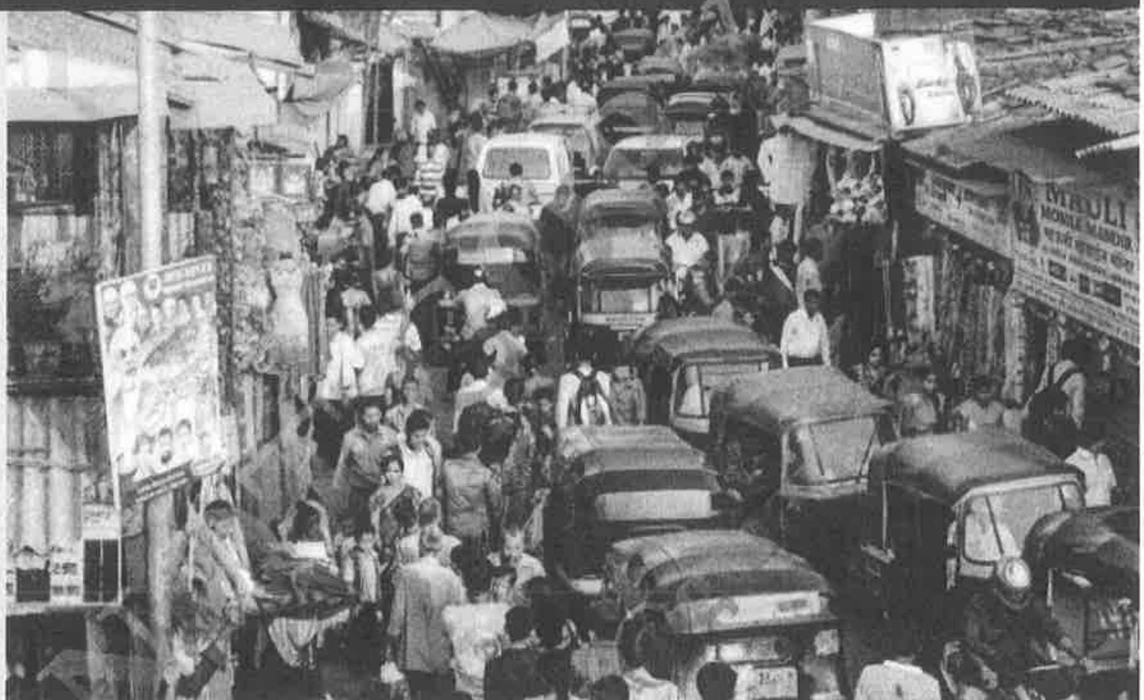
5 Goods and Service Design

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- **5-1** Describe the steps involved in designing goods and services.
- **5-2** Explain the concept and application of quality function deployment.
- **5-3** Describe how the Taguchi loss function, reliability, design for manufacturability, and design for sustainability are used for designing manufactured goods.
- **5-4** Define the five elements of service-delivery system design.
- **5-5** Describe the four elements of service-encounter design.
- **5-6** Explain how goods and service design concepts are integrated at LensCrafters.



Fuel efficiency and environmental concerns are important in developing nations as the number of vehicles on their streets continues to rise.

In developing markets such as China and India, consumers can't afford large, expensive cars, much less drive them in overcrowded population centers. Fuel efficiency as well as environmental concerns are also important, as developing nations seek to cap carbon emissions even as the number of vehicles on their streets continues to rise. But these consumers are not willing to buy inferior cars that simply cost less. Rather, like most of us, they want low-cost vehicles that are designed to meet their needs and still have high quality, reliability, and style—in other words, have value. Consumers in India, for instance, need cars that maximize passenger room because they use their autos primarily as family vehicles to drive around town; by contrast, in the West, with its better roads and routine long-distance driving, cargo capacity matters more. Indian drivers are willing to pay a bit more for cars that offer the latest in comfort, safety, and utility, but not for cars with power windows and locks or fancy sound systems. Automatic transmissions are desirable in India and China—nobody wants to keep pressing the clutch and shifting gears in the inevitable stop-and-go traffic—but powerful engines are not. Succeeding in developing markets, therefore, requires rethinking from start to finish how new cars should be designed and built. It calls for a deep understanding of the unique needs of consumers and the ability to assemble the combination of power trains, bodies, features, and options that best match those desires—at affordable prices.[1]

WHAT DO YOU THINK?

How important are design and value in your purchasing decisions? Provide some examples for goods and services.

Perhaps the most important strategic decision that any firm makes involves the design and development of new goods and services, and the value chain structure and processes that make and deliver them. In fact, decisions about what goods and services to offer and how to position them in the marketplace often determine the ultimate growth, profitability, and success of the firm. Every design project—a new automobile or cell phone, a new online or financial service, even a new pizza—is a series of trade-offs: between technology and functionality, between ambition and affordability, between the desires of the people creating the object and the needs of the people using it.[1]

In today's world, the complexity of customer benefit packages requires a high level of coordination throughout the value chain. As the authors of the opening anecdote about automobile design note, design for value "involves a series of complex, varied, carefully thought-out decisions about which types of engines to use, which equipment should be standard, what safety add-ons to include, how parts and materials are engineered, and which designs are most attractive to the target customer base." At the other end of the value chain, sales and maintenance, and even financing, should also be examined for new ideas. Given limited dealer networks, might roving mechanics be sent out to perform regular maintenance? Could entire extended families enter into financing deals for new cars? Similar questions apply to the design of every good and service.

5-1 Designing Goods and Services

To design and improve goods and services, most companies use some type of structured process. The typical goods and services development processes are shown in Exhibit 5.1. In general, the designs of both goods and services follow a similar path. The critical differences lie in the detailed product and process design phases.

