MANAGING QUALITY

INTEGRATING THE SUPPLY CHAIN

Sixth Edition

S. THOMAS FOSTER

Managing Quality

Integrating the Supply Chain

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S. Thomas Foster
Brigham Young University

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To Camille: You Rock!

BRIEF CONTENTS

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PREFACE

Welcome to the sixth edition of *Managing Quality: Integrating the Supply Chain*. We are using the theme of supply chain management as a unifying theme for quality improvement. Previous adopters of *Managing Quality* will note that the coverage of quality topics is just as comprehensive as ever. We simply adopt the unifying theme of the supply chain to enhance our emphasis on the integration of systems with customers, suppliers, technology, and people. We think you will find that your customers—the students—will find this quality management course ever more relevant and interesting. Of course, the new edition of the text has been updated with many changes to keep our coverage of quality topics on the cutting edge.

NEW TO THIS EDITION

- The acceptance sampling supplement to Chapter 9 is back. It provides coverage of important quality management tools.
- We have added coverage of process chain network (PCN) diagramming. This little-known tool provides an excellent way to redesign services processes.
- The main theme for this update is *currency*. We have worked hard to update vignettes and references to keep the book state-of-the-art.
- Many references have been updated to reflect the state of the art in research.
- This book includes the ISO 9000:2015 standard and the most recent Baldrige criteria available at the time of publication.
- All Excel templates (and MS Project) have been updated to the most recent version.
- There is increased focus on lean in this edition.
- Many other changes, too numerous to mention, have been incorporated into this book. However, while adding new content, we have not added to the bulk of the book. This allowed us to keep our focus on a lean and mean book that will hold the interest of students.

MAJOR THEMES

Supply Chain as a Unifying Theme

Today's firms are ever more focused on improving supply chain performance, and key to this improvement is quality management. As we look upstream, we need to develop our suppliers. Downstream, we focus on customer service and after-sales service. Implicit in this process is service design. In your classes, you can drive these concepts home by emphasizing the systems view implicit in supply chain management. This unifying theme provides a linkage between the roots of quality management (Shewhart and Deming) and new developments such as Six Sigma and service quality. *For clarification, this is not a supply chain management text. This is a quality management text that uses supply chain management as a unifying theme*.

Integrative Approach

Workers and managers in organizations are somewhat limited by their particular functional preparation and specialization (going back to their educational training). This narrow presentation filter is how they analyze and cognitively interpret information. However, quality management has emerged as a discipline that is not owned by any of the functional areas such as operations management, supply chain management, human resources, or marketing. We all have to work together to satisfy customers.

Contingency Approach

This is a concept we have emphasized for a long time that is gaining traction in the research and practitioner literature. We passionately believe that the future of quality management will involve learning the contingencies associated with managing quality. There is no "one way" or "magic pill" that companies can implement to improve quality. Therefore, the contingency approach is used to instruct students how to assess the current position of the firm and identify an effective strategy for improvement based on a profound understanding of their company, market, customers, and so on. Thus improvement is based on the contingent variables that are operative in the firm as it exists. This contingency approach is introduced in Chapter 1 and permeates the rest of the text.

The author and more than 300 universities around the world have successfully taught quality management using this contingency approach. This approach, coupled with the unifying theme of the supply chain, makes it pedagogically even more powerful. To manage quality effectively, a few conditions must be present: Students must understand their businesses, understand the quality body of knowledge, understand the available tools, and have a method for planning quality based on this knowledge. This text provides a basis for accomplishing this—when combined with an instructor's insight.

SUPPORT FOR THIS EDITION

Active Models

There are interactive Excel spreadsheets located at **www.pearsonhighered.com/foster** that correspond to examples in Chapter 12 and Chapter 13 and allow the student to explore and better understand important quantitative concepts. Students or instructors can adjust inputs to the model and, in effect, they can answer a whole series of "what if" questions that are provided (e.g., What if variation in the process changes? What if the process indicates changes are needed? What if we change the sample size?). These Active Models are great for classroom presentation and/or homework.

FOR THE INSTRUCTOR

Besides the changes and additions to the text, we've made substantial revisions to the support materials for this book.

Instructor's Resource Center

At the Instructor Resource Center, **www.pearsonhighered.com/irc**, instructors can easily register to gain access to a variety of instructor resources available with this text in downloadable format. If assistance is needed, our dedicated technical support team is ready to help with the media supplements that accompany this text. Visit **http://247pearsoned.custhelp.com/** for answers to frequently asked questions and toll-free user-support phone numbers.

