Design of Goods and Services

CHAPTER 5

CHAPTER OUTLINE

Alaska Airlines

Alaska Airlines

10 OM STRATEGY DECISIONS

- *Design of Goods and Services*
- Managing Quality
- Process Strategy
- Location Strategies
- Layout Strategies
- Human Resources
- Supply-Chain Management
- Inventory Management
- Scheduling
- Maintenance

CHAPTER 5

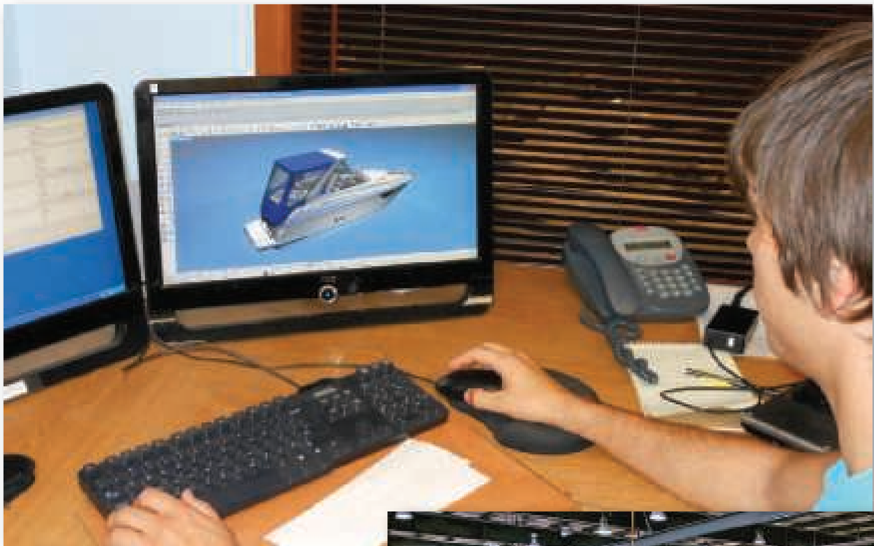
GLOBAL COMPANY PROFILE
Regal Marine

Product Strategy Provides Competitive Advantage at Regal Marine

Forty years after its founding by potato farmer Paul Kuck, Regal Marine has become a powerful force on the waters of the world. The world's third-largest boat manufacturer (by global sales), Regal exports to 30 countries, including Russia and China. Almost one-third of its sales are overseas.

Product design is critical in the highly competitive pleasure boat business: "We keep in touch with our customers and we respond to the marketplace," says Kuck. "We're introducing six new models this year alone. I'd say we're definitely on the aggressive end of the spectrum."

With changing consumer tastes, compounded by material changes and ever–improving marine engineering, the design function is under constant pressure. Added to these pressures



Barry Render

CAD/CAM is used to design the rain cover of a new product. This process results in faster and more efficient design and production.

Barry Render

Here the deck, suspended from ceiling cranes, is being finished prior to being moved to join the hull. Regal is one of the first boat builders in the world to earn the ISO 9001 quality certification.

Barry Render

Here the finishing touches are being put on a mold used for forming the hull.

Barry Render

Once a hull has been pulled from the mold, it travels down a monorail assembly path. JIT inventory delivers engines, wiring, seats, flooring, and interiors when needed.

is the constant issue of cost competitiveness combined with the need to provide good value for customers.

Consequently, Regal Marine is a frequent user of computer-aided design (CAD). New designs come to life via Regal's three-dimensional CAD system, borrowed from automotive technology. Regal's naval architect's goal is to continue to reduce the time from concept to prototype to production. The sophisticated CAD system not only has reduced product development time and cost, but also has reduced problems with tooling and production, resulting in a superior product.

All of Regal's products, from its $14,000 19-foot boat to the $500,000 52-foot Sports yacht, follow a similar production process. Hulls and decks are separately hand-produced by spraying preformed molds with three to five layers of a fiberglass laminate. The hulls and decks harden and are removed to become the lower and upper structure of the boat. As they move to the assembly line, they are joined and components added at each workstation.

Wooden components, precut in-house by computer-driven routers, are delivered on a just-in-time basis for installation at one station. Engines—one of the few purchased components—are installed at another. Racks of electrical wiring harnesses, engineered and rigged in-house, are then installed. An in-house upholstery department delivers customized seats, beds, dashboards, or other cushioned components. Finally, chrome fixtures are put in place, and the boat is sent to Regal's test tank for watertight, gauge, and system inspection.

Barry Render

At the final stage, smaller boats, such as this one, are placed in this test tank, where a rain machine ensures watertight fits.

LEARNING OBJECTIVES

Goods and Services Selection

STUDENT TIP Product strategy is critical to achieving competitive advantage.

Global firms like Regal Marine know that the basis for an organization's existence is the good or service it provides society. Great products are the keys to success. Anything less than an excellent product strategy can be devastating to a firm. To maximize the potential for success, many companies focus on only a few products and then concentrate on those products. For instance, Honda's focus, its core competency, is engines. Virtually all of Honda's sales (autos, motorcycles, generators, lawn mowers) are based on its outstanding engine technology. Likewise, Intel's focus is on microprocessors, and Michelin's is on tires.

However, because most products have a limited and even predictable life cycle, companies must constantly be looking for new products to design, develop, and take to market. Operations managers insist on strong communication among customer, product, processes, and suppliers that results in a high success rate for their new products. 3M's goal is to produce 30% of its profit from products introduced in the past 4 years. Apple generates almost 60% of its revenue from products launched in the past 4 years. Benchmarks, of course, vary by industry; Regal introduces six new boats a year, and Rubbermaid introduces a new product each day!

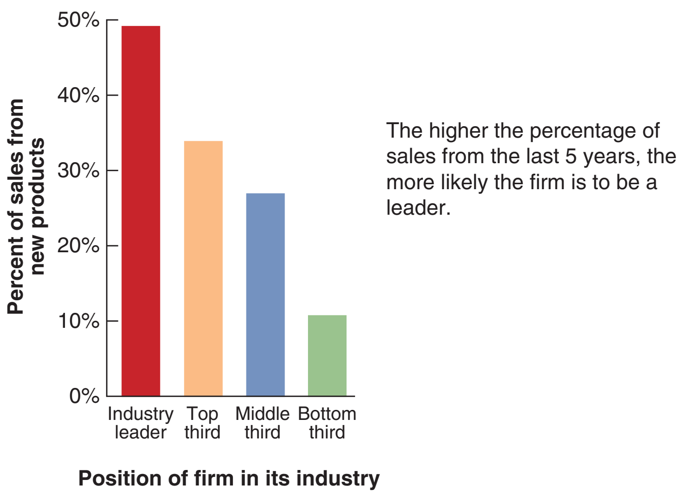
VIDEO 5.1 Product Strategy at Regal Marine

The importance of new products cannot be overestimated. As Figure 5.1 shows, leading companies generate a substantial portion of their sales from products less than 5 years old. The need for new products is why Gillette developed its multiblade razors, in spite of continuing high sales of its phenomenally successful Sensor razor, and why Disney continues to innovate with new rides and new parks even though it is already the world's leading family entertainment company.

Despite constant efforts to introduce viable new products, many new products do not succeed. Product selection, definition, and design occur frequently—perhaps hundreds of times

Figure **5.1**

Innovation and New Products



for each financially successful product. DuPont estimates that it takes 250 ideas to yield one *marketable* product. Operations managers and their organizations build cultures that accept this risk and tolerate failure. They learn to accommodate a high volume of new product ideas while maintaining the production activities to which they are already committed.

STUDENT TIP
Motorola went through 3,000 working models before it developed its first pocket cell phone.

Although the term *products* often refers to tangible goods, it also refers to offerings by service organizations. For instance, when Allstate Insurance offers a new homeowner's policy, it is referred to as a new "product." Similarly, when Citicorp opens a mortgage department, it offers a number of new mortgage "products."

An effective product strategy links product decisions with investment, market share, and product life cycle, and defines the breadth of the product line. The *objective of the* **product decision** *is to develop and implement a product strategy that meets the demands of the marketplace with a competitive advantage*. As one of the 10 decisions of OM, product strategy may focus on developing a competitive advantage via differentiation, low cost, rapid response, or a combination of these.

Product decision
The selection, definition, and design of products.

Product Strategy Options Support Competitive Advantage

A world of options exists in the selection, definition, and design of products. Product selection is choosing the good or service to provide customers or clients. For instance, hospitals specialize in various types of patients and medical procedures. A hospital's management may decide to operate a general-purpose hospital or a maternity hospital or, as in the case of the Canadian hospital Shouldice, to specialize in hernias. Hospitals select their products when they decide what kind of hospital to be. Numerous other options exist for hospitals, just as they exist for Taco Bell and Toyota.

Service organizations like Shouldice Hospital *differentiate* themselves through their product. Shouldice differentiates itself by offering a distinctly unique and high-quality product. Its world-renowned specialization in hernia-repair service is so effective it allows patients to return

(a) Markets: In its creative way, the market has moved athletic shoes from utilitarian footwear into fashionable accessories.

(b) Technology: Samsung's latest technology: radical new smart phones that are bendable.

(c) Packaging: Sherwin-Williams' Dutch Boy has revolutionized the paint industry with its square Twist & Pour paint container.

Product Innovation Can Be Driven By Markets, Technology, and Packaging. Whether it is design focused on changes in the market (a), the application of technology at Samsung (b), or a new container at Sherwin-Williams (c), operations managers need to remind themselves that the creative process is ongoing with major production implications.

to normal living in 8 days as opposed to the average 2 weeks—and with very few complications. The entire production system is designed for this one product. Local anesthetics are used; patients enter and leave the operating room on their own; meals are served in a common dining room, encouraging patients to get out of bed for meals and join fellow patients in the lounge. As Shouldice demonstrates, product selection affects the entire production system.

Taco Bell has developed and executed a *low-cost* strategy through product design. By designing a product (its menu) that can be produced with a minimum of labor in small kitchens, Taco Bell has developed a product line that is both low cost and high value. Successful product design has allowed Taco Bell to increase the food content of its products from 27¢ to 45¢ of each sales dollar.

Toyota's strategy is *rapid response* to changing consumer demand. By executing the fastest automobile design in the industry, Toyota has driven the speed of product development down to well under 2 years in an industry whose standard is still over 2 years. The shorter design time allows Toyota to get a car to market before consumer tastes change and to do so with the latest technology and innovations.

Product decisions are fundamental to an organization's strategy and have major implications throughout the operations function. For instance, GM's steering columns are a good example of the strong role product design plays in both quality and efficiency. The redesigned steering column is simpler, with about 30% fewer parts than its predecessor. The result: Assembly time is one-third that of the older column, and the new column's quality is about seven times higher. As an added bonus, machinery on the new line costs a third less than that on the old line.

Product Life Cycles

Products are born. They live and they die. They are cast aside by a changing society. It may be helpful to think of a product's life as divided into four phases. Those phases are introduction, growth, maturity, and decline.

Product life cycles may be a matter of a few days (a concert t-shirt), months (seasonal fashions), years (Madden NFL football video game), or decades (Boeing 737). Regardless of the length of the cycle, the task for the operations manager is the same: to design a system that helps introduce new products successfully. If the operations function cannot perform effectively at this stage, the firm may be saddled with losers—products that cannot be produced efficiently and perhaps not at all.

LO 5.1 *Define* product life cycle

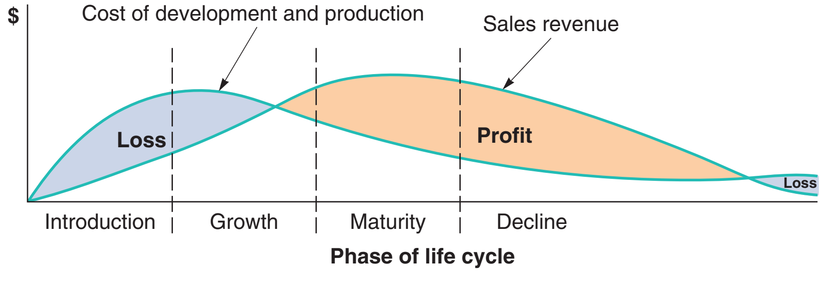
Figure 5.2 shows the four life cycle stages and the relationship of product sales, cash flow, and profit over the life cycle of a product. Note that typically a firm has a negative cash flow while it develops a product. When the product is successful, those losses may be recovered. Eventually, the successful product may yield a profit prior to its decline. However, the profit is fleeting—hence, the constant demand for new products.

Life Cycle and Strategy

Just as operations managers must be prepared to develop new products, they must also be prepared to develop *strategies* for new and *existing* products. Periodic examination of

Figure **5.2**

Product Life Cycle, Sales, Cost, Profit, and Loss



products is appropriate because *strategies change as products move through their life cycle*. Successful product strategies require determining the best strategy for each product based on its position in its life cycle. A firm, therefore, identifies products or families of products and their position in the life cycle. Let us review some strategy options as products move through their life cycles.

Introductory Phase Because products in the introductory phase are still being "fine-tuned" for the market, as are their production techniques, they may warrant unusual expenditures for (1) research, (2) product development, (3) process modification and enhancement, and (4) supplier development. For example, when the iPhone was first introduced, the features desired by the public were still being determined. At the same time, operations managers were still groping for the best manufacturing techniques.

Growth Phase In the growth phase, product design has begun to stabilize, and effective forecasting of capacity requirements is necessary. Adding capacity or enhancing existing capacity to accommodate the increase in product demand may be necessary.

Maturity Phase By the time a product is mature, competitors are established. So high-volume, innovative production may be appropriate. Improved cost control, reduction in options, and a paring down of the product line may be effective or necessary for profitability and market share.

Decline Phase Management may need to be ruthless with those products whose life cycle is at an end. Dying products are typically poor products in which to invest resources and managerial talent. Unless dying products make some unique contribution to the firm's reputation or its product line or can be sold with an unusually high contribution, their production should be terminated.[1]

Product-by-Value Analysis

The effective operations manager selects items that show the greatest promise. This is the Pareto principle applied to product mix: Resources are to be invested in the critical few and not the trivial many. **Product-by-value analysis** lists products in descending order of their *individual dollar contribution* to the firm. It also lists the *total annual dollar contribution* of the product. Low contribution on a per-unit basis by a particular product may look substantially different if it represents a large portion of the company's sales.

Product-by-value analysis
A list of products, in descending order of their individual dollar contribution to the firm, as well as the *total annual dollar contribution* of the product.

A product-by-value report allows management to evaluate possible strategies for each product. These may include increasing cash flow (e.g., increasing contribution by raising selling price or lowering cost), increasing market penetration (improving quality and/or reducing cost or price), or reducing costs (improving the production process). The report may also tell management which product offerings should be eliminated and which fail to justify further investment in research and development or capital equipment. Product-by-value analysis focuses attention on the strategic direction for each product.

Generating New Products

STUDENT TIP
Societies reward those who supply new products that reflect their needs.

Because products die; because products must be weeded out and replaced; because firms generate most of their revenue and profit from new products—product selection, definition, and design take place on a continuing basis. Consider recent product changes: DVDs to video streaming, coffee shops to Starbucks lifestyle coffee, traveling circuses to Cirque du Soleil, landlines to cell phones, cell phone to smart phones, and an Internet of digital information to an Internet of "things" that connects you and your smart phone to your home, car, and doctor. And the list goes on. Knowing how to successfully find and develop new products is a requirement.

Aggressive new product development requires that organizations build structures internally that have open communication with customers, innovative product development cultures, aggressive R&D, strong leadership, formal incentives, and training. Only then can a firm profitably and energetically focus on specific opportunities such as the following:

1. *Understanding the customer* is the premier issue in new-product development. Many commercially important products are initially thought of and even prototyped by users rather than producers. Such products tend to be developed by "lead users"—companies, organizations, or individuals that are well ahead of market trends and have needs that go far beyond those of average users. The operations manager must be "tuned in" to the market and particularly these innovative lead users.
2. *Economic change* brings increasing levels of affluence in the long run but economic cycles and price changes in the short run. In the long run, for instance, more and more people can afford automobiles, but in the short run, a recession may weaken the demand for automobiles.
3. *Sociological and demographic change* may appear in such factors as decreasing family size. This trend alters the size preference for homes, apartments, and automobiles.
4. *Technological change* makes possible everything from smart phones to iPads to artificial hearts.
5. *Political and legal change* brings about new trade agreements, tariffs, and government requirements.
6. Other changes may be brought about through *market practice, professional standards, suppliers*, and *distributors*.

Operations managers must be aware of these dynamics and be able to anticipate changes in product opportunities, the products themselves, product volume, and product mix.

Product Development

Product Development System

LO 5.2 *Describe* a product development system

An effective product strategy links product decisions with other business functions, such as R&D, engineering, marketing, and finance. A firm requires cash for product development, an understanding of the marketplace, and the necessary human talents. The product development system may well determine not only product success but also the firm's future. Figure 5.3 shows the stages of product development. In this system, product options go through a series of steps, each having its own screening and evaluation criteria, but providing a continuing flow of information to prior steps.

Optimum product development depends not only on support from other parts of the firm but also on the successful integration of all 10 of the OM decisions, from product design to maintenance. Identifying products that appear likely to capture market share, be cost-effective, and be profitable but are, in fact, very difficult to produce may lead to failure rather than success.

Quality function deployment (QFD)
A process for determining customer requirements (customer "wants") and translating them into the attributes (the "hows") that each functional area can understand and act on.

House of quality
A part of the quality function deployment process that utilizes a planning matrix to relate customer "wants" to "how" the firm is going to meet those "wants."

Quality Function Deployment (QFD)

Quality function deployment (QFD) refers to both (1) determining what will satisfy the customer and (2) translating those customer desires into the target design. The idea is to capture a rich understanding of customer wants and to identify alternative process solutions. This information is then integrated into the evolving product design. QFD is used early in the design process to help determine *what will satisfy the customer* and *where to deploy quality efforts*.

One of the tools of QFD is the **house of quality**, a graphic technique for defining the relationship between customer desires and product (or service). Only by defining this relationship in a rigorous way can managers design products and processes with features desired by customers.

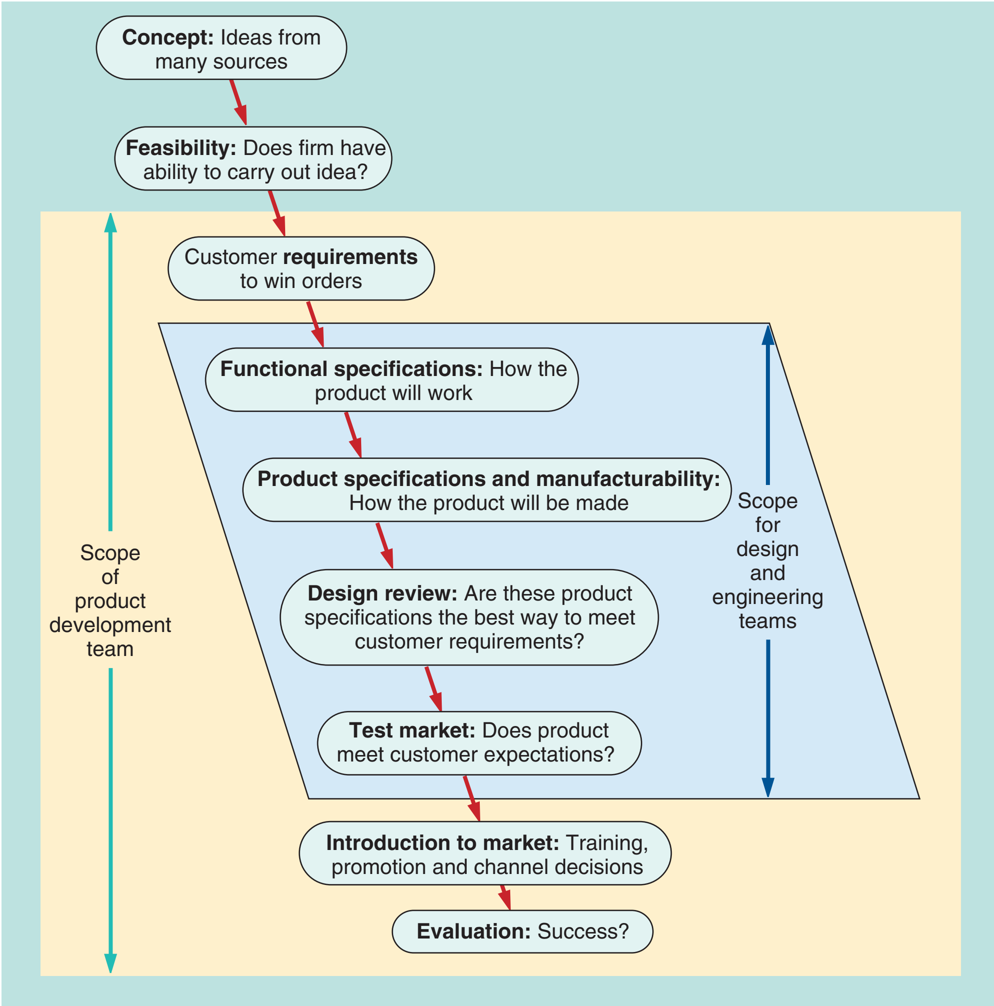


Figure 5.3

Product Development Stages

Product concepts are developed from a variety of sources, both external and internal to the firm. Concepts that survive the product idea stage progress through various stages, with nearly constant review, feedback, and evaluation in a highly participative environment to minimize failure.

