design. Market researchers collect customer information by studying customer buying patterns and using tools such as customer surveys and focus groups. Management may love an idea, but if market analysis shows that customers do not like it, the idea is not viable. Analyzing customer preferences is an ongoing process. Customer preferences next year may be quite different from what they are today. For this reason, the related process of forecasting future consumer preferences is important, though difficult.

Marketing

Competitors are another source of ideas. A company learns by observing its competitors' products and their success rate. This includes looking at product design, pricing strategy, and other aspects of the operation. Studying the practices of companies considered "best in class" and comparing the performance of our company against theirs is called **benchmarking.** We can benchmark against a company in a completely different line of business and still learn from some aspect of that company's operation. For example, Lands' End is well known for its successful catalog business, and companies considering catalog sales often benchmark against Lands' End. Similarly, American Express is a company known for its success at resolving complaints, and it, too, is used for benchmarking.

▶ **Benchmarking**
The process of studying the practices of companies considered "best in class" and comparing your company's performance against theirs.

LINKS TO PRACTICE

IBM Corporation
www.ibm.com

The importance of benchmarking can be seen by the efforts taken by IBM to improve its distribution system. In 1997 IBM found its distribution costs increasing, while customers were expecting decreasing cycle times from factory to delivery. It appeared that IBM's supply chain practices were not keeping up with those of its competitors. To evaluate and solve this problem IBM hired Mercer Management Consultants, who performed a large benchmarking study. IBM's practices were compared to those of market leaders in the personal computer (PC) industry, as well as to the best logistics practices outside the technology area. The objective was to evaluate IBM's current performance, that of companies considered best-in-class, and identify the gaps. Through the study, IBM discovered which specific costs exceeded industry benchmarks and which parts of the cycle time were excessively long. It also uncovered ways to simplify and reorganize its processes to gain efficiency. Based on findings from the benchmarking effort, IBM made changes in its operations. The results were reduced costs, improved delivery, and improved relationships with suppliers. IBM found benchmarking so beneficial that it plans to perform similar types of studies on an ongoing basis in the future.

Reverse Engineering Another way of using competitors' ideas is to buy a competitor's new product and study its design features. Using a process called **reverse engineering,** a company's engineers carefully disassemble the product and analyze its parts and features. This approach was used by the Ford Motor Company to design its Taurus model. Ford engineers disassembled and studied many other car models, such as BMW and Toyota, and adapted and combined their best features. Product design

▶ **Reverse engineering**
The process of disassembling a product to analyze its design features.

ideas are also generated by a company's R & D (research and development) department, whose role is to develop product and process innovation.

Suppliers are another source of product design ideas. To remain competitive more companies are developing partnering relationships with their suppliers, to jointly satisfy the end customer. For example, Daimler Chrysler chooses its suppliers well before parts are designed. Suppliers participate in a program called **early supplier involvement (ESI)** where suppliers are involved in the early stages of product design.

▶ **Early supplier involvement (ESI)** Involving suppliers in the early stages of product design.

Product Screening

After a product idea has been developed it is evaluated to determine its likelihood of success. This is called *product screening.* The company's product screening team evaluates the product design idea according to the needs of the major business functions. In their evaluation, executives from each function area may explore issues such as the following:

Marketing, Finance

- **Operations** What are the production needs of the proposed new product and how do they match our existing resources? Will we need new facilities and equipment? Do we have the labor skills to make the product? Can the material for production be readily obtained?
- **Marketing** What is the potential size of the market for the proposed new product? How much effort will be needed to develop a market for the product and what is the long-term product potential?
- **Finance** The production of a new product is a financial investment like any other. What is the proposed new product's financial potential, cost, and return on investment?

Unfortunately, there is no magic formula for deciding whether or not to pursue a particular product idea. Managerial skill and experience, however, are key. Companies generate new product ideas all the time, whether for a new brand of cereal or a new design for a car door. Approximately 80 percent of ideas do not make it past the screening stage. Management analyzes operations, marketing, and financial factors, and then makes the final decision. Fortunately, we have decision-making tools to help us evaluate new product ideas. A popular one is break-even analysis, which we look at next.

▶ **Break-even analysis** A technique used to compute the amount of goods a company would need to sell to cover its costs.

Break-Even Analysis: A Tool for Product Screening **Break-even analysis** is a technique that can be useful when evaluating a new product. This technique computes the quantity of goods a company needs to sell just to cover its costs, or break even, called the "break-even" point. When evaluating an idea for a new product it is helpful to compute its break-even quantity. An assessment can then be made as to how difficult or easy it will be to cover costs and make a profit. A product with a break-even quantity that is hard to attain might not be a good product choice to pursue. Next we look at how to compute the break-even quantity.

▶ **Fixed costs** Costs a company incurs regardless of how much it produces.

▶ **Variable costs** Costs that vary directly with the amount of units produced.

The total cost of producing a product or service is the sum of its fixed and variable costs. A company incurs **fixed costs** regardless of how much it produces. Fixed costs include overhead, taxes, and insurance. For example, a company must pay for overhead even if it produces nothing. **Variable costs,** on the other hand, are costs that vary directly with the amount of units produced, and include items such as direct materials and labor. Together, fixed and variable costs add up to total cost:

$$\text{Total cost} = F + (VC)\,Q$$

where F = fixed cost
VC = variable cost per unit
Q = number of units sold

Figure 3-2 shows a graphical representation of these costs as well as the break-even quantity. Fixed cost is represented by a horizontal line as this cost is the same regardless of how much is produced. Adding variable cost to fixed cost creates *total cost*, represented by the diagonal line above fixed cost. When $Q = 0$, total cost is only equal to fixed cost. As Q increases, total cost increases through the variable cost component. The blue diagonal in the figure is revenue, the amount of money brought in from sales:

$$\text{Revenue} = (SP)\,Q$$

where SP = selling price per unit

When $Q = 0$, revenue is zero. As sales increase, so does revenue. Remember, however, that to cover all costs we have to sell the break-even amount. This is the quantity Q_{BE}, where revenue equals total cost. If we sell below the break-even point we incur a loss, since costs exceed revenue. To make a profit, we have to sell above the break-even point. Since revenue equals total cost at the break-even point, we can use the previous equations to compute the value of the break-even quantity:

$$\text{Total cost} = \text{total revenue}$$
$$F + (VC)\,Q = (SP)\,Q$$

Solving for Q, we get the following equation:

$$Q_{BE} = \frac{F}{SP - VC}$$

Note that we could also find the break-even point by drawing the graph and finding where the total cost and revenue lines cross.

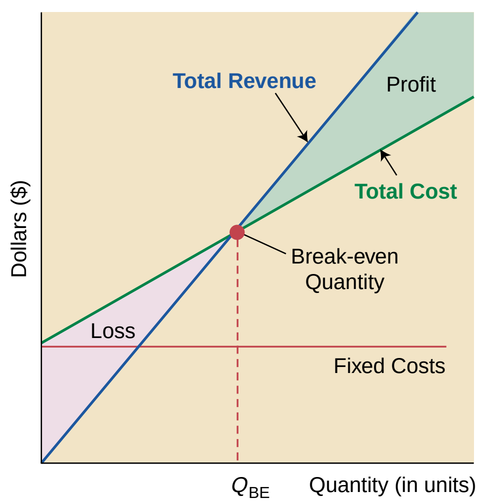


FIGURE 3-2
Graphical approach to break-even analysis

EXAMPLE 3.1

Computing the Break-Even Quantity

Fred Boulder, owner of Sports Feet Manufacturing, is considering whether to produce a new line of footwear. Fred has considered the processing needs for the new product as well as the market potential. He has also estimated that the variable cost for each product manufactured and sold is $9 and the fixed cost per year is $52,000.

(a) If Fred offers the footwear at a selling price of $25, how many pairs must he sell to break even?

(b) If Fred sells 4000 pairs at the $25 price, what will be the contribution to profit?

• Solution

(a) To compute the break-even quantity:

$$Q = \frac{F}{SP - VC}$$

$$= \frac{\$52{,}000}{\$25 - \$9} = 3250 \text{ pairs}$$

The break-even quantity is 3250 pairs. This is how much Fred would have to sell to cover costs.

(b) To compute the contribution to profit with sales of 4000 pairs we can go back to the relationship between cost and revenue:

$$\text{Profit} = \text{total revenue} - \text{total cost}$$
$$= (SP)\,Q - [F + (VC)\,Q]$$

$$\text{Profit} = \$25\,(4000) - [\$52{,}000 + \$9\,(4000)]$$
$$= \$12{,}000$$

The contribution to profit is $12,000 if Fred can sell 4000 pairs from his new line of footwear.

Break-even analysis is useful for more than just deciding between different products. It can be used to make other decisions, such as evaluating different processes or deciding whether the company should make or buy a product.

Preliminary Design and Testing

Once a product idea has passed the screening stage, it is time to begin preliminary design and testing. At this stage, design engineers translate general performance specifications into technical specifications. Prototypes are built and tested. Changes are made based on test results, and the process of revising, rebuilding a prototype, and testing continues. For service companies this may entail testing the offering on a small scale and working with customers to refine the service offering. Fast-food restaurants are known for this type of testing, where a new menu item may be tested in only one particular geographic area. Product refinement can be time consuming, and there may be a desire on the part of the company to hurry through this phase to rush the product to market. However, rushing creates the risk that all the "bugs" have not been worked out, which can prove very costly.

Final Design

Following extensive design testing the product moves to the final design stage. This is where final product specifications are drawn up. The final specifications are then translated into specific processing instructions to manufacture the product, which include selecting equipment, outlining jobs that need to be performed, identifying specific materials needed and suppliers that will be used, and all the other aspects of organizing the process of product production.

FACTORS IMPACTING PRODUCT DESIGN

Here are some additional factors that need to be considered during the product design stage.

Design for Manufacture

When we think of product design we generally first think of how to please the customer. However, we also need to consider how easy or difficult it is to manufacture the product. Otherwise, we might have a great idea that is difficult or too costly to manufacture. **Design for manufacture (DFM)** is a series of guidelines that we should follow to produce a product easily and profitably. DFM guidelines focus on two issues:

▶ **Design for manufacture (DFM)**
A series of guidelines to follow in order to produce a product easily and profitably.

1. *Design simplification* means reducing the number of parts and features of the product whenever possible. A simpler product is easier to make, costs less, and gives us higher quality.
2. *Design standardization* refers to the use of common and interchangeable parts. By using interchangeable parts we can make a greater variety of products with less inventory and significantly lower cost and provide greater flexibility. Table 3-1 shows guidelines for DFM.

An example of the benefits of applying these rules is seen in Figure 3-3. We can see the progression in the design of a toolbox using the DFM approach. All of the pictures show a toolbox. However, the first design shown requires 20 parts. Through simplification and use of modular design the number of parts required has been reduced to 2. It would certainly be much easier to make the product with 2 parts versus 20 parts. This means fewer chances for error, better quality, and lower costs due to shorter assembly time.

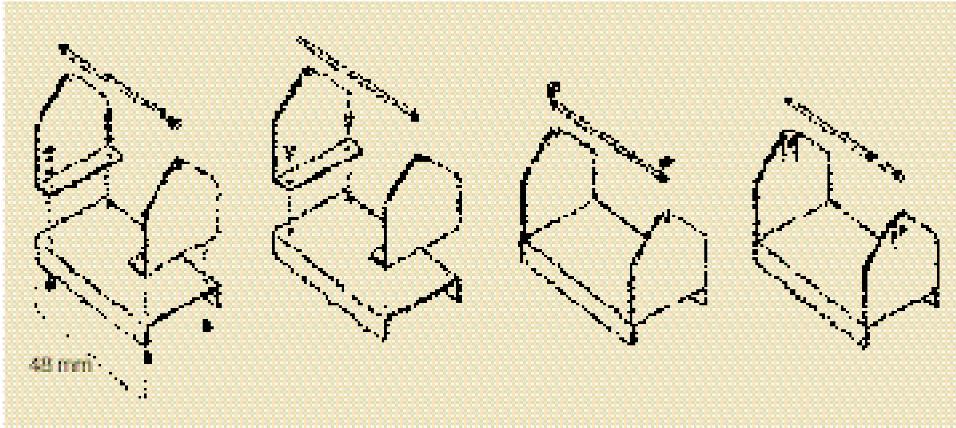
TABLE 3-1

Guidelines for DFM

DFM guidelines include the following:
1. Minimize parts.
2. Design parts for different products.
3. Use modular design.
4. Avoid tools.
5. Simplify operations.

FIGURE 3-3

Progressive design of a toolbox using DFM



Product Life Cycle

▶ **Product life cycle**
A series of stages that products pass through in their lifetime, characterized by changing product demands over time.

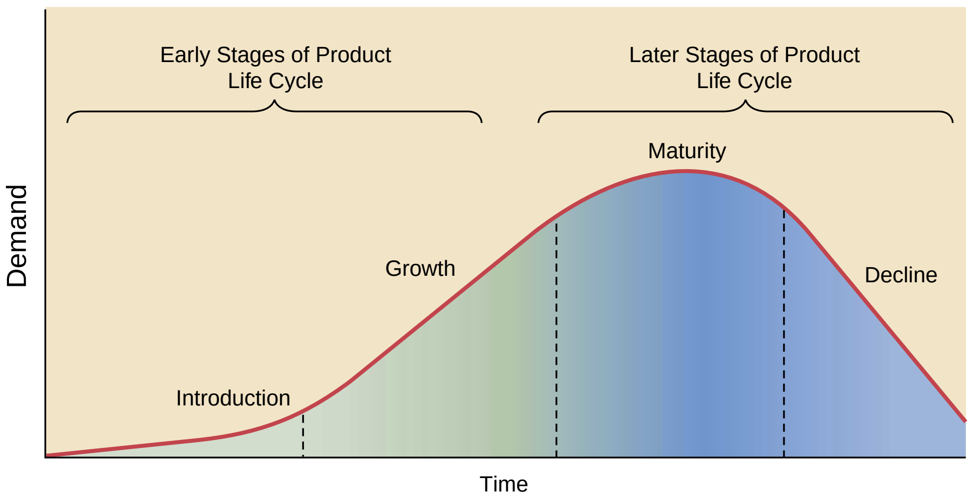
Another factor in product design is the stage of the life cycle of the product. Most products go through a series of stages of changing product demand called the **product life cycle.** There are typically four stages of the product life cycle: introduction, growth, maturity, and decline. These are shown in Figure 3-4.

