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William J. Stevenson

Operations Management

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Mc Graw Hill

Operations Management

Operations Management

FOURTEENTH EDITION

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Rochester Institute of Technology

OPERATIONS MANAGEMENT

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Preface

The material in this book is intended as an introduction to the field of operations management. The topics covered include both strategic issues and practical applications. Among the topics are forecasting, product and service design, capacity planning, management of quality and quality control, inventory management, scheduling, supply chain management, and project management.

My purpose in revising this book continues to be to provide a clear presentation of the concepts, tools, and applications of the field of operations management. Operations management is evolving and growing, and I have found updating and integrating new material to be both rewarding and challenging, particularly due to the plethora of new developments in the field, while facing the practical limits on the length of the book.

This text offers a comprehensive and flexible amount of content that can be selected as appropriate for different courses and formats, including undergraduate, graduate, and executive education.

This allows instructors to select the chapters, or portions of chapters, that are most relevant for their purposes. That flexibility also extends to the choice of relative weighting of the qualitative or quantitative aspects of the material, and the order in which chapters are covered, because chapters do not depend on sequence. For example, some instructors cover project management early, others cover quality or lean early, and so on.

As in previous editions, there are major pedagogical features designed to help students learn and understand the material. This section describes the key features of the book, the chapter elements, the supplements that are available for teaching the course, highlights of the fourteenth edition, and suggested applications for classroom instruction. By providing this support, it is our hope that instructors and students will have the tools to make this learning experience a rewarding one.

What's New in This Edition

In many places, content has been rewritten or added to improve clarity, shorten wording, or update information. New material has been added on supply chains, and other topics. Some problems are new, and others have been revised. Many new readings and new photos have been added.

Some of the class preparation exercises have been revised. The purpose of these exercises is to introduce students to the subject matter before class in order to enhance classroom learning. They have proved to be very popular with students, both as an introduction to new material and for study purposes. These exercises are available in the Instructor's Resource Manual. Special thanks to Linda Brooks for her help in developing the exercises.

Acknowledgments

I want to thank the many contributors to this edition. Reviewers and adopters of the text have provided a "continuously improving" wealth of ideas and suggestions. It is encouraging to me as an author. I hope all reviewers and readers will know their suggestions were valuable, were carefully considered, and are sincerely appreciated. The list includes post-publication reviewers.

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William J. Stevenson

Walkthrough

MAJOR STUDY AND LEARNING FEATURES

A number of key features in this text have been specifically designed to help introductory students learn, understand, and apply operations concepts and problem-solving techniques.

Examples with Solutions

Throughout the text, wherever a quantitative or analytic technique is introduced, an example is included to illustrate the application of that technique. These are designed to be easy to follow.

Determining a Regression Equation

EXAMPLE 8

eXcel

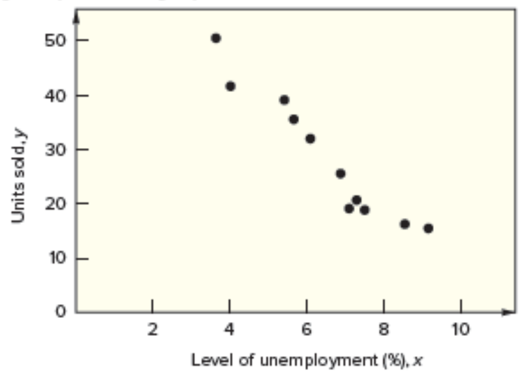
mhhe.com/stevenson14e

Sales of new houses and three-month lagged unemployment are shown in the following table. Determine if unemployment levels can be used to predict demand for new houses and, if so, derive a predictive equation.

Period	1	2	3	4	5	6	7	8	9	10	11
Units sold	20	41	17	35	25	31	38	50	15	19	14
Unemployment % (three-month lag)	7.2	4.0	7.3	5.5	6.8	6.0	5.4	3.6	8.4	7.0	9.0

SOLUTION

1. Plot the data to see if a *linear* model seems reasonable. In this case, a linear model seems appropriate *for the range of the data*.



2. Check the correlation coefficient to confirm that it is not close to zero using the website template, and then obtain the regression equation:

   $r = -.966$

   This is a fairly high negative correlation. The regression equation is

   $y = 71.85 - 6.91x$

Note that the equation pertains only to unemployment levels in the range 3.6 to 9.0, because sample observations covered only that range.

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Solved Problems

At the end of chapters and chapter supplements, “Solved Problems” are provided to illustrate problem solving and the core concepts in the chapter. These have been carefully prepared to help students understand the steps involved in solving different types of problems. The Excel logo indicates that a spreadsheet is available on the text’s website.

SOLVED PROBLEMS

Computing Productivity

Problem 1

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A company that processes fruits and vegetables is able to produce 400 cases of canned peaches in one-half hour with four workers. What is labor productivity?

Solution

$$\text{Labor productivity} = \frac{\text{Quantity produced}}{\text{Labor hours}} = \frac{400\text{ cases}}{4\text{ workers} \times 1/2\text{ hour/worker}}$$

$$= 200\text{ cases per labor hour}$$

Computing Multifactor Productivity

Problem 2

mhhe.com/stevenson14e

A wrapping-paper company produced 2,000 rolls of paper in one day. Labor cost was \$160, material cost was \$50, and overhead was \$320. Determine the multifactor productivity.

Solution

$$\text{Multifactor productivity} = \frac{\text{Quantity produced}}{\text{Labor cost} + \text{Material cost} + \text{Overhead}}$$

$$= \frac{2{,}000\text{ rolls}}{\$160 + \$50 + \$320} = 3.77\text{ rolls per dollar input}$$

A variation of the multifactor productivity calculation incorporates the standard price in the numerator by multiplying the units by the standard price.

Excel Spreadsheet Solutions

Where applicable, the examples and solved problems include screen shots of a spreadsheet solution.

TABLE 16.5 Excel solution for Example 2a

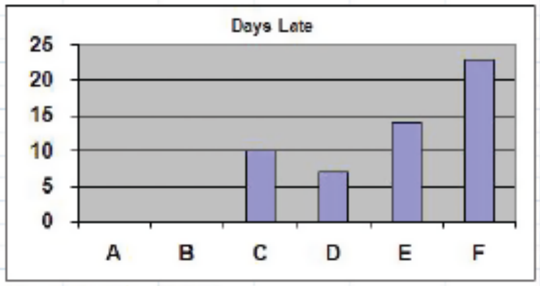
Job Sequencing
<Back Notes

Clear | FCFS | SPT | DD | CR | S/O

Current Date: 23

Job	Process. Time	Due Date	Remain Oper.	CR Sequence	Critical Ratio	Slack	S/O	Flow Time	Days Late
A	2	7		3		5		2	0
B	8	16		5		8		10	0
C	4	4		1		0		14	10
D	10	17		6		7		24	7
E	5	15		4		10		29	14
F	12	18		2		6		41	23
Totals	41		0			36		120	54

Method	FCFS
Average Flow Time	20.00
Average Tardiness	9.00
Average Number of Jobs	2.93



See notes below.

Notes:

1. Enter Job Name, Processing Time, and Due Date for each job.
2. For the FCFS, SPT, and DD rules, simply press the appropriate button.
3. For the CR rule, perform the following BEFORE pressing the CR button:
   a. Select job with lowest Critical Ratio
   b. Schedule that job next by entering next sequence number (start with 1) in the CR Sequence column.
   c. Add the processing time for that job to the current date.
   d. Repeat steps a, b, and c until all jobs have been scheduled (i.e. the CR Sequence column is filled in).
   e. Then press the CR button.
4. Fill in the Remaining Operations column and then press the S/O button.

CHAPTER ELEMENTS

Within each chapter, you will find the following elements that are designed to facilitate study and learning. All of these have been carefully developed over many editions and have proven to be successful.

Learning Objectives

Every chapter and supplement lists the learning objectives to achieve when studying the chapter material. The learning objectives are also included next to the specific material in the margins of the text.


4 CHAPTER

Product and Service Design

LEARNING OBJECTIVES

After completing this chapter, you should be able to:

LO4.1 Explain the strategic importance of product and service design.
LO4.2 Describe what product and service design does.
LO4.3 Name the key questions of product and service design.
LO4.4 Identify some reasons for design or redesign.
LO4.5 List some of the main sources of design ideas.
LO4.6 Discuss the importance of legal, ethical, and sustainability considerations in product and service design.
LO4.7 Explain the purpose and goal of life-cycle assessment.
LO4.8 Explain the phrase "the 3 Rs."
LO4.9 Briefly describe the phases in product design and development.
LO4.10 Discuss several key issues in product or service design.
LO4.11 Discuss the two key issues in service design.
LO4.12 List the characteristics of well-designed service systems.
LO4.13 List some guidelines for successful service design.

CHAPTER OUTLINE

The essence of a business organization is the products and services it offers, and every aspect of the organization and its supply chain are structured around those products and services. Organizations that have well-designed products or services are more likely to realize their goals than those with poorly designed products or services. Hence, organizations have a strategic interest in product and service design. Product or service design should be closely tied to an organization's strategy. It is a major factor in cost, quality, time-to-market, customer satisfaction, and competitive advantage. Consequently, marketing, finance, operations, accounting, IT, and HR need to be involved. Demand forecasts and projected costs are important, as is the expected impact on the supply chain. It is significant to note that an important cause of operations failures can be traced to faulty design. Designs that have not been well thought out, or are incorrectly implemented, or instructions for assembly or usage that are wrong or unclear, can be the cause of product and service failures, leading to lawsuits, injuries and deaths, product recalls, and damaged reputations.

LO4.1 Explain the strategic importance of product and service design.

continued

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Chapter Outlines

Every chapter and supplement includes an outline of the topics covered.

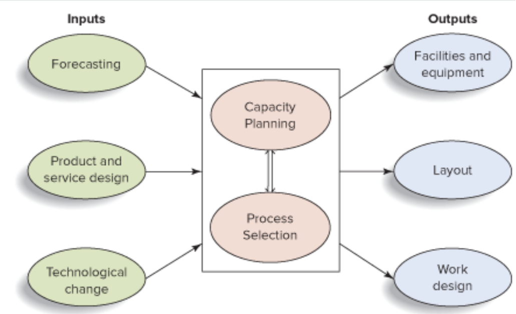
Opening Vignettes

Each chapter opens with an introduction to the important operations topics covered in the chapter. This enables students to see the relevance of operations management in order to actively engage in learning the material.

Figures and Photos

The text includes photographs and graphic illustrations to support student learning and provide interest and motivation. Approximately 100 carefully selected photos highlight the 14th edition. The photos illustrate applications of operations and supply chain concepts in man successful companies. More than 400 graphic illustrations, more than any other text in the field, are included and all are color coded with pedagogical consistency to assist students in understanding concepts

FIGURE 6.1
Process selection and capacity planning influence system design



A major key to Apple's continued success is its ability to keep pushing the boundaries of innovation. Apple has demonstrated how to create growth by dreaming up products so new and ingenious that they have upended one industry after another.

Operations Strategies

An Operations Strategy section is included at the end of most chapters. These sections discuss how the chapters' concepts can be applied and how they impact the operations of a company.

5.12 OPERATIONS STRATEGY

The strategic implications of capacity decisions can be enormous, impacting all areas of the organization. From an operations management standpoint, capacity decisions establish a set of conditions within which operations will be required to function. Hence, it is extremely important to include input from operations management people in making capacity decisions.

Flexibility can be a key issue in capacity decisions, although flexibility is not always an option, particularly in capital-intensive industries. However, where possible, flexibility allows an organization to be agile—that is, responsive to changes in the marketplace. Also, it reduces to a certain extent the dependence on long-range forecasts to accurately predict demand. And flexibility makes it easier for organizations to take advantage of technological and other innovations. Maintaining excess capacity (a capacity cushion) may provide a degree of flexibility, albeit at added cost.

Some organizations use a strategy of maintaining a capacity cushion for the purpose of blocking entry into the market by new competitors. The excess capacity enables them to produce at costs lower than what new competitors can. However, such a strategy means higher-than-necessary unit costs, and it makes it more difficult to cut back if demand slows, or to shift to new product or service offerings.

Efficiency improvements and utilization improvements can provide capacity increases. Such improvements can be achieved by streamlining operations and reducing waste. The chapter on lean operations describes ways for achieving those improvements.

Bottleneck management can be a way to increase effective capacity, by scheduling non-bottleneck operations to achieve maximum utilization of bottleneck operations.

In cases where capacity expansion will be undertaken, there are two strategies for determining the timing and degree of capacity expansion. One is the *expand-early* strategy (i.e., before demand materializes). The intent might be to achieve economies of scale, to expand market share, or to preempt competitors from expanding. The risks of this strategy include an oversupply that would drive prices down, and underutilized equipment that would result in higher unit costs.

The other approach is the *wait-and-see strategy* (i.e., to expand capacity only after demand materializes, perhaps incrementally). Its advantages include a lower chance of oversupply due

Readings

Readings highlight important real-world applications, provide example of production/operations issues, and offer further elaboration of the text material. They also provide a basis for classroom discussion and generate interest in the subject matter. Many of the end-of-chapter readings include assignment questions.

READING

DUTCH BOY BRUSHES UP ITS PAINTS

Sherwin-Williams' Dutch Boy Group put a revolutionary spin on paint cans with its innovative square-shaped Twist & PourTM paint-delivery container for the Dirt Fighter interior latex paint line. The four-piece square container could be the first major change in how house paint is packaged in decades. Lightweight but sturdy, the Twist & Pour "bucket" is packed with so many conveniences, it is next to impossible to mess up a painting project.

Winning Best of Show in an AmeriStar packaging competition sponsored by the Institute of Packaging Professionals, the exclusive, all-plastic paint container stands almost 7½ in. tall and holds 126 oz., a bit less than 1 gal. Rust-resistant and moisture-resistant, the plastic bucket gives users a new way to mix, brush, and store paint.

A hollow handle on one side makes it comfortable to pour and carry. A convenient, snap-in pour spout neatly pours paint into a tray with no dripping but can be removed if desired, to allow a wide brush to be dipped into the 5¾-in.-diameter mouth. Capping the container is a large, twist-off lid that requires no tools to open or close. Molded with two lugs for a snug-finger-tight closing, the threaded cap provides a tight seal to extend the shelf life of unused paint.

While the lid requires no tools to access, the snap-off carry bail is assembled on the container in a "locked-down position" and can be pulled up after purchase for toting or hanging on a ladder. Large, nearly 4½-inch-tall label panels allow glossy front and back labels printed and UV-coated to wrap around the can's rounded corners, for an impressive display.

Jim MacDonald, co-designer of the Twist & Pour and a packaging engineer at Cleveland-based Sherwin-Williams, tells *Packaging Digest* that the space-efficient, square shape is easier to ship and easier to stack in stores. It can also be nested, courtesy of a recess

Jerry Simon

in the bottom that mates with the lid's top ring. "The new design allows for one additional shelf facing on an eight-foot rack or shelf area."

The labels are applied automatically, quite a feat, considering their complexity, size, and the hollow handle they likely encounter during application. MacDonald admits, "Label application was a challenge. We had to modify the bottle several times to accommodate the labeling machinery available."

Source: "Dutch Boy Brushes Up Its Paints," *Packaging Digest*, October 2002. Copyright ©2002 Reed Business Information. Used with permission.

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END-OF-CHAPTER RESOURCES

For student study and review, the following items are provided at the end of each chapter or chapter supplement.

Summaries and Key Points

Chapters contain summaries that provide an overview of the material covered, and the key points of the chapter are emphasized in a separate section.

Key Terms

Key terms are highlighted in the text and then repeated in the margin with brief definitions for emphasis. They are listed at the end of each chapter (along with page references) to aid in reviewing.

KEY TERMS

associative model, 80
bias, 109
centered moving average, 96
control chart, 107
correlation, 102
cycle, 82
Delphi method, 81
error, 105
exponential smoothing, 87
focus forecasting, 88
forecast, 76
judgmental forecasts, 80
least squares line, 99
linear trend equation, 89
mean absolute deviation (MAD), 106
mean absolute percent error (MAPE), 106
mean squared error (MSE), 106
moving average, 84
naive forecast, 82
predictor variables, 98
regression, 98
seasonality, 82
seasonal relative, 94
seasonal variations, 93
standard error of estimate, 100
time series, 82
time-series forecasts, 80
tracking signal, 109
trend, 82
trend-adjusted exponential smoothing, 92

Taking Stock and Critical Thinking Exercises

These activities encourage analytical thinking and help broaden conceptual understanding. A question related to ethics is included in the Critical Thinking Exercises.

TAKING STOCK

This item appears at the end of each chapter. It is intended to focus your attention on three key issues for business organizations in general, and operations management in particular. Those issues are trade-off decisions, collaboration among various functional areas of the organization, and the impact of technology. You will see three or more questions relating to these issues. Here is the first set of questions:

1. What are trade-offs? Why is careful consideration of trade-offs important in decision making?
2. Why is it important for the various functional areas of a business organization to collaborate?
3. In what general ways does technology have an impact on operations management decision making?

CRITICAL THINKING EXERCISES

This item also will appear in every chapter. It allows you to critically apply information you learned in the chapter to a practical situation. Here is the first set of exercises:

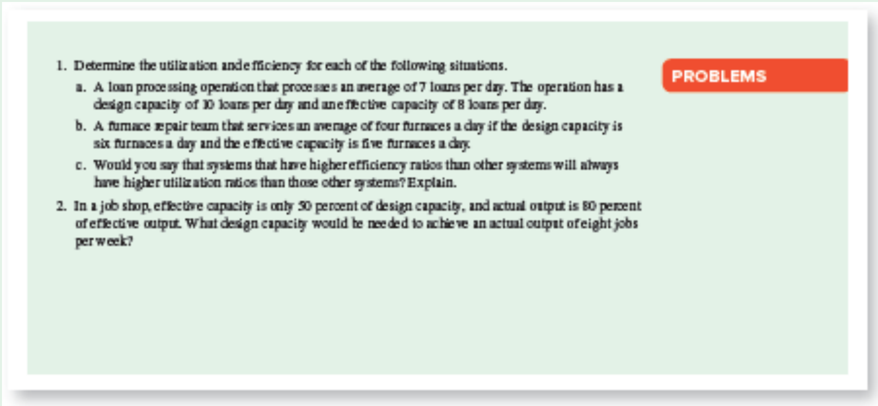
1. Many organizations offer a combination of goods and services to their customers. As you learned in this chapter, there are some key differences between the production of goods and the delivery of services. What are the implications of these differences relative to managing operations?
2. Why is it important to match supply and demand? If a manager believes that supply and demand will not be equal, what actions could the manager take to increase the probability of achieving a match?
3. One way that organizations compete is through technological innovation. However, there can be downsides for both the organization and the consumer. Explain.

Discussion and Review Questions

Each chapter and each supplement have a list of discussion and review questions. These precede the problem sets and are intended t serve as a student self-review or as class discussion starters.

Problem Sets

Each chapter includes a set of problems for assignment. The problem have been refined over many editions and are intended to be challenging but doable for students. Short answers to most of the problems are included in Appendix A so students can check their understanding and see immediately how they are progressing.


1. Determine the utilization and efficiency for each of the following situations.
   a. A loan processing operation that processes an average of 7 loans per day. The operation has a design capacity of 10 loans per day and an effective capacity of 8 loans per day.
   b. A furnace repair team that services an average of four furnaces a day if the design capacity is six furnaces a day and the effective capacity is five furnaces a day.
   c. Would you say that systems that have higher efficiency ratios than other systems will always have higher utilization ratios than those other systems? Explain.
2. In a job shop, effective capacity is only 50 percent of design capacity, and actual output is 80 percent of effective output. What design capacity would be needed to achieve an actual output of eight jobs per week?

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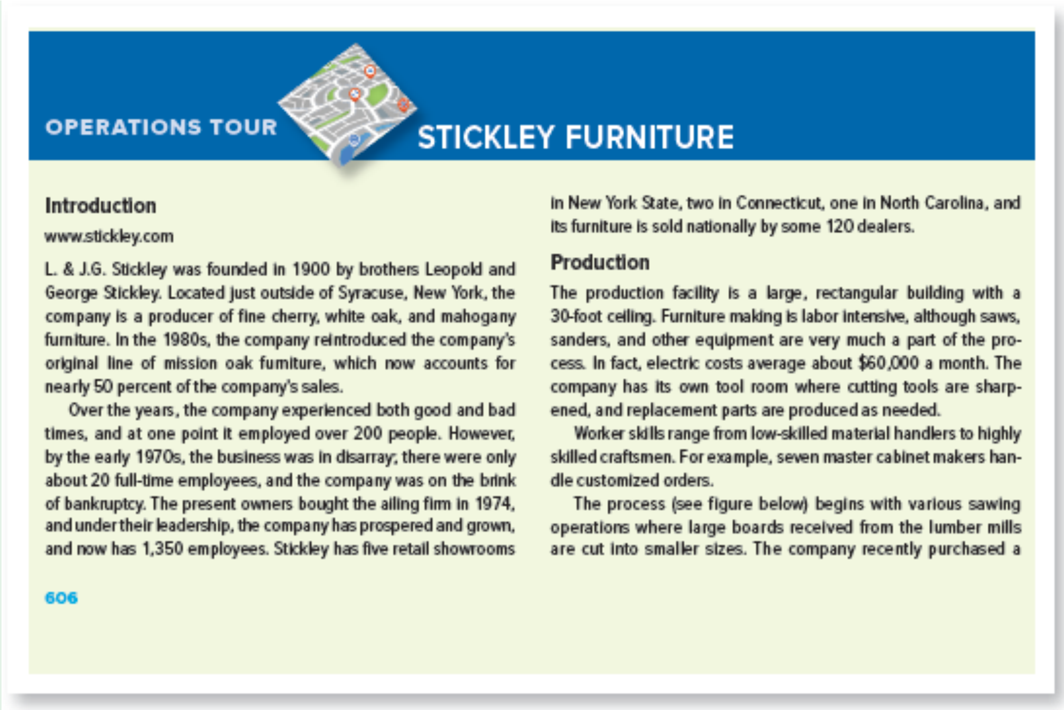
Operations Tours

These provide a simple “walkthrough” of an operation for students, describing the company, its product or service, and its process of managing operations. Companies featured include Wegmans Food Markets, Morton Salt, Stickley Furniture, and Boeing.



OPERATIONS TOUR

STICKLEY FURNITURE

Introduction

www.stickley.com

L. & J.G. Stickley was founded in 1900 by brothers Leopold and George Stickley. Located just outside of Syracuse, New York, the company is a producer of fine cherry, white oak, and mahogany furniture. In the 1980s, the company reintroduced the company's original line of mission oak furniture, which now accounts for nearly 50 percent of the company's sales.

Over the years, the company experienced both good and bad times, and at one point it employed over 200 people. However, by the early 1970s, the business was in disarray; there were only about 20 full-time employees, and the company was on the brink of bankruptcy. The present owners bought the ailing firm in 1974, and under their leadership, the company has prospered and grown, and now has 1,350 employees. Stickley has five retail showrooms in New York State, two in Connecticut, one in North Carolina, and its furniture is sold nationally by some 120 dealers.

Production

The production facility is a large, rectangular building with a 30-foot ceiling. Furniture making is labor intensive, although saws, sanders, and other equipment are very much a part of the process. In fact, electric costs average about $60,000 a month. The company has its own tool room where cutting tools are sharpened, and replacement parts are produced as needed.

Worker skills range from low-skilled material handlers to highly skilled craftsmen. For example, seven master cabinet makers handle customized orders.

The process (see figure below) begins with various sawing operations where large boards received from the lumber mills are cut into smaller sizes. The company recently purchased a

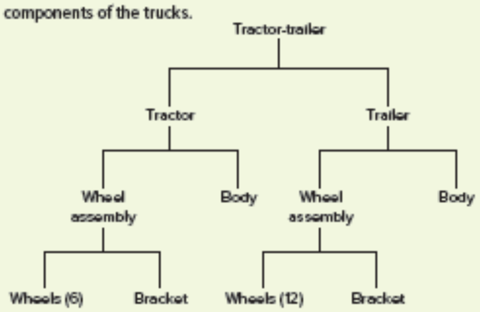
606

Cases

The text includes short cases. The cases were selected to provide a broader, more integrated thinking opportunity for students without taking a full case approach.

CASE PROMOTIONAL NOVELTIES

Promotional Novelties provides a wide range of novelty items for its corporate customers. It has just received an order for 20,000 toy tractor-trailers that will be sold by a regional filling station company as part of a holiday promotion. The order is to be shipped at the beginning of week 8. The tree diagram shows the various components of the trucks.



The company can complete final assembly of th trailers at the rate of 10,000 a week. The tractor and trai are purchased; lead time is three weeks. The whee manager's main concern.

The company has a sufficient supply of brackets Assembly time is one week each for tractors, trailers, a assembly. However, the wheel department can only wheels at the rate of 100,000 a week. The manage use the wheel department to full capacity, starting i of the schedule, and order additional wheels from a as needed. Ordered wheels come in sets of 6,400. time for delivery from the supplier is expected to b three weeks. Use lot-for-lot ordering for all items e purchased wheels.

Questions

1. How many wheel sets should the manager order?
2. When should the wheel sets be ordered?

INSTRUCTOR RESOURCES

Available within Connect, instructors have access to teaching suppor such as electronic files of the ancillary materials: Solutions Manua Instructor's Manual, Test Bank, PowerPoint Lecture Slides, Digit Image Library, and accompanying Excel files.

Instructor's Manual. This manual, revised for the new edition b Tracie Lee, Idaho State University, includes teaching notes, chapte overview, an outline for each chapter, and solutions to the problems the text.

Test Bank. Updated for the new edition by Leslie Sukup, Ferris Sta University, and reviewed by Nancy Lambe, University of Sou Alabama, the Test Bank includes over 2,000 true/false, multiple choice, and discussion questions/problems at varying levels difficulty. The Test Bank is available to assign within Connect, as Wo files available in the Instructor Resource Library, and through ou online test generator. Instructors can organize, edit, and customiz questions and answers to rapidly generate tests for paper or onlin administration.

PowerPoint Lecture Slides. Revised by Avanti Sethi, University Texas-Dallas, the PowerPoint slides draw on the highlights of eac chapter and provide an opportunity for the instructor to emphasize th key concepts in class discussions.

Digital Image Library. All the figures in the book are included f insertion in PowerPoint slides or for class discussion.