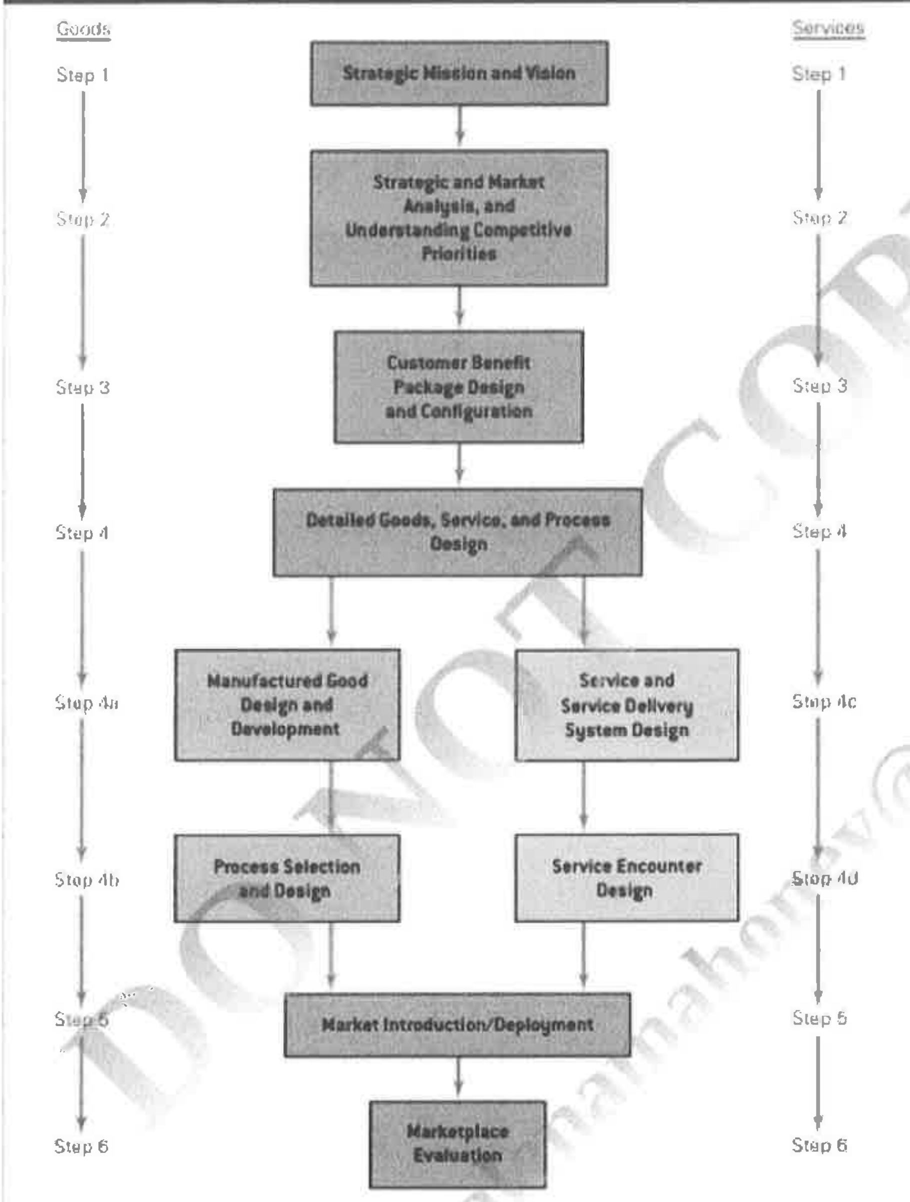
Steps 1 and 2—Strategic Mission, Analysis, and Competitive Priorities Strategic directions and competitive priorities should be consistent with and support the firm's mission and vision. These steps require a significant amount of research and innovation involving marketing, engineering, operations, and sales functions, and should involve customers, suppliers, and employees throughout the value chain. The data and information that result from this effort provide the key input for designing the final customer benefit package.

Step 3—Customer Benefit Package Design and Configuration Clearly, firms have a large variety of possible choices in configuring a customer benefit package (CBP). For example, when buying a new vehicle, an automobile dealer might include such options as leasing, free oil changes and/or maintenance, a performance driving school, free auto washes, service pickup and delivery, loaner cars, and so on.

Essentially, CBP design and configuration choices revolve around a solid understanding of customer needs and target markets, and the value that customers place on such attributes as the following:

- **Time**—Many grocery stores now offer self-service checkout to reduce customer waiting time. Manufacturers such as Dell use the Internet to acquire customer information for more responsive product design.
- **Place**—UPS has UPS Stores strategically located for customer convenience that also provide packaging services; many companies offer day-care centers on-site to provide convenience to their employees.

EXHIBIT 5.1 An Integrated Framework for Goods and Service Design



- **Information**—Bank of America provides an Internet search capability for the best home equity loan. A business dedicated to providing guitar music books and videos (www.ChordMelody.com) offers a telephone hot line to speak with a professional guitarist for questions on selecting the proper instructional and performance material.
- **Entertainment**—Some Dick's Sporting Goods Stores provide a rock-climbing wall for children while other family members shop. A pianist serenades shoppers at Nordstrom's department stores. Some minivans have built-in DVD players.
- **Exchange**—Retail stores such as Best Buy allow customers to travel to the store and buy the goods, purchase goods on their websites and have them delivered, or purchase goods on their websites and have them ready to be picked up at the store.
- **Form**—For manufactured goods, form is associated with the physical characteristics of the good and addresses the important customer need of aesthetics. An interior designer might use methods such as sketches, photographs, physical samples, or even computer-simulated renderings to show how a kitchen might be transformed.

A job-seeking service such as Monster.com provides pure information value, whereas buying an automobile or going on a vacation involves all six types.

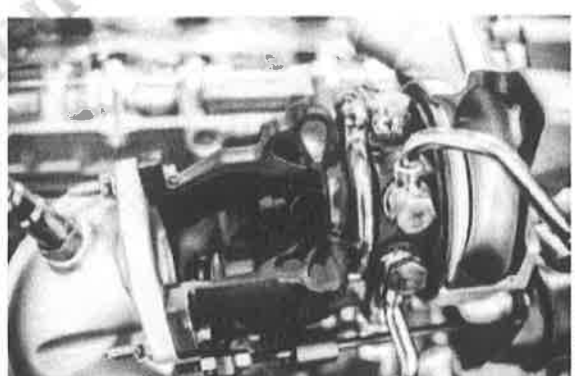
Step 4—Detailed Goods, Services, and Process Design If a proposal survives the concept stage—and many do not—each good or service in the CBP, as well as the process that creates it, must be designed in more detail. This is where the designs of goods and services differ, as suggested by the alternate paths in Exhibit 5.1. The first three steps in Exhibit 5.1 are more strategic and conceptual in nature, whereas step 4 focuses on detailed design and implementation.

