PART THREE

System Design

Satisfying the customer begins with product and service design. Moreover, decisions made in this area impact on operations and on the organization's overall success.

Similarly, process selection and capacity planning impact on the ability of the production system to perform and to satisfy customers, in addition to cost of production. Flexibility, production time, and cost are key considerations in process design.

Process selection and layout are closely related. Layout decisions involve the arrangement of the workplace, which affects the flow of work through the system. Layout impacts productivity, cost, and flexibility, in addition to being an important part of most services.

Work design focuses on the human element in production systems. Increasingly, managers are realizing that workers are a valuable asset and can contribute greatly to the organization's success. Strategic planning is beginning to incorporate employee participation to help improve production systems.

Location decision influences operating costs and the ability to respond to customer demand. Location decision also impacts transportation costs, labour availability, material costs, and access to markets.

Design decisions have strategic significance for business organizations. Many of these decisions are made jointly with the CEO and top managers of other functional areas of the organization.

System design encompasses decisions involving:


Canada

CHAPTER FOUR

Product and Service Design

CHAPTER OUTLINE

LEARNING OBJECTIVES

After completing this chapter, you should be able to:

1. List the steps involved in new product/service designs.
2. Name some sources of ideas for new or revised designs.
3. Discuss key issues in product and service design.
4. Explain the importance of manufacturability.
5. Name the advantages and disadvantages of standardization in product and service design.
6. Discuss mass customization.
7. Discuss special considerations for service design.
8. Describe quality function deployment (QFD).

As more and more women join the workforce and more families rely on two incomes, the spending and eating habits of North Americans are changing. Quick meals have replaced leisurely meals. There is an increased awareness of healthy foods. Fast-food chains, food companies, and supermarkets are scrambling to meet the challenge.

www.mccain.ca

French fries giant McCain Foods of Florenceville, N.B., has become the largest producer of French fries in the world, with a revenue of over $5 billion and 55 processing plants in 11 countries. McCain has achieved this growth by introducing products such as Super Quick Fries, Tators, frozen vegetables, frozen juices, pizza, desserts, and dinners. Supermarkets are offering a wide array of already prepared foods as well as recipes for quick meals in their stores and on their Web pages.

For these and other companies, from high-tech to no-tech, product and service design plays an important role in their profitability and their very survival.

The essence of any organization is the products or services it offers. There is an obvious link between the *design* of those products or services and the *success* of the organization. In addition, the quality of the product/service is mainly, perhaps as much as 80 percent, determined during the design stage. Hence, organizations have a vital stake in achieving good product and service design.

In this chapter you will find many insights into product and service design. Among the topics covered are the steps involved in product and service design or redesign, sources of ideas for design or redesign, legal, ethical and other issues, design elements for both manufacturing and service, and quality function deployment (QFD).

Product and service design—or redesign—should be closely tied to an organization's strategy. It is a major factor in cost, quality, time to market, customer satisfaction, and competitive advantage.

Introduction

In this section you will learn what product and service design involves, the reasons for design (or redesign), and the objectives of design.

What Does Product and Service Design Involve?

The usual process for product and service design is:

1. Market and competitor analysis; determine what customers want ("voice of the customer") and establish product/service goals (performance, cost, quality, etc.).
2. Quality function deployment (QFD); translate the "voice of customer" into technical (physical) product/service specifications, such as product size/nature of service, features, and so on. As part of this, a concept is developed and/or chosen. A *concept* is an idea and a general way to materialize it. This may involve some (engineering) tests. Revise the target market/product goals if necessary.
3. Build product prototypes; test; and revise the design if necessary.
4. Design production/service delivery process, tooling/equipment, and quality control; revise product design if necessary.
5. Conduct pilot production/service delivery runs; revise the process and/or product/service design if necessary.
6. Produce and distribute/render service.

A product or service design is best conducted as a project by a team that is responsible for the product from the start (idea) to the end (distribution). The team usually consists of a product manager, product designers (usually engineers), and manufacturing/operations representatives. The team is expanded during each phase of design with marketing representatives (at the start and at the end), accountants (to establish cost goals), process engineers (for process design, tooling/equipment), quality control, and purchasing and supplier representatives (component design and manufacturing).

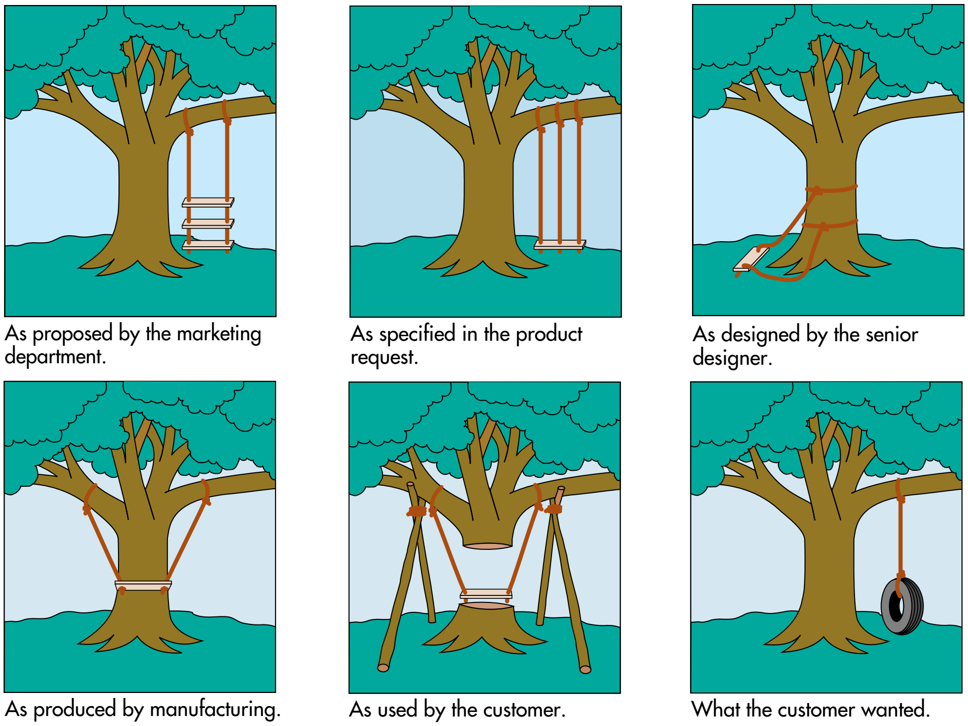


FIGURE 4–1

Differing views of design created through lack of information

Source: *Educational Center Newsletter*, Minneapolis, Minnesota.

At the General Motors Tech Center designers carve a clay model of their new model styling.

www.gm.com

This team-based approach of simultaneously designing the product and process is called *concurrent engineering*. In contrast, in the past, because of time pressure and the "silo" mentality, each functional area performed their part of design in isolation and "threw" their work "over the wall" to the next department in design. The order was (1) marketing, (2) product design/engineering, (3) manufacturing, and (4) sales. This frequently resulted in late launch dates and costly design revisions. Figure 4–1 offers a humorous look at the old "throw over the wall" practice. Concurrent engineering is further discussed later in the chapter.

Reasons for Product or Service Design or Redesign

Organizations become involved in product or service design for a variety of reasons. An obvious one is to be competitive by offering new products or services. Another one is to make the business grow and increase profits. Furthermore, the best organizations try to develop new products or services as an alternative to downsizing. When productivity gains result in the need for fewer workers, developing new products or services can mean adding jobs and retaining people instead of letting them go.

Sometimes product or service design is actually *redesign.* This, too, occurs for a number of reasons such as customer complaints, accidents or injuries, excessive warranty claims, or low demand. The desire to achieve cost reductions in labour or materials can also be a motivating factor.

Objectives of Product and Service Design

The overall objective is to satisfy the customer while making a reasonable profit. These objectives typically include the product or service performance, cost, and quality.

It is *crucial* for designers to take into account the capabilities of the organization to produce or deliver a given product or service. This is sometimes referred to as **design for operations**. When the operations involve manufacturing, the term often used is **manufacturability**: the ease with which design features can be achieved by manufacturing and assembly. Failure to take this into consideration can result in reduced productivity, reduced quality, and increased costs. For these reasons, it is wise for design to solicit input from manufacturing people throughout the design process. Likewise, in the design of services, it is important to involve service people in the design process to reduce the risk of achieving a design that looks good on paper, but doesn't work in the real world.

design for operations Taking into account the capabilities of the organization in designing goods and services.

manufacturability The ease of fabrication and/or assembly.

In some cases, there are regulatory requirements for safety and environment. Finally, a design project has its own targets for development time and costs.

Sources of Ideas for New or Redesigned Products and Services

Ideas for new and improved products or services can come from a wide range of sources, both from within the organization and from outside it.

Employees—including those who make products or deliver services to customers, salespeople, and purchasing agents, can be a rich source of ideas, if they are motivated to offer suggestions. In addition to these are two more primary sources of ideas: marketing and research. Along with assessing current needs of customers, marketing people typically are aware of problems with products or services. Similarly, product failures and warranty claims indicate where improvements are needed. Marketing people are often sources of ideas based on their studies of markets, buying patterns, and familiarity with demographics. Also, marketing can help craft a vision of what customers are likely to want in the future. Customers may submit suggestions for improvements or new products, or they may be queried through the use of surveys or focus groups. In certain instances market research may not be the best approach, as explained in the "Design for Response" reading later in the chapter.

One of the strongest motivators for new and improved products or services is competitors' products and services. Some companies purchase a competitor's product and then carefully dismantle and inspect it, searching for ways to improve their own product. This is called **reverse engineering**. The Ford Motor Company used this tactic in developing its highly successful Taurus model: It examined competitors' automobiles, searching for best-in-class components (e.g., best hood release, best dashboard display, best door handle). Sometimes reverse engineering can enable a company to "leapfrog" the competition by developing an even better product.

reverse engineering Dismantling and inspecting a competitor's product to discover product improvements.

Suppliers are still another source of ideas for the best way to design the components they make and the use of new technology.

The next section describes research and development, followed by a section on legal and ethical issues.

DaimlerChrysler's automated durability track simulates bad roads and is used to test the integrity of automobiles and trucks. The vehicles are "guided" by computer-controlled robots.

A milestone crash test performed at Ford Motor Corporation is used to plan for new side-impact head and chest air bags.

Research and Development

research and development (R&D) Organized efforts for product innovation.