Defining this relationship is the first step in building a world-class production system. To build the house of quality, we perform seven basic steps:

LO 5.3 *Build* a house of quality

1. Identify customer *wants*. (What do customers want in this product?)
2. Identify *how* the good/service will satisfy customer wants. (Identify specific product characteristics, features, or attributes and show how they will satisfy customer *wants*.)
3. Relate customer *wants* to product *hows*. (Build a matrix, as in Example 1, that shows this relationship.)
4. Identify relationships between the firm's *hows*. (How do our *hows* tie together? For instance, in the following example, there is a high relationship between low electricity requirements and auto focus, auto exposure, and number of pixels because they all require electricity. This relationship is shown in the "roof" of the house in Example 1.)
5. Develop importance ratings. (Using the *customer's* importance ratings and weights for the relationships shown in the matrix, compute *our* importance ratings, as in Example 1.)
6. Evaluate competing products. (How well do competing products meet customer wants? Such an evaluation, as shown in the two columns on the right of the figure in Example 1, would be based on market research.)
7. Determine the desirable technical attributes, your performance, and the competitor's performance against these attributes. (This is done at the bottom of the figure in Example 1.)

The following series of overlays for Example 1 show how to construct a house of quality.

Example 1

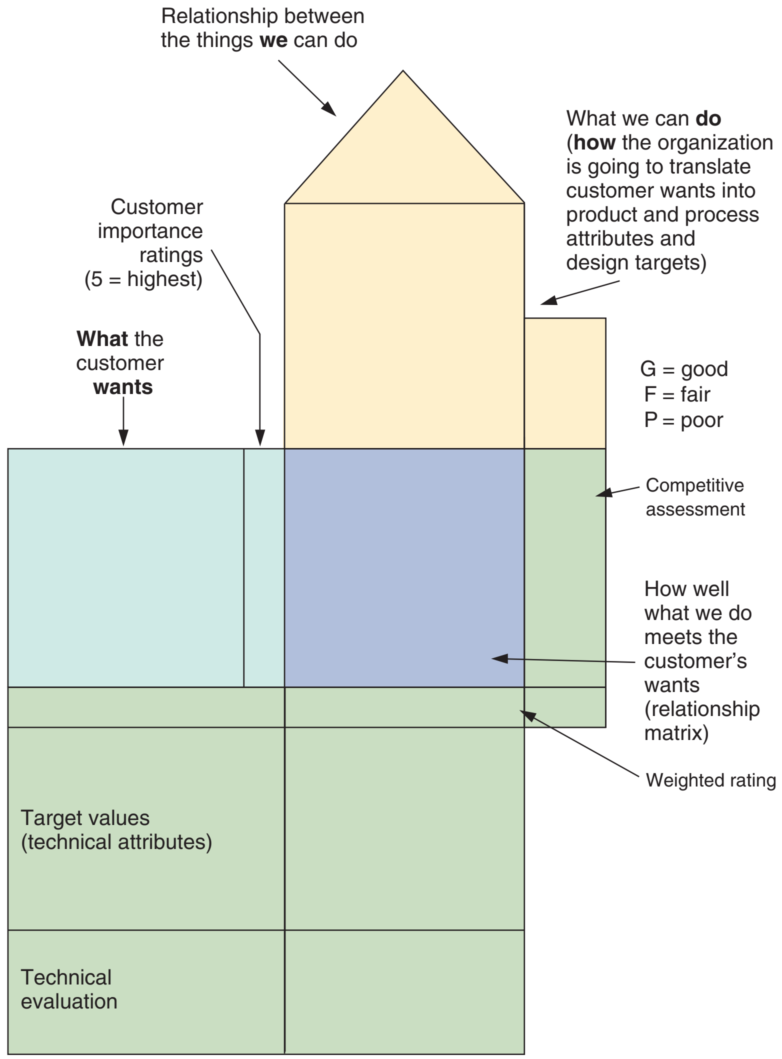
CONSTRUCTING A HOUSE OF QUALITY

Great Cameras, Inc., wants a methodology that strengthens its ability to meet customer desires with its new digital camera.

APPROACH ▶ Use QFD's house of quality.

SOLUTION ▶ Build the house of quality for Great Cameras, Inc. We do so here using Overlays 1, 2, 3, and 4.

Quality Function Deployment's (QFD) House of Quality



INSIGHT ▶ QFD provides an analytical tool that structures design features and technical issues, as well as providing importance rankings and competitor comparison.

LEARNING EXERCISE ▶ If the market research for another country indicates that "lightweight" has the most important customer ranking (5), and reliability a 3, what is the new total importance ranking for low electricity requirements, aluminum components, and ergonomic design? [Answer: 18, 15, 27, respectively.]

RELATED PROBLEMS ▶ 5.4, 5.5, 5.6, 5.7, 5.8

Another use of quality function deployment (QFD) is to show how the quality effort will be *deployed*. As Figure 5.4 shows, *design characteristics* of House 1 become the inputs to House 2, which are satisfied by *specific components* of the product. Similarly, the concept is carried to House 3, where the specific components are to be satisfied through particular *production processes*. Once those production processes are defined, they become requirements of House 4 to be satisfied by a *quality plan* that will ensure conformance of those processes. The quality plan is a set of specific tolerances, procedures, methods, and sampling techniques that will ensure that the production process meets the customer requirements.

The QFD effort is devoted to meeting customer requirements. The *sequence* of houses is a very effective way of identifying, communicating, and deploying production resources. In this way we produce quality products, meet customer requirements, and win orders.

Organizing for Product Development

Let's look at four approaches to organizing for product development. *First*, the traditional U.S. approach to product development is an organization with distinct departments: a research and development department to do the necessary research; an engineering department to design the product; a manufacturing engineering department to design a product that can be produced; and a production department that produces the product. The distinct advantage of this approach is that fixed duties and responsibilities exist. The distinct disadvantage is lack of forward thinking: How will downstream departments in the process deal with the concepts, ideas, and designs presented to them, and ultimately what will the customer think of the product?

A *second* and popular approach is to assign a product manager to "champion" the product through the product development system and related organizations. However, a *third*, and perhaps the best, product development approach used in the U.S. seems to be the use of teams.

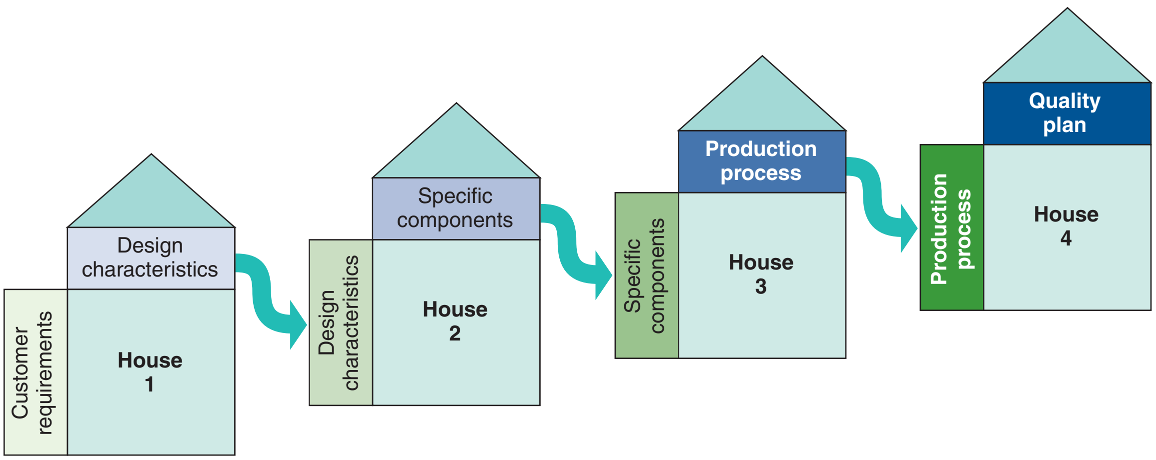


Figure **5.4**

House of Quality Sequence Indicates How to Deploy Resources to Achieve Customer Requirements

Such teams are known variously as *product development teams, design for manufacturability teams*, and *value engineering teams*.

The Japanese use a *fourth* approach. They bypass the team issue by not subdividing organizations into research and development, engineering, production, and so forth. Consistent with the Japanese style of group effort and teamwork, these activities are all in one organization. Japanese culture and management style are more collegial and the organization less structured than in most Western countries. Therefore, the Japanese find it unnecessary to have "teams" provide the necessary communication and coordination. However, the typical Western style, and the conventional wisdom, is to use teams.

Product development teams
Teams charged with moving from market requirements for a product to achieving product success.

Product development teams are charged with the responsibility of moving from market requirements for a product to achieving a product success (refer to Figure 5.3 on page 167). Such teams often include representatives from marketing, manufacturing, purchasing, quality assurance, and field service personnel. Many teams also include representatives from vendors. Regardless of the formal nature of the product development effort, research suggests that success is more likely in an open, highly participative environment where those with potential contributions are allowed to make them. The objective of a product development team is to make the good or service a success. This includes marketability, manufacturability, and serviceability.

Concurrent engineering
Simultaneous performance of the various stages of product development.

Concurrent engineering implies speedier product development through simultaneous performance of the various stages of product development (as we saw earlier in Figure 5.3). Often the concept is expanded to include all elements of a product's life cycle, from customer requirements to disposal and recycling. Concurrent engineering is facilitated by teams representing all affected areas (known as *cross-functional* teams).

Manufacturability and Value Engineering

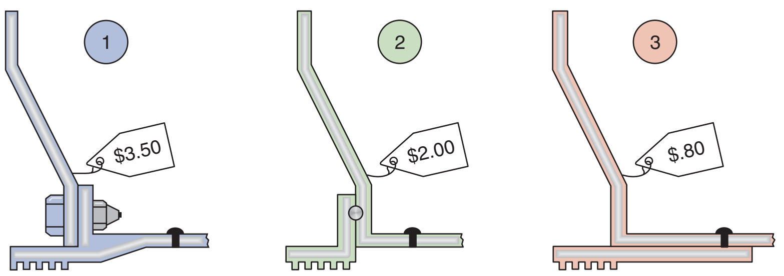
Manufacturability and value engineering
Activities that help improve a product's design, production, maintainability, and use.

Manufacturability and value engineering activities are concerned with improvement of design and specifications at the research, development, design, and preproduction stages of product development. In addition to immediate, obvious cost reduction, design for manufacturability and value engineering may produce other benefits. These include:

1. Reduced complexity of the product.
2. Reduction of environmental impact.
3. Additional standardization of components.
4. Improvement of functional aspects of the product.
5. Improved job design and job safety.
6. Improved maintainability (serviceability) of the product.
7. Robust design.

Manufacturability and value engineering activities may be the best cost-avoidance technique available to operations management. They yield value improvement by focusing on achieving the functional specifications necessary to meet customer requirements in an optimal way. Value engineering programs typically reduce costs between 15% and 70% without reducing quality, with every dollar spent yielding $10 to $25 in savings. The cost reduction achieved for a specific bracket via value engineering is shown in Figure 5.5.

Figure 5.5
Cost Reduction of a Bracket via Value Engineering



STUDENT TIP
Each time the bracket is redesigned and simplified, we are able to produce it for less.

Issues for Product Design

In addition to developing an effective system and organization structure for product development, several considerations are important to the design of a product. We will now review six of these: (1) robust design, (2) modular design, (3) computer-aided design/computer-aided manufacturing (CAD/CAM), (4) virtual reality technology, (5) value analysis, and (6) sustainability/life cycle assessment (LCA).

Robust Design

Robust design means that the product is designed so that small variations in production or assembly do not adversely affect the product. For instance, Lucent developed an integrated circuit that could be used in many products to amplify voice signals. As originally designed, the circuit had to be manufactured very expensively to avoid variations in the strength of the signal. But after testing and analyzing the design, Lucent engineers realized that if the resistance of the circuit was reduced—a minor change with no associated costs—the circuit would be far less sensitive to manufacturing variations. The result was a 40% improvement in quality.

Robust design
A design that can be produced to requirements even with unfavorable conditions in the production process.

Modular Design

Products designed in easily segmented components are known as **modular designs**. Modular designs offer flexibility to both production and marketing. Operations managers find modularity helpful because it makes product development, production, and subsequent changes easier. Marketing may like modularity because it adds flexibility to the ways customers can be satisfied. For instance, virtually all premium high-fidelity sound systems are produced and sold this way. The customization provided by modularity allows customers to mix and match to their own taste. This is also the approach taken by Harley-Davidson, where relatively few different engines, chassis, gas tanks, and suspension systems are mixed to produce a huge variety of motorcycles. It has been estimated that many automobile manufacturers can, by mixing the available modules, never make two cars alike. This same concept of modularity is carried over to many industries, from airframe manufacturers to fast-food restaurants. Airbus uses the same wing modules on several planes, just as McDonald's and Burger King use relatively few modules (cheese, lettuce, buns, sauces, pickles, meat patties, french fries, etc.) to make a variety of meals.

Modular design
A design in which parts or components of a product are subdivided into modules that are easily interchanged or replaced.

Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM)

Computer-aided design (CAD) is the use of computers to interactively design products and prepare engineering documentation. CAD uses three-dimensional drawing to save time and money by shortening development cycles for virtually all products (see the 3-D design photo in the Regal Marine Global Company Profile that opens this chapter). The speed and ease with which sophisticated designs can be manipulated, analyzed, and modified with CAD makes review of numerous options possible before final commitments are made. Faster development, better products, and accurate flow of information to other departments all contribute to a tremendous payoff for CAD. The payoff is particularly significant because most product costs are determined at the design stage.

Computer-aided design (CAD)
Interactive use of a computer to develop and document a product.

One extension of CAD is **design for manufacture and assembly (DFMA)** software, which focuses on the effect of design on assembly. For instance, DFMA allows Ford to build new vehicles in a virtual factory where designers examine how to put a transmission in a car on the production line, even while both the transmission and the car are still in the design stage.

Design for manufacture and assembly (DFMA)
Software that allows designers to look at the effect of design on manufacturing of the product.

CAD systems have moved to the Internet through e-commerce, where they link computerized design with purchasing, outsourcing, manufacturing, and long-term maintenance. This move also speeds up design efforts, as staff around the world can work on their unique work schedules. Rapid product change also supports the trend toward "mass customization" and, For prototypes, spares, and in the case of Jay Leno's classic car collection, difficult-to-replace parts, 3D printing is often the answer. By scanning the original part, creating a digital file, making the necessary modifications, and feeding that data into a 3D printer, Jay's shop can make parts not otherwise available for his 1906 Stanley Steamer.

Paul Drinkwater/NBC/NBCU Photo Bank/Getty Images

when carried to an extreme, allows customers to enter a supplier's design libraries and make changes. The result is faster and less expensive customized products. As product life cycles shorten, designs become more complex, and global collaboration has grown, the European Community (EU) has developed a **standard for the exchange of product data (STEP; ISO 10303)**. STEP permits 3-D product information to be expressed in a standard format so it can be exchanged internationally.

Standard for the exchange of product data (STEP)
A standard that provides a format allowing the electronic transmission of three-dimensional data.

Computer-aided manufacturing (CAM) refers to the use of specialized computer programs to direct and control manufacturing equipment. When CAD information is translated into instructions for CAM, the result of these two technologies is CAD/CAM. The combination is a powerful tool for manufacturing efficiency. Fewer defective units are produced, translating into less rework and lower inventory. More precise scheduling also contributes to less inventory and more efficient use of personnel.

Computer-aided manufacturing (CAM)
The use of information technology to control machinery.

A related extension of CAD is **3-D printing**. This technology is particularly useful for prototype development and small lot production (as shown in the photo above). 3-D printing speeds development by avoiding a more lengthy and formal manufacturing process, as we see in the *OM in Action* box "3-D Printers Hit the Mainstream."

3-D printing
An extension of CAD that builds prototypes and small lots.

Virtual Reality Technology

Virtual reality is a visual form of communication in which images substitute for the real thing but still allow the user to respond interactively. The roots of virtual reality technology in operations are in CAD. Once design information is in a CAD system, it is also in electronic digital form for other uses, such as developing 3-D layouts of everything from retail stores and restaurant layouts to amusement parks. Procter & Gamble, for instance, builds walk-in virtual

Virtual reality
A visual form of communication in which images substitute for reality and typically allow the user to respond interactively.

OM in Action 3-D Printers Hit the Mainstream

3-D printers are revolutionizing the product design process. With instructions from 3-D CAD models, these printers "build" products by laying down successive thin layers of plastic, metal, glass, or ceramics. Indeed, for many firms, 3-D printers have become indispensable.

The medical field uses the machines to make custom hearing aids. Invisalign Corp. produces individualized braces for teeth. Architects use the technology to produce models of buildings, and consumer electronics companies build prototypes of their latest gadgets. Microsoft uses 3-D printers to help design computer mouse devices and keyboards, while Mercedes, Honda, Boeing, and Lockheed Martin use them to fashion prototypes and to make parts that go into final products. Eventually, "a person who buys a BMW will want a part of the car with their name on it or to customize the seats to the contours of their bodies," says 3-D Systems's CEO. And currently 3-D printing at Hershey's Chocolate World attraction means customers can order their likeness or wedding cake decoration in chocolate.

The cost of 3-D printing continues to drop. Now anyone can buy a 3-D printer, hook it up to a Wi-Fi network, and begin downloading files that will turn into real objects. Another beauty and value of 3-D printing is that it has the power to unleash a world of creative energy: People who previously only thought about an invention or improved product can now quickly make it real.

Sources: Advertising Age (January 28, 2015); *BusinessWeek* (April 30, 2012); and *The Wall Street Journal* (July 16, 2011).

stores to rapidly generate and test ideas. Changes to mechanical design, layouts, and even amusement park rides are much less expensive at the design stage than they are later.

Value Analysis

Although value engineering (discussed on page 170) focuses on *preproduction* design and manufacturing issues, value analysis, a related technique, takes place *during* the production process, when it is clear that a new product is a success. **Value analysis** seeks improvements that lead to either a better product, or a product made more economically, or a product with less environmental impact. The techniques and advantages for value analysis are the same as for value engineering, although minor changes in implementation may be necessary because value analysis is taking place while the product is being produced.

Value analysis
A review of successful products that takes place during the production process.

Sustainability and Life Cycle Assessment (LCA)

Product design requires that managers evaluate product options. Addressing sustainability and life cycle assessment (LCA) are two ways of doing this. *Sustainability* means meeting the needs of the present without compromising the ability of future generations to meet their needs. An LCA is a formal evaluation of the environmental impact of a product. Both sustainability and LCA are discussed in depth in the supplement to this chapter.

Product Development Continuum

STUDENT TIP
Fast communication, rapid technological change, and short product life cycles push product development.

As product life cycles shorten, the need for faster product development increases. And as technological sophistication of new products increases, so do the expense and risk. For instance, drug firms invest an average of 12 to 15 years and $1 billion before receiving regulatory approval for a new drug. And even then, only 1 of 5 will actually be a success. Those operations managers who master this art of product development continually gain on slower product developers. To the swift goes the competitive advantage. This concept is called **time-based competition**.

Time-based competition
Competition based on time; rapidly developing products and moving them to market.

Often, the first company into production may have its product adopted for use in a variety of applications that will generate sales for years. It may become the "standard." Consequently, there is often more concern with getting the product to market than with optimum product design or process efficiency. Even so, rapid introduction to the market may be good management because until competition begins to introduce copies or improved versions, the product can sometimes be priced high enough to justify somewhat inefficient production design and methods.

LO 5.4 *Explain* how time-based competition is implemented by OM

Because time-based competition is so important, instead of developing new products from scratch (which has been the focus thus far in this chapter), a number of other strategies can be used. Figure 5.6 shows a continuum that goes from new, internally developed products (on the lower left) to "alliances." *Enhancements* and *migrations* use the organization's existing product strengths for innovation and therefore are typically faster while at the same time being less risky than developing entirely new products.

Enhancements may be changes in color, size, weight, taste, or features, such as are taking place in fast-food menu items (see the *OM in Action* box "Product Development at Taco Bell" on the next page), or even changes in commercial aircraft. Boeing's enhancements of the 737 since its introduction in 1967 has made the 737 the largest-selling commercial aircraft in history.

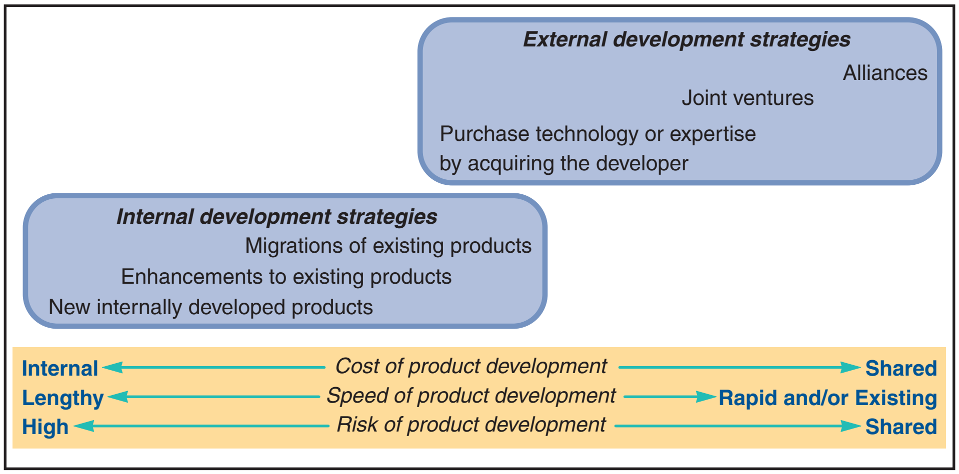
Boeing also uses its engineering prowess in air frames to *migrate* from one model to the next. This allows Boeing to speed development while reducing both cost and risk for new designs. This approach is also referred to as building on *product platforms*. Similarly, Volkswagen is using a versatile automobile platform (the MQB chassis) for small to midsize front-wheel-drive cars. This includes VW's Polo, Golf, Passat, Tiguan, and Skoda Octavia, and it may eventually include 44 different vehicles. The advantages are downward pressure on cost as well as faster development. Hewlett-Packard has done the same in the printer business. Enhancements and platform migrations are a way of building on existing expertise, speeding product development, and extending a product's life cycle.