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Note to Students

The material in this text is part of the core knowledge in your education. Consequently, you will derive considerable benefit from your study of operations management, *regardless of your major.* Practically speaking, operations is a course in *management.*

This book describes principles and concepts of operations management. You should be aware that many of these principles and concepts are applicable to other aspects of your professional and personal life. You can expect the benefits of your study of operations management to serve you in those other areas as well.

Some students approach this course with apprehension, and perhaps even some negative feelings. It may be that they have heard that the course contains a certain amount of quantitative material that they feel uncomfortable with, or that the subject matter is dreary, or that the course is about "factory management." This is unfortunate, because the subject matter of this book is interesting and vital for all business students. While it is true that some of the material is quantitative, numerous examples, solved problems, and answers at the back of the book help with the quantitative material. As for "factory management," there is material on manufacturing, as well as on services. Manufacturing is important, and something that you should know about for a number of reasons. Look around you. Most of the "things" you see were manufactured: cars, trucks, planes, clothing, shoes, computers, books, pens and pencils, desks, and cell phones. And these are just the tip of the iceberg. So it makes sense to know something about how these things are produced. Beyond all that is the fact that manufacturing is largely responsible for the high standard of living people have in industrialized countries.

After reading each chapter or supplement in the text, attending related classroom lectures, and completing assigned questions and problems, you should be able to do each of the following:

- *Identify the key features* of that material.
- *Define and use terminology.*
- *Solve typical problems.*
- *Recognize applications* of the concepts and techniques covered.
- *Discuss the subject matter* in some depth, including its relevance, managerial considerations, and advantages and limitations.

You will encounter a number of chapter supplements. Check with your course syllabus to determine which ones are included.

This book places an emphasis on problem solving. There are many examples throughout the text illustrating solutions. In addition, at the end of most chapters and supplements you will find a group of solved problems. The examples within the chapter itself serve to illustrate concepts and techniques. Too much detail at those points would be counterproductive. Yet, later on, when you begin to solve the end-of-chapter problems, you will find the solved problems quite helpful. Moreover, those solved problems usually illustrate more and different details than the problems within the chapter.

I suggest the following approach to increase your chances of getting a good grade in the course:

- Do the class preparation exercises for each chapter if they are available from your instructor.
- Look over the chapter outline and learning objectives.
- Read the chapter summary, and then skim the chapter.
- Read the chapter and take notes.
- Look over and try to answer some of the discussion and review questions.

. Work the assigned problems, referring to the solved problems and chapter examples as needed.

Note that the answers to many problems are given at the end of the book. Try to solve each problem before turning to the answer. Remember—tests don't come with answers.

And here is one final thought: Homework is on the Highway to Success, whether it relates to your courses, the workplace, or life! So do your homework, so you can have a successful journey!

W.J.S.

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Operations Management

CHAPTER 1

Introduction to Operations Management

LEARNING OBJECTIVES

After completing this chapter, you should be able to:

LO1.1 Define the terms *operations management* and *supply chain.*

LO1.2 Identify similarities and differences between production and service operations.

LO1.3 Explain the importance of learning about operations management.

LO1.4 Identify the three major functional areas of organizations and describe how they interrelate.

LO1.5 Summarize the two major aspects of process management.

LO1.6 Describe the operations function and the nature of the operations manager's job.

LO1.7 Explain the key aspects of operations management decision making.

LO1.8 Briefly describe the historical evolution of operations management.

LO1.9 Describe current issues in business that impact operations management.

LO1.10 Explain the importance of ethical decision making.

LO1.11 Explain the need to manage the supply chain

CHAPTER OUTLINE

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Recalls of automobiles, foods, toys, and other products; major oil spills; and even dysfunctional state and federal legislatures are all examples of operations failures. They underscore the need for effective operations management. Examples of operations successes include the many electronic devices we all use, medical breakthroughs in diagnosing and treating ailments, and high-quality goods and services that are widely available.

Operations is what businesses do. Operations are processes that either provide services or create goods. Operations take place in businesses such as restaurants, retail stores, supermarkets, factories, hospitals, and colleges and universities. In fact, they take place in every business organization. Moreover, operations are the core of what a business organization does.

As you read this book, you will learn about managing those operations. The subject matter is relevant for you regardless of your major. Productivity, quality, e-business, competition, and customer satisfaction are important for every aspect of a business organization. This first chapter presents an introduction and overview of operations management. Among the issues it addresses are: What is operations management? Why is it important? What do operations management professionals do?

The chapter also provides a description of the historical evolution of operations management and a discussion of the trends and issues that impact operations management.

You will learn about (1) the economic balance that every business organization seeks to achieve; (2) the condition that generally exists that makes achieving the economic balance challenging; (3) the line function that is the core of every business organization; (4) key steps in the history and evolution of operations management; (5) the differences and similarities between producing products and delivering services; (6) what a supply chain is, and why it is essential to manage it; and (7) the key issues for today's business operations.

1.1 INTRODUCTION

LO1.1
Define the terms *operations management* and *supply chain.*

Operations is that part of a business organization that is responsible for producing goods and/or services. **Goods** are physical items that include raw materials, parts, subassemblies such as motherboards that go into computers, and final products such as cell phones and automobiles. **Services** are activities that provide some combination of time, location, form, or psychological value. Examples of goods and services are found all around you. Every book you read, every video you watch, every e-mail or text message you send, every telephone conversation you have, and every medical treatment you receive involves the operations function of one or more organizations. So does everything you wear, eat, travel in, sit on, and access through the internet. The operations function in business can also be viewed from a more far-reaching perspective: The collective success or failure of companies' operations functions has an impact on the ability of a nation to compete with other nations, and on the nation's economy.

Goods Physical items produced by business organizations.

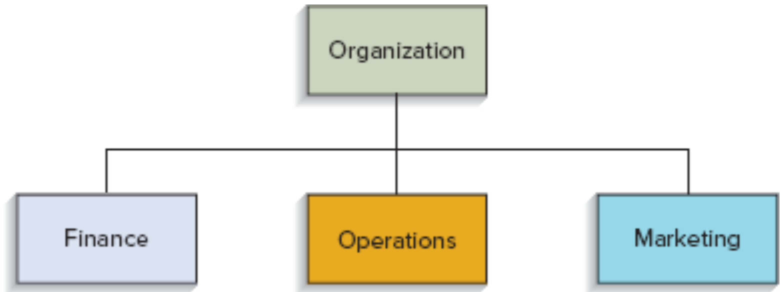
Services Activities that provide some combination of time, location, form, and psychological value.

The ideal situation for a business organization is to achieve an economic match of supply and demand. Having excess supply or excess capacity is wasteful and costly; having too little means lost opportunity and possible customer dissatisfaction. The key functions on the supply side are operations and supply chains, and sales and marketing on the demand side.

While the operations function is responsible for producing products and/or delivering services, it needs the support and input from other areas of the organization. Business organizations have three basic functional areas, as depicted in Figure 1.1: finance, marketing, and operations. It doesn't matter whether the business is a retail store, a hospital, a manufacturing firm, a car wash, or some other type of business; all business organizations have these three basic functions.

FIGURE 1.1

The three basic functions of business organizations



Finance is responsible for securing financial resources at favorable prices and allocating those resources throughout the organization, as well as budgeting, analyzing investment proposals, and providing funds for operations. Marketing is responsible for assessing consumer wants and needs, and selling and promoting the organization's goods or services. Operations is responsible for producing the goods or providing the services offered by the organization. To put this into perspective, if a business organization were a car, operations would be its engine. And just as the engine is the core of what a car does, in a business organization, operations is the core of what the organization does. Operations management is responsible for managing that core. Hence, **operations management** is the management of systems or processes that create goods and/or provide services.

Operations management The management of systems or processes that create goods and/or provide services.

Operations and supply chains are intrinsically linked, and no business organization could exist without both. A **supply chain** is the sequence of organizations—their facilities, functions, and activities—that are involved in producing and delivering a product or service. The sequence begins with basic suppliers of raw materials and extends all the way to the final customer. See Figure 1.2. Facilities might include warehouses, factories, processing centers, offices, distribution centers, and retail outlets. Functions and activities include forecasting, purchasing, inventory management, information management, quality assurance, scheduling, production, distribution, delivery, and customer service.

Supply chain A sequence of organizations—their facilities, functions, and activities—that are involved in producing and delivering a product or service.

FIGURE 1.2

A simple product supply chain

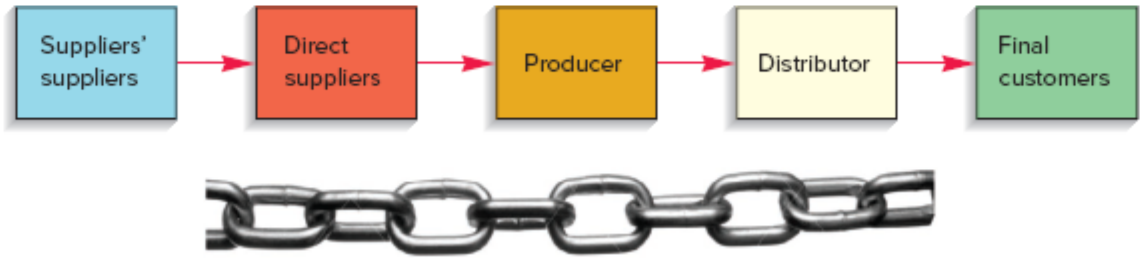
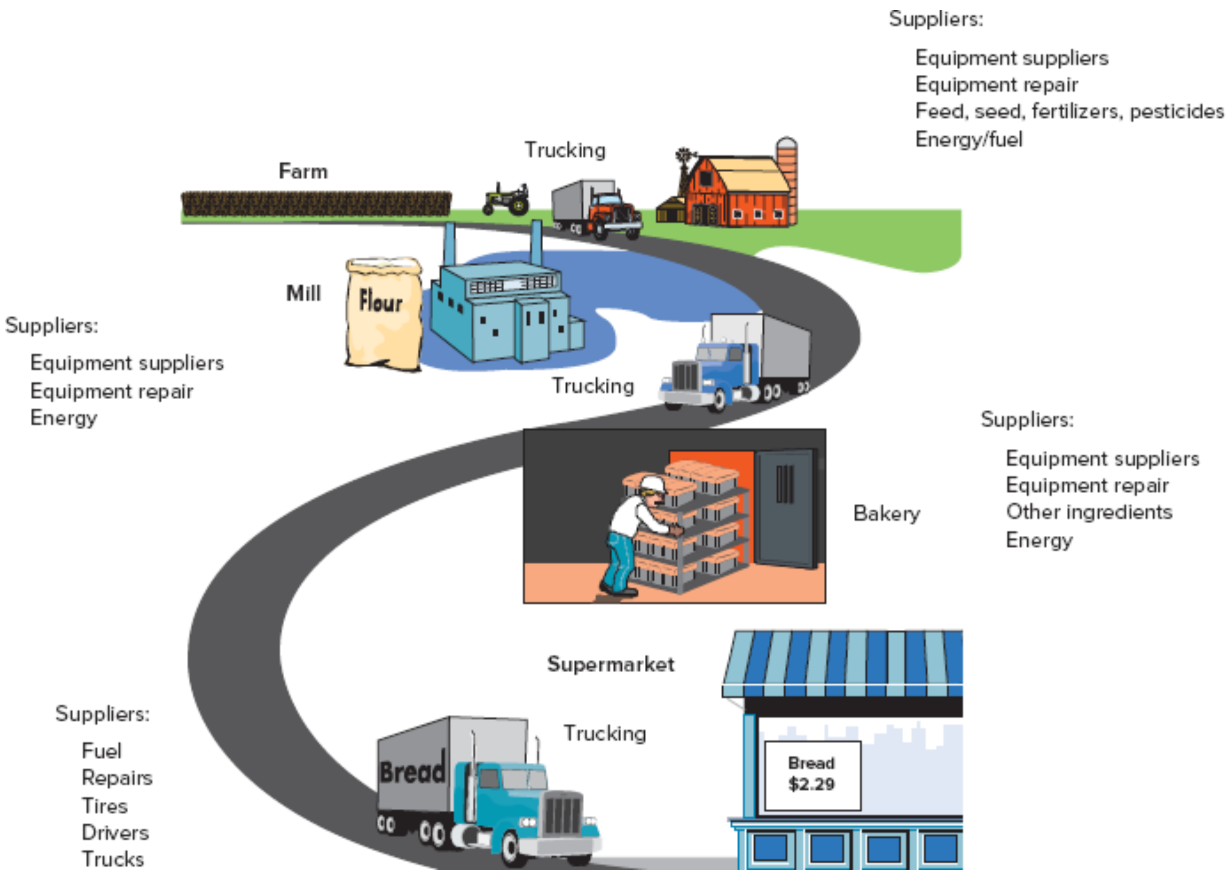


Figure 1.3a provides another illustration of a supply chain: a chain that extends from wheat growing on a farm and ends with a customer buying a loaf of bread in a supermarket. The value of the product increases as it moves through the supply chain.

page 5

FIGURE 1.3A

A supply chain for bread



One way to think of a supply chain is that it is like a chain, as its name implies. This is shown in Figure 1.2. The links of the chain would represent various production and/or service operations, such as factories, storage facilities, activities, and modes of transportation (trains, railroads, ships, planes, cars, and people). The chain illustrates both the *sequential* nature of a supply chain and the interconnectedness of the elements of the supply chain. Each link is a customer of the previous link and a supplier to the following link. It also helps to understand that if any one of the links fails for any reason (quality or delivery issues, weather problems, or some other problem [there are numerous possibilities]), that can interrupt the flow in the supply chain for the following portion of the chain.

Another way to think of a supply chain is as a tree with many branches, as shown in Figure 1.3b. The main branches of the tree represent key suppliers and transporters (e.g., trucking companies). That view is helpful in grasping the size and complexity that often exists in supply chains. Notice that the main branches of the tree have side branches (their own key suppliers), and those side branches also have their own side branches (their own key suppliers). In fact, an extension of the tree view of a supply chain is that each supplier (branch) has its own supply tree. page 6 Referring to Figure 1.3a, the farm, mill, and bakery of the trucking companies would have their own "tree" of suppliers.

FIGURE 1.3B

Supply chains are both external and internal to the organization. The external parts of a supply chain provide raw materials, parts, equipment, supplies, and/or other inputs to the organization, and they deliver outputs that are goods to the organization's customers. The internal parts of a supply chain are part of the operations function itself, supplying operations with parts and materials, performing work on products, and/or performing services.

The creation of goods or services involves transforming or converting inputs into outputs. Various inputs such as capital, labor, and information are used to create goods or services using one or more *transformation processes* (e.g., storing, transporting, repairing). To ensure that the desired outputs are obtained, an organization takes measurements at various points in the transformation process (*feedback*) and then compares them with previously established standards to determine whether corrective action is needed (*control*). Figure 1.4 depicts the conversion *system.*

FIGURE 1.4

The operations function involves systems for converting inputs into outputs

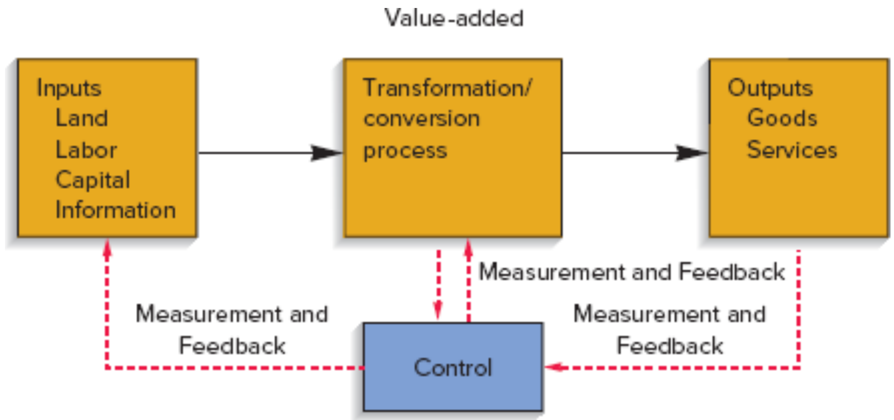


Table 1.1 provides some examples of inputs, transformation processes, and outputs. Although goods and services are listed separately in Table 1.1, it is important to note that goods and services often occur jointly. For example, having the oil changed in your car is a service, but the oil that is delivered is a good. Similarly, house painting is a service, but the paint is a good. The goods–service combination is a continuum. It can range from primarily goods, with little service, to primarily service, with few goods. Figure 1.5 illustrates this continuum. Because there are relatively few pure goods or pure services, companies usually sell *product packages,* which are a combination of goods and services. There are elements of both goods production and service delivery in these product packages. This makes managing operations more interesting, and also more challenging.

TABLE 1.1

Examples of inputs, transformation, and outputs

Inputs	Transformation	Outputs
Land	Processes	High goods percentage

Inputs	Transformation	Outputs
Human	Cutting, drilling	Houses
Physical labor	Transporting	Automobiles
Intellectual labor	Teaching	Clothing
Capital	Farming	Computers
Raw materials	Mixing	Machines
Water	Packing	Televisions
Metals	Copying	Food products
Wood	Analyzing	Textbooks
Equipment	Developing	Cell phones
Machines	Searching	High service percentage
Computers	Researching	Health care
Trucks	Repairing	Entertainment
Tools	Innovating	Vehicle repair
Facilities	Debugging	Legal

Inputs	Transformation	Outputs
Hospitals	Selling	Banking
Factories	Emailing	Communication
Retail stores	Writing	
Energy		
Other		
Information		
Time		
Legal constraints		
Government regulations		

FIGURE 1.5

The goods–service continuum

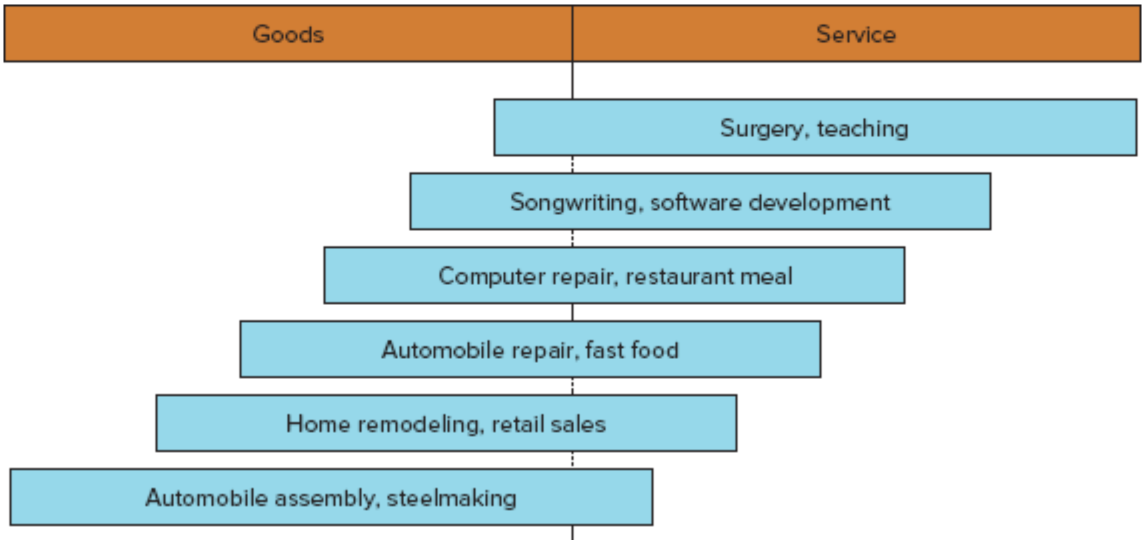


Table 1.2 provides some specific illustrations of the transformation process.

TABLE 1.2

Illustrations of the transformation process

	Inputs	Processing	Output
Food Processor	Raw vegetables	Cleaning	Canned vegetables
	Metal sheets	Making cans	
	Water	Cutting	
	Energy	Cooking	
	Labor	Packing	
	Building	Labeling	

	Inputs	Processing	Output
	Equipment		
Hospital	Doctors, nurses	Examination	Treated patients
	Hospital	Surgery	
	Medical supplies	Monitoring	
	Equipment	Medication	
	Laboratories	Therapy	

The essence of the operations function is to *add value* during the transformation process. **Value-added** is the term used to describe the difference between the cost of inputs and the value or price of outputs. In nonprofit organizations, the value of outputs (e.g., highway construction, police and fire protection) is their value to society; the greater the value-added, the greater the effectiveness of these operations. In for-profit organizations, the value of outputs is measured by the prices that customers are willing to pay for those goods or services. Firms use the money generated by value-added for research and development, investment in new facilities and equipment, worker salaries, and *profits.* Consequently, the greater the value-added, the greater the amount of funds available for these purposes. Value can also be psychological, as in *branding.*

Value-added The difference between the cost of inputs and the value or price of outputs.

Many factors affect the design and management of operations systems. Among them are the degree of involvement of customers in the process and the degree to which technology is used to produce and/or deliver a product or service. The greater the degree of customer involvement, the more challenging it can be to

design and manage the operation. Technology choices can have a major impact on productivity, costs, flexibility, and quality and customer satisfaction.

1.2 PRODUCTION OF GOODS VERSUS PROVIDING SERVICES

LO1.2
Identify the similarities and differences between production and service operations.

Although goods and services often go hand in hand, there are some very basic differences between the two, differences that impact the management of the goods portion versus management of the service portion. There are also many similarities between the two.

Production of goods results in a *tangible output,* such as an automobile, eyeglasses, a golf ball, a refrigerator—anything that we can see or touch. It may take place in a factory, but it can occur elsewhere. For example, farming and restaurants produce *nonmanufactured* goods. Delivery of service, on the other hand, generally implies an *act.* A physician's examination, TV and auto repair, lawn care, and the projection of a film in a theater are examples of services. The majority of service jobs fall into these categories:

Professional services (e.g., financial, health care, legal)

Mass services (e.g., utilities, internet, communications)

Service shops (e.g., tailoring, appliance repair, car wash, auto repair/maintenance)

Personal care (e.g., beauty salon, spa, barbershop)

Government (e.g., Medicare, mail, social services, police, fire)

Education (e.g., schools, universities)

Food service (e.g., catering)

Services within organizations (e.g., payroll, accounting, maintenance, IT, HR, janitorial)

Retailing and wholesaling

Shipping and delivery (e.g., truck, railroad, boat, air)

Residential services (e.g., lawn care, painting, general repair, remodeling, interior design)

Transportation (e.g., mass transit, taxi, airlines, ambulance)

Travel and hospitality (e.g., travel bureaus, hotels, resorts)

Miscellaneous services (e.g., copy service, temporary help)

Manufacturing and service are often different in terms of *what* is done, but quite similar in terms of *how* it is done.

Consider these points of comparison:

Degree of customer contact. Many services involve a high degree of customer contact, although services such as internet providers, utilities, and mail service do not. When there is a high degree of contact, the interaction between server and customer becomes a “moment of truth” that will be judged by the customer every time the service occurs.

Labor content of jobs. Services often have a higher degree of labor content than manufacturing jobs do, although automated services are an exception.

Uniformity of inputs. Service operations are often subject to a higher degree of variability of inputs. Each client, patient, customer, repair job, and so on presents a somewhat unique situation that requires assessment and flexibility. Conversely, manufacturing operations often have a greater ability to control the variability of inputs, which leads to more-uniform job requirements.

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Measurement of productivity. Measurement of productivity can be more difficult for service jobs due largely to the high variations of inputs. Thus, one doctor might have a higher level of routine cases to deal with, while another might have more difficult cases. Unless a careful analysis is conducted, it may appear that the doctor with the difficult cases has a much lower productivity than the one with the routine cases.

Quality assurance. Quality assurance is usually more challenging for services due to the higher variation in input, and because delivery and consumption occur at the same time. Unlike manufacturing, which typically occurs away from the customer and allows mistakes that are identified to be corrected, services have less opportunity to avoid exposing the customer to mistakes.

Inventory. Many services tend to involve less use of inventory than manufacturing operations, so the costs of having inventory on hand are lower than they are for manufacturing. However, unlike manufactured goods, services cannot be stored. Instead, they must be provided “on demand.”

Wages. Manufacturing jobs are often well paid, and have less wage variation than service jobs, which can range from highly paid professional services to minimum-wage workers.

Ability to patent. Product designs are often easier to patent than service designs, and some services cannot be patented, making them easier for competitors to copy.

There are also many *similarities* between managing the production of products and managing services. In fact, most of the topics in this book pertain to both. When there are important service considerations, these are highlighted in separate sections. Here are some of the primary factors for both:

a. Forecasting and capacity planning to match supply and demand
b. Process management
c. Managing variations
d. Monitoring and controlling costs and productivity
e. Supply chain management
f. Location planning, inventory management, quality control, and scheduling

Note that many service activities are essential in goods-producing companies. These include training, human resource management, customer service, equipment repair, procurement, and administrative services.

Table 1.3 provides an overview of the differences between the production of goods and service operations. Remember, though, that most systems involve a blend of goods and services.

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TABLE 1.3

Typical differences between production of goods and provision of services

Characteristic	Goods	Services
Output	Tangible	Intangible
Customer contact	Low	High
Labor content	Low	High
Uniformity of input	High	Low
Measurement of productivity	Easy	Difficult
Opportunity to correct problems before delivery	High	Low
Inventory	Much	Little
Wages	Narrow range	Wide range
Patentable	Usually	Not usually

1.3 WHY LEARN ABOUT OPERATIONS MANAGEMENT?

LO1.3
Explain the importance of learning about operations management
.

Whether operations management is your major or not, the skill set you gain studying operations management will serve you well in your career.

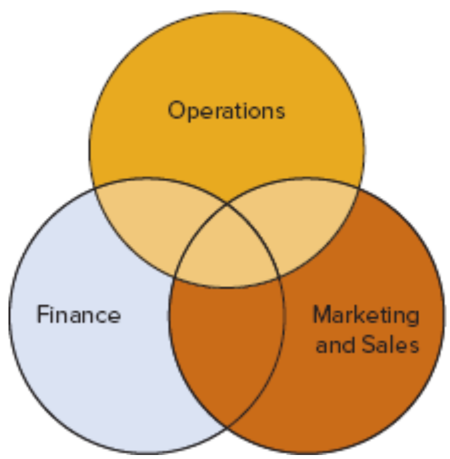
There are many career-related reasons for wanting to learn about operations management, whether you plan to work in the field of operations or not. This is because every aspect of business affects or is affected by operations. Operations and sales are the two line functions in a business organization. All other functions—accounting, finance, marketing, IT, and so on—support the two line functions. Among the service jobs that are closely related to operations are financial services (e.g., stock market analyst, broker, investment banker, and loan officer), marketing services (e.g., market analyst, marketing researcher, advertising manager, and product manager), accounting services (e.g., corporate accountant, public accountant, and budget analyst), and information services (e.g., corporate intelligence, library services, management information systems design services).