The design of a manufactured goods focuses on its physical characteristics—dimensions, materials, color, and so on. Much of this work is done by artists and engineers to translate customer requirements into physical specifications. This is the focus of step 4a in the exhibit. The process by which the good is manufactured (i.e., the configuration of machines and labor) can be designed as a separate activity (step 4b), with, of course, proper communication and coordination with the designers of the good.

The design of a service in steps 4c and 4d in Exhibit 5.1, however, cannot be done independently from the "process" by which the service is delivered. The process by which the service is created and delivered (i.e., "produced") is, in essence, the service itself! For example, the steps that a desk clerk follows to check in a guest at a hotel represent the process by which the guest is served and (hopefully) experiences a sense of satisfaction. Thus, service design must be addressed from two perspectives—the service delivery system and the service encounter—as noted in steps 4c and 4d in Exhibit 5.1.

> Every design project—a new automobile or cell phone, a new online or financial service, even a new pizza—is a series of trade-offs: between technology and functionality, between ambition and affordability, between the desires of the people creating the object and the needs of the people using it.

For both goods and services, this phase usually includes prototype testing. **Prototype testing** *is the process by which a model (real or simulated) is constructed to test the product's performance under actual operating conditions, as well as consumer reactions to the prototypes.* For example, at General Motors (GM), parts are designed and digitally analyzed using special software; one-third scale models are produced, assembled, and tested in a wind tunnel to evaluate the aerodynamics of automobile designs. Today, many companies use advanced technology to perform rapid prototyping—the process of building prototypes quickly to reduce product development cost and time to market. GM has a laboratory where 15 specialists take part orders from GM design centers all over the world, build them within hours, and then express ship them back, allowing designers and engineers to quickly evaluate them.[5]



Engines like this are designed and digitally analyzed as part of the prototype testing process.

Step 5—Market Introduction/Deployment In this step, the final bundle of goods and services—the customer benefit package—is advertised, marketed, and offered to customers. For manufactured goods, this includes making the item in the factory and shipping it to warehouses or wholesale and retail stores; for services, it might include hiring and training employees or staying open an extra hour in the evening. For many services it means building sites such as branch banks or hotels or retail stores.

LaRosa's Pizzeria: Understanding the Voice of the Customer

LaRosa's Pizzeria, a regional chain of informal Italian restaurants in the greater Cincinnati area, realized that customers know what they want. To gather information to help design a new restaurant configuration, LaRosa's went out to current and potential customers and noncustomers in nonmarket areas to acquire the voice of the customer. Here are some real examples of customers' experiences at other restaurants that LaRosa's clearly wanted to avoid:

- "So there I was, like herded cattle, standing on the hard concrete floor, cold wind blasting my ankles every time the door opened, waiting and waiting for our name to be called."
- "And then I saw a dirty rag being slopped around a dirty table."
- "I swear! The salad looked like the server ran down to the river bank and picked weeds and grass—I'm never going back!"
- "When they're that age, going to the bathroom is a full-contact sport—they're reaching and grabbing at everything, and you're trying to keep them from touching anything because the bathroom is so dirty."

In the last example, what the customer really was saying is "The bathroom tells me what the kitchen might be like. Do I really want to eat here?" Clean bathrooms turned out to be the most important customer requirement that the company learned from listening to the voice of the customer.

What are the implications of the other customer comments? Interestingly, none of these comments revolves totally around the physical good (food) itself; service-facility and service-encounter quality are clearly important customer requirements!

> The process by which the service is created and delivered (i.e., "produced") is, in essence, the service itself!

Step 6—Marketplace Evaluation The marketplace is a graveyard of missed opportunities: poorly designed goods and services and failed execution resulting from ineffective operations. The final step in designing and delivering a customer benefit package is to constantly evaluate how well the goods and services are selling, and customers' reactions to them.

5-2 Customer-Focused Design

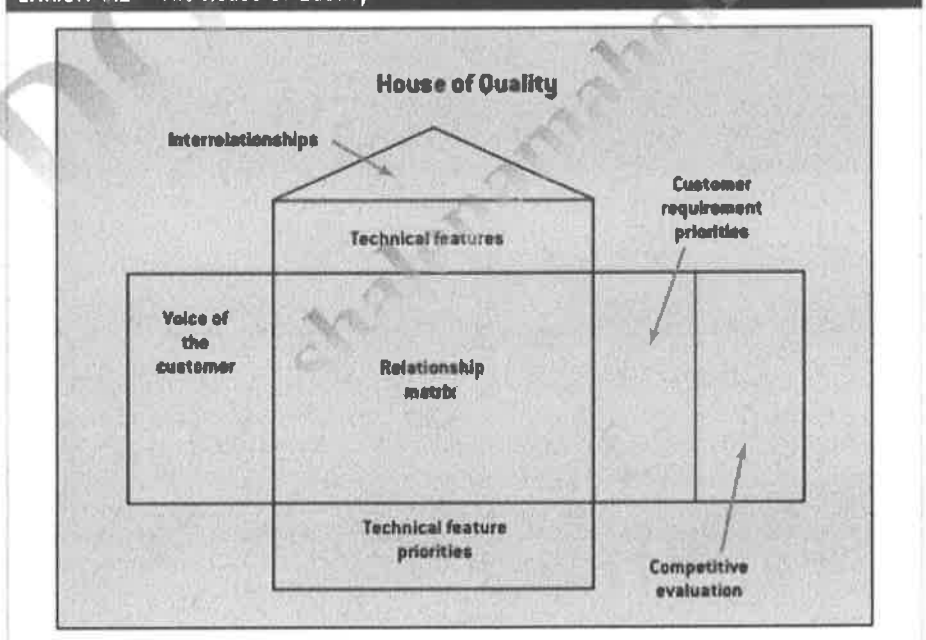
The design of a good or service should reflect customer wants and needs, which are often termed customer requirements. *Customer requirements, as expressed in the customer's own words, are called the* **voice of the customer**. The design process must translate the voice of the customer into specific technical features that characterize a design and provide the "blueprint" for manufacturing or service delivery. Technical features are generally expressed in the language of designers and engineers; examples include the type and amount of materials, size and shape of parts, strength requirements, service procedures to follow, and employee behavior during service interactions. An effective approach for doing this is called *quality function deployment*. **Quality function deployment (QFD)** *is an approach to guide the design, creation, and marketing of goods and services by integrating the voice of the customer into all decisions.* QFD can be applied to a specific manufactured good or service, or to the entire CBP. The process is initiated with a matrix, which, because of its structure (as shown in Exhibit 5.2), is often called the *House of Quality*.