Research and development (R&D) refers to organized efforts that are directed toward product or process innovation. Most of the advances in semiconductors, medicine, communications, and space technology can be attributed to R&D efforts at colleges and universities, research foundations, government agencies, and private enterprises.

The benefits of successful R&D can be tremendous. Some research leads to patents, with the potential of licensing and royalties. However, many discoveries are not patentable, or companies don't wish to divulge details of their ideas so they avoid the patent route. Even so, the first organization to bring a new product or service to the market generally stands to profit from it before the others can catch up. Early products may be priced higher because a temporary monopoly exists until competitors bring their versions out.

The costs of R&D can be high. Nortel Networks, for example, at its height spent more than $7 million *a day* on R&D. Large companies in the automotive, computer, communications, and pharmaceutical industries spend a lot, too. Canada spends only 1.5 percent of its GDP on R&D, in contrast with three percent by the United States, Japan, and Germany.

It is interesting to note that some companies are now shifting from a focus primarily on *products* to a more balanced approach that explores both product and *process* R&D. One reason is that in too many instances, product innovations (e.g., for televisions, VCRs, and microwave ovens) made by North American companies have ended up being produced more competitively by foreign companies with better processes.

The following readings give examples of Canadian high-tech products and illustrate some sources of ideas for product and service design.

READING

Design for Response

Willard I. Zangwill

www.sony.com

Customer research is often touted as a necessary precursor to product introduction. The problem—especially for innovative products—is that it often proves wrong. For example, hair styling mousse is now a massive hit. Yet in its initial market tests it flopped. "Goopy and gunky" was what people said about it, and they did not like its feel when it "mooshed" through their hair.

Similarly, when the telephone answering machine was consumer tested, it faced an almost universally negative reaction. Back then, most individuals felt that using a mechanical device to answer a phone was rude and disrespectful. Today, of course, many people regard their answering machines as indispensable, and consider scheduling their daily activities without them as impossible. In the same vein, the computer mouse in its initial testing flunked, being evaluated by potential customers as awkward and unnecessary.

Because of these difficulties, some companies have gone so far as to eliminate customer research for their innovative products. According to Sony executive Kozo Ohsone, "When you introduce products that have never been invented before, what good is market research?" The Walkman was launched without the standard customer research, as is typical at Sony.

With customer research not only costly, but often in error, how can a manager determine the innovations customers want? The solution may be design-for-purpose, a new approach in which a firm uses speed and flexibility to gain customer information instead of, or in addition to, standard customer research.

To illustrate, Sony obtains information from the actual sales of various Walkman models and then quickly adjusts its product mix to conform to those sales patterns. Specifically, the process design of each Walkman model is based on a core platform containing the essential technology. But the platform is designed to be flexible, which allows a wide range of models to be easily built on it, such as a beach model, a child's model, one that attaches to the arm, and so on.

Depending upon which models sell, the models or features are changed, but the platform remains the same. If pink is a hot-selling colour, they make more pink models. If beach models sell well, they make more of the existing models and also expand the line. This technique is far more accurate than deciding what to make using traditional customer research.

Similarly, without customer research, every season Seiko "throws" into the market several hundred new models of its watches. Those that customers buy, it makes more of; the others, it drops. Capitalizing on the design-for-response strategy, Seiko has a highly flexible design and production process that lets it quickly and inexpensively introduce products. Do they worry if a high percentage of the watches they introduce fail, rejected by the customers? No (unless the failure rate is extremely high), because their fast, flexible product design process has slashed the cost of failure.

When creating a new magazine, Hearst Magazines also follows this approach. Hearst learned that it was almost impossible to customer test the magazine ideas, and that it was better to launch the magazine and see what happens. To do this, Hearst has created a special group of editors with the talent and flexibility to launch almost any new magazine. Based upon the initial sales of the new magazine, they will either revise the content and format or drop the publication. Any new magazine that proves successful is spun off to run independently.

Crucial to this approach, however, is reducing the cost of the failures by keeping expenses down. Hearst accomplishes this by initially hiring one overall editor on a short-time basis, using stringers as writers, and borrowing advertising people. Also, with experience it has discovered the tricks of launching new magazine products inexpensively. For example, it has learned how to test different cover designs efficiently, and how to test sales in different markets, such as newsstands or subscribers.

Many other firms also follow the strategy of using customer research data less and fast-flexible response more, with the food industry in the lead. One of the problems with customer research into foods is that a person's desire for food is powerfully influenced by the ambiance, the dining companions and what foods were eaten recently, all of which confound and confuse the results of the customer research. Even more erratic are the results with children's food, say a new cereal or snack. The responses of kids are strongly swayed by how well they like the people doing the test and the playthings available. Worse, kids quickly change their minds, and in a taste test of several foods a child can judge one food the best but one hour later proclaim the same food as "icky."

Arthur D. Little & Co. discovered that of all new cereals introduced to the market, 92 percent had failed. Since using the full array of customer research techniques produces a success rate of only 8 percent, more and more companies are revising their thinking about doing customer research as usual. Innovative firms such as Keebler and the leading cereal makers are reducing their expenditure for customer research and instead are vigorously cutting the cost of launching new products, including making their manufacturing processes more flexible.

Design-for-response enables firms not only to employ customer research when beneficial but also to respond quickly to what the customers really want, keeping the firm on top of market shifts and surprises.

Question

What is design-for-response?

Source: Adapted from *The Wall Street Journal*, March 8, 1993, p. A12. Reprinted by permission of *The Wall Street Journal*,

READING

Two Significant Canadian Contributions to World Technology

After the Second World War, the Canadian and Ontario governments supported research in the use of nuclear power for electricity generation, and in partnership with GE Canada set up a research lab in Chalk River, Ontario. This eventually led to the design of Candu reactors, which use heavy water and natural uranium to generate steam that is in turn transformed into electricity through turbines. Natural uranium bars are simpler to make than the enriched uranium used by U.S. reactors. This invention has been used in Canada and sold to several countries. Approximately half of Ontario's power comes from Candu reactors. Candu reactors are constantly redesigned in order to make them provide more power. See www.AECL.ca for more information.

Other highly recognized Canadian contributions are the Canadarm and Canadarm 2, the robotic arms for space shuttles and the space station, respectively. They both were made to work in a very inhospitable environment (space) with a high degree of reliability required. In addition to the arm-like motions, Canadarm 2 is expected to actually hop around the space station (i.e., it is not permanently anchored in one place, like the Canadarm). Both arms were made by Spar Aerospace, which was sold to Vancouver's MacDonald Dettwiler in 1999. See www.mdrobotics.ca for more information.

READING

Knowledge Mining for New-Product Successes

DaimlerChrysler's new-concept cars, Intel's Pentium chips—even the offerings of Rubbermaid, Black & Decker, Coleman, and Gillette—have something in common: they all resulted in new corporate vitality because of robust demand for the new products.

But why does a new Gillette deodorant or DaimlerChrysler car catch on in the market when so many others fail? Sales of some new products simply displace sales of other products by the same company, resulting in no new growth. Others might become "regional hits" without gaining anything approaching global success. As consumers become more fickle and competitors become more competitive, risk becomes an even more important factor in the product planning process.

What, then, is the best way to find new product ideas? Consider the following approaches that have shown success in the past:

1. Listening to the Market

Many companies have made their products successful by listening to consumer complaints about products already on the market. Complaints about the inadequacies of two-ply tissues inspired Kimberly-Clark to create three-ply Cold Care Tissues, and Gillette found it could satisfy customers with complaints about white residue from their deodorants by creating the Clear Stick. (An equivalent complaint about lipstick smearing on coffee cups and shirt collars resulted in Lancome's transfer-resistant Rouge Idole lipsticks.) Mirro/Wear-Ever Company's Airbake Insulated cookie sheets reduce the scorching of cookies—an innovation that resulted in a 70-percent global market share.

2. Watching the Market

3M used focus groups to create its Pop-up Tape Dispenser—it noticed consumers were one hand short of being able to hold wrapping paper, scissors, and tape when wrapping gifts. The new patented creation fit like a wristwatch, precutting tape strips and otherwise giving gift-wrappers a hand up. DeWalt introduced its cordless power tools for professionals who needed powerful equipment (such as drills) and could get this only from corded tools.

3. Understanding the Market

While Gillette, Lancome, and 3M can all point to fulfilling customer needs as the source of their success, Levi Strauss found its success in a deeper understanding of its customers' underlying desires. The Personal Pair software designs the perfect-fitting pair of jeans for each customer by factoring in each unique body shape. Delivered within two weeks, the jeans offer comfort that can otherwise elude shoppers trying to buy off the racks.

4. Exploring Pockets of the Market

For drivers who have been dropped by their insurance carriers because they are considered risky, Kingsway Financial Services Company of Mississauga, Ontario, provides an unparallelled service: offering car insurance to drivers like these, Kingsway has seen its annual revenue rocket from less than $20 million to more than $141 million in a mere five years.

Coleman, traditionally a manufacturer of camping gear, found a lucrative niche in the market when it produced smoke detectors with large "broom button" alarm testers. Using a broom handle to shut off nuisance alarms triggered by burnt toast appealed especially to the elderly and gave Coleman a 40-percent market share as a result.

5. Astounding the Market

Many new products have found that they could attract the attention of the market by exploiting a new science or art, whether it is a once-a-month pill to rid cats and dogs of fleas (Novartis), or frosted windows that clear up with the flip of a switch (3M). Companies have found that innovative design can be enough to shift the market in their direction, whether they are producing newly styled automobiles (DaimlerChrysler's Sebring) or "elegant" jet printers (Lexmark's 2030).

6. Filling Gaps in the Market

Black & Decker has mastered the art of finding holes in its competitors' offerings and filling these holes with products that suit customers' needs. The Black & Decker Snakelite twistable flashlight allows for hands-free use during repairs in tight-fitting spaces like bathrooms or furnaces.

John Deere Co.'s "Gator" is an inexpensive, six-wheel, off-road 11-terrain personnel utility vehicle suitable for transporting everything from and equipment to farming debris to wounded soldiers from the battlefield. The Gator simply doesn't have any direct competitors.

Question

Can you name some more examples of the above sources of product ideas?

Sources: Adapted from Allan J. Magrath, "Mining for New Product Successes," *Business Quarterly*, 62(2), Winter 1997, pp. 64–68; "The Edison Best New Product Awards," *Marketing News*, 31(6), March 17, 1997, pp. E4–E12.