The following supplements are available with this text

- Companion Website
- Instructor's Resource Manual
- Test Bank
- TestGen® Computerized Test Bank (and various conversions)
- PowerPoint Presentation

ACKNOWLEDGMENTS

I wish to first thank my family for putting up with the fences left unmended, the mountains not explored, the rivers not rafted, the snow unskied, the music not played, and the many hours spent in front of a computer screen over the last years writing and updating this book. It has truly been a labor of love for me. I believe that these concepts are important for the future of the world.

I would like to thank my parents, who always emphasized the importance of education as a means of achieving a happy life. I thank Everett E. Adam Jr. for mentoring me. I would like to acknowledge my colleagues at Brigham Young University for providing encouragement for this project. Thanks to all my students and those individuals who have hired me as a consultant. These people have helped me pursue lifelong learning.

Dan Tylman, my editor at Pearson, deserves recognition for the great encouragement he has given to me. Finally, I am thankful for my faith, which keeps me progressing eternally.

ABOUT THE AUTHOR

Dr. Tom Foster is a professor, researcher, and consultant in the field of quality management. Among his areas of expertise are strategic quality planning, service quality, Six Sigma, government quality, and the role of technology in improving quality. Tom is the Donald L. Staheli Professor of quality and global supply chain management in the Marriott School of Management at Brigham Young University. He has also taught at Pennsylvania State University and Boise State University. He received his Ph.D. from the University of Missouri–Columbia.

Tom has professional experience in manufacturing, financial services operations, and international oil exploration. He has consulted for more than 30 companies, including Trus Joist MacMillan, the U.S. Department of Energy, Hewlett-Packard, Heinz Frozen Food, and Cutler Hammer/Eaton Corporation. Tom recently served on the 12-person Board of Overseers for the Malcolm Baldrige Award and has served as a judge for state awards.

Tom is on the editorial boards of the *Journal of Operations Management,* the *Quality Management Journal,* and *Decision Sciences*. He has published more than 80 quality-related research articles in journals such as *The Journal of Operations Management, Decision Sciences*, the *International Journal of Production Research*, the *Quality Management Journal*, and *Quality Progress*. He is listed in *Who's Who in America* and *Who's Who in the World*.

Tom is the founder of www.freequality.org, was awarded the ASBSU Outstanding Faculty Award, and served as guest editor for the *Journal of Operations Management* and *Quality Management Journal* special issue on supply chain quality. In addition, he was the winner of the 2002 Decision Sciences Institute Innovative Education Award. Tom is coauthor of *Managing Supply Chain and Operations*, published by Pearson.

Tom has ten children and fourteen grandchildren, and is married to the former Camille Curtis. In his spare time, he skis, enjoys the Rocky Mountains, and plays his Gibson Les Paul Custom.

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PART ONE

Understanding Quality Concepts

To understand quality in the supply chain, we need a common language. In the general public, the language of quality is imprecise and inconsistent. The language of quality professionals is much more precise and consistent.

To understand the advanced concepts in the later chapters, in Chapters 1 through 3 we build a conceptual foundation of quality theory. This forms the basis of the contingency approach. To apply quality improvement on a contingent basis, you need to understand the foundation that has been laid by leaders in the quality movement such as W. Edwards Deming, Joseph Juran, Philip Crosby, Kaoru Ishikawa, and others. These people have made huge contributions to the world of quality and a knowledge of their teachings and ideas is necessary for quality application.

In Chapter 3, we consider important frameworks, such as ISO 9000, the Deming Prize, and the Baldrige criteria. They provide models for improvement that are being used in many countries around the world.

CHAPTER 1

Differing Perspectives on Quality

Chapter Objectives

After completing this chapter, you should be able to:

1. Recognize that different dimensions of quality.
2. Be able to discuss quality dimensions.
3. Communicate the seven different functional perspectives on quality.
4. Understand why it is important to know that the different perspectives exist.
5. Define a quality system using the three spheres.
6. Understand how the three spheres complement each other.
7. Understand the value-added perspective on quality.
8. Discuss differing cultural perspectives on quality.