The product development strategies on the lower left of Figure 5.6 are *internal* development strategies, while the three approaches we now introduce can be thought of as *external*

Figure **5.6**

Product Development Continuum

Product Development Continuum



STUDENT TIP

Managers seek a variety of approaches to obtain speed to market. As the president of one U.S. firm said: "If I miss one product cycle, I'm dead."

development strategies. Firms use both. The external strategies are (1) purchase the technology, (2) establish joint ventures, and (3) develop alliances.

Purchasing Technology by Acquiring a Firm

Microsoft and Cisco Systems are examples of companies on the cutting edge of technology that often speed development by *acquiring entrepreneurial firms* that have already developed the technology that fits their mission. The issue then becomes fitting the purchased organization, its technology, its product lines, and its culture into the buying firm, rather than a product development issue.

Joint ventures

Firms establishing joint ownership to pursue new products or markets.

Joint Ventures

In an effort to reduce the weight of new cars, GM is in a joint venture with Tokyo-based Teijin Ltd. to bring lightweight carbon fiber to GM's customers. **Joint ventures** such as this are

OM in Action — Product Development at Taco Bell

Chains such as Chipotle, Carl's Jr., and In-N-Out Burger may rely on a stable menu of popular items, but Taco Bell creates a constant rotation of products in hopes of not only keeping consumers coming back, but also uncovering the next big seller. Taco Bell seeks to be the leader in fast-food innovation and believes there is no finish line when it comes to being first and staying relevant. Breakfast is the fastest-growing part of the fast-food market—with dinner sales declining and lunch sales flat. Moreover, breakfast items tend to have good margins, making the crafting of breakfast hits, such as Taco Bell's new A.M. Crunchwrap and Waffle Taco, lucrative additions.

In search of ideas, the product developers mine social media, consider new ingredients, and track rivals. Some Fridays, the team does what they've dubbed a "grocery store hustle" to see what's new in retail. But the basic pillars of anything they develop remain taste, value, and speed—all of which must be attainable within the constraints and operations capability of the Taco Bell kitchen. The less a restaurant has to change its kitchen operations, ingredients, or equipment, the better.

Taco Bell's 40-person product innovation team looks at 4,000 to 4,500 ideas every year. From there developers come up with 300 to 500 prototypes, which they then test on consumers in the lab and in test restaurants. From this huge array, Taco Bell selects dozens of items in various permutations for further review. Usually, only 8 to 10 of the new product ideas make the Taco Bell menu.

The typical product goes through about 100 iterations by the time it is launched. The Waffle Taco, for instance, was changed 80 times through various characteristics such as shape, weight, thickness, intensity of vanilla flavor in the shell, and fillings.

Jonathan Leibson/Getty Images

Taco Bell's New Waffle Taco

Sources: BusinessWeek (June 2–9, 2014); *The Wall Street Journal* (Dec. 4, 2014); www.grubgrade.com; investorplace.com/2014/03.

combined ownership, usually between just two firms, to form a new entity. Ownership can be 50–50, or one owner can assume a larger portion to ensure tighter control. Joint ventures are often appropriate for exploiting specific product opportunities that may not be central to the firm's mission. Such ventures are more likely to work when the risks are known and can be equitably shared.

Alliances

When new products are central to the mission, but substantial resources are required and sizable risk is present, then alliances may be a good strategy for product development. **Alliances** are cooperative agreements that allow firms to remain independent but use complementing strengths to pursue strategies consistent with their individual missions. Alliances are particularly beneficial when the products to be developed also have technologies that are in ferment. For example, Microsoft is pursuing alliances with a variety of companies to deal with the convergence of computing, the Internet, and television broadcasting. Alliances in this case are appropriate because the technological unknowns, capital demands, and risks are significant. Similarly, three firms, Mercedes-Benz, Ford Motor, and Ballard Power Systems, have formed an alliance to develop "green" cars powered by fuel cells. Alliances are much more difficult to achieve and maintain than joint ventures because of the ambiguities associated with them. It may be helpful to think of an alliance as an incomplete contract between the firms. The firms remain separate.

Alliances
Cooperative agreements that allow firms to remain independent, but pursue strategies consistent with their individual missions.

Enhancements, migration, acquisitions, joint ventures, and alliances are all strategies for speeding product development. Moreover, they typically reduce the risk associated with product development while enhancing the human and capital resources available.

Defining a Product

STUDENT TIP
Before anything can be produced, a product's functions and attributes must be defined.

Once new goods or services are selected for introduction, they must be defined. First, a good or service is defined in terms of its *functions*—that is, what it is to *do*. The product is then designed, and the firm determines how the functions are to be achieved. Management typically has a variety of options as to how a product should achieve its functional purpose. For instance, when an alarm clock is produced, aspects of design such as the color, size, or location of buttons may make substantial differences in ease of manufacture, quality, and market acceptance.

LO 5.5 *Describe* how products and services are defined by OM

Rigorous specifications of a product are necessary to ensure efficient production. Equipment, layout, and human resources cannot be determined until the product is defined, designed, and documented. Therefore, every organization needs documents to define its products. This is true of everything from meat patties, to cheese, to computers, to a medical procedure. In the case of cheese, a written specification is typical. Indeed, written specifications or standard grades exist and provide the definition for many products. For instance, Monterey Jack cheese has a written description that specifies the characteristics necessary for each Department of Agriculture grade. A portion of the Department of Agriculture grade for Monterey Jack Grade AA is shown in Figure 5.7. Similarly, McDonald's Corp. has 60 specifications for potatoes that are to be made into french fries.

Most manufactured items, as well as their components, are defined by a drawing, usually referred to as an engineering drawing. An **engineering drawing** shows the dimensions, tolerances, materials, and finishes of a component. The engineering drawing will be an item on a bill of material. An engineering drawing is shown in Figure 5.8. The **bill of material (BOM)** lists the hierarchy of components, their description, and the quantity of each required to make one unit of a product. A bill of material for a manufactured item is shown in Figure 5.9(a). Note that subassemblies and components (lower-level items) are indented at each level to indicate their subordinate position. An engineering drawing shows how to make one item on the bill of material.

Engineering drawing
A drawing that shows the dimensions, tolerances, materials, and finishes of a component.

Bill of material (BOM)
A list of the hierarchy of components, their description, and the quantity of each required to make one unit of a product.

Figure **5.7**

Monterey Jack

A portion of the general requirements for the U.S. grades of Monterey Jack cheese is shown here.

Source: Based on 58.2469 Specifications for U.S. grades of Monterey (Monterey Jack) cheese, (May 10, 1996).

§ 58.2469 Specifications for U.S. grades of Monterey (Monterey Jack) cheese

(a) *U.S. grade AA.* Monterey Cheese shall conform to the following requirements:

(1) *Flavor.* Is fine and highly pleasing, free from undesirable flavors and odors. May possess a very slight acid or feed flavor.

(2) *Body and texture.* A plug drawn from the cheese shall be reasonably firm. It shall have numerous small mechanical openings evenly distributed throughout the plug. It shall not possess sweet holes, yeast holes, or other gas holes.

(3) *Color.* Shall have a natural, uniform, bright, attractive appearance.

(4) *Finish and appearance—bandaged and paraffin-dipped.* The rind shall be sound, firm, and smooth, providing a good protection to the cheese.

Code of Federal Regulation, Parts 53 to 109, General Service Administration.

David Murray/Dorling Kindersley, Ltd.

In the food-service industry, bills of material manifest themselves in *portion-control standards*. The portion-control standard for Hard Rock Cafe's hickory BBQ bacon cheeseburger is shown in Figure 5.9(b). In a more complex product, a bill of material is referenced on other bills of material of which they are a part. In this manner, subunits (subassemblies) are part of the next higher unit (their parent bill of material) that ultimately makes a final product. In addition to being defined by written specifications, portion-control documents, or bills of material, products can be defined in other ways. For example, products such as chemicals, paints, and petroleums may be defined by formulas or proportions that describe how they are to be made. Movies are defined by scripts, and insurance coverage by legal documents known as policies.

Make-or-Buy Decisions

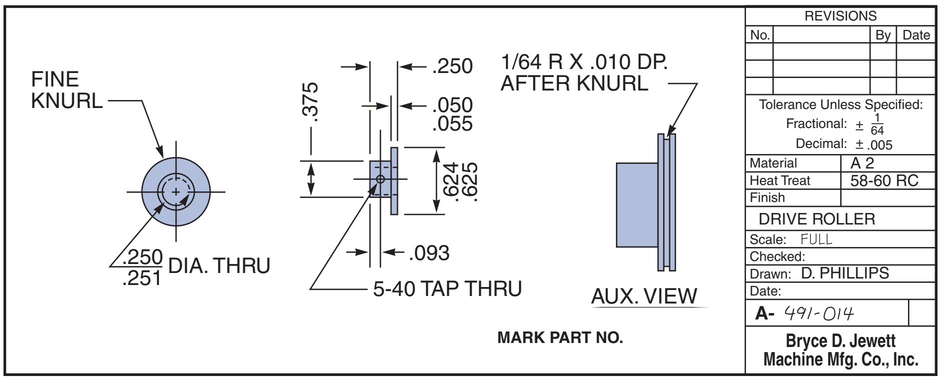
Make-or-buy decision

The choice between producing a component or a service and purchasing it from an outside source.

For many components of products, firms have the option of producing the components themselves or purchasing them from outside sources. Choosing between these options is known as the make-or-buy decision. The **make-or-buy decision** distinguishes between what the firm wants to *produce* and what it wants to *purchase*. Because of variations in quality, cost, and delivery schedules, the make-or-buy decision is critical to product definition. Many items can be purchased as a "standard item" produced by someone else. Examples are the standard bolts listed twice on the bill of material shown in Figure 5.9(a), for which there will be SAE (Society

Figure **5.8**

Engineering Drawings Such as This One Show Dimensions, Tolerances, Materials, and Finishes



(a) **Bill of Material for a Panel Weldment**

NUMBER	DESCRIPTION	QTY
A 60-71	PANEL WELDM'T	1
A 60-7	LOWER ROLLER ASSM.	1
R 60-17	ROLLER	1
R 60-428	PIN	1
P 60-2	LOCKNUT	1
A 60-72	GUIDE ASSM. REAR	1
R 60-57-1	SUPPORT ANGLE	1
A 60-4	ROLLER ASSEM.	1
02-50-1150	BOLT	1
A 60-73	GUIDE ASSM. FRONT	1
A 60-74	SUPPORT WELDM'T	1
R 60-99	WEAR PLATE	1
02-50-1150	BOLT	1

(b) **Hard Rock Cafe's Hickory BBQ Bacon Cheeseburger**

DESCRIPTION	QTY
Bun	1
Hamburger patty	8 oz.
Cheddar cheese	2 slices
Bacon	2 strips
BBQ onions	1/2 cup
Hickory BBQ sauce	1 oz.
Burger set	
Lettuce	1 leaf
Tomato	1 slice
Red onion	4 rings
Pickle	1 slice
French fries	5 oz.
Seasoned salt	1 tsp.
11-inch plate	1
HRC flag	1

Figure **5.9**

Bills of Material Take Different Forms in a (a) Manufacturing Plant and (b) Restaurant, but in Both Cases, the Product Must Be Defined

STUDENT TIP

Hard Rock's recipe here serves the same purpose as a bill of material in a factory: It defines the product for production.

of Automotive Engineers) specifications. Therefore, there typically is no need for the firm to duplicate this specification in another document.

Group Technology

Engineering drawings may also include codes to facilitate group technology. **Group technology** identifies components by a coding scheme that specifies size, shape, and the type of processing (such as drilling). This facilitates standardization of materials, components, and processes as well as the identification of families of parts. As families of parts are identified, activities and machines can be grouped to minimize setups, routings, and material handling. An example of how families of parts may be grouped is shown in Figure 5.10. Group technology provides a systematic way to review a family of components to see if an existing component might suffice on a new project. Using existing or standard components eliminates all the costs connected with the design and development of the new part, which is a major cost reduction.

Group technology

A product and component coding system that specifies the size, shape, and type of processing; it allows similar products to be grouped.

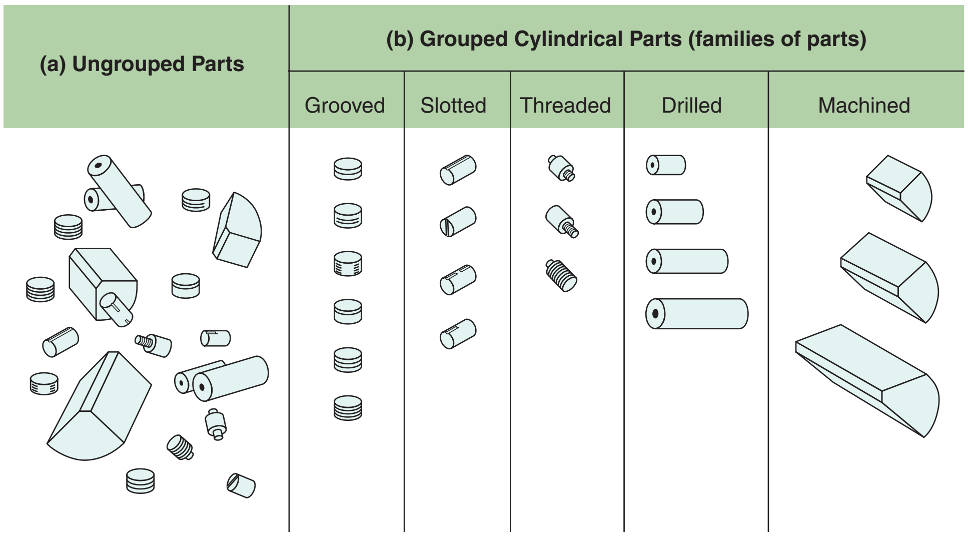


Figure **5.10**

A Variety of Group Technology Coding Schemes Move Manufactured Components from (a) Ungrouped to (b) Grouped (families of parts)

Documents for Production

STUDENT TIP Production personnel need clear, specific documents to help them make the product.

Once a product is selected, designed, and ready for production, production is assisted by a variety of documents. We will briefly review some of these.

An **assembly drawing** simply shows an exploded view of the product. An assembly drawing is usually a three-dimensional drawing, known as an *isometric drawing*; the relative locations of components are drawn in relation to each other to show how to assemble the unit [see Figure 5.11(a)].

Assembly drawing
An exploded view of the product.

The **assembly chart** shows in schematic form how a product is assembled. Manufactured components, purchased components, or a combination of both may be shown on an assembly chart. The assembly chart identifies the point of production at which components flow into subassemblies and ultimately into a final product. An example of an assembly chart is shown in Figure 5.11(b).

Assembly chart
A graphic means of identifying how components flow into subassemblies and final products.

The **route sheet** lists the operations necessary to produce the component with the material specified in the bill of material. The route sheet for an item will have one entry for each operation to be performed on the item. When route sheets include specific methods of operation and labor standards, they are often known as *process sheets*.

Route sheet
A listing of the operations necessary to produce a component with the material specified in the bill of material.

The **work order** is an instruction to make a given quantity of a particular item, usually to a given schedule. The ticket that a waiter writes in your favorite restaurant is a work order. In a hospital or factory, the work order is a more formal document that provides authorization to draw items from inventory, to perform various functions, and to assign personnel to perform those functions.

Work order
An instruction to make a given quantity of a particular item.

Engineering change notices (ECNs) change some aspect of the product's definition or documentation, such as an engineering drawing or a bill of material. For a complex product that has a long manufacturing cycle, such as a Boeing 777, the changes may be so numerous that no two 777s are built exactly alike—which is indeed the case. Such dynamic design change has fostered the development of a discipline known as configuration management, which is concerned with product identification, control, and documentation. **Configuration management** is the system by which a product's planned and changing configurations are accurately identified and for which control and accountability of change are maintained.

Engineering change notice (ECN)
A correction or modification of an engineering drawing or bill of material.

Configuration management
A system by which a product's planned and changing components are accurately identified.

Product Life-Cycle Management (PLM)

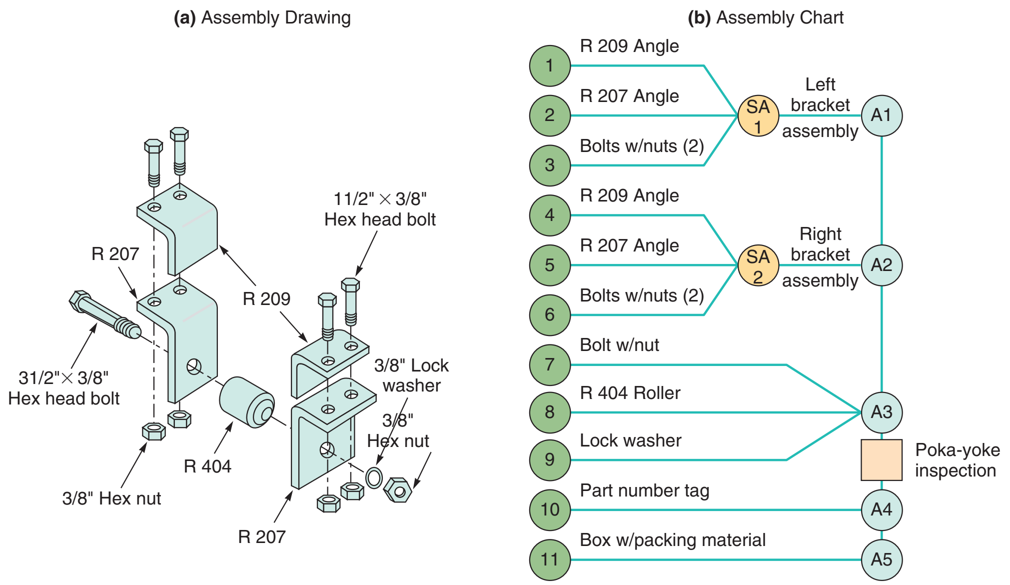
Product life-cycle management (PLM) is an umbrella of software programs that attempts to bring together phases of product design and manufacture—including tying together many of

Product life-cycle management (PLM)
Software programs that tie together many phases of product design and manufacture.

Figure **5.11**

Assembly Drawing and Assembly Chart

Source: Assembly drawing and assembly chart produced by author.




J.R. Simplot Company


J.R. Simplot Company

Each year the JR Simplot potato-processing facility in Caldwell, Idaho, produces billions of french fries for quick-service restaurant chains and many other customers, both domestically and overseas (left photo). Sixty specifications (including a special blend of frying oil, a unique steaming process, and exact time and temperature for prefrying and drying) define how these potatoes become french fries. Further, 40% of all french fries must be 2 to 3 inches long, 40% must be over 3 inches long, and a few stubby ones constitute the final 20%. Quality control personnel use a micrometer to measure the fries (right photo).

the techniques discussed in the prior two sections, *Defining a Product* and *Documents for Production*. The idea behind PLM software is that product design and manufacture decisions can be performed more creatively, faster, and more economically when the data are integrated and consistent.

Although there is not one standard, PLM products often start with product design (CAD/CAM); move on to design for manufacture and assembly (DFMA); and then into product routing, materials, layout, assembly, maintenance, and even environmental issues. Integration of these tasks makes sense because many of these decision areas require overlapping pieces of data. PLM software is now a tool of many large organizations, including Lockheed Martin, GE, Procter & Gamble, Toyota, and Boeing. Boeing estimates that PLM will cut final assembly of its 787 jet from 2 weeks to 3 days. PLM is now finding its way into medium and small manufacture as well.

LO 5.6 *Describe* the documents needed for production

Shorter life cycles, more technologically challenging products, more regulations regarding materials and manufacturing processes, and more environmental issues all make PLM an appealing tool for operations managers. Major vendors of PLM software include SAP PLM (www.mySAP.com), Parametric Technology Corp. (www.ptc.com), Siemens (www.plm.automation.siemens.com), and Proplanner (www.proplanner.com).

Service Design

STUDENT TIP
Services also need to be defined and documented.

Much of our discussion so far has focused on what we can call tangible products—that is, goods. On the other side of the product coin are, of course, services. Service industries include banking, finance, insurance, transportation, and communications. The products offered by service firms range from a medical procedure that leaves only the tiniest scar after an appendectomy, to a shampoo and cut at a hair salon, to a great sandwich. Designing services is challenging because they have a unique characteristic—customer interaction.

Process–Chain–Network (PCN) Analysis

Process–chain–network (PCN) analysis
Analysis that focuses on the ways in which processes can be designed to optimize interaction between firms and their customers.