> The marketplace is a graveyard of missed opportunities: poorly designed goods and services and failed execution resulting from ineffective operations.

Building a House of Quality begins by identifying the voice of the customer and technical features of the design and listing them in the appropriate places in the diagram. As shown in Exhibit 5.2, the voice of the customer and the technical features create a matrix structure in the center of the diagram. By evaluating how each technical feature relates to each customer requirement (using a scale such as "very strong," "strong," "weak," or "no relationship"), designers can determine how well a design reflects the actual customer requirements. This might be based on expert experience, customer surveys, or other experiments. The lack of a relationship between a customer requirement and any of the technical features would suggest that the final good or service will have difficulty in meeting customer needs. Similarly, if a technical feature does not relate to any customer requirement, it may be unnecessary in the design. The roof of the House of Quality shows the interrelationships between any pair of technical features, and these relationships help in answering questions such as "How does a change in one product characteristic affect others?" This can help refine a design and evaluate trade-offs in design decisions.

To the right of the relationship matrix is an assessment of the importance of each customer requirement and how competitors' products compare with the proposed design in

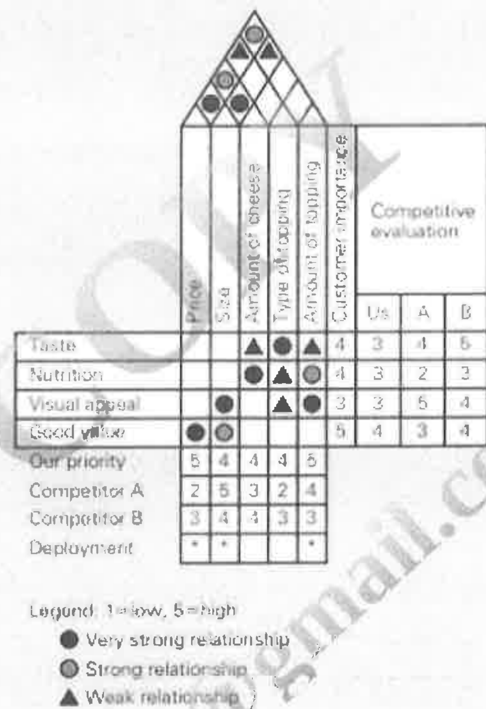
EXHIBIT 5.2 The House of Quality



Using the House of Quality: Building a Better Pizza

A restaurant wants to develop a "signature" pizza. The voice of the customer in this case consists of four attributes. The pizza should be tasty, healthy, and visually appealing, and should provide good value. The "technical features" that can be designed into this particular product are price, size, amount of cheese, type of additional toppings, and amount of additional toppings. The symbols in the matrix in the exhibit at the right show the relationships between each customer requirement and technical feature. For example, taste bears a moderate relationship with amount of cheese and a strong relationship with type of additional toppings. In the roof, the price and size area seem to be strongly related (as size increases, the price must increase). The competitive evaluation shows that competitors are currently weak on nutrition and value, so those attributes can become key selling points in a marketing plan if the restaurant can capitalize on them. Finally, at the bottom of the house are targets for the technical features based on an analysis of customer-importance ratings and competitive ratings. The features with asterisks are the ones to be "deployed," or emphasized, in subsequent design and production activities.

House of Quality Example for a Pizza



terms of meeting the voice of the customer. This helps identify key "selling points" and features that would help to differentiate the good or service from competitors' products.

The final step (bottom of the House) is to identify those technical features that have the strongest relationships to customer requirements, have poor competitive performance, or will be strong selling points. This helps prioritize those technical features that should be "deployed," or paid the most attention to during subsequent design and production or service delivery activities. This will ensure that the voice of the customer will be maintained in subsequent detailed design, manufacturing or service, and control activities.

QFD has been used successfully by many companies, such as Mitsubishi, Toyota, Motorola, Xerox, IBM, Procter & Gamble, and AT&T. Toyota, for example, reduced start-up costs by over 60 percent and product development time by one-third using QFD.

5-3 Designing Manufactured Goods

For a manufactured good such as an automobile, computer, or textbook, design involves determining technical specifications such as dimensions, tolerances, materials, and purchased components; or choice of fonts and page layout for a textbook. This step also requires coordination with operations managers to ensure that manufacturing processes can produce the design (step 4b of Exhibit 5.1). Many different tools and techniques are used to support product design activities; we review some of the most important ones in this section.

5-3a Tolerance Design and the Taguchi Loss Function

For most manufactured goods, design blueprints specify a target dimension (called the *nominal*), along with a range of permissible variation (called the *tolerance*); for example, 0.500 ± 0.020 cm. The nominal dimension is 0.500 cm but may vary anywhere in the range from 0.480 to 0.520 cm. This is sometimes called the *goal-post model* (see Exhibit 5.3). Tolerance design involves determining the acceptable tolerance. Narrow tolerances improve product functionality and performance, but tend to raise manufacturing costs because they usually require higher-precision technology. Wide tolerances, on the other hand, reduce costs, but may have a negative impact on product performance. Thus, designers must consider these trade-offs and should use sound scientific and engineering approaches to optimizing tolerances rather than simply setting them judgmentally.