Quality management involves flows. There are process flows, information flows, material flows, and flows of funds. Each of these flows has to operate effectively, efficiently, and with outstanding quality. Like a river, we refer to these as upstream and downstream flows. The sums of these flows comprise the supply chain.

Considering the **supply chain** causes us to think about quality differently. One of the problems with quality efforts has been that they tend to be too internally oriented. The supply chain causes us to expand our vision as we *externalize* processes that had previously been *internalized.* They include **upstream** processes relating to our dealing with suppliers—negotiating, selecting, and improving supplier performance—and **downstream** processes—delivering products and services and serving customers.

The supply chain encompasses many differing functions and processes. It includes all the core activities from the raw materials stage to after-sale service. To execute all of these processes correctly involves integrating differing functions, expertise, and dimensions of quality. This need for integration increases the requirement for flexible, cross-functional problem solving and employees who can adapt to rapidly changing markets.

There are many different definitions and dimensions of quality in the supply chain. We present several of these definitions and dimensions in this chapter. For the present, you can view quality as a measure of goodness that is inherent to a product or service. Employees working for the same firm often view quality differently. Think of the different functions involved in creating

A CLOSER LOOK AT QUALITY 1-1 Buying Clothing in Asia

One of the benefits of the global supply chain has been the opening of new markets in places such as China and India. A recent study by PwC[1] shows that Asian preferences for apparel among affluent shoppers are very different from the United States and Europe. It is fair to say that wealthy Asian shoppers are addicted to luxury-brand products. Affluent Asian shoppers are four times more likely to pay high prices for luxury brands such as Gucci, Prada, and Hermes than U.S. and European consumers. Why is this true? In Asian cultures, these name-brand products signal a shopper's wealth or social status. Affluent Asians crave conspicuous consumption.

In developing Asia, product quality and guaranteed authenticity are more important than price. In developed countries, price is considered a much more important purchase criterion. In developing countries, upward mobility is a newer reality, and luxury products are seen as a method for moving up the social ladder and tapping into the newest fashions. Asians are twice as likely as developed country people to use the Internet and social media to identify which brands are currently the hottest.

As a result, retailers moving into Asian countries can maximize their success by building brand equity, using web-based brand advocates, and tapping celebrities to advertise their products. Using social media in this way can influence perceptions of quality in these rapidly growing markets.

[1]Based on Shah, S., et al., "The Rise of the Affluent Asian Shopper," PwC's Experience Radar 2013, PwC, 2013.

products and services. They include design engineering, marketing, operations, cost accounting, financial management, and others throughout the supply chain. A product design engineer might feel that customer satisfaction is mostly influenced by product design and product attributes, and take great pains to design a product that satisfies the customer. However, the product also needs to satisfy marketing's need for quick design cycle times and accounting's need for low-cost products. So perceptions differ on a variety of levels, including what our goals for the product or service are. A Closer Look at Quality 1-1 illustrates this point by comparing Asian perceptions concerning apparel purchases.

Perceptions affect every aspect of our world—including the business world. To communicate effectively about quality, managers need to recognize that differences in perceptions of quality exist. Although this observation may not seem too startling, many managers have strong opinions about what quality is. Sometimes these opinions can be at variance with the beliefs of the majority of their customers, which may hurt the competitiveness of a firm. For that reason, in this chapter we study quality from a variety of perspectives. Later we provide a means for recognizing and resolving differences in perception. Finally, we introduce the contingency view of quality management that we emphasize throughout this book.

WHAT IS QUALITY?

If you ask 10 people to define quality, you probably will probabily get 10 different definitions.

Product Quality Dimensions

There are several definitions of quality, or **quality dimensions.** One of the most respected collections of quality dimensions was compiled by David Garvin[2] of the Harvard Business School (see Table 1-1).

Garvin developed a list of eight quality dimensions (see Table 1-1). These dimensions describe product quality specifically in the following paragraphs.

[2]Garvin, D., "What Does 'Product Quality' Really Mean?" *Sloan Management Review* (Fall 1984): 25–43.

TABLE 1-1 Product Quality Dimensions

Performance
Features
Reliability
Conformance
Durability
Serviceability
Aesthetics
Perceived quality

Source: © 1984 from MIT Sloan Management Review/ Massachusetts Institute of Technology.

Performance refers to the efficiency with which a product achieves its intended purpose. This might be the return on a mutual fund investment, the fuel efficiency of an automobile, or the acoustic range of a pair of stereo speakers. Better performance is usually synonymous with better quality.