A common complaint from employers is that college graduates come to them very focused, when employers would prefer them to have more of a general knowledge of how business organizations operate. This book provides some of the breadth that employers are looking for in their new hires. Apart from the career-related reasons, there is a not-so-obvious one: Through learning about operations and supply chains, you will have a much better understanding of the world you live in, the global dependencies of companies and nations, some of the reasons that companies succeed or fail, and the importance of working with others.

Working together successfully means that all members of the organization understand not only their own role, but they also understand the roles of others. In practice, there is significant interfacing and *collaboration* among the various functional areas, involving *exchange of information* and *cooperative decision making.* For example, although the three primary functions in business organizations perform different activities, many of their decisions impact the other areas of the organization. Consequently, these functions have numerous interactions, as depicted by the overlapping circles shown in Figure 1.6.

FIGURE 1.6

The three major functions of business organizations overlap



Finance and operations management personnel cooperate by exchanging information and expertise in such activities as the following:

- **Budgeting.** Budgets must be periodically prepared to plan financial requirements. Budgets must sometimes be adjusted, and performance relative to a budget must be evaluated.

. **Economic analysis of investment proposals.** Evaluation of alternative investments in plant and equipment requires inputs from both operations and finance people.

. **Provision of funds.** The necessary funding of operations and the amount and timing of funding can be important and even critical when funds are tight. Careful planning can help avoid cash-flow problems.

LO1.4
Identify the three major functional areas of organizations and describe how they interrelate.

Marketing's focus is on selling and/or promoting the goods or services of an organization. Marketing is also responsible for assessing customer wants and needs, and for communicating those to operations people (short term) and to design people (long term). That is, operations needs information about demand over the short to intermediate term so that it can plan accordingly (e.g., purchase materials or schedule work), while design people need information that relates to improving current products and services and designing new ones. Marketing, design, and production must work closely together to successfully implement design changes and to develop and produce new products. Marketing can provide valuable insight on what competitors are doing. Marketing also can supply information on consumer preferences so that design will know the kinds of products and features needed; operations can supply information about capacities and judge the *manufacturability* of designs. Operations will also have advance warning if new equipment or skills will be needed for new products or services.

Finance people should be included in these exchanges in order to provide information on what funds might be available (short term) and to learn what funds might be needed for new products or services (intermediate to long term). One important piece of information marketing needs from operations is the manufacturing or service **lead time** in order to give customers realistic estimates of how long it will take to fill their orders.

Lead time The time between ordering a good or service and receiving it.

Thus, marketing, operations, and finance must interface on product and process design, forecasting, setting realistic schedules, quality and quantity decisions, and keeping each other informed on the other's strengths and weaknesses.

People in every area of business need to appreciate the importance of managing and coordinating operations decisions that affect the supply chain and the matching of supply and demand, and how those decisions impact other functions in an organization.

Operations also interacts with other functional areas of the organization, including legal, management information systems (MIS), accounting, personnel/human resources, and public relations, as depicted in Figure 1.7.

FIGURE 1.7

Operations interfaces with a number of supporting functions

The *legal* department must be consulted on contracts with employees, customers, suppliers, and transporters, as well as on liability and environmental issues.

Accounting supplies information to management on costs of labor, materials, and overhead, and may provide reports on items such as scrap, downtime, and inventories.

Management information systems (MIS) is concerned with providing management with the information it needs to effectively manage. This occurs mainly through designing systems to capture relevant information and designing reports. MIS is also important for managing the control and decision-making tools used in operations management.

The *personnel* or *human resources* department is concerned with the recruitment and training of personnel, labor relations, contract negotiations, wage and salary administration, assisting in manpower projections, and ensuring the health and safety of employees.

Public relations is responsible for building and maintaining a positive public image of the organization. Good public relations provides many potential benefits. An obvious one is in the marketplace. Other potential benefits include public awareness of the organization as a good place to work (labor supply), improved chances of approval of zoning change requests, community acceptance of expansion plans, and instilling a positive attitude among employees.

1.4 CAREER OPPORTUNITIES AND PROFESSIONAL SOCIETIES

There are many career opportunities in the operations management and supply chain fields. Among the numerous job titles are operations manager, production analyst, production manager, inventory manager, purchasing manager, schedule coordinator, distribution manager, supply chain manager, quality analyst, and quality manager. Other titles include office manager, store manager, and service manager.

People who work in the operations field should have a skill set that includes both people skills and knowledge skills. People skills include political awareness; mentoring ability; and collaboration, negotiation, and communication skills. Knowledge skills, necessary for credibility and good decision making, include product and/or service knowledge, process knowledge, industry and global knowledge, financial and accounting skills, and project management skills. See Table 1.4.

TABLE 1.4

Sample operations management job descriptions

Production Supervisor	Supply Chain Manager	Social Media Product Manager

Production Supervisor	Supply Chain Manager	Social Media Product Manager
• Manage a production staff of 10–20. • Ensure the department meets daily goals through the management of productivity. • Enforce safety policies. • Coordinate work between departments. • Have strong problem-solving skills, and strong written and oral communication skills.	• Have a general knowledge of materials management, information systems, and basic statistics. • Direct, monitor, evaluate, and motivate employee performance. • Be knowledgeable about shipping regulations. • Manage budgetary accounts. • Manage projects.	• Identify ways to increase consumer engagement. • Analyze the key performance indicators and recommend improvements. • Lead cross-functional teams to define product specifications. • Collaborate with design and technical to create key product improvements. • Develop requirements for new website enhancements. • Monitor the competition to identify need for changes.

If you are thinking of a career in operations management, you can benefit by joining one or more of the following professional societies.

APICS, the Association for Operations Management 8430 West Bryn Mawr Avenue, Suite 1000, Chicago, Illinois 60631 www.apics.org

American Society for Quality (ASQ) 230 West Wells Street, Milwaukee, Wisconsin 53203 www.asq.org

Institute for Supply Management (ISM) 2055 East Centennial Circle, Tempe, Arizona 85284 www.ism.ws

Institute for Operations Research and the Management Sciences (INFORMS) 901 Elkridge Landing Road, Linthicum, Maryland 21090-2909 www.informs.org

The Production and Operations Management Society (POMS) College of Engineering, Florida International University, EAS 2460, 10555 West Flagler Street, Miami, Florida 33174 www.poms.org

The Project Management Institute (PMI) 4 Campus Boulevard, Newtown Square, Pennsylvania 19073-3299 www.pmi.org

Council of Supply Chain Management Professionals (CSCMP) 333 East Butterfield Road, Suite 140, Lombard, Illinois 60148 https://cscmp.org

APICS, ASQ, ISM, and other professional societies offer a practitioner certification examination that can enhance your qualifications. Information about job opportunities can be obtained from all of these societies, as well as from other sources, such as the Decision Sciences Institute (University Plaza, Atlanta, Georgia 30303) and the Institute of Industrial Engineers (25 Technology Park, Norcross, Georgia 30092).

1.5 PROCESS MANAGEMENT

LO1.5 Summarize the two major aspects of process management
.

A key aspect of operations management is process management. A **process** consists of one or more actions that transform inputs into outputs. In essence, the central role of all management is process management.

Process One or more actions that transform inputs into outputs.

Businesses are composed of many interrelated processes. Generally speaking, there are three categories of business processes:

- **Upper-management processes.** These govern the operation of the entire organization. Examples include organizational governance and organizational strategy.
- **Operational processes.** These are the core processes that make up the value stream. Examples include purchasing, production and/or service, marketing, and sales.
- **Supporting processes.** These support the core processes. Examples include accounting, human resources, and IT (information technology).

Business processes, large and small, are composed of a series of supplier–customer relationships, where every business organization, every department, and every individual operation is both a customer of the previous step in the process and a supplier to the next step in the process. Figure 1.8 illustrates this concept.

FIGURE 1.8

Business processes form a sequence of suppliers and customers

A major process can consist of many subprocesses, each having its own goals that contribute to the goals of the overall process. Business organizations and supply chains have many such processes and subprocesses, and they benefit greatly when management is using a process perspective. Business process management (BPM) activities include process design, process execution, and process monitoring. Two basic aspects of this for operations and supply chain management are managing processes to meet demand and dealing with process variability.

Managing a Process to Meet Demand

Ideally, the capacity of a process will be such that its output just matches demand. Excess capacity is wasteful and costly; too little capacity means dissatisfied customers and lost revenue. Having the right capacity requires having accurate forecasts of demand, the ability to translate forecasts into capacity requirements, and a process in place capable of meeting expected demand. Even so, process variation and demand variability can make the achievement of a match between process output and demand difficult. Therefore, to be effective, it is also necessary for managers to be able to deal with variation.

Process Variation

Variation occurs in all business processes. It can be due to variety or variability. For example, random variability is inherent in every process; it is always present. In addition, variation can occur as the result of deliberate management choices to offer customers variety.

There are four basic sources of variation:

- **The variety of goods or services being offered.** The greater the variety of goods and services, the greater the variation in production or service requirements.
- **Structural variation in demand.** These variations, which include trends and seasonal variations, are generally predictable. They are particularly important for capacity planning.
- **Random variation.** This natural variability is present to some extent in all processes, as well as in demand for services and products, and it cannot generally be influenced by managers.
- **Assignable variation.** These variations are caused by defective inputs, incorrect work methods, out-of-adjustment equipment, and so on. This type of variation can be reduced or eliminated by analysis and corrective action.

Variations can be disruptive to operations and supply chain processes, interfering with optimal functioning. Variations result in additional cost, delays and shortages, poor quality, and inefficient work systems. Poor quality and product shortages or service delays can lead to dissatisfied customers and can damage an organization's reputation and image. It is not surprising, then, that the ability to deal with variability is absolutely necessary for managers.

Throughout this book, you will learn about some of the tools managers use to deal with variation. An important aspect of being able to deal with variation is to use metrics to describe it. Two widely used metrics are the *mean* (average) and the *standard deviation.* The standard deviation quantifies variation around the mean. The mean and standard deviation are used throughout this book in conjunction with variation. So, too, is the normal distribution. Because you will come across many examples of how the normal distribution is used, you may find the overview on working with the normal distribution in the appendix at the end of the book helpful.

1.6 THE SCOPE OF OPERATIONS MANAGEMENT

LO1.6
Describe the operations function and the nature of the operations manager's job.

The scope of operations management ranges across the organization. Operations management people are involved in product and service design, process selection, selection and management of technology, design of work systems, location planning, facilities planning, and quality improvement of the organization's products or services.

The operations function includes many interrelated activities, such as forecasting, capacity planning, scheduling, managing inventories, assuring quality, motivating employees, deciding where to locate facilities, and more.

We can use an airline company to illustrate a service organization's operations system. The system consists of the airplanes, airport facilities, and maintenance facilities, sometimes spread out over a wide territory. The activities include:

Forecasting such things as weather and landing conditions, seat demand for flights, and the growth in air travel.

Capacity planning, essential for the airline to maintain cash flow and make a reasonable profit. (Too few or too many planes, or even the right number of planes but in the wrong places, will hurt profits.)

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Scheduling planes, cargo, and flight and ground crews is an operations function for an airline.

1000 Words/Shutterstock

Locating facilities according to managers' decisions on which cities to provide service for, where to locate maintenance facilities, and where to locate major and minor hubs.

Facilities and layout, important in achieving effective use of workers and equipment.

Scheduling of planes for flights and for routine maintenance; scheduling of pilots and flight attendants; and scheduling of ground crews, counter staff, and baggage handlers.

Managing inventories of such items as foods and beverages, first-aid equipment, in-flight magazines, pillows and blankets, and life preservers.

Assuring quality, essential in flying and maintenance operations, where the emphasis is on safety. This is important in dealing with customers at ticket counters, check-in, telephone and electronic reservations, and curb service, where the emphasis is on efficiency and courtesy.

Motivating and training employees in all phases of operations.

Managing the Supply Chain to Achieve Schedule, Cost, and Quality Goals

Consider a bicycle factory. This might be primarily an *assembly* operation: buying components such as frames, tires, wheels, gears, and other items from suppliers, and then assembling bicycles. The factory also might do some of the *fabrication* work itself, forming frames and making the gears and chains, and it might buy mainly raw materials and a few parts and materials such as paint, nuts and bolts, and tires. Among the key management tasks in either case are scheduling production, deciding which components to make and which to buy, ordering parts and materials, deciding on the style of bicycle to produce and how many, purchasing new equipment to replace old or worn-out equipment, maintaining equipment, motivating workers, and ensuring that quality standards are met.

Obviously, an airline company and a bicycle factory are completely different types of operations. One is primarily a service operation, the other a producer of goods. Nonetheless, these two operations have much in common. Both involve scheduling activities, motivating employees, ordering and managing supplies, selecting and maintaining equipment, satisfying quality standards, and—above all—satisfying customers. Also, in both businesses, the success of the business depends on short- and long-term planning.

Bicycle manufacturing and repair is one of the many jobs the require operations management expertise.

Jetta Productions/Blend Images LLC

A primary function of an operations manager is to guide the system by decision making. Certain decisions affect the *design* of the system, and others affect the *operation* of the system.

System design involves decisions that relate to system capacity, the geographic location of facilities, the arrangement of departments and the placement of equipment within physical structures, product and service planning, and the acquisition of equipment. These decisions usually, but not always, require long-term commitments. Moreover, they are typically *strategic* decisions. *System operation* involves management of personnel, inventory planning and control, scheduling, project management, and quality assurance. These are generally *tactical* and *operational* decisions. Feedback on these decisions involves *measurement* and *control.* In many instances, the operations manager is more involved in day-to-day operating decisions than with decisions relating to system design. However, the operations manager has a vital stake in system design because *system design essentially determines many of the parameters of system operation.* For example, costs, space, capacities, and quality are directly affected by design decisions. Even though the operations manager is not responsible for making all design decisions, he or she can provide those decision makers with a wide range of information that will have a bearing on their decisions.

A number of other areas are part of, or support, the operations function. They include purchasing, industrial engineering, distribution, and maintenance.

Purchasing is responsible for the procurement of materials, supplies, and equipment. Close contact with operations is necessary to ensure correct quantities and timing of purchases. The purchasing department is often called on to evaluate vendors for quality, reliability, service, price, and ability to adjust to changing demand. Purchasing is also involved in receiving and inspecting the purchased goods.

Industrial engineering is often concerned with scheduling, performance standards, work methods, quality control, and material handling.

Distribution involves the shipping of goods to warehouses, retail outlets, or final customers.

Maintenance is responsible for general upkeep and the repair of equipment, the buildings and grounds, heating and air-conditioning, parking, removing toxic wastes, and perhaps security.

The operations manager is the key figure in the system. He or she has the ultimate responsibility for the creation of goods or provision of services.

READING

WHY MANUFACTURING MATTERS

The U.S. economy is becoming more and more service-based. The percentage of employment in manufacturing continues to decrease, while the percentage employed in services continues to increase. However, it would be unwise to assume that manufacturing isn't important to the economy, or that service is more important. Let's see why.

Not only is the percentage of manufacturing jobs decreasing, but the actual number of manufacturing jobs is also decreasing. There are two main reasons for the decline: increases in productivity (many times due to increases in automation), which means fewer workers are needed to maintain manufacturing output; and outsourcing, especially offshoring to countries that have much lower wages, an attractive option for companies seeking to maintain their competitiveness and boost their bottom lines.

However, when companies outsource part (or in some cases, all) of their manufacturing to lower-cost countries, the loss of jobs results in the loss of service jobs as well. Some are lost in the community in retail businesses patronized by the manufacturing workers. Also included in that figure are factory service workers (e.g., workers who do machine repairs, maintenance, material handling, packaging, and so on). General estimates are that four service jobs are lost for each manufacturing job lost.

As the manufacturing base shrinks, workers who lose their manufacturing jobs are finding it tougher to find another opening in manufacturing. Instead, they join the ranks of the unemployed, or take a service job, usually at a lower wage rate than what manufacturing paid.

From a national perspective, not only is work transferred to a foreign country, intellectual knowledge is transferred. Moreover, as time passes, the domestic base of manufacturing skills and know-how is lost.

There are important consequences for taxes as well. Unemployment benefits are costly, and the erosion of federal, state, and local tax bases results in lower tax revenues collected from individuals and from corporations.

Lastly, manufacturing is an important source of innovation. It is responsible for 70 percent of private-sector R&D and 90 percent of U.S. patents (Rana Foroohar, "Go Glocal," *Time,* August 20, 2012, p. 30). Much of the work in getting a product ready for volume production is high-value-added knowledge work that supports future innovation. And innovation generates jobs. "Intel has invested tens of billions of dollars in its factories in Oregon, Arizona, and New Mexico so that they are able to produce the most advanced semiconductors."

Source: Willy Shih and Gary Pisano,"Why Manufacturing Matters for America," Special to CNN, Sept. 21, 2012.

Questions

1. How important is the loss of manufacturing jobs to the nation?
2. Can you suggest some actions the government (federal, state, or local) can take to stem the job loss?
3. What evidence is there of the importance of manufacturing innovation?

The kinds of jobs that operations managers oversee vary tremendously from organization to organization, largely because of the different products or services involved. Thus, managing a banking operation obviously requires a different kind of expertise than managing a steelmaking operation. However, in a very important respect, the *jobs* are the same: They are both essentially *managerial.* The same thing can be said for the job of any operations manager regardless of the kinds of goods or services being created.

The service sector and the manufacturing sector are both important to the economy. The service sector now accounts for more than 70 percent of jobs in the United States, and it is growing in other countries as well. Moreover, the number of people working in services is increasing, while the number of people working in manufacturing is not. The reason for the decline in manufacturing jobs is twofold: As the operations function in manufacturing companies finds more productive ways of producing goods, the companies are able to maintain or even increase their output using fewer workers. Furthermore, some manufacturing work has been *outsourced* to more productive companies, many in other countries, that are able to produce goods at lower costs. Outsourcing and productivity will be discussed in more detail in this and other chapters.

Many of the concepts presented in this book apply equally to manufacturing and service. Consequently, whether your interest at this time is on manufacturing or on service, these concepts will be important, regardless of whether a manufacturing example or service example is used to illustrate the concept.

The Why Manufacturing Matters reading gives another reason for the importance of manufacturing jobs.

1.7 OPERATIONS MANAGEMENT AND DECISION MAKING

LO1.7
Explain the key aspects of operations management decision making.

The chief role of an operations manager is that of planner and decision maker. In this capacity, the operations manager exerts considerable influence over the degree to which the goals and objectives of the organization are realized. Most decisions involve many possible alternatives that can have quite different impacts on costs or profits. Consequently, it is important to make *informed* decisions.

Operations management professionals make a number of key decisions that affect the entire organization. These include the following:

What: What resources will be needed, and in what amounts?

When: When will each resource be needed? When should the work be scheduled? When should materials and other supplies be ordered? When is corrective action needed?

Where: Where will the work be done?

How: How will the product or service be designed? How will the work be done (organization, methods, equipment)? How will resources be allocated?

Who: Who will do the work?

An operations manager's daily concerns include costs (budget), quality, and schedules (time).

Throughout this book, you will encounter the broad range of decisions that operations managers must make, and you will be introduced to the tools necessary to handle those decisions. This section describes general approaches to decision making, including the use of models, quantitative methods, analysis of trade-offs, establishing priorities, ethics, and the systems approach. Models are often a key tool used by all decision makers.

Models

A **model** is an abstraction of reality, a simplified representation of something. For example, a toy car is a model of a real automobile. It has many of the same visual features (shape, relative proportions, wheels) that make it suitable for the child's learning and playing. But the toy does not have a real engine, it cannot transport people, and it does not weigh 3,000 pounds.

Model An abstraction of reality; a simplified representation of something.

Other examples of models include automobile test tracks and crash tests; formulas, graphs, and charts; balance sheets and income statements; and financial ratios. Common statistical models include descriptive statistics such as the mean, median, mode, range, and standard deviation, as well as random sampling, the normal distribution, and regression equations.

Models are sometimes classified as physical, schematic, or mathematical.

> **Physical models** look like their real-life counterparts. Examples include miniature cars, trucks, airplanes, toy animals and trains, and scale-model buildings. The advantage of these models is their visual correspondence with reality. 3-D printers (explained in Chapter 6) are often used to prepare scale models.
>
> **Schematic models** are more abstract than their physical counterparts; that is, they have less resemblance to the physical reality. Examples include graphs and charts, blueprints, pictures,

and drawings. The advantage of schematic models is that they are often relatively simple to construct and change. Moreover, they have some degree of visual correspondence.

Mathematical models are the most abstract: They do not look at all like their real-life counterparts. Examples include numbers, formulas, and symbols. These models are usually the easiest to manipulate, and they are important forms of inputs for computers and calculators.

The variety of models in use is enormous. Nonetheless, all have certain common features: They are all decision-making aids and simplifications of more complex real-life phenomena. Real life involves an overwhelming amount of detail, much of which is irrelevant for any particular problem. Models omit unimportant details so that attention can be concentrated on the most important aspects of a situation.

Because models play a significant role in operations management decision making, they are heavily integrated into the material of this text. For each model, try to learn (1) its purpose, (2) how it is used to generate results, (3) how these results are interpreted and used, and (4) what assumptions and limitations apply.

The last point is particularly important because virtually every model has an associated set of assumptions or conditions under which the model is valid. Failure to satisfy all of the assumptions will make the results suspect. Attempts to apply the results to a problem under such circumstances can lead to disastrous consequences.

Managers use models in a variety of ways and for a variety of reasons. Models are beneficial because they:

- Are generally easy to use and less expensive than dealing directly with the actual situation.

- Require users to organize and sometimes quantify information and, in the process, often indicate areas where additional information is needed.
- Increase understanding of the problem.
- Enable managers to analyze what-if questions.
- Serve as a consistent tool for evaluation and provide a standardized format for analyzing a problem.
- Enable users to bring the power of mathematics to bear on a problem.

This impressive list of benefits notwithstanding, models have certain limitations of which you should be aware. The following are three of the more important limitations.

- Quantitative information may be emphasized at the expense of qualitative information.
- Models may be incorrectly applied and the results misinterpreted. The widespread use of computerized models adds to this risk because highly sophisticated models may be placed in the hands of users who are not sufficiently knowledgeable to appreciate the subtleties of a particular model; thus, they are unable to fully comprehend the circumstances under which the model can be successfully employed.
- The use of models does not guarantee good decisions.

Quantitative Approaches

Quantitative approaches to problem solving often embody an attempt to obtain mathematically optimal solutions to managerial problems. *Quantitative approaches* to decision making in operations management (and in other functional business areas) have been accepted because of calculators and computers capable of handling the required calculations. Computers have had a major impact on operations management. Moreover, the growing availability of software packages for quantitative techniques has greatly increased management's use of those techniques.

Although quantitative approaches are widely used in operations management decision making, it is important to note that managers typically use a combination of qualitative and quantitative approaches, and many important decisions are based on qualitative approaches.

Performance Metrics

Managers use metrics to manage and control operations. There are many metrics in use, including those related to profits, costs, quality, productivity, flexibility, assets, inventories, schedules, and forecast accuracy. As you read each chapter, note the metrics being used and how they are applied to manage operations.

Analysis of Trade-Offs

Operations personnel frequently encounter decisions that can be described as *trade-off* decisions. For example, in deciding on the amount of inventory to stock, the decision maker must take into account the trade-off between the increased level of customer service that the additional inventory would yield and the increased costs required to stock that inventory.

Decision makers sometimes deal with these decisions by listing the advantages and disadvantages—the pros and cons—of a course of action to better understand the consequences of the decisions they must make. In some instances, decision makers add weights to the items on their list that reflect the relative importance of various factors. This can help them "net out" the potential impacts of the trade-offs on their decision.

READING  ANALYTICS

Analytics uses descriptive and predictive models to obtain insight from data and then uses that insight to recommend action or to guide decision making.

Commercial analytics software is available for the challenges of analyzing very large, dynamic data sets, referred to as big data. Analyzing big data presents opportunities for businesses such as those that operate transactional online systems that generate massive volumes of data. For example, the McKinsey Global Institute estimates that the U.S. health care system could save $300 billion from analyzing big data.[1]

[1] "Big Data: The Next Frontier for Innovation, Competition and Productivity as Reported in Building with Big Data," *The Economist*, May 26, 2011.

Degree of Customization

A major influence on the entire organization is the degree of customization of products or services being offered to its customers. Providing highly customized products or services such as home remodeling, plastic surgery, and legal counseling tends to be more labor intensive than providing standardized products such as those you would buy "off the shelf" at a mall store or a supermarket or standardized services such as public utilities and internet services. Furthermore, production of customized products or provision of customized services is generally more time consuming, requires more highly skilled people, and involves more flexible equipment than what is needed for standardized products or services.

Customized processes tend to have a much lower volume of output than standardized processes, and customized output carries a higher price tag. The degree of customization has important implications for process selection and job requirements. The impact goes beyond operations and supply chains. It affects marketing, sales, accounting, finance, and information systems.

A Systems Perspective

A systems perspective is almost always beneficial in decision making. Think of it as a "big picture" view. A **system** can be defined as a set of interrelated parts that must work together. In a business organization, the organization can be thought of as a system composed of subsystems (e.g., marketing subsystem, operations subsystem, finance subsystem), which in turn are composed of lower subsystems. The systems approach emphasizes interrelationships among subsystems, but its main theme is that *the whole is greater than the sum of its individual parts.* Hence, from a systems viewpoint, the output and objectives of the organization as a whole take precedence over those of any one subsystem.

System A set of interrelated parts that must work together.

A systems perspective is essential whenever something is being designed, redesigned, implemented, improved, or otherwise changed. It is important to take into account the impact on all parts of the system. For example, if the upcoming model of an automobile will add forward collision braking, a designer must take into account how customers will view the change, the cost of producing the new system, installation procedures, and repair procedures. In addition, workers will need training to make and/or assemble the new system, production scheduling may change, inventory procedures may have to change, quality standards will have to be established, advertising must be informed of the new features, and parts suppliers must be selected.

Establishing Priorities

In virtually every situation, managers discover that certain issues or items are more important than others. Recognizing this enables the managers to direct their efforts to where they will do the most good.