Genichi Taguchi, a Japanese engineer, maintained that the traditional practice of setting design specifications is inherently flawed. The goal-post model assumes that any value within the tolerance range is acceptable, but those outside are not. In the previous example, what is the real difference between 0.479 and 0.481? Not much; the impact of either value on the performance characteristic of the product would be about the same, yet a part having the dimension of 0.481 would be acceptable, whereas the other would not be. In reality, neither value is close to the nominal specification. Taguchi argued that the smaller the variation from the nominal specification, the better the quality. In turn, products are more consistent and fail less frequently, and thus are less costly in the long run.

Taguchi measured quality as the variation from the target value of a design specification and then translated that variation into an economic "loss function" that expresses the cost of variation in monetary terms. This approach can be applied to both goods and services.

Taguchi proposed measuring the loss resulting from the deviation from the target by a quadratic function so that larger deviations cause increasingly larger losses. The loss function is

$$L(x) = k(x - T)^2 \qquad [5.1]$$

where

$L(x)$ is the monetary value of the loss associated with deviating from the target, T;

x is the actual value of the dimension; and

k is a constant that translates the deviation into dollars.

Exhibit 5.4 illustrates this Taguchi loss function. The constant, k, is estimated by determining the cost of repair or replacement if a certain deviation from the target occurs. Solved problems 5.1 and 5.2 show an example of the Taguchi loss function and how it can be used to set design tolerances.

EXHIBIT 5.3 Traditional Goal-Post View of Conforming to Specifications

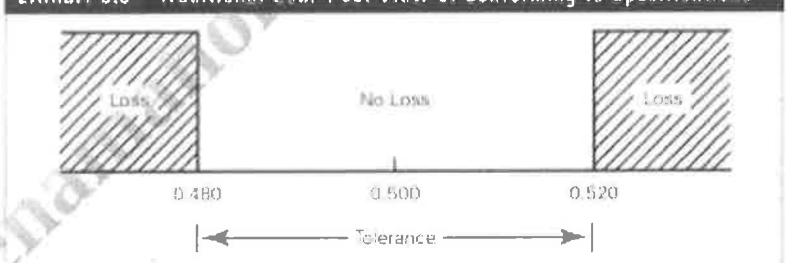
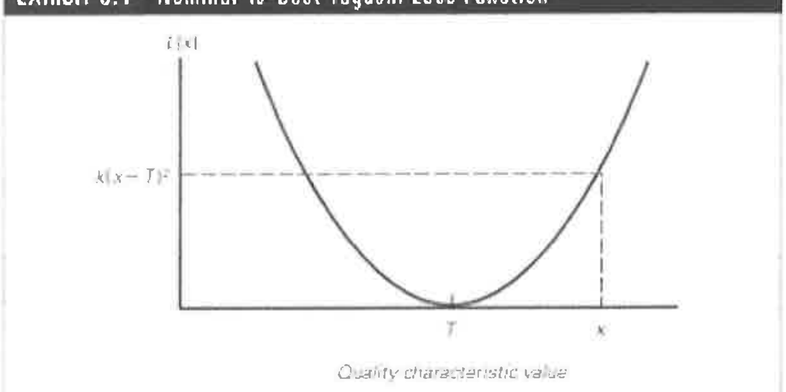


EXHIBIT 5.4 Nominal-Is-Best Taguchi Loss Function



SOLVED PROBLEM 5.1: FINDING THE TAGUCHI LOSS FUNCTION

Cassette tapes are still used in some handheld recording devices and in less expensive portable musical instrument recording devices. The desired speed of a cassette tape is 1.875 inches per second. Any deviation from this value causes a change in pitch and tempo and thus poor sound quality. Suppose that adjusting the tape speed under warranty when a customer complains and returns a device costs a manufacturer \$20. Based on past information, the company knows the average customer will return a device if the tape speed is off the target by at least 0.15 inch per second; in other words, when the speed is either 2.025 or 1.725. Find the Taguchi loss function.

EXHIBIT 5.5 Portion of Excel *Taguchi* Template

	A	B	C	D
1	**Taguchi Loss Function**			
2	Enter data only in yellow cells.			
3				
4	**Calculation of *k* for the Loss Function**			
5	**Deviation from target**	0.15		
6	**Loss associated with deviation**	\$20.00		
7	**k**	\$888.89		
8				
9	**Loss Calculation for a Specific *x***			
10	**Target specification, T**	1.875		
11	**Dimensional value, x**	1.925		
12	**k**	\$888.89		
13	**Loss**	\$2.22		

Solution:

The loss associated with a deviation of $(x - T) = 0.15$ from the target is $L(x) = \$20$. To find the loss function for any value of x, we substitute these values into Equation 5.1 and solve for k:

$$20 = k(0.15)^2$$
$$k = 888.9$$

and thus the loss function is

$$L(x) = 888.9(x - 1.875)^2$$

For example, if the actual speed is 1.925 inches per second, the Taguchi loss function estimates that the economic loss will be $L(1.9) = 888.89(1.925 - 1.875)^2 = \$2.22$. Some, but not all, customers might perceive poor sound quality for this small of a deviation and return the product for adjustment, so the average loss is smaller. Exhibit 5.5 shows a portion of the Excel *Taguchi* template in MindTap that can be used to perform these calculations.

SOLVED PROBLEM 5.2: USING THE TAGUCHI LOSS FUNCTION TO SET ECONOMIC SPECIFICATIONS

For the scenario in Solved Problem 5.1, suppose that a technician tests the tape speed prior to packaging and can adjust the speed to the target of 1.875 at a cost of \$5. What should the economic specification limits be?

Solution:

The accompanying table shows the loss associated with tape speeds from 1.725 to 2.025. Note that if the tape speed is less than 1.800 or greater than 1.950, the loss incurred by not adjusting the tape is greater than \$5. Therefore, it is more economical to inspect and adjust the tape if the actual speed is outside of these limits. If the speed is greater than 1.800 or less than 1.950 (shown in red), then clearly it costs more to inspect and adjust than to simply ship the unit as is. Therefore, 1.800 and 1.950 represent the economical design specifications that the company should try to achieve. The Excel Taguchi template computes these economic specifications using a break-even analysis approach in rows 15–19, as shown in Exhibit 5.6.