Features are attributes of a product that supplement the product's basic performance. They include many of the "bells and whistles" contained in products. A visit to any television or computer retail store will reveal that features such as surround sound, HDTV capability, 3-D, and size are powerful marketing tools for which customers will pay a premium. A full-line television retail store may carry televisions priced from $200 to $12,000. This range represents a 6,000% price premium for additional features!

Reliability refers to the propensity for a product to perform consistently over its useful design life. A subfield in quality management has emerged, called *reliability management,* based on the application of probability theory to quality. A product is considered reliable if the chance that it will fail during its designed life is very low. For example, if a refrigerator has a 2% chance of failure in a useful life of 10 years, we say that it is 98% reliable.

Conformance is perhaps the most traditional dimension of quality. When a product is designed, certain numeric dimensions for the product's performance are established, such as capacity, speed, size, durability, or the like. These numeric product dimensions are referred to as *specifications.* The number of ounces of pulp allowed in a half-gallon container of "pulp-free" orange juice is one example. Specifications typically are allowed to vary a small amount called *tolerance.* If a particular dimension of a product is within the allowable range of tolerance of the specification, it conforms.

The advantage of the conformance definition of quality for products is that it is easily quantified. However, it is often difficult for a service to conform to numeric specifications. For example, imagine trying to measure the quality of a counselor's work versus that of a carmaker. Because counseling is intangible, it is almost impossible to measure.

Durability is the degree to which a product tolerates stress or trauma without failing. An example of a product that is not very durable is a lightbulb. Lightbulbs can be damaged easily and cannot be repaired. In contrast, a trash can is a very durable product that can be subjected to much wear and tear.

Serviceability is the ease of repair for a product. A product is very serviceable if it can be repaired easily and cheaply. Many products require service by a technician, such as the technician who repairs your personal computer. If this service is rapid, courteous, easy to acquire, and competent, the product generally is considered to have good serviceability. Note that different dimensions of quality are not mutually exclusive.

Aesthetics are subjective sensory characteristics such as taste, feel, sound, look, and smell. Although vinyl interiors in automobiles require less maintenance, are less expensive, and are more durable, leather interiors are usually considered more aesthetically pleasing. We measure aesthetic quality as the degree to which product attributes are matched to consumer preferences.

Perceived quality is based on customer opinion. As we said in the beginning of this chapter, quality is as the customer perceives it. Customers imbue products and services with their understanding of their goodness. This is perceived quality. We can witness an example of the effect of perceived quality every year in college football polls that rank teams. In many cases, the rankings are based on past records, team recognition, university tradition, and other factors that are generally poor indicators of team quality on a given Saturday. In the same way that these factors affect sportswriters' perceptions, factors such as brand image, brand recognition, amount of advertising, and word of mouth can affect consumers' perceptions of quality.

The Garvin list of quality dimensions, although it is the most widely cited and used, is not exhaustive. Other authors have proposed lists of additional quality measures, such as safety. Carol King[3] identified dimensions of service quality such as *responsiveness, competence, access, courtesy, communication, credibility, security,* and *understanding.* Allowed time, you probably could think of additional dimensions as well.

Service Quality Dimensions

Service quality is even more difficult to define than product quality. Although services and production share many attributes, services have more diverse quality attributes than products. This often results from wide variation created by high customer involvement. For example, the consumer of a fountain pen probably will not care that the factory worker producing the pen was in a foul mood (as long as the quality of the pen is good). However, excellent food served in a restaurant generally will not suffice if the server is in a foul mood. In addition, a consumer probably will not consider a pen poor quality if he or she is in a bad mood when using the pen. However, food and service in a restaurant could be excellent and still be perceived poorly if the patron is feeling bad.

Parasuraman, Zeithamel, and Berry (PZ&B), three marketing professors from Texas A&M University, published a widely recognized set of service quality dimensions. These dimensions have been used in many service firms to measure quality performance. The PZ&B dimensions are defined here (see Table 1-2).

Tangibles include the physical appearance of the service facility, the equipment, the personnel, and the communication materials. For example, a hotel with yellowed linens will be rated low for quality. Hair salons catering to an elite clientele might invest in ambient lighting and employ only well-dressed hairstylists. That the hairstylist is dressed well does not affect the service being provided; however, clients believe that their hair will be better styled by someone who is dressed stylishly.

