

Design of Goods and Services

5

CHAPTER

CHAPTER OUTLINE

GLOBAL COMPANY PROFILE: *Regal Marine*

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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

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



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

LEARNING OBJECTIVES

- LO 5.1** *Define* product life cycle 164
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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!

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.

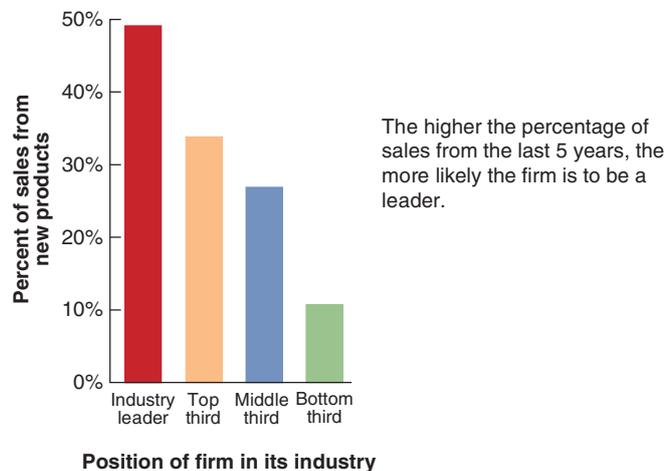
Despite constant efforts to introduce viable new products, many new products do not succeed. Product selection, definition, and design occur frequently—perhaps hundreds of times

VIDEO 5.1

Product Strategy at Regal Marine

Figure 5.1

Innovation and New Products



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.

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.

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.

Generating New Products

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.

STUDENT TIP

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

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

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.

LO 5.2 Describe a product development system

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.

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,

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

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**.

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.

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*

STUDENT TIP

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

Time-based competition

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

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

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.

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.

Alliances

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

Defining a Product

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.

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.

STUDENT TIP

Before anything can be produced, a product’s functions and attributes must be defined.

LO 5.5 Describe how products and services are defined by OM

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.

STUDENT TIP  **Documents for Production**

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

Assembly drawing

An exploded view of the product.

Assembly chart

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

Route sheet

A listing 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.

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)].

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).

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*.

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.

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.

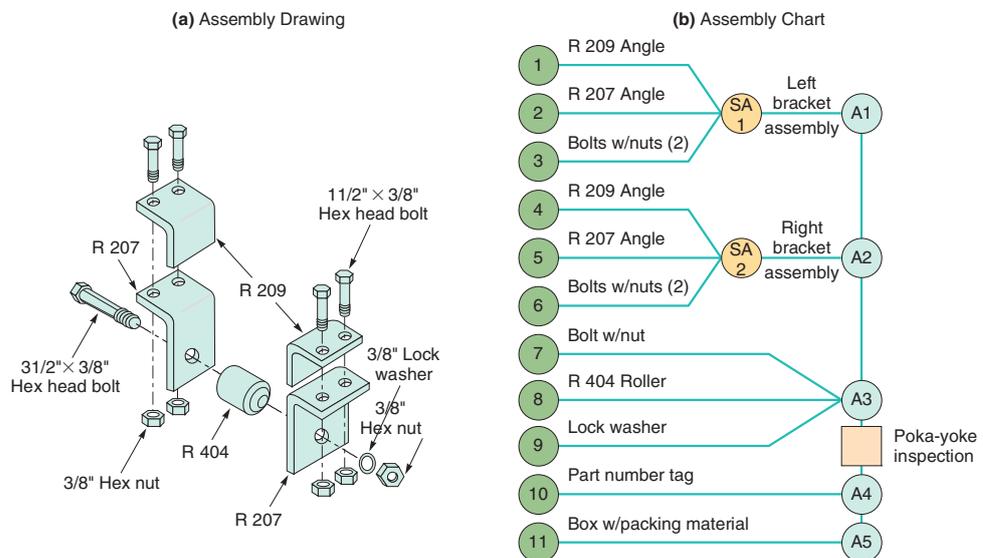
Product Life-Cycle Management (PLM)

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

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 pre-frying 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.

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).

LO 5.6 Describe the documents needed for production

Service Design

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, developed by Professor Scott Sampson, focuses on the ways in which processes can be designed to optimize interaction between firms and

STUDENT TIP

Services also need to be defined and documented.

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.

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:

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.

LO 5.8 Apply decision trees to product issues

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

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?