Products in the introductory stage are not well defined and neither is their market. Often all the "bugs" have not been worked out and customers are uncertain about the product. In the growth stage, the product takes hold and both product and market continue to be refined. The third stage is that of maturity, where demand levels off and there are usually no design changes: The product is predictable at this stage and so is its market. Many products, such as toothpaste, can stay in this stage for many years. Finally, there is a decline in demand, because of new technology, better product design, or market saturation.

The first two stages of the life cycle can collectively be called the early stages of the product life cycle because the product is still being improved and refined, and the

FIGURE 3-4

Stages of the product life cycle



market is still in the process of being developed. The last two stages of the life cycle can be referred to as the later stages because here the product and market are both well defined.

Understanding the stages of the product life cycle is important for product design purposes, such as knowing at which stage to focus on design changes. Also, when considering a new product, the expected length of the life cycle is critical in order to estimate future profitability relative to the initial investment. The product life cycle can be quite short for certain products, as seen in the computer industry. For other products it can be extremely long, as in the aircraft industry. A few products, such as paper, pencils, nails, milk, sugar, and flour, do not go through a life cycle. However, almost all products do, and some may spend a long time in one stage.

Concurrent Engineering

Concurrent engineering is an approach that brings many people together in the early phase of product design in order to simultaneously design the product and the process. This type of approach has been found to achieve a smooth transition from the design stage to actual production in a shorter amount of development time with improved quality results.

▶ **Concurrent engineering** An approach that brings together multifunction teams in the early phase of product design in order to simultaneously design the product and the process.

The old approach to product and process design was to first have the designers of the idea come up with the exact product characteristics. Once their design was complete they would pass it on to operations who would then design the production process needed to produce the product. This was called the "over-the-wall" approach, because the designers would throw their design "over-the-wall" to operations who then had to decide how to produce the product.

There are many problems with the old approach. First, it is very inefficient and costly. For example, there may be certain aspects of the product that are not critical for product success but are costly or difficult to manufacture, such as a dye color that is difficult to achieve. Since manufacturing does not understand which features are not critical, it may develop an unnecessarily costly production process with costs passed down to the customers. Because the designers do not know the cost of the added feature, they may not have the opportunity to change their design or may do so much later in the process, incurring additional costs. Concurrent engineering allows everyone to work together so these problems do not occur. Figure 3-5 shows the difference between the "over-the-wall" approach and concurrent engineering.

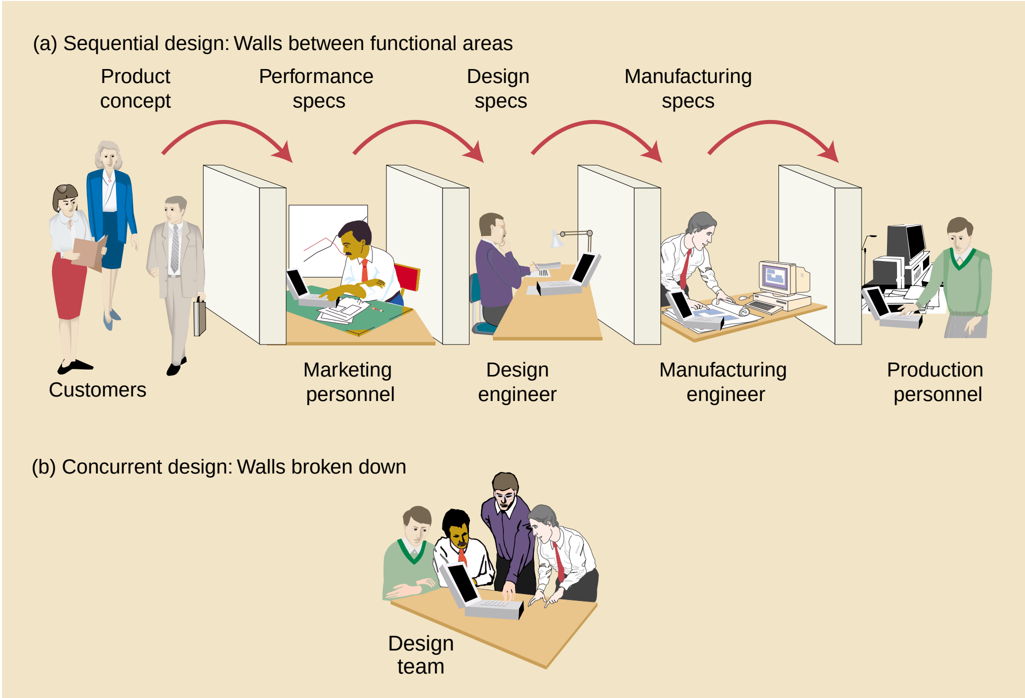
A second problem is that the "over-the-wall" approach takes a longer amount of time than when product and process design are performed concurrently. As you can see in Figure 3-5, when product and process design are made together much of the work is done in parallel rather than in sequence. In today's markets, new product introductions are expected to occur faster than ever. Companies do not have the luxury of enough time to follow a sequential approach and then work the "bugs" out. They may eventually get a great product, but by then the market may not be there!

Marketing, Engineering

The third problem is that the old approach does not create a team atmosphere, which is important in today's work environment. Rather, it creates an atmosphere where each function views its role separately in a type of "us versus them" mentality. With the old approach, when the designers were finished with the designs, they considered their job done. If there were problems, each group blamed the other. With concurrent engineering the team is responsible for designing and getting the product to market. Team members continue working together to resolve problems with the product and improve the process.

FIGURE 3-5

The first illustration shows sequential design with walls between functional areas. The second illustration shows concurrent design with walls broken down.



Remanufacturing

▶ **Remanufacturing**
The concept of using components of old products in the production of new ones.

Remanufacturing is a concept that has been gaining increasing importance, as our society becomes more environmentally conscious and focuses on efforts such as recycling and eliminating waste. **Remanufacturing** uses components of old products in the production of new ones. In addition to the environmental benefits, there are significant cost benefits because remanufactured products can be half the price of their new counterparts. Remanufacturing has been quite popular in the production of computers, televisions, and automobiles.

PROCESS SELECTION

So far we have discussed issues involved in product design. Though product design is important for a company, it cannot be considered separately from the selection of the process. In this section we will look at issues involved in process design. Then we will show how product design and process selection issues are linked together.

Types of Processes

When you look at different types of companies, ranging from a small coffee shop to IBM, it may seem like there are hundreds of different types of processes. Some locations are small, like your local Starbuck's, and some are very large, like a Ford Motor Company plant. Some produce standardized "off-the-shelf" products, like Pepperidge Farm's frozen chocolate cake, and some work with customers to customize their product, like a gourmet bakery that makes cakes to order. Though there seem to be large differences between the processes of companies, many companies have certain processing characteristics in common. In this section we will divide these processes into groups with similar characteristics, allowing us to understand problems inherent with each type of process.

All processes can be grouped into two broad categories: intermittent operations and repetitive operations. These two categories differ in almost every way. Once we understand these differences we can easily identify organizations based on the category of process they use.

Intermittent Operations **Intermittent operations** are used to produce a variety of products with different processing requirements in lower volumes. Examples are an auto body shop, a tool and die shop, or a health-care facility. Because different products have different processing needs, there is no standard route that all products take through the facility. Instead, resources are grouped by function and the product is routed to each resource as needed. Think about a health-care facility. Each patient, "the product," is routed to different departments as needed. One patient may need to get an X ray, go to the lab for blood work, and then go to the examining room. Another patient may need to go to the examining room and then to physical therapy.

▶ **Intermittent operations** Processes used to produce a variety of products with different processing requirements in lower volumes.

To be able to produce products with different processing requirements, intermittent operations tend to be labor intensive rather than capital intensive. Workers need to be able to perform different tasks depending on the processing needs of the products produced. Often we see skilled and semiskilled workers in this environment with a fair amount of worker discretion in performing their jobs. Workers need to be flexible and able to perform different tasks as needed for the different products that are being produced. Equipment in this type of environment is more general purpose to satisfy different processing requirements. Automation tends to be less common, because automation is typically product specific. Given that many products are being produced with different processing requirements, it is usually not cost efficient to invest in automation for only one product type. Finally, the volume of goods produced is directly tied to the number of customer orders.

Repetitive Operations **Repetitive operations** are used to produce one or a few standardized products in high volume. Examples are a typical assembly line, cafeteria, or automatic car wash. Resources are organized in a line flow to efficiently accommodate production of the product. Note that in this environment it is possible to arrange resources in a line because there is only one type of product. This is directly the opposite of what we find with intermittent operations.

▶ **Repetitive operations** Processes used to produce one or a few standardized products in high volume.

To efficiently produce a large volume of one type of product these operations tend to be capital intensive rather than labor intensive. An example is "mass production" operations, which usually have much invested in their facilities and equipment to provide a high degree of product consistency. Often these facilities rely on automation and technology to improve efficiency and increase output rather than on labor skill. The volume produced is usually based on a forecast of future demands rather than on direct customer orders.

The most common differences between intermittent and repetitive operations relate to two dimensions: (1) the amount of product volume produced, and (2) the degree of product standardization. Product volume can range from making a single unique product one at a time to producing a large number of products at the same time. Product standardization refers to a lack of variety in a particular product. Examples of standardized products are Fruit of the Loom white undershirts, calculators, toasters, and television sets. The type of operation used, including equipment and labor, is quite different if a company produces one product at a time to customer specifications instead of mass production of one standardized product. Specific differences between intermittent and repetitive operations are shown in Table 3-2.

The Continuum of Process Types Dividing processes into two fundamental categories of operations is helpful in our understanding of their general characteristics. To be more detailed, we can further divide each category according to product volume and degree of product standardization as follows. Intermittent operations can be divided into *project processes* and *batch processes*. Repetitive operations can be divided into *line processes* and *continuous processes*. Figure 3-6 shows a continuum of process types. Next we look at what makes these processes different from each other.

▶ **Project process**
A type of process used to make a one-at-a-time product exactly to customer specifications.

▶ **Batch process**
A type of process used to produce a small quantity of products in groups or batches based on customer orders or specifications.

- **Project processes** are used to make one-of-a-kind products exactly to customer specifications. These processes are used when there is high customization and low product volume, because each product is different. Examples can be seen in construction, shipbuilding, medical procedures, creation of artwork, custom tailoring, and interior design. With project processes the customer is usually involved in deciding on the design of the product. The artistic baker you hired to bake a wedding cake to your specifications uses a project process.
- **Batch processes** are used to produce small quantities of products in groups or batches based on customer orders or product specifications. They are also known as job shops. The volumes of each product produced are still small and

TABLE 3-2

Differences between Intermittent and Repetitive Operations

Decision	Intermittent Operations	Repetitive Operations
Product variety	Great	Small
Degree of standardization	Low	High
Organization of resources	Grouped by function	Line flow to accommodate processing needs
Path of products through facility	In a varied pattern, depending on product needs	Line flow
Factor driving production	Customer orders	Forecast of future demands
Critical resource	Labor-intensive operation (worker skills important)	Capital-intensive operation (equipment automation, technology important)
Type of equipment	General purpose	Specialized
Degree of automation	Low	High
Throughput time	Longer	Shorter
Work-in-process inventory	More	Less

Designing a custom-made cake is an example of an intermittent operation.

An assembly line is an example of a repetitive operation.

there can still be a high degree of customization. Examples can be seen in bakeries, education, and printing shops. The classes you are taking at the university use a batch process.

- **Line processes** are designed to produce a large volume of a standardized product for mass production. They are also known as flow shops, flow lines, or assembly lines. With line processes the product that is produced is made in high volume with little or no customization. Think of a typical assembly line that produces everything from cars, computers, television sets, shoes, candy bars, even food items.

▶ **Line process**
A type of process used to produce a large volume of a standardized product.

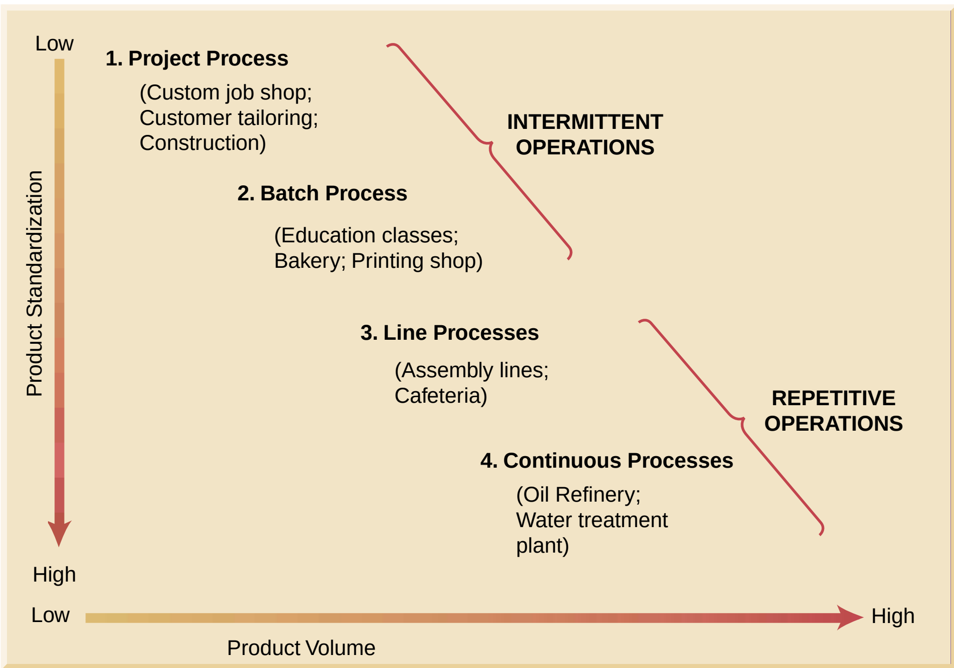


FIGURE 3-6

Types of processes based on product volume and product standardization

Source: Adapted from Robert H. Hayes and Steven C. Wheelwright, "Link Manufacturing Process and Product Life Cycles," *Harvard Business Review*, January-February, 1979, pp. 133–140.

▶ **Continuous process**
A type of process that operates continually to produce a high volume of a fully standardized product.