Service reliability differs from product reliability in that it relates to the ability of the service provider to perform the promised service dependably and accurately. For example, a firm might hire a consultant based on reputation alone. If the consultant delivers what the customer wants, the customer will be satisfied and pay the consultancy fee. If the consultant delivers something other than what the customer expects, the customer will not pay the consultancy fee.

TABLE 1-2 PZ&B's Service Quality Dimensions

Tangibles
Service reliability
Responsiveness
Assurance
Empathy

Adapted from Parasuraman, A., Zeithamel, V., and Berry, L., "A Conceptual Model of Service Quality" (Report No. 84–106). Copyright © 1984 by Marketing Science Institute. Reprinted by permission.

[3]King, C., "A Framework for a Service Quality Assurance System," *Quality Progress* 20, 9 (1987): 27–32.

Responsiveness is the willingness of the service provider to be helpful and prompt in providing service. When you last called your bank for service, how long did it take for a response? Were your problems taken care of quickly, or did you have to wait while you listened to "elevator music" for an hour? Does your service provider always respond to you within three rings of the phone—without forwarding your call to another location?

Assurance refers to the knowledge and courtesy of employees and their ability to inspire trust and confidence. If you needed heart surgery, you probably would not opt for a doctor who appeared forgetful and disorganized during an office consultation. Rather, you would want assurance that the doctor is competent.

Finally, consumers of services desire **empathy** from the service provider. In other words, the customer desires caring, individualized attention from the service firm. A maxim in the restaurant industry is that "if you are in it for the money, you probably won't survive." A restaurant in which the employees are constantly focused on efficiency will not give the customers the feeling that their needs are important. Therefore, no empathy will be shared, and restaurant employees will not adequately provide service that will make customers want to return again and again.

Just as there are many quality dimensions relating to production, there are several other dimensions of service quality, such as *availability, professionalism, timeliness, completeness*, and *pleasantness.* Note that service design strives to address these different service dimensions simultaneously. It is not sufficient for a services firm to provide only empathy if responsiveness and service reliability are inadequate.

Why Does It Matter That Different Definitions of Quality Exist?

One problem with having multiple dimensions of quality is communication. It is difficult to devise a coherent strategic plan relating to quality when communication is imprecise. One important attribute of a strategic plan is functional alignment or consistency. If different departments in a company understand quality differently, the strategic plan will not be in alignment. Understanding that different definitions and dimensions of quality exist allows measures to be taken to provide a good basis for communication and planning. By sharing a common definition of quality, each department within a company can work toward a common goal. In addition, understanding the multiple dimensions of quality desired by consumers can lead to improved product and service design. Hewlett-Packard Corporation, a producer of laser printers, understands this concept very well. Early in its quality journey, Hewlett-Packard developed products that consistently conformed to specifications. This involved years of product design, process control, and process improvement. Once the printers conformed to specifications, the company emphasized reliability. After the printers were found to be reliable, the company was able to improve the aesthetics of its printers. After years of working on these different quality dimensions, Hewlett-Packard embarked on a "customer one-on-one" program that emphasized customer interaction with production workers. In this program, Hewlett-Packard production workers take time to call customers on the phone to assess and improve the "relationship" that the customer has with a printer.

DIFFERING FUNCTIONAL PERSPECTIVES ON QUALITY

One of the important determinants of how we perceive quality is the functional role we fulfill organizationally. Just as artists and scientists process information differently, so do employees who perform different functions in an organization.

Differences between artists and scientists are only one instance of different perspectives created by functional differences. Accountants are interested in information for accounting and tax purposes, operations people want information for process control and scheduling, finance people need information to manage cash, and marketing needs information to see whether sales quotas are being met.

The **organic view of the organization**[4] sees the whole as the sum of different parts uniting to achieve an end. The heart and the liver do not perform the same function in a body, but they each perform processes that are necessary for survival of the whole. Just as the body is subject to breakdown when different parts do not perform properly, so are organizations. Unfortunately, firms do not have the magnificent communication network (i.e., the central nervous system) to coordinate activities that human bodies have. For this reason, firms must constantly improve their communication. Recognizing fundamental differences between how different functions view quality is an important first step in understanding and resolving problems associated with mismatches of quality perceptions within organizations.