Nikolay Stefanov Dimitrov / Shutterstock

Discussion Questions

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

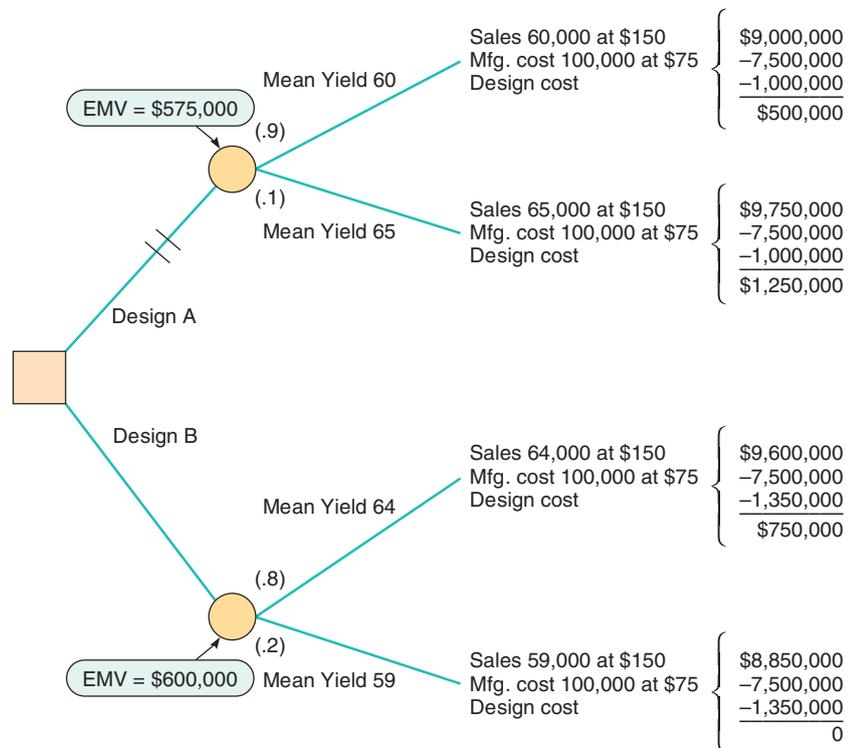
$$EMV(\text{design A}) = (.9)(\$500,000) + (.1)(\$1,250,000) = \$575,000$$

For design B:

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

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

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."

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

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?

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 Reiniger

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)	<p>Although the term <i>products</i> may often refer to tangible goods, it also refers to offerings by service organizations.</p> <p><i>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.</i></p> <ul style="list-style-type: none"> ■ Product Decision—The selection, definition, and design of products. <p>The four phases of the product life cycle are introduction, growth, maturity, and decline.</p> <ul style="list-style-type: none"> ■ Product-by-value analysis—A list of products, in descending order of their individual dollar contribution to the firm, as well as the <i>total annual dollar contribution</i> 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)	<p>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.</p>	Concept Question: 2.1
PRODUCT DEVELOPMENT (pp. 166–170)	<ul style="list-style-type: none"> ■ 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)	<ul style="list-style-type: none"> ■ 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. <p>Sustainability is meeting the needs of the present without compromising the ability of future generations to meet their needs.</p> <p>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.</p>	Concept Questions: 4.1–4.4
PRODUCT DEVELOPMENT CONTINUUM (pp. 173–175)	<ul style="list-style-type: none"> ■ Time-based competition—Competition based on time; rapidly developing products and moving them to market. <p><i>Internal development strategies</i> include (1) new internally developed products, (2) enhancements to existing products, and (3) migrations of existing products.</p> <p><i>External development strategies</i> include (1) purchase the technology or expertise by acquiring the developer, (2) establish joint ventures, and (3) develop alliances.</p> <ul style="list-style-type: none"> ■ 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*

MyOMLab

Main Heading	Review Material	
DEFINING A PRODUCT (pp. 175–177)	<ul style="list-style-type: none"> ■ 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)	<ul style="list-style-type: none"> ■ 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)	<ul style="list-style-type: none"> ■ 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 <i>transition to production</i> .	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

5
SUPPLEMENT

SUPPLEMENT OUTLINE

- ◆ Corporate Social Responsibility 194
- ◆ Sustainability 195
- ◆ Design and Production for Sustainability 198
- ◆ Regulations and Industry Standards 203



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 3Rs for sustainability 198
- LO S5.4** Calculate design for disassembly 199
- LO S5.5** Explain the impact of sustainable regulations on operations 203

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.



Lex Van Lieshout/EPA/Newscom

Corporate Social Responsibility¹

LO S5.1 Describe corporate social responsibility

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.

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 competitiveness 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.

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*.

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.

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 *Ps*: *people*, *planet*, and *profit* (see Figure S5.1), which we will now discuss.

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.

Sustainability

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

LO S5.2 Describe sustainability

VIDEO S5.1

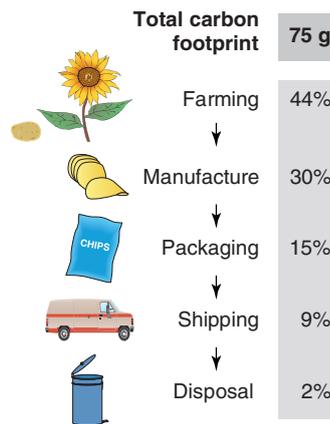
Building Sustainability at the Orlando Magic’s Amway Center

STUDENT TIP

Profit is now just one of the three *Ps*: people, planet, and profit.