- **Continuous processes** operate continually to produce a very high volume of a fully standardized product. Examples include oil refineries, water treatment plants, and certain paint facilities. The products produced by continuous processes are usually in continual rather than discrete units, such as liquid or gas. They usually have a single input and a limited number of outputs. Also, these facilities are usually highly capital intensive and automated.

Note that both project and batch processes have low product volumes and offer customization. The difference is in the volume and degree of customization. Project processes are more extreme cases of intermittent operations compared to batch processes. Also, note that both line and continuous processes primarily produce large volumes of standardized products. Again, the difference is in the volume and degree of standardization. Continuous processes are more extreme cases of high volume and product standardization than are line processes.

Figure 3-6 positions these four process types along the diagonal to show the best process strategies relative to product volume and product customization. Companies whose process strategies do not fall along this diagonal may not have made the best process decisions. Bear in mind, however, that not all companies fit into only one of these categories: a company may use both batch and project processing to good advantage. For example, a bakery that produces breads, cakes, and pastries in batch may also bake and decorate cakes to order.

DESIGNING PROCESSES

Now that we know about different types of processes, let's look at a technique that can help with process design.

▶ **Process flow analysis**
A technique used for evaluating a process in terms of the sequence of steps from inputs to outputs with the goal of improving its design.

▶ **Process flowchart**
A chart showing the sequence of steps in producing the product or service.

Process flow analysis is a technique used for evaluating a process in terms of the sequence of steps from inputs to outputs with the goal of improving its design. One of the most important tools in process flow analysis is a process flowchart. A **process flowchart** is used for viewing the sequence of steps involved in producing the product, and the flow of the product through the process. It is useful for seeing the totality of the operation and for identifying potential problem areas.

There is no exact format for designing a flowchart. The flowchart can be very simple or highly detailed. The typical symbols used in a flowchart are arrows to represent flows, triangles to represent decision points, inverted triangles to represent storage of goods, and rectangles as tasks. Let's begin by looking at some elements used in developing a flowchart, as shown in Figure 3-7. Shown first, in Figure 3-7(a), are flows between stages in a simple multistage process, which is a process with multiple activities ("stages"). You can see that the arrows indicate a simple flow of materials between the different stages.

Often multiple stages have storage areas or "buffers" between them for placement of either partially completed (work-in-process) or fully completed (finished goods) inventory, shown in Figure 3-7(b). This enables the two stages to operate independently of each other. Otherwise, the first stage would have to produce a product at the same exact rate as the second stage. For example, let's say that the first stage of a multistage process produces one product in 40 seconds and the second stage in 60 seconds. That means that for every unit produced the first stage would have to stop and wait 20 seconds for the second stage to finish its work. Because the capacity of the second stage is holding up the speed of the process, it is

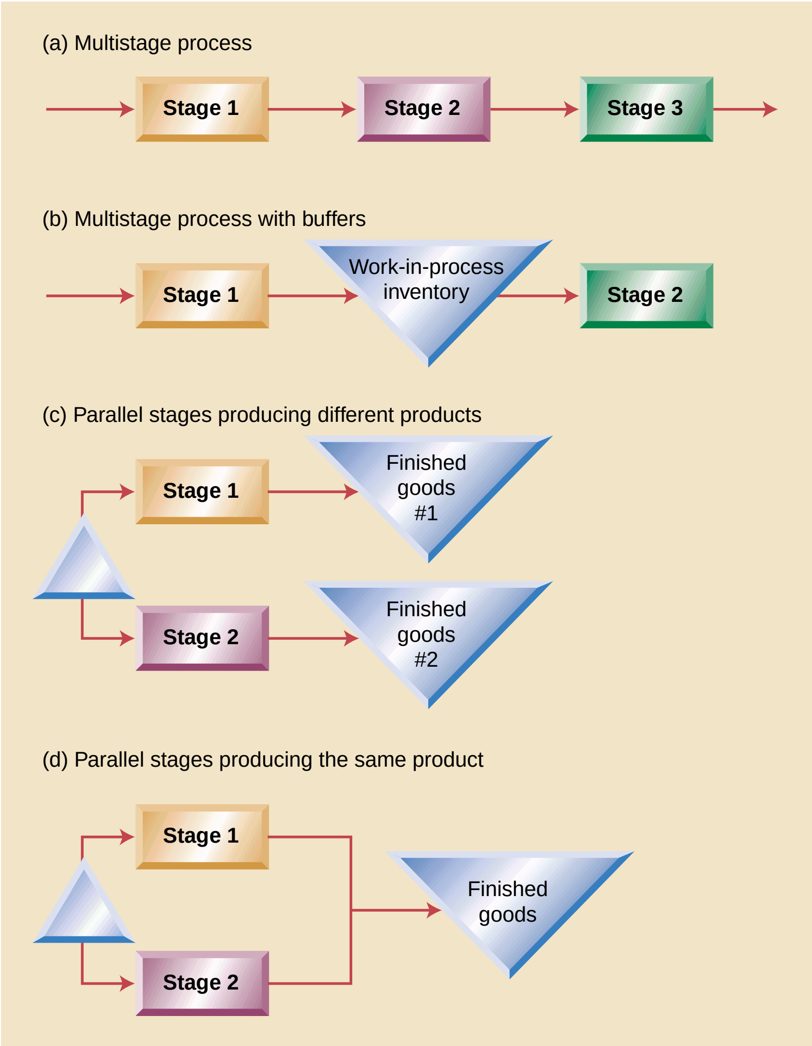


FIGURE 3-7

Elements of flowchart development

called a **bottleneck.** Now let's see what happens if the first stage takes 60 seconds to produce a product and the second stage 40 seconds. In this case the first stage becomes the bottleneck, and the second stage has to wait 20 seconds to receive a product. Obviously the best is for both stages to produce at the same rate, though this is often not possible. Inventory is then placed between the stages to even out differences in production capacity.

▶ **Bottleneck**
Longest task in the process.

Often stages in the production process can be performed in parallel, as shown in Figure 3-7(c) and (d). The two stages can produce different products (c) or the same product (d). Notice that in the latter case this would mean that the capacity of the stage performed in parallel has effectively been doubled.

Now let's look at an illustration of a flowchart using Antonio's Pizzeria as an example. Let's say that Antonio produces three different styles of pizzas to satisfy different types of customers. The first are cheese pizzas made with standard ingredients and a

▶ **Make-to-stock strategy** Produces standard products and services for immediate sale or delivery.

▶ **Assemble-to-order strategy** Produces standard components that can be combined to customer specifications.

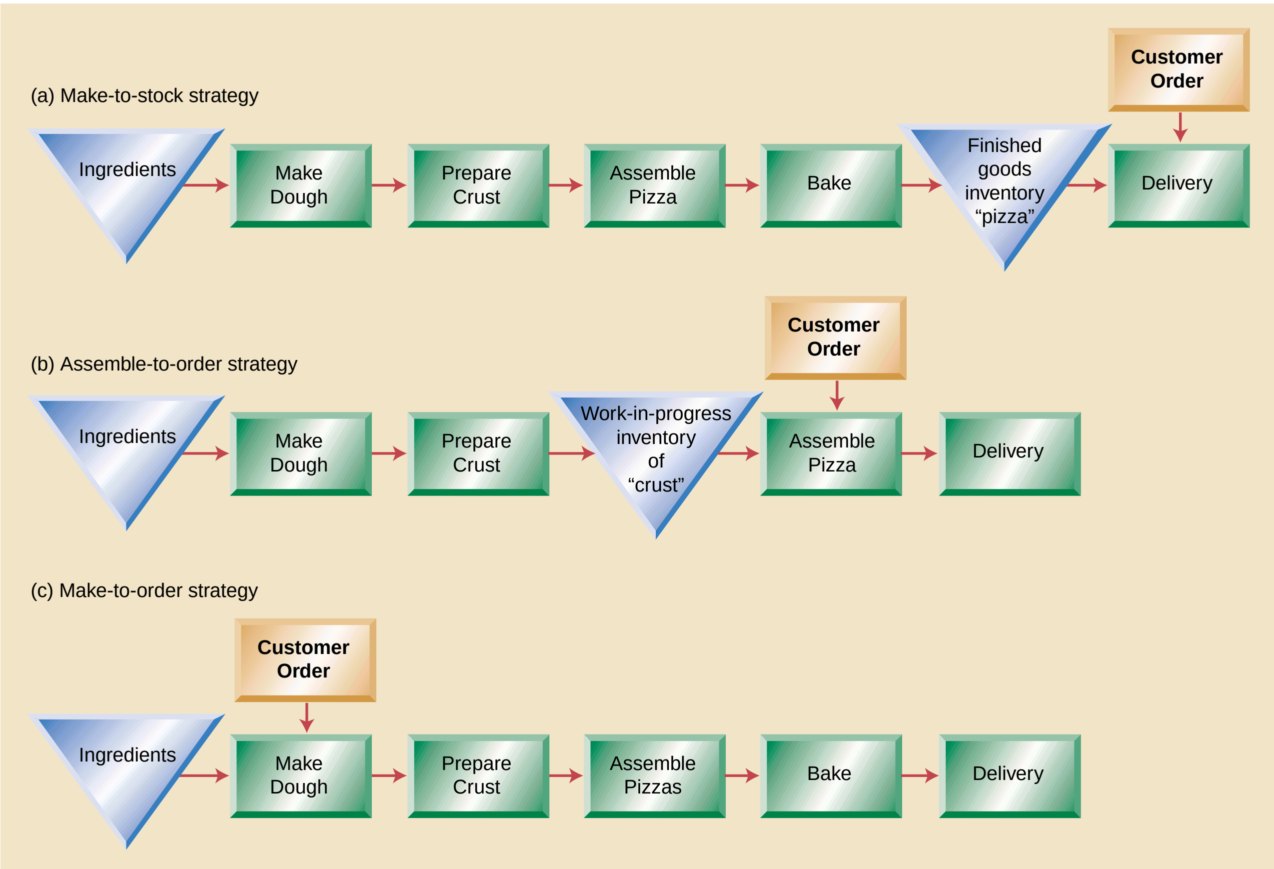
▶ **Make-to-order strategy** Produces products to customer specifications after an order has been received.

standard crust. They are the most popular items and Antonio makes them ahead of time to ensure that they are always available upon demand. This is called a **make-to-stock strategy.** The second are pizzas that use a standard crust prepared ahead of time, but are assembled based on specific customer requests. This is called an **assemble-to-order strategy.** Lastly are pizzas made-to-order based on specific customer requirements, allowing choices of different types of crusts and toppings. This is called a **make-to-order strategy.** We will look at these product strategies more closely later in this chapter. For now, let's look at the flowcharts for the three processes in Figure 3-8. Notice that although the flowcharts are similar, they show customer interaction at different points in the processes.

Process flowcharts can also be used to map the flow of the customer through the process and to identify potential problem areas. Figure 3-9 shows a flowchart for Antonio's Pizzeria that includes the steps involved in placing and processing a customer order. The points in the process for potential problems are indicated. Management can then monitor these problem areas. The chart could be even more detailed, including information such as frequency of errors or approximate time to complete a task. As you can see, process flowcharts are very useful tools when designing and evaluating processes.

FIGURE 3-8

Flowcharts for different product strategies at Antonio's Pizzeria



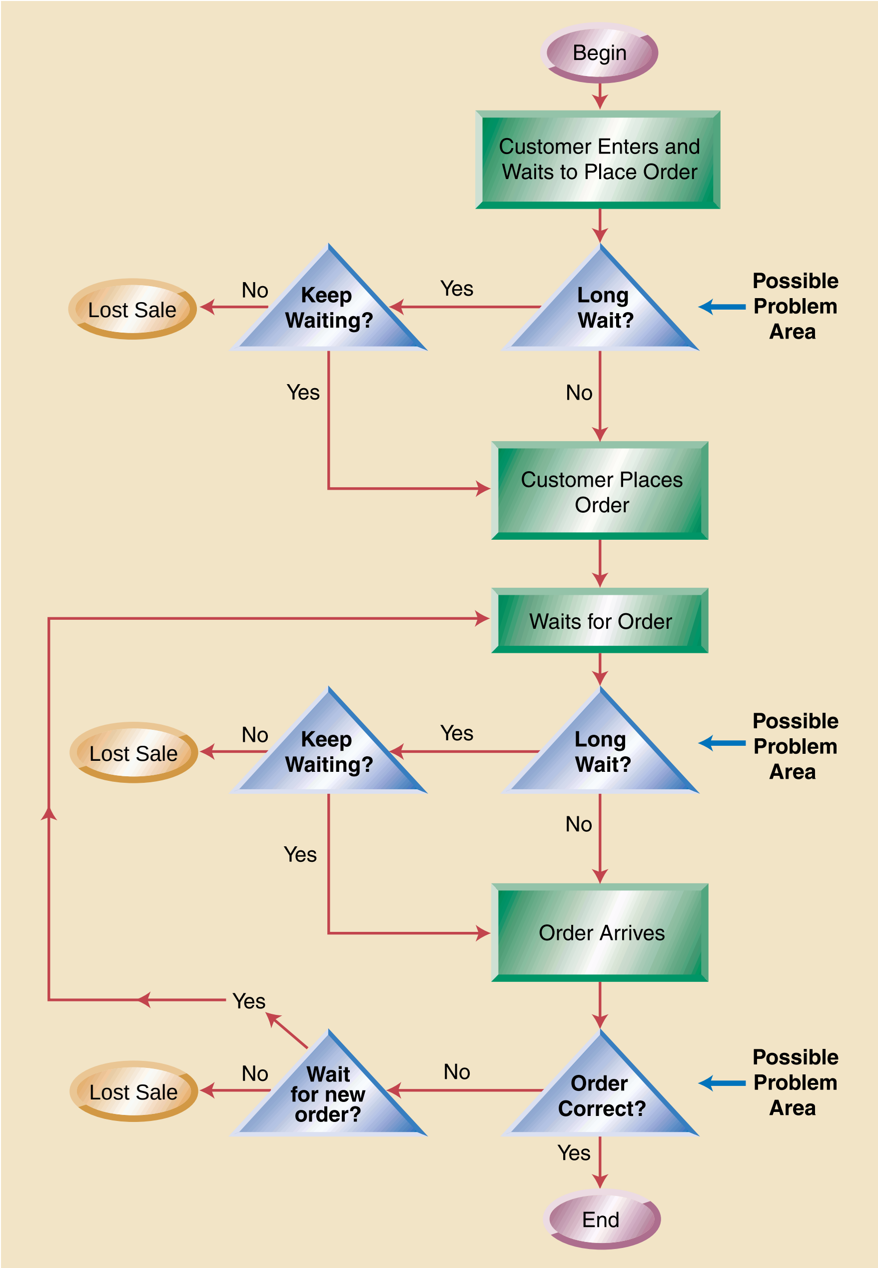


FIGURE 3-9

Process flowchart of customer flow at Antonio's Pizzeria

PROCESS PERFORMANCE METRICS

An important way of ensuring that a process is functioning properly is to regularly measure its performance. **Process performance metrics** are measurements of different process characteristics that tell us how a process is performing. Just as accountants and finance managers use financial metrics, operations managers use process performance metrics to determine how a process is performing and how it is changing over time. There are many process performance metrics that focus on different aspects of

▶ **Process performance metrics**
Measurements of different process characteristics that tell how a process is performing.

the process. In this section we will look at some common metrics used by operations managers. These are summarized in Table 3-3.