Legal and Ethical Issues

Designers must be careful to take into account a wide array of legal and ethical considerations. Organizations have been faced with a large array of government (federal, provincial, municipal) acts and regulations, administered by government agencies and boards designed to regulate their activities. Among the more familiar ones are the Food and Drug Acts (Health Canada), the Canadian Environmental Protection Act (Environment Canada), the Motor Vehicle Safety Act (Transport Canada), and the Hazardous Products Act (Industry Canada). Bans or regulations on saccharin, CFCs, phosphates, and asbestos have sent designers scurrying back to their drawing boards to find alternative designs that were acceptable to both government regulators and customers. Similarly, automobile pollution standards and safety features, such as seat belts, air bags, safety glass, and energy-absorbing bumpers and frames, have had a substantial impact on automotive design. Much attention also has been directed toward toy design to remove sharp edges, small pieces that can cause choking, and toxic materials. In construction, government (municipal) regulations require access to public buildings for persons with disabilities, and standards for insulation, electrical wiring, plumbing, and fire protection.

product liability A manufacturer is liable for any injuries or damages caused by a faulty product.

Sales of Goods Act Products carry an implication of merchantability and fitness.

www.gc.ca

Product liability can be a strong incentive for design improvements. **Product liability** means that a manufacturer is liable for any injuries or damages caused by a faulty product because of poor workmanship or design. Product liability is more strictly enforced in the United States, where many business firms—including Ford and General Motors—have faced lawsuits related to their products. Manufacturers also are faced with the implied warranties provided in the **Sales of Goods Act**, which says that products carry an implication of *merchantability* and *fitness*; that is, a product must be usable for its intended purposes.

The suits and potential suits have led to increased legal and insurance costs, expensive settlements with injured parties, and costly recalls. Moreover, increasing customer awareness of product safety can adversely affect product image and subsequent demand for a product.

Thus, it is extremely important to design products that are reasonably free of hazards. When hazards do exist, it is necessary to install safety guards or other devices for reducing accident potential, and to provide adequate warning notices of risks. Consumer groups, business firms, and various government agencies often work together to develop industrywide standards that help avoid some of the hazards.

Ethical issues often arise in the design of products and services; it is important for managers to be aware of these issues and for designers to adhere to ethical standards. Designers are often under pressure to speed up the design process and to cut costs. These pressures often require them to make trade-off decisions, many of which involve ethical considerations. One example is: should a software company release a product as scheduled when it struggles with bugs in the software, or wait until most of the bugs have been removed?

Orangex Ojex Manual Juicer was produced with employees' ideas for efficiency, low cost and great tasting juice; Steelcase Leap chair has independently adjustable upper and lower back supports. Segway Scooter is deemed to be the breakthrough innovation of the decade.

Other Issues in Product and Service Design

Aside from legal and ethical issues, designers must also take into account product or service life cycles, how much standardization to incorporate, how to "customize" basically standard products, product or service reliability, and robust design: the range of operating conditions under which a product or service must function. These topics are discussed in this section. We begin with life cycles.

Life Cycles

Many new products and services go through a **life cycle** in terms of demand. When an item is introduced, it may be treated as a curiosity. Demand is generally low because potential buyers are not yet familiar with the item. Many potential buyers recognize that all of the bugs have probably not been worked out and that the price may drop after the introductory period. Production methods are designed for low volume. With the passage of time, design improvements usually create a more reliable and less costly product. Demand then grows for these reasons and because of increasing awareness of the product or service. Higher production volume will involve different methods and contribute to lower costs. At the next stage in the life cycle, the product or service reaches maturity: there are few, if any, design changes, and demand levels off. Eventually, the market becomes saturated, which leads to a decline in demand. In the last stage of a life cycle, some firms adopt a defensive research posture whereby they attempt to prolong the useful life of a product or service by improving its reliability, reducing costs of producing it (and, hence, the price), redesigning it, or changing the packaging. These stages are illustrated in Figure 4–2.

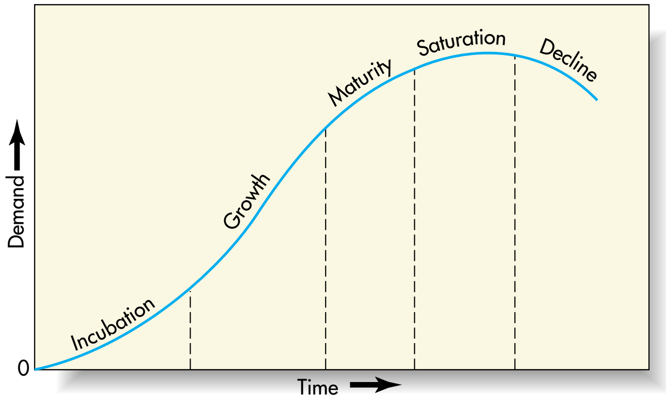
life cycle Incubation, growth, maturity, saturation, and decline.

Consider the products in various stages of the life cycle in the music industry: Digital audio tapes are in the introductory stage, compact discs are in the growth stage, cassettes are moving from the maturity-saturation stage into the decline stage. Digital audio tapes are similar to the old audio tapes, but have high-grade tape and can store two gigabytes of data (popular in Japan).

Some products do not exhibit life cycles: wooden pencils, paper clips, nails, knives, forks and spoons, drinking glasses, and similar items. However, most new products do.

FIGURE 4–2

Products or services may exhibit life cycles over time



Services, too, experience life cycles. Often these are related to the life cycles of products. For example, as older products are phased out, services such as installation and repair of the older products also phase out.

Wide variations exist in the amount of time a particular product or service takes to pass through a given phase of its life cycle: some pass through various stages in a relatively short period; others take considerably longer. Often it is a matter of the basic *need* for the item and the *rate of technological change.* Some toys, novelty items, personal computers, and style items have a life cycle of less than one year, whereas other items, such as clothes washers and dryers, may last for decades before yielding to technological change.

Standardization

standardization Extent to which there is absence of variety in a product, service, or process.

An important issue that often arises in both product/service design and process design is the degree of standardization. **Standardization** refers to the extent to which there is absence of variety in a product, service, or process. Standardized products are made in large quantities of identical items; paper, gasoline, and 2 percent milk are examples. Standardized service implies that every customer or item processed receives essentially the same service. An automatic car wash is a good example; each car, regardless of how clean or dirty it is, receives the same service. Standardized processes deliver standardized service or produce standardized goods.

Standardization carries a number of important benefits as well as certain disadvantages. Standardized components and parts are *interchangeable*, which greatly lowers the cost of production while increasing productivity and making replacement or repair relatively easy. Large-volume production and purchase of only a few types of standardized parts would reduce costs due to economies of scale. Design costs are generally lower. For example, General Motors recently has attempted to standardize key components of its automobiles across product lines; components such as brakes, electrical systems, and other "under-the-skin" parts would be the same for all GM car models. By reducing variety, GM saves time and money while increasing quality and reliability in its products.

www.gm.com

Another benefit of standardization is reduced time and cost to train employees and reduced time to design jobs. Similarly, scheduling of work, inventory handling, and purchasing and accounting activities become much more routine. WestJet using only Boeing 737 airplanes is an example.

Lack of standardization can at times lead to serious difficulties and competitive struggles, particularly when systems running under different conditions are incompatible. Consider a few examples: When VCRs were first introduced, there were two formats for tapes: VHS and Beta. Machines could play one or the other, but not both. This meant that producers needed to make two sets of tapes. High-definition television might have been introduced much earlier, but three competing—and incompatible—systems were proposed, which led to prolonged debate and study before one system could be agreed upon. The lack of standardization in computer software and operating systems (Apple versus IBM) has presented users with hard choices because of the difficulty in switching from one system to the other. And the use by U.S. manufacturers of the English imperial system of measurement, while most of the rest of the world's manufacturers use the metric system, has led to problems in selling U.S. goods in foreign countries and in buying foreign machines for use in the United States. This may make it more difficult for U.S. firms to compete in the European Union. Similarly, U.S. auto manufacturers have complained for years about their inability to freely enter the Japanese market, but only recently have they begun to offer cars with steering wheels on the right side—the universal standard in Japan.

Standardization also has disadvantages. A major one relates to the reduction in variety. This can limit the range of customers to whom a product or service appeals. Customers may reluctantly accept a product only because nothing else suits their needs. But that creates a risk that a competitor will introduce a better product or greater variety and realize a competitive advantage. Another disadvantage is that a manufacturer may freeze (standardize) a design prematurely and, once frozen, it may find compelling reasons to resist modification. A familiar example of this is the keyboard arrangement of typewriters and computer keyboards. Studies have demonstrated that another arrangement of keys would be more efficient, but the cost of replacing all of the equipment in existence and retraining millions of typists and word processors would not be worth the benefit.

DESIGNING FOR MASS CUSTOMIZATION

Companies like standardization because it enables them to produce high volumes of relatively low-cost products, albeit products with little variety. Customers, on the other hand, typically prefer more variety, although they like the low cost. The question for producers is how to resolve these issues without (1) losing the benefits of standardization and (2) incurring a host of problems that are often linked to variety. These include increasing variety in the production process, which would add to the skills and machines necessary to produce products, creating an additional inventory burden during and after production, and adding to the difficulty of diagnosing and repairing failed products. The answer, at least for some companies, is **mass customization**, a strategy of producing standardized goods or services but incorporating some degree of customization in the final product or service. Several tactics make this possible. One is *delayed differentiation*, and another is *modular design.*

mass customization Producing basically standardized goods, but incorporating some degree of customization.

Delayed differentiation is a *postponement* tactic: the process of producing, but not quite completing, a product or service, postponing completion until customer preferences or specifications are known. There are a number of variations of this. In the case of goods, almost-finished units might be held in inventory until customer orders are received, at which time customized features are incorporated, according to customer requests. For example, furniture makers can produce dining room sets but not apply stain, allowing customers a choice of stains. Once the choice is made, the stain can be applied in a relatively short time, thus eliminating a long wait for customers, giving the seller a competitive advantage. The result of delayed differentiation is a product or service with customized features that can be quickly produced, appealing to the customers' desire for variety and speed of delivery, and yet one that for the most part is standardized, enabling the producer to realize the benefits of standardized production. This technique is not new. Manufacturers of men's clothing, for example, produce suits with pants that have legs that are unfinished, allowing customers to tailor choices as to the exact length and whether to have cuffs or no cuffs. What is new is the extent to which business organizations are finding ways to incorporate this concept into a broad range of products and services.

delayed differentiation Producing, but not quite completing, a product or service until customer preferences are known.

modular design A form of standardization in which component parts are grouped into modules that are easily replaced or interchanged.