Tape Speed, x	L(x)
1.725	\$20.00
1.740	\$16.20
1.755	\$12.80
1.770	\$9.80
1.785	\$7.20
1.800	\$5.00
1.815	\$3.20
1.830	\$1.80
1.845	\$0.80
1.860	\$0.20
1.875	\$0
1.890	\$0.20
1.905	\$0.80

Tape Speed, x	$L(x)$
1.920	$1.80
1.935	$3.20
1.950	$5.00
1.965	$7.20
1.980	$9.80
1.995	$12.80
2.010	$16.20
2.025	$20.00

EXHIBIT 5.6 Economic Design Specifications Using the Excel *Taguchi* Template

	A	B	C	D
1	**Taguchi Loss Function**			
2	Enter data only in yellow cells.			
3				
4	**Calculation of k for the Loss Function**			
5	**Deviation from target**	0.15		
6	**Loss associated with deviation**	$20.00		
7	**k**	$888.89		
8				
9	**Loss Calculation for a Specific x**			
10	**Target specification, T**	1.875		
11	**Dimensional value, x**	1.925		
12	**k**	$888.89		
13	**Loss**	$2.22		
14				
15	**Economic Design Specifications**			
16	**Target specification, T**	1.875		
17	**k**	$888.89		
18	**Cost of inspection and adjustment**	$5.00		
19	**Break-Even Tolerance**	0.075		
20	**Lower specification limit**	1.800		
21	**Upper specification limit**	1.950		

5-3b Design for Reliability

Everyone expects their car to start each morning and their computer to work without crashing. **Reliability** *is the probability that a manufactured good, piece of equipment, or system performs its intended function for a stated period of time under specified operating conditions.* Reliability applies to services as well as manufacturing; a system could be a service process where each stage (work activity or station) is analogous to a component part in a manufactured good.

Reliability is a *probability*, that is, a value between 0 and 1. For example, a reliability of 0.97 indicates that, on average, 97 out of 100 times the item will perform its function for a given period of time under specified operating conditions. Often, reliability is expressed as a percentage simply to be more descriptive (97 percent reliable). Reliability can be improved by using better components or by adding redundant components. In either case, costs increase; thus, trade-offs must be made.

Automotive Gremlins

Have you even encountered mysterious noises and rattles in your engine or transmission? While some might attribute such mischievous behavior to gremlins, there is usually an engineering explanation. In transmissions, for example, which consist of many gears and other parts in a "stack-up" assembly, the lack of precision tolerances can lead to problems in performance such as gear clashes upon shifting and, eventually, premature failure. When the parts in the assembly are at the high end of the tolerance range, the stack-up becomes too tight; if they are at the low end of the tolerance range, the stack-up is too loose. In either case, drivers will notice the difference. This is why Taguchi advocated producing parts on the nominal specification with minimal variation.

Many manufactured goods consist of several components that are arranged in series but are assumed to be independent of one another, as illustrated in Exhibit 5.7. If one component or process step fails, the entire system fails. If we know the individual reliability, p_j, for each component, j, we can compute the total reliability of an n-component series system, R_s. If the individual reliabilities are denoted by $p_1, p_2, \ldots, p_n$ and the system reliability is denoted by R_s, then

$$R_s = (p_1)(p_2)(p_3)\cdots(p_n) \quad [5.2]$$

Other designs consist of several parallel components that function independently of each other, as illustrated in Exhibit 5.8. The entire system will fail only if all components fail; this is an example of redundancy. The system reliability of an n-component parallel system is computed as

$$R_p = 1 - (1 - p_1)(1 - p_2)(1 - p_3)\cdots(1 - p_n) \quad [5.3]$$

Many other systems are combinations of series and parallel components. To compute the reliability of such systems, you have to analyze the structure and use formulas 5.2 or 5.3 to replace series subsystems or parallel subsystems with equivalent single components until the final structure is either a simple series or parallel system. These formulas can help designers and engineers assess the reliability of proposed designs and optimize their performance. Solved Problems 5.3–5.6 illustrate the use of these formulas and an Excel template for reliability analysis.

EXHIBIT 5.7 Structure of a Serial System

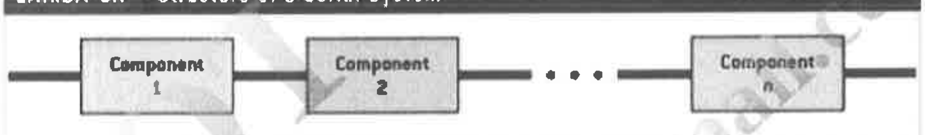
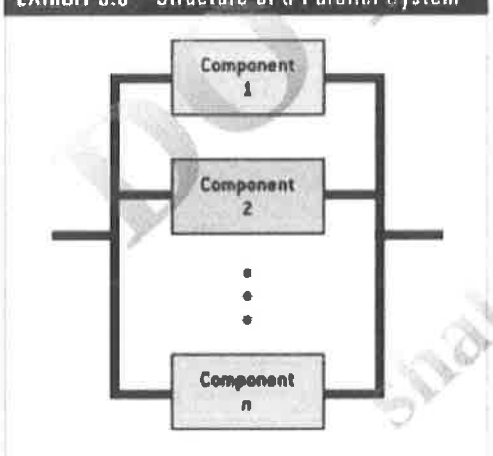


EXHIBIT 5.8 Structure of a Parallel System



5-3c Design for Manufacturability

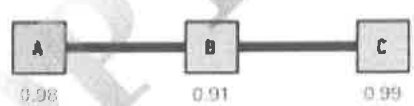
Many aspects of product design can adversely affect manufacturability and, hence, quality. Some parts may be designed with features difficult to fabricate repeatedly or with unnecessarily tight tolerances.[5] Some parts may lack details for self-alignment or features for correct insertion. In other cases, parts so fragile or so susceptible to corrosion or contamination may be damaged in shipping or by internal handling. Sometimes a design simply has more parts than are needed to perform the desired functions, which increases the chance of assembly error. Thus, problems of poor design may show up as errors, poor yield, damage, or functional failure in fabrication, assembly, test, transport, and end use.