▶ **Throughput time**
Average amount of time it takes a product to move through the system.

A basic process performance metric is **throughput time,** which is the average amount of time it takes a product to move through the system. This includes the time someone is working on the product as well as the waiting time. A lower throughput time means that more products can move through the system. One goal of process improvement is to reduce throughput time. For example, think about the time spent at your last doctor's appointment. The total amount of time you spent at the facility, regardless of whether you were waiting, talking with the physician, or having lab work performed, is throughput time.

▶ **Process velocity**
Ratio of throughput time to value-added time.

Quite possibly much of the time at your last doctor's appointment was spent waiting. An important metric that measures how much wasted time exists in a process is **process velocity.** Process velocity is computed as a ratio of throughput time to value-added time:

$$\text{Process velocity} = \frac{\text{Throughput time}}{\text{Value-added time}}$$

where value-added time is the time spent actually working on the product. Notice that the closer this ratio is to 1.00, the lower the amount of time the product spends on nonvalue adding activities (e.g., waiting). Again recall your last doctor's appointment. What was the value-added time? What was the throughput time? Can you estimate the process velocity?

▶ **Productivity**
Ratio of outputs over inputs.

▶ **Utilization**
Ratio of time a resource is used to time it is available for use.

▶ **Efficiency**
Ratio of actual output to standard output.

Another important metric is **productivity,** which is the ratio of outputs over inputs. Productivity measures how well a company converts its inputs to outputs. Productivity was discussed in detail in Chapter 2, so we will not repeat its computation here. Also important is **utilization,** which is the ratio of the time a resource is actually used versus the time it is available for use. Unlike productivity, which tends to focus on financial measures (e.g., dollars of output), utilization measures the actual time that a resource (e.g., equipment or labor) is being used. Last, **efficiency** is a metric that measures actual output relative to some standard of output. It tells us whether we are performing at, above, or below standard.

TABLE 3-3
Process Performance Metrics

Measure	Definition
1. Throughput time	Average amount of time product takes to move through the system.
2. Process velocity $= \frac{\text{Throughput time}}{\text{Value-added time}}$	A measure of wasted time in the system.
3. Productivity $= \frac{\text{Output}}{\text{Input}}$	A measure of how well a company uses its resources.
4. Utilization $= \frac{\text{Time a resource used}}{\text{Time a resource available}}$	The proportion of time a resource is actually used.
5. Efficiency $= \frac{\text{Actual output}}{\text{Standard output}}$	Measures performance relative to a standard.

EXAMPLE 3.2

Measuring Process Performance

Frantz Title Company is analyzing its operation in an effort to improve performance. The following data have been collected:

It takes an average of 4 hours to process and close a title, with value-added time estimated at 30 minutes per title;
Each title officer is on payroll for 8 hours per day, though working 6 hours per day on average, accounting for lunches and breaks. Industry standard for labor utilization is 80 percent;
The company closes on 8 titles per day, with an industry standard of 10 titles per day for a comparable facility.

Determine process velocity, labor utilization, and efficiency for the company. Can you draw any conclusions?

• Solution

$$\text{Process Velocity} = \frac{\text{Throughput time}}{\text{Value-added time}} = \frac{4 \text{ hours/title}}{\frac{1}{2} \text{ hour/title}} = 8$$

$$\text{Labor utilization} = \frac{6 \text{ hours/day}}{8 \text{ hours/day}} = .75 \text{ or } 75\%$$

$$\text{Efficiency} = \frac{8 \text{ titles/day}}{10 \text{ titles/day}} = .80 \text{ or } 80\%$$

A process velocity of 8 indicates that the amount of time spent on nonvalue activities is 8 times that of value-added activities. Also, labor utilization and efficiency are both below standard.

Before You Go On

Make sure that you understand the key issues in product design. Be familiar with the different stages of the product life cycle. Recall that products in the early stages of the life cycle are still being refined based on the needs of the market. This includes product characteristics and features. At this stage the market for the product has not yet been fully developed and product volumes have not reached their peak. By contrast, products in the later stages of their life cycle have well-developed characteristics and demand volumes for them are fairly stable.

Review the different types of processes and their characteristics. Recall that intermittent processes are designed to produce products with different processing requirements in smaller volumes. Repetitive operations, on the other hand, are designed for one or a few types of products produced in high volumes.

Next we discuss how product design and process selection decisions are interrelated.

LINKING PRODUCT DESIGN AND PROCESS SELECTION

Marketing

Decisions of product design and process selection are directly linked and cannot be made independently of one another. The type of product a company produces defines the type of operation needed. The type of operation needed, in turn, defines many other aspects of the organization. This includes how a company competes in the marketplace (competitive priorities), the type or equipment and its arrangement in the facility, the type of organizational structure, and future types of products that can be

TABLE 3-4

Differences in Key Organizational Decisions for Different Types of Operations

Decision	Intermittent Operations	Repetitive Operations
Product design	Early stage of product life cycle	Later stage of product life cycle
Competitive priorities	Delivery, flexibility, and quality	Cost and quality
Facility layout	Resources grouped by function	Resources arranged in a line
Product strategy	Make-to-order/assemble-to-order	Make-to-stock
Vertical integration	Low	High

produced by the facility. Table 3-4 summarizes some key decisions and how they differ for intermittent and repetitive types of operations. Next we look at each of these decision areas.

Product Design Decisions

Intermittent and repetitive operations typically focus on producing products in different stages of the product life cycle. Intermittent operations focus on products in the early stage of the life cycle because facilities are general purpose and can be adapted to the needs of the product. As products in the early stage of the life cycle are still being refined, intermittent operations are ideally suited for these types of products. Also, demand volumes for these products are still uncertain, and intermittent operations are designed to focus on producing lower volumes of products with differing characteristics.

Once a product reaches the later stages of the life cycle both its product features and its demand volume are predictable. As volumes are typically larger at this stage, a facility that is dedicated to producing a large volume of one type of product is best from both efficiency and cost perspectives. This is what a repetitive operation provides. Recall that repetitive operations are capital intensive, with much automation dedicated to the efficient production of one type of product. It would not be a good decision to invest such a large amount of resources for a product that is uncertain relative to its features or market. However, once a product is well defined with a sizable market, repetitive types of operations are a better business alternative. This is why repetitive operations tend to focus on products in the later stages of their life cycle.

The product focus of both types of operations has significant implications for a company's future product choices. Once a company has an intermittent operation in place, designed to produce a variety of products in low volumes, it is a poor strategic decision to pursue production of a highly standardized product in the same facility. The same holds true for attempting to produce a newly introduced product in a repetitive operation.

The differences between the two types of operations are great, including the way they are managed. Not understanding their differences is a mistake often made by companies. A company may be very successful at managing a repetitive operation that produces a standardized product. Management may then see an opportunity involving products in the early stage of the life cycle. Not understanding the differences in the operational requirements, management may decide to produce this new product by applying their "know-how." The results can prove disastrous.

LINKS TO PRACTICE

The Babcock & Wilcox Company
www.babcock.com

The problems that can arise when a company does not understand the differences between intermittent and repetitive operations are illustrated by the experience of The Babcock & Wilcox Company in the late 1960s. B & W was very successful at producing fossil fuel boilers, a standardized product made via repetitive operation. Then the company decided to pursue production of nuclear pressure vessels, a new product in the early stages of its life cycle that required an intermittent operation. B & W saw the nuclear pressure vessels as a wave of the future. Because they were successful at producing boilers, they believed they could apply those same skills to production of the new product. They began managing the production of nuclear pressure vessels—an intermittent operation—as if it were a repetitive operation. They focused primarily on cost rather than delivery, did not give enough time for product refinement, and did not invest in labor skills necessary for a new product. Consequently, the venture failed and the company almost went out of business. It was saved by its success in the production of boilers to which it was able to return.

Competitive Priorities

Marketing

The decision of how a company will compete in the marketplace—its competitive priorities—is largely affected by the type of operation it has in place. Intermittent operations are typically less competitive on cost than repetitive operations. The reason is that repetitive operations mass produce a large volume of one product. The cost of the product is spread over a large volume, allowing the company to offer that product at a comparatively lower price.

Think about the cost difference you would incur if you decided to buy a business suit "off the rack" from your local department store (produced by a repetitive operation) versus having it custom made by a tailor (an intermittent operation). Certainly a custom-made suit would cost considerably more. The same product produced by a repetitive operation typically costs less than one made by an intermittent operation. However, intermittent operations have their own advantages. Having a custom-made suit allows you to choose precisely what you want in style, color, texture, and fit. Also, if you were not satisfied you could easily return it for adjustments and alterations. Intermittent operations compete more on flexibility and delivery compared to continuous operations.

Today all organizations understand the importance of quality. However, the elements of quality that a company focuses on may be different depending on the type of operation used. Repetitive operations provide greater consistency between products. The first and last products made in the day are almost identical. Intermittent operations, on the other hand, offer greater variety of features and workmanship not available with mass production.

It is important that companies understand the competitive priorities best suited for the type of process that they use. It would not be a good strategic decision for an intermittent operation to try to compete primarily on cost, as it would not be very successful. Similarly, the primary competitive priority for a repetitive operation should not be variety of features, because this would take away from the efficiency of the process design.

Facility Layout

Facility layout, covered in Chapter 10, is concerned with the arrangement of resources of a facility to enhance the production process. If resources are not arranged properly, a company will have inefficiency and waste. The type of process a company uses directly affects the facility layout of the organization and the inherent problems encountered.

Resources of intermittent operations are grouped based on similar processes or functions. There is no one typical product that is produced; rather, a large variety of items are produced in low volumes, each with its own unique processing needs. Since no one product justifies the dedication of an entire facility, resources are grouped based on their function. Products are then moved from resource to resource, based on their processing needs. The challenge with intermittent operations is to arrange the location of resources to maximize efficiency and minimize waste of movement. If the intermittent operation has not been designed properly, many products will be moved long distances. This type of movement adds nothing to the value of the product and contributes to waste. Any two work centers that have much movement between them should be placed close to one another. However, this often means that another work center will have to be moved out of the way. This can make the problem fairly challenging.

Intermittent operations are less efficient and have longer production times due to the nature of the layout. Material handling costs tend to be high and resource scheduling is a challenge. Intermittent operations are common in practice. Examples include a doctor's office or a hospital. Departments are grouped based on their function, with examining rooms in one area, lab in another, and X-rays in a third. Patients are moved from one department to another based on their needs. Another example is a bakery that makes custom cakes and pastries. The work centers are set up to perform different functions, such as making different types of dough, different types of fillings, and different types of icing and decorations. The product is routed to different workstations depending on the product requirements. Some cakes have the filling in the center (e.g., Boston cream pie), others only on top (e.g., sheet cake), and some have no filling at all (e.g., pound cake).

Repetitive operations have resources arranged in sequence to allow for efficient production of a standardized product. Since only one product or a few highly similar products are being produced, all resources are arranged to efficiently meet production needs. Examples are seen on an assembly line, in a cafeteria, or even a car wash. Numerous products, from breakfast cereals to computers, are made using repetitive operations.

Though repetitive operations have faster processing rates, lower material handling costs, and greater efficiency than intermittent operations, they also have their shortcomings. Resources are highly specialized and the operation is inflexible relative to the market. This type of operation cannot respond rapidly to changes in market needs for the products wanted or to changes in demand volume. The challenge is to arrange workstations in sequence and designate the jobs that will be performed by each to produce the product in the most efficient way possible. Figure 3-10 illustrates the differences in facility layout between intermittent and repetitive operation.

Product and Service Strategy

The type of operation a company has in place is directly related to its product and service strategy. As we learned earlier in this chapter in the example of Antonio's Pizzeria, product and service strategies can be classified as make-to-stock, assemble-to-order, and

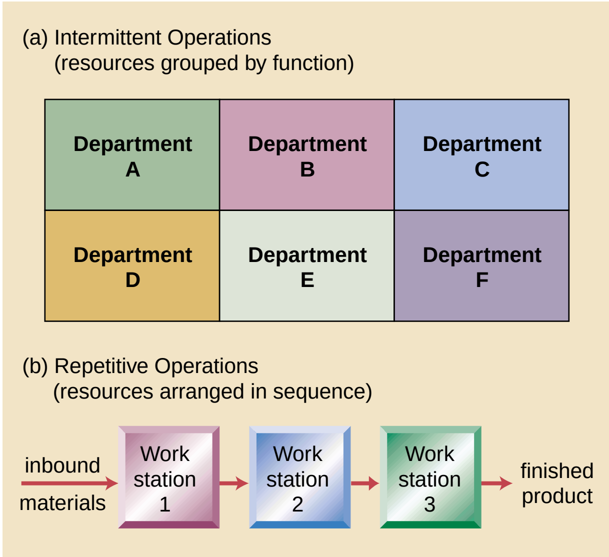


FIGURE 3-10

Facility layouts for intermittent versus repetitive operations

make-to-order. These strategies differ by the length of their delivery lead time, which is the amount of time from when the order is received to when the product is delivered. These strategies also differ by the degree of product customization. Figure 3-11 illustrates these differences.