Modular designs are groupings of parts into components that are easily interchanged or replaced. One familiar example of modular design is computers that have modular parts that can be replaced if they become defective. By arranging modules in different configurations, different computer capabilities can be obtained. This is the major reason why Dell Computers can assemble and have delivered to its direct-sell Internet customers custom-ordered computers in a matter of days. For mass customization, modular design enables producers to quickly assemble modules to achieve a customized configuration for an individual customer, avoiding the long customer wait that would occur if individual parts had to be assembled. Modular design is also found in the construction industry. One firm in Rochester, New York, makes prefabricated motel rooms complete with wiring, plumbing, and even room decorations in its factory and then moves the complete rooms by rail to the construction site where they are integrated into the structure.

One advantage of modular design of equipment compared with nonmodular design is that failures are often easier to diagnose and remedy because there are fewer pieces to investigate. Similar advantages are found in ease of repair and replacement; the faulty module is conveniently removed and replaced with a good one. The manufacture and assembly of modules generally involves simplifications: fewer parts are involved, so purchasing and inventory control become more routine, fabrication and assembly operations become more standardized, and training costs often are relatively low.

The main disadvantage of modular design is the inability to disassemble some modules in order to replace a faulty part; the entire module must be scrapped—usually at a higher cost.

READING

Tesma's Advances in Powertrain Modules

www.tesma.com

Automakers are increasingly looking to reduce the number of components under the hood by moving to larger and more sophisticated powertrain modules. Tesma's front-engine-cover module is one of the industry's most advanced and value-added powertrain modules. The engine module incorporates a wide range of components, including the front engine cover, water pump, oil pump, idler, tensioner, pulleys, and fasteners. The front engine cover module provides vehicle manufacturers with one-stop shopping in terms of design, development, prototyping, testing, and manufacturing, as well as complete program management. The module also provides OEMs with significant reductions in assembly time, which in turn results in cost savings.

Source: *Magna 2001 Annual Report*, pp. 12–13.

Reliability

reliability The ability of a product, part, or system to perform its intended function under a prescribed set of conditions.

Reliability is a measure of the ability of a product, a part, a service, or an entire system to perform its intended function under a prescribed set of conditions. The importance of reliability is underscored by its use by prospective buyers in comparing alternatives and by sellers as one determinant of price. Reliability also can have an impact on repeat sales, reflect on the product's image, and, if it is too low, create legal implications.

failure Situation in which a product, part, or system does not perform as intended.

The term **failure** is used to describe a situation in which an item does not perform as intended. This includes not only instances in which the item does not function at all, but also instances in which the item's performance is substandard or it functions in a way not intended. For example, a smoke alarm might fail to respond to the presence of smoke (not operate at all), it might sound an alarm that is too faint to provide an adequate warning (substandard performance), or it might sound an alarm even though no smoke is present (unintended response).

Reliabilities are always specified with respect to certain conditions, called **normal operating conditions**. These can include load, temperature, and humidity ranges as well as operating procedures and maintenance schedules. Failure of users to heed these conditions often results in premature failure of parts or complete systems. For example, using a passenger car to tow heavy loads will cause excess wear and tear on the drive train; driving over potholes or curbs often results in untimely tire failure; and using a calculator to drive nails might have a marked impact on its usefulness for performing mathematical operations.

normal operating conditions The set of conditions under which an item's reliability is specified.

Improving Reliability. Reliability can be improved in a number of ways. Because overall system reliability is a function of the reliability of individual components, improvements in their reliability can increase system reliability. Unfortunately, inadequate production or assembly procedures can negate even the best of designs, and this is often a source of failures. System reliability can be increased by the use of backup components. Failures in actual use can often be reduced by upgrading user education and refining maintenance recommendations or procedures. Finally, it may be possible to increase the overall reliability of the system by simplifying the system (thereby reducing the number of components that could cause the system to fail) or altering component relationships (e.g., increasing the reliability of interfaces).

A fundamental question concerning improving reliability is this: How much reliability is needed? Obviously, the reliability that is needed for a lightbulb isn't in the same category as the reliability that is needed for an airplane. So the answer to the question depends on the potential benefits of improvements and on the cost of those improvements. Generally speaking, reliability improvements become increasingly costly. Thus, although benefits initially may be larger than costs, the opposite eventually becomes true. The optimal level of reliability is the point where the incremental benefit received equals the incremental cost of obtaining it. In the short term, this trade-off is made in the context of relatively fixed parameters (e.g., costs). However, in the longer term, efforts to improve reliability and reduce costs will lead to higher optimal levels of reliability.

Robust Design

Some products or services will function as designed only within a narrow range of conditions, while others will perform over a much broader range of conditions. The latter have **robust design**. Consider a pair of fine leather boots—obviously not made for trekking through mud or snow. Now consider a pair of heavy rubber boots—just the thing for mud or snow. The rubber boots have a design that is more *robust* than the fine leather boots.

robust design Design that results in products or services that can function over a broad range of conditions.

The more robust a product or service, the less likely that it will fail due to a change in the environment in which it is used or in which it is performed. Hence, the more designers can build robustness into the product or service, the better it should hold up, resulting in a higher level of customer satisfaction.

A similar argument can be made for robust design as it pertains to the production process. Manufacturing factors can have a negative effect on the quality of a product or service. The more resistant a design is to these influences, the less likely is a negative effect. For example, many products go through a heating process: food products, ceramics, steel, petroleum products, and pharmaceutical products. Furnaces often do not heat uniformly; heat may vary either by position in an oven or over an extended period of production. One approach to this problem might be to develop a superior oven; another might be to design a system that moves the product during heating to achieve uniformity. A robust-design approach would develop a product that is unaffected by minor variations in temperature during processing.

Taguchi's Approach. Japanese engineer Genichi Taguchi's approach is based on the robust design. His premise is that it is often easier to design a product that is insensitive to environmental factors, either in manufacturing or in use, than to control the environmental factors.

The central feature of Taguchi's approach—and the feature used most often by North American companies—is *parameter design.* This involves determining the specification settings for both the product and the process that will result in robust design in terms of manufacturing variations, product deterioration, and conditions during use.

The Taguchi approach modifies the conventional statistical methods of experimental design. Consider this example. Suppose a company will use 11 chemicals in a new product it intends to produce. There are two suppliers for these chemicals, and the chemical concentrations vary slightly between the two suppliers. Classical design of experiments would require $2^{11} = 2{,}048$ test runs to determine which combination of chemicals would be optimum. Taguchi's approach would involve testing only a portion of the possible combinations. The number of combinations is dramatically reduced, to 12. The value of this approach is its ability to achieve major advances in product or process design fairly quickly, using a relatively small number of experiments.

Designing for Manufacturing

In this section, you will learn about design techniques that have greater applicability for the design of products than the design of services. Even so, you will see that they do have some relevance for service design. The topics include concurrent engineering, computer-aided design, designing for manufacturing and assembly, recycling, and remanufacturing.

Concurrent Engineering

concurrent engineering Bringing engineering design and manufacturing personnel together early in the design phase.

To achieve a smoother transition from product design to production, and to decrease product development time, many companies are using *simultaneous development*, or concurrent engineering. In its narrowest sense, **concurrent engineering** means bringing design and manufacturing engineering people together early in the design phase to simultaneously develop the product and the processes for creating the product. More recently, this concept has been enlarged to include manufacturing personnel (e.g., materials specialists) and marketing and purchasing personnel in loosely integrated, cross-functional teams. In addition, the views of suppliers are frequently sought.

Traditionally, designers developed a new product without any input from manufacturing, and then turned over the design to manufacturing, which would then have to develop a process for making the new product. This "over-the-wall" approach created tremendous challenges for manufacturing, generating numerous conflicts and greatly increasing the time needed to successfully produce a new product. It also contributed to an "us versus them" mentality.

For these and similar reasons, the simultaneous development approach has great appeal. Among the key advantages of this approach are the following:

1. Manufacturing personnel are able to identify production capabilities. Very often, there is some latitude in design in terms of selecting suitable materials and processes. Knowledge of production capabilities can help in the selection process. In addition, cost and quality considerations can be greatly influenced.
2. Early opportunities for design or procurement of critical tooling, some of which might have long lead times. This can result in a major shortening of the product development process, which could be a key competitive advantage.
3. Early consideration of the technical feasibility of a particular design or a component.

However, a number of potential difficulties exist in this codevelopment approach. Two key ones are the following:

1. Longstanding existing boundaries between design and manufacturing can be difficult to overcome. Simply bringing a group of people together and thinking that they will be able to work together effectively is probably naive.

2. There must be extra communication and flexibility if the process is to work, and these can be difficult to achieve.

Hence, managers should plan to devote special attention if this approach is to work.

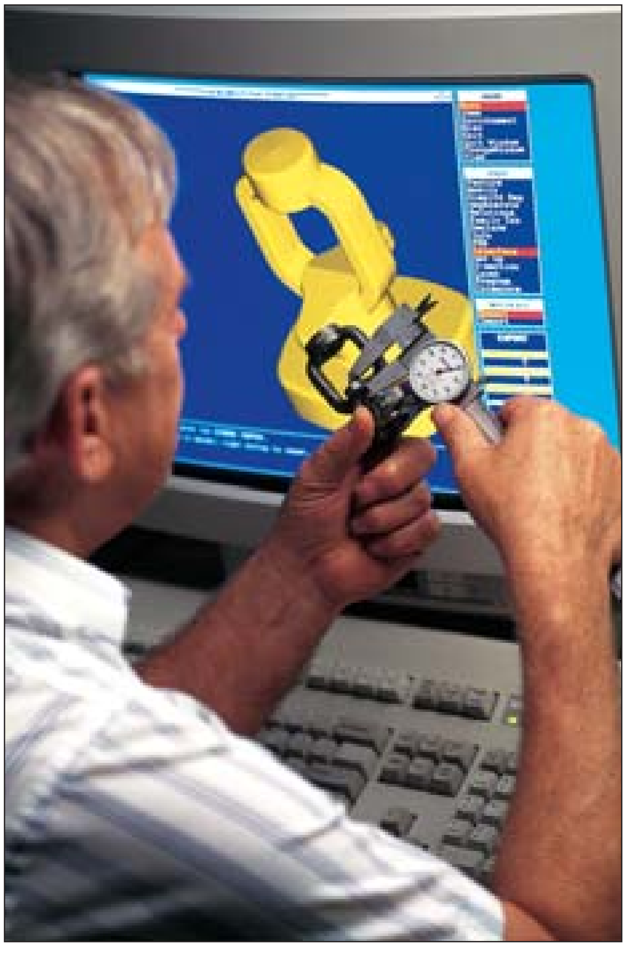
COMPUTER-AIDED DESIGN (CAD)

Computers are increasingly used for product design. **Computer-aided design (CAD)** uses computer graphics for product design. The designer can modify an existing design or create a new one on a display unit by means of a light pen, a keyboard, a joystick, or a mouse. Once the design is entered into the computer, the designer can manoeuvre it on the screen: It can be rotated to provide the designer with different perspectives, it can be split apart to give the designer a view of the inside, and a portion of it can be enlarged for closer examination. The designer can obtain a printed version of the completed design and file it electronically, making it accessible to people in the firm who need this information (e.g., manufacturing).

computer-aided design (CAD) Product design using computer graphics.