Process–chain–network (PCN) analysis, developed by Professor Scott Sampson, focuses on the ways in which processes can be designed to optimize interaction between firms and

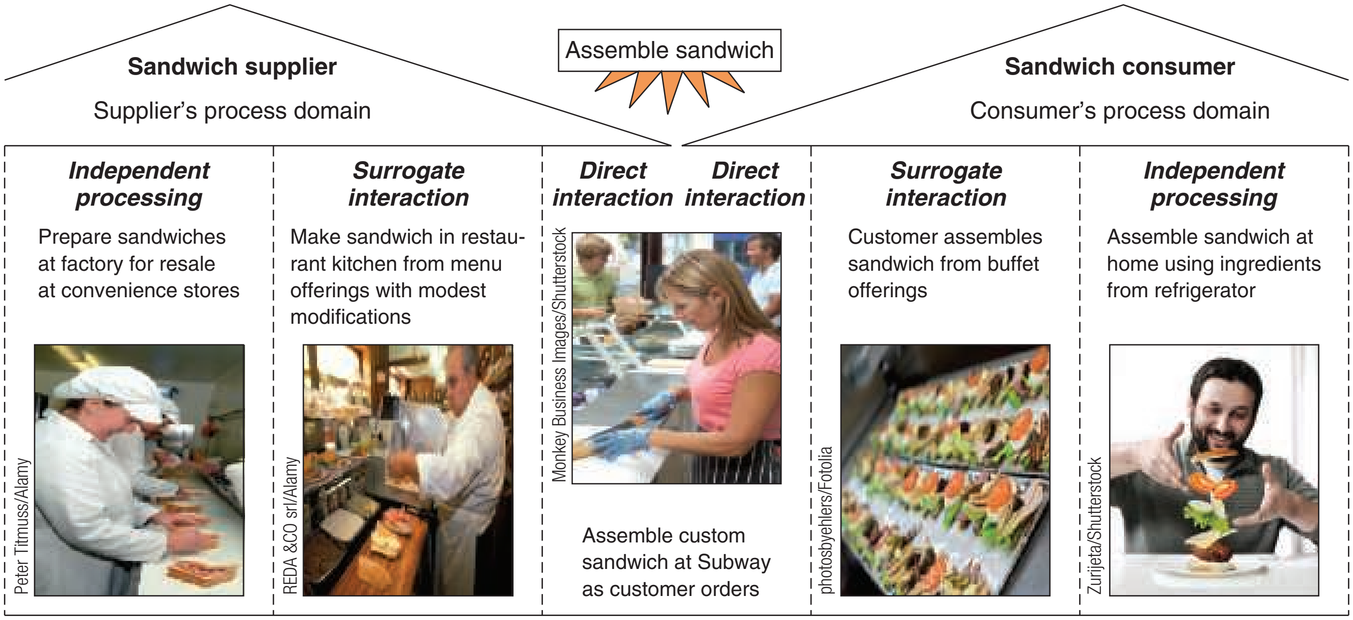


Figure 5.12

Customer Interaction Is a Strategic Choice

Process chain

A sequence of steps that accomplishes an identifiable purpose (of providing value to process participants).

their customers.[2] A **process chain** is a sequence of steps that accomplishes an activity, such as building a home, completing a tax return, or preparing a sandwich. A process participant can be a manufacturer, a service provider, or a customer. A network is a set of participants.

Each participant has a *process domain* that includes the set of activities over which it has control. The domain and interactions between two participants for sandwich preparation are shown in the PCN diagram (Figure 5.12). The activities are organized into three *process regions* for each participant:

1. The *direct interaction* region includes process steps that involve interaction between participants. For example, a sandwich buyer directly interacts with employees of a sandwich store (e.g., Subway, in the middle of Figure 5.12).
2. The *surrogate (substitute) interaction* region includes process steps in which one participant is acting on another participant's resources, such as their information, materials, or technologies. This occurs when the sandwich *supplier* is making sandwiches in the restaurant kitchen (left side of Figure 5.12) or, alternately, when the *customer* has access to buffet ingredients and assembles the sandwich himself (right side of the figure). Under surrogate interaction, *direct* interaction is limited.
3. The *independent processing* region includes steps in which the sandwich supplier and/or the sandwich customer is acting on resources where each has maximum control. Most make-to-stock production fits in this region (left side of Figure 5.12; think of the firm that assembles all those prepackaged sandwiches available in vending machines and convenience stores). Similarly, those sandwiches built at home occur to the right, in the customer's independent processing domain.

LO 5.7 *Explain* how the customer participates in the design and delivery of services

All three process regions have similar operating issues—quality control, facility location and layout, job design, inventory, and so on—but the appropriate way of handling the issues differs across regions. Service operations exist only within the area of *direct* and *surrogate interaction*.

From the operations manager's perspective, the valuable aspect of PCN analysis is insight to aid in positioning and designing processes that can achieve strategic objectives. A firm's operations are strategic in that they can define what type of business the firm is in and what value proposition it desires to provide to customers. For example, a firm may assume a low-cost strategy, operating on the left of Figure 5.12 as a manufacturer of premade sandwiches. Other firms (e.g., Subway) adopt a differentiation strategy with high customer interaction. Each of the process regions depicts a unique operational strategy.

Firms wanting to achieve high economies of scale or more control in their operations should probably position toward the independent processing region of their process domain. Firms intending to provide a value offering that focuses on customization should be positioned more toward the consumer's process domain. PCN analysis can be applied in a wide variety of business settings.

Adding Service Efficiency

Service productivity is notoriously low, in part because of customer involvement in the *design* or *delivery* of the service, or both. This complicates the product design challenge. We will now discuss a number of ways to increase service efficiency and, among these, several ways to limit this interaction.

Limit the Options Because customers may participate in the *design* of the service (e.g., for a funeral or a hairstyle), design specifications may take the form of everything from a menu (in a restaurant), to a list of options (for a funeral), to a verbal description (a hairstyle). However, by providing a list of options (in the case of the funeral) or a series of photographs (in the case of the hairstyle), ambiguity may be reduced. An early resolution of the product's definition can aid efficiency as well as aid in meeting customer expectations.

Delay Customization Design the product so that *customization is delayed* as late in the process as possible. This is the way a hair salon operates. Although shampoo and condition are done in a standard way with lower-cost labor, the color and styling (customizing) are done last. It is also the way most restaurants operate: How would you like that cooked? Which dressing would you prefer with your salad?

Modularization *Modularize* the service so that customization takes the form of changing modules. This strategy allows for "custom" services to be designed as standard modular entities. Just as modular design allows you to buy a high-fidelity sound system with just the features you want, modular flexibility also lets you buy meals, clothes, and insurance on a mix-and-match (modular) basis. Investments (portfolios of stocks and bonds) and education (college curricula) are examples of how the modular approach can be used to customize a service.

Automation Divide the service into small parts, and identify those parts that lend themselves to automation. For instance, by isolating check-cashing activity via ATM, banks have been very effective at designing a product that both increases customer service and reduces costs. Similarly, airlines have moved to ticketless service via kiosks. A technique such as kiosks reduces both costs and lines at airports—thereby increasing customer satisfaction—and providing a win–win "product" design.

Moment of Truth High customer interaction means that in the service industry there is a *moment of truth* when the relationship between the provider and the customer is crucial. At that moment, the customer's satisfaction with the service is defined. The moment of truth is the moment that exemplifies, enhances, or detracts from the customer's expectations. That moment may be as simple as a smile from a Starbucks barista or having the checkout clerk focus on you rather than talking over his shoulder to the clerk at the next counter. Moments of truth can occur when you order at McDonald's, get a haircut, or register for college courses. The operations manager's task is to identify moments of truth and design operations that meet or exceed the customer's expectations.

Documents for Services

Because of the high customer interaction of most services, the documents for moving the product to production often take the form of explicit *job instructions* or *script*. For instance, regardless of how good a bank's products may be in terms of checking, savings, trusts, loans, mortgages, and so forth, if the interaction between participants is not done well, the product may be poorly received. Example 2 shows the kind of documentation a bank may use to move a product (drive-up window banking) to "production." Similarly, a telemarketing service has the product design communicated to production personnel in the form of a *telephone script*, while a *manuscript* is used for books, and a *storyboard* is used for movie and TV production.

Example 2

SERVICE DOCUMENTATION FOR PRODUCTION

First Bank Corp. wants to ensure effective delivery of service to its drive-up customers.

APPROACH ▶ Develop a "production" document for the tellers at the drive-up window that provides the information necessary to do an effective job.

SOLUTION ▶

Documentation for Tellers at Drive-up Windows

Customers who use the drive-up teller windows rather than walk-in lobbies require a different customer relations technique. The distance and machinery between the teller and the customer raises communication barriers. Guidelines to ensure good customer relations at the drive-up window are:

- Be especially discreet when talking to the customer through the microphone.
- Provide written instructions for customers who must fill out forms you provide.
- Mark lines to be completed or attach a note with instructions.
- Always say "please" and "thank you" when speaking through the microphone.
- Establish eye contact with the customer if the distance allows it.
- If a transaction requires that the customer park the car and come into the lobby, apologize for the inconvenience.

Source: Adapted with permission from *Teller Operations* (Chicago, IL: The Institute of Financial Education, 1999): 32.

INSIGHT ▶ By providing documentation in the form of a script/guideline for tellers, the likelihood of effective communication and a good product/service is improved.

LEARNING EXERCISE ▶ Modify the guidelines above to show how they would be different for a drive-through restaurant. [Answer: Written instructions, marking lines to be completed, or coming into the store are seldom necessary, but techniques for making change and proper transfer of the order should be included.]

RELATED PROBLEM ▶ 5.11

Application of Decision Trees to Product Design

STUDENT TIP A decision tree is a great tool for thinking through a problem.

Decision trees can be used for new-product decisions as well as for a wide variety of other management problems when uncertainty is present. They are particularly helpful when there are a series of decisions and various outcomes that lead to *subsequent* decisions followed by other outcomes. To form a decision tree, we use the following procedure:

LO 5.8 *Apply* decision trees to product issues

1. Be sure that all possible alternatives and states of nature (beginning on the left and moving right) are included in the tree. This includes an alternative of "doing nothing."
2. Payoffs are entered at the end of the appropriate branch. This is the place to develop the payoff of achieving this branch.
3. The objective is to determine the expected monetary value (EMV) of each course of action. We accomplish this by starting at the end of the tree (the right-hand side) and working toward the beginning of the tree (the left), calculating values at each step and "pruning" alternatives that are not as good as others from the same node.

Example 3 shows the use of a decision tree applied to product design.

Example 3

DECISION TREE APPLIED TO PRODUCT DESIGN

Silicon, Inc., a semiconductor manufacturer, is investigating the possibility of producing and marketing a microprocessor. Undertaking this project will require either purchasing a sophisticated CAD system or hiring and training several additional engineers. The market for the product could be either favorable or unfavorable. Silicon, Inc., of course, has the option of not developing the new product at all.

With favorable acceptance by the market, sales would be 25,000 processors selling for $100 each. With unfavorable acceptance, sales would be only 8,000 processors selling for $100 each. The cost of CAD equipment is $500,000, but that of hiring and training three new engineers is only $375,000. However, manufacturing costs should drop from $50 each when manufacturing without CAD to $40 each when manufacturing with CAD.

The probability of favorable acceptance of the new microprocessor is .40; the probability of unfavorable acceptance is .60.

APPROACH ▶ Use of a decision tree seems appropriate as Silicon, Inc., has the basic ingredients: a choice of decisions, probabilities, and payoffs.

SOLUTION ▶ In Figure 5.13 we draw a decision tree with a branch for each of the three decisions, assign the respective probabilities and payoff for each branch, and then compute the respective EMVs. The expected monetary values (EMVs) have been circled at each step of the decision tree. For the top branch:

$$\text{EMV (Purchase CAD system)} = (.4)(\$1{,}000{,}000) + (.6)(-\$20{,}000) = \$388{,}000$$

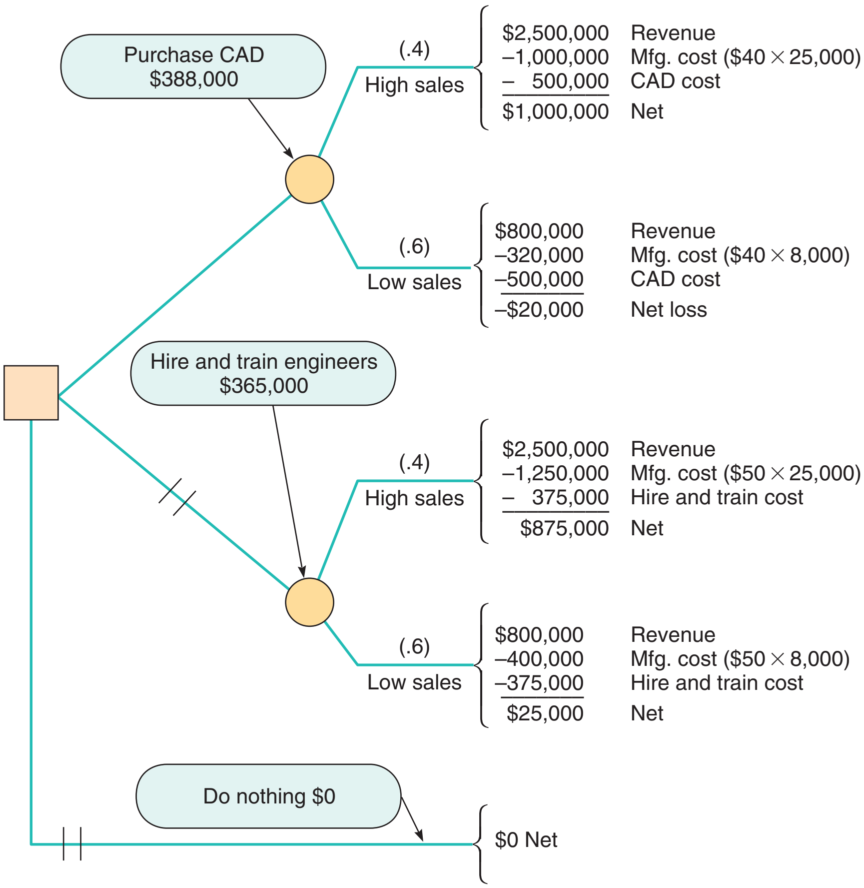
This figure represents the results that will occur if Silicon, Inc., purchases CAD.

The expected value of hiring and training engineers is the second series of branches:

$$\text{EMV (Hire/train engineers)} = (.4)(\$875{,}000) + (.6)(\$25{,}000) = \$365{,}000$$

Figure **5.13**

Decision Tree for Development of a New Product



STUDENT TIP

The manager's options are to purchase CAD, hire/train engineers, or do nothing. Purchasing CAD has the highest EMV.

The EMV of doing nothing is $0.

Because the top branch has the highest expected monetary value (an EMV of $388,000 vs. $365,000 vs. $0), it represents the best decision. Management should purchase the CAD system.

INSIGHT ▶ Use of the decision tree provides both objectivity and structure to our analysis of the Silicon, Inc., decision.

LEARNING EXERCISE ▶ If Silicon, Inc., thinks the probabilities of high sales and low sales may be equal, at .5 each, what is the best decision? [Answer: Purchase CAD remains the best decision, but with an EMV of $490,000.]

RELATED PROBLEMS ▶ 5.21–5.27 (5.28 is available in MyOMLab)

ACTIVE MODEL 5.1 This example is further illustrated in Active Model 5.1 in MyOMLab.

STUDENT TIP One of the arts of management is knowing when a product should move from development to production.

Transition to Production

Eventually, a product, whether a good or service, has been selected, designed, and defined. It has progressed from an idea to a functional definition, and then perhaps to a design. Now, management must make a decision as to further development and production or termination of the product idea. One of the arts of management is knowing when to move a product from development to production; this move is known as *transition to production*. The product development staff is always interested in making improvements in a product. Because this staff tends to see product development as evolutionary, they may never have a completed product, but as we noted earlier, the cost of late product introduction is high. Although these conflicting pressures exist, management must make a decision—more development or production.

Once this decision is made, there is usually a period of trial production to ensure that the design is indeed producible. This is the manufacturability test. This trial also gives the operations staff the opportunity to develop proper tooling, quality control procedures, and training of personnel to ensure that production can be initiated successfully. Finally, when the product is deemed both marketable and producible, line management will assume responsibility.

To ensure that the transition from development to production is successful, some companies appoint a *project manager*; others use *product development teams*. Both approaches allow a wide range of resources and talents to be brought to bear to ensure satisfactory production of a product that is still in flux. A third approach is *integration of the product development and manufacturing organizations*. This approach allows for easy shifting of resources between the two organizations as needs change. The operations manager's job is to make the transition from R&D to production seamless.

Summary

Effective product strategy requires selecting, designing, and defining a product and then transitioning that product to production. Only when this strategy is carried out effectively can the production function contribute its maximum to the organization. The operations manager must build a product development system that has the ability to conceive, design, and produce products that will yield a competitive advantage for the firm. As products move through their life cycle (introduction, growth, maturity, and decline), the options that the operations manager should pursue change. Both manufactured and service products have a variety of techniques available to aid in performing this activity efficiently.

Written specifications, bills of material, and engineering drawings aid in defining products. Similarly, assembly drawings, assembly charts, route sheets, and work orders are often used to assist in the actual production of the product. Once a product is in production, value analysis is appropriate to ensure maximum product value. Engineering change notices and configuration management provide product documentation.

Key Terms

Product decision (p. 163)
Product-by-value analysis (p. 165)
Quality function deployment (QFD) (p. 166)
House of quality (p. 166)
Product development teams (p. 170)
Concurrent engineering (p. 170)
Manufacturability and value engineering (p. 170)
Robust design (p. 171)
Modular design (p. 171)
Computer-aided design (CAD) (p. 171)
Design for manufacture and assembly (DFMA) (p. 171)
Standard for the exchange of product data (STEP) (p. 172)
Computer-aided manufacturing (CAM) (p. 172)
3-D printing (p. 172)
Virtual reality (p. 172)
Value analysis (p. 173)
Time-based competition (p. 173)
Joint ventures (p. 174)
Alliances (p. 175)
Engineering drawing (p. 175)
Bill of material (BOM) (p. 175)
Make-or-buy decision (p. 176)
Group technology (p. 177)
Assembly drawing (p. 178)
Assembly chart (p. 178)
Route sheet (p. 178)
Work order (p. 178)
Engineering change notice (ECN) (p. 178)
Configuration management (p. 178)
Product life-cycle management (PLM) (p. 178)
Process–chain–network (PCN) analysis (p. 179)
Process chain (p. 179)

Ethical Dilemma

John Sloan, president of Sloan Toy Company, Inc., in Oregon, has just reviewed the design of a new pull-toy locomotive for 1- to 3-year-olds. John's design and marketing staff are very enthusiastic about the market for the product and the potential of follow-on circus train cars. The sales manager is looking forward to a very good reception at the annual toy show in Dallas next month. John, too, is delighted, as he is faced with a layoff if orders do not improve.

John's production people have worked out the manufacturing issues and produced a successful pilot run. However, the quality assessment staff suggests that under certain conditions, a hook to attach cars to the locomotive and the crank for the bell can be broken off. This is an issue because children can choke on small parts such as these. In the quality test, 1- to 3-year-olds were unable to break off these parts; there were *no* failures. But when the test simulated the force of an adult tossing the locomotive into a toy box or a 5-year-old throwing it on the floor, there were failures. The estimate is that one of the two parts can be broken off 4 times out of 100,000 throws. Neither the design nor the material people know how to make the toy safer and still perform as designed. The failure rate is low and certainly normal for this type of toy, but not at the Six Sigma level that John's firm strives for. And, of course, someone, someday may sue. A child choking on the broken part is a serious matter. Also, John was recently reminded in a discussion with legal counsel that U.S. case law suggests that new products may not be produced if there is "actual or foreseeable knowledge of a problem" with the product.

The design of successful, ethically produced new products, as suggested in this chapter, is a complex task. What should John do?

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Discussion Questions

1. Why is it necessary to document a product explicitly?
2. What techniques do we use to define a product?
3. In what ways is product strategy linked to product decisions?
4. Once a product is defined, what documents are used to assist production personnel in its manufacture?
5. What is time-based competition?
6. Describe the differences between joint ventures and alliances.
7. Describe four organizational approaches to product development. Which of these is generally thought to be best?
8. Explain what is meant by robust design.
9. What are three specific ways in which computer-aided design (CAD) benefits the design engineer?
10. What information is contained in a bill of material?
11. What information is contained in an engineering drawing?
12. What information is contained in an assembly chart? In a process sheet?
13. Explain what is meant in service design by the "moment of truth."
14. Explain how the house of quality translates customer desires into product/service attributes.
15. What strategic advantages does computer-aided design provide?
16. What is a process chain?
17. Why are the direct interaction and surrogate interaction regions in a PCN diagram important in service design?
18. Why are documents for service useful? Provide examples of four types.

Solved Problem

Virtual Office Hours help is available in MyOMLab.

SOLVED PROBLEM 5.1

Sarah King, president of King Electronics, Inc., has two design options for her new line of high-resolution monitors for CAD workstations. The production run is for 100,000 units.

Design option A has a .90 probability of yielding 60 good monitors per 100 and a .10 probability of yielding 65 good monitors per 100. This design will cost $1,000,000.

Design option B has a .80 probability of yielding 64 good units per 100 and a .20 probability of yielding 59 good units per 100. This design will cost $1,350,000.

Good or bad, each monitor will cost $75. Each good monitor will sell for $150. Bad monitors are destroyed and have no salvage value. We ignore any disposal costs in this problem.

SOLUTION

We draw the decision tree to reflect the two decisions and the probabilities associated with each decision. We then determine the payoff associated with each branch. The resulting tree is shown in Figure 5.14.