Design for manufacturability (DFM) *is the process of designing a product for efficient production at the highest level of quality.* One way of doing this is through product simplification. **Product simplification** *is the process of trying to simplify designs to reduce complexity and costs and thus improve productivity, quality, flexibility, and customer satisfaction.* The simpler the design, the

SOLVED PROBLEM 5.3: COMPUTING RELIABILITY OF A SERIES SYSTEM

Consider a new laboratory blood analysis machine consisting of three major subassemblies: A, B, and C. The manufacturer is evaluating the preliminary design of this piece of equipment. The reliabilities of each subassembly are shown in Exhibit 5.9. What is the system reliability?

EXHIBIT 5.9 Subassembly Reliabilities



Solution:

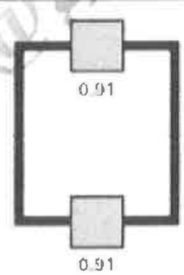
Because this is a series system, we use Equation 5.2:

$$R_s = (0.98)(0.91)(0.99) = 0.883 \text{ or } 88.3 \text{ percent}$$

SOLVED PROBLEM 5.4: COMPUTING RELIABILITY OF A PARALLEL SYSTEM

The reliability of an electronic component in an automated machine tool is 0.91. The design engineer is considering creating a parallel (backup) system as shown in Exhibit 5.10. (Assume equipment software switches to the working component if one fails.) How much is reliability improved?

EXHIBIT 5.10 Parallel System



Solution:

Using Equation 6.3, the reliability of the parallel system is

$$R_s = 1 - (1 - 0.91)(1 - 0.91) = 1 - 0.0081 = 0.9919$$

The reliability has increased from 91 percent to over 99 percent by adding the redundant component.

SOLVED PROBLEM 5.5: COMPUTING THE RELIABILITY OF A SERIES SYSTEM WITH A PARALLEL SUBSYSTEM

Exhibit 5.11 shows as series system with parallel redundancy for component B. What is the reliability of this system?

Solution:

First, compute the reliability of the parallel subsystem for component B using formula 5.3: $R_B = 1 - (1 - 0.9)^3 = 0.999$. We use the Excel template *System Reliability* available on MindTap to facilitate the calculations as shown in Exhibit 5.12. Replace this parallel system with a single component having this reliability, resulting in a series system shown in Exhibit 5.13. Next, compute the reliability of this equivalent series system using formula 5.2 or the Excel template as shown in Exhibit 5.14. $R_s = (0.99)(0.999)(0.96)(0.98) = 0.93$. The reliability of the original system is therefore 0.93.

EXHIBIT 5.11 A Series–Parallel System

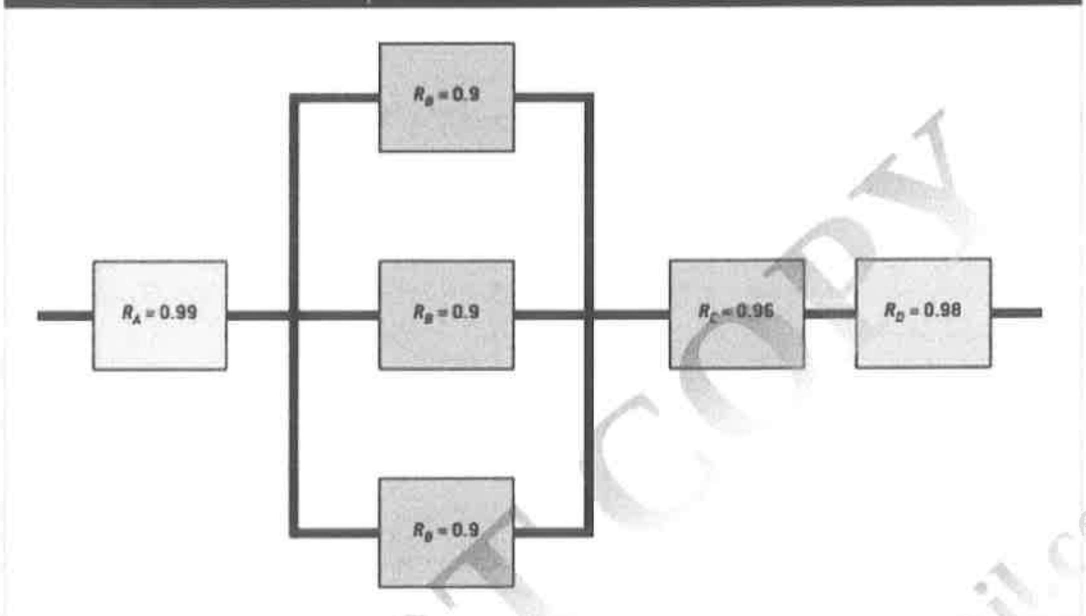


EXHIBIT 5.12 Using the *System Reliability* Excel Template for Component B

	A	B	C	D	E
1	System Reliability			Copyright © 2019 Cengage Learning	
2	Enter data only in yellow cells			Not for commercial use.	
3					
4	Series Systems			Parallel Systems	
5					
6	Component	Reliability		Component	Reliability
7	Component 1			Component 1	0.9
8	Component 2			Component 2	0.9
9	Component 3			Component 3	0.9
10	Component 4			Component 4	
11	Component 5			Component 5	
12	Component 6			Component 6	
13	Component 7			Component 7	
14	Component 8			Component 8	
15	Component 9			Component 9	
16	Component 10			Component 10	
17	System Reliablity	0.000000000		System Reliablity	0.9990000000

EXHIBIT 5.13 Equivalent Series System

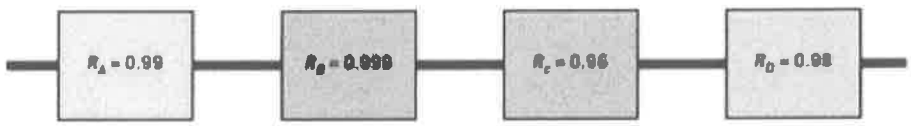


EXHIBIT 5.14 Using the *System Reliability* Template for the Equivalent Series System

	A	B	C	D	E
1	System Reliability			Copyright © 2019 Cengage Learning	
2	Enter data only in yellow cells			Not for commercial use.	
3					
4	Series Systems			Parallel Systems	
5					
6	Component	Reliability		Component	Reliability
7	Component 1	0.99		Component 1	
8	Component 2	0.999		Component 2	
9	Component 3	0.96		Component 3	
10	Component 4	0.98		Component 4	
11	Component 5			Component 5	
12	Component 6			Component 6	
13	Component 7			Component 7	
14	Component 8			Component 8	
15	Component 9			Component 9	
16	Component 10			Component 10	
17	System Reliablity	0.930460608		System Reliablity	0.0000000000

SOLVED PROBLEM 5.6: COMPUTING THE RELIABILITY OF A PARALLEL SYSTEM WITH SERIES SUBSYSTEMS

Exhibit 5.15 shows a parallel system that consists of two series subsystems. What is the reliability of this system?