Typically, a relatively few issues or items are very important, so that dealing with those factors will generally have a disproportionately large impact on the results achieved. This well-known effect is referred to as the **Pareto phenomenon**. This is one of the most important and pervasive concepts in operations management. In fact, this concept can be applied at all levels of management and to every aspect of decision making, both professional and personal.

Pareto phenomenon A few factors account for a high percentage of the occurrence of some event(s).

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1.8 THE HISTORICAL EVOLUTION OF OPERATIONS MANAGEMENT

LO1.8 Briefly describe the historical evolution of operations management.

Systems for production have existed since ancient times. For example, the construction of pyramids and Roman aqueducts involved operations management skills. The production of goods for sale, at least in the modern sense, and the modern factory system had their roots in the Industrial Revolution.

The Industrial Revolution

The Industrial Revolution began in the 1770s in England and spread to the rest of Europe and to the United States during the 19th century. Prior to that time, goods were produced in small shops by craftsmen and their apprentices. Under that system, it was common for one person to be responsible for making a product, such as a horse-drawn wagon or a piece of furniture, from start to finish. Only simple tools were available; the machines in use today had not been invented.

Then, a number of innovations in the 18th century changed the face of production forever by substituting machine power for human power. Perhaps the most significant of these was the steam engine, because it provided a source of power to operate machines in factories. Ample supplies of coal and iron ore provided materials for generating power and making machinery. The new machines, made of iron, were much stronger and more durable than the simple wooden machines they replaced.

In the earliest days of manufacturing, goods were produced using **craft production**: Highly skilled workers using simple, flexible tools produced goods according to customer specifications.

Craft production System in which highly skilled workers use simple, flexible tools to produce small quantities of customized goods.

Craft production had major shortcomings. Because products were made by skilled craftsmen who custom-fitted parts, production was slow and costly. And when parts failed, the replacements also had to be custom made, which was also slow and costly. Another shortcoming was that production costs did not decrease as volume increased; there were no *economies of scale,* which would have provided a major incentive for companies to expand. Instead, many small companies emerged, each with its own set of standards.

A major change occurred that gave the Industrial Revolution a boost: the development of standard gauging systems. This greatly reduced the need for custom-made goods. Factories began to spring up and grow rapidly, providing jobs for countless people who were attracted in large numbers from rural areas.

Despite the major changes that were taking place, management theory and practice had not progressed much from early days. What was needed was an enlightened and more systematic approach to management.

Scientific Management

The scientific management era brought widespread changes to the management of factories. The movement was spearheaded by the efficiency engineer and inventor Frederick Winslow Taylor, who is often referred to as the father of scientific management. Taylor believed in a “science of management” based on observation, measurement, analysis and improvement of work methods, and economic incentives. He studied work methods in great detail to identify the best method for doing each job. Taylor also believed that management should be responsible for planning, carefully selecting and training workers, finding the best way to perform each job, achieving cooperation between management and workers, and separating management activities from work activities.

Taylor’s methods emphasized maximizing output. They were not always popular with workers, who sometimes thought the methods were used to unfairly increase output without a corresponding increase in compensation. Certainly, some companies did abuse workers in their quest for efficiency. Eventually, the public outcry reached the halls of Congress, and hearings were held on the matter. Taylor himself was called to testify in 1911, the same year in which his classic book, *The Principles of Scientific Management,* was published. The publicity from those hearings actually helped scientific management principles to achieve wide acceptance in industry.

A number of other pioneers also contributed heavily to this movement, including the following:

Frank Gilbreth was an industrial engineer who is often referred to as the father of motion study. He developed principles of motion economy that could be applied to incredibly small portions of a task.

Henry Gantt recognized the value of nonmonetary rewards to motivate workers, and developed a widely used system for scheduling, called Gantt charts.

Harrington Emerson applied Taylor's ideas to organization structure and encouraged the use of experts to improve organizational efficiency. He testified in a congressional hearing that railroads could save a million dollars a day by applying principles of scientific management.

Henry Ford, the great industrialist, employed scientific management techniques in his factories.

During the early part of the 20th century, automobiles were just coming into vogue in the United States. Ford's Model T was such a success that the company had trouble keeping up with orders for the cars. In an effort to improve the efficiency of operations, Ford adopted the scientific management principles espoused by Frederick Winslow Taylor. He also introduced the *moving assembly line,* which had a tremendous impact on production methods in many industries.

Among Ford's many contributions was the introduction of **mass production** to the automotive industry, a system of production in which large volumes of standardized goods are produced by low-skilled or semiskilled workers using highly specialized, and often costly, equipment. Ford was able to do this by taking advantage of a number of important concepts. Perhaps the key concept that launched mass production was **interchangeable parts**, sometimes attributed to Eli Whitney, an American inventor who applied the concept to assembling muskets in the late 1700s. The basis for interchangeable parts was to standardize parts so that any part in a batch of parts would fit any automobile coming down the assembly line. This meant that parts did not have to be custom fitted, as they were in craft production. The standardized parts could also be used for replacement parts. The result was a tremendous decrease in assembly time and cost. Ford accomplished this by standardizing the gauges used to measure parts during production and by using newly developed processes to produce uniform parts.

Mass production System in which low-skilled workers use specialized machinery to produce high volumes of standardized goods.

Interchangeable parts Parts of a product made to such precision that they do not have to be custom fitted.

Model A's, being manufactured on an early Ford assembly line.
Hulton Archive/Getty Images

A second concept used by Ford was the **division of labor**, which Adam Smith wrote about in *The Wealth of Nations* (1776). Division of labor means that an operation, such as assembling an automobile, is divided up into a series of many small tasks, and individual workers are assigned to one of those tasks. Unlike craft production, where each worker was responsible for doing many tasks, and thus required skill, with division of labor the tasks were so narrow that virtually no skill was required.

Division of labor The breaking up of a production process into small tasks, so that each worker performs a small portion of the overall job.

Together, these concepts enabled Ford to tremendously increase the production rate at his factories using readily available inexpensive labor. Both Taylor and Ford were despised by many workers, because they held workers in such low regard, expecting them to perform like robots. This paved the way for the human relations movement.

The Human Relations Movement

Whereas the scientific management movement heavily emphasized the technical aspects of work design, the human relations movement emphasized the importance of the human element in job design. Lillian Gilbreth, a psychologist and the wife of Frank Gilbreth, worked with her husband, focusing on the human factor in work. (The Gilbreths were the subject of a classic film, *Cheaper by the Dozen.*) Many of her studies dealt with worker fatigue. In the following decades, there was much emphasis on motivation. Elton Mayo conducted studies at the Hawthorne division of Western Electric. His studies revealed that in addition to the physical and technical aspects of work, worker motivation is critical for improving productivity. Abraham Maslow developed motivational theories, which Frederick Hertzberg refined. Douglas McGregor added Theory X and Theory Y. These theories represented the two ends of the spectrum of how employees view work. Theory X, on the negative end, assumed that workers do not like to work, and have to be controlled—rewarded and punished—to get them to do good work. This attitude was quite common in the automobile industry and in some other industries, until the threat of global competition forced them to rethink that approach. Theory Y, on the other end of the spectrum, assumed that workers enjoy the physical and mental aspects of work and become committed to work. The Theory X approach resulted in an adversarial environment, whereas the Theory Y approach resulted in empowered workers and a more cooperative spirit. William Ouchi added Theory Z, which combined the Japanese approach with such features as lifetime employment, employee problem solving, and consensus building, and the traditional Western approach that features short-term employment, specialists, and individual decision making and responsibility.

Decision Models and Management Science

The factory movement was accompanied by the development of several quantitative techniques. F. W. Harris developed one of the first models in 1915: a mathematical model for inventory order size. In the 1930s, three coworkers at Bell Telephone Labs—H. F. Dodge, H. G. Romig, and W. Shewhart—developed statistical procedures for sampling and quality control. In 1935, L.H.C. Tippett conducted studies that provided the groundwork for statistical sampling theory.

At first, these quantitative models were not widely used in industry. However, the onset of World War II changed that. The war generated tremendous pressures on manufacturing output, and specialists from many disciplines combined efforts to achieve advancements in the military and in manufacturing. After the war, efforts to develop and refine quantitative tools for decision making continued, resulting in decision models for forecasting, inventory management, project management, and other areas of operations management.

During the 1960s and 1970s, management science techniques were highly regarded; in the 1980s, they lost some favor. However, the widespread use of personal computers and user-friendly software in the workplace contributed to a resurgence in the popularity of these techniques.

The Influence of Japanese Manufacturers

A number of Japanese manufacturers developed or refined management practices that increased the productivity of their operations and the quality of their products, due in part to the influence of Americans W. Edwards Deming and Joseph Juran. This made them very competitive, sparking interest in their page 24 approaches by companies outside Japan. Their approaches emphasized quality and continual improvement, worker teams and empowerment, and achieving customer satisfaction. The Japanese can be credited with spawning the “quality revolution” that occurred in industrialized countries, and with generating widespread interest in lean production.

The influence of the Japanese on U.S. manufacturing and service companies has been enormous and promises to continue for the foreseeable future. Because of that influence, this book will provide considerable information about Japanese methods and successes.

Table 1.5 provides a chronological summary of some of the key developments in the evolution of operations management.

TABLE 1.5

Historical summary of operations management

Approximate Date	Contribution/Concept	Originator
1776	Division of labor	Adam Smith
1790	Interchangeable parts	Eli Whitney
1911	Principles of scientific management	Frederick W. Taylor

Approximate Date	Contribution/Concept	Originator
1911	Motion study, use of industrial psychology	Frank and Lillian Gilbreth
1912	Chart for scheduling activities	Henry Gantt
1913	Moving assembly line	Henry Ford
1915	Mathematical model for inventory ordering	F. W. Harris
1930	Hawthorne studies on worker motivation	Elton Mayo
1935	Statistical procedures for sampling and quality control	H. F. Dodge, H. G. Romig, W. Shewhart, L.H.C. Tippett
1940	Operations research applications in warfare	Operations research groups
1947	Linear programming	George Dantzig
1951	Commercial digital computers	Sperry Univac, IBM
1950s	Automation	Numerous

Approximate Date	Contribution/Concept	Originator
1960s	Extensive development of quantitative tools	Numerous
1960s	Industrial dynamics	Jay Forrester
1975	Emphasis on manufacturing strategy	W. Skinner
1980s	Emphasis on flexibility, time-based competition, lean production	T. Ohno, S. Shingo, Toyota
1980s	Emphasis on quality	W. Edwards Deming, J. Juran, K. Ishikawa
1990s	Internet, supply chain management	Numerous
2000s	Applications service providers and outsourcing	Numerous
	Social media, YouTube, and others	Numerous

1.9 OPERATIONS TODAY

LO1.9 Describe current issues in business that impact operations management.

Advances in information technology and global competition have had a major influence on operations management. While the *internet* offers great potential for business organizations, the potential, as well as the risks, must be clearly understood in order to determine if and how to exploit this potential. In many cases, the internet has altered the way companies compete in the marketplace.

Electronic business, or **e-business**, involves the use of the internet to transact business. E-business is changing the way business organizations interact with their customers and their suppliers. Most familiar to the general public is **e-commerce**, consumer–business transactions, such as buying online or requesting information. However, business-to-business transactions such as e-procurement represent an increasing share of e-business. E-business is receiving increased attention from business owners and managers in developing strategies, planning, and decision making.

E-business The use of electronic technology to facilitate business transactions.

E-commerce Consumer-to-business transactions.

The word **technology** has several definitions, depending on the context. Generally, *technology* refers to the application of scientific knowledge to the development and improvement of goods and services. It can involve knowledge, materials, methods, and equipment. The term *high technology* refers to the most advanced and developed machines and methods. Operations management is primarily concerned with three kinds of technology: product and service technology, process technology, and information technology (IT). All three can have a major impact on costs, productivity, and competitiveness.

Technology The application of scientific discoveries to the development and improvement of products and services and operations processes.

Product and service technology refers to the discovery and development of new products and services. This is done mainly by researchers and engineers, who use the scientific approach to develop new knowledge and translate that into commercial applications.

Process technology refers to methods, procedures, and equipment used to produce goods and provide services. They include not only processes within an organization but also supply chain processes.

Information technology (IT) refers to the science and use of computers and other electronic equipment to store, process, and send information. Information technology is heavily ingrained in today's business operations. This includes electronic data processing, the use of bar codes to identify and track goods, obtaining point-of-sale information, data transmission, the internet, e-commerce, e-mail, and more.

Management of technology is high on the list of major trends, and it promises to be high well into the future. For example, computers have had a tremendous impact on businesses in many ways, including new product and service features, process management, medical diagnosis, production planning and scheduling, data processing, and communication. Advances in materials, methods, and equipment also have had an impact on competition and productivity. Advances in information technology also have had a major impact on businesses. Obviously, there have been—and will continue to be—many benefits from technological advances. However, technological advance also places a burden on management. For example, management must keep abreast of changes and quickly assess both their benefits and risks. Predicting advances can be tricky at best, and new technologies often carry a high price tag and usually a high cost to operate or repair. And in the case of computer operating systems, as new systems are introduced, support for older versions is discontinued, making periodic upgrades necessary. Conflicting technologies can exist that make technological choices even more difficult. Technological innovations in both *products* and *processes* will continue to change the way businesses operate, and hence require continuing attention.

The General Agreement on Tariffs and Trade (GATT) of 1994 reduced tariffs and subsidies in many countries, expanding world trade. However, new tariffs in 2018 and 2019, some temporary, have had an impact on the strategies and operations of businesses large and small around the world. One effect is the importance business organizations are giving to management of their supply chains.

Globalization and the need for global supply chains have broadened the scope of supply chain management. However, tightened border security in certain instances and new tariffs have added challenges and uncertainties to managing supply chain operations. In some instances, organizations are reassessing their use of offshore outsourcing.

Competitive pressures and changing economic conditions have caused business organizations to put more emphasis on operations strategy, working with fewer resources, revenue management, process analysis and improvement, quality improvement, agility, and lean production.

During the latter part of the 1900s, many companies neglected to include *operations strategy* in their corporate strategy. Some of them paid dearly for that neglect. Now, more and more

companies are recognizing the importance of operations strategy on the overall success of their business, as well as the necessity for relating it to their overall business strategy.

READING 

AGILITY CREATES A COMPETITIVE EDGE

There is a huge demand in the United States and elsewhere for affordable women's clothing. Low-cost clothing retailers such as Spain's Zara and Sweden's H&M are benefiting from their ability to quickly get mass-produced, trendy new fashions to store shelves while some less-agile competitors, like Macy's and Gap, struggle to achieve the same results. A key factor for the agile retailers is their nearness to low-cost producers in Romania and Turkey, which greatly shortens transportation time. American retailers often source from China, but increasing wages there and the longer distance lessen their ability to take advantage of quickly introducing new low-cost fashions.

Question

What possible solutions do you see for competitors such as Macy's and Gap?

Source: Based on Roya Wolverson, "Need for Speed: Glamorizing Cheap Fashion Costs More than You Think," *Time,* August 6, 2012, p. 18.

Working with fewer resources due to layoffs, corporate downsizing, and general cost cutting is forcing managers to make trade-off decisions on resource allocation, and to place increased emphasis on cost control and productivity improvement.

Revenue management is a method used by some companies to maximize the revenue they receive from fixed operating capacity by influencing demand through price manipulation. Also known as yield management, it has been successfully used in the travel and tourism industries by airlines, cruise lines, hotels, amusement parks, and rental car companies, and in other industries such as trucking and public utilities.

Process analysis and improvement includes cost and time reduction, productivity improvement, process yield improvement, and quality improvement and increasing customer satisfaction. This is sometimes referred to as a **Six Sigma** process.

Six Sigma A process for reducing costs, improving quality, and increasing customer satisfaction.

Given a boost by the “quality revolution” of the 1980s and 1990s, *quality* is now ingrained in business. Some businesses use the term *total quality management (TQM)* to describe their quality efforts. A quality focus emphasizes *customer satisfaction* and often involves *teamwork. Process improvement* can result in improved quality, cost reduction, and *time reduction.* Time relates to costs and to competitive advantage, and businesses seek ways to reduce the time to bring new products and services to the marketplace to gain a competitive edge. If two companies can provide the same product at the same price and quality, but one can deliver it four weeks earlier than the other, the quicker company will invariably get the sale. Time reductions are being achieved in many companies now. Union Carbide was able to cut $400 million of fixed expenses, and Bell Atlantic was able to cut the time needed to hook up long-distance carriers from 15 days to less than 1, at a savings of $82 million.

Agility refers to the ability of an organization to respond quickly to demands or opportunities. It is a strategy that involves maintaining a flexible system that can quickly respond to changes in either the volume of demand or changes in product/service offerings. This is particularly important as organizations scramble to remain competitive and cope with increasingly shorter product life cycles and strive to achieve shorter development times for new or improved products and services.

Agility The ability of an organization to respond quickly to demands or opportunities.

Lean production, a new approach to production, emerged in the 1990s. It incorporates a number of the recent trends listed here, with an emphasis on quality, flexibility, time reduction, and teamwork. This has led to a *flattening* of the organizational structure, with fewer levels of management.

Lean systems are so named because they use much less of certain resources than typical mass production systems use—space, inventory, and workers—to produce a comparable amount of output. Lean systems use a highly skilled workforce and flexible equipment. In effect, they incorporate advantages of both mass production (high volume, low unit cost) and craft production (variety and flexibility). Quality is also higher than in mass production. This approach has now spread to services, including health care, offices, and shipping and delivery.

Lean system System that uses minimal amounts of resources to produce a high volume of high-quality goods with some variety.

The skilled workers in lean production systems are more involved in maintaining and improving the system than their mass production counterparts. They are taught to stop an operation if they discover a defect, and to work with other employees to find and correct the cause of the defect so that it won't recur. This results in an increasing level of quality over time and eliminates the need to inspect and rework at the end of the line.

Because lean production systems operate with lower amounts of inventory, additional emphasis is placed on anticipating when problems might occur *before* they arise and avoiding those problems through planning. Even so, problems can still occur at times, and quick resolution is important. Workers participate in both the planning and correction stages.

Compared to workers in traditional systems, much more is expected of workers in lean production systems. They must be able to function in teams, playing active roles in operating and improving the system. Individual creativity is much less important than team success. Responsibilities also are much greater, which can lead to pressure and anxiety not present in traditional systems. Moreover, a flatter organizational structure means career paths are not as steep in lean production organizations. Workers tend to become generalists rather than specialists, another contrast to more traditional organizations.

1.10 KEY ISSUES FOR TODAY'S BUSINESS OPERATIONS

There are a number of issues that are high priorities of many business organizations. Although not every business is faced with these issues, many are. Chief among the issues are the following.

Economic conditions. Trade disputes and tariffs have created uncertainties for decision makers.

Innovating. Finding new or improved products or services are only two of the many possibilities that can provide value to an organization. Innovations can be made in processes, the use of the internet, or the supply chain that reduce costs, increase productivity, expand markets, or improve customer service.

Quality problems. The numerous operations failures mentioned at the beginning of the chapter underscore the need to improve the way operations are managed. That relates to product design and testing, oversight of suppliers, risk assessment, and timely response to potential problems.

Risk management. The need for managing risk is underscored by recent events that include financial crises, product recalls, accidents, natural and man-made disasters, and economic ups and downs. Managing risks starts with identifying risks, assessing vulnerability and potential damage (liability costs, reputation, demand), and taking steps to reduce or share risks.

Cyber-security. The need to guard against intrusions from hackers whose goal is to steal personal information of employees and customers is becoming increasingly necessary. Moreover, interconnected systems increase intrusion risks in the form of industrial espionage.

Competing in a global economy. Low labor costs in third-world countries have increased pressure to reduce labor costs. Companies must carefully weigh their options, which include outsourcing some or all of their operations to low-wage areas, reducing costs internally, changing designs, and working to improve productivity.

Three other key areas require more in-depth discussion: environmental concerns, ethical conduct, and managing the supply chain.

Environmental Concerns

Concern about global warming and pollution has had an increasing effect on how businesses operate.

Stricter environmental regulations, particularly in developed nations, are being imposed. Furthermore, business organizations are coming under increasing pressure to reduce their carbon footprint (the amount of carbon dioxide generated by their operations and their supply chains) and to generally operate sustainable processes. **Sustainability** refers to service and production

processes that use resources in ways that do not harm ecological systems that support both current and future human existence. Sustainability measures often go beyond traditional environmental and economic measures to include measures that incorporate social criteria in decision making.

Sustainability Using resources in ways that do not harm ecological systems that support human existence.

READING 

SUSTAINABLE KISSES

BY LISA SPENCER

Hershey's "Cocoa for Good" initiative promises to spend $500 million dollars through 2030 to promote sustainable cocoa sourcing. This move should sweeten its image with consumers and help improve productivity of small farmers in Ghana and the Ivory Coast, the source of about 70 percent of the world's cocoa supply. Last year, Hershey's bought more than 75 percent of its cocoa from certified and sustainable sources, and it plans to increase that to 100 percent in the next few years.[1]

Hershey's holistic strategy for West Africa includes four distinct goals: providing nutritious food to children, eliminating child labor, economically empowering women, and working with farmers to increase productivity with shade-grown cocoa and other farming techniques. Shade-grown cocoa plants can be productive for up to 15 years longer than plants grown in full sun. By teaching small farmers to grow cocoa more efficiently, Hershey's can help them increase yields without further encroachment on forested areas.

Six months into the program, Hershey's daily provides 50,000 Ghanaian school children with Vivi packets, a vitamin-rich nut-paste snack. Other milestones include helping 9,000 West African farmers to improve their business skills, building five schools, and supporting 31 other educational facilities.[2]

More and more consumers prefer to do business with companies that practice sustainable sourcing of supplies and the ethical treatment of workers. In addition, leadership in many companies also hold these same values themselves. Thus, from an operations standpoint, having a low-cost strategy may take a back seat to one which includes sustainable crop production and the ethical treatment of workers.

Questions

1. Why are companies like Hershey's engaging in sustainability initiatives such as this?
2. How might Hershey's actions affect others in the supply chain? How might they affect competitors or customers?

Based on:

[1] "Hershey to Spend $500 Million Making More Sustainable Kisses," Marvin G. Perez and Emily Chasen, *Bloomberg,* April 3, 2018, https://www.bloomberg.com/news/articles/2018-04-03/hershey-to-invest-500-million-in-making-more-sustainable-kisses.

[2] "Hershey's Cocoa for Good Program Already Making an Impact in West Africa," Anthony Myers, November 5, 2018, https://www.confectionerynews.com/Article/2018/11/05/Hershey-s-Cocoa-for-Good-program-already-making-an-impact-in-West-Africa.

Puma's "Clever Little Bag" changes the idea of the shoebox by wrapping footwear in a cardboard structure with 65 percent less cardboard. It uses a bag made of recycled plastic as the outer layer that holds the inner cardboard structure together. Puma expects to cut carbon dioxide emissions by 10,000 tons per year and water, energy, and diesel use by 60 percent by using fewer materials—8,500 fewer tons of paper to be specific—and the new packaging's lighter weight.

nicostock/Shutterstock

All areas of business will be affected by this. Areas that will be most affected include product and service design, consumer education programs, disaster preparation and response, supply chain waste management, and outsourcing decisions.

Note that outsourcing of goods production increases not only transportation costs, but also fuel consumption and carbon released into the atmosphere. Consequently, sustainability thinking may have implications for outsourcing decisions.

READING 

DIET AND THE ENVIRONMENT: VEGETARIAN VS. NONVEGETARIAN

It is interesting to examine the environmental impact of dietary choices. There's ample evidence that agricultural practices pollute the soil, air, and water. Factors range from the distance food travels to get to the consumer, to the amount of water and fertilizer used. Of particular concern is the environmental impact of a diet high in animal protein. The Food and Agricultural Organization (FAO) of the United Nations recently reported that livestock production is one of the major causes of global warming and air and water pollution. Using a methodology that considers the entire supply chain, the FAO estimated that livestock accounts for 18 percent of greenhouse gas emissions.

A Vegetarian vs. Nonvegetarian Diet and the Environment
The eco-friendliness of a meat eater's diet was the subject of a study conducted by researchers from the Departments of Environmental Health and Nutrition of Loma Linda University in California. They compared the environmental effects of a vegetarian vs. nonvegetarian diet in California in terms of agricultural production inputs, including pesticides and fertilizers, water, and energy.

The study indicated that, in the combined production of 11 food items, the nonvegetarian diet required 2.9 times more water, 2.5 times more primary energy, 13 times more fertilizer, and 1.4 times more pesticides than the vegetarian diet. The greatest differences stemmed from including beef in the diet.

Source: Based on "Finding a Scientific Connection Between Food Choices and the Environment," *Environmental Nutrition Newsletter,* October 2009, p. 3.

Because they all fall within the realm of operations, operations management is central to dealing with these issues. Sometimes referred to as "green initiatives," the possibilities include reducing packaging, materials, water and energy use, and the environmental impact of the supply chain, including buying locally. Other possibilities include reconditioning used equipment (e.g., printers and copiers) for resale, and recycling.

The reading above suggests that even our choice of diet can affect the environment.

Ethical Conduct

LO1.10 Explain the importance of ethical decision making.

The need for ethical conduct in business is becoming increasingly obvious, given numerous examples of questionable actions in recent history. In making decisions, managers must consider how their decisions will affect shareholders, management, employees, customers, the community at large, and the environment. Finding solutions that will be in the best interests of all of these stakeholders is not always easy, but it is a goal that all managers should strive to achieve. Furthermore, even managers with the best intentions will sometimes make mistakes. If mistakes do occur, managers should act responsibly to correct those mistakes as quickly as possible, and to address any negative consequences.

Many organizations have developed *codes of ethics* to guide employees' or members' conduct. **Ethics** is a standard of behavior that guides how one should act in various situations. The Markula Center for Applied Ethics at Santa Clara University identifies five principles for thinking ethically:

Ethics A standard of behavior that guides how one should act in various situations.

- The **Utilitarian Principle:** The good done by an action or inaction should outweigh any harm it causes or might cause. An example is not allowing a person who has had too much to drink to drive.
- The **Rights Principle:** Actions should respect and protect the moral rights of others. An example is not taking advantage of a vulnerable person.
- The **Fairness Principle:** Equals should be held to, or evaluated by, the same standards. An example is equal pay for equal work.
- The **Common Good Principle:** Actions should contribute to the common good of the community. An example is an ordinance on noise abatement.
- The **Virtue Principle:** Actions should be consistent with certain ideal virtues. Examples include honesty, compassion, generosity, tolerance, fidelity, integrity, and self-control.