For design A:

$$\text{EMV(design A)} = (.9)(\$500{,}000) + (.1)(\$1{,}250{,}000) = \$575{,}000$$

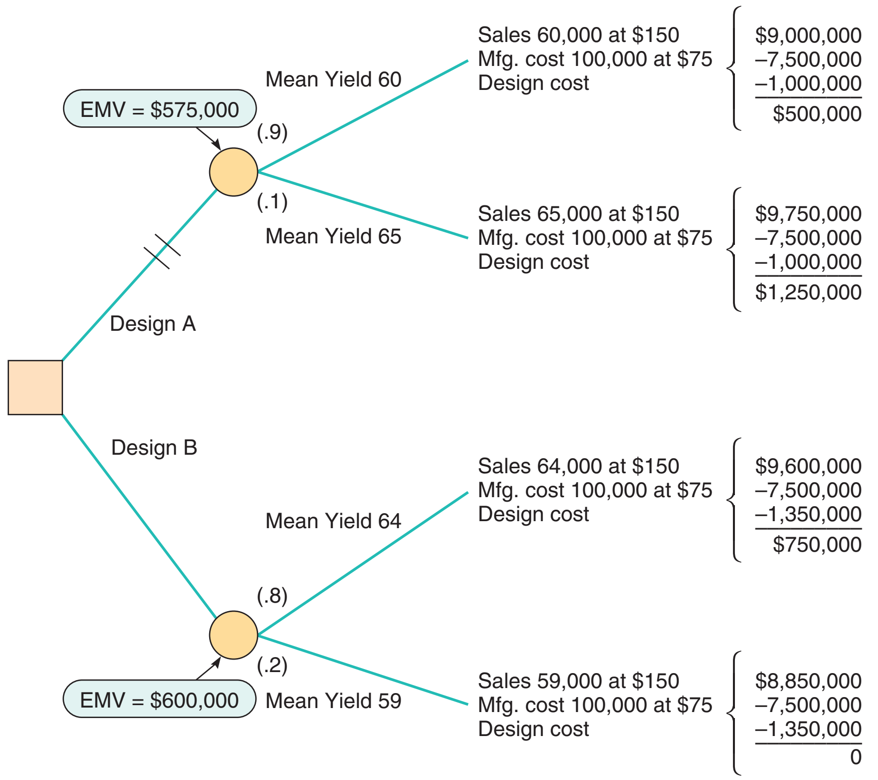
For design B:

$$\text{EMV(design B)} = (.8)(\$750{,}000) + (.2)(\$0) = \$600{,}000$$

The highest payoff is design option B, at $600,000.

Figure 5.14

Decision Tree for Solved Problem 5.1



Problems

Note: Px means the problem may be solved with POM for Windows and/or Excel OM.

Problems 5.1–5.3 relate to Goods and Services Selection

••• **5.1** Prepare a product-by-value analysis for the following products, and given the position in its life cycle, identify the issues likely to confront the operations manager and his or her possible actions. Product Alpha has annual sales of 1,000 units and a contribution of $2,500; it is in the introductory stage. Product Bravo has annual sales of 1,500 units and a contribution of $3,000; it is in the growth stage. Product Charlie has annual sales of 3,500 units and a contribution of $1,750; it is in the decline stage.

•• **5.2** Given the contribution made on each of the three products in the following table and their position in the life cycle, identify a reasonable operations strategy for each:

PRODUCT	PRODUCT CONTRIBUTION (% OF SELLING PRICE)	COMPANY CONTRIBUTION (%: TOTAL ANNUAL CONTRIBUTION DIVIDED BY TOTAL ANNUAL SALES)	POSITION IN LIFE CYCLE
Smart watch	30	40	Introduction
Tablet	30	50	Growth
Hand calculator	50	10	Decline

Problem **5.3** *is available in* MyOMLab.

Problems 5.4–5.8 relate to Product Development

•• **5.4** Construct a house of quality matrix for a wristwatch. Be sure to indicate specific customer wants that you think the general public desires. Then complete the matrix to show how an operations manager might identify specific attributes that can be measured and controlled to meet those customer desires.

•• **5.5** Using the house of quality, pick a real product (a good or service) and analyze how an existing organization satisfies customer requirements.

•• **5.6** Prepare a house of quality for a mousetrap.

•• **5.7** Conduct an interview with a prospective purchaser of a new bicycle and translate the customer's *wants* into the specific *hows* of the firm.

•••• **5.8** Using the house of quality sequence, as described in Figure 5.4 on page 169, determine how you might deploy resources to achieve the desired quality for a product or service whose production process you understand.

Problems 5.9–5.17 relate to Defining a Product

•• **5.9** Prepare a bill of material for (a) a pair of eyeglasses and its case or (b) a fast-food sandwich (visit a local sandwich shop like Subway, McDonald's, Blimpie, Quizno's; perhaps a clerk or the manager will provide you with details on the quantity or weight of various ingredients—otherwise, estimate the quantities).

•• **5.10** Draw an assembly chart for a pair of eyeglasses and its case.

•• **5.11** Prepare a script for telephone callers at the university's annual "phone-a-thon" fund raiser.

•• **5.12** Prepare an assembly chart for a table lamp.

Problems **5.13–5.17** *are available in* MyOMLab.

Problems 5.18–5.20 relate to Service Design

•• **5.18** Draw a two-participant PCN diagram (similar to Figure 5.12) for one of the following processes:

a) The process of having your computer repaired.
b) The process of pizza preparation.
c) The process of procuring tickets for a concert.

•• **5.19** Review strategic process positioning options for the regions in Figure 5.12, discussing the operational impact (in terms of the 10 strategic OM decisions) for:

a) Manufacturing the sandwiches.
b) Direct interaction.
c) Establishing a sandwich buffet.

••• **5.20** Select a service business that involves interaction between customers and service providers, and create a PCN diagram similar to Figure 5.12. Pick a key step that could be performed either by the service provider or by the customers. Show process positioning options for the step. Describe how the options compare in terms of efficiency, economies of scale, and opportunity for customization.

Problems 5.21–5.28 relate to the Application of Decision Trees to Product Design

•• **5.21** The product design group of Iyengar Electric Supplies, Inc., has determined that it needs to design a new series of switches. It must decide on one of three design strategies. The market forecast is for 200,000 units. The better and more sophisticated the design strategy and the more time spent on value engineering, the less will be the variable cost. The chief of engineering design, Dr. W. L. Berry, has decided that the following costs are a good estimate of the initial and variable costs connected with each of the three strategies:

a) *Low-tech:* A low-technology, low-cost process consisting of hiring several new junior engineers. This option has a fixed cost of $45,000 and variable-cost probabilities of .3 for $.55 each, .4 for $.50, and .3 for $.45.
b) *Subcontract:* A medium-cost approach using a good outside design staff. This approach would have a fixed cost of $65,000 and variable-cost probabilities of .7 of $.45, .2 of $.40, and .1 of $.35.
c) *High-tech:* A high-technology approach using the very best of the inside staff and the latest computer-aided design technology. This approach has a fixed cost of $75,000 and variable-cost probabilities of .9 of $.40 and .1 of $.35.

What is the best decision based on an expected monetary value (EMV) criterion? (*Note:* We want the lowest EMV, as we are dealing with costs in this problem.) Px

•• **5.22** MacDonald Products, Inc., of Clarkson, New York, has the option of (a) proceeding immediately with production of a new top-of-the-line stereo TV that has just completed prototype testing or (b) having the value analysis team complete a study. If Ed Lusk, VP for operations, proceeds with the existing prototype (option a), the firm can expect sales to be 100,000 units at $550 each, with a probability of .6, and a .4 probability of 75,000 at $550. If, however, he uses the value analysis team (option b), the firm expects sales of 75,000 units at $750, with a probability of .7, and a .3 probability of 70,000 units at $750. Value analysis, at a cost of $100,000, is only used in option b. Which option has the highest expected monetary value (EMV)? Px

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• • **5.23** Residents of Mill River have fond memories of ice skating at a local park. An artist has captured the experience in a drawing and is hoping to reproduce it and sell framed copies to current and former residents. He thinks that if the market is good he can sell 400 copies of the elegant version at $125 each. If the market is not good, he will sell only 300 at $90 each. He can make a deluxe version of the same drawing instead. He feels that if the market is good he can sell 500 copies of the deluxe version at $100 each. If the market is not good, he will sell only 400 copies at $70 each. In either case, production costs will be approximately $35,000. He can also choose to do nothing. If he believes there is a 50% probability of a good market, what should he do? Why? PX

• • **5.24** Ritz Products's materials manager, Tej Dhakar, must determine whether to make or buy a new semiconductor for the wrist TV that the firm is about to produce. One million units are expected to be produced over the life cycle. If the product is made, start-up and production costs of the *make* decision total $1 million, with a probability of .4 that the product will be satisfactory and a .6 probability that it will not. If the product is not satisfactory, the firm will have to reevaluate the decision. If the decision is reevaluated, the choice will be whether to spend another $1 million to redesign the semiconductor or to purchase. Likelihood of success the second time that the make decision is made is .9. If the second *make* decision also fails, the firm must purchase. Regardless of when the purchase takes place, Dhakar's best judgment of cost is that Ritz will pay $.50 for each purchased semiconductor plus $1 million in vendor development cost.

a) Assuming that Ritz must have the semiconductor (stopping or doing without is not a viable option), what is the best decision?
b) What criteria did you use to make this decision?
c) What is the worst that can happen to Ritz as a result of this particular decision? What is the best that can happen? PX

• • **5.25** Sox Engineering designs and constructs air conditioning and heating systems for hospitals and clinics. Currently, the company's staff is overloaded with design work. There is a major design project due in 8 weeks. The penalty for completing the design late is $14,000 per week, since any delay will cause the facility to open later than anticipated and cost the client significant revenue. If the company uses its inside engineers to complete the design, it will have to pay them overtime for all work. Sox has estimated that it will cost $12,000 per week (wages and overhead), including late weeks, to have company engineers complete the design. Sox is also considering having an outside engineering firm do the design. A bid of $92,000 has been received for the completed design. Yet another option for completing the design is to conduct a joint design by having a third engineering company complete all electromechanical components of the design at a cost of $56,000. Sox would then complete the rest of the design and control systems at an estimated cost of $30,000.

Sox has estimated the following probabilities of completing the project within various time frames when using each of the three options. Those estimates are shown in the following table:

	PROBABILITY OF COMPLETING THE DESIGN			
OPTION	ON TIME	1 WEEK LATE	2 WEEKS LATE	3 WEEKS LATE
Internal Engineers	.4	.5	.1	—
External Engineers	.2	.4	.3	.1
Joint Design	.1	.3	.4	.2

What is the best decision based on an expected monetary value criterion? (*Note:* You want the lowest EMV because we are dealing with costs in this problem.) PX

• • • **5.26** Use the data in Solved Problem 5.1 to examine what happens to the decision if Sarah King can increase all of Design B yields from 59,000 to 64,000 by applying an expensive phosphorus to the screen at an added manufacturing cost of $250,000. Prepare the modified decision tree. What are the payoffs, and which branch has the greatest EMV?

• • • • **5.27** McBurger, Inc., wants to redesign its kitchens to improve productivity and quality. Three designs, called designs K1, K2, and K3, are under consideration. No matter which design is used, daily production of sandwiches at a typical McBurger restaurant is for 500 sandwiches. A sandwich costs $1.30 to produce. Non-defective sandwiches sell, on the average, for $2.50 per sandwich. Defective sandwiches cannot be sold and are scrapped. The goal is to choose a design that maximizes the expected profit at a typical restaurant over a 300-day period. Designs K1, K2, and K3 cost $100,000, $130,000, and $180,000, respectively. Under design K1, there is a .80 chance that 90 out of each 100 sandwiches are non-defective and a .20 chance that 70 out of each 100 sandwiches are non-defective. Under design K2, there is a .85 chance that 90 out of each 100 sandwiches are non-defective and a .15 chance that 75 out of each 100 sandwiches are non-defective. Under design K3, there is a .90 chance that 95 out of each 100 sandwiches are non-defective and a .10 chance that 80 out of each 100 sandwiches are non-defective. What is the expected profit level of the design that achieves the maximum expected 300-day profit level?

Problem **5.28** *is available in* MyOMLab.

CASE STUDIES

De Mar's Product Strategy

De Mar, a plumbing, heating, and air-conditioning company located in Fresno, California, has a simple but powerful product strategy: *Solve the customer's problem no matter what, solve the problem when the customer needs it solved, and make sure the customer feels good when you leave*. De Mar offers guaranteed, same-day service for customers requiring it. The company provides 24-hour-a-day, 7-day-a-week service at no extra charge for customers whose air conditioning dies on a hot summer Sunday or whose toilet overflows at 2:30 A.M. As assistant service coordinator Janie Walter puts it: "We will be there to fix your A/C on the fourth of July, and it's not a penny extra. When our competitors won't get out of bed, we'll be there!"

De Mar guarantees the price of a job to the penny before the work begins. Whereas most competitors guarantee their work for 30 days, De Mar guarantees all parts and labor for one year. The company assesses no travel charge because "it's not fair to charge customers for driving out." Owner Larry Harmon says: "We are in an industry that doesn't have the best reputation. If we start making money our main goal, we are in trouble. So I stress customer satisfaction; money is the by-product."

De Mar uses selective hiring, ongoing training and education, performance measures, and compensation that incorporate customer satisfaction, strong teamwork, peer pressure, empowerment, and aggressive promotion to implement its strategy. Says credit manager Anne Semrick: "The person who wants a nine-to-five job needs to go somewhere else."

De Mar is a premium pricer. Yet customers respond because De Mar delivers value—that is, benefits for costs. In 8 years, annual sales increased from about $200,000 to more than $3.3 million.

Discussion Questions

1. What is De Mar's product? Identify the tangible parts of this product and its service components.
2. How should other areas of De Mar (marketing, finance, personnel) support its product strategy?
3. Even though De Mar's product is primarily a service product, how should each of the 10 strategic OM decisions in the text be managed to ensure that the product is successful?

Source: Reprinted with the permission of The Free Press, from *On Great Service: A Framework for Action* by Leonard L. Berry.

Product Design at Regal Marine

Video Case

With hundreds of competitors in the boat business, Regal Marine must work to differentiate itself from the flock. As we saw in the *Global Company Profile* that opened this chapter, Regal continuously introduces innovative, high-quality new boats. Its differentiation strategy is reflected in a product line consisting of 22 models.

To maintain this stream of innovation, and with so many boats at varying stages of their life cycles, Regal constantly seeks design input from customers, dealers, and consultants. Design ideas rapidly find themselves in the styling studio, where they are placed onto CAD machines in order to speed the development process. Existing boat designs are always evolving as the company tries to stay stylish and competitive. Moreover, with life cycles as short as 3 years, a steady stream of new products is required. A few years ago, the new product was the three-passenger $11,000 Rush, a small but powerful boat capable of pulling a water-skier. This was followed with a 20-foot inboard–outboard performance boat with so many innovations that it won prize after prize in the industry. Another new boat is a redesigned 52-foot sports yacht that sleeps six in luxury staterooms. With all these models and innovations, Regal designers and production personnel are under pressure to respond quickly.

By getting key suppliers on board early and urging them to participate at the design stage, Regal improves both innovations and quality while speeding product development. Regal finds that the sooner it brings suppliers on board, the faster it can bring new boats to the market. After a development stage that constitutes concept and styling, CAD designs yield product specifications. The first stage in actual production is the creation of the "plug," a foam-based carving used to make the molds for fiberglass hulls and decks. Specifications from the CAD system drive the carving process. Once the plug is carved, the permanent molds for each new hull and deck design are formed. Molds take about 4 to 8 weeks to make and are all handmade. Similar molds are made for many of the other features in Regal boats—from galley and

Barry Render

stateroom components to lavatories and steps. Finished molds can be joined and used to make thousands of boats.

Discussion Questions*

1. How does the concept of product life cycle apply to Regal Marine products?
2. What strategy does Regal use to stay competitive?
3. What kind of engineering savings is Regal achieving by using CAD technology rather than traditional drafting techniques?
4. What are the likely benefits of the CAD design technology?

*You may wish to view the video accompanying this case before addressing these questions.

Endnotes

1. *Contribution* is defined as the difference between direct cost and selling price. Direct costs are directly attributable to the product, namely labor and material that go into the product.
2. See Scott Sampson, "Visualizing Service Operations," *Journal of Service Research* (May 2012). More details about PCN analysis are available at **services.byu.edu.**

Chapter 5 *Rapid* Review

Main Heading	Review Material	MyOMLab
GOODS AND SERVICES SELECTION (pp. 162–165)	Although the term *products* may often refer to tangible goods, it also refers to offerings by service organizations. *The objective of the product decision is to develop and implement a product strategy that meets the demands of the marketplace with a competitive advantage.* ■ **Product Decision**—The selection, definition, and design of products. The four phases of the product life cycle are introduction, growth, maturity, and decline. ■ **Product-by-value analysis**—A list of products, in descending order of their individual dollar contribution to the firm, as well as the *total annual dollar* contribution of the product.	Concept Questions: 1.1–1.4 Problems: 5.1–5.3 **VIDEO 5.1** Product Strategy at Regal Marine
GENERATING NEW PRODUCTS (pp. 165–166)	Product selection, definition, and design take place on a continuing basis. Changes in product opportunities, the products themselves, product volume, and product mix may arise due to understanding the customer, economic change, sociological and demographic change, technological change, political/legal change, market practice, professional standards, suppliers, or distributors.	Concept Question: 2.1
PRODUCT DEVELOPMENT (pp. 166–170)	■ **Quality function deployment (QFD)**—A process for determining customer requirements (customer "wants") and translating them into attributes (the "hows") that each functional area can understand and act on. ■ **House of quality**—A part of the quality function deployment process that utilizes a planning matrix to relate customer wants to how the firm is going to meet those wants. ■ **Product development teams**—Teams charged with moving from market requirements for a product to achieving product success. ■ **Concurrent engineering**—Simultaneous performance of the various stages of product development. ■ **Manufacturability and value engineering**—Activities that help improve a product's design, production, maintainability, and use.	Concept Questions: 3.1–3.4
ISSUES FOR PRODUCT DESIGN (pp. 171–173)	■ **Robust design**—A design that can be produced to requirements even with unfavorable conditions in the production process. ■ **Modular design**—A design in which parts or components of a product are subdivided into modules that are easily interchanged or replaced. ■ **Computer-aided design (CAD)**—Interactive use of a computer to develop and document a product. ■ **Design for manufacture and assembly (DFMA)**—Software that allows designers to look at the effect of design on manufacturing of a product. ■ **Standard for the exchange of product data (STEP)**—A standard that provides a format allowing the electronic transmission of three-dimensional data. ■ **Computer-aided manufacturing (CAM)**—The use of information technology to control machinery. ■ **3-D printing**—An extension of CAD that builds prototypes and small lots. ■ **Virtual reality**—A visual form of communication in which images substitute for reality and typically allow the user to respond interactively. ■ **Value analysis**—A review of successful products that takes place during the production process. Sustainability is meeting the needs of the present without compromising the ability of future generations to meet their needs. Life cycle assessment (LCA) is part of ISO 14000; it assesses the environmental impact of a product from material and energy inputs to disposal and environmental releases. Both sustainability and LCA are discussed in depth in Supplement 5.	Concept Questions: 4.1–4.4
PRODUCT DEVELOPMENT CONTINUUM (pp. 173–175)	■ **Time-based competition**—Competition based on time; rapidly developing products and moving them to market. *Internal development strategies* include (1) new internally developed products, (2) enhancements to existing products, and (3) migrations of existing products. *External development strategies* include (1) purchase the technology or expertise by acquiring the developer, (2) establish joint ventures, and (3) develop alliances. ■ **Joint ventures**—Firms establishing joint ownership to pursue new products or markets. ■ **Alliances**—Cooperative agreements that allow firms to remain independent but pursue strategies consistent with their individual missions.	Concept Questions: 5.1–5.4

Chapter 5 *Rapid Review* continued

Main Heading	Review Material	MyOMLab
DEFINING A PRODUCT (pp. 175–177)	■ **Engineering drawing**—A drawing that shows the dimensions, tolerances, materials, and finishes of a component. ■ **Bill of material (BOM)**—A list of the components, their description, and the quantity of each required to make one unit of a product. ■ **Make-or-buy decision**—The choice between producing a component or a service and purchasing it from an outside source. ■ **Group technology**—A product and component coding system that specifies the size, shape, and type of processing; it allows similar products to be grouped.	Concept Questions: 6.1–6.4 Problems: 5.9, 5.10, 5.12–5.17
DOCUMENTS FOR PRODUCTION (pp. 178–179)	■ **Assembly drawing**—An exploded view of a product. ■ **Assembly chart**—A graphic means of identifying how components flow into subassemblies and final products. ■ **Route sheet**—A list of the operations necessary to produce a component with the material specified in the bill of material. ■ **Work order**—An instruction to make a given quantity of a particular item. ■ **Engineering change notice (ECN)**—A correction or modification of an engineering drawing or bill of material. ■ **Configuration management**—A system by which a product's planned and changing components are accurately identified. ■ **Product life cycle management (PLM)**—Software programs that tie together many phases of product design and manufacture.	Concept Questions: 7.1–7.4
SERVICE DESIGN (pp. 179–182)	■ **Process-chain-network (PCN) analysis**—A way to design processes to optimize interaction between firms and their customers. ■ **Process chain**—A sequence of steps that provide value to process participants. To enhance service efficiency, companies: (1) limit options, (2) delay customization, (3) modularize, (4) automate, and (5) design for the "moment of truth."	Concept Questions: 8.1–8.4
APPLICATION OF DECISION TREES TO PRODUCT DESIGN (pp. 182–184)	To form a decision tree, (1) include all possible alternatives (including "do nothing") and states of nature; (2) enter payoffs at the end of the appropriate branch; and (3) determine the expected value of each course of action by starting at the end of the tree and working toward the beginning, calculating values at each step and "pruning" inferior alternatives.	Concept Questions: 9.1–9.2 Problems: 5.21–5.25, 5.27–5.28 Virtual Office Hours for Solved Problem: 5.1 ACTIVE MODEL 5.1
TRANSITION TO PRODUCTION (p. 184)	One of the arts of management is knowing when to move a product from development to production; this move is known as *transition to production*.	Concept Questions: 10.1–10.2

Self Test

■ **Before taking the self-test,** refer to the learning objectives listed at the beginning of the chapter and the key terms listed at the end of the chapter.