Make-to-stock is a strategy that produces finished products for immediate sale or delivery, in anticipation of demand. Companies using this strategy produce a standardized product in larger volumes. Typically this strategy is seen in repetitive operations. Delivery lead time is the shortest, but the customer has no involvement in product design. Examples include off-the-shelf retail apparel, soft drinks, standard automotive parts, or airline flights. A hamburger patty at a fast-food restaurant such as McDonald's, Burger King, or Wendy's is made-to-stock as is a taco at Taco Bell. As a customer you gain speed of delivery, but lose the ability to customize the product.

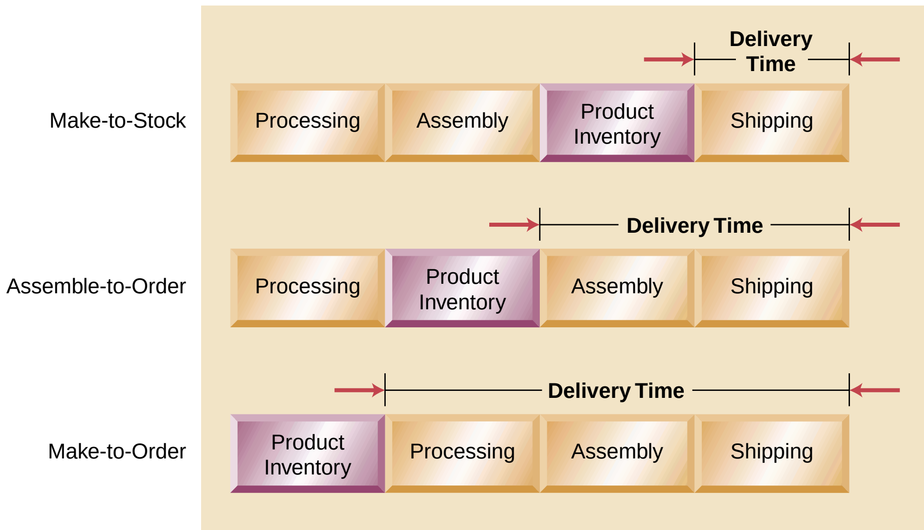


FIGURE 3-11

Product and service strategy options

Assemble-to-order strategy, also known as build-to-order, produces standard components that can be combined to customer specifications. Delivery time is longer than in the make-to-stock strategy, but allows for some customization. Examples include computer systems, pre-fabricated furniture with choices of fabric colors, or vacation packages with standard options.

Make-to-order is a strategy used to produce products to customer specifications after an order has been received. The delivery time is longest and product volumes are low. Examples are custom-made clothing, custom-built homes, and customized professional services. Ordering a hamburger to your liking in a sit-down restaurant is another example of this strategy. This strategy is best for an intermittent operation.

Degree of Vertical Integration

The larger the number of processes performed by a company in the chain from raw materials to product delivery, the higher the vertical integration. Vertical integration is a strategic decision that should support the future growth direction of the company. Vertical integration is a good strategic option when there are high volumes of a small variety of input materials, as is the case with repetitive operations. The reason is that the high volume and narrow variety of input material allows task specialization and cost justification. An example is Dole Food Company, which owns and controls most of its canned pineapple production from pineapple farms to the processing plant. The company has chosen to be vertically integrated so as to have greater control of costs and product quality.

It is typically not a good strategic decision to vertically integrate into specialized processes that provide inputs in small volumes. This would be the case for intermittent operations. For example, let's consider a bakery that makes a variety of different types of cakes and pies. Maybe the bakery purchases different fillings from different sources, such as apple pie filling from one company, chocolate filling from another, and cream filling from a third. If the company were to purchase production of the apple filling, it would not gain much strategically because it still relies on other suppliers. In this case outsourcing may be a better choice. However, if the bakery shifted its production to only making apple pies, then the vertical integration might be a good choice.

In summary, vertical integration is typically a better strategic decision for repetitive operations. For intermittent operations it is generally a poor strategic choice.

TECHNOLOGY DECISIONS

Advancements in technology have had the greatest impact on process design decisions. Technological advances have enabled companies to produce products faster, with better quality, at a lower cost. Many processes that were not imaginable only a few years ago have been made possible through the use of technology. In this section we look at some of the greatest impacts technology has had on process design.

Information Technology

▶ **Information technology** Technology that enables storage, processing, and communication of information within and between firms.

Information technology (IT) is technology that enables storage, processing, and communication of information within and between firms. It is also used to organize information to help managers with decision making. One type of information technology we are all familiar with is the *Internet*, which has had the greatest impact on the way companies conduct business. The Internet has linked trading partners—customers, buyers, and suppliers—and has created electronic commerce and the virtual marketplace.

Enterprise software is another powerful information technology, such as **enterprise resource planning (ERP).** These are large software programs used for planning and coordinating all resources throughout the entire enterprise. They allow data sharing and communication within and outside of the firm, enabling collaborative decision making. We will learn more about ERP in Chapter 14.

► **Enterprise resource planning (ERP)**
Large software programs used for planning and coordinating all resources throughout the entire enterprise.

Other examples of IT include *wireless communication technologies.* We are all familiar with cellular phones and pagers in our own lives. These technologies can also significantly improve business operations. For example, wireless homing devices and wearable computers are being used in warehouses to quickly guide workers to locations of goods. Wireless technologies enhanced by satellite transmission can rapidly transmit information from one source to another. For example, Wal-Mart uses company-owned satellites to automatically transmit point-of-sale data to computers at replenishment warehouses.

Global positioning systems (GPS) are another type of wireless technology that uses satellite transmission to communicate exact locations. GPS was originally developed by the Department of Defense in 1978, in order to help coordinate U.S. military operations. Today GPS has numerous business and individual applications. Large trucking companies use GPS technology to identify the exact locations of their vehicles. Farmers use GPS while riding on tractors to identify their exact location and apply the proper mix of nutrients to the correct plot of land. GPS capability is also available for personal use in handheld computers, such as the Palm Garmin iQue, that can identify the person's location and plot a route to where she is going.

► **Global positioning systems (GPS)**
A type of wireless technology that uses satellite transmission to communicate exact locations.

LINKS TO PRACTICE

Using GPS Technology in Product Advertising

GPS has even found its use in advertising. For example, Nielsen Media Research, the firm known for rating television viewers, is using GPS to test billboard advertising. The company has recruited a sample of adults with known demographic characteristics, and is using GPS to monitor their minute-by-minute movements. This information will then be used to determine the best placement for particular billboard advertisements targeted to the particular demographic group.

Radio frequency identification (RFID) is another wireless technology that promises to dramatically change business operations. RFID uses memory chips equipped with tiny radio antennas that can be attached to objects to transmit streams of data about the object. For example, RFID can be used to identify any product movement, reveal a missing product's location, or have a shipment of products "announce" their arrival. Empty store shelves can signal that it is time for replenishment using RFID, or low inventories can signal the vendor that it is time to ship more products. In fact, RFID has the potential to become the backbone of an infrastructure that can identify and track billions of individual objects all over the world, in real time.

► **Radio frequency identification (RFID)**
A wireless technology that uses memory chips equipped with radio antennas attached to objects used to transmit streams of data.

An early adopter of RFID is Wal-Mart, which is investing heavily in RFID tags for its warehouses. Wal-Mart has already begun tracking products at some stores, such as cases of Coca-Cola, Bounty paper towels, and MACH3 razors at one of its Sam's Club stores. Home Depot (HD) is another company that is considering adopting the technology.

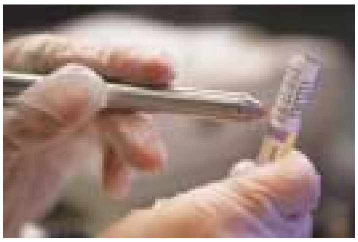
Automation

▶ **Automation**
Using machinery to perform work without human operators.

An important decision in designing processes is deciding whether the firm should automate, to what degree, and the type of automation that should be used. **Automation** uses machinery that is able to perform work without human operators and can be a single machine or an entire factory. Although there are tremendous advantages to automation, there are also disadvantages. Companies need to consider these carefully before making the final decision.

Automation has the advantage of product consistency and ability to efficiently produce large volumes of product. With automated equipment the last part made in the day will be exactly like the first one made. Because automation brings consistency, quality tends to be higher and easier to monitor. Production can flow uninterrupted throughout the day, without breaks for lunch, and there is no fatigue factor.

However, automation does have its disadvantages. First, automation is typically very costly. These costs can be justified only through a high volume of production. Second, automation is typically not flexible in accommodating product and process changes. Therefore, automation would probably not be good for products in the early stages of their life cycle or for products with short life cycles. Automation needs to be viewed as another capital investment decision: financial payback is critical. For all these reasons automation is typically less present in intermittent than in repetitive operations.



Handheld scanner reading a barcode.

Automated Material Handling

The primary method of moving products used in the past was the conveyor in the form of belts or chains. Today's material handling devices can read bar codes that tell them which location to go to and that are capable of moving in many directions. One such device is an *automated guided vehicle (AGV)*, a small battery-driven truck that moves materials from one location to the other. The AGV is not operated by a human and takes its directions from either an on-board or central computer. Even AGVs have become more sophisticated over time. The older models followed a cable that was installed under the floor. The newer models follow optical paths and can go anywhere there is aisle space.

One of the biggest advantages of AGVs is that they can pretty much go anywhere, as compared to traditional conveyor belts. Managers can use them to move materials wherever they are needed, even avoiding piles of inventory in their way.

Another type of automated material handling includes *automated storage and retrieval systems (AS/RSs)*, which are basically automated warehouses. AS/RSs use AGVs to move material and also computer control racks and storage bins. The storage bins can typically rotate like a carousel, so that the desired storage bin is available for either storage or retrieval. All this is controlled by a computer that keeps track of the exact location and quantity of each item. The computer controls how much will be stored or retrieved in a particular area. AS/RSs can have great advantages over traditional warehouses. Though they are much more costly to operate, they are also much more efficient and accurate.

▶ **Flexible manufacturing system (FMS)**
A type of automated system that provides the flexibility of intermittent operations with the efficiency of continuous operations.

Flexible Manufacturing Systems (FMS)

A **flexible manufacturing system (FMS)** is a type of automation system that provides the flexibility of intermittent operations with the efficiency of repetitive operations. As you can see by the definition, this is a *system* of automated machines, not just a single machine. An FMS consists of groups of computer-controlled machines and/or robots, automated handling devices for moving, loading, and unloading, and a computer-control center.

Based on the instructions from the computer-control center, parts and materials are automatically moved to appropriate machines or robots. The machines perform their tasks and then the parts are moved to the next set of machines where the parts automatically are loaded and unloaded. The routes taken by each product are determined with the goal of maximizing efficiency of the operation. Also, the FMS "knows" when one machine is down due to maintenance or if there is a backlog of work on a machine, and it will automatically route the materials to an available machine.

Flexible manufacturing systems are still fairly limited in the variety of products that they handle. Usually they can only produce similar products from the same family. Flexible manufacturing systems are not very widespread. One of the primary reasons is their high cost. A decision to use an FMS needs to be long term and strategic, requiring a sizable financial outlay.

Production line robot placing windshield on car

Robotics A robot in manufacturing is usually nothing more than a mechanical arm with a power supply and a computer-control mechanism that controls the movements of the arm. The arm can be used for many tasks, such as painting, welding, assembly, loading, and unloading of machines. Robots are excellent for physically dangerous jobs such as working with radioactive or toxic materials. Also, robots can work 24 hours a day to produce a highly consistent product.

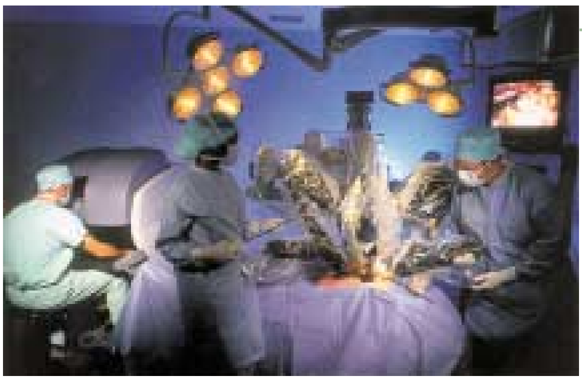
Robots range in their degree of sophistication. Some robots are fairly simple and follow a repetitive set of instructions. Other robots follow complex instructions, and some can be programmed to recognize objects and even make simple decisions. One type of automation that is similar to simple robotics is the **numerically controlled (NC) machine.** NC machines are controlled by a computer and can do a variety of tasks such as drilling, boring, or turning parts of different sizes and shapes. Factories of the future will most likely be composed of a number of robots and NC machines working together.

▶ **Numerically controlled (NC) machine**
A machine controlled by a computer that can perform a variety of tasks.

The use of robots has not been very widespread in U.S. firms. However, this is an area that can provide a competitive advantage for a company. Cost justification should not only consider reduction in labor costs but also the increased flexibility of operation and improvement in quality. The cost of robots can vary greatly and depends on the robots' size and capabilities. Generally, it is best for a company to consider purchasing multiple robots or forms of automation to spread the costs of maintenance and software support. Also, the decision to purchase automation such as robotics needs to be a long-term strategic decision that considers the totality of the production process. Otherwise, the company may have one robot working 24 hours a day and piling up inventory while it waits for the other processes to catch up.

LINKS TO PRACTICE

Performing Robotic Surgery



Robots can be used to improve operations of almost any business—even literal "operations." Recently robots have begun to be used in performing certain medical surgeries. For example, at New York University doctors use minimally invasive robotic surgery to repair human heart valves. To perform the surgery, doctors use a robot arm to cut a six-centimeter incision between the ribs and place an endoscope to allow the surgeons to see what they are doing. The robot arm is controlled through a complex robotic surgical system. The doctors, seated at a workstation, manipulate conventional surgical instruments while the robotic surgical system mirrors these movements on an ultra-fine scale. The advantage of using robots is that they can perform delicately fine, small, motor movements, have consistent finger dexterity, and require only tiny incisions. The prediction is that robots will become involved in performing many surgeries, such as eye surgery, neurosurgery, and cosmetic surgery.

e-Manufacturing

Today's Web-based environment has created numerous opportunities for business collaboration. This includes collaboration in product and process design, where customers, buyers, and designers can share information and jointly make decisions in real time. Let's look at some of the computer systems that can aid e-manufacturing.