A growing number of products are being designed in this way, including transformers, automobile parts, aircraft parts, integrated circuits, and electric motors.

A major benefit of CAD is the increased productivity of designers. No longer is it necessary to laboriously prepare manual drawings of products or parts and revise them repeatedly to correct errors or incorporate revisions. A rough estimate is that CAD increases the productivity of designers from 3 to 10 times. A second major benefit of CAD is the creation of a database for manufacturing that can supply needed information on product geometry and dimensions, tolerances, material specifications, and so on.



Computer-aided design (CAD) is used to design components and products to exact measurement and detail. This firehead sprinkler was designed to exact specifications.

Some CAD systems allow the designer to perform engineering and cost analyses on proposed designs. For instance, the computer can determine the weight and volume of a part and do stress analysis as well. When there are a number of alternative designs, the computer can quickly go through the possibilities and identify the best one, given the designer's criteria.

Production Requirements

As noted earlier in the chapter, designers must take into account *production capabilities*. Design needs to clearly understand the capabilities of production (e.g., equipment, skills, types of materials, technologies). This will help in choosing designs that match capabilities. When opportunities and capabilities do not match, management must consider the potential for expanding or changing capabilities to take advantage of those opportunities.

Manufacturability is a key concern for manufactured goods: Ease of fabrication and/or assembly is important for cost, productivity, and quality.

design for manufacturing (DFM) Designers take into account the organization's manufacturing capabilities when designing a product.

design for assembly (DFA) Design focus on reducing the number of parts in a product and on assembly methods and sequence.

The term **design for manufacturing (DFM)** is used to indicate the designing of products that are compatible with an organization's manufacturing capabilities. A related concept in manufacturing is **design for assembly (DFA)**. A good design must take into account not only how a product will be fabricated, but also how it will be assembled. Design for assembly focuses on reducing the number of parts in an assembly, as well as on the assembly methods and sequence that will be employed.

Recycling

recycling Recovering materials for future use.

Recycling is sometimes an important consideration for designers. **Recycling** means recovering materials for future use. This applies not only to manufactured parts, but also to materials used during production, such as lubricants and solvents. Reclaimed metal or plastic parts may be melted down and used to make different products.

Companies recycle for a variety of reasons, including:

1. Cost savings.
2. Environmental concerns.
3. Environmental regulations.

design for recycling (DFR) Design focus to facilitate the recovery of materials and components in used products for reuse.

An interesting note: Companies that want to do business in the European Economic Community must show that a specified proportion of their products are recyclable.

The pressure to recycle has given rise to the term **design for recycling (DFR)**, referring to product design that takes into account the ability to disassemble a used product to recover the recyclable parts.

NEWSCLIP

More Cars Come with a Shade of Green—Recycled Materials

www.ford.com
www.gm.com
www.daimlerchrysler.com

Detroit's Big Three automakers, doing their best to build cars that don't fall apart, have a new goal: building cars that are easy to take apart.

The reason: Easy-to-remove parts are easy to recycle.

Car companies are putting the ability to recycle parts on the same level as safety, fuel economy, and costs when they design new vehicles.

For example, the Oldsmobile Aurora … uses scrap metal in its radiator mounting, and the bumper beams contain recycled copper and aluminum. Chrysler Corp. uses recycled tires for the splash guards on its midsize sedans.

Car parts have been recycled for years. But the auto industry only recently began to build cars with the idea of using recycled material. About 75 percent of new cars contain recycled material, mostly iron or steel used in the body.

Auto dismantlers usually buy a vehicle and remove all the parts that still work, such as seats, engines and headlights. The vehicle then goes to a shredder where it is reduced to small fragments and a huge magnet separates out the metal parts.

The challenge for auto companies is to find ways to separate the more than 20,000 different grades of plastic found in cars. About 24 percent of shredded material, known as "fluff," contains plastic, fluids, rubber, glass and other material. Most "fluff" can't be recycled.

Ford, GM and Chrysler have jointly formed the Vehicle Recycling Partnership in hopes of improving the technology to recover plastics and other material found in "fluff." Suppliers of material and the recycling industry are included in the partnership.

Manufacturers aren't suddenly becoming Friends of the Earth. "All of the recycling programs undertaken by Ford have been cost-effective," says Susan Day, vehicle recycling coordinator.

Source: *Rochester Democrat and Chronicle*, February 20, 1994, p. 11.

REMANUFACTURING

An emerging concept in manufacturing is the remanufacturing of products. **Remanufacturing** refers to refurbishing used products by replacing worn-out or defective parts, and reselling the products. This can be done by the original manufacturer or another company. Among the products that have remanufactured components are automobiles, printers, copiers, cameras, computers, and telephones.

remanufacturing Refurbishing used products by replacing worn-out or defective parts.

There are a number of important reasons for doing this. One is that a remanufactured product can be sold for about 50 percent of the cost of a new product. Another is that the process requires mostly unskilled and semiskilled workers. And in the global market, European lawmakers are increasingly requiring manufacturers to take back used products, because this means fewer products end up in landfills and there is less depletion of natural resources such as raw materials and fuel.

Designing products so that they can be more easily taken apart has given rise to yet another design consideration: **Design for disassembly (DFD)** includes using fewer parts and less material, and using snap-fits where possible instead of screws or nuts and bolts.

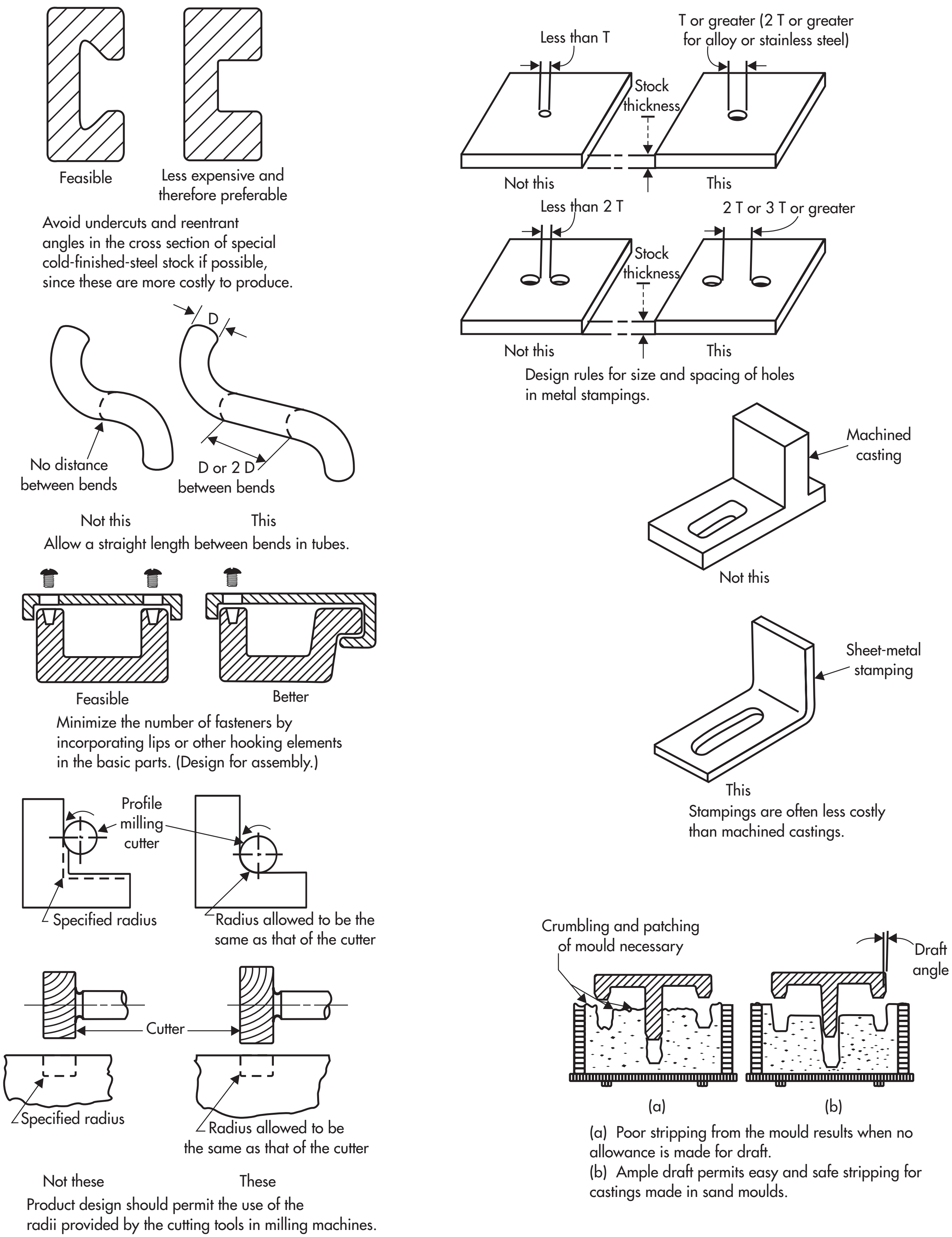
design for disassembly (DFD) Design so that used products can be easily taken apart.

The examples of design for manufacturing and assembly on the next page show what some companies are doing.

www.cadillac.com

By redesigning the Seville's rear bumper, Cadillac cut the number of parts, thus reducing assembly time and labour costs. The new design also led to high quality as there were few parts and steps that might be defective.

Reprinted by special permission of Business Week *©1991*. Art reprinted from October 25, 1991, issue of *Business Week* by special permission, copyright 1991 by McGraw-Hill, Inc.