LO 5.1 A product's life cycle is divided into four stages, including:
- **a)** introduction.
- **b)** growth.
- **c)** maturity.
- **d)** all of the above.

LO 5.2 Product development systems include:
- **a)** bills of material.
- **b)** routing charts.
- **c)** functional specifications.
- **d)** product-by-values analysis.
- **e)** configuration management.

LO 5.3 A house of quality is:
- **a)** a matrix relating customer "wants" to the firm's "hows."
- **b)** a schematic showing how a product is put together.
- **c)** a list of the operations necessary to produce a component.
- **d)** an instruction to make a given quantity of a particular item.
- **e)** a set of detailed instructions about how to perform a task.

LO 5.4 Time-based competition focuses on:
- **a)** moving new products to market more quickly.
- **b)** reducing the life cycle of a product.
- **c)** linking QFD to PLM.
- **d)** design database availability.
- **e)** value engineering.

LO 5.5 Products are defined by:
- **a)** value analysis.
- **b)** value engineering.
- **c)** routing sheets.
- **d)** assembly charts.
- **e)** engineering drawings.

LO 5.6 A route sheet:
- **a)** lists the operations necessary to produce a component.
- **b)** is an instruction to make a given quantity of a particular item.
- **c)** is a schematic showing how a product is assembled.
- **d)** is a document showing the flow of product components.
- **e)** all of the above.

LO 5.7 The three process regions in a process–chain–network diagram are:
- **a)** manufacture, supplier, customer
- **b)** direct and surrogate, customer, provider
- **c)** independent, dependent, customer interaction
- **d)** direct interaction, surrogate interaction, independent processing

LO 5.8 Decision trees use:
- **a)** probabilities.
- **b)** payoffs.
- **c)** logic.
- **d)** options.
- **e)** all of the above.

Answers: LO 5.1. d; LO 5.2. c; LO 5.3. a; LO 5.4. a; LO 5.5. e; LO 5.6. a; LO 5.7. d; LO 5.8. e.

Sustainability in the Supply Chain

SUPPLEMENT 5

SUPPLEMENT OUTLINE

Alaska Airlines

Alaska Airlines

LEARNING OBJECTIVES

LO S5.1 ***Describe*** corporate social responsibility 194

LO S5.2 ***Describe*** sustainability 195

LO S5.3 ***Explain*** the 3*R*s for sustainability 198

LO S5.4 ***Calculate*** design for disassembly 199

LO S5.5 ***Explain*** the impact of sustainable regulations on operations 203

Lex Van Lieshout/EPA/Newscom

Airlines from around the world, including Air China, Virgin Atlantic Airways, KLM, Alaska, Air New Zealand, and Japan Airlines, are experimenting with alternative fuels to power their jets in an effort to reduce greenhouse gas emissions and to reduce their dependence on traditional petroleum-based jet fuel. Alternative biofuels are being developed from recycled cooking oil, sewage sludge, municipal waste, coconuts, sugar cane, and genetically modified algae that feed on plant waste.

Corporate Social Responsibility[1]

LO S5.1 *Describe* corporate social responsibility

Managers must consider how the products and services they provide affect both people and the environment. Certainly, firms must provide products and services that are innovative and attractive to buyers. But today's technologies allow consumers, communities, public interest groups, and regulators to be well informed about all aspects of an organization's performance. As a result, stakeholders can have strong views about firms that fail to respect the environment or that engage in unethical conduct. Firms need to consider all the implications of a product—from design to disposal.

Many companies now realize that "doing what's right" and doing it properly can be beneficial to all stakeholders. Companies that practice **corporate social responsibility (CSR)** introduce policies that consider environmental, societal, and financial impacts in their decision making. As managers consider approaches to CSR, they find it helpful to consider the concept of creating **shared value**. *Shared value* suggests finding policies and practices that enhance the organization's competitiveness while simultaneously advancing the economic and social conditions in the communities in which it operates. For instance, note how automakers Tesla, Toyota, and Nissan find shared value in low-emission vehicles . . . vehicles that enhance their competeveness in a global market while meeting society's interest in low-emission vehicles. Similarly, Dow Chemical finds social benefits and profit in Nexera canola and sunflower seeds. These seeds yield twice as much cooking oil as soybeans, enhancing profitability to the grower. They also have a longer shelf life, which reduces operating costs throughout the supply chain. As an added bonus, the oils have lower levels of saturated fat than traditional products and contain no trans fats. A win–win for Dow and society.

Corporate social responsibility (CSR)
Managerial decision making that considers environmental, societal, and financial impacts.

Shared value
Developing policies and practices that enhance the competitiveness of an organization while advancing the economic and social conditions in the communities in which it operates.

Operations functions—from supply chain management to product design to production to packaging and logistics—provide an opportunity for finding shared value and meeting CSR goals.[2]

Sustainability

Sustainability is often associated with corporate social responsibility. The term **sustainability** refers to meeting the needs of the present without compromising the ability of future generations to meet their needs. Many people who hear of sustainability for the first time think of green products or "going green"—recycling, global warming, and saving rainforests. This is certainly part of it. However, it is more than this. True sustainability involves thinking not only about environmental resources but also about employees, customers, community, and the company's reputation. Three concepts may be helpful as managers consider sustainability decisions: a *systems* view, the *commons*, and the *triple bottom line*.

Sustainability
Meeting the needs of the present without compromising the ability of future generations to meet their needs.

LO S5.2 *Describe* sustainability

Systems View

Managers may find that their decisions regarding sustainability improve when they take a *systems* view. This means looking at a product's life from design to disposal, including all the resources required. Recognizing that both raw materials and human resources are subsystems of any production process may provide a helpful perspective. Similarly, the product or service itself is a small part of much larger social, economic, and environmental systems. Indeed, managers need to understand the inputs and interfaces between the interacting systems and identify how changes in one system affect others. For example, hiring or laying off employees can be expected to have morale implications for internal systems (within an organization), as well as socioeconomic implications for external systems. Similarly, dumping chemicals down the drain has implications on systems beyond the firm. Once managers understand that the systems immediately under their control have interactions with systems below them and above them, more informed judgments regarding sustainability can be made.

VIDEO S5.1
Building Sustainability at the Orlando Magic's Amway Center

Commons

Many inputs to a production system have market prices, but others do not. Those that do not are those held by the public, or in the *common*. Resources held in the *common* are often misallocated. Examples include depletion of fish in international waters and polluted air and waterways. The attitude seems to be that just a little more fishing or a little more pollution will not matter, or the adverse results may be perceived as someone else's problem. Society is still groping for solutions for use of those resources in the *common*. The answer is slowly being found in a number of ways: (1) moving some of the *common* to private property (e.g., selling radio frequency spectrum), (2) allocation of rights (e.g., establishing fishing boundaries), and (3) allocation of yield (e.g., only a given quantity of fish can be harvested). As managers understand the issues of the *commons*, they have further insight about sustainability and the obligation of caring for the *commons*.

Triple Bottom Line

Firms that do not consider the impact of their decisions on all their stakeholders see reduced sales and profits. Profit maximization is not the only measure of success. A one-dimensional bottom line, profit, will not suffice; the larger socioeconomic systems beyond the firm demand more. One way to think of sustainability is to consider the systems necessary to support the triple bottom line of the three *P*s: *people, planet*, and *profit* (see Figure S5.1), which we will now discuss.

STUDENT TIP
Profit is now just one of the three *P*s: people, planet, and profit.

People Companies are becoming more aware of how their decisions affect people—not only their employees and customers but also those who live in the communities in which they operate. Most employers want to pay fair wages, offer educational opportunities, and provide a safe and healthy workplace. So do their suppliers. But globalization and the reliance on outsourcing to suppliers around the world complicate the task. This means companies must create policies that guide supplier selection and performance. Sustainability suggests that supplier selection and performance criteria evaluate safety in the work environment, whether living wages are paid, if child labor is used, and whether work hours are excessive. Apple, GE, Procter & Gamble, and Walmart are examples of companies that conduct supplier audits to uncover any harmful or exploitative business practices that are counter to their sustainability goals and objectives.

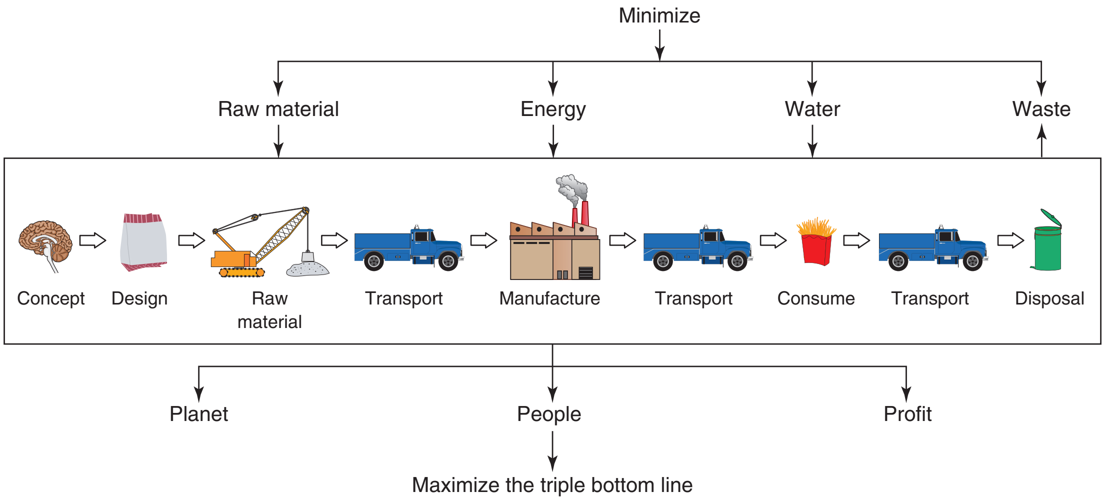


Figure **S5.1**

Improving the Triple Bottom Line with Sustainability

Recognizing that customers increasingly want to know that the materials in the products they buy are safe and produced in a responsible way, Walmart initiated the development of the worldwide sustainable product index for evaluating the sustainability of products. The goals of that initiative are to create a more transparent supply chain, accelerate the adoption of best practices, and drive product innovation.

STUDENT TIP Walmart has become a global leader in sustainability. Read *Force of Nature: The Unlikely Story of Walmart's Green Revolution.*

Walmart found a correlation between supply-chain transparency, positive labor practices, community involvement, *and* quality, efficiency, and cost. Walmart is committed to working with its suppliers to sell quality products that are safe, that create value for customers, and that are produced in a sustainable way. The firm is accomplishing this in four ways:

1. Improving livelihoods through the creation of productive, healthy, and safe workplaces and promoting quality of life
2. Building strong communities through access to affordable, high-quality services such as education and job training that support workers and their families
3. Preventing exposure to substances that are considered harmful or toxic to human health
4. Promoting health and wellness by increasing access to nutritious products, encouraging healthy lifestyles, and promoting access to health care

Walmart's CEO has said that companies that are unfair to their people are also likely to skimp on quality and that he will not continue to do business with those suppliers. Accordingly, operations managers must consider the working conditions in which they place their employees. This includes training and safety orientations, before-shift exercises, earplugs, safety goggles, and rest breaks to reduce the possibility of worker fatigue and injury. Operations managers must also make decisions regarding the disposal of material and chemical waste, including hazardous materials, so they don't harm employees or the community.

Planet When discussing the subject of sustainability, our planet's environment is the first thing that comes to mind, so it understandably gets the most attention from managers. Operations managers look for ways to reduce the environmental impact of their operations, whether from raw material selection, process innovation, alternative product delivery methods, or disposal of products at their end-of-life. The overarching objective for operations managers is to conserve scarce resources, thereby reducing the negative impact on the environment. Here are a few examples of how organizations creatively make their operations more environmentally friendly:

- S.C. Johnson, the company that makes Windex, Saran Wrap, Pledge, Ziploc bags, and Raid, developed *Greenlist*, a classification system that evaluates the impact of raw materials on human and environmental health. By using *Greenlist*, S.C. Johnson has eliminated millions of pounds of pollutants from its products.

- Thirty-one public school districts across the state of Kentucky operate hybrid electric school buses. They estimate fuel savings as high as 40%, with fuel mileage of 7.5 mpg increasing to 12 miles per gallon, relative to standard diesel buses.
- Levi has started a campaign to save water in the creation of jeans, as seen in the *OM in Action* box "Blue Jeans and Sustainability."

To gauge their environmental impact on the planet, many companies are measuring their carbon footprint. **Carbon footprint** is a measure of the total greenhouse gas (GHG) emissions caused directly and indirectly by an organization, a product, an event, or a person. A substantial portion of greenhouse gases are released naturally by farming, cattle, and decaying forests and, to a lesser degree, by manufacturing and services. The most common greenhouse gas produced by human activities is carbon dioxide, primarily from burning fossil fuels for electricity generation, heating, and transport. Operations managers are being asked to do their part to reduce GHG emissions.

Carbon footprint
A measure of total greenhouse gas emissions caused directly or indirectly by an organization, a product, an event, or a person.

Industry leaders such as Frito-Lay have been able to break down the carbon emissions from various stages in the production process. For instance, in potato chip production, a 34.5-gram (1.2-ounce) bag of chips is responsible for about twice its weight in emissions—75 grams per bag (see Figure S5.2).

VIDEO S5.2
Green Manufacturing and Sustainability at Frito-Lay

Profit Social and environmental sustainability do not exist without economic sustainability. **Economic sustainability** refers to how companies remain in business. Staying in business requires making investments, and investments require making profits. Though profits may be relatively easy to determine, other measures can also be used to gauge economic sustainability. The alternative measures that point to a successful business include risk profile, intellectual property, employee morale, and company valuation. To support economic sustainability, firms may supplement standard financial accounting and reporting with some version of *social accounting*. Social accounting can include brand equity, management talent, human capital development and benefits, research and development, productivity, philanthropy, and taxes paid.

Economic sustainability
Appropriately allocating scarce resources to make a profit.

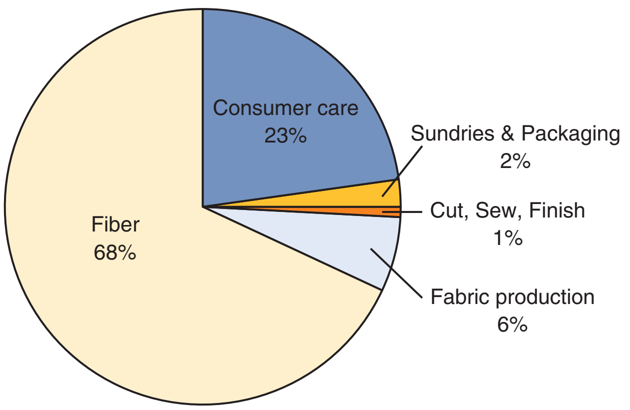
OM in Action — Blue Jeans and Sustainability

The recent drought in California is hurting more than just farmers. It is also having a significant impact on the fashion industry and spurring changes in how jeans are made and how they should be laundered. Southern California is estimated to be the world's largest supplier of so-called premium denim, the $100 to $200-plus-a-pair of designer jeans. Water is a key component in the various steps of the processing and repeated washing with stones, or bleaching and dyeing that create that "distressed" vintage look. Southern California produces 75% of the high-end denim in the U.S. that is sold worldwide. The area employs about 200,000 people, making it the largest U.S. fashion manufacturing hub.

Now that water conservation is a global priority, major denim brands are working to cut water use. Levi, with sales of $5 billion, is using ozone machines to replace the bleach traditionally used to lighten denim. It is also reducing the number of times it washes jeans. The company has saved more than a billion liters of water since 2011 with its Levi's Water Less campaign. By 2020, the company plans to have 80% of Levi's brand products made using the Water Less process, up from about 25% currently.

Traditionally, about 34 liters of water are used in the cutting, sewing, and finishing process to make a pair of Levi's signature 501 jeans. Nearly 3,800 liters of water are used throughout the lifetime of a pair of Levi's 501. A study found cotton cultivation represents 68% of that and consumer washing another 23%. So Levi is promoting the idea that jeans only need washing after 10 *wears*. (The average American consumer washes after 2 *wears*.) Levi's CEO recently urged people to stop washing their jeans, saying he hadn't washed his one-year-old jeans at the time. "You can air dry and spot clean instead," he said.

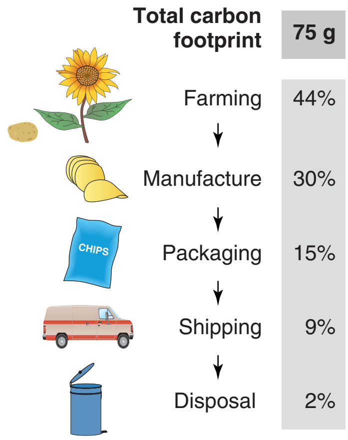
Cradle to grave water consumption percentage



Sources: The Wall Street Journal (April 10, 2015) and *New York Times* (March 31, 2015).

Figure **S5.2**

Carbon Footprint of a 34.5-gram Bag of Frito-Lay Chips



Design and Production for Sustainability

Life cycle assessment
Analysis of environmental impacts of products from the design stage through end-of-life.

The operations manager's greatest opportunity to make substantial contributions to the company's environmental objectives occurs during product life cycle assessment. **Life cycle assessment** evaluates the environmental impact of a product, from raw material and energy inputs all the way to the disposal of the product at its end-of-life. The goal is to make decisions that help reduce the environmental impact of a product throughout its entire life. Focusing on the 3*R*s—*reduce, reuse,* and *recycle*— can help accomplish this goal. By incorporating the 3*R*s, product design teams, process managers, and supply-chain personnel can make great strides toward reducing the environmental impact of products—to the benefit of all stakeholders.

Product Design

LO S5.3 *Explain* the 3*R*s for sustainability

Product design is the most critical phase in product life cycle assessment. The decisions that are made during this phase greatly affect materials, quality, cost, processes, related packaging and logistics, and ultimately how the product will be processed when discarded. During design, one of the goals is to incorporate a systems view in the product or service design that lowers the environmental impact. This is the first *R*. Such an approach reduces waste and energy costs at the supplier, in the logistics system, and for the end user. For instance, by taking a systems view, Procter & Gamble developed *Tide Coldwater*, a detergent that gets clothes clean with cold water, saving the consumer about three-fourths of the energy used in a typical wash.

Other successful design efforts include:

- Boston's Park Plaza Hotel eliminated bars of soap and bottles of shampoo by installing pump dispensers in its bathrooms, saving the need for 1 million plastic containers a year.
- UPS reduced the amount of materials it needs for its envelopes by developing its *reusable express envelopes,* which are made from 100% recycled fiber. These envelopes are designed to be used twice, and after the second use, the envelope can be recycled.
- Coca-Cola's redesigned Dasani bottle reduced the amount of plastic needed and is now 30% lighter than when it was introduced.

Product design teams also look for *alternative* materials from which to make their products. Innovating with alternative materials can be expensive, but it may make autos, trucks, and aircraft more environmentally friendly while improving payload and fuel efficiency. Aircraft and auto makers, for example, constantly seek lighter materials to use in their products. Lighter materials translate into better fuel economy, fewer carbon emissions, and reduced operating cost. For instance:

- Mercedes is building some car exteriors from a banana fiber that is both biodegradable and lightweight.
- Some Fords have seat upholstery made from recycled plastic soda bottles and old clothing.


Dan Bates/The Herald/AP Images

Alaska Airlines

An excellent place for operations managers to begin the sustainability challenge is with good product design. Here Tom Malone, CEO, of MicroGreen Polymers, discusses the company's new ultra light cup with production personnel (left). The cup can be recycled over and over and never go to a landfill. Another new design is the "winglet" (right). These wing tip extensions increase climb speed, reduce noise by 6.5%, cut CO_2 emissions by 5%, and save 6% in fuel costs. Alaska Air has retrofitted its entire 737 fleet with winglets, saving $20 million annually.

- Boeing is using carbon fiber, epoxy composites, and titanium graphite laminate to reduce weight in its new 787 Dreamliner.

Product designers often must decide between two or more environmentally friendly design alternatives. Example S1 deals with a *design for disassembly* cost–benefit analysis. This process focuses on the second and third *R*s: reuse and recycle. The design team analyzes the amount of revenue that might be reclaimed against the cost of disposing of the product at its end-of-life.

STUDENT TIP
A fourth *R*, *improved reputation,* follows the success of reduce, reuse, and recycle.

Example S1

LO S5.4 *Calculate* design for disassembly

DESIGN FOR DISASSEMBLY

Sound Barrier, Inc., needs to decide which of two speaker designs is better environmentally.