The center expands these principles to create a framework for ethical conduct. An **ethical framework** is a sequence of steps intended to guide thinking and subsequent decisions or actions. Here is the one developed by the Markula Center for Applied Ethics:

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Ethical framework A sequence of steps intended to guide thinking and subsequent decision or action.

. Recognize an ethical issue by asking if an action could be damaging to a group or an individual. Is there more to it than just what is legal?

. Make sure the pertinent facts are known, such as who will be impacted, and what options are available.

. Evaluate the options by referring to the appropriate preceding ethical principle.

. Identify the “best” option and then further examine it by asking how someone you respect would view it.

. In retrospect, consider the effect your decision had and what you can learn from it.

The Fair Trade Certified™ label guarantees to consumers that strict economic, social, and environmental criteria were met in the production and trade of an agricultural product.

pixelliebe/Shutterstock

More detail is available at the Center’s website: http://www.scu.edu/ethics/practicing/decision/framework.html.

Operations managers, like all managers, have the responsibility to make ethical decisions. Ethical issues arise in many aspects of operations management, including:

- Financial statements: accurately representing the organization's financial condition.
- Worker safety: providing adequate training, maintaining equipment in good working condition, maintaining a safe working environment.
- Product safety: providing products that minimize the risk of injury to users or damage to property or the environment.
- Quality: honoring warranties, avoiding hidden defects.
- The environment: not doing things that will harm the environment.
- The community: being a good neighbor.
- Hiring and firing workers: avoiding false pretenses (e.g., promising a long-term job when that is not what is intended).
- Closing facilities: taking into account the impact on a community, and honoring commitments that have been made.
- Workers' rights: respecting workers' rights, dealing with workers' problems quickly and fairly.

The Ethisphere Institute recognizes companies worldwide for their ethical leadership. Here are some samples from their list:

Apparel: Gap

Automotive: Ford Motor Company

Business services: Paychex

Café: Starbucks

Computer hardware: Intel

Computer software: Adobe Systems, Microsoft

Consumer electronics: Texas Instruments, Xerox

E-commerce: eBay

General retail: Costco, Target

Groceries: Safeway, Wegmans, Whole Foods

Health and beauty: L'Oreal

Logistics: UPS

You can see a complete list of recent recipients and the selection criteria at Ethisphere.com.

The Need to Manage the Supply Chain

LO1.11 Explain the need to manage the supply chain.

Supply chain management is being given increasing attention as business organizations face mounting pressure to improve management of their supply chains. In the past, most organizations did little to manage their supply chains. Instead, they tended to concentrate on their own operations and on their immediate suppliers. Moreover, the planning, marketing, production and inventory management functions in organizations in supply chains have often operated independently of each other. As a result, supply chains experienced a range of problems that were seemingly beyond the control of individual organizations. The problems included large oscillations of inventories, inventory stockouts, late deliveries, and quality problems. These and other issues now make it clear that management of supply chains is essential to business success. The other issues include the following:

. **The need to improve operations.** Efforts on cost and time reduction, and productivity and quality improvement, have expanded in recent years to include the supply chain. Opportunity now lies largely with procurement, distribution, and logistics—the supply chain.

- **Increasing levels of outsourcing**. Organizations are increasing their levels of **outsourcing**, buying goods or services instead of producing or providing them themselves. As outsourcing increases, some organizations are spending increasing amounts on supply-related activities (wrapping, packaging, moving, loading and unloading, and sorting). A significant amount of the cost and time spent on these and other related activities may be unnecessary. Issues with imported products, including tainted food products, toothpaste, and pet foods, as well as unsafe tires and toys, have led to questions of liability and the need for companies to take responsibility for monitoring the safety of outsourced goods.

Outsourcing Buying goods or services instead of producing or providing them in-house.

In Kachchh, India, Fair trade allows cotton farmers to have the assurance of a minimum price, which gives them more security to plan their business and invest in their communities.

age fotostock/Alamy Stock Photo

- **Increasing transportation costs**. Transportation costs are increasing, and they need to be more carefully managed.
- **Competitive pressures**. Competitive pressures have led to an increasing number of new products, shorter product development cycles, and increased demand for customization. And in some industries, most notably consumer electronics, product life cycles are relatively short. Added to this are the adoption of quick-response strategies and efforts to reduce lead times.
- **Increasing globalization**. Increasing globalization has expanded the physical length of supply chains. A global supply chain increases the challenges of managing a supply chain. Having far-flung customers and/or suppliers means longer lead times and greater opportunities for disruption of deliveries. Often, currency differences and monetary fluctuations are factors, as well page 32 as language and cultural differences. Also, tightened border security in some instances has slowed shipments of goods.
- **Increasing importance of e-business**. The increasing importance of e-business has added new dimensions to business buying and selling and has presented new challenges.
- **The complexity of supply chains**. Supply chains are complex; they are dynamic, and they have many inherent uncertainties that can adversely affect them, such as inaccurate forecasts, late deliveries, substandard quality, equipment breakdowns, and canceled or changed orders.
- **The need to manage inventories**. Inventories play a major role in the success or failure of a supply chain, so it is important to coordinate inventory levels throughout a supply chain. Shortages can severely disrupt the timely flow of work and have far-reaching impacts, while excess inventories add unnecessary costs. It would not be unusual to find inventory shortages in some parts of a supply chain and excess inventories in other parts of the same supply chain.
- **The need to deal with trade wars.** Trade wars can occur if a country objects to its trade imbalance with another country. This

can result in tariffs and retaliatory tariffs, causing changes in cost structures. Uncertainty about how long and to what degree tariffs will be in place can greatly increase pressure on companies that have global supply chains.

Elements of Supply Chain Management

Supply chain management involves coordinating activities across the supply chain. Central to this is taking customer demand and translating it into corresponding activities at each level of the supply chain.

The key elements of supply chain management are listed in Table 1.6. The first element, customers, is the driving element. Typically, marketing is responsible for determining what customers want, as well as forecasting the quantities and timing of customer demand. Product and service design must match customer wants with operations capabilities.

TABLE 1.6

Elements of supply chain management

Element	Typical Issues	Chapter(s)
Customers	Determining what products and/or services customers want	3, 4
Forecasting	Predicting the quantity and timing of customer demand	3
Design	Incorporating customers, wants, manufacturability, and time to market	4

Element	Typical Issues	Chapter(s)
Capacity planning	Matching supply and demand	5, 11
Processing	Controlling quality, scheduling work	10, 16
Inventory	Meeting demand requirements while managing the costs of holding inventory	12, 13, 14
Purchasing	Evaluating potential suppliers, supporting the needs of operations on purchased goods and services	15
Suppliers	Monitoring supplier quality, on-time delivery, and flexibility; maintaining supplier relations	15
Location	Determining the location of facilities	8
Logistics	Deciding how to best move information and materials	15

Processing occurs in each component of the supply chain: It is the core of each organization. The major portion of processing occurs in the organization that produces the product or service for the final customer (the organization that assembles the computer, services the car, etc.). A major aspect of this for both the internal and external portions of a supply chain is scheduling.

Inventory is a staple in most supply chains. Balance is the main objective; too little causes delays and disrupts schedules, but too much adds unnecessary costs and limits flexibility.

Purchasing is the link between an organization and its suppliers. It is responsible for obtaining goods and/or services that will be used to produce products or provide services for the organization's customers. Purchasing selects suppliers, negotiates contracts, establishes alliances, and acts as a liaison between suppliers and various internal departments.

The supply portion of a value chain is made up of one or more suppliers, all links in the chain, and each one capable of having an impact on the effectiveness—or the ineffectiveness—of the supply chain. Moreover, it is essential that the planning and execution be carefully coordinated between suppliers and all members of the demand portion of their chains.

Location can be a factor in a number of ways. Where suppliers are located can be important, as can the location of processing facilities. Nearness to market, nearness to sources of supply, or nearness to both may be critical. Also, delivery time and cost are usually affected by location.

Two types of decisions are relevant to supply chain management —strategic and operational. The strategic decisions are the design and policy decisions. The operational decisions relate to day-to-day activities: managing the flow of material and product and other aspects of the supply chain in accordance with strategic decisions.

The major decision areas in supply chain management are location, production, distribution, and inventory. The *location* decision relates to the choice of locations for both production and distribution facilities. Production and transportation costs and delivery lead times are important. *Production* and *distribution* decisions focus on what customers want, when they want it, and how much is needed. Outsourcing can be a consideration. Distribution decisions are strongly influenced by transportation cost and delivery times, because transportation costs often represent a significant portion of total cost. Moreover, shipping alternatives are closely tied to production and inventory decisions. For example, using air transport means higher costs but faster deliveries and less inventory in transit than sea, rail, or trucking options. Distribution decisions must also take into account capacity and quality issues. Operational decisions focus on scheduling, maintaining equipment, and meeting customer demand. Quality control and workload balancing are also important considerations. *Inventory* decisions relate to determining inventory needs and coordinating production and stocking decisions throughout the supply chain. Logistics management plays the key role in inventory decisions.

Enterprise Resource Planning (ERP) is being increasingly used to provide information sharing in real time among organizations and their major supply chain partners. This important topic is discussed in more detail in Chapter 13.

Operations Tours

Throughout the book you will discover operations tours that describe operations in all sorts of companies. The tour below is of Wegmans Food Markets, a major regional supermarket chain. Wegmans has been consistently ranked high on *Fortune* magazine's list of the 100 Best Companies to Work For since the inception of the survey a decade ago.

OPERATIONS TOUR

WEGMANS FOOD MARKETS

Wegmans Food Markets, Inc., is one of the premier grocery chains in the United States. Headquartered in Rochester, New York, Wegmans operates about 100 stores, mainly in

Rochester, Buffalo, and Syracuse. There are also a handful of stores elsewhere in New York State, as well as in New Jersey, Massachusetts, North Carolina, Pennsylvania, and Virginia. The company employs over 45,000 people, and has annual sales of over $3 billion.

Wegmans has a strong reputation for offering its customers high product quality and excellent service. Through a combination of market research, trial and error, and listening to its customers, Wegmans has evolved into a very successful organization. Its sales per square foot are 50 percent higher than the industry average.

Superstores

Many of the company's stores are giant 100,000-square-foot superstores, double or triple the size of average supermarkets. You can get an idea about the size of these stores from this: They usually have between 25 and 35 checkout lanes, and during busy periods, all of the checkouts are in operation. A superstore typically employs from 500 to 600 people.

Individual stores differ somewhat in terms of actual size and some special features. Aside from the features normally found in supermarkets, they generally have a full-service deli (typically a 40-foot display case), a 500-square-foot fisherman's wharf that has perhaps 10 different fresh fish offerings most days, a large bakery section (each store bakes its own bread, rolls, cakes, pies, and pastries), and extra-large produce sections. They also offer a complete pharmacy, a card shop, and an Olde World Cheese section. In-store floral shops range in size up to 800 square feet of floor space and offer a wide variety of fresh-cut flowers, flower arrangements, vases, and plants. In-store card shops cover over 1,000 square feet of floor space. The bulk foods department provides customers with the opportunity to select the quantities they desire from a vast array of foodstuffs and some nonfood items such as birdseed and pet food.

Each store is a little different. Some stores feature a Market Café that has different food stations, each devoted to preparing and serving a certain type of food. For example, one station will have pizza and other Italian specialties, another will have Asian food, and still another chicken or fish. There will also be a sandwich bar, a salad bar, and a dessert station.

Customers often wander among stations as they decide what to order. In some Market Cafés, diners can have wine with their meals and have brunch on Sundays. In most locations, customers can stop in on their way home from work and choose from a selection of freshly prepared dinner entrees such as medallions of beef with herb butter, chicken marsala, stuffed flank steak with mushrooms, Cajun tuna, crab cakes, and side dishes such as roasted red potatoes, grilled vegetables, and Caesar salad. Many Wegmans stores offer ready-made sandwiches, as well as made-to-order sandwiches. Some stores have a coffee-shop section with tables and chairs where shoppers can enjoy regular or specialty coffees and a variety of tempting pastries.

Produce Department

The company prides itself on fresh produce, which is replenished as often as 12 times a day. Its larger stores have produce sections that are four to five times the size of a produce section in an average supermarket. Wegmans offers locally grown produce in season, and uses a “farm to market” system whereby some local growers deliver their produce directly to individual stores, bypassing the main warehouse. This reduces the company’s inventory holding costs and gets the produce into the stores as quickly as possible. Growers may use specially designed containers that go right onto the store floor instead of large bins. This avoids the bruising that often occurs when fruits and vegetables are transferred from bins to display shelves, and reduces the labor needed to transfer the produce to shelves.

Meat Department

In addition to large display cases of both fresh and frozen meat products, many stores have a full-service butcher shop that offers a variety of fresh meat products and where butchers are available to provide customized cuts of meat for customers.

Meat department employees attend Wegmans' "Meat University," where they learn about different cuts of meat and how to best prepare them. They also learn about other items to pair with various meats, and suggest side dishes, breads, and wine. This helps instill a "selling culture" among employees, who often spend 75 percent of their time talking with customers.

Wegmans continually analyzes store operations to improve processes. In the meat department, a change from in-store cutting and traditional packaging to using a centralized meat processing facility and vacuum packaging extended the shelf life of meats and reduced staffing requirements in meat departments, reducing costs and providing customers with an improved product.

Ordering

Each department handles its own ordering. Although sales records are available from records of items scanned at the checkouts, they are not used directly for replenishing stock. Other factors—such as pricing, special promotions, and local circumstances (e.g., festivals, weather conditions)—must all be taken into account. However, for seasonal periods, such as holidays, managers often check scanner records to learn what past demand was during a comparable period.

The superstores typically receive one truckload of goods per day from the main warehouse. During peak periods, a store may receive two truckloads from the main warehouse. The short lead time greatly reduces the length of time an item might be out of stock, unless the main warehouse is also out of stock.

tarheel1776/Shutterstock

The company exercises strict control over suppliers, insisting on product quality and on-time deliveries.

Inventory Management

Some stores carry as many as 70,000 individual units. Wegmans uses a companywide system to keep track of inventory. Departments take a monthly inventory count to verify the amount shown in the companywide system. Departments receive a periodic report indicating how many days of inventory the department has on hand. Having an appropriate amount on hand is important to department managers: If they have too much inventory on hand, that will add to their department's costs, whereas having too little inventory will result in shortages and thus lost sales and dissatisfied customers.

Employees

The company recognizes the value of good employees. It typically invests an average of $7,000 to train each new employee. In addition to learning about store operations, new employees learn the importance of good customer service and how to provide it. The employees are helpful, cheerfully answering customer questions or handling complaints. Employees are motivated through a combination of compensation, profit sharing, and benefits. Employee turnover for full-time workers is about 6 percent, compared to the industry average of about 20 percent.

Quality

Quality and customer satisfaction are utmost in the minds of Wegmans' management and its employees. Private-label food items, as well as name brands, are regularly evaluated in test kitchens, along with potential new products. Managers are responsible for checking and maintaining product and service quality in their departments. Moreover, employees are encouraged to report problems to their managers.

If a customer is dissatisfied with an item, and returns it, or even a portion of the item, the customer is offered a choice of a replacement or a refund. If the item is a Wegmans brand food item, it is then sent to the test kitchen to determine the cause of the problem. If the cause can be determined, corrective action is taken.

Wegmans' Patisserie is an authentic French pastry shop.

Suzanne Kreiter/The Boston Globe/Getty Images

Technology

Wegmans continues to adopt new technologies to maintain its competitive edge, including new approaches to tracking inventory and managing its supply chain, and new ways to maintain freshness in the meat and produce departments.

Sustainability

Wegmans replaced incandescent light bulbs with compact fluorescent bulbs, generating 3,000 fewer tons of carbon dioxide each year. Also, the company installed sensors in its dairy cases that reduced the time the cooling systems run by 50 percent.

Questions

1. How do customers judge the quality of a supermarket?
2. Indicate how and why each of these factors is important to the successful operation of a supermarket:
   a. Customer satisfaction
   b. Forecasting
   c. Capacity planning
   d. Location
   e. Inventory management
   f. Layout of the store
   g. Scheduling
3. What are some of the ways Wegmans uses technology to gain an edge over its competition?

Wegmans' chefs prepare ready-to-eat entrees, side dishes, salads, sandwiches, and ready-to-heat entrees.

Mark Gail/The Washington Post/Getty Images

SUMMARY

The operations function in business organizations is responsible for producing goods and providing services. It is a core function of every business. Supply chains are the sequential system of suppliers and customers that begins with basic sources of inputs and ends with final customers of the system. Operations and supply chains are interdependent—one couldn't exist without the other, and no business organization could exist without both.

Operations management involves system design and operating decisions related to product and service design, capacity planning, process selection, location selection, work management, inventory and supply management, production planning, quality assurance, scheduling, and project management.

The historical evolution of operations management provides interesting background information on the continuing evolution of this core business function.

The Operations Tours and Readings included in this and subsequent chapters provide insights into actual business operations.

KEY POINTS

1. The operations function is that part of every business organization that produces products and/or delivers services.
2. Operations consists of processes that convert inputs into outputs. Failure to manage those processes effectively will have a negative impact on the organization.
3. Organizations are systems made up of interrelated subsystems. Because of this, a systems perspective in decision making is essential.
4. A key goal of business organizations is to achieve an economic matching of supply and demand. The operations function is responsible for providing the supply or service capacity for expected demand.
5. All processes exhibit variation that must be managed.
6. Although there are some basic differences between services and products that must be taken into account from a managerial standpoint, there are also many similarities between the two.
7. Environmental issues will increasingly impact operations decision making.
8. Ethical behavior is an integral part of good management practice.
9. All business organizations have, and are part of, a supply chain that must be managed.

KEY TERMS

agility, 26
craft production, 21
division of labor, 23
e-business, 24
e-commerce, 25
ethical framework, 29
ethics, 29
goods, 4
interchangeable parts, 22
lead time, 11
lean systems, 26
mass production, 22
model, 18
operations management, 4
outsourcing, 31
Pareto phenomenon, 20
process, 13
services, 4
Six Sigma, 26

DISCUSSION AND REVIEW QUESTIONS

1. Briefly describe the terms *operations management* and *supply chain.*
2. Identify the three major functional areas of business organizations and briefly describe how they interrelate.
3. Describe the operations function and the nature of the operations manager's job.
4. List five important differences between goods production and service operations; then list five important similarities.
5. Briefly discuss each of these terms related to the historical evolution of operations management:
   a. Industrial Revolution
   b. Scientific management
   c. Interchangeable parts
   d. Division of labor
6. Why are services important? Why is manufacturing important? What are nonmanufactured goods?

7. What are models and why are they important?
8. Why is the degree of customization an important consideration in process planning?
9. List the trade-offs you would consider for each of these decisions:
   a. Driving your own car versus public transportation.
   b. Buying a computer now versus waiting for an improved model.
   c. Buying a new car versus buying a used car.
   d. Speaking up in class versus waiting to get called on by the instructor.
   e. A small business owner having a website versus newspaper advertising.
10. Describe each of these systems: craft production, mass production, and lean production.
11. Why might some workers prefer not to work in a lean production environment?
12. Discuss the importance of each of the following:
    a. Matching supply and demand
    b. Managing a supply chain

13. List and briefly explain the four basic sources of variation, and explain why it is important for managers to be able to effectively deal with variation.
14. Why do people do things that are unethical?
15. Explain the term *value-added.*
16. Discuss the various impacts of outsourcing.
17. Discuss the term *sustainability,* and its relevance for business organizations.

TAKING STOCK

This item appears at the end of each chapter. It is intended to focus your attention on three key issues for business organizations in general, and operations management in particular. Those issues are trade-off decisions, collaboration among various functional areas of the organization, and the impact of technology. You will see three or more questions relating to these issues. Here is the first set of questions:

1. What are trade-offs? Why is careful consideration of trade-offs important in decision making?
2. Why is it important for the various functional areas of a business organization to collaborate?
3. In what general ways does technology have an impact on operations management decision making?

CRITICAL THINKING EXERCISES

This item also will appear in every chapter. It allows you to critically apply information you learned in the chapter to a practical situation. Here is the first set of exercises:

1. Many organizations offer a combination of goods and services to their customers. As you learned in this chapter, there are some key differences between the production of goods and the delivery of services. What are the implications of these differences relative to managing operations?
2. Why is it important to match supply and demand? If a manager believes that supply and demand will not be equal, what actions could the manager take to increase the probability of achieving a match?
3. One way that organizations compete is through technological innovation. However, there can be downsides for both the organization and the consumer. Explain.
4. What ethical considerations are important in development of technology in general, as well as AI (artificial intelligence)?
5. a. What would cause a businessperson to make an unethical decision?
   b. What are the risks of doing so?

CASE

HAZEL

Hazel had worked for the same *Fortune* 500 company for almost 15 years. Although the company had gone through some tough times, things were starting to turn around. Customer orders were up, and quality and productivity had improved dramatically from what they had been only a few years earlier due to a companywide quality improvement program. So it came as a real shock to Hazel and about 400 of her coworkers when they were suddenly terminated following the new CEO's decision to downsize the company.

After recovering from the initial shock, Hazel tried to find employment elsewhere. Despite her efforts, after eight months of searching she was no closer to finding a job than the day she started. Her funds were being depleted and she was getting more discouraged. There was one bright spot, though: She was able to bring in a little money by mowing lawns for her neighbors. She got involved quite by chance when she heard one neighbor remark that now that his children were on their own, nobody was around to cut the grass. Almost jokingly, Hazel asked him how much he'd be willing to pay. Soon Hazel was mowing the lawns of five neighbors. Other neighbors wanted her to work on their lawns, but she didn't feel that she could spare any more time from her job search.

However, as the rejection letters began to pile up, Hazel knew she had to make a decision. On a sunny Tuesday morning, she decided, like many others in a similar situation, to go into business for herself—taking care of neighborhood lawns. She was relieved to give up the stress of job hunting, and she was excited about the prospect of being her own boss.

But she was also fearful of being completely on her own. Nevertheless, Hazel was determined to make a go of it.

At first, business was a little slow, but once people realized Hazel was available, many asked her to take care of their lawns. Some people were simply glad to turn the work over to her; others switched from professional lawn care services. By the end of her first year in business, Hazel knew she could earn a living this way. She also performed other services such as fertilizing lawns, weeding gardens, and trimming shrubbery. Business became so good that Hazel hired two part-time workers to assist her and, even then, she believed she could expand further if she wanted to.

QUESTIONS

1. Hazel is the operations manager of her business. Among her responsibilities are forecasting, inventory management, scheduling, quality assurance, and maintenance.
   a. What kinds of things would likely require forecasts?
   b. What inventory items does Hazel probably have? Name one inventory decision she has to make periodically.
   c. What scheduling must she do? What things might occur to disrupt schedules and cause Hazel to reschedule?
   d. How important is quality assurance to Hazel's business? Explain.
   e. What kinds of maintenance must be performed?
2. In what ways are Hazel's customers most likely to judge the quality of her lawn care services?
3. What are some of the trade-offs that Hazel probably considered relative to:
   a. Working for a company instead of for herself?
   b. Expanding the business?
   c. Launching a website?

4. The town is considering an ordinance that would prohibit putting grass clippings at the curb for pickup because local landfills cannot handle the volume. What options might Hazel consider if the ordinance is passed? Name two advantages and two drawbacks of each option.
5. Hazel decided to offer the students who worked for her a bonus of $25 for ideas on how to improve the business, and they provided several good ideas. One idea that she initially rejected now appears to hold great promise. The student who proposed the idea has left, and is currently working for a competitor. Should Hazel send that student a check for the idea? What are the possible trade-offs?
6. All managers have to cope with variation.
   a. What are the major sources of variation that Hazel has to contend with?
   b. How might these sources of variation impact Hazel's ability to match supply and demand?
   c. What are some ways she can cope with variation?
7. Hazel is thinking of making some of her operations sustainable. What are some ideas she might consider?

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PROBLEM-SOLVING GUIDE

Here is a procedure that will help you solve most of the end-of-chapter problems in this book and on exams:

1. Identify the question to be answered. This is critical.
2. Summarize the information given in the problem statement using the appropriate symbols.
3. Determine what type of problem it is so you can select the appropriate problem-solving tools such as a formula or table. Check your notes from class, chapter examples, and the Solved Problems section of the chapter, and any preceding chapter problems you have already solved for guidance.
4. Solve the problem and be sure to indicate your answer.

Example 1

Department A can produce parts at a rate of 50/day. Department B uses those parts at a rate of 10/day. Each day unused parts are added to inventory. At what rate does the inventory of unused parts build up?

Solution

1. The question to be answered: At what rate does inventory of unused parts build up (i.e., increase) per day?
2. The given information: $\text{Production rate} = 50 \text{ parts/day}$
   $\text{Usage rate} = 10 \text{ parts/day}$
3. For this simple problem, no formula or table is needed. Inventory buildup is simply the difference between the production and usage rates.
4. $$\begin{array}{ll} \text{Production rate} & = 50 \text{ parts/day} \\ \text{Usage rate} & = 10 \text{ parts/day} \\ \hline \text{Inventory buildup} & = 40 \text{ parts/day} \end{array}$$

Example 2

Companies often use this formula to determine how much of a certain item to order:

$$Q = \sqrt{\frac{2DS}{H}}$$

where

Q = order quantity
D = annual demand
S = ordering cost
H = annual holding cost per unit

If annual demand is 400 units, ordering cost is \$36, and annual holding cost is \$2 per unit, what is the order quantity?

Solution

1. The question to be answered: What is the order quantity, Q?
2. The information given in the problem: D = 400 units/year, S = \$36, H = \$2 per year
3. To solve the problem, substitute the values given in the problem into the formula.
4. Solution:

$$Q = \sqrt{\frac{2(400\ \mathit{units/yr.})\$36}{\$2/\mathit{unit/yr.}}} = 120 \text{ units}$$

Problem-Solving Template
Problem number:
The question to be answered:
Information given:
Solve using:
Solution:

Design element: Operations Tour (city map icon): tovovan/Shutterstock

CHAPTER 2

Competitiveness, Strategy, and Productivity

LEARNING OBJECTIVES

After completing this chapter, you should be able to:

LO2.1 List several ways that business organizations compete.

LO2.2 Name several reasons that business organizations fail.

LO2.3 Define the terms *mission* and *strategy* and explain why they are important.

LO2.4 Discuss and compare organization strategy and operations strategy and explain why it is important to link the two.