As organizational processes become more cross-functional, many of these communications issues will find resolution. However, experience with cross-functional teams has been difficult for many firms because of poor communication skills among team members. Therefore, it is expected that cognitive differences between different functions will continue to be a major problem that firms must overcome.

This section of the chapter views quality management from the perspectives of several different functions. Many of the topics discussed in this chapter are presented in concept only. More in-depth discussions of these topics appear in later chapters. This chapter is designed to lay out the field of quality management from an interdisciplinary, integrative perspective. The functions discussed here include supply chain management, engineering, operations, strategic management, marketing, finance/accounting, and human resources.

A Supply Chain Perspective

Supply chain management grew out of the concept of the value chain, which includes **inbound logistics, core processes,** and **outbound logistics.** Other functions, such as human resources, information systems, and purchasing, support these core processes. Operations, purchasing, logistics, and marketing are the primary participants in the supply chain. In recent years, supply chain management has moved to the forefront in importance. This is largely due to the opportunity for cost savings along with quality and service improvement. There are many important quality-related activities that are part of supply chain management. We discuss these separately as upstream activities, core processes, and downstream activities.

Figure 1-1 shows a global supply chain management model.[5] The two-way arrow at the center is the supply chain with the suppliers upstream and the customers downstream. At the center of the supply chain is operations management, or the transformation of inputs into products and services. (Operations management is discussed later in the chapter.) Upstream is supplier and purchasing management, which is associated with bringing in parts and components used in production. Downstream is marketing and customer relationship management. As is shown at the bottom, logistics and quality management are used to optimize performance throughout the entire supply chain. The entire model is tied together by strategy.

Upstream activities include all those activities involving interaction with suppliers. **Supplier qualification** involves evaluating supplier performance to determine whether they are worthy providers. This often requires grading suppliers using established criteria, such as conformance rates, cost levels, and delivery reliability. Many times, **supplier filters** are used, such as **ISO 9000,** an international standard. This means that you can filter suppliers based on whether they are ISO 9000 registered. **Supplier development** activities include evaluating, training, and implementing systems with suppliers. This often includes the use of **electronic data interchange (EDI)** to link customer purchasing systems to supplier enterprise resource planning systems. **Acceptance sampling** may be needed to determine whether

[4]Foster, S. T., Howard, L., and Shannon, P., "The Role of Quality Tools in Improving Satisfaction with Government," *Quality Management Journal* 9, 3 (2002): 20–31.
[5]Holstein, W., "Hyundai's Capability Play," *Strategy and Business* 70 (Spring 2013): 13–18.

FIGURE 1-1 A Global Supply Chain Model *Source:* Foster, S. Thomas; Sampson, Scott E.; Wallin, Cynthia; Webb, Scott W, Managing Supply Chain And Operations: An Integrative Approach, 1st Ed., © 2016, p.15. Reprinted and Electronically reproduced by permission of Pearson Education, Inc., New York, NY.

supplier products meet requirements. **Global sourcing** is an important supply chain issue with many companies—especially in China. This is discussed in more depth in Chapter 3.

Core process activities include traditional process improvement as well as **value stream mapping.** This requires flowcharting processes to determine where customer value is created as well as identifying non-value-added process steps. Value stream mapping involves analyzing processes from a systems perspective such that upstream and downstream effects of core process changes can be evaluated. **Six Sigma** is a procedure for implementing quality improvement analysis to reduce costs and improve product, service, and process design. Six Sigma black belts become supply chain quality consultants who can lead value-adding improvements. The steps in Six Sigma include **define, measure, analyze, improve, and control (DMAIC)**-related activities. A major tool used in Six Sigma is the **design of experiments (DOE).**

Downstream activities include shipping and logistics, customer support, and focusing on delivery reliability. Supply chain management has also focused more attention on **after-sale service.**

An Engineering Perspective

Engineering is an applied science. As such, engineers are interested in applying mathematical problem–solving skills and models to the problems of business and industry. One outgrowth of this approach is the field of operations research. For example, in the early twentieth century, Sir R. A. Fisher and other researchers in England expanded the field of mathematical statistics to problems related to variation experienced in the production area.