APPROACH ▶ The design team collected the following information for two audio speaker designs, the *Harmonizer* and the *Rocker:*

1. Resale value of the components minus the cost of transportation to the disassembly facility
2. Revenue collected from recycling
3. Processing costs, which include disassembly, sorting, cleaning, and packaging
4. Disposal costs, including transportation, fees, taxes, and processing time

SOLUTION ▶ The design team developed the following revenue and cost information for the two speaker design alternatives:

Harmonizer

PART	RESALE REVENUE PER UNIT	RECYCLING REVENUE PER UNIT	PROCESSING COST PER UNIT	DISPOSAL COST PER UNIT
Printed circuit board	$5.93	$1.54	$3.46	$0.00
Laminate back	0.00	0.00	4.53	1.74
Coil	8.56	5.65	6.22	0.00
Processor	9.17	2.65	3.12	0.00
Frame	0.00	0.00	2.02	1.23
Aluminum case	11.83	2.10	2.98	0.00
Total	$35.49	$11.94	$22.33	$2.97

Rocker

PART	RESALE REVENUE PER UNIT	RECYCLING REVENUE PER UNIT	PROCESSING COST PER UNIT	DISPOSAL COST PER UNIT
Printed circuit board	$7.88	$3.54	$2.12	$0.00
Coil	6.67	4.56	3.32	0.00
Frame	0.00	0.00	4.87	1.97
Processor	8.45	4.65	3.43	0.00
Plastic case	0.00	0.00	4.65	3.98
Total	$23.00	$12.75	$18.39	$5.95

Using the Equation (S5-1), the design team can compare the two design alternatives:

Revenue retrieval =
Total resale revenue + Total recycling revenue − Total processing cost − Total disposal cost (S5-1)

Revenue retrieval for Harmonizer = \$35.49 + \$11.94 − \$22.33 − \$2.97 = \$22.13

Revenue retrieval for Rocker = \$23.00 + \$12.75 − \$18.39 − \$5.95 = \$11.41

INSIGHT ▶ After analyzing both environmental revenue and cost components of each speaker design, the design team finds that the Harmonizer is the better environmental design alternative as it achieves a higher revenue retrieval opportunity. Note that the team is assuming that both products have the same market acceptance, profitability, and environmental impact.

LEARNING EXERCISE ▶ What would happen if there was a change in the supply chain that caused the processing and disposal costs to triple for the laminate back part of the Harmonizer? [Answer: The revenue retrieval from the Harmonizer is \$35.49 + \$11.94 − \$31.39 − \$6.45 = \$9.59. This is less than the Rocker's revenue retrieval of \$11.41, so the Rocker becomes the better environmental design alternative, as it achieves a higher revenue retrieval opportunity.]

RELATED PROBLEMS ▶ S5.1, S5.2, S5.3, S5.9, S5.12, S5.13, S5.14

Production Process

Manufacturers look for ways to reduce the amount of resources in the production process. Opportunities to reduce environmental impact during production typically revolve around the themes of energy, water, and environmental contamination. Conservation of energy and improving energy efficiency come from the use of alternative energy and more energy-efficient machinery. For example:

- S.C. Johnson built its own power plant that runs on natural gas and methane piped in from a nearby landfill, cutting back its reliance on coal-fired power.
- PepsiCo developed *Resource Conservation (ReCon)*, a diagnostic tool for understanding and reducing in-plant water and energy usage. In its first 2 years, *ReCon* helped sites across the world identify 2.2 billion liters of water savings, with a corresponding cost savings of nearly \$2.7 million.
- Frito-Lay decided to extract water from potatoes, which are 80% water. Each year, a single factory processes 350,000 tons of potatoes, and as those potatoes are processed, the company reuses the extracted water for that factory's daily production.

STUDENT TIP Las Vegas, always facing a water shortage, pays residents \$40,000 an acre to take out lawns and replace them with rocks and native plants.

These and similar successes in the production process reduce both costs and environmental concerns. Less energy is consumed, and less material is going to landfills.

Logistics

As products move along in the supply chain, managers strive to achieve efficient route and delivery networks, just as they seek to drive down operating cost. Doing so reduces environmental impact. Management analytics (such as linear programming, queuing, and vehicle routing software) help firms worldwide optimize elaborate supply-chain and distribution networks. Networks of container ships, airplanes, trains, and trucks are being analyzed to


NG Images/Alamy


Ted Foxx/Alamy

Three key success factors in the trucking industry are (1) getting shipments to customers promptly (rapid response), (2) keeping trucks busy (capacity utilization), and (3) buying inexpensive fuel (driving down costs). Many firms have now developed devices like the one shown on the right to track location of trucks and facilitate communication between drivers and dispatchers. Some systems use global positioning satellites (shown on the left), to speed shipment response, maximize utilization of the truck, and ensure purchase of fuel at the most economical location. Sensors are also being added inside trailers. These sensors communicate whether the trailer is empty or full and detect if the trailer is connected to a truck or riding on a railroad car.

reduce the number of miles traveled or the number of hours required to make deliveries. For example:

- UPS has found that making left turns increases the time it takes to make deliveries. This in turn increases fuel usage and carbon emissions. So UPS plans its delivery truck routes with the fewest possible left turns. Likewise, airplanes fly at different altitudes and routes to take advantage of favorable wind conditions in an effort to reduce fuel use and carbon emissions.
- Food distribution companies now have trucks with three temperature zones (frozen, cool, and nonrefrigerated) instead of using three different types of trucks.
- Whirlpool radically revised its packaging to reduce “dings and dents” of appliances during delivery, generating huge savings in transportation and warranty costs.

To further enhance logistic efficiency, operations managers also evaluate equipment alternatives, taking into account cost, payback period, and the firm’s stated environmental objectives. Example S2 deals with decision making that takes into account life cycle ownership costs. A firm must decide whether to pay *more* up front for vehicles to further its sustainability goals or to pay *less* up front for vehicles that do not.

Example S2

LIFE CYCLE OWNERSHIP AND CROSSOVER ANALYSIS

Blue Star is starting a new distribution service that delivers auto parts to the service departments of auto dealerships in the local area. Blue Star has found two light-duty trucks that would do the job well, so now it needs to pick one to perform this new service. The Ford TriVan costs $28,000 to buy and uses regular unleaded gasoline, with an average fuel efficiency of 24 miles per gallon. The TriVan has an operating cost of $.20 per mile. The Honda CityVan, a hybrid truck, costs $32,000 to buy and uses regular unleaded gasoline and battery power; it gets an average of 37 miles per gallon. The CityVan has an operating cost of $.22 per mile. The distance traveled annually is estimated to be 22,000 miles, with the life of either truck expected to be 8 years. The average gas price is $4.25 per gallon.

APPROACH ▶ Blue Star applies Equation (S5-2) to evaluate total life cycle cost for each vehicle:

$$\text{Total life cycle cost} = \text{Cost of vehicle} + \text{Life cycle cost of fuel} + \text{Life cycle operating cost} \qquad \text{(S5-2)}$$

a) Based on life cycle cost, which model truck is the best choice?
b) How many miles does Blue Star need to put on a truck for the costs to be equal?
c) What is the crossover point in years?

SOLUTION ▶

a) Ford TriVan:

$$\text{Total life-cycle cost} = \$28{,}000 + \left[\frac{22{,}000\dfrac{miles}{year}}{24\dfrac{miles}{gallon}}\right](\$4.25/gallon)(8\ years) + \left(22{,}000\frac{miles}{year}\right)(\$.20/mile)(8\ years)$$

$$= \$28{,}000 + \$31{,}167 + \$35{,}200 = \$94{,}367$$

Honda CityVan:

$$\text{Total life-cycle cost} = \$32{,}000 + \left[\frac{22{,}000\dfrac{miles}{year}}{37\dfrac{miles}{gallon}}\right](\$4.25/gallon)(8\ years) + \left(22{,}000\frac{miles}{year}\right)(\$.22/mile)(8\ years)$$

$$= \$32{,}000 + \$20{,}216 + \$38{,}720 = \$90{,}936$$

b) Blue Star lets M be the crossover (break-even) point in miles, sets the two life cycle cost equations equal to each other, and solves for M:

$$\text{Total cost for Ford TriVan} = \text{Total cost for Honda CityVan}$$

$$\$28{,}000 + \left[\frac{4.25\dfrac{\$}{gallon}}{24\dfrac{miles}{gallon}} + .20\frac{\$}{mile}\right](M\ miles) = \$32{,}000 + \left[\frac{4.25\dfrac{\$}{gallon}}{37\dfrac{miles}{gallon}} + .22\frac{\$}{mile}\right](M\ miles)$$

or,

$$\$28{,}000 + \left(.3770\frac{\$}{mile}\right)(M) = \$32{,}000 + \left(.3349\frac{\$}{mile}\right)(M)$$

or,

$$\left(.0421\frac{\$}{mile}\right)(M) = \$4{,}000$$

$$M = \frac{\$4{,}000}{.0421\dfrac{\$}{mile}} = 95{,}012\ miles$$

c) The crossover point in years is:

$$\text{Crossover point} = \frac{95{,}012\ miles}{22{,}000\dfrac{miles}{year}} = 4.32\ years$$

INSIGHTS ▶

a) Honda CityVan is the best choice, even though the initial fixed cost and variable operating cost per mile are higher. The savings comes from the better fuel mileage (more miles per gallon) for the Honda CityVan.
b) The crossover (break-even) point is at 95,012 miles, which indicates that at this mileage point, the cost for either truck is the same.
c) It will take 4.32 years to recoup the cost of purchasing and operating either vehicle. It will cost Blue Star approximately $.03 per mile less to operate the Honda CityVan than the Ford TriVan over the 8-year expected life.

LEARNING EXERCISE ▶ If the cost of gasoline drops to $3.25, what will be the total life-cycle cost of each van, the break-even point in miles, and the crossover point in years? [Answer: The cost of the Ford TriVan is $87,033; the Honda CityVan costs $86,179; the break-even is 144,927 miles; and the crossover point is 6.59 years.]

RELATED PROBLEMS ▶ S5.4, S5.5, S5.6, S5.10, S5.11, S5.15, S5.16, S5.17, S5.18, S5.19

End-of-Life Phase

We noted earlier that during product design, managers need to consider what happens to a product or its materials after the product reaches its end-of-life stage. Products with less material, with recycled material, or with recyclable materials all contribute to sustainability efforts, reducing the need for the "burn or bury" decision and conserving scarce natural resources.

Innovative and sustainability-conscious companies are now designing **closed-loop supply chains**, also called *reverse logistics*. Firms can no longer sell a product and then forget about it. They need to design and implement end-of-life systems for the physical return of products that facilitate recycling or reuse.

Closed-loop supply chains
Supply chains that consider forward and reverse product flows over the entire life cycle.

Caterpillar, through its expertise in remanufacturing technology and processes, has devised *Cat Reman,* a remanufacturing initiative, in an effort to show its commitment to sustainability. Caterpillar remanufactures parts and components that provide same-as-new performance and reliability at a fraction of new cost, while reducing the impact on the environment. The remanufacturing program is based on an exchange system where customers return a used component in exchange for a remanufactured product. The result is lower operating costs for the customer, reduced material waste, and less need for raw material to make new products. In a 1-year period, Caterpillar took back 2.1 million end-of-life units and remanufactured over 130 million pounds of material from recycled iron.

The *OM in Action* box "From Assembly Lines to Green Disassembly Lines" describes one automaker's car design philosophy to facilitate the disassembly, recycling, and reuse of its autos that have reached their end-of-life.

Regulations and Industry Standards

LO S5.5 *Explain* the impact of sustainable regulations on operations

Government, industry standards, and company policies are all important factors in operational decisions. Failure to recognize these constraints can be costly. Over the last 100 years, we have seen development of regulations, standards, and policies to guide managers in product design, manufacturing/assembly, and disassembly/disposal.

To guide decisions in *product design*, U.S. laws and regulations, such as those of the Food and Drug Administration, Consumer Product Safety Commission, and National Highway Safety Administration, provide guidance and often explicit regulations.

Manufacturing and assembly activities have their own set of regulatory agencies providing guidance and standards of operations. These include the Occupational Safety and Health

OM in Action — From Assembly Lines to Green Disassembly Lines

A century has passed since assembly lines were developed to make automobiles—and now we're developing *disassembly* lines to take them apart. So many automobiles are disassembled that recycling is the 16th-largest industry in the U.S. The motivation for this comes from many sources, including mandated industry recycling standards and a growing consumer interest in purchasing cars based on how "green" they are.

New car designs have traditionally been unfriendly to recyclers, with little thought given to disassembly. Some components, such as air bags, are hard to handle and dangerous, and they take time to disassemble. However, manufacturers now design in such a way that materials can be easily reused in the next generation of cars. The 2015 Mercedes S-class is 95% recyclable. BMW has disassembly plants in Europe, Japan, New York, Los Angeles, and Orlando.

A giant 200,000-square-foot facility in Baltimore (called CARS) can disassemble up to 30,000 vehicles per year. At CARS's initial "greening station," special tools puncture tanks and drain fluids and remove the battery and gas tank. Then wheels, doors, hood, and trunk are removed; next come the interior items; plastic parts are removed and sorted for recycling; then glass and interior and trunk materials. Eventually the chassis is a bale and sold as a commodity to minimills that use scrap steel. Reusable parts are bar-coded and entered into a database. The photo shows an operator controlling the car recycling plant.


Ton Koene/Alamy

Sources: Wall Street Journal (April 29, 2008) and *Time* (February 4, 2010).

Administration (OSHA), Environmental Protection Agency (EPA), and many state and local agencies that regulate workers' rights and employment standards.

STUDENT TIP
A group of 100 apparel brands and retailers have created the Eco Index to display an eco-value on a tag, like the Energy Star rating does for appliances.

U.S. agencies that govern the *disassembly and disposal of hazardous products* include the EPA and the Department of Transportation. As product life spans shorten due to ever-changing trends and innovation, product designers are under added pressure to *design for disassembly*. This encourages designers to create products that can be disassembled and whose components can be recovered, minimizing impact on the environment.

Organizations are obliged by society and regulators to reduce harm to consumers, employees, and the environment. The result is a proliferation of community, state, federal, and even international laws that often complicate compliance. The lack of coordination of regulations and reporting requirements between jurisdictions adds not just complexity but cost.

From the following examples it is apparent that nearly all industries must abide by regulations in some form or another:

- Commercial homebuilders are required not just to manage water runoff but to have a pollution prevention plan for each site.
- Public drinking water systems must comply with the Federal Safe Drinking Water Act's arsenic standard, even for existing facilities.
- Hospitals are required to meet the terms of the Resource Conservation and Recovery Act, which governs the storage and handling of hazardous material.

The consequences of ignoring regulations can be disastrous and even criminal. The EPA investigates environmental crimes in which companies and individuals are held accountable. Prison time and expensive fines can be handed down. (British Petroleum paid billions of dollars in fines in the past few years for breaking U.S. environmental and safety laws.) Even if a crime has not been committed, the financial impacts and customer upheaval can be disastrous to companies that do not comply with regulations. Due to lack of supplier oversight, Mattel, Inc., the largest U.S. toymaker, has recalled over 10 million toys in recent years because of consumer health hazards such as lead paint.

International Environmental Policies and Standards

Organizations such as the U.N. Framework Convention on Climate Change (UNFCCC), International Organization for Standardization (ISO), and governments around the globe are guiding businesses to reduce environmental impacts from disposal of materials to reductions in greenhouse gas (GHG) emissions. Some governments are implementing laws that mandate the outright reduction of GHG emissions by forcing companies to pay taxes based on the amount of GHG emissions that are emitted. We now provide an overview of some of the international standards that apply to how businesses operate, manufacture, and distribute goods and services.

European Union Emissions Trading System The European Union has developed and implemented the EU Emissions Trading System (EUETS) to combat climate change. This is the key tool for reducing industrial greenhouse gas emissions in the EU. The EUETS works on the "cap-and-trade" principle. This means there is a cap, or limit, on the total amount of certain greenhouse gases that can be emitted by factories, power plants, and airlines in EU airspace. Within this cap, companies receive emission allowances, which they can sell to, or buy from, one another as needed.

ISO 14000 The International Organization for Standardization (ISO) is widely known for its contributions in ISO 9000 quality assurance standards (discussed in Chapter 6). The ISO 14000 family grew out of the ISO's commitment to support the 1992 U.N. objective of sustainable development. ISO 14000 is a series of environmental management standards that contain five core elements: (1) environmental management, (2) auditing, (3) performance evaluation, (4) labeling, and (5) life cycle assessment. Companies that demonstrate these elements may apply for certification. ISO 14000 has several advantages:

ISO 14000
A series of environmental management standards established by the International Organization for Standardization (ISO).

- Positive public image and reduced exposure to liability
- Good systematic approach to pollution prevention through minimization of ecological impact of products and activities

OM in Action — Subaru's Clean, Green Set of Wheels with ISO 14001

"Going green" had humble beginnings. First, it was newspapers, soda cans and bottles, and corrugated packaging—the things you typically throw into your own recycling bins. Similarly, at Subaru's Lafayette, Indiana, plant, the process of becoming the first completely waste-free auto plant in North America began with employees dropping these items in containers throughout the plant. Then came employee empowerment. "We had 268 suggestions for different things to improve our recycling efforts," said Denise Coogan, plant ISO 14001 environmental compliance leader.

Some ideas were easy to handle. "With plastic shrink wrap, we found some (recyclers) wouldn't take colored shrink wrap. So we went back to our vendors and asked for only clear shrink wrap," Coogan said. Some suggestions were a lot dirtier. "We went dumpster diving to see what we were throwing away and see what we could do with it."

The last load of waste generated by Subaru made its way to a landfill 7 years ago. Since then, everything that enters the plant eventually exits as a usable product. Coogan adds, "We didn't redefine 'zero.' Zero means zero. Nothing from our manufacturing process goes to the landfill."

Last year alone, the Subaru plant recycled 13,142 tons of steel, 1,448 tons of paper products, 194 tons of plastics, 10 tons of solvent-soaked rags,

Cnky Photography/Fotolia

and 4 tons of light bulbs. Doing so conserved 29,200 trees, 670,000 gallons of oil, 34,700 gallons of gas, 10 million gallons of water, and 53,000 million watts of electricity. "Going green" isn't easy, but it can be done!

Sources: IndyStar (May 10, 2014) and *BusinessWeek* (June 6, 2011).

- Compliance with regulatory requirements and opportunities for competitive advantage
- Reduction in the need for multiple audits

ISO 14000 standards have been implemented by more than 200,000 organizations in 155 countries. Companies that have implemented ISO 14000 standards report environmental and economic benefits such as reduced raw material/resource use, reduced energy consumption, lower distribution costs, improved corporate image, improved process efficiency, reduced waste generation and disposal costs, and better utilization of recoverable resources.

ISO 14001, which addresses environmental management systems, gives guidance to companies to minimize harmful effects on the environment caused by their activities. The *OM in Action* box "Subaru's Clean, Green Set of Wheels with ISO 14001" illustrates the growing application of the ISO 14000 standards.

Summary

If a firm wants to be viable and competitive, it must have a strategy for corporate social responsibility and sustainability. Operations and supply-chain managers understand that they have a critical role in a firm's sustainability objectives. Their actions impact all the stakeholders. They must continually seek new and innovative ways to design, produce, deliver, and dispose of profitable, customer-satisfying products while adhering to many environmental regulations. Without the expertise and commitment of operations and supply-chain managers, firms are unable to meet their sustainability obligations.

Key Terms

Corporate social responsibility (CSR) (p. 194)
Shared value (p. 194)
Sustainability (p. 195)
Carbon footprint (p. 197)
Economic sustainability (p. 197)
Life cycle assessment (p. 198)
Closed-loop supply chains (p. 203)
ISO 14000 (p. 204)

Discussion Questions

1. Why must companies practice corporate social responsibility?
2. Find statements of sustainability for a well-known company online and analyze that firm's policy.
3. Explain sustainability.
4. Discuss the 3*R*s.
5. Explain closed-loop supply chains.
6. How would you classify a company as green?
7. Why are sustainable business practices important?

Solved Problems

Virtual Office Hours help is available in MyOMLab.

SOLVED PROBLEM S5.1

The design team for Superior Electronics is creating a mobile audio player and must choose between two design alternatives. Which is the better environmental design alternative, based on achieving a higher revenue retrieval opportunity?

SOLUTION

Collecting the resale revenue per unit, recycling revenue per unit, processing cost per unit, and the disposal cost per unit, the design team computes the revenue retrieval for each design:

Design 1

PART	RESALE REVENUE PER UNIT	RECYCLING REVENUE PER UNIT	PROCESSING COST PER UNIT	DISPOSAL COST PER UNIT
Tuner	$4.93	$2.08	$2.98	$0.56
Speaker	0.00	0.00	4.12	1.23
Case	6.43	7.87	4.73	0.00
Total	$11.36	$9.95	$11.83	$1.79

Design 2

PART	RESALE REVENUE PER UNIT	RECYCLING REVENUE PER UNIT	PROCESSING COST PER UNIT	DISPOSAL COST PER UNIT
Tuner	$6.91	$4.92	$3.41	$2.13
Case	5.83	3.23	2.32	1.57
Amplifier	1.67	2.34	4.87	0.00
Speaker	0.00	0.00	3.43	1.97
Total	$14.41	$10.49	$14.03	$5.67

Using the following formula [Equation (S5-1)], compare the two design alternatives:

Revenue retrieval = Total resale revenue + Total recycling revenue − Total processing cost − Total disposal cost

$$\text{Revenue retrieval Design 1} = \$11.36 + \$9.95 - \$11.83 - \$1.79 = \$7.69$$

$$\text{Revenue retrieval Design 2} = \$14.41 + \$10.49 - \$14.03 - \$5.67 = \$5.20$$

Design 1 brings in the most revenue from its design when the product has reached its end-of-life.