LO2.5 Describe and give examples of time-based strategies.

LO2.6 Define the term *productivity* and explain why it is important to organizations and to countries.

LO2.7 Describe several factors that affect productivity.

CHAPTER OUTLINE

igorPHOTOserg/Shutterstock

THE COLD HARD FACTS

The name of the game is competition. The playing field is global. Those who understand how to play the game will succeed; those who don't are doomed to failure. And don't think the game is just companies competing with each other. In companies that have multiple factories or divisions producing the same good or service, factories or divisions sometimes find themselves competing with each other. When a competitor—another company or a sister factory or division in the same company—can turn out products better, cheaper, and faster, that spells real trouble for the factory or division that is performing at a lower level. The trouble can be layoffs or even a shutdown if the managers can't turn things around. The bottom line? Better quality, higher productivity, lower costs, and the ability to quickly respond to customer needs are more important than ever, and the bar is getting higher. Business organizations need to develop solid strategies for dealing with these issues.

This chapter discusses competitiveness, strategy, and productivity—three separate but related topics that are vitally important to business organizations. *Competitiveness* relates to the effectiveness of an organization in the marketplace relative to other organizations that offer similar products or services. Operations and marketing have a major impact on competitiveness. *Strategy* relates to the plans that determine how an organization pursues its goals. Operations strategy is particularly important in this regard. *Productivity* relates to the effective use of resources and has a direct impact on competitiveness. Operations management is chiefly responsible for productivity.

2.1 INTRODUCTION

In this chapter, you will learn about the different ways companies compete and why some firms do a very good job of competing. You will learn how effective strategies can lead to competitive organizations, as well as what productivity is, why it is important, and what organizations can do to improve it.

2.2 COMPETITIVENESS

LO2.1 List several ways that business organizations compete.

Companies must be competitive to sell their goods and services in the marketplace. **Competitiveness** is an important factor in determining whether a company prospers, barely gets by, or fails. Business organizations compete through some combination of price, delivery time, and product or service differentiation.

Competitiveness How effectively an organization meets the wants and needs of customers relative to others that offer similar goods or services.

Marketing influences competitiveness in several ways, including identifying consumer wants and needs, pricing, and advertising and promotion.

- **Identifying consumer wants and/or needs** is a basic input in an organization’s decision-making process, and central to competitiveness. The ideal is to achieve a perfect match between those wants and needs and the organization’s goods and/or services.
- **Price and quality** are key factors in consumer buying decisions. It is important to understand the trade-off decision consumers make between price and quality.
- **Advertising and promotion** are ways organizations can inform potential customers about features of their products or services, and attract buyers.

Operations has a major influence on competitiveness through product and service design, cost, location, quality, response time, flexibility, inventory and supply chain management, and service. Many of these are interrelated.

- **Product and service design** should reflect joint efforts of many areas of the firm to achieve a match between financial resources, operations capabilities, supply chain capabilities, and consumer wants and needs. Special characteristics or features of a product or service can be a key factor in consumer buying decisions. Other key factors include **innovation** and the **time-to-market** for new products and services.
- **Cost** of an organization’s output is a key variable that affects pricing decisions and profits. Cost-reduction efforts are generally ongoing in business organizations. **Productivity** (discussed later in the chapter) is an important determinant of cost. Organizations with higher productivity rates than their competitors have a competitive cost advantage. A company may outsource a portion

of its operation to achieve lower costs, higher productivity, or better quality.

- **Location** can be important in terms of cost and convenience for customers. Location near inputs can result in lower input costs. Location near markets can result in lower transportation costs and quicker delivery times. Convenient location is particularly important in the retail sector.
- **Quality** refers to materials, workmanship, design, and service. Consumers judge quality in terms of how well they think a product or service will satisfy its intended purpose. Customers are generally willing to pay more for a product or service if they perceive the product or service has a higher quality than that of a competitor.
- **Quick response** can be a competitive advantage. One way is quickly bringing new or improved products or services to the market. Another is being able to quickly deliver existing products and services to a customer after they are ordered, and still another is quickly handling customer complaints.
- **Flexibility** is the ability to respond to changes. Changes might relate to alterations in design features of a product or service, or to the volume demanded by customers, or the mix of products or services offered by an organization. High flexibility can be a competitive advantage in a changeable environment.

Indian operators take calls at Quatro call center in Gurgaon on the outskirts of New Delhi. Companies take advantage of communications and software support offshore to drive down costs. This industry in India already provides over one million jobs.

Terry Vine/Blend Images/Getty Images

- **Inventory management** can be a competitive advantage by effectively matching supplies of goods with demand.
- **Supply chain management** involves coordinating internal and external operations (buyers and suppliers) to achieve timely and cost-effective delivery of goods throughout the system.
- **Service** might involve after-sale activities customers perceive as value-added, such as delivery, setup, warranty work, and technical support. Or it might involve extra attention while work is in progress, such as courtesy, keeping the customer informed, and attention to details. **Service quality** can be a key differentiator; and it is one that is often sustainable. Moreover, businesses rated highly by their customers for service quality tend to be more

profitable, and grow faster, than businesses that are not rated highly.

- **Managers** and **workers** are the people at the heart and soul of an organization, and if they are competent and motivated, they can provide a distinct competitive edge via their skills and the ideas they create. One often overlooked skill is answering the telephone. How complaint calls or requests for information are handled can be a positive or a negative. If a person answering is rude or not helpful, that can produce a negative image. Conversely, if calls are handled promptly and cheerfully, that can produce a positive image and, potentially, a competitive advantage.

Why Some Organizations Fail

LO2.2 Name several reasons that business organizations fail.

Organizations fail, or perform poorly, for a variety of reasons. Being aware of those reasons can help managers avoid making similar mistakes. Among the chief reasons are the following:

- Neglecting operations strategy.
- Failing to take advantage of strengths and opportunities, and/or failing to recognize competitive threats.
- Putting too much emphasis on short-term financial performance at the expense of research and development.
- Placing too much emphasis on product and service design and not enough on process design and improvement.

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- Neglecting investments in capital and human resources.

- Failing to establish good internal communications and cooperation among different functional areas.
- Failing to consider customer wants and needs.

The key to successfully competing is to determine what customers want and then directing efforts toward meeting (or even exceeding) customer expectations. Two basic issues must be addressed. First: What do the customers want? (Which items on the preceding list of the ways business organizations compete are important to customers?) Second: What is the best way to satisfy those wants?

Operations must work with marketing to obtain information on the relative importance of the various items to each major customer or target market.

Understanding competitive issues can help managers develop successful strategies.

2.3 MISSION AND STRATEGIES

LO2.3 Define the terms *mission* and *strategy* and explain why they are important.

An organization's **mission** is the reason for its existence. It is expressed in its **mission statement**. For a business organization, the mission statement should answer the question "What business are we in?" Missions vary from organization to organization, depending on the nature of their business. Table 2.1 provides several examples of mission statements.

Mission The reason for the existence of an organization.

Mission statement States the purpose of an organization.

TABLE 2.1

Selected portions of company mission statements

Microsoft	To help people and businesses throughout the world to realize their full potential.
Verizon	To help people and businesses communicate with each other.
Starbucks	To inspire and nurture the human spirit—one cup and one neighborhood at a time.
U.S. Dept. of Education	To promote student achievement and preparation for global competitiveness and fostering educational excellence and ensuring equal access.

A mission statement serves as the basis for organizational **goals**, which provide more detail and describe the scope of the mission. The mission and goals often relate to how an organization wants to be perceived by the general public, and by its employees, suppliers, and customers. Goals serve as a foundation for the development of organizational strategies. These, in turn, provide the basis for strategies and tactics of the functional units of the organization.

Goals Provide detail and scope of the mission.

Organizational strategy is important because it guides the organization by providing direction for, and alignment of, the goals and **strategies** of the functional units. Moreover, strategies can be the main reason for the success or failure of an organization.

Strategies Plans for achieving organizational goals.

There are three basic business strategies:

- Low cost
- Responsiveness
- Differentiation from competitors

IS IT A STRATEGIC, TACTICAL, OR OPERATIONAL ISSUE?

Sometimes the same issue may apply to all three levels. However, a key difference is the time frame. From a strategic perspective, long-term implications are most relevant. From tactical and operational perspectives, the time frames are much shorter. In fact, the operational time frame is often measured in days.

Responsiveness relates to the ability to respond to changing demands. Differentiation can relate to product or service features, quality, reputation, or customer service. Some organizations focus on a single strategy, while others employ a combination of strategies. One company that has multiple strategies is Amazon.com. Not only does it offer low-cost and quick, reliable deliveries, it also excels in customer service.

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READING

AMAZON RANKS HIGH IN

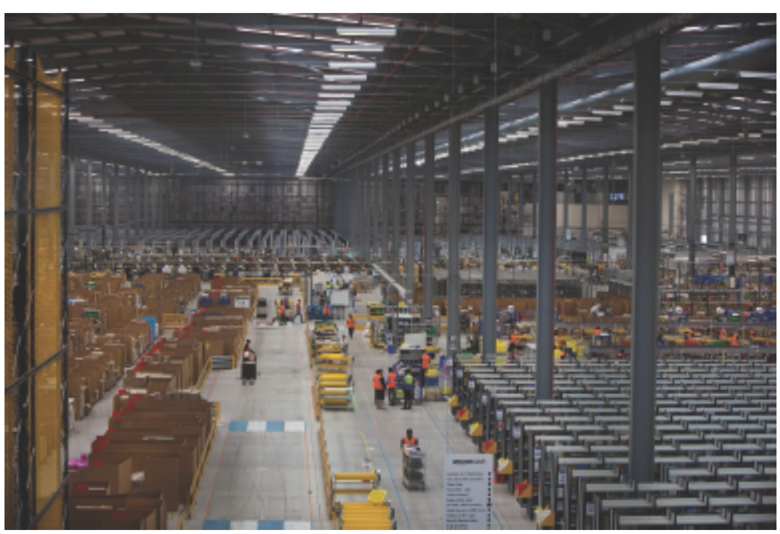
CUSTOMER SERVICE

Amazon received the 4th spot in customer service in a *Forbes* ranking in 2018. Although most Amazon customers never talk with an employee, when something goes wrong, Amazon excels in dealing with the problem. In one case, when a New Jersey woman received a workbook she ordered that was described as “like new,” she was surprised to discover that it wasn’t even close to new—worksheets had already been filled in. She complained to the merchant but didn’t get a response. Then, she complained to Amazon. She promptly received a refund, even though she had paid the merchant, not Amazon.

And she wasn’t asked to return the book.

Amazon sees its customer service as a way to enhance customer experience, and as a way to identify potential problems with merchants. In fact, if merchants have problems with more than 1 percent of their orders, that can get them removed from the site.

Source: *Forbes*, July 2018.



Amazon's service helped propel the company to a double-digit sales increase. Amazon started same-day shipping in major cities, launched a program to urge manufacturers to drop frustrating packaging, and extended its service reach by acquiring free-shipping pioneer Zappos.com.

SWNS/Alamy Stock Photo

Strategies and Tactics

If you think of goals as destinations, then strategies are the roadmaps for reaching those destinations. Strategies provide *focus* for decision making. Generally speaking, organizations have overall strategies called *organizational strategies,* which relate to the entire organization. They also have *functional strategies,* which relate to each of the functional areas of the organization. The functional strategies should support the overall strategies of the organization, just as the organizational strategies should support the goals and mission of the organization.

Tactics are the methods and actions used to accomplish strategies. They are more specific than strategies, and they provide guidance and direction for carrying out actual *operations,* which need the most specific and detailed plans and decision making in an organization. You might think of tactics as the "how to" part of the process (e.g., how to reach the destination, following the strategy roadmap), and operations as the actual "doing" part of the process. Much of this book deals with tactical operations.

Tactics The methods and actions taken to accomplish strategies.

It should be apparent that the overall relationship that exists from the mission down to actual operations is *hierarchical.* This is illustrated in Figure 2.1.

FIGURE 2.1

Planning and decision making are hierarchical in organizations

A simple example may help to put this hierarchy into perspective.

EXAMPLE 1

Rita is a high school student in Southern California. She would like to have a career in business, have a good job, and earn enough income to live comfortably.

A possible scenario for achieving her goals might look something like this:

Mission: Live a good life.

Goal: Successful career, good income.

Strategy: Obtain a college education.

Tactics: Select a college and a major; decide how to finance college.

Operations: Register, buy books, take courses, study.

Here are some examples of different strategies an organization might choose from:

Low cost. Outsource operations to third-world countries that have low labor costs.

Scale-based strategies. Use capital-intensive methods to achieve high output volume and low unit costs.

Specialization. Focus on narrow product lines or limited service to achieve higher quality.

Newness. Focus on innovation to create new products or services.

Flexible operations. Focus on quick response and/or customization.

High quality. Focus on achieving higher quality than competitors.

Service. Focus on various aspects of service (e.g., helpful, courteous, reliable, etc.).

Sustainability. Focus on environmental-friendly and energy-efficient operations.

A wide range of business organizations are beginning to recognize the strategic advantages of sustainability, not only in economic terms, but also through promotional benefits by publicizing their sustainability efforts and achievements.

Sometimes, organizations will combine two or more of these, or other approaches, into their strategy. However, unless they are careful, they risk losing focus and not achieving advantage in any category. Generally speaking, strategy formulation takes into account the way organizations compete and a particular organization's assessment of its own strengths and weaknesses in order to take advantage of its **core competencies**—those special attributes or abilities possessed by an organization that give it a *competitive edge.*

Core competencies The special attributes or abilities that give an organization a competitive edge.

The most effective organizations use an approach that develops core competencies based on customer needs, as well as on what the competition is doing. Marketing and operations work closely to match customer needs with operations capabilities. Competitor competencies are important for several reasons. For example, if a competitor is able to supply high-quality products, it may be necessary to meet that high quality as a baseline. However, merely *matching* a competitor is usually not sufficient to gain market share. It may be necessary to exceed the quality level of the competitor or gain an edge by excelling in one or more other dimensions, such as rapid delivery or service after the sale. Walmart, for example, has been very successful in managing its supply chain, which has contributed to its competitive advantage.

To be effective, strategies and core competencies need to be aligned. Table 2.2 lists examples of strategies and companies that have successfully employed those strategies.

TABLE 2.2

Examples of operations strategies

Organization Strategy	Operations Strategy	Examples of Companies or Services

Organization Strategy	Operations Strategy	Examples of Companies or Services
Low price	Low cost	U.S. first-class postage Walmart Southwest Airlines
Responsiveness	Short processing time On-time delivery	McDonald’s restaurants Express Mail, UPS, FedEx Uber, Lyft, Grubhub Domino’s Pizza FedEx
Differentiation: High quality	High-performance design and/or high-quality processing Consistent quality	TV: Sony, Samsung, LG Lexus Disneyland Five-star restaurants or hotels Coca-Cola, PepsiCo Wegmans Electrical power

Organization Strategy	Operations Strategy	Examples of Companies or Services
Differentiation: Newness	Innovation	3M, Apple Google
Differentiation: Variety	Flexibility Volume	Burger King (“Have it your way”) Hospital emergency room McDonald’s (“Buses welcome”) Toyota Supermarkets (additional checkouts)
Differentiation: Service	Superior customer service	Disneyland Amazon IBM Nordstrom, Von Maur
Differentiation: Location	Convenience	Supermarkets, dry cleaners Mall stores Service stations Banks, ATMs

Strategy Formulation

Strategy formulation is almost always critical to the success of a strategy. Walmart discovered this when it opened stores in Japan. Although Walmart thrived in many countries on its reputation for low-cost items, Japanese consumers associated low cost with low quality, causing Walmart to rethink its strategy in the Japanese market. And many felt that Hewlett-Packard (HP) committed a strategic error when it acquired Compaq Computers at a cost of $19 billion. HP's share of the computer market was less after the merger than the sum of the shares of the separate companies before the merger. In another example, U.S. automakers adopted a strategy in the early 2000s of offering discounts and rebates on a range of cars and SUVs, many of which were on low-margin vehicles. The strategy put a strain on profits, but customers began to expect those incentives, and the companies maintained them to keep from losing additional market share.

On the other hand, Coach, the maker of leather handbags and purses, successfully changed its longtime strategy to grow its market by creating new products. Long known for its highly durable leather goods in a market where women typically owned few handbags, Coach created a new market for itself by changing women's view of handbags by promoting "different handbags for different occasions" such as party bags, totes, clutches, wristlets, overnight bags, purses, and day bags. And Coach introduced many fashion styles and colors.

To formulate an effective strategy, senior managers must take into account the core competencies of the organizations, and they must *scan the environment.* They must determine what

competitors are doing, or planning to do, and take that into account. They must critically examine other factors that could have either positive or negative effects. This is sometimes referred to as the **SWOT** analysis (strengths, weaknesses, opportunities, and threats). Strengths and weaknesses have an internal focus and are typically evaluated by operations people. Threats and opportunities have an external focus and are typically evaluated by marketing people. SWOT is often regarded as the link between organizational strategy and operations strategy.

SWOT Analysis of strengths, weaknesses, opportunities, and threats.

An alternative to SWOT analysis is Michael Porter's five forces model,[1] which takes into account the threat of new competition, the threat of substitute products or services, the bargaining power of customers, the bargaining power of suppliers, and the intensity of competition.

In formulating a successful strategy, organizations must take into account both order qualifiers and order winners. **Order qualifiers** are those characteristics that potential customers perceive as minimum standards of acceptability for a product to be considered for purchase. However, that may not be sufficient to get a potential customer to purchase from the organization. **Order winners** are those characteristics of an organization's goods or services that cause them to be perceived as better than the competition.

Order qualifiers Characteristics that customers perceive as minimum standards of acceptability to be considered as a potential for purchase.

Order winners Characteristics of an organization's goods or services that cause it to be perceived as better than the competition.

Characteristics such as price, delivery reliability, delivery speed, and quality can be order qualifiers or order winners. Thus, quality may be an order winner in some situations, but in others only an order qualifier. Over time, a characteristic that was once an order winner may become an order qualifier.

Obviously, it is important to determine the set of order qualifier characteristics and the set of order winner characteristics. It is also necessary to decide on the relative importance of each characteristic so that appropriate attention can be given to the various characteristics. Marketing must make that determination and communicate it to operations.

Environmental scanning is the monitoring of events and trends that present either threats or opportunities for the organization. Generally, these include competitors' activities; changing consumer needs; legal, economic, political, and environmental issues; the potential for new markets; and the like.

Environmental scanning The monitoring of events and trends that present threats or opportunities for a company.

Another key factor to consider when developing strategies is technological change, which can present real opportunities and threats to an organization. Technological changes occur in products (high-definition TV, improved computer chips, improved cellular telephone systems, and improved designs for earthquake-proof structures); in services (faster order processing, faster delivery); and in processes (robotics, automation, computer-assisted processing, point-of-sale scanners, and flexible manufacturing systems). The obvious benefit is a competitive edge; the risk is that incorrect choices, poor execution, and higher-than-expected operating costs will create competitive *disadvantages.*

Important factors may be internal or external. The following are key external factors:

. **Economic conditions.** These include the general health and direction of the economy, inflation and deflation, interest rates, tax laws, and tariffs.

. **Political conditions.** These include favorable or unfavorable attitudes toward business, political stability or instability, and wars.

. **Legal environment.** This includes antitrust laws, government regulations, trade restrictions, minimum wage laws, product liability laws and recent court experience, labor laws, and patents.

. **Technology.** This can include the rate at which product innovations are occurring, current and future process technology (equipment, materials handling), and design technology.

- **Competition.** This includes the number and strength of competitors, the basis of competition (price, quality, special features), and the ease of market entry.
- **Customers.** Loyalty, existing relationships, and understanding of wants and needs are important.

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- **Suppliers.** Supplier relationships, dependability of suppliers, quality, flexibility, and service are typical considerations.
- **Markets.** This includes size, location, brand loyalties, ease of entry, potential for growth, long-term stability, and demographics.

The organization also must take into account various *internal factors* that relate to possible strengths or weaknesses. Among the key internal factors are the following:

- **Human resources.** These include the skills and abilities of managers and workers, special talents (creativity, designing, problem solving), loyalty to the organization, expertise, dedication, and experience.
- **Facilities and equipment.** Capacities, location, age, and cost to maintain or replace can have a significant impact on operations.
- **Financial resources.** Cash flow, access to additional funding, existing debt burden, and cost of capital are important considerations.
- **Products and services.** These include existing products and services, and the potential for new products and services.
- **Technology.** This includes existing technology, the ability to integrate new technology, and the probable impact of technology on current and future operations.
- **Other.** Other factors include patents, labor relations, company or product image, distribution channels, relationships with distributors, maintenance of facilities and equipment, access to resources, and access to markets.

After assessing internal and external factors and an organization's distinctive competence, a strategy or strategies must be formulated that will give the organization the best chance of success. Among the types of questions that may need to be addressed are the following:

What role, if any, will the internet play?

Will the organization have a global presence?

To what extent will *outsourcing* be used?

What will the supply chain management strategy be?

To what extent will new products or services be introduced?

What rate of growth is desirable and *sustainable*?

What emphasis, if any, should be placed on lean production?

How will the organization differentiate its products and/or services from competitors'?

The organization may decide to have a single, dominant strategy (e.g., be the price leader) or have multiple strategies. A single strategy would allow the organization to concentrate on one particular strength or market condition. On the other hand, multiple strategies may be needed to address a particular set of conditions.

Many companies are increasing their use of outsourcing to reduce overhead, gain flexibility, and take advantage of suppliers' expertise. Amazon provides a great example of some of the potential benefits of outsourcing as part of a business strategy.

Growth is often a component of strategy, especially for new companies. A key aspect of this strategy is the need to seek a growth rate that is sustainable. In the 1990s, fast-food company Boston Market dazzled investors and fast-food consumers alike. Fueled by its success, it undertook rapid expansion. By the end of the decade, the company was nearly bankrupt; it had overexpanded. In 2000, it was absorbed by fast-food giant McDonald's.

Companies increase their risk of failure not only by missing or incomplete strategies; they also fail due to poor execution of strategies. And sometimes they fail due to factors beyond their control, such as natural or man-made disasters, major political or economic changes, or competitors that have an overwhelming advantage (e.g., deep pockets, very low labor costs, less rigorous environmental requirements).

A useful resource on successful business strategies is the Profit Impact of Market Strategy (PIMS) database (www.pimsonline.com). The database contains profiles of over 3,000 businesses located primarily in the United States, Canada, and western Europe. It is used by companies and academic institutions to guide strategic thinking. It allows subscribers to answer strategy questions about their business. Moreover, they can use it to generate benchmarks and develop successful strategies.

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READING

LOW INVENTORY CAN INCREASE AGILITY

In 1984, Michael Dell, then a college student, started selling personal computers from his dorm room. He didn't have the resources to make computer components, so he let others do that, choosing instead to concentrate on selling the computers. And, unlike the major computer producers, he didn't sell to dealers. Instead, he sold directly to PC buyers, eliminating some intermediaries, which allowed for lower cost and faster delivery. Although direct selling of PCs is fairly commonplace now, in those days it was a major departure from the norm.

What did Dell do that was so different from the big guys? To start, he bought components from suppliers instead of making them. That gave him tremendous leverage. He had little inventory, no R&D expenditures, and relatively few employees. And the risks of this approach were spread among his suppliers. Suppliers were willing to do this because Dell worked closely with them, and kept them informed. And because he was in direct contact with his customers, he gained tremendous insight into their expectations and needs, which he communicated to his suppliers.

Having little inventory gave Dell several advantages over his competitors. Aside from the lower costs of inventory, when new, faster computer chips became available, there was little inventory to work off, so he was able to offer the newer models much sooner than competitors with larger inventories. Also, when the prices of various components dropped, as they frequently did, he was able to take advantage of the lower prices, which kept his average costs lower than competitors' costs.

Today, the company is worth billions, and so is Michael Dell.

STRATEGY FORMULATION

The key steps in strategy formulation are:

1. Link strategy directly to the organization's mission or vision statement.
2. Assess strengths, weaknesses, threats, and opportunities, and identify core competencies.
3. Identify order winners and order qualifiers.
4. Select one or two strategies (e.g., low cost, speed, customer service) to focus on.

According to the PIMS website,

> The *database* is a collection of statistically documented experiences drawn from thousands of businesses, designed to help understand what kinds of strategies (e.g., quality, pricing, vertical integration, innovation, advertising) work best in what kinds of business environments. The data constitute a key resource for such critical management tasks as evaluating business performance, analyzing new business opportunities, evaluating and reality testing new strategies, and screening business portfolios. *The primary role* of the PIMS Program of the Strategic Planning Institute is to help managers understand and react to their business environment. PIMS does this by assisting managers as they develop and test strategies that will achieve an acceptable level of winning as defined by various strategies and financial measures.
>
> Source: https://www.inc.com/encyclopedia/profit-impact-of-market-strategies-pims.html

Supply Chain Strategy

A supply chain strategy specifies how the supply chain should function to achieve supply chain goals. The supply chain strategy should be aligned with the business strategy. If it is well executed, it can create value for the organization. It establishes how the organization should work with suppliers and policies relating to customer relationships and sustainability. Supply chain strategy is covered in more detail in a later chapter.

Sustainability Strategy

Society is placing increasing emphasis on corporate sustainability practices in the form of governmental regulations and interest groups. For these and other reasons, business organizations are or should be devoting attention to sustainability goals. To be successful, they will need a sustainability strategy. That requires elevating sustainability to the level of organizational governance; formulating goals for products and services, for processes, and for the entire supply chain; measuring achievements and striving for improvements; and possibly linking executive compensation to the achievement of sustainability goals.

Global Strategy

Global strategies have two different aspects. One relates to where parts or products are made, or where services such as customer support are performed. The other relates to where products or service are sold. With wages and standards of living increases in countries such as China and India, new market opportunities present themselves, requiring well-thought out strategies to take advantage of those potential opportunities while minimizing any associated risks.

As globalization increased, many companies realized that strategic decisions with respect to globalization had to be made. One issue companies face today is that what works in one country or region does not necessarily work in another, and strategies must be carefully crafted to take these variabilities into account. Another issue is the threat of political or social upheaval. Still another issue is the difficulty of coordinating and managing far-flung operations. Indeed, “In today’s global markets, you don’t have to go abroad to experience international competition. Sooner or later the world comes to you.”[2]

At this McDonald's in Singapore, one variable is the use of rice as a staple of the Chinese diet. This ad highlights rice burgers.