Solution:

Convert each series subsystem to an individual component. Using the *System Reliability* template or formula 5.2, we see that $R_{ABC} = (0.95)(0.98)(0.99) = 0.92169$ and $R_{DE} = (0.99)(0.97) = 0.9603$. This results in the equivalent parallel system shown in Exhibit 5.16. The reliability of this parallel system is $R = (1 - 0.92169)(1 - 0.9603) = 0.9969$.

EXHIBIT 5.15 A Parallel System with Series Subsystems

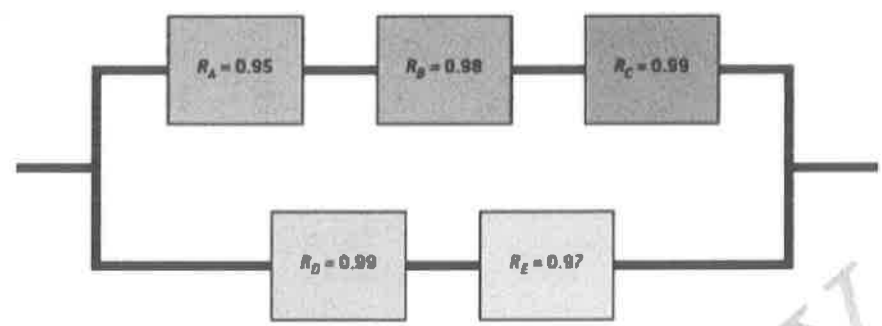
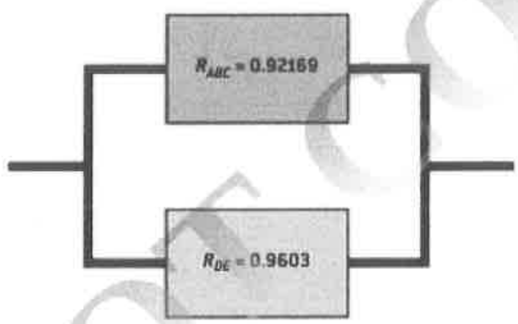


EXHIBIT 5.16 Equivalent Parallel System



fewer opportunities for error, the faster the flow time, the better the chance of high process efficiency, and the more reliable the manufactured good or service process. For example, the redesign of the Cadillac Seville rear-bumper assembly reduced the number of parts by half and cut assembly time by 57 percent, to less than eight minutes, saving the company over $450,000 annually in labor costs.[7] Because many of the eliminated parts were squeak- and rattle-causing fasteners, nuts, bolts, and screws, the change also improved the quality of the car.

Toyota: Simple Design Simplifies Operations

Manufacturing complexity is driven by choices and options. For the Toyota Venza, simplicity is key. In effect, there is one model that is available in four versions: a four-cylinder engine with front-wheel drive or all-wheel drive, or a six-cylinder engine with the same. Not only does this design strategy give consumers a nicely equipped vehicle right from the get-go, but it also makes things comparatively easier at the Toyota Georgetown assembly plant by reducing the complexity of assembling a much larger variety of different models and options.[6]

5-3d Design for Sustainability

Environmental concerns are placing increased pressure on design. Pressures from environmental groups clamoring for "socially responsible" designs, states and municipalities that are running out of space for landfills, and consumers who want the most for their money have caused designers and managers to look carefully at the concept of Design for Environment. **Design for Environment (DfE)** *is the explicit consideration of environmental concerns during the design of goods, services, and processes, and includes such practices as designing for recycling and disassembly.* For example, Energy Star dishwashers use advanced technology to get your dishes clean while using less water and energy. A dishwasher built in 1994 uses considerably more water per cycle than today's Energy Star–certified models and costs an extra $40 a year in electrical utility bills. In addition, an Energy Star dishwasher results in a reduction of 1,140 pounds of carbon dioxide that is released to the air due to less demand on electrical power and water plants. One aspect of designing for sustainability is designing products that can easily be repaired and refurbished or otherwise salvaged for reuse.

5-4 Service-Delivery System Design

As we illustrated in Exhibit 5.1, the design of services revolves around designing the service-delivery system and service encounters. **Service-delivery system design** *includes facility location and layout, the servicescape, service process and job design, and technology and information support systems.* Integrating all of these elements is necessary to design a service that provides value to customers and can create a competitive advantage. A poor choice on any one of these components, such as technology or job design, can degrade service system efficiency and effectiveness.

5-4a Facility Location and Layout

Location affects a customer's travel time and is an important competitive priority in a service business. Health clinics, rental car firms, post offices, health clubs, branch banks, libraries, hotels, emergency service facilities, retail stores, and many other types of service facilities depend on good location decisions. Starbucks Coffee shops, for example, are ubiquitous in many cities, airports, and shopping malls. The layout of a facility affects process flow, costs, and customer perception and satisfaction.

5-4b Servicescape

The **servicescape** *is all the physical evidence a customer might use to form an impression.* *The servicescape also provides the behavioral setting where service encounters take place.* People around the world,

Pepsi: From Plastic- to Plant-Based Bottles

Pepsi introduced new soft-drink bottles made entirely from plant material such as switch grass, pine bark, and corn husks instead of oil-based plastic. The new bottles look, feel, and protect the drink inside exactly the same as Pepsi's current bottles. Pepsi is conducting tests of the bottles, and after it can be sure that it can successfully produce them on a large scale, Pepsi will begin to convert all of its products—billions of bottles each year—to the new design. Pepsi noted that the cost to research and design the new bottle was in the millions of dollars.[7]