Examples of design for manufacturing and assembly

Source: J. G. Bralla, *Design for Manufacturability Handbook*, 2nd ed., New York: McGraw-Hill, 1999.

Designing for Services

As noted, some of the discussion on product design also applies to service design. This stems from the fact that goods and services often exist in combination. For example, getting an oil change for your car involves a service (draining the old oil and putting in new oil) and a good (the new oil). Likewise, having new carpeting installed involves a service (the installation) and a good (the carpet). In some cases, what a customer receives is essentially a *pure* service, as in getting a haircut or your lawn mowed. However, the vast majority of cases involve some combination of goods and services. The proportion of service might be relatively low, as is the case in manufacturing, where the emphasis is on the production of goods. But even in manufacturing, there are services such as machine repair, employee training, safety inspections, and so on. Because goods and services are so intertwined, managers must be knowledgeable about both in order to be able to manage effectively. However, there are some key differences between manufacturing and service that warrant special consideration for service design. This section outlines these key differences, gives an overview of product design, and provides a brief list of guidelines for service design.

Differences between Service Design and Product Design

1. Products are generally tangible; services are generally intangible. Consequently, service design often focuses more on intangible factors (e.g., peace of mind, ambiance) than does product design.
2. In many instances services are created and delivered at the same time (e.g., a haircut, a car wash). In such instances there is less latitude in finding and correcting errors *before* the customer has a chance to discover them. Consequently, training, process design, and customer relations are particularly important.
3. Services cannot be inventoried. This poses restrictions on flexibility and makes capacity design very important. In addition, because of customization, there will be variability in length of service which adds to capacity requirements.
4. Services are highly visible to consumers because there is customer contact. This adds an extra dimension to process design, one that usually is not present in product design.
5. Some services have low barriers to entry and exit. This places additional pressures on service design to be innovative and cost-effective.
6. Location is often important to service design, with convenience as a major factor. Hence, design of services and choice of location are often closely linked.

Let's consider some of these differences in more detail. One is the need to consider the degree of customer contact in service design. That can range from no contact to high contact. When there is little or no contact, service design can be very much like product design. However, the greater the degree of customer contact, the greater the difference between service and product design, and the more complex service design becomes. The customer contact means that service design must incorporate *process* design; when there is customer contact, the process *is* part of the service. Although it is desirable to consider the manufacturability of a product when designing products, the product and the process are nonetheless separate entities. The following example of service design illustrates the inseparable nature of the service/process connection when customers are a part of the system. If a refrigerator manufacturer changes the procedure it uses for assembling a refrigerator, that change will be hidden to the person who purchases the refrigerator. Conversely, if a bus company makes changes to the bus schedule, or the bus routes, or the types of buses used, those changes will not be hidden to the riders. Obviously, this service redesign could not be done realistically without considering the *process* for delivering the service.

Overview of Service Design

Service design begins with the choice of a service strategy, which determines the nature and focus of the service and the target market. This requires an assessment by top management

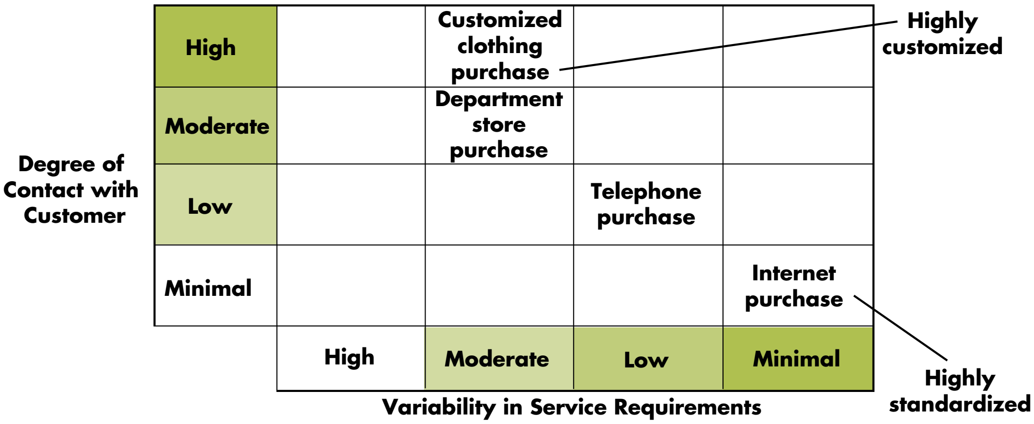


FIGURE 4–3

Service variability and customer contact influence service design

of the potential market and profitability (or need, in the case of a nonprofit organization) of a particular service, and an assessment of the organization's ability to provide the service. Once decisions on the focus of the service and the target market have been made, the customer requirements and expectations of the target market must be determined.

Two key issues in service design are the degree of variation in service requirements and the degree of customer contact and customer involvement in the delivery system. These have an impact on the degree to which service can be standardized or must be customized. The lower the degree of customer contact and service requirement variability, the more standardized the service can be. Service design with no contact and little or no processing variability is very much like product design. Conversely, high variability and high customer contact generally mean that the service must be highly customized. These concepts are illustrated in Figure 4–3.

A related consideration in service design is the opportunity for selling: The greater the degree of customer contact, the greater the opportunities for selling.

Design Guidelines

A number of simple but highly effective rules are often used to guide the development of service systems. The key rules are the following:

1. Have a single, unifying theme, such as convenience or speed. This will help personnel to work together rather than at cross-purposes.
2. Make sure the system has the capability to handle any expected variability in service requirements.
3. Include design features and checks to ensure that service will be reliable and will provide consistently high quality.
4. Design the system to be user-friendly. This is especially true for self-service systems.

Quality Function Deployment

quality function deployment (QFD) An approach that integrates the "voice of the customer" into the product development process.

Quality function deployment (QFD) is a structured approach for integrating the "voice of the customer" into the product or service development process. Listening to and understanding the customer is the central feature of QFD. Requirements often take the form of a general statement such as, "It should be easy to adjust the cutting height of the lawn mower." Once the requirements are known, they must be translated into technical terms related to the product or service. For example, a statement about changing the height of the lawn mower may relate to the mechanism used to accomplish that, its position, instructions for use, tightness of the spring that controls the mechanism, or materials needed.

The structure of QFD is based on a set of matrices. The main matrix relates customer requirements (what) and their corresponding technical requirements (how). This concept is illustrated in Figure 4–4.

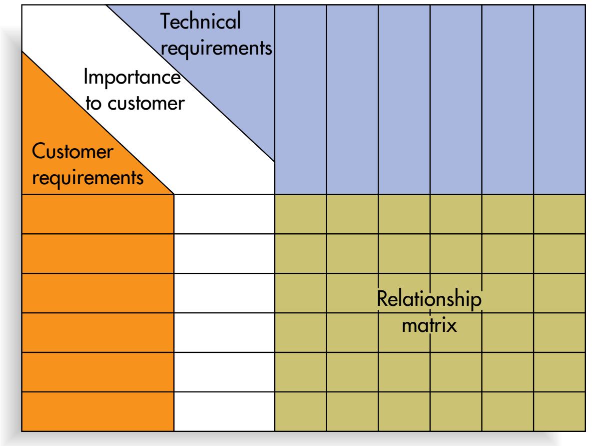


FIGURE 4–4

An example of the house of quality: the main QFD matrix
Source: Ernst and Young Consulting Group, *Total Quality* (Homewood, IL.: Dow-Jones Irwin, 1991), p. 121. Reprinted by permission.

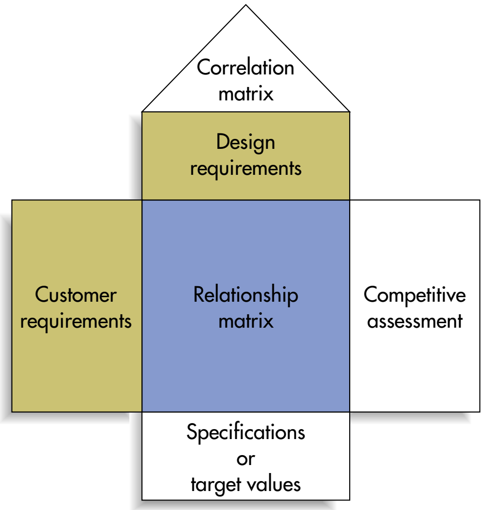


FIGURE 4–5

The house of quality

Additional features are usually added to the basic matrix to broaden the scope of analysis. Typical additional features include importance weightings and competitive evaluations. A correlational matrix is usually constructed for technical requirements; this can reveal conflicting technical requirements. Finally, target values for technical requirements are added. With these additional features, the matrix has the form illustrated in Figure 4–5. It is often referred to as the *house of quality* because of its houselike appearance.