▶ **Computer-aided design (CAD)**
A system that uses computer graphics to design new products.

Computer-Aided Design (CAD)

Computer-aided design (CAD) is a system that uses computer graphics to design new products. Gone are the days of drafting designs by hand. Today's powerful desktop computers combined with graphics software allow the designer to create drawings on the computer screen and then manipulate them geometrically to be viewed from any angle. With CAD the designer can rotate the object, split it to view the inside, and magnify certain sections for closer view.

CAD can also perform other functions. Engineering design calculations can be performed to test the reactions of the design to stress and to evaluate strength of materials. This is called *computer-aided engineering (CAE)*. For example, the designer can test how different dimensions, tolerances, and materials respond to different conditions such as rough handling or high temperatures. The designer can use the computer to compare alternative designs and determine the best design for a given set of conditions. The designer can also perform cost analysis on the design, evaluating the advantages of different types of materials.

Using computer technology in molecular modeling of proteins

Another advantage of CAD is that it can be linked to manufacturing. We already discussed the importance of linking product design to process selection. Through CAD this integration is made easy. *Computer-aided manufacturing (CAM)* is the process of controlling manufacturing through computers. Since the product designs are stored in the computer database, the equipment and tools needed can easily be simulated to match up with the processing needs. Efficiencies of various machine choices and different process alternatives can be computed.

CAD can dramatically increase the speed and flexibility of the design process. Designs can be made on the computer screen and printed out when desired. Electronic versions can be shared by many members of the organization for their input. Also, electronic versions can be archived and compared to future versions. The designer can catalogue features based on their characteristics—a very valuable feature. As future product designs are being considered, the designer can quickly retrieve certain features from past designs and test them for inclusion in the design being currently developed. Also, by using *collaborative product commerce (CPC) software*, sharing designs with suppliers is possible.

▶ **Computer-integrated manufacturing (CIM)**
A term used to describe the integration of product design, process planning, and manufacturing using an integrated computer system.

Computer-Integrated Manufacturing

Computer-integrated manufacturing (CIM) is a term used to describe the integration of product design, process planning, and manufacturing using an integrated computer system. Computer-integrated manufacturing systems vary greatly in their complexity. Simple systems might integrate computer-aided design (CAD) with some numerically controlled machines (NC machines). A complex system, on the other hand, might integrate purchasing, scheduling, inventory control, and distribution, in addition to the other areas of product design.

The key element of CIM is the integration of different parts of the operation process to achieve greater responsiveness and flexibility. The purpose of CIM is to improve how quickly the company can respond to customer needs of product design and availability, as well as quality and productivity, and to improve overall efficiency.

DESIGNING SERVICES

Most of the issues discussed in this chapter are as applicable to manufacturing as they are to service organizations. However, there are issues unique to services that pose special challenges for service design.

Most of us think we know what is needed to run a good service organization. After all, we encounter services almost every day, at banks, fast-food restaurants, doctor's offices, barber shops, grocery stores, and even the university. We have all experienced poor service quality and would gladly offer advice as to how we think it could be run better. However, there are some very important features of services you may have not thought about. Let's see what they are.

How Are Services Different from Manufacturing?

In Chapter 1 we learned about two basic features that make service organizations different from manufacturing. These are the intangibility of the product produced and the high degree of customer contact. Next we briefly review these and see how they impact service design.

Intangible Product Service organizations produce an intangible product, which cannot be touched or seen. It cannot be stored in inventory for later use or traded in for another model. The service produced is *experienced* by the customer. The design of the service needs to specify exactly what the customer is supposed to experience. For example, it may be relaxation, comfort, and pampering such as offered by Canyon Ranch Spa. It may be efficiency and speed, such as offered by FedEx. Defining the customer experience is part of the service design. It requires identifying precisely what the customer is going to feel and think, and consequently how he or she is going to behave. This is not always as easy as it might seem.

The experience of the customer is directly related to customer expectations. For services to be successful the customer experience needs to meet or even exceed these expectations. However, customer expectations can greatly vary depending on the type of customer and customer demographic. This includes customer age, gender, background, and knowledge. The expectation is made through product marketing to a particular market segment. It is highly important in designing the service to identify the target market the service is geared to and create the correct expectation.

Marketing

High Degree of Customer Contact Service organizations typically have a high degree of customer contact. The customer is often present while the service is being delivered, such as at a theater, restaurant, or bank. Also, the contact between the customer and service provider is often the service itself, such as what you experience at a doctor's office. For a service to be successful this contact needs to be a positive experience for the customer, and this depends greatly on the service provider.

Unfortunately, since services often have multiple service providers, there can be great variation in the type of service delivered. We have all had experiences where the service of one organization varied greatly depending on the skills of the service provider. This could be a hairdresser at a hair salon, a food server at a restaurant, or a teller at a bank. We have all heard people say something similar to "I often have dinner at Aussie Steak Grill and I insist that Jenny be my server." Similarly, someone might say "I go to Olentangy Family Physicians, but I won't see Dr. Jekyl because he is rude and unfriendly." For a service to be successful, the service experience must be consistent at all times. This requires close quality management to ensure high consistency and reliability. Many of the procedures we use in manufacturing to ensure high quality, such as standardization and simplification, are used in services as well. Fast-food restaurants such as McDonald's and Wendy's are known for their consistency. The same is true of hotel chains such as Holiday Inn and Embassy Suites.

To ensure that the service contact is a positive experience for the customer, employees of the service need to have training that encompasses a great array of skills that include courtesy, friendliness, and overall disposition. The service company also needs to structure the proper incentive system to motivate employees. For example, studies have shown that employee performance is motivated more by monetary incentives rather than by their belief in the idea of the service.

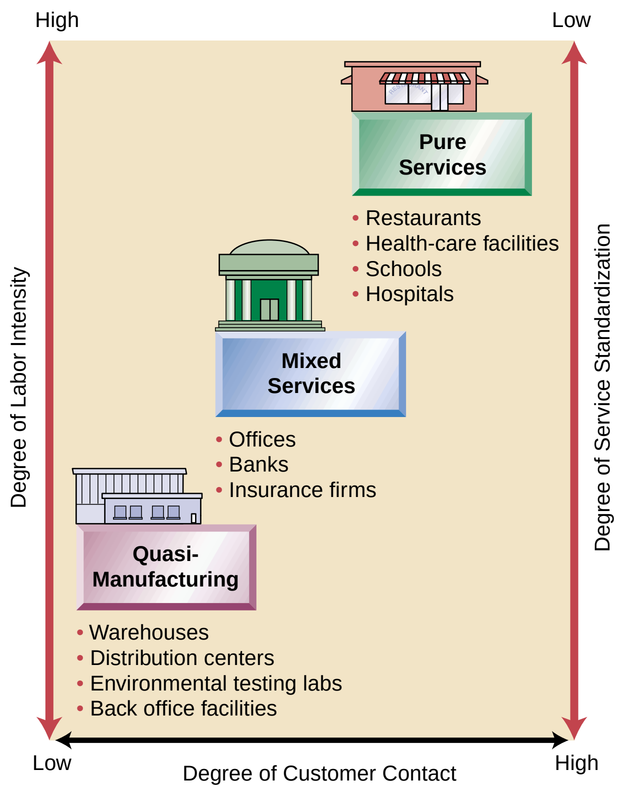
How Are Services Classified?

We can classify service organizations based on similar characteristics in order to understand them better. A common way to classify services is based on the degree of customer contact. This is illustrated in Figure 3-12.

Services with low customer contact are called "quasi-manufacturing." These firms have a high degree of service standardization, have higher sales volumes, and are typically

FIGURE 3-12

Classification of service operations



less labor intensive. These firms have almost no face-to-face contact with customers and are in many ways similar to manufacturing operations. Examples include warehouses, distribution centers, environmental testing laboratories, and back-office operations.

Services with high customer contact are called "pure services." These firms have high face-to-face contact and are highly labor intensive. There is low product standardization as each customer has unique requirements, and sales volumes tend to be low. Pure service firms have an environment of lowest system efficiency compared to other service firms. The reason is that the service is typically customized. As each customer has unique requirements, there is less predictability in managing the operating environment. Examples include hospitals, restaurants, barber shops, and beauty salons.

Services that combine elements of both of these extremes are called "mixed services." Some parts of their operation have face-to-face customer contact, though others do not. They include offices, banks, and insurance firms.

It is important to understand that companies with different levels of customer contact need to be managed differently. These differences also apply to high-contact and low-contact areas of firms. For example, companies should specifically hire people-oriented workers for high-contact areas, whereas technical skills are more important in low-contact areas. Also, noncontact activities should be partitioned from the customer to avoid disruptions in the flow of work. Noncontact areas can be managed borrowing tools from manufacturing, whereas high-contact areas need to focus on accommodating the customer.

The Service Package

The really successful service organizations do not happen spontaneously. They are carefully thought out and planned, down to every employee action. To design a successful service we must first start with a service concept or idea, which needs to be very comprehensive. We have learned that when purchasing a service, customers actually buy a **service package** or service bundle. The service package is a grouping of features that are purchased together as part of the service. There are three elements of the service package: (1) the physical goods, (2) the sensual benefits, and (3) the psychological benefits. The physical goods of the service are the tangible aspects of the service that we receive, or are in contact with, during service delivery. In a fine-dining restaurant the physical goods are the food consumed, as well as facilities such as comfortable tables and chairs, table cloths, and fine china. The sensual benefits are the sights, smell, and sounds of the experience—all the items we experience through our senses. Finally, the psychological benefits include the status, comfort, and well-being of the experience.

▶ **Service package**
A grouping of physical, sensual, and psychological benefits that are purchased together as part of the service.

It is highly important that the design of the service specifically identify every aspect of the service package. When designing the service we should not focus only on the tangible aspects; it is often the sensual and psychological benefits that are the deciding factors in the success of the service. The service package needs to be designed to precisely meet the expectations of the target customer group.

OM

Marketing

Once the service package is identified it can then be translated into a design using a process that is not too different from the one used in manufacturing. Details of the service, such as quality standards and employee training, can later be defined in keeping with the service concept. The service providers—the individuals who come in direct contact with the customers—must be trained and motivated to precisely understand and satisfy customer expectations.

Imagine going to a fast-food restaurant and having the server take his time asking you how you want your hamburger cooked and precisely what condiments you would like to accompany it, then waiting a long time to receive your food. Similarly, imagine going to an expensive hair salon and having the staff rush you through the process. In both cases, you as the customer would not be satisfied because the service delivery did not meet your expectations. Next time you might choose to go somewhere else. These examples illustrate what happens when there is a mismatch between the service concept and the service delivery.

Differing Service Designs

There is no one model of successful service design. The design selected should support the company's service concept and provide the features of the service package that the target customers want. Different service designs have proved successful in different environments. In this section we look at three very different service designs that have worked well for the companies that adopted them.

Substitute Technology for People Substituting technology for people is an approach to service design that was advocated some years ago by Theodore Levitt.[1] Levitt argued that one way to reduce the uncertainty of service delivery is to use technology to develop a production-line approach to services. One of the most successful companies to use this approach is McDonald's. Technology has been substituted wherever possible to provide product consistency and take the guesswork away from employees. Some examples of the use of technology include the following:

- Buzzers and lights are used to signal cooking time for frying perfect french fries.
- The size of the french fryer is designed to produce the correct amount of fries.
- The french fry scoop is the perfect size to fill an order.
- "Raw materials" are received in usable form (e.g., hamburger patties are premade; pickles and tomatoes are presliced; french fries are precut).
- There are 49 steps for producing perfect french fries.
- Steps for producing the perfect hamburger are detailed and specific.
- Products have different colored wrappings for easy identification.

In addition to the use of technology in the production of the product, there is consistency in facilities and a painstaking focus on cleanliness. For example, the production process at McDonald's is not left to the discretion of the workers. Rather, their job is to follow the technology and preset processes.

Today, we are all accustomed to the product consistency, speed of delivery, and predictability that are a feature of most fast-food restaurants. However, this concept was very new in the early 1970s. It is this approach to services that has enabled McDonald's to establish its global reputation.

Substituting technology for people is an approach we have seen over the years in many service industries. For example, almost all gas stations have reduced the number of cashiers and attendants with the advent of credit card usage at self-serve pumps. Also, many hospitals are using technology to monitor patient heart rate and blood pressure without relying exclusively on nurses. As technologies develop in different service industries we will continue to see an ever increasing reliance on its use and an increase in the elimination of workers.

[1]Theodore Levitt, "Production Line Approach to Services," *Harvard Business Review* 50, no. 5 (September–October 1972), pp. 41–52.

Get the Customer Involved A different approach to service design was proposed by C. H. Lovelock and R. F. Young.[2] Their idea was to take advantage of the customer's presence during the delivery of the service and have him or her become an active participant. This is different from traditional service designs where the customer passively waits for service employees to deliver the service. Lovelock and Young proposed that since the customers are already there, "get them involved."

We have all seen a large increase in the self-serve areas of many service firms. Traditional salad bars have led to self-serve food buffets of every type. Many fast-food restaurants no longer fill customer drink orders, but have the customers serve themselves. Grocery stores allow customers to select and package baked goods on their own. Many hotels provide in-room coffee makers and prepackaged coffee, allowing customers to make coffee at their convenience.

This type of approach has a number of advantages. First, it takes a large burden away from the service provider. The delivery of the service is made faster and costs are reduced due to lowered staffing requirements. Second, this approach empowers customers and gives them a greater sense of control in terms of getting what they want. This approach provides a great deal of customer convenience and increases satisfaction. However, as different types of customers have different preferences, many facilities are finding that it is best to offer full-service and self-service options. For example, many breakfast bars still allow a request for eggs cooked and served to order, and most gas stations still offer some full-service pumps.

High Customer Attention Approach A third approach to service design is providing a high level of customer attention. This is in direct contrast to the first two approaches we discussed. The first approach discussed automates the service and makes it more like manufacturing. The second approach requires greater participation and responsibility from the customer. The third approach is different from the first two in that it does not standardize the service and does not get the customer involved. Rather, it is based on customizing the service needs unique to each customer and having the customer be the passive and pampered recipient of the service. This approach relies on developing a personal relationship with each customer and giving the customer precisely what he or she wants.