Figure S5.2

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



Design and Production for Sustainability

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 *3Rs*—*reduce, reuse, and recycle*—can help accomplish this goal. By incorporating the *3Rs*, 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.

Life cycle assessment

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

Product Design

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.

LO S5.3 Explain the *3Rs* for sustainability

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.

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.

Closed-loop supply chains

Supply chains that consider forward and reverse product flows over the entire life cycle.

Regulations and Industry Standards

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

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

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



Tom Koene/Alamy

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.

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

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,



Crky 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 3Rs.
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:

$$\begin{aligned} & \$80,000 + \left[\frac{25,000 \frac{\text{miles}}{\text{year}}}{10 \frac{\text{miles}}{\text{gallon}}} \right] (\$3.50/\text{gallon})(10 \text{ years}) + \left(25,000 \frac{\text{miles}}{\text{year}} \right) (\$.28/\text{mile})(10 \text{ years}) \\ & = \$80,000 + \$87,500 + \$70,000 = \$237,500 \end{aligned}$$

Yellow Transport:

$$\begin{aligned} & \$105,000 + \left[\frac{25,000 \frac{\text{miles}}{\text{year}}}{22 \frac{\text{miles}}{\text{gallon}}} \right] (\$3.50/\text{gallon})(10 \text{ years}) + \left(25,000 \frac{\text{miles}}{\text{year}} \right) (\$.32/\text{mile})(10 \text{ years}) \\ & = \$105,000 + \$39,773 + \$80,000 = \$224,773 \end{aligned}$$

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 :

Total cost for Eagle Mover = Total cost for Yellow Transport

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

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

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

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

c) What is the crossover point in years?

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

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



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.

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.

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- **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)	<p>Managers must consider how the products and services they make affect people and the environment in which they operate.</p> <ul style="list-style-type: none"> ■ 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)	<ul style="list-style-type: none"> ■ Sustainability—Meeting the needs of the present without compromising the ability of future generations to meet their needs. <p>Systems view—Looking at a product’s life from design to disposal, including all of the resources required.</p> <p>The commons—Inputs or resources for a production system that are held by the public.</p> <p>Triple bottom line—Systems needed to support the three <i>Ps</i>: <i>people</i>, <i>planet</i>, and <i>profit</i>.</p> <p>To support their <i>people</i>, 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.</p> <p>To support the <i>planet</i>, operation managers look for ways to reduce the environmental impact of their operations.</p> <ul style="list-style-type: none"> ■ Carbon footprint—A measure of the total GHG emissions caused directly and indirectly by an organization, product, event or person. <p>To support their <i>profits</i>, company investments must be sustainable economically. Firms may supplement standard accounting with social accounting.</p>	<p>Concept Questions: 2.1–2.4</p> <p>VIDEO S5.1 Building Sustainability at the Orlando Magic’s Amway Center</p> <p>VIDEO S5.2 Green Manufacturing and Sustainability at Frito-Lay</p>
DESIGN AND PRODUCTION FOR SUSTAINABILITY (pp. 198–203)	<ul style="list-style-type: none"> ■ Life cycle assessment—Analysis of environmental impacts of products from the design stage through end-of-life. <p>The 3 Rs: <i>reduce</i>, <i>reuse</i>, and <i>recycle</i>. These must be incorporated by design teams, process managers, and supply-chain personnel.</p> <p>Product design is the most critical phase in the product life cycle assessment.</p> <p>Design for disassembly focuses on reuse and recycle.</p> <p>Revenue retrieval = $\text{Total resale revenue} + \text{Total recycling revenue} - \text{Total processing cost} - \text{Total disposal cost} \quad (\text{S5-1})$ </p> <p>Manufacturers also look for ways to reduce the amount of scarce resources in the production process.</p> <p>As products move along the supply chain, logistics managers strive to achieve efficient route and delivery networks, which reduce environmental impact.</p> <p>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.</p> <p>Total life cycle cost = $\text{Cost of vehicle} + \text{Life cycle cost of fuel} + \text{Life cycle operating cost} \quad (\text{S5-2})$ </p> <ul style="list-style-type: none"> ■ Closed-loop supply chains, also called <i>reverse logistics</i>—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. 	<p>Concept Questions: 3.1–3.4</p> <p>Problems: S5.1–S5.19</p> <p>Virtual Office Hours for Solved Problems S5.1–S5.2</p>
REGULATIONS AND INDUSTRY STANDARDS (pp. 203–205)	<p>To guide <i>product design</i> decisions, U.S. laws and regulations often provide explicit regulations.</p> <p><i>Manufacturing and assembly activities</i> are guided by OSHA, EPA, and many state and local agencies. There are also U.S. agencies that govern the <i>disassembly and disposal of hazardous products</i>.</p> <p>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.</p> <ul style="list-style-type: none"> ■ 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 3Rs 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 NHTSA.
- 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.