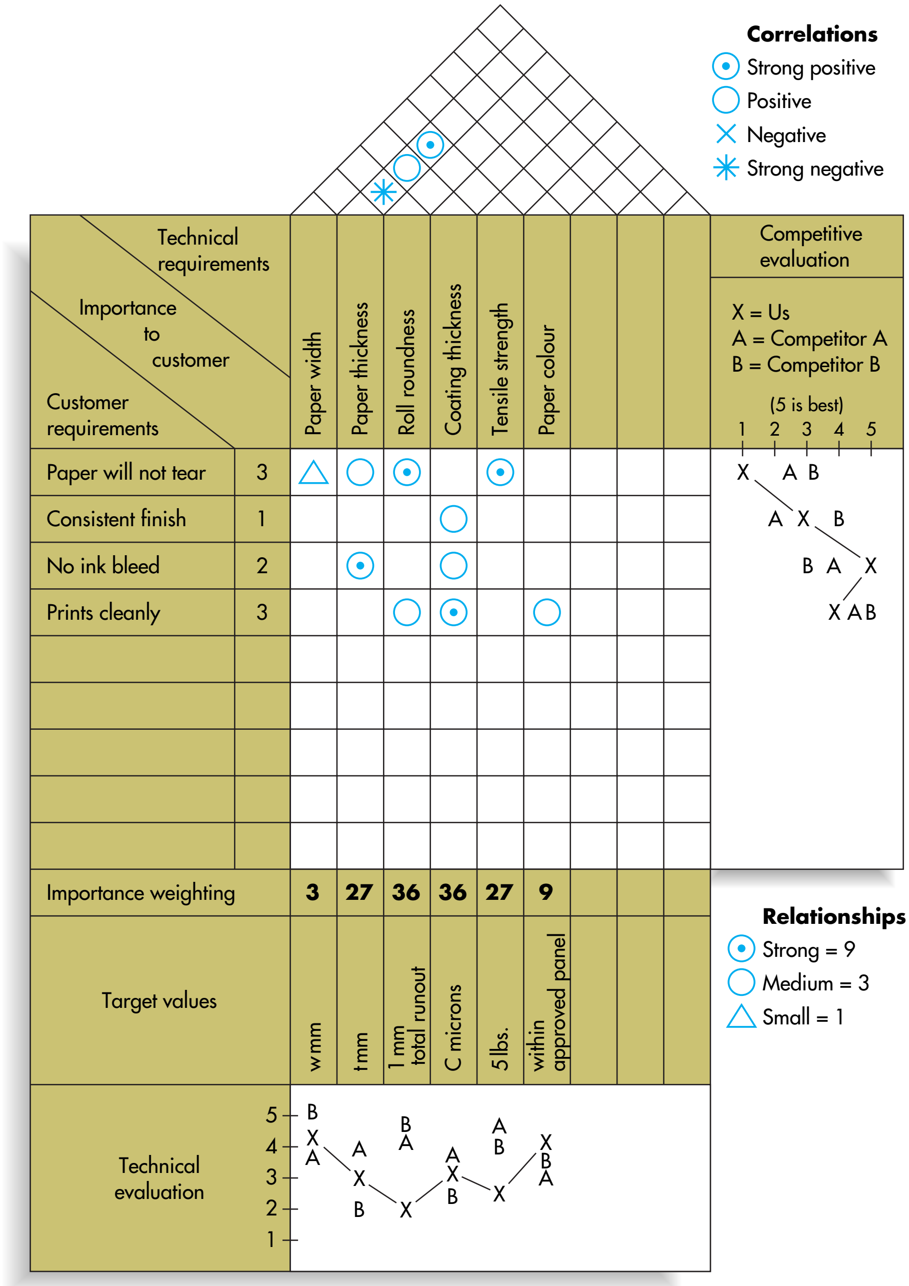
An analysis using this format is shown in Figure 4–6. The data relate to a commercial printer (customer) and the company that supplies the paper. To start, a key part is the list of customer requirements on the left side of the figure. Next, note the technical requirements, listed vertically near the top. The key relationships and their degree of importance are shown in the centre of the figure. The circle with a dot inside indicates the strongest positive relationship; that is, it denotes the most important technical requirement for satisfying the customer requirement (see the lower right-hand key for relationship weights). Now look at the "importance to customer" numbers that are shown next to each customer requirement (3 is the most important). Designers will take into account the importance values and the strength of relationship in determining where to focus the greatest effort.

Next, consider the correlation matrix at the top of the "house." Of special interest is the strong negative correlation between "paper thickness" and "roll roundness." Designers will have to find some way to overcome that or make a trade-off decision.

On the right side of the figure is a competitive evaluation comparing the company's performance on the customer requirements with each of the two key competitors (A and B). For example, the company (X) is worst on the first customer requirement and best on the

FIGURE 4–6

An example of the house of quality for papers used by a commercial printer



third customer requirement. A line connects the X performances. Ideally, design will cause all of the Xs to be in the highest positions.

Across the bottom of Figure 4–6 are importance weightings, target values, and technical evaluations. The technical evaluations can be interpreted in a manner similar to that of the competitive evaluations (note the line connecting the Xs). The target values typically contain technical specifications that are the result of the QFD process. The importance weightings are the sums of values assigned to the relationships times importance to customer. For example, the 3 in the first column is the product of the importance to the customer, 3, and the small (△) weight, 1. The importance weightings and technical and competitive evaluations help designers focus on desired target values. In this example, the first technical requirement has the lowest importance weighting, while the next four technical requirements all have relatively high importance weightings.

NEWSCLIP

A QFD Snapshot

How a pencilmaker sharpened up its product by listening to "the voice of the customer" through quality function deployment.

Devised by Japan's Professor Yoji Akao, QFD has been winning adherents since it was transplanted to North America in the late 1980s. In this example of how it works, Writesharp Inc. is imaginary, but the technique in the accompanying diagram is real.

First, Writesharp's customers were surveyed to determine what they value in a pencil and how they rate the leading brands. Each wish list item was correlated with a pencil's functional characteristics (see FUNCTIONAL CHARACTERISTICS matrix). "Reverse engineering"—tearing down a competitors' product to see what makes it tick—produced the competitive benchmark measurements for the various functions.

An analysis of the plots quickly revealed that the improvement with the biggest potential was a better-quality lead (see CUSTOMER SATISFACTION/CUSTOMER DEMANDS matrix). An interdepartmental team was assigned the task of evaluating new lead formulations that would last longer and generate less dust. Another team ran tests to determine whether substituting cedar for oak in the wood casing would improve shape quality, or hexagonality, and thus reduce the pencil's tendency to roll down slanted desktops.

Japanese Professor Akao devised the system and coined the phrase "quality function deployment." The QFD matrix combines benchmarking, customer demands, a product's characteristics, and customer satisfaction to measure and improve product quality.

Functional characteristics: △ Strong correlation ○ Some correlation □ Possible correlation

Customer satisfaction: Scale: 1 to 5 (5 = best)

Customer demands	Pencil length (inches)	Time between sharpenings (written lines)	Lead dust (particles per line)	Hexagonality	Importance rating (5 = highest)	Writesharp (now)	Competitor X (now)	Competitor Y (now)	Writesharp (target)
Easy to hold	○			○	3	4	3	3	4
Does not smear		○	△		4	5	4	5	5
Point lasts	□	△	○		5	4	5	3	5
Does not roll	□			△	2	3	3	3	4

Benchmarks	Pencil length (inches)	Time between sharpenings (written lines)	Lead dust (particles per line)	Hexagonality
Writesharp (now)	5	56	10	70%
Competitor X (now)	5	84	12	80%
Competitor Y (now)	4	41	10	60%
Writesharp (target)	5.5	100	6	80%

	Writesharp (now)	Competitor X (now)	Competitor Y (now)	Writesharp (target)
Market price	15¢	18¢	14¢	16¢
Market share	16%	12%	32%	20%
Profit	2¢	3¢	2¢	4¢

Example of the house of quality for a type of pencil.

The lead-formulation team organized its work with a similar matrix chart, segmented to show the functional contributions of the ingredients in pencil lead. This revealed that the binder, or glue, used in forming the lead was the key variable. Tests found a polymer that dramatically reduced dusting by retaining more moisture and also wore down more slowly. While this binder was more expensive, better production controls—going slightly beyond the performance of Competitor Y—promised to reduce waste enough to trim total per-pencil manufacturing costs by 1¢.

Changing the wood, meanwhile, yielded only marginal enhancements. So the company decided to upgrade the process controls used for cutting the wood and match the quality of Competitor X (see BENCHMARKS matrix).

Source: Reprinted from October 25, 1991, issue of *Business Week* by special permission, copyright © 1991 by The McGraw-Hill Companies, Inc.

The Kano Model

The *Kano model* breaks down the customer requirements into three categories: "must have" characteristics, "expected" characteristics, and "excitement" characteristics. The relationship between each category and customer satisfaction is illustrated in Figure 4–7.

The "must have" characteristics are those that yield a basic level of satisfaction, but do not have the potential for increasing customer satisfaction beyond a certain level. For instance, increasing the length of refrigerator cords beyond a reasonable length will not increase customer satisfaction. Neither will making flour whiter, or producing chewing gum that keeps its flavour (while being chewed) for four weeks. In contrast, the "expected" characteristics in a design will yield a steady increase in customer satisfaction. For example, increasing the life of a tire, or the life of a roof, will yield additional customer satisfaction. And the longer the life of a tire or a roof, the higher the level of customer satisfaction. However, the greatest yield comes from "excitement" characteristics, perhaps evoking a "wow" from customers. These characteristics generate a disproportionate increase in customer satisfaction.

A possible design strategy would be to incorporate the "must have" characteristics, and then conduct a cost–benefit analysis of characteristics in the other two categories to achieve desired results. This may not be as easy as it seems, especially in the case of the "excitement" characteristics, because those are often the most difficult to identify. In fact, customers may not be able to articulate them.

FIGURE 4–7

The Kano model

Operations Strategy

Product and service design is a fertile area for achieving competitive advantage and/or increasing customer satisfaction. Potential sources of such benefits include:

1. Shortening the time to market using concurrent engineering, QFD, and DFMA.
2. Designing environmentally friendly products.
3. Increasing emphasis on component commonality and standardization such as using multiple-use platforms. Auto manufacturers use the same platform (basic chassis, say) for several nameplates (e.g., Jaguar S type, Lincoln LS, and Ford Thunderbird have shared the same platform).
4. Implementing tactics that will achieve the benefits of high volume while satisfying customer needs for variety, such as mass customization.
5. Continually monitoring products and services for small improvements.

Summary

Product and service design is a key factor in satisfying the customer. To be successful, organizations must be continually aware of what customers want, what the competition is doing, what government regulations are, and what new technologies are available.

The design process involves market/competitor analysis, goal setting (performance, cost, quality), quality function deployment, concept development, product specification, building and testing prototypes, process and tooling design, arranging for component purchasing, quality control design, and pilot production. The idea for a new product or a redesign can come from customers, employees, competitors, and the research and development department. The stage of life cycle of a product influences the nature of its redesign. Using standard parts and common modules saves operation costs, but it is possible to provide some mass customization by allowing customers options on modules. The reliability of well-designed products has to be extensively tested and improved. It may be cheaper to design robust products that perform consistently in varied production and use conditions. It is faster and less costly for the product team to perform both product and process designs concurrently. CAD has helped reduce the design time significantly. It is cheaper overall to design products that have fewer parts and are easier to manufacture and assemble. Environmental concerns have pushed companies to think of disposal of the products in the form of recycling and remanufacturing. Services need to deal with customer presence and involvement, and inherent variability in service requirement. QFD is a multi-functional process for design that starts with the "voice of customer" and ends with its translation into product and process design.