Christopher Kerrigan/McGraw-Hill Education

2.4 OPERATIONS STRATEGY

LO2.4
Discuss and compare organization strategy and operations strategy and explain why it is important to link the two.

The organization strategy provides the overall direction for the organization. It is broad in scope, covering the entire organization. **Operations strategy** is narrower in scope, dealing primarily with the operations aspect of the organization. Operations strategy relates to products, processes, methods, operating resources, quality, costs, lead times, and scheduling. Table 2.3 provides a comparison of an organization's mission, its overall strategy, and its operations strategy, tactics, and operations.

Operations strategy The approach, consistent with the organization strategy, that is used to guide the operations function.

TABLE 2.3

Comparison of mission, organization strategy, and operations strategy

		Management Level	Time Horizon	Scope	Level of Detail	Relates to
The overall organization	Mission	Top	Long	Broad	Low	Survival, profitability
	Strategy	Senior	Long	Broad	Low	Growth rate, market share
Operations	Strategic	Senior	Moderate to long	Broad	Low	Product design, choice of location, choice of technology, new facilities
	Tactical	Middle	Moderate	Moderate	Moderate	Employment levels, output levels, equipment selection, facility layout
	Operational	Low	Short	Narrow	High	Scheduling personnel, adjusting output rates, inventory management, purchasing

In order for operations strategy to be truly effective, it is important to link it to organization strategy; that is, the two should not be formulated independently. Rather, formulation of organization strategy should take into account the realities of operations' strengths and weaknesses, capitalizing on strengths and dealing with weaknesses. Similarly, operations strategy must be consistent with the overall strategy of the organization, and with the other functional units of the organization. This requires that senior managers work with functional units to formulate strategies that will support, rather than conflict with, each other and the overall strategy of the organization. As obvious as this may seem, it doesn't always happen in practice. Instead, we may find power struggles between various functional units. These struggles are detrimental to the organization because they pit functional units against each other rather than focusing their energy on making the organization more competitive and better able to serve the customer. Some of the latest approaches in organizations, involving teams of managers and workers, may reflect a growing awareness of the synergistic effects of working together rather than competing internally.

In the 1970s and early 1980s, operations strategy in the United States was often neglected in favor of marketing and financial strategies. That may have occurred because many chief executive officers did not come from operations backgrounds and perhaps did not fully appreciate the importance of the operations function. Mergers and acquisitions were common; leveraged buyouts were used, and conglomerates were formed that joined dissimilar operations. These did little to add value to the organization; they were purely financial in nature. Decisions were often made by individuals who were unfamiliar with the business, frequently to the detriment of that business. Meanwhile, foreign competitors began to fill the resulting vacuum with a careful focus on operations strategy.

In the late 1980s and early 1990s, many companies began to realize this approach was not working. They recognized that they were less competitive than other companies. This caused them to focus attention on operations strategy. A key element of both organization strategy and operations strategy is strategy formulation.

Operations strategy can have a major influence on the competitiveness of an organization. If it is well designed and well executed, there is a good chance the organization will be successful; if it is not well designed or executed, it is far less likely that the organization will be successful.

Strategic Operations Management Decision Areas

Operations management people play a strategic role in many strategic decisions in a business organization. Table 2.4 highlights some key decision areas. Notice that most of the decision areas have cost implications.

TABLE 2.4

Strategic operations management decisions

Decision Area	What the Decisions Affect

Decision Area	What the Decisions Affect
1. Product and service design	Costs, quality, liability, and environmental issues
2. Capacity	Cost structure, flexibility
3. Process selection and layout	Costs, flexibility, skill level needed, capacity
4. Work design	Quality of work life, employee safety, productivity
5. Location	Costs, visibility
6. Quality	Ability to meet or exceed customer expectations
7. Inventory	Costs, shortages
8. Maintenance	Costs, equipment reliability, productivity
9. Scheduling	Flexibility, efficiency
10. Supply chains	Costs, quality, agility, shortages, vendor relations
11. Projects	Costs, new products, services, or operating systems

Two factors that tend to have universal strategic operations importance relate to quality and time. The following section discusses quality and time strategies.

Quality and Time Strategies

LO2.5
Describe and give examples of time-based strategies.

Traditional strategies of business organizations have tended to emphasize cost minimization or product differentiation. While not abandoning those strategies, many organizations have embraced strategies based on *quality* and/or *time.*

Quality-based strategies focus on maintaining or improving the quality of an organization's products or services. Quality is generally a factor in both attracting and retaining customers. Quality-based strategies may be motivated by a variety of factors. They may reflect an effort to overcome an image of poor quality, a desire to catch up with the competition, a desire to maintain an existing image of high quality, or some combination of these and other factors. Interestingly enough, quality-based strategies can be part of another strategy such as cost reduction, increased productivity, or time, all of which benefit from higher quality.

Quality-based strategies Strategy that focuses on quality in all phases of an organization.

Time-based strategies focus on reducing the time required to accomplish various activities (e.g., develop new products or services and market them, respond to a change in customer demand, or deliver a product or perform a service). By doing so, organizations seek to improve service to the customer and to gain a competitive advantage over rivals who take more time to accomplish the same tasks.

Time-based strategies Strategies that focus on the reduction of time needed to accomplish tasks.

Time-based strategies focus on reducing the time needed to conduct the various activities in a process. The rationale is that by reducing time, costs are generally less, productivity is higher, quality tends to be higher, product innovations appear on the market sooner, and customer service is improved.

Organizations have achieved time reduction in some of the following:

Planning time: The time needed to react to a competitive threat, to develop strategies and select tactics, to approve proposed changes to facilities, to adopt new technologies, and so on.

Product/service design time: The time needed to develop and market new or redesigned products or services.

Processing time: The time needed to produce goods or provide services. This can involve scheduling, repairing equipment, methods used, inventories, quality, training, and the like.

Changeover time: The time needed to change from producing one type of product or service to another. This may involve new equipment settings and attachments, different methods, equipment, schedules, or materials.

Delivery time: The time needed to fill orders.

Response time for complaints: These might be customer complaints about quality, timing of deliveries, and incorrect shipments. These might also be complaints from employees about working conditions (e.g., safety, lighting, heat or cold), equipment problems, or quality problems.

It is essential for marketing and operations personnel to collaborate on strategy formulation in order to ensure that the buying criteria of the most important customers in each market segment are addressed.

Agile operations is a strategic approach for competitive advantage that emphasizes the use of flexibility to adapt and prosper in an environment of change. Agility involves a blending of several distinct competencies such as cost, quality, and reliability along with flexibility. Processing aspects of flexibility include quick equipment changeovers, scheduling, and innovation. Product or service aspects include varying output volumes and product mix.

Successful agile operations requires careful planning to achieve a system that includes people, flexible equipment, and information technology. Reducing the time needed to perform work is one of the ways an organization can improve a key metric: *productivity.*

2.5 IMPLICATIONS OF ORGANIZATION STRATEGY FOR OPERATIONS MANAGEMENT

Organization strategy has a major impact on operations and supply chain management strategies. For example, organizations that use a low-cost, high-volume strategy limit the amount of variety offered to customers. As a result, variations for operations and the supply chain are minimal, so they are easier to deal with. Conversely, a strategy to offer a wide variety of products or services, or to perform customized work, creates substantial operational and supply chain variations and, hence, more challenges in achieving a smooth flow of goods and services throughout the supply chain, thus making the matching of supply to demand more difficult. Similarly, increasing service reduces the ability to compete on price. Table 2.5 provides a brief overview of variety and some other key implications.

TABLE 2.5

Organization strategies and their implications for operations management

Organization Strategy	Implications for Operations Management
Low price	Requires low variation in products/services and a high-volume, steady flow of goods results in maximum use of resources through the system. Standardized work, material, and inventory requirements.

Organization Strategy	Implications for Operations Management
High quality	Entails higher initial cost for product and service design, and process design, and more emphasis on assuring supplier quality.
Quick response	Requires flexibility, extra capacity, and higher levels of some inventory items.
Newness/innovation	Entails large investment in research and development for new or improved products and services plus the need to adapt operations and supply processes to suit new products or services.
Product or service variety	Requires high variation in resource and more emphasis on product and service design; higher worker skills needed, cost estimation more difficult; scheduling more complex; quality assurance more involved; inventory management more complex; and matching supply to demand more difficult.
Sustainability	Affects location planning, product and service design, process design, outsourcing decisions, returns policies, and waste management.

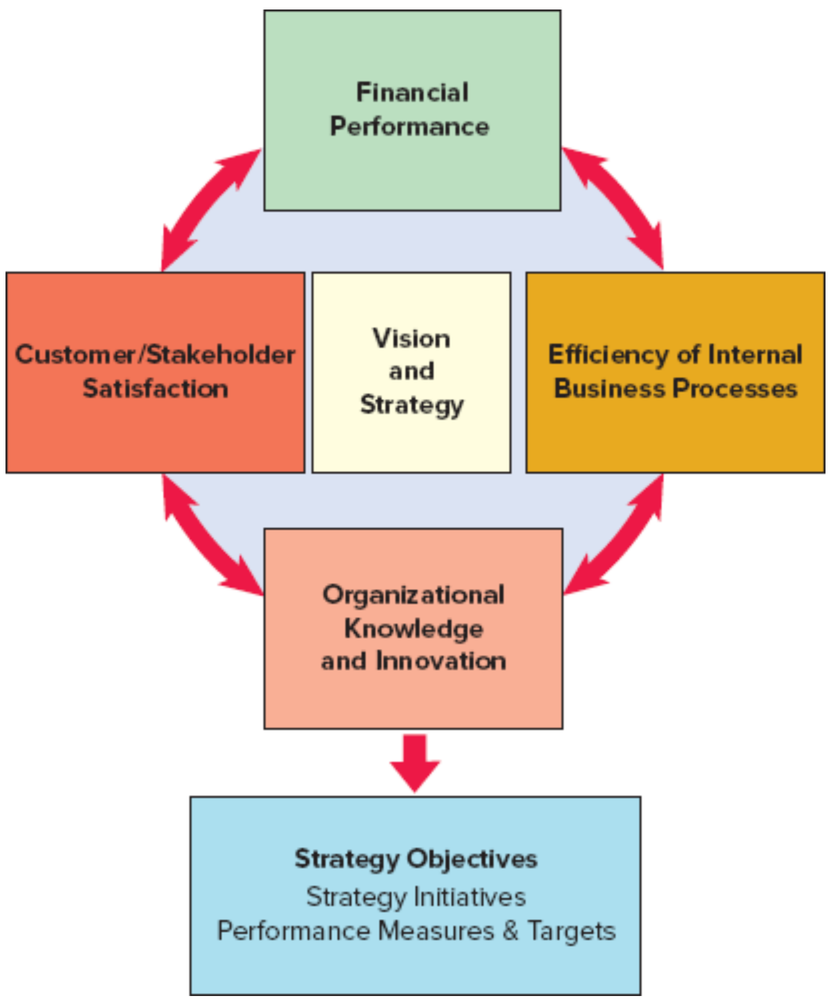
2.6 TRANSFORMING STRATEGY INTO ACTION: THE BALANCED SCORECARD

The Balanced Scorecard (BSC) is a top-down *management system* that organizations can use to clarify their vision and strategy and transform them into action. It was introduced in the early 1990s by Robert Kaplan and David Norton,[3] and it has been revised and improved since then. The idea was to move away from a purely financial perspective of the organization and integrate other perspectives such as customers, internal business processes, and learning and growth. Using this approach, managers develop objectives, metrics, and targets for each objective and initiatives to achieve objectives, and they identify links among the various perspectives. Results are monitored and used to improve strategic performance results. Figure 2.2 illustrates the conceptual framework of this approach. Many organizations employ this or a similar approach.

FIGURE 2.2

The Balanced Scorecard

Source: Adapted from Robert S. Kaplan and David P. Norton, "Using the Balanced Scorecard as a Strategic Management System," Harvard Business Review (January-Febrary 1996): 76.



As seen in Figure 2.2, the four perspectives are intended to balance not only financial and nonfinancial performance, but also internal and external performance, as well as past and future performance. This approach can also help organizations focus on how they differ from the competition in each of the four areas if their vision is realized. Table 2.6 has some examples of factors for key focal points.

TABLE 2.6

Balanced scorecard factors examples

Focal Point	Factors
Suppliers	Delivery performance Quality performance Number of suppliers Supplier locations Duplicate activities
Internal Processes	Bottlenecks Automation potential Turnover
Employees	Job satisfaction Learning opportunities Delivery performance
Customers	Quality performance Satisfaction Retention rate

Although the Balanced Scorecard helps focus managers' attention on strategic issues and the implementation of strategy, it is important to note that it has no role in strategy formulation.

A major key to Apple's continued success is its ability to keep pushing the boundaries of innovation. Apple has demonstrated how to create growth by dreaming up products so new and ingenious that they have upended one industry after another.

Pieter Beens/Shutterstock

Moreover, this approach pays little attention to suppliers and government regulations, and community, environmental, and sustainability issues are missing. These are closely linked, and business organizations need to be aware of the impact they are having in these areas and respond accordingly. Otherwise, organizations may be subject to attack by pressure groups and risk damage to their reputation.

2.7 PRODUCTIVITY

LO2.6 Define the term *productivity* and explain why it is important to companies and to countries.

One of the primary responsibilities of a manager is to achieve *productive use* of an organization's resources. The term *productivity* is used to describe this. **Productivity** is an index that measures output (goods and services) relative to the input (labor, materials, energy, and other resources) used to produce it. It is usually expressed as the ratio of output to input:

Productivity A measure of the effective use of resources, usually expressed as the ratio of output to input.

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}} \qquad (2\text{–}1)$$

Although productivity is important for all business organizations, it is particularly important for organizations that use a strategy of low cost, because the higher the productivity, the lower the cost of the output.

A productivity ratio can be computed for a single operation, a department, an organization, or an entire country. In business organizations, productivity ratios are used for planning workforce requirements, scheduling equipment, financial analysis, and other important tasks.

Productivity has important implications for business organizations and for entire nations. For nonprofit organizations, higher productivity means lower costs; for profit-based organizations, productivity is an important factor in determining how competitive a company is. For a nation, the rate of *productivity growth* is of great importance. Productivity growth is the increase in productivity from one period to the next relative to the productivity in the preceding period. Thus,

$$\text{Productivity growth} = \frac{\text{Current productivity} - \text{Previous productivity}}{\text{Previous productivity}} \times 100 \quad (2\text{–}2)$$

For example, if productivity increased from 80 to 84, the growth rate would be

$$\frac{84 - 80}{80} \times 100 = 5\%$$

Productivity growth is a key factor in a country's rate of inflation and the standard of living of its people. Productivity increases add value to the economy while keeping inflation in check. Productivity growth was a major factor in the long period of sustained economic growth in the United States in the 1990s.

Productivity can be enhanced by the use of robotic equipment. Robots can operate for long periods with consistent precision and high speed. The Hyundai Motor Company manufacturing plant in Montgomery, Alabama, uses robots for assembly work. This $1.4 billion automotive plant is one of the most advanced assembly plants in North America.

Betastock/Shutterstock

Computing Productivity

Productivity measures can be based on a single input (partial productivity), on more than one input (multifactor productivity), or on all inputs (total productivity). Table 2.7 lists some examples of productivity measures. The choice of productivity measure depends primarily on the purpose of the measurement. If the purpose is to track improvements in labor productivity, then labor becomes the obvious input measure.

TABLE 2.7

Some examples of different types of productivity measures

Partial measures	$\frac{\text{Output}}{\text{Labor}}$	$\frac{\text{Output}}{\text{Machine}}$	$\frac{\text{Output}}{\text{Capital}}$	$\frac{\text{Output}}{\text{Energy}}$
Multifactor measures	$\frac{\text{Output}}{\text{Labor + Machine}}$		$\frac{\text{Output}}{\text{Labor + Capital + Energy}}$	
Total measure	$\frac{\text{Goods or services produced}}{\text{All inputs used to produce them}}$			

Partial measures are often of greatest use in operations management. Table 2.8 provides some examples of partial productivity measures.

TABLE 2.8

Some examples of partial productivity measures

Labor productivity	Units of output per labor hour Units of output per shift Value-added per labor hour Dollar value of output per labor hour
Machine productivity	Units of output per machine hour Dollar value of output per machine hour
Capital productivity	Units of output per dollar input Dollar value of output per dollar input
Energy productivity	Units of output per kilowatt-hour

Dollar value of output per kilowatt-hour

The units of output used in productivity measures depend on the type of job performed. The following are examples of labor productivity:

$$\frac{\text{Yards of carpet installed}}{\text{Labor hours}} = \text{Yards of carpet installed per labor hour}$$

$$\frac{\text{Number of motel rooms cleaned}}{\text{Number of workers}} = \text{Number of motel rooms cleaned per worker}$$

Similar examples can be listed for *machine productivity* (e.g., the number of pieces per hour turned out by a machine).

EXAMPLE 2 **Computing Productivity**

eXcel

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Determine the productivity for these cases:

a. Four workers installed 720 square yards of carpeting in eight hours.

b. A machine produced 70 pieces in two hours. However, two pieces were unusable.

SOLUTION

a.
$$\begin{aligned}\text{Productivity} &= \frac{\text{Yards of carpet installed}}{\text{Labor hours worked}}\\ &= \frac{720 \text{ square yards}}{4 \text{ workers} \times 8 \text{ hours/worker}}\\ &= \frac{720 \text{ yards}}{32 \text{ hours}}\\ &= 22.5 \text{ yards/hour}\end{aligned}$$

b. $$\text{Productivity} = \frac{\text{Usable pieces}}{\text{Production time}} = \frac{70 - 2 = 68 \text{ usable pieces}}{2 \text{ hours}} = 34 \text{ pieces/hour}$$

Calculations of multifactor productivity measure inputs and outputs using a common unit of measurement, such as cost. For instance, the measure might use cost of inputs and units of the output:

$$\frac{\text{Quantity of production}}{\text{Labor cost} + \text{Materials cost} + \text{Overhead}} \tag{2–3}$$

Note: The unit of measure must be the same for all factors in the denominator

EXAMPLE 3 Computing Multifactor Productivity

eXcel

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Determine the multifactor productivity for the combined input of labor and machine time using the following data:

Output: 7,040 units

Input

Labor: $1,000

Materials: $520

Overhead: $2,000

SOLUTION

$$\text{Multifactor productivity} = \frac{\text{Output}}{\text{Labor} + \text{Materials} + \text{Overhead}}$$

$$= \frac{7{,}040 \text{ units}}{\$1{,}000 + \$520 + \$2{,}000} = 2 \text{ units per dollar input}$$

READING

WHY PRODUCTIVITY MATTERS

It is sometimes easy to overlook the importance of productivity. National figures are often reported in the media. They may seem to be ho-hum; there's nothing glamorous about them to get our attention. But make no mistake; they are key economic indicators—barometers, if you will, that affect everybody. How? High productivity and high standard of living go hand-in-hand. If a country becomes more service-based, as the United States has become, if some (but not all) high-productivity manufacturing jobs are replaced by lower-productivity service jobs, that makes it more difficult to support a high standard of living.

Productivity gains can offset inflationary pressures related to wage increases. Productivity increases result in lower costs per unit. Those savings not only generate higher profits, they also help pay for wage increases.

Productivity levels are also important for industries and companies. For companies, a higher productivity relative to their competitors gives them a competitive advantage in the marketplace. With a higher productivity, they can afford to undercut competitors' prices to gain market share or charge the same prices but realize greater profits! For an industry, higher relative productivity means it is less likely to be supplanted by foreign industry.

Questions

1. Why is high productivity important for a nation?
2. Why do you suppose that service jobs have lower productivity than manufacturing jobs?
3. How can a company gain a competitive advantage by having higher productivity than its competitors have?

Productivity measures are useful on a number of levels. For an individual department or organization, productivity measures can be used to track performance *over time.* This allows managers to judge performance and to decide where improvements are needed. For example, if productivity has slipped in a certain area, operations staff can examine the factors used to compute productivity to determine what has changed and then devise a means of improving productivity in subsequent periods.

Productivity measures also can be used to judge the performance of an entire industry or the productivity of a country as a whole. These productivity measures are *aggregate* measures.

In essence, productivity measurements serve as scorecards of the effective use of resources. Business leaders are concerned with productivity as it relates to *competitiveness:* If two firms both have the same level of output but one requires less input because of higher productivity, that one will be able to charge a lower price and consequently increase its share of the market. Or that firm might elect to charge the same price, thereby reaping a greater profit. Government leaders are concerned with national productivity because of the close relationship between productivity and a nation's standard of living. High levels of productivity are largely responsible for the relatively high standards of living enjoyed by people in industrial nations. Furthermore, wage and price increases not accompanied by productivity increases tend to create inflationary pressures on a nation's economy.

Advantages of domestic-based operations for domestic markets often include higher worker productivity, better control of quality, avoidance of intellectual property losses, lower shipping costs, political stability, low inflation, and faster delivery.

Productivity in the Service Sector

Service productivity is more problematic than manufacturing productivity. In many situations, it is more difficult to measure, and thus to manage, because it involves intellectual activities and a high degree of variability. Think about medical diagnoses, surgery, consulting, legal services, customer service, and computer repair work. This makes productivity improvements more difficult to achieve. Nonetheless, because service is becoming an increasingly large portion of our economy, the issues related to service productivity will have to be dealt with. It is interesting to note that government statistics normally do not include service firms.

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READING

DUTCH TOMATO GROWERS' PRODUCTIVITY ADVANTAGE

Tomato growers in the Netherlands have a huge productivity advantage over their competitors in Italy and Greece. Although those countries are sun drenched while the Netherlands are anything but, computerized, climate-controlled greenhouses, and a “soil” spun from basalt and chalk that resembles cotton candy, allows for precise control of humidity and nutrition, and enables growers to produce their crops year round. Growers in Italy and Greece generally grow their crops outdoors or in unheated greenhouses, and can only manage two crops a year. Dutch growers are able to achieve yields that are about ten times per square yard of those of Italian and Greek growers. And the Dutch have a supply chain advantage: an integrated Dutch trading company works closely with supermarket chains in Europe and suppliers around the world, so farmers are able to sell their output in high volume, rather than locally the way many farmers in other countries do. That enables Dutch growers to more closely match supply with supermarket demand. Finally, the Dutch tomato has been engineered to achieve a firmness that allows growers to harvest and ship tomatoes at their peak, while the “outdoor” farmers typically need to harvest their tomatoes before they are fully ripe to allow for firmness during shipping.

Questions

1. What factors enable Dutch tomato growers to achieve much higher productivity than the Italian and Greek growers?
2. Discuss the importance of the Dutch growers’ supply chain.

Source: Based on “Tomato,” *Time,* March 25, 2013, pp. 9–14.

A useful measure closely related to productivity is *process yield.* Where products are involved, process yield is defined as the ratio of output of good product (i.e., defective product is not included) to the quantity of raw material input. Where services are involved, process yield measurement is often dependent on the particular process. For example, in a car rental agency, a measure of yield is the ratio of cars rented to cars available for a given day. In education, a measure for college and university admission yield is the ratio of student acceptances to the total number of students approved for admission. For subscription services, yield is the ratio of new subscriptions to the number of calls made or the number of letters mailed. However, not all services lend themselves to a simple yield measurement. For example, services such as automotive, appliance, and computer repair don't readily lend themselves to such measures.

Factors that Affect Productivity

LO2.7
Describe several factors that affect productivity.

Numerous factors affect productivity. Generally, they are methods, capital, quality, technology, and management.

A commonly held misconception is that workers are the main determinant of productivity. According to that theory, the route to productivity gains involves getting employees to work harder. However, the fact is that many productivity gains in the past have come from *technological* improvements. Familiar examples include:

Drones	Automation	GPS devices
Copiers and scanners	Calculators	Smartphones
The internet, search engines	Computers	Apps
Voicemail	Email	3D printers

Radio frequency ID tags	Software	Medical imaging

However, technology alone won’t guarantee productivity gains; it must be used wisely and thoughtfully. Without careful planning, technology can actually *reduce* productivity, especially if it leads to inflexibility, high costs, or mismatched operations. Another current productivity pitfall results from employees’ use of computers or smartphones for nonwork-related activities (playing games or checking stock prices or sports scores on the internet or smartphones, and texting friends and relatives). Beyond all of these is the dip in productivity that results while employees learn to use new equipment or procedures that will eventually lead to productivity gains after the learning phase ends.

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Other factors that affect productivity include the following:

Standardizing processes and procedures wherever possible to reduce variability can have a significant benefit for both productivity and quality.

Quality differences may distort productivity measurements. One way this can happen is when comparisons are made over time, such as comparing the productivity of a factory now with one 30 years ago. Quality is now much higher than it was then, but there is no simple way to incorporate quality improvements into productivity measurements.

Use of the internet can lower costs of a wide range of transactions, thereby increasing productivity. It is likely that this effect will continue to increase productivity in the foreseeable future.

Computer viruses can have an immense negative impact on productivity.

Searching for lost or misplaced items wastes time, hence negatively affecting productivity.

Scrap rates have an adverse effect on productivity, signaling inefficient use of resources.

New workers tend to have lower productivity than seasoned workers. Thus, growing companies may experience a productivity lag.

Safety should be addressed. Accidents can take a toll on productivity.

A shortage of technology-savvy workers hampers the ability of companies to update computing resources, generate and sustain growth, and take advantage of new opportunities.

Layoffs often affect productivity. The effect can be positive and negative. Initially, productivity may increase after a layoff, because the workload remains the same but fewer workers do the work—although they have to work harder and longer to do it. However, as time goes by, the remaining workers may experience an increased risk of burnout, and they may fear additional job cuts. The most capable workers may decide to leave.

Labor turnover has a negative effect on productivity; replacements need time to get up to speed.

Design of the workspace can impact productivity. For example, having tools and other work items within easy reach can positively impact productivity.

Incentive plans that reward productivity increases can boost productivity.

And there are still other factors that affect productivity, such as *equipment breakdowns* and *shortages* of parts or materials. The education level and training of workers and their health can greatly affect productivity. The opportunity to obtain lower costs due to higher productivity elsewhere is a key reason many organizations turn to *outsourcing.* Hence, an alternative to outsourcing can be improved productivity. Moreover, as a part of their strategy for quality, the best organizations strive for *continuous improvement.* Productivity improvements can be an important aspect of that approach.