There are a number of examples of this type of approach. Nordstrom, Inc. department stores is recognized in the retail industry for its attention to customer service. Salespeople typically know their customers by name and keep a record of their preferences. Returns are handled without question and the customer is always right. Another example of this is a midwestern grocer called Dorothy Lane Market. Dorothy Lane prides itself on its ability to provide unique cuts of specialty meats precisely to customer order. As at Nordstrom, a list is kept of primary customers and their preferences. Customers are notified of special purchases, such as unique wines, specialty chocolates, and special cuts of meat.

Whereas the first two approaches to service design result in lowered service costs, this third approach is geared toward customers that are prepared to pay a higher amount for the services they receive. As you can see, different approaches are meant to serve different types of customers. The design chosen needs to support the specific service concept of the company.

[2]C. H. Lovelock and R. F. Young. "Look to Customers to Increase Productivity," *Harvard Business Review* 57, 2, pp. 168–178.

OM ACROSS THE ORGANIZATION

The strategic and financial impact of product design and process selection mandates that operations work closely with other organizational functions to make these decisions. Operations is an integral part of this decision because it understands issues of production, ease of fabrication, productivity, and quality. Now let's see how the other organizational functions are involved with product design and process selection.

Marketing is impacted by product design issues because they determine the types of products that will be produced and affect marketing's ability to sell them. Marketing's input is critical at this stage because marketing is the function that interfaces with customers and understands the types of product characteristics customers want. It is marketing that can provide operations with information on customer preferences, competition, and future trends.

Process selection decisions impact marketing as well. Process selection decisions typically require large capital outlays. Once in place, process decisions are typically difficult to change and are in place for a long time. Process decisions affect the types of future products that the company can produce. Because of this, marketing needs to be closely involved in ensuring that the process can meet market demands for many years to come.

Finance plays an integral role in product design and process selection issues because these decisions require large financial outlays. Finance needs to be a part of these decisions to evaluate the financial impact on the company. Process selection decisions should be viewed as any other financial investment, with risks and rewards. Finance must ensure that the trade-off between the risks and rewards is acceptable. Also, it is up to finance to provide the capital needed for this investment and to balance that against future capital requirements.

Information systems needs to be part of the process selection decision. Operations decisions, such as forecasting, purchasing, scheduling, and inventory control, differ based on the type of operation the company has. Information systems will be quite different for intermittent, versus continuous, operations. Therefore, the information system has to be developed to match the needs of the production process being planned.

Human resources provides important input to process selection decisions because it is the function directly responsible for hiring employees. If special labor skills are needed in the process of production, human resources needs to be able to provide information on the available labor pool. The two types of operations discussed, intermittent and continuous, typically require very different labor skills. Intermittent operations usually require higher-skilled labor than continuous operations. Human resources needs to understand the specific skills that are needed.

Purchasing works closely with suppliers to get the needed parts and raw materials at a favorable price. It is aware of product and material availability, scarcity, and price. Often certain materials or components can use less expensive substitutes if they are designed properly. For this reason it is important to have purchasing involved in product design issues from the very beginning.

Engineering needs to be an integral part of the product design and process selection decision because this is the function that understands product measurement, tolerances, strength of materials, and specific equipment needs. There can be many product design ideas, but it is up to engineering to evaluate their manufacturability.

As you can see, product design and process selection issues involve many functions and affect the entire organization. For this reason, product design and process selection decisions need to be made using a team effort, with all these functions working closely together to come up with a product plan that is best for the company.

INSIDE OM

Product design decisions are strategic in nature. The features and characteristics of a product need to support the overall strategic direction of the company. In turn, product design decisions directly dictate the type of process selected. They determine the types of facilities that will be needed to produce the product, types of machines, worker skills, degree of automation, and other decisions. Most companies continually design new products. The design of these new products has to take into account the type of processes the company has, otherwise facilities may not be available to produce the new product design. Therefore, product design and process selection decisions are directly tied to each other.

Product design and process selection decisions are further linked to all other areas of operations management. They are linked to decisions such as the level of capacity needed, degree of quality, layout and location of facilities, types of workers, and many others. As we go through this book we will see how product design and process selection specifically impact other operations decisions.

Chapter Highlights

1. Product design is the process of deciding on the unique characteristics and features of a company's product. Process selection, on the other hand, is the development of the process necessary to produce the product we design. Product design is a big strategic decision for a company, because the design of the product defines who the company's customers will be, as well as the company's image, its competition, and its overall future growth.
2. Steps in product design include idea generation, product screening, preliminary design and testing, and final design. A useful tool at the product-screening stage is break-even analysis.
3. Break-even analysis is a technique used to compute the amount of goods we would have to sell just to cover our costs.
4. Production processes can be divided into two broad categories: intermittent and repetitive operations. Intermittent operations are used when products with different characteristics are being produced in smaller volumes. These types of operations tend to organize their resources by grouping similar processes together and having the product routed through the facility based on their needs. Repetitive operations are used when one or a few similar products are produced in high volume. These operations arrange resources in sequence to allow for an efficient buildup of the product. Both intermittent and repetitive operations have their advantages and disadvantages. Intermittent operations provide great flexibility but have high material handling costs and challenge scheduling resources. Repetitive operations are highly efficient but inflexible.
5. Product design and process selection decisions are linked. The type of operation a company has in place is defined by the product the company produces. The type of operation then affects other organizational decisions, such as competitive priorities, facility layout, and degree of vertical integration.
6. A process flowchart is used for viewing the flow of the processes involved in producing the product. It is a very useful tool for seeing the totality of the operation and for identifying potential problem areas. There is no exact format for designing the chart. The flowchart can be very simple or very detailed.
7. Different types of technologies can significantly enhance product and process design. These include automation, automated material handling devices, computer-aided design (CAD), numerically controlled (NC) equipment, flexible manufacturing systems (FMS), and computer-integrated manufacturing (CIM).
8. Designing services has more complexities than manufacturing, because services produce an intangible product and typically have a high degree of customer contact. Different service designs include substituting technology for people, getting the customer involved, and the high customer attention approach.

Key Terms

manufacturability 55
product design 55
service design 56
benchmarking 57
reverse engineering 57
early supplier involvement (ESI) 58
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design for manufacture (DFM) 61
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Formula Review

1. Total cost = fixed cost + variable cost
2. Revenue = $(SP)\,Q$
3. $F + (VC)\,Q = (SP)\,Q$
4. $Q_{BE} = \dfrac{F}{SP - VC}$
5. Process Velocity = $\dfrac{\text{Throughput time}}{\text{Value-added time}}$
6. Utilization = $\dfrac{\text{Time a resource used}}{\text{Time a resource available}}$
7. Efficiency = $\dfrac{\text{Actual output}}{\text{Standard output}}$

Solved Problems

• Problem 1

Joe Jenkins, owner of Jenkins Manufacturing, is considering whether to produce a new product. He has considered the operations requirements for the product as well as the market potential. Joe estimates the fixed costs per year to be $40,000 and variable costs for each unit produced to be $50.

(a) If Joe sells the product at a price of $70, how many units of product does he have to sell in order to break even? Use both the algebraic and graphical approach.
(b) If Joe sells 3000 units at the product price of $70, what will be his contribution to profit?

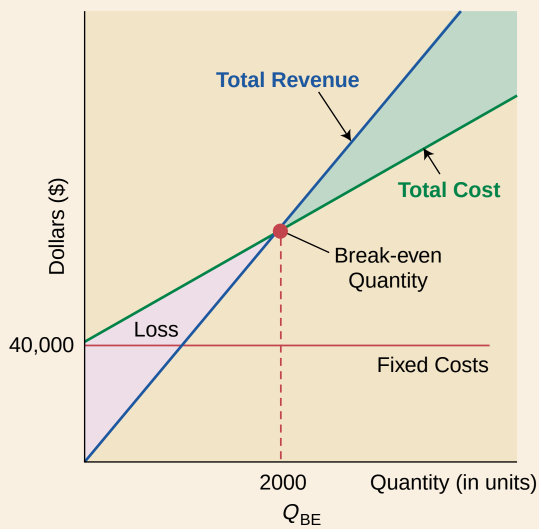
• *Solution*

(a) To compute the break-even quantity we follow the equation and substitute the appropriate numerical values:

$$Q = \frac{F}{SP - VC} = \frac{\$40{,}000}{\$70 - \$50} = 2000 \text{ units}$$

The break-even quantity is 2000 units. This is how much Joe would have to sell in order to cover costs.

Graphically we can obtain the same result. This is shown in the figure.



(b) To compute the contribution to profit with sales of 3000 units:

$$\text{Profit} = \text{total revenue} - \text{total cost}$$
$$= (SP)Q - [F + (VC)\,Q]$$

Now we can substitute numerical values:

$$\text{Profit} = \$70\,(3000) - [\$40{,}000 + \$50\,(3000)]$$
$$= \$20{,}000$$

The contribution to profit is $20,000 if Joe can sell 3000 units of product.

• Problem 2

Joe Jenkins, owner of Jenkins Manufacturing, has decided to produce the new product discussed in Problem 1. The product can be produced with the current equipment in place. However, Joe is considering the purchase of new equipment that would produce the product more efficiently. Joe's fixed cost would be raised to $60,000 per year, but the variable cost would be reduced to $25 per unit. Joe still plans to sell the product at $70 per unit.

Should Joe produce the new product with the new or current equipment described in Problem 1? Specify the volume of demand for which you would choose each process.

• *Solution*

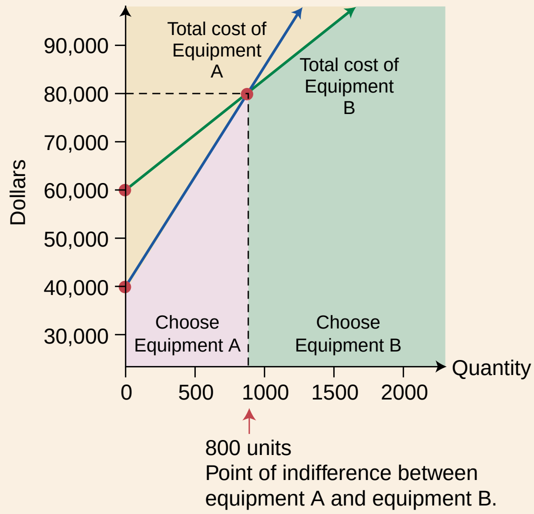
As we mentioned in the chapter, break-even analysis can also be used to evaluate different processes. Here we show how this can be done. To decide which process to use we first need to compute the point of indifference between the two processes. The point of indifference is where the cost of the two processes is equal. If we label the current equipment A and the new equipment B the point of indifference occurs when the costs for each process are equal. This is shown as:

$$\text{Total Cost}_{\text{Equipment A}} = \text{Total Cost}_{\text{Equipment B}}$$

Again, total cost is the sum of fixed and variable costs:

$$\$40{,}000 + \$50\,Q = \$60{,}000 + \$25\,Q$$
$$\$25\,Q = 20{,}000$$
$$Q = 800 \text{ units produced}$$

$Q = 800$ units is the point of indifference, that is, the point where the cost of either equipment is the same. If demand is expected to be less than 800 units, equipment A should be used given that it has a lower fixed cost. If demand is expected to be greater than 800 units, equipment B should be used given that it has a lower variable cost. This is shown graphically.



• Problem 3

Zelle's Dry Cleaners has collected the following data for its processing of dress shirts:

- It takes an average of $3\frac{1}{2}$ hours to dry clean and press a dress shirt, with value added time estimated at 110 minutes per shirt.
- Workers are paid for a 7-hour workday and work $5\frac{1}{2}$ hours per day on average, accounting for breaks and lunch; labor utilization is 75 percent in the industry.
- The dry cleaner completes 25 shirts per day, with an industry standard of 28 shirts per day for a comparable facility.

Determine process velocity, labor utilization, and efficiency for the company.

• *Solution*

$$\text{Process Velocity} = \frac{\text{Throughput time}}{\text{Value-added time}}$$
$$= \frac{210 \text{ minutes/shirt}}{110 \text{ minutes/shirt}} = 1.90$$

$$\text{Labor utilization} = \frac{5\frac{1}{2} \text{ hours/day}}{7 \text{ hours/day}} = .786 \text{ or } 78.6\%$$

$$\text{Efficiency} = \frac{25 \text{ shirts/day}}{28 \text{ shifts/day}} = .89 \text{ or } 89\%$$

Process velocity shows room for process improvement, as throughput time is almost twice that of value-added time. Labor utilization is just above the industry standard, though overall efficiency is below.

Discussion Questions

1. Define product design and explain its relationship to business strategy.

2. What are the differences between product and service design?

3. Explain the meanings of *benchmarking* and *reverse engineering.*

4. Explain the meaning of *design for manufacture (DFM)* and give some examples.

5. Describe the stages of the product life cycle. What are demand characteristics at each stage?

6. Explain the term *concurrent engineering.* Why is it important?

7. Identify the two general types of operations. What are their characteristics?

8. What is meant by the term *vertical integration?* What types of companies are more likely to become vertically integrated?

9. What is a process flow chart and what is it used for?

10. Give some examples of automation. How has automation changed the production process?

11. Discuss the benefits of computer-aided design (CAD).

12. What is meant by the term *service package?*

13. Name three service companies and describe their service package.

14. Give examples of services that have a good match between customer expectations and service delivery. Give examples of services that do not have a good match.

Problems

1. See-Clear Optics is considering producing a new line of eyewear. After considering the costs of raw materials and the cost of some new equipment, the company estimates fixed costs to be $40,000 with a variable cost of $45 per unit produced.

(a) If the selling price of each new product is set at $100, how many units need to be produced and sold to break even? Use both the graphical and algebraic approaches.

(b) If the selling price of the product is set at $80 per unit, See-Clear expects to sell 2000 units. What would be the total contribution to profit from this product at this price?

(c) See-Clear estimates that if it offers the price at the original target of $100 per unit, the company will sell about 1500 units. Will the pricing strategy of $100 per unit or $80 per unit yield a higher contribution to profit?

2. Med-First is a medical facility that offers outpatient medical services. The facility is considering offering an additional service, mammography screening tests on site. The facility estimates the annual fixed cost of the equipment and skills necessary for the service to be $120,000. Variable costs for each patient processed are estimated at $35 per patient. If the clinic plans to charge $55 for each screening test, how many patients must it process a year in order to break even?