Key Terms

computer-aided design (CAD), 139
concurrent engineering, 138
delayed differentiation, 135
design for assembly (DFA), 140
design for disassembly (DFD), 141
design for manufacturing (DFM), 140
design for operations, 128
design for recycling (DFR), 140
failure, 136
life cycle, 133
manufacturability, 128
mass customization, 135
modular design, 136
normal operating conditions, 137
product liability, 132
quality function deployment (QFD), 144
recycling, 140
reliability, 136
remanufacturing, 141
research and development (R&D), 129
reverse engineering, 128
robust design, 137
Sales of Goods Act, 132
standardization, 134

Discussion and Review Questions

1. What are some of the factors that cause organizations to redesign their products or services?
2. What is involved in product/service design?
3. What is CAD? Describe some of the ways a product designer can use it.
4. Name some of the main advantages and disadvantages of standardization.
5. What is modular design? What are its main advantages and disadvantages?

6. Explain the term *design for manufacturing* and briefly explain why it is important.
7. What are some of the competitive advantages of concurrent engineering?
8. Explain the term *remanufacturing.*
9. What is meant by the term *life cycle*? Why would this be a consideration in product or service design?
10. Why is R&D a key factor in productivity improvement? Name some ways R&D contributes to productivity improvements.
11. What is *mass customization*?
12. Name two factors that could make service design much different from product design.
13. Explain the term *robust design.*
14. Explain what *quality function deployment* is and how it can be useful.
15. What is reverse engineering? Do you feel this is unethical?

Memo-Writing Exercises

1. At a recent presentation, your company's CEO stated the company's intent to expand into the service sector. Currently, your company is devoted exclusively to manufacturing. Of particular interest to your supervisor, Tom Henry, were the following statements: "In all likelihood, we will use some of our own product designers for service design. They know our products and, besides, product design and service design are pretty much the same." Tom has asked you to look into this proposal. Write him a half-page memo indicating the circumstances under which this proposal might work and those under which it might not.
2. Suppose you have just received a memo questioning the merits of remanufacturing, a proposed new approach to be used by your company. The writer, Mary Barkley, a group leader in another department, is skeptical. Write a half-page memo to Mary on the benefits of remanufacturing.

Problems

1. Prepare a table similar to Figure 4–3. Then place each of these banking transactions in the appropriate cell of the table:
   a. Make a cash withdrawal from an automated banking machine (ABM).
   b. Make a savings deposit using a teller.
   c. Direct deposit by employer.
   d. Open a savings account.
   e. Apply for a home equity loan.
2. Prepare a table similar to Figure 4–3. Then place each of these post office transactions in the appropriate cell of the table:
   a. Buy stamps from a postal clerk.
   b. Mail a package that involves checking first class and express rates.
   c. File a complaint.
3. *a.* Refer to Figure 4–6. What two technical requirements have the highest impact on the customer requirement that the paper not tear?
   b. The following table presents technical requirements and customer requirements for a laser printer. First, decide if any of the technical requirements relate to each customer requirement. Decide which technical requirement, if any, has the greatest impact on that customer requirement.

	TECHNICAL REQUIREMENTS		
Customer requirements	**Automated feed of original papers**	**Feed mechanism for copy paper**	**Cylinder print element**
Copy paper doesn't jam			
Prints clearly			
Easy to use			

4. Prepare a table similar to that shown in Problem 3b for cookies sold in a bakery. List what you believe are the three most important customer requirements (not including cost) and the three most relevant technical requirements (not including sanitary conditions). Next, indicate by a checkmark which customer requirements and which technical requirements are related.

CASE

Open Wide and Say "Ultra"

www.harveys.ca

In fourth place behind McDonald's, A&W, and Burger King, Harvey's, the Canadian quick-service hamburger chain with more than 300 restaurants, needed a new idea in the mid-1990s. Harvey's is part of Cara operations Ltd., the airline food-services company that also owns the Swiss Chalet chain of restaurants. Harvey's had had new ideas before (open grill and fresh vegetables, for one), but these had become old hat by 1995. Gabe Tsampalieros, Cara's new president, who was a major franchisee with 60 Harvey's and Swiss Chalet restaurants, started working on the idea in October 1995, and by the following month the mission was clear: "Create Canada's best-selling hamburger." Tsampalieros and Harvey's vice-president planned the launch of the new burger for May 1996.

Harvey's began polling burger lovers across Canada in January 1996, first by telephone and later in focus groups of 8 to 12 people. While the tradition of burgers had so far led to flattened-out, Frisbee-like burgers that hung over the edges of the buns (giving customers the impression that they were getting more for their money), feedback from the market produced another idea: go thicker, juicier, chewier, and tastier. To bring this simple idea to life, Harvey's brought in chef Michael Bonacini, whose upscale Toronto restaurants had been a big hit.

Bonacini's challenge was not only to produce a tasty burger, but also to produce a burger that could handily survive the fast-food process (mechanically produced, frozen for weeks, and shipped around the country). Bonacini produced 12 "taste profiles"—from the bland to the bizarre—and introduced them to the Harvey's executives at a suburban Harvey's training centre. This would be the first in a long series of tasting exercises. (Bonacini thinks he ate 275 bite-sized burgers in a four-month period.)

Each of Harvey's executives tasted a portion of the 12 unlabelled patties and ranked it for "mouth feel," taste, linger, fill factor, and bite. Then they did it again, to ensure their palates had not become confused during tasting. Exotic offerings (Cajun, Oriental, falafel, and so forth) were rejected, leaving three simply seasoned burgers on the short list.

McCormick Canada Inc., Harvey's spice supplier, was employed to determine the final proportions of seasonings and secret ingredients to replicate the taste of Bonacini's samples in a way that could survive the fast-food process. "They [the meat packagers] would give us a 500-pound batch—that's 2,000 burgers—and we would taste them a couple of days after they had been mixed. Then we would also taste them at one-, two-, three-, and four-week intervals to see how the flavours would change," said Bonacini. McCormick's Food Technologists varied the seasonings by slight amounts with different results, and each change would start the testing period at the beginning. For two months, all of Harvey's head-office workers gathered before breakfast to test the newest batches; it became clear that the May launch date was unrealistic, so they bumped back the launch to mid-September.

Though missing deadlines is rarely advisable, in this case it was fortuitous. On May 9, exactly one week before the original launch date, competitor McDonald's introduced the Arch Deluxe with the most aggressive marketing campaign yet seen from McDonald's.

As the burger making neared completion, Harvey's turned its attention to choosing a name for the new burger. They considered several (the Ultimate, the Canadian, the Big Burger, the One and Only), but settled wisely on the Ultra, a bilingual name. They chose a foil packaging for better heat retention (and because the traditional box would appear larger than the burger itself), and reinitiated the advertising campaign, promoting a $1.88 price. Testing the burger in Calgary, Sudbury, and Quebec, Harvey's found customer reaction to be very positive ("It's more like a home-made burger," "It has a steak-like bite"), but went through five more adjustments to the amounts and mixing time of the ingredients.

On September 16, 1996, Ultra was launched and resulted in record sales, transaction counts, and restaurant visits. With over a million sold in the first two weeks, the Ultra resulted in more than 85 percent of Harvey's sales. Since then, Harvey's has introduced other types of hamburgers such as mushroom, bacon, and veggie burgers, as well as salads and chicken fajitas, and has opened small restaurants in some Home Depot Stores. Also, Cara has expanded its restaurant offerings by purchase the kelseys chain and the Second Cup chair.

Questions

1. Identify the steps of the product design process used by Harvey's. (Specifically, consider market analysis, quality function deployment, concept development, prototype development, and production pilot).
2. Did Harvey's use any other concepts discussed in the chapter?
3. Prepare a house of quality table similar to Figure 4–6 for the Ultra design. Fill it in as much as you can.

Sources: Adapted from "Open wide and say 'Ultra' (Harvey's had a brilliant idea about burgers)," *Canadian Business*, 69(15), December 1996, pp. 26–30; "Stay Hungry: Gabe Tsampalieros knows the Food Business from the Kitchen Floor Up (Will that Be Enough for Cara?)," *Canadian Business*, 69(11), Sept. 1996, pp. 104–110; Cara Operations Annual Reports, 1999–2002, www.cara.com.

Selected Bibliography and Further Reading

Baldwin, Carliss C., and Kim B. Clark. "Managing in the Age of Modularity." *Harvard Business Review*, September–October 1997, pp. 84–93.

Clausing, Don. "Total Quality Development." New York: The American Society of Mechanical Engineers, 1995.

Cohen, Morris A., and Uday M. Apte. *Manufacturing Automation.* McGraw-Hill, 1997.

Duray, Rebecca, and Glenn W. Milligan. "Improving Customer Satisfaction Through Mass Customization." *Quality Progress*, August 1999, pp. 60–66.

Feitzinger, Edward, and Hau L. Lee. "Mass Customization at Hewlett-Packard: The Power of Postponement." *Harvard Business Review*, January–February 1997, pp. 116–121.

Gilmore, James, and B. Joseph Pine II. "The Four Faces of Mass Customization." *Harvard Business Review*, January–February 1997, pp. 91–101.

Gilmore, James, and B. Joseph Pine II. *Markets of One: Creating Customer-Unique Value Through Mass Customization.* Boston: Harvard Business School Press, 2000.

Gorman, Michael E. *Transforming Nature: Ethics, Invention, and Design.* Boston: Kluwer Academic Publishers, 1998.

Groover, Mikell P. *Automation, Production Systems, and Computer-Aided Manufacturing.* 2nd ed. Englewood Cliffs, NJ: Prentice Hall, 2001.

Heskett, James L., W. Earl Sasser Jr, and Leonard A. Schlesinger. *The Service Profit Chain.* New York: Free Press, 1997.

Lovelock, Christopher H. *Service Marketing: People, Technology, Strategy.* 2nd ed. Englewood Cliffs, NJ: Prentice Hall, 2001.

Peace, Glen Stuart. *Taguchi Methods—A Hands-On Approach*. Reading, MA: Addison-Wesley, 1993.

Prasad, Biren. *Concurrent Engineering Fundamentals: Integrated Product Development.* Englewood Cliffs, NJ: Prentice Hall PTR, 1997.

Rosenthal, Stephen R. *Effective Product Development.* Burr Ridge, IL: Irwin, 1992.

Shaw, John C. *The Service Focus.* Burr Ridge, IL: Irwin, 1990.

Smyth, J. E., D. A. Soberman, and A. J. Easson. *The Law and Business Administration in Canada,* 7th ed. Scarborough, ON: Prentice-Hall Canada, 1995.

Ternicko, John. *Step-by-Step QFD: Customer-Driven Product Design.* 2nd ed. Boca Raton, FL: CRC Press, 1997.

Ulrich, Karl T., and Steven D. Eppinger. *Product Design and Development.* New York: McGraw-Hill, 1995.