Two of the major emphases in engineering are the areas of product design and process design. **Product design engineering** involves all those activities associated with developing a product from concept development to final design and implementation. Figure 1-2 demonstrates

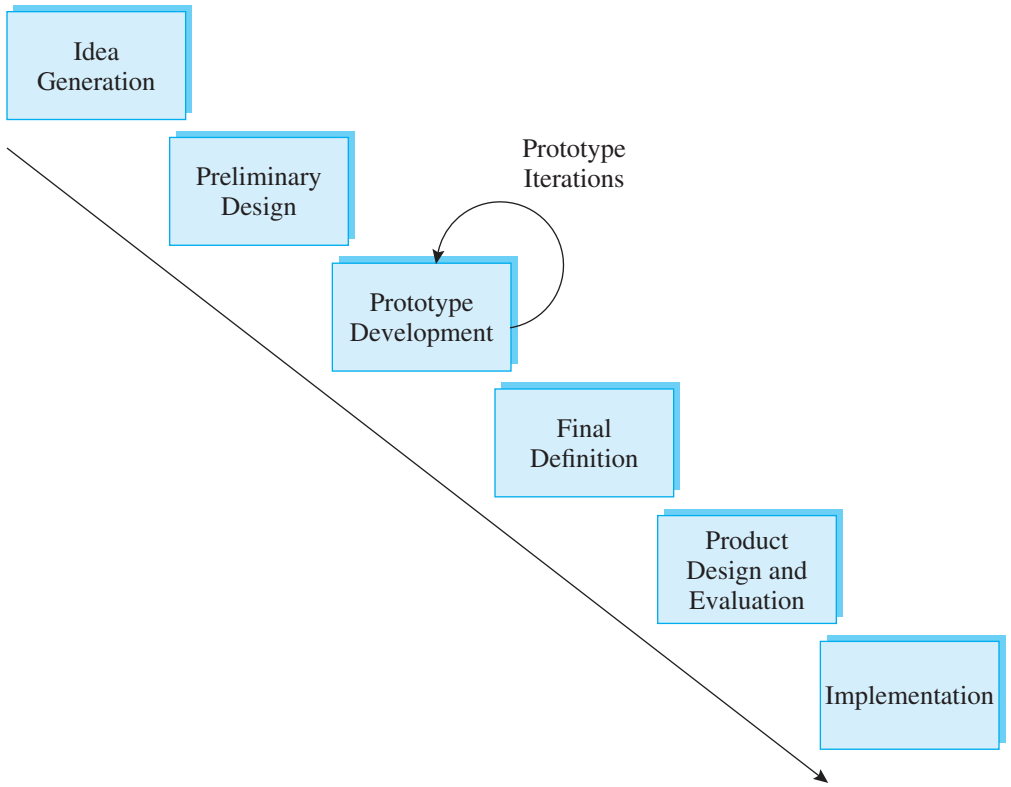

FIGURE 1-2 Design Life Cycle

the six steps in the engineering life cycle for the design of products. The product design process results in a final design, possibly generated using a computer-aided design (CAD) system. Product design is the key because quality is assured at the design stage.

Product and process design are fields of engineering that have experienced major changes in recent years. Whereas traditionally they were considered separate and in most cases sequential activities, **concurrent engineering** has resulted in the simultaneous performance of these activities. Typically, concurrent engineering involves the formation of cross-functional teams, which allow engineers and managers of differing disciplines to work together simultaneously in developing product and process designs. The result of concurrent design has been improved quality and faster speed to market for new products.

Engineers also have applied statistical thinking to the problem of *reliability*. As already discussed, reliability management is concerned with assessing and reducing the propensity of a product to fail. Reliability engineers use probability theory to determine the rate of failure that a product will experience over its useful life. **Life testing** is a facet of reliability engineering that determines whether a product will fail under controlled conditions during a specified life. Also, reliability engineers are interested in knowing whether failure of certain product components will result in failure of the overall product. If a component has a relatively high probability for failure that will affect the overall function of a product, **redundancy** is applied so that a backup system can take over for the failed primary system. Many redundant systems are used on the NASA space shuttle in case of primary system breakdown. After all, if a hard drive crashes in space, it is not easy to find a replacement close by.

Another engineering-related contribution to quality management is **statistical process control (SPC),** which is concerned with monitoring process capability and process stability. If a process is capable, it will consistently produce products that meet specification. If a process is stable, it will only exhibit random or **common cause variation** instead of nonrandom **special cause variation.** This type of variation is often acceptable, if kept within limits. The control process as specified by Walter Shewhart in his book *Statistical Method from the Viewpoint of*