3. Tasty Ice Cream is a year-round take-out ice cream restaurant that is considering offering an additional product, hot chocolate. Considering the additional machine it would need plus cups and ingredients, it estimates fixed cost per year to be $200 per year and the variable cost at $.20. If it charges $1.00 for each hot chocolate, how many hot chocolates does it need to sell in order to break even?

4. Slick Pads is a company that manufactures laptop notebook computers. The company is considering adding its own line of computer printers as well. It has considered the implications from marketing and financial perspectives and estimates fixed costs to be $500,000. Variable costs are estimated at $200 per unit produced and sold.

(a) If the company plans to offer the new printers at a price of $350, how many printers does it have to sell to break even?

(b) Describe the types of operations considerations that the company needs to consider before making the final decision.

5. Perfect Furniture is a manufacturer of kitchen tables and chairs. The company is currently deciding between two new methods for making kitchen tables. The first process is estimated to have a fixed cost of $80,000 and a variable cost of $75 per unit. The second process is estimated to have a fixed cost of $100,000 and a variable cost of $60 per unit.

(a) Graphically plot the total costs for both methods. Identify which ranges of product volume are best for each method.

(b) If the company produces 500 tables a year, which method provides a lower total cost?

6. Harrison Hotels is considering adding a spa to its current facility in order to improve its list of amenities. Operating the spa would require a fixed cost of $25,000 a year. Variable cost is estimated at $35 per customer. The hotel wants to break even if 12,000 customers use the spa facility. What should be the price of the spa services?

7. Kaizer Plastics produces a variety of plastic items for packaging and distribution. One item, container #145, has had a low contribution to profits. Last year, 20,000 units of container #145 were produced and sold. The selling price of the container was $20 per unit, with a variable cost of $18 per unit and a fixed cost of $70,000 per year.

(a) What is the break-even quantity for this product? Use both graphic and algebraic methods to get your answer.

(b) The company is currently considering ways to improve profitability by either stimulating sales volumes or reducing variable costs. Management believes that sales can be increased by 35 percent of their current levels or that variable cost can be reduced to 90 percent of their current level. Assuming all other costs equal, identify which alternative would lead to a higher profit contribution.

8. George Fine, owner of Fine Manufacturing, is considering the introduction of a new product line. George has considered factors such as costs of raw materials, new equipment, and requirements of a new production process. He estimates that the variable costs of each unit produced would be $8 and fixed cost would be $70,000.

(a) If the selling price is set at $20 each, how many units have to be produced and sold for Fine Manufacturing to break even? Use both graphical and algebraic approaches.

(b) If the selling price of the product is set at $18 per unit, Fine Manufacturing expects to sell 15,000 units. What would be the total contribution to profit from this product at this price?

(c) Fine Manufacturing estimates that if it offers the price at the original target of $20 per unit, the company will sell about 12,000 units. Which pricing strategy—$18 per unit or $20 per unit—will yield a higher contribution to profit?

(d) Identify additional factors that George Fine should consider in deciding whether to produce and sell the new product.

9. Handy-Maid Cleaning Service is considering offering an additional line of services to include professional office cleaning. Annual fixed costs for this additional service are estimated to be $9000. Variable costs are estimated at $50 per unit of service. If the price of the new service is set at $80 per unit of service, how many units of service are needed for Handy-Maid to break even?

10. Easy-Tech Software Corporation is evaluating the production of a new software product to compete with the popular word processing software currently available. Annual fixed costs of producing the item are estimated at $150,000 while the variable cost is $10 per unit. The current selling price of the item is $35 per unit, and the annual sales volume is estimated at 50,000 units.

(a) Easy-Tech is considering adding new equipment that would improve software quality. The negative aspect of this new equipment would be an increase in both fixed and variable costs. Annual fixed cost would increase by $50,000 and variable cost by $3. However, marketing expects the better quality product to increase demand to 70,000 units. Should Easy-Tech purchase this new equipment and keep the price of their product the same? Explain your reasoning.

(b) Another option being considered by Easy-Tech is the increase in the selling price to $40 per unit to offset the additional equipment costs. However, this increase would result in a decrease in demand to 40,000 units. Should Easy-Tech increase its selling price if it purchases the new equipment? Explain your reasoning.

11. Zodiac Furniture is considering the production on a new line of metal office chairs. The chairs can be produced in-house using either process A or process B. The chairs can also be purchased from an outside supplier. Specify the levels of demand for each processing alternative given the costs below.

	Fixed Cost	Variable Cost
Process A	$20,000	$30
Process B	$30,000	$15
Outside Supplier	$0	$50

12. Mop and Broom Manufacturing is evaluating whether to produce a new type of mop. The company is considering the operations requirements for the mop, as well as the market potential. Estimates of fixed costs per year are $40,000 and variable cost for each mop produced is $20.

(a) If the company sells the product at a price of $25, how many units of product have to be sold in order to break even? Use both the algebraic and graphical approach.

(b) If the company sells 10,000 mops at the product price of $25, what will be the contribution to profit?

13. Mop and Broom Manufacturing, from Problem 12, has decided to produce a new type of mop. The mop can be made with the current equipment in place. However, the company is considering the purchase of new equipment that would produce the mop more efficiently. The fixed cost would be raised to $50,000 per year, but the variable cost would be reduced to $15 per unit. The company still plans to sell the mops at $25 per unit. Should Mop and Broom produce the mop with the new or current equipment described in Problem 12? Specify the volume of demand for which you would choose each process.

14. Jacob's Baby Food Company must go through the following steps to make mashed carrots: 1) unload carrots from truck; 2) inspect carrots; 3) weigh carrots; 4) move to storage; 5) wait until needed; 6) move to washer; 7) boil in water; 8) mash carrots; 9) inspect. Draw a process flow diagram for these steps.

15. Draw a process flow diagram of your last doctor's office visit. Identify bottlenecks. Did any activities occur in parallel?

16. Oakwood Outpatient Clinic is analyzing its operation in an effort to improve performance. The clinic estimates that a patient spends on average $3\frac{1}{2}$ hours at the facility. The amount of time the patient is in contact with staff (i.e., physicians, nurses, office staff, lab technicians) is estimated at 40 minutes. On average the facility sees 42 patients per day. Their standard has been 40 patients per day. Determine process velocity and efficiency for the clinic.

17. Oakwood Outpatient Clinic rents a magnetic resonance imaging (MRI) machine for 30 hours a month for use on its patients. Last month the machine was used 28 hours out of the month. What was machine utilization?

18. Mop and Broom Manufacturing estimates that it takes $4\frac{1}{2}$ hours for each broom to be produced, from raw materials to final product. An evaluation of the process reveals that the amount of time spent working on the product is 3 hours. Determine process velocity.

CASE: Biddy's Bakery (BB)

Biddy's Bakery was founded by Elizabeth McDoogle in 1984. Nicknamed "Biddy," Elizabeth started the home-style bakery in Cincinnati, Ohio as an alternative to commercially available baked goods. The mission of Biddy's Bakery was to produce a variety of baked goods with old-fashioned style and taste. The goods produced included a variety of pies and cakes, and were sold to the general public and local restaurants.

The operation was initially started as a hobby by Elizabeth and a group of her friends. Many of the recipes they used had been passed down for generations in their families. The small production and sales facility was housed in a mixed commercial and residential area on the first floor of "Biddy's" home. Elizabeth ("Biddy") and three of her friends worked in the facility from 6 AM to 2 PM making and selling the pies. The operation was arranged as a job-shop with work stations set up to perform a variety of tasks as needed. Most of the customers placed advanced orders and Biddy's Bakery took pride in accepting special requests. The Bakery's specialty was the McDoogle Pie, a rich chocolate confection in a cookie crust.

Meeting Capacity Needs

Initially sales were slow and there were periods when the business operated at a loss. However, after a few years Biddy's Bakery began to attract a loyal customer following. Sales continued to grow slowly but steadily. In 1994, a first floor storage area was expanded to accommodate the growing business. However, Biddy's Baker quickly outgrew its current capacity. In May of 2000 Elizabeth decided to purchase the adjacent building and move the entire operation into the much larger facility. The new facility had considerably more capacity than needed, but the expectation was that business would continue to grow. Unfortunately, by the end of 2000 Elizabeth found that her sales expectations had not been met and she was paying for a facility with unused space.

Getting Management Advice

Elizabeth knew that her operations methods, though traditional, were sound. A few years ago she had called upon a team of business students from a local university for advice, as part of their course project. They had offered some suggestions, but were most impressed with the efficient manner with which she ran her operation. Recalling this experience she decided to contact the same university for another team of business students to help her with her predicament.

After considerable analysis the team of business students came up with their plan: Biddy's Bakery should primarily focus on production of the McDoogle Pie in large volumes, with major sales to go to a local grocery store. The team of business students discussed this option with a local grocery store chain that was pleased with the prospect. Under the agreement Biddy's Bakery would focus its production on the McDoogle Pie, which would be delivered in set quantities to one store location twice a week. The volume of pies required would use up all of the current excess capacity and take away most of capacity from production of other pies.

Elizabeth was confused. The alternative being offered would solve her capacity problems, but it seemed that the business would be completely different, though she did not understand how or why. For the first time in managing her business she did not know what to do.

Case Questions

1. Explain the challenge faced by Elizabeth in meeting her capacity needs. What should she have considered before moving into the larger facility?
2. What is wrong with the proposal made by the team of business students? Why?
3. What type of operation does Biddy's Bakery currently have in place? What type of operation is needed to meet the proposal made by the team of business students? Explain the differences between these two operations.
4. Elizabeth senses that the business would be different if she accepts the proposal, but does not know how and why. Explain how it would be different.
5. What would you advise Elizabeth?

CASE: Creature Care Animal Clinic (B)

Company Background

Creature Care Animal Clinic is a suburban veterinary clinic specializing in the medical care of dogs and cats. Dr. Julia Barr opened the clinic three years ago, hiring another full-time veterinarian, a staff of three nurses, an office manager, and an office assistant. The clinic operates Monday through Friday during regular business hours, with half days on Saturdays and extended hours on Wednesday evenings. Both doctors work during the week and take turns covering Wednesday evenings and Saturdays.

Dr. Barr opened the Clinic with the intent to provide outpatient animal care. Overnight services are provided for surgical patients only. No other specialized services are offered. The facility of the clinic was designed for this type of service, with a spacious waiting and reception area. The examining and surgical rooms are in the rear, just large enough to accommodate their initial purpose.

As time has passed, however, the number of patients requesting specialized services has increased. Initially the requests were few, so Dr. Barr tried to accommodate them. As one of the nurses was also trained in grooming services, she began to alternate between her regular duties and pet grooming. Pet grooming was performed in the rear of the reception area, as it was spacious and there was no other room for this job. At first this was not a problem. However, as the number of pets being groomed increased, the flow of work began being interrupted. Customers waiting with their pets would comment to the groomer in the rear, who had difficulty focusing on the work. The receptionist was also distracted, as were the animals.

The number of customers requesting grooming services was growing rapidly. Customers wanted to drop off their pets for a "package" of examining, grooming, and even minor surgical procedures requiring overnight stays. The space for grooming and overnight services was rapidly taking over room for other tasks. Also, most of the staff was not trained in providing the type of service customers were now requiring.

The Dilemma

Dr. Barr sat at her desk wondering how to handle the operations dilemma she was faced with. She started her business as a medical clinic, but found that she was no longer sure what business she was in. She didn't understand why it was so complicated given that she was only providing a service. She was not sure what to do.

Case Questions

1. Identify the operations management problems that Dr. Barr is having at the clinic.
2. How would you define the "service bundle" currently being offered? How is this different from the initial purpose of the clinic?
3. Identify the high-contact and low-contact segments of the operation. How should each be managed?
4. What should Dr. Barr have done differently to avoid the problems she is currently experiencing? What should Dr. Barr do now?

Interactive Learning

Enhance and test your knowledge of Chapter 3. Use the CD and visit our dynamic Web site, www.wiley.com/college/reid, for cases, Web links, and additional information.

1. **Simulation** Understanding Intermittent and Continuous Operations
2. **Company Tour** *Ercol Furniture Ltd.*
3. **Additional Web Resources** Institute for Supply Management, www.ism.ws
4. **Internet Challenge** *Country Comfort Furniture*

You have just taken a position with Country Comfort Furniture, a furniture manufacturer known for its custom-designed country furniture. The primary focus of the company has been on kitchen and dining room furniture in the upper portion of the high-price range. Due to competitive pressures and changes in the market, Country Comfort is now considering production of prefabricated kitchen and dining room furniture in the medium-price range.

You have been asked to help Country Comfort evaluate the new product design it is considering. Perform an Internet search to identify at least two major competitors that Country Comfort would have if it chooses to pursue the new product line. Next, identify key product design features of each competitor's products, their target market, and price range. Based on your search, what are your recommendations to Country Comfort on product design and current competition?

Virtual Company: Valley Memorial Hospital

Assignment: *Service Package and Processes at Valley Memorial Hospital* With just a couple of weeks left before you start working at Kaizen for its client Valley Memorial Hospital, it is essential for you to get some specific insights into the company's operations. This assignment will enable you to enhance your knowledge of the material in Chapter 3 while continuing to prepare you for a successful internship. Add a character from VMH or Bob Reilly and say that this person suggested you learn more about the service package at VMH.

www.wiley.com/college/reid

To complete this assignment, go to www.wiley.com/college/reid to get more details to answer the following questions.

1. What is the Service Package offered by VMH to its customers?
2. Is the Service Package offered by VMH consistent with the company's mission statement and the competitive priorities?
3. Visualize the series of steps customers go through between entering the facility and leaving it after getting served. Draw a simple process flow diagram.
4. In the classification of service operations, where would you place VMH?
5. In its service design, to what extent does VMH use technology? Can you think of any areas where VMH could substitute technology for people?
6. Does VMH use outsourcing in its operations? Are there any operations that you think could be outsourced? If so, what are the benefits and limitations of outsourcing?

To access the Web site:

- Go to www.wiley.com/college/reid
- Click Student Companion Site
- Click Virtual Company
- Click Kaizen Consulting, Inc.
- Click Consulting Assignments
- Click Service Package and Processes at Valley Memorial Hospital

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