SOLVED PROBLEM S5.2

The City of High Point is buying new school buses for the local school system. High Point has found two models of school buses that it is interested in. Eagle Mover costs $80,000 to buy and uses diesel fuel, with an average fuel efficiency of 10 miles per gallon. Eagle Mover has an operating cost of $.28 per mile. Yellow Transport, a hybrid bus, costs $105,000 to buy and uses diesel fuel and battery power, getting an average of 22 miles per gallon. Yellow Transport has an operating cost of $.32 per mile. The distance traveled annually is determined to be 25,000 miles, with the expected life of either bus to be 10 years. The average diesel price is $3.50 per gallon.

SOLUTION

a) Based on life cycle cost, which bus is the better choice?

Eagle Mover:

$$\$80{,}000 + \left[\frac{25{,}000\,\frac{miles}{year}}{10\,\frac{miles}{gallon}}\right](\$3.50/gallon)(10\ years) + \left(25{,}000\,\frac{miles}{year}\right)(\$.28/mile)(10\ years)$$

$$= \$80{,}000 + \$87{,}500 + \$70{,}000 = \$237{,}500$$

Yellow Transport:

$$\$105{,}000 + \left[\frac{25{,}000\,\frac{miles}{year}}{22\,\frac{miles}{gallon}}\right](\$3.50/gallon)(10\ years) + \left(25{,}000\,\frac{miles}{year}\right)(\$.32/mile)(10\ years)$$

$$= \$105{,}000 + \$39{,}773 + \$80{,}000 = \$224{,}773$$

Yellow Transport is the better choice.

b) How many miles does the school district need to put on a bus for costs to be equal?

Let M be the break-even point in miles, set the equations equal to each other, and solve for M:

$$\text{Total cost for Eagle Mover} = \text{Total cost for Yellow Transport}$$

$$\$80{,}000 + \left[\frac{3.50\frac{\$}{gallon}}{10\frac{miles}{gallon}} + .28\frac{\$}{mile}\right](M\ miles) = \$105{,}000 + \left[\frac{3.50\frac{\$}{gallon}}{22\frac{miles}{gallon}} + .32\frac{\$}{mile}\right](M\ miles)$$

$$\$80{,}000 + \left(.630\frac{\$}{mile}\right)(M) = \$105{,}000 + \left(.479\frac{\$}{mile}\right)(M)$$

$$\left(.151\frac{\$}{mile}\right)(M) = \$25{,}000$$

$$M = \frac{\$25{,}000}{.151\frac{\$}{mile}} = 165{,}563\ miles$$

c) What is the crossover point in years?

$$\text{Crossover point} = \frac{165{,}563\,miles}{25{,}000\dfrac{miles}{year}} = 6.62\,years$$

Problems

Problems S5.1–S5.19 relate to Design and Production for Sustainability

• • **S5.1** The Brew House needs to decide which of two coffee maker designs is better environmentally. Using the following tables, determine which model is the better design alternative.

Brew Master

PART	RESALE REVENUE PER UNIT	RECYCLING REVENUE PER UNIT	PROCESSING COST PER UNIT	DISPOSAL COST PER UNIT
Metal frame	$1.65	$2.87	$1.25	$0.75
Timer	0.50	0.00	1.53	1.45
Plug/cord	4.25	5.65	6.22	0.00
Coffee pot	2.50	2.54	2.10	1.35

Brew Mini

PART	RESALE REVENUE PER UNIT	RECYCLING REVENUE PER UNIT	PROCESSING COST PER UNIT	DISPOSAL COST PER UNIT
Plastic frame	$1.32	$3.23	$0.95	$0.95
Plug/cord	3.95	4.35	5.22	0.00
Coffee pot	2.25	2.85	2.05	1.25

• • **S5.2** Using the information in Problem S5.1, which design alternative is the better environmental choice if the Brew House decided to add a timer to the Brew Mini model? The timer revenue and costs are identical to those of the Brew Master.

• • **S5.3** Using the information in Problem S5.1, which design alternative is the better environmental choice if the Brew House decided to remove the timer from the Brew Master model?

• • **S5.4** What is the total vehicle life cycle cost of this hybrid car, given the information provided in the following table?

VEHICLE PURCHASE COST	$17,000
VEHICLE OPERATING COST PER MILE	$0.12
USEFUL LIFE OF VEHICLE	15 years
MILES PER YEAR	14,000
MILES PER GALLON	32
AVERAGE FUEL PRICE PER GALLON	$3.75

• • **S5.5** What is the crossover point in miles between the hybrid vehicle in Problem S5.4 and this alternative vehicle from a competing auto manufacturer?

VEHICLE PURCHASE COST	$19,000
VEHICLE OPERATING COST PER MILE	$0.09
USEFUL LIFE OF VEHICLE	15 years
MILES PER YEAR	14,000
MILES PER GALLON	35
AVERAGE FUEL PRICE PER GALLON	$3.75

• • **S5.6** Given the crossover mileage in Problem S5.5, what is the crossover point in years?

• • **S5.7** In Problem S5.5, if gas prices rose to $4.00 per gallon, what would be the new crossover point in miles?

• • **S5.8** Using the new crossover mileage in Problem S5.7, what is the crossover point in years?

• • **S5.9** Mercedes is assessing which of two windshield suppliers provides a better environmental design for disassembly. Using the tables below, select between PG Glass and Glass Unlimited.

PG Glass

PART	RESALE REVENUE PER UNIT	RECYCLING REVENUE PER UNIT	PROCESSING COST PER UNIT	DISPOSAL COST PER UNIT
Glass	$12	$10	$6	$2
Steel frame	2	1	1	1
Rubber insulation	1	2	1	1

Glass Unlimited

PART	RESALE REVENUE PER UNIT	RECYCLING REVENUE PER UNIT	PROCESSING COST PER UNIT	DISPOSAL COST PER UNIT
Reflective glass	$15	$12	$7	$3
Aluminium frame	4	3	2	2
Rubber insulation	2	2	1	1

• • **S5.10** Environmentally conscious Susan has been told that a new electric car will only generate 6 ounces of greenhouse gases (GHG) per mile, but that a standard internal combustion car is double that at 12 ounces per mile. However, the nature of electric cars is such that the new technology and electric batteries generate 30,000 lbs. of GHG to manufacture and another 10,000 lbs. to recycle. A standard car generates only 14,000 lbs. of GHG to manufacture, and recycling with established technology is only 1,000 lbs. Susan is interested in taking a systems approach that considers the life-cycle impact of her decision. How many miles must she drive the electric car for it to be the preferable decision in terms of reducing greenhouse gases?

• • • **S5.11** A Southern Georgia school district is considering ordering 53 propane-fueled school buses. "They're healthier, they're cleaner burning, and they're much quieter than the diesel option," said a school administrator. Propane-powered buses also reduce greenhouse gasses by 22% compared to gasoline-powered buses and 6% compared to diesel ones. But they come at a premium—$103,000 for a propane model, $15,000 more than the diesel equivalent.

The propane bus operating cost (above and beyond fuel cost) is 30 cents/mile, compared to 40 cents for the diesel. Diesel fuel costs about $2/gallon in Georgia, about $1 more than propane.

Bus mileage is 12 mpg for the propane model vs. 10 mpg for diesel. The life of a school bus in the district averages 9 years, and each bus travels an average of 30,000 miles per year because the district is so large and rural.

Which bus is the better choice based on a life-cycle analysis?

•• **S5.12** Green Forever, a manufacturer of lawn equipment, has preliminary drawings for two grass trimmer designs. Charla Fraley's job is to determine which is better environmentally. Specifically, she is to use the following data to help the company determine:

a) The revenue retrieval for the GF Deluxe
b) The revenue retrieval for the Premium Mate
c) Which model is the better design alternative based on revenue retrieval

GF Deluxe

PART	RESALE REVENUE PER UNIT	RECYCLING REVENUE PER UNIT	PROCESSING COST PER UNIT	DISPOSAL COST PER UNIT
Metal drive	$3.27	$4.78	$1.05	$0.85
Battery	0.00	3.68	6.18	3.05
Motor housing	3.93	2.95	2.05	1.25
Trimmer head	1.25	0.75	1.00	0.65

Premium Mate

PART	RESALE REVENUE PER UNIT	RECYCLING REVENUE PER UNIT	PROCESSING COST PER UNIT	DISPOSAL COST PER UNIT
Metal drive	$3.18	$3.95	$1.15	$0.65
Battery	0.00	2.58	4.98	2.90
Motor housing	4.05	3.45	2.45	1.90
Trimmer head	1.05	0.85	1.10	0.75

•• **S5.13** Green Forever (see Problem S5.12) has decided to add an automatic string feeder system with cost and revenue estimates as shown below to the GF Deluxe model.

a) What is the new revenue retrieval value for each model?
b) Which model is the better environmental design alternative?

PART	RESALE REVENUE PER UNIT	RECYCLING REVENUE PER UNIT	PROCESSING COST PER UNIT	DISPOSAL COST PER UNIT
String feeder system	$1.05	$1.25	$1.50	$1.40

•• **S5.14** Green Forever's challenge (see Problem S5.12) is to determine which design alternative is the better environmental choice if it uses a different battery for the Premium Mate. The alternate battery revenue and costs are as follows:

PART	RESALE REVENUE PER UNIT	RECYCLING REVENUE PER UNIT	PROCESSING COST PER UNIT	DISPOSAL COST PER UNIT
Battery	$0.00	$3.68	$4.15	$3.00

a) What is the revenue retrieval for the GF Deluxe?
b) What is the revenue retrieval for the Premium Mate?
c) Which is the better environmental design alternative?

•• **S5.15** Hartley Auto Supply delivers parts to area auto service centers and is replacing its fleet of delivery vehicles. What is the total vehicle life-cycle cost of this gasoline engine truck given the information provided in the following table?

VEHICLE PURCHASE COST	$25,000
VEHICLE OPERATING COST PER MILE	$0.13
USEFUL LIFE OF VEHICLE	10 years
MILES PER YEAR	18,000
MILES PER GALLON	25
AVERAGE FUEL PRICE PER GALLON	$2.55

•• **S5.16** Given the data in Problem S5.15 and an alternative hybrid vehicle with the specifications shown below:

a) What is the crossover point in miles?
b) Which vehicle is has the lowest cost until the crossover point is reached?

VEHICLE PURCHASE COST	$29,000
VEHICLE OPERATING COST PER MILE	$0.08
USEFUL LIFE OF VEHICLE	10 years
MILES PER YEAR	18,000
MILES PER GALLON	40
AVERAGE FUEL PRICE PER GALLON	$2.55

• **S5.17** Based the crossover point in miles found in Problem S5.16, what is this point in years?

•• **S5.18** Using the data from Problem S5.16, if gas prices rose to $3.00 per gallon, what would be the new crossover point in miles?

• **S5.19** Using the new crossover point in Problem S5.18, how many years does it take to reach that point?

CASE STUDIES

Building Sustainability at the Orlando Magic's Amway Center

Video Case

When the Amway Center opened in Orlando in 2011, it became the first LEED (Leadership in Energy and Environmental Design) gold–certified professional basketball arena in the country. It took 10 years for Orlando Magic's management to develop a plan for the new state-of-the-art sports and entertainment center. The community received not only an entertainment center but an environmentally sustainable building to showcase in its revitalized downtown location. "We wanted to make sure we brought the most sustainable measures to the construction, so in operation we can be a good partner to our community and our environment," states CEO Alex Martins. The new 875,000-square foot facility—almost triple the size of the Amway Arena it replaced—is now the benchmark for other sports facilities.

Here are a few of the elements in the Amway Center project that helped earn the LEED certification:

- The roof of the building is designed to minimize daytime heat gain by using reflective and insulated materials.
- Rainwater and air-conditioning condensation are captured and used for irrigation.
- There is 40% less water usage than in similar arenas (saving 800,000 gallons per year), mostly through use of high-efficiency restrooms, including low-flow, dual-flush toilets.
- There is 20% energy savings (about $750,000 per year) with the use of high-efficiency heating and cooling systems.
- The center used environmentally friendly building materials and recycled 83% of the wood, steel, and concrete construction waste that would have ended up in a landfill.
- There is preferred parking for hybrids and other energy-efficient cars.
- The center is maintained using green-friendly cleaning products.

LEED certification means five environmental measures and one design measure must be met when a facility is graded by the U.S. Green Building Council, which is a nationally accepted benchmark program. The categories are sustainability of site, water efficiency, energy, materials/resources, indoor environmental quality, and design innovation.

Other Amway Center design features include efficient receiving docks, food storage layouts, and venue change-over systems. Massive LED electronic signage controlled from a central control room also contributes to lower operating costs. From an operations management perspective, combining these savings with the

Fernando Medina

significant ongoing savings from reduced water and energy usage will yield a major reduction in annual operating expenses. "We think the LEED certification is not only great for the environment but good business overall," says Martins.

Discussion Questions*

1. Find a LEED-certified building in your area and compare its features to those of the Amway Center.
2. What does a facility need to do to earn the gold LEED rating? What other ratings exist?
3. Why did the Orlando Magic decide to "go green" in its new building?

*You may wish to view the video that accompanies this case before addressing these questions.

Green Manufacturing and Sustainability at Frito-Lay

Video Case

Frito-Lay, the multi-billion-dollar snack food giant, requires vast amounts of water, electricity, natural gas, and fuel to produce its 41 well-known brands. In keeping with growing environmental concerns, Frito-Lay has initiated ambitious plans to produce environmentally friendly snacks. But even environmentally friendly snacks require resources. Recognizing the environmental impact, the firm is an aggressive "green manufacturer," with major initiatives in resource reduction and sustainability.

For instance, the company's energy management program includes a variety of elements designed to engage employees in reducing energy consumption. These elements include scorecards and customized action plans that empower employees and recognize their achievements.

At Frito-Lay's factory in Casa Grande, Arizona, more than 500,000 pounds of potatoes arrive every day to be washed, sliced, fried, seasoned, and portioned into bags of Lay's and Ruffles chips. The process consumes enormous amounts of energy and creates vast amounts of wastewater, starch, and potato peelings. Frito-Lay plans to take the plant off the power grid and run it almost entirely on renewable fuels and recycled water. The managers at the Casa Grande plant have also installed skylights in conference rooms, offices, and a finished goods warehouse to reduce the need for artificial light. More fuel-efficient ovens recapture heat from exhaust stacks. Vacuum hoses that pull moisture from potato slices to recapture the water and to reduce the amount of heat needed to cook the potato chips are also being used.

Frito-Lay has also built over 50 acres of solar concentrators behind its Modesto, California, plant to generate solar power. The solar power is being converted into heat and used to cook Sun Chips. A biomass boiler, which will burn agricultural waste, is also planned to provide additional renewable fuel.

Frito-Lay is installing high-tech filters that recycle most of the water used to rinse and wash potatoes. It also recycles corn by-products to make Doritos and other snacks; starch is reclaimed and sold, primarily as animal feed, and leftover sludge is burned to create methane gas to run the plant boiler.

There are benefits besides the potential energy savings. Like many other large corporations, Frito-Lay is striving to establish its green credentials as consumers become more focused on environmental issues. There are marketing opportunities, too. The company, for example, advertises that its popular Sun Chips snacks are made using solar energy.

At Frito-Lay's Florida plant, only 3.5% of the waste goes to landfills, but that is still 1.5 million pounds annually. The goal is zero waste to landfills. The snack food maker earned its spot in the National Environmental Performance Task Program by maintaining a sustained environmental compliance record and making new commitments to reduce, reuse, and recycle at this facility.

Substantial resource reductions have been made in the production process, with an energy reduction of 21% across Frito-Lay's 34 U.S. plants. But the continuing battle for resource reduction continues. The company is also moving toward biodegradable packaging and seasoning bags and cans and bottles. While these multiyear initiatives are expensive, they have the backing at the highest levels of Frito-Lay as well as corporate executives at PepsiCo, the parent company.

Discussion Questions*

1. What are the sources of pressure on firms such as Frito-Lay to reduce their environmental footprint?
2. Identify the specific techniques that Frito-Lay is using to become a "green manufacturer."
3. Select another company and compare its green policies to those of Frito-Lay.

*You may wish to view the video that accompanies this case before answering these questions.

- **Additional Case Study:** Visit MyOMLab for this free case study:
  Environmental Sustainability at Walmart: Walmart's experiment with global sustainability.

Endnotes

1. The authors wish to thank Dr. Steve Leon, University of Central Florida, for his contributions to this supplement.
2. See related discussions in M. E. Porter and M. R. Kramer, "Creating Shared Value," *Harvard Business Review* (Jan.–Feb. 2011) and M. Pfitzer, V. Bockstette, and M. Stamp, "Innovating for Shared Values," *Harvard Business Review* (Sept. 2013).

Supplement 5 *Rapid* Review

Main Heading	Review Material	MyOMLab
CORPORATE SOCIAL RESPONSIBILITY (p. 194)	Managers must consider how the products and services they make affect people and the environment in which they operate. ■ **Corporate social responsibility (CSR)**—Managerial decision making that considers environmental, societal, and financial impacts. ■ **Shared value**—Developing policies and practices that enhance the competitiveness of an organization, while advancing the economic and social conditions in the communities in which it operates.	Concept Question: 1.1
SUSTAINABILITY (pp. 195–197)	■ **Sustainability**—Meeting the needs of the present without compromising the ability of future generations to meet their needs. Systems view—Looking at a product's life from design to disposal, including all of the resources required. The commons—Inputs or resources for a production system that are held by the public. Triple bottom line—Systems needed to support the three *Ps: people, planet*, and *profit*. To support their *people,* many companies evaluate safety in the work environment, the wages paid, work hours/week. Apple, GE, P&G, and Walmart conduct audits of their suppliers to make sure sustainability goals are met. To support the *planet,* operation managers look for ways to reduce the environmental impact of their operations. ■ **Carbon footprint**—A measure of the total GHG emissions caused directly and indirectly by an organization, product, event or person. To support their *profits,* company investments must be sustainable economically. Firms may supplement standard accounting with social accounting.	Concept Questions: 2.1–2.4 **VIDEO S5.1** Building Sustainability at the Orlando Magic's Amway Center **VIDEO S5.2** Green Manufacturing and Sustainability at Frito-Lay
DESIGN AND PRODUCTION FOR SUSTAINABILITY (pp. 198–203)	■ **Life cycle assessment**—Analysis of environmental impacts of products from the design stage through end-of-life. The 3*R*s: *reduce, reuse,* and *recycle*. These must be incorporated by design teams, process managers, and supply-chain personnel. Product design is the most critical phase in the product life cycle assessment. Design for disassembly focuses on reuse and recycle. Revenue retrieval = Total resale revenue + Total recycling revenue − Total processing cost − Total disposal cost (S5-1) Manufacturers also look for ways to reduce the amount of scarce resources in the production process. As products move along the supply chain, logistics managers strive to achieve efficient route and delivery networks, which reduce environmental impact. Vehicles are also evaluated on a life cycle ownership cost basis. A firm must decide whether to pay more up front for sustainable vehicles or pay less up front for vehicles that may be less sustainable. Total life cycle cost = Cost of vehicle + Life cycle cost of fuel + Life cycle operating cost (S5-2) ■ **Closed-loop supply chains,** also called *reverse logistics*—Supply chains that consider the product or its materials after the product reaches its end-of-life stage. This includes forward and reverse product flows. Green disassembly lines help take cars apart so that parts can be recycled. Recycling is the 16th-largest industry in the U.S.	Concept Questions: 3.1–3.4 Problems: S5.1–S5.19 Virtual Office Hours for Solved Problems S5.1–S5.2
REGULATIONS AND INDUSTRY STANDARDS (pp. 203–205)	To guide *product design* decisions, U.S. laws and regulations often provide explicit regulations. *Manufacturing and assembly activities* are guided by OSHA, EPA, and many state and local agencies. There are also U.S. agencies that govern the *disassembly and disposal of hazardous products.* International environmental policies and standards come from the U.N., ISO, the EU, and governments around the globe. The EU has implemented the Emissions Trading System to help reduce greenhouse gas emissions. It works on a "cap-and-trade" principle. ■ **ISO 14000**—The International Organization of Standardization family of guidelines for sustainable development. ISO 14000 has been implemented by more than 200,000 organizations in 155 countries. ISO 14001 addresses environmental management systems.	Concept Questions: 4.1–4.4

Self Test

■ **Before taking the self-test,** refer to the learning objectives listed at the beginning of the supplement and the key terms listed at the end of the supplement.

LO S5.1 Corporate social responsibility includes:
a) doing what's right.
b) having policies that consider environmental, societal, and financial impact.
c) considering a product from design to disposal.
d) all of the above.
e) a and b only.

LO S5.2 Sustainability deals:
a) solely with green products, recycling, global warming, and rain forests.
b) with keeping products that are not recyclable.
c) with meeting the needs of present and future generations.
d) with three views—systems, commons, and defects.
e) with not laying off older workers.

LO S5.3 The 3*R*s of sustainability are:
a) reputation, reuse, reduce.
b) reputation, recycle, reuse.
c) reputation, reverse logistics, renewal.
d) reuse, reduce, recycle.
e) recycle, review, reuse.

LO S5.4 Design for disassembly is:
a) cost–benefit analysis for old parts.
b) analysis of the amount of revenue that might be reclaimed versus the cost of disposing of a product.
c) a means of recycling plastic parts in autos.
d) the use of lightweight materials in products.

LO S5.5 U.S. and international agencies provide policies and regulations to guide managers in product design, manufacturing/assembly, and disassembly/disposal. They include:
a) U.N. Commission on Resettlement.
b) World Health Organization (WHO).
c) OSHA, FDA, EPA, and NHSA.
d) EPA, ISO, and British High Commission.
e) GHG Commission, UN, and ISO.

Answers: LO S5.1. d; LO S5.2. c; LO S5.3. d; LO S5.4. b; LO S5.5. c.