Improving Productivity

A company or a department can take a number of key steps toward improving productivity:

- Develop productivity measures for all operations. Measurement is the first step in managing and controlling an operation.
- Look at the system as a whole in deciding which operations are most critical. It is overall productivity that is important. Managers need to reflect on the value of potential productivity improvements *before* okaying improvement efforts. The issue is *effectiveness.* There are several aspects of this. One is to make sure the result will be something customers want. For example, if a company is able to increase its output through productivity improvements, but then is unable to sell the increased output, the increase in productivity isn't effective. Second, it is important to adopt a systems viewpoint: A productivity increase in one part of an operation that doesn't increase the productivity of the system would not be effective. For example, suppose a system consists of a sequence of two operations, where the output of the first operation is the input to the second operation, and each operation can complete its part of the process at a rate of 20 units per hour. If the productivity of the first operation is increased, but the productivity of the second operation is not, the output of the system will still be 20 units per hour.
- Develop methods for achieving productivity improvements, such as soliciting ideas from workers (perhaps organizing teams of workers, engineers, and managers), studying how other firms have increased productivity, and reexamining the way work is done.
- Establish reasonable goals for improvement.

- Make it clear that management supports and encourages productivity improvement. Consider incentives to reward workers for contributions.
- Measure improvements and publicize them.

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READING

PRODUCTIVITY IMPROVEMENT

Stryker Howmedica set up a team to improve the running of its packaging line. A strategy focus on productivity improvement was used. The team adopted an approach based on the production system of Toyota. The goal was to satisfy the customer expectations for delivery and quality, while achieving gains in productivity. After the team identified needs and set objectives, a number of improvements were implemented. A one-piece flow was established that reduced bottlenecks in the flow of devices through a clean room and the total time spent blister sealing devices was lowered. Within a short time, productivity nearly doubled from 36 devices per hour to 60 devices per hour, work-in-progress inventory fell, and a 10 percent reduction in the standard cost of product was achieved.

Source: Based on Lauraine Howley, “A Strategy for Company Improvement,” *Medical Device Technology* 11, no. 2 (March 2000), p. 33.

Don't confuse productivity with *efficiency.* Efficiency is a narrower concept that pertains to getting the most out of a *fixed* set of resources; productivity is a broader concept that pertains to effective use of overall resources. For example, an efficiency perspective on mowing a lawn with a hand mower would focus on the best way to use the hand mower; a productivity perspective would include the possibility of using a power mower.

Fracking productivity improvement is another example. Drilling methods have become more effective. Drillers are now adopting a hydraulic fracturing method pioneered by companies such as Liberty Resources and EOG Resources that uses larger amounts of water and minerals. Although it is a more costly process, it has increased production rates in the first year of a well's life, after which output tends to drop off dramatically. Processes such as these have reduced the break-even cost of producing a barrel of oil and kept profitable some acreage that drillers might otherwise have left idle.

SUMMARY

Competition is the driving force in many organizations. It may involve price, quality, special features or services, time, or other factors. To develop effective strategies for business, it is essential for organizations to determine what combinations of factors are important to customers, which factors are order qualifiers, and which are order winners. Moreover, managers must be constantly on the lookout for changes in internal or external conditions that could necessitate a change in strategy.

It is essential that goals and strategies be aligned with the organization's mission. Strategies are plans for achieving organizational goals. They provide focus for decision making. Strategies must take into account present and future customer wants, as well as the organization's strengths and weaknesses, and threats and opportunities. These can run the gamut from what competitors are doing, or are likely to do, to technology, supply chain management, and e-business. Organizations generally have overall strategies that pertain to the entire organization, and strategies that pertain to each of the functional areas. Functional strategies are narrower in scope and should be linked to overall strategies. Time-based strategies and quality-based strategies are among the most widely used strategies business organizations employ to serve their customers and to become more productive. The chapter includes a description of the Balanced Scorecard approach, which can be helpful for transforming strategies into actions, and the implications of organization strategy for operations management.

Productivity is a measure of the use of resources. There is considerable interest in productivity both from an organizational standpoint and from a national standpoint. Business organizations want higher productivity because it yields lower costs and helps them to become more competitive. Nations want higher productivity because it makes their goods and services more attractive, offsets inflationary pressures associated with higher wages, and results in a higher standard of living for their people.

KEY POINTS

1. Competitive pressure often means that business organizations must frequently assess their competitors' strengths and weaknesses, as well as their own, to remain competitive.
2. Strategy formulation is critical because strategies provide direction for the organization, so they can play a role in the success or failure of a business organization.
3. Functional strategies and supply chain strategies need to be aligned with the goals and strategies of the overall organization.
4. The three primary business strategies are low cost, responsiveness, and differentiation.
5. Productivity is a key factor in the cost of goods and services. Increases in productivity can become a competitive advantage.
6. High productivity is particularly important for organizations that have a strategy of low costs.

KEY TERMS

SOLVED PROBLEMS

Problem 1

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Computing Productivity

A company that processes fruits and vegetables is able to produce 400 cases of canned peaches in one-half hour with four workers. What is labor productivity?

Solution

$$\text{Labor productivity} = \frac{\text{Quantity produced}}{\text{Labor hours}} = \frac{400 \text{ cases}}{4 \text{ workers} \times 1/2 \text{ hour/worker}}$$
$$= 200 \text{ cases per labor hour}$$

Problem 2

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Computing Multifactor Productivity

A wrapping-paper company produced 2,000 rolls of paper in one day. Labor cost was $160, material cost was $50, and overhead was $320. Determine the multifactor productivity.

Solution

$$\text{Multifactor productivity} = \frac{\text{Quantity produced}}{\text{Labor cost} + \text{Material cost} + \text{Overhead}}$$

$$= \frac{2{,}000 \text{ rolls}}{\$160 + \$50 + \$320} = 3.77 \text{ rolls per dollar input}$$

A variation of the multifactor productivity calculation incorporates the standard price in the numerator by multiplying the units by the standard price.

Problem 3

eXcel

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Computing Multifactor Productivity

Compute the multifactor productivity measure for an eight-hour day in which the usable output was 300 units, produced by three workers who used 600 pounds of materials. Workers have an hourly wage of \$20, and material cost is \$1 per pound. Overhead is 1.5 times labor cost.

Solution

$$\text{Multifactor productivity} = \frac{\text{Usable output}}{\text{Labor cost} + \text{Material cost} + \text{Overhead cost}}$$

$$= \frac{300 \text{ units}}{(3 \text{ workers} \times 8 \text{ hours} \times \$20/\text{hour}) + (600 \text{ pounds} \times \$1/\text{pound}) + (3 \text{ workers} \times 8 \text{ hours} \times \$20/\text{hour} \times 1.50)}$$

$$= \frac{300 \text{ units}}{\$480 + \$600 + \$720}$$

$$= .167 \text{ units of output per dollar of input}$$

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Problem 4

eXcel

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Computing Multifactor Productivity

A health club has two employees who work on lead generation. Each employee works 40 hours a week, and is paid $20 an hour. Each employee identifies an average of 400 possible leads a week from a list of 8,000 names. Approximately 10 percent of the leads become members and pay a onetime fee of $100. Material costs are $130 per week, and overhead costs are $1,000 per week. Calculate the multifactor productivity for this operation in fees generated per dollar of input.

Solution

$$\text{MFP} = \frac{(\text{Possible leads})(\text{No. of workers})(\text{Fee})(\text{Conversion percentage})}{\text{Labor cost} + \text{Material cost} + \text{Overhead cost}}$$

$$= \frac{(400)(2)(\$100)(.10)}{2(40)(\$20) + \$130 + \$1{,}000} = \frac{\$8{,}000}{\$2{,}730} = 2.93$$

DISCUSSION AND REVIEW QUESTIONS

1. From time to time, various groups clamor for import restrictions or tariffs on foreign-produced goods, particularly automobiles. How might these be helpful? Harmful?
2. List the key ways that organizations compete.
3. Explain the importance of identifying and differentiating order qualifiers and order winners.
4. Select two stores you shop at, and state how they compete.
5. What is the Balanced Scorecard and how is it useful?
6. Contrast the terms *strategies* and *tactics.*
7. Contrast *organization strategy* and *operations strategy.*
8. Explain the term *time-based strategies* and give three examples.
9. Productivity should be a concern of every business organization.
   a. How is productivity defined?
   b. How are productivity measures used?

c. Why is productivity important?
d. What part of the organization has the primary responsibility of productivity?
e. How is efficiency different from productivity?

10. List some factors that can affect productivity, as well as some ways that productivity can be improved.
11. It has been said that a typical Japanese automobile manufacturer produces more cars with fewer workers than its U.S. counterpart. What are some possible explanations for this, assuming that U.S. workers are as hardworking as Japanese workers?
12. Boeing's strategy appears to focus on its 777 midsize plane's ability to fly into smaller, nonhub airports. Rival European Airbus's strategy appears to focus on large planes. Compare the advantages and disadvantages of these two strategies.
13. Name 10 ways that banks compete for customers.
14. Explain the rationale of an operations strategy that seeks to increase the opportunity for use of technology by reducing variability in processing requirements.
15. Identify two companies that have time-based strategies, and two that have quality-based strategies.

TAKING STOCK

1. Who needs to be involved in formulating organizational strategy?
2. Name some of the competitive trade-offs that might arise in a fast-food restaurant.
3. How can technology improve:
   a. competitiveness?
   b. productivity?

CRITICAL THINKING EXERCISES

1. In the past, there was concern about a "productivity paradox" related to IT services. More recently, there have been few references to this phenomenon. Using the internet, explain the term *productivity paradox.* Why do you think that the discussion of that topic has faded?
2. A U.S. company has two manufacturing plants, one in the United States and one in another country. Both produce the same item, each for sale in their respective countries. However, their productivity figures are quite different. The analyst thinks this is because the U.S. plant uses more automated equipment for processing, while the other plant uses a higher percentage of labor. Explain how that factor can cause productivity figures to be misleading. Is there another way to compare the two plants that would be more meaningful?

3. While it is true that increases in efficiency generate productivity increases, it is possible to get caught in an "efficiency improvement trap." Explain what this means.
4. It is common knowledge that Sam's boss Dom has been fudging the weekly productivity figures. Several employees, including Sam, have spoken to him about this, but he continues to do it. Sam has observed a drop in morale among his coworkers due to this. Sam is thinking about sending an anonymous note to Dom's boss. Would that be ethical? What would you do if you were Sam?
5. Give two examples of what would be considered unethical involving competition and the ethical principles (see Chapter 1) that would be violated.

PROBLEMS

1. A catering company prepared and served 300 meals at an anniversary celebration last week using eight workers. The week before, six workers prepared and served 240 meals at a wedding reception.
   a. For which event was the labor productivity higher? Explain.
   b. What are some possible reasons for the productivity differences?
2. The manager of a crew that installs carpeting has tracked the crew's output over the past several weeks, obtaining these figures:

Week	Crew Size	Yards Installed
1	4	96
2	3	72
3	4	92
4	2	50
5	3	69
6	2	52

   Compute the labor productivity for each of the weeks. On the basis of your calculations, what can you conclude about crew size and productivity?
3. Compute the multifactor productivity measure for each of the weeks shown for production of chocolate bars. What do the productivity figures suggest? Assume 40-hours work in a week and an hourly wage of $12. Overhead is 1.5 times weekly labor cost. Material cost is $6 per pound.

Week	Output (units)	Workers	Material (lbs)

Week	Output (units)	Workers	Material (lbs)
1	30,000	6	450
2	33,600	7	470
3	32,200	7	460
4	35,400	8	480

4. A company that makes shopping carts for supermarkets and other stores recently purchased some new equipment that reduces the labor content of the jobs needed to produce the shopping carts. Prior to buying the new equipment, the company used five workers, who produced an average of 80 carts per hour. Workers receive $10 per hour, and machine cost was $40 per hour. With the new equipment, it was possible to transfer one of the workers to another department, and equipment cost increased by $10 per hour, while output increased by four carts per hour.
   a. Compute labor productivity under each system. Use carts per worker per hour as the measure of labor productivity.
   b. Compute the multifactor productivity under each system. Use carts per dollar cost (labor plus equipment) as the measure.
   c. Comment on the changes in productivity according to the two measures, and on which one you believe is the more pertinent for this situation.

5. An operation has a 10 percent scrap rate. As a result, 72 pieces per hour are produced. What is the potential increase in labor productivity that could be achieved by eliminating the scrap?
6. A manager checked production records and found that a worker produced 160 units while working 40 hours. In the previous week, the same worker produced 138 units while working 36 hours. Did the worker's productivity increase, decrease, or remain the same? Explain.
7. The following table shows data on the average number of customers processed by several bank service units each day. The hourly wage rate is $25, the overhead rate is 1.0 times labor cost, and material cost is $5 per customer.

Unit	Employees	Customers Processed/Day
A	4	36
B	5	40
C	8	60
D	3	20

a. Compute the labor productivity and the multifactor productivity for each unit. Use an eight-hour day for multifactor productivity.
b. Suppose a new, more standardized procedure is to be introduced that will enable each employee to process one additional customer per day. Compute the expected labor and multifactor productivity rates for each unit.

8. A property title search firm is contemplating using online software to increase its search productivity. Currently, an average of 40 minutes is needed to do a title search. The researcher cost is $2 per minute. Clients are charged a fee of $400. Company A's software would reduce the average search time by 10 minutes, at a cost of $3.50 per search. Company B's software would reduce the average search time by 12 minutes at a cost of $3.60 per search. Which option would have the higher productivity in terms of revenue per dollar of input?
9. A company offers ID theft protection using leads obtained from client banks. Three employees work 40 hours a week on the leads, at a pay rate of $25 per hour per employee. Each employee identifies an average of 3,000 potential leads a week from a list of 5,000. An average of 4 percent actually sign up for the service, paying a one-time fee of $70. Material costs are $1,000 per week, and overhead costs are $9,000 per week. Calculate the multifactor productivity for this operation in fees generated per dollar of input.

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CASE

CASE HOME-STYLE COOKIES

The Company

The baking company is located in a small town in New York State. The bakery is run by two brothers. The company employs fewer than 200 people, mainly blue-collar workers, and the atmosphere is informal.

The Product

The company's only product is soft cookies, of which it makes over 50 varieties. Larger companies, such as Nabisco, Sunshine, and Keebler, have traditionally produced biscuit cookies, in which most of the water has been baked out, resulting in crisp cookies. The cookies have no additives or preservatives. The high quality of the cookies has enabled the company to develop a strong market niche for its product.

The Customers

The cookies are sold in convenience stores and supermarkets throughout New York, Connecticut, and New Jersey. The company markets its cookies as “good food”—no additives or preservatives—and this appeals to a health-conscious segment of the market. Many customers are over 45 years of age, and prefer a cookie that is soft and not too sweet. Parents with young children also buy the cookies.

The Production Process

The company has two continuous band ovens that it uses to bake the cookies. The production process is called a batch processing system. It begins as soon as management gets orders from distributors. These orders are used to schedule production. At the start of each shift, a list of the cookies to be made that day is delivered to the person in charge of mixing. That person checks a master list, which indicates the ingredients needed for each type of cookie, and enters that information into the computer. The computer then determines the amount of each ingredient needed, according to the quantity of cookies ordered, and relays that information to storage silos located outside the plant where the main ingredients (flour, sugar, and cake flour) are stored. The ingredients are automatically sent to giant mixing machines where the ingredients are combined with proper amounts of eggs, water, and flavorings. After the ingredients have been mixed, the batter is poured into a cutting machine where it is cut into individual cookies. The cookies are then dropped onto a conveyor belt and transported through one of two ovens.

Filled cookies, such as apple, date, and raspberry, require an additional step for filling and folding.

The nonfilled cookies are cut on a diagonal rather than round. The diagonal-cut cookies require less space than straight-cut cookies, and the result is a higher level of productivity. In addition, the company recently increased the length of each oven by 25 feet, which also increased the rate of production.

As the cookies emerge from the ovens, they are fed onto spiral cooling racks 20 feet high and 3 feet wide. As the cookies come off the cooling racks, workers place the cookies into boxes manually, removing any broken or deformed cookies in the process. The boxes are then wrapped, sealed, and labeled automatically.

Inventory

Most cookies are loaded immediately onto trucks and shipped to distributors. A small percentage are stored temporarily in the company's warehouse, but they must be shipped shortly because of their limited shelf life. Other inventory includes individual cookie boxes, shipping boxes, labels, and cellophane for wrapping. Labels are reordered frequently, in small batches, because FDA label requirements are subject to change, and the company does not want to get stuck with labels it can't use. The bulk silos are refilled two or three times a week, depending on how quickly supplies are used.

Cookies are baked in a sequence that minimizes downtime for cleaning. For instance, light-colored cookies (e.g., chocolate chip) are baked before dark-colored cookies (e.g., fudge), and oatmeal cookies are baked before oatmeal raisin cookies. This lets the company avoid having to clean the processing equipment every time a different type of cookie is produced.

Quality

The bakery prides itself on the quality of its cookies. Cookies are sampled randomly by a quality control inspector as they come off the line to assure that their taste and consistency are satisfactory, and that they have been baked to the proper degree. Also, workers on the line are responsible for removing defective cookies when they spot them. The company has also installed an X-ray machine on the line that can detect small bits of metal filings that may have gotten into cookies during the production process. The use of automatic equipment for transporting raw materials and mixing batter has made it easier to maintain a sterile process.

Scrap

The bakery is run very efficiently and has minimal amounts of scrap. For example, if a batch is mixed improperly, it is sold for dog food. Broken cookies are used in the oatmeal cookies. These practices reduce the cost of ingredients and save on waste disposal costs. The company also uses heat reclamation: The heat that escapes from the two ovens is captured and used to boil the water that supplies the heat to the building. Also, the use of automation in the mixing process has resulted in a reduction in waste compared with the manual methods used previously.

New Products

Ideas for new products come from customers, employees, and observations of competitors' products. New ideas are first examined to determine whether the cookies can be made with existing equipment. If so, a sample run is made to determine the cost and time requirements. If the results are satisfactory, marketing tests are conducted to see if there is a demand for the product.

Potential Improvements

There are a number of areas of potential improvement at the bakery. One possibility would be to automate packing the cookies into boxes. Although labor costs are not high, automating the process might save some money and page 68 increase efficiency. So far, the owners have resisted making this change because they feel an obligation to the community to employ the 30 women who now do the boxing manually. Another possible improvement would be to use suppliers who are located closer to the plant. That would reduce delivery lead times and transportation costs, but the owners are not convinced that local suppliers could provide the same good quality. Other opportunities have been proposed in recent years, but the owners rejected them because they feared that the quality of the product might suffer.

Questions

1. Briefly describe the cookie production process.
2. What are two ways that the company has increased productivity? Why did increasing the length of the ovens result in a faster output rate?
3. Do you think that the company is making the right decision by not automating the packing of cookies? Explain your reasoning. What obligation does a company have to its employees in a situation such as this? What obligation does it have to the community? Is the size of the town a factor? Would it make a difference if the company was located in a large city? Is the size of the company a factor? What if it were a much larger company?
4. What factors cause the company to carry minimal amounts of certain inventories? What benefits result from this policy?
5. As a consumer, what things do you consider in judging the quality of cookies you buy in a supermarket?
6. What advantages and what limitations stem from the company's not using preservatives in cookies?
7. Briefly describe the company's strategy.

CASE

HAZEL REVISITED

(Refer to the Hazel Case at the end of chapter 1.)

1. What competitive advantage does Hazel have over a professional lawn care service?
2. Hazel would like to increase her profits, but she doesn't believe it would be wise to raise her prices considering the current state of the local economy. Instead, she has given some thought to increasing productivity.
   a. Explain how increased productivity could be an alternative to increased prices.
   b. What are some ways that Hazel could increase productivity?
3. Hazel is thinking about the purchase of new equipment. One would be power sidewalk edgers. She believes edgers will lead to an increase in productivity. Another would be a chain saw, which would be used for tree pruning. What trade-offs should she consider in her analysis?
4. Hazel has been fairly successful in her neighborhood, and now wants to expand to other neighborhoods, including some that are five miles away. What would be the advantages and disadvantages of doing this?
5. Hazel does not have a mission statement or a set of objectives. Take one of the following positions and defend it:
   a. Hazel doesn't need a formal mission statement and objectives. Many small businesses don't have them.
   b. She definitely needs a mission statement and a set of objectives. They would be extremely beneficial.
   c. There may be some benefit to Hazel's business, and she should consider developing one.

CASE "YOUR GARDEN GLOVES"

JOSEPH MURRAY, GRAND VALLEY STATE UNIVERSITY

"Your Garden Gloves" is a small gardening business located in Michigan. The company plants and maintains flower gardens for both commercial and residential clients. The company was founded about five years ago, and has since grown substantially, averaging about 10 new clients and one new employee a year. The company currently employs eight seasonal employees who are responsible for a certain number of clients.

Each morning, crews are assigned to jobs by the owner. Crew sizes range from two to four workers. Crew size and composition are a function of the square footage of the garden and requirements of the job. The owner feels that large jobs should be assigned to crews of four workers in order to complete the job in a reasonable amount of time.

From time to time, the owner noticed that some jobs, especially the largest ones, took longer than she had estimated, based on the square footage of the garden space involved. The owner's son, Joe, decided to investigate. He kept records of job times and crew sizes, and then used those records to compute labor productivity. The results were:

Crew Size	Average Productivity per Crew
2	4,234 square feet per day
3	5,352 square feet per day
4	7,860 square feet per day

The company operates on a small profit margin, so it is especially important to take worker productivity into account.

Questions

1. Which crew size had the highest productivity per worker? Which crew size had the lowest productivity per worker? What are some possible explanations for these results?
2. After a recent storm, a customer called in a panic, saying she had planned a garden party for the upcoming weekend and her garden was in a shambles. The owner decided to send a crew of four workers, even though a two-worker crew would have a higher productivity. Explain the rationale for this decision.
3. What is a possible qualitative issue that may very well influence productivity levels that the productivity ratios fail to take into account?

CASE

GIRLFRIEND COLLECTIVE

BY LISA SPENCER

Girlfriend Collective wants customers to love its products and wear them with pride. Designing for an audience that cares about where clothes come from, as well as how they look and fit, the founders of Girlfriend Collective made transparency a top priority. Its website freely shares the details of the production process so consumers can learn about its high standards and how it operates. Every part of the process, including sourcing materials, designing products, choosing facilities, and selecting partners, was carefully and painstakingly done with ethics and sustainability in mind.

Recycled Polyester

Girlfriend Collective's innovative leggings are made from 25 RPET recycled plastic water bottles combined with 21 percent spandex. The company sources its post-consumer water bottles from Taiwan, a country known as "Garbage Island" until its government initiated a sweeping program that put the small country on the forefront of global recycling. In communities throughout the country, people come together every night to sort their waste into containers for recyclables, food waste, and garbage. When they finish, neighbors linger to socialize until the collection trucks come, building relationships and community ties. In rural areas, various programs and volunteer groups set up micro-recycling centers where people can drop off recyclables and learn more about environmental stewardship. Whereas the United States only recycles about 35 percent of its waste, Taiwan now recycles 55 percent.

Recycled Fabric

Once bottles are collected, they are sorted into various grades and sent to processing centers. Girlfriend Collective uses only #1 plastic, known as Polyethylene Terephthalate (PET), to make its polyester yarn and fabric. Plastics containing BPA, which some believe pose a health threat, are never used.

The #1 bottles are cleaned and shredded at a Taiwanese processing center that is family owned and operated and has a long-standing history of doing things right. The facility is also certified by the Taiwanese government. Thus, in addition to having permission to process and resell plastic, security measures are in place, and plastic intake and output are carefully tracked. Certification means a lot in a world where lax standards often let unscrupulous recyclers purchase brand new plastic bottles, lie about their sourcing, and sell them to unwitting companies that want to use recyclables in their products. This is much cheaper than the process required to clean and process post-consumer bottles. It is also completely at odds with sustainability goals.

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At the bottle processing facility used by Girlfriend Collective, bales of bottles collected from across Taiwan are weighed, logged, steam washed to remove caps and labels, and then separated by color. Clear bottles are used to make fibers for leggings, and colored bottles are sent away for other uses. Next, bottles are shred into tiny chips, washed again, bagged, and sent to the fiber-making facility. By weighing and logging each bag, the factory verifies that the output equals the input of plastic bottles used to create it. Thus, buyers like Girlfriend Collective know with certainty that the chips came from the same post-consumer bottles originally taken in.

Making Fabric

Bags of raw PET chips travel from the recycling facility to the spinning mill where they are washed again, dried, and sent to storage silos. Next, the chips are heated and extruded. The process yields long, spaghetti-like strands that will be cut into tiny pellets. Pellets go through one more round of heating and extrusion, eventually yielding superfine thread. The thread is spun into yarn and onto large bobbins for packaging and shipment. Once the yarn arrives at Girlfriend Collective's highly unique knitting factory, it will be turned into a material that is softer and more stable than traditional fabrics. The innovative knitting technique, however, is a very slow and precise process that in 24 hours only yields enough fabric to make about 100 pairs of leggings.

From knitting, the fabric goes to the dye house. For many companies, this is an environmentally harmful process that dumps red or blue wastewater from chemicals and dyes into streams and rivers on their way to community water tables, harming both people and crops. In contrast, Girlfriend Collective's facility treats all wastewater at a plant located 100 feet from the dyeing process. Certified safe dyes and any remaining fibers are removed from the water, and the water is tested for safety, approved by Taiwan's environmental agency, and only then released into a stream. Finally, while many companies send dye mud to landfills, Girlfriend Collective's facility sends it to a factory that turns it into pavers for community sidewalks.

Recycled Nylon

Always looking for new ideas, Girlfriend Collective has fashioned its newest line of LITE leggings from recycled fishing nets and other nylon waste that would typically be dumped in oceans or landfills. Instead, the nylon discards make their way to a recycling facility to be given a new life. This helps to cut down on the 14 billion pounds of waste dumped into oceans every year, 10 percent of which is old fishing gear. It also means fewer brand-new raw materials, like crude oil, are needed in the nylon production process.

Cutting and Sewing

Fourteen people are needed to cut and sew every pair of leggings, making these steps the most labor-intensive part of the clothing manufacturing process. Girlfriend Collective takes pride in caring for workers, as well as caring for the environment. It partners with an SA8000 Danish, family-owned sewing facility in Vietnam with a history of treating employees well and paying them fairly. Some employee perks include a pay rate 25 percent above minimum wage, company-led exercise breaks, free catered meals, free bi-annual health checks, and health insurance. The SA8000 certification specifically ensures no forced labor or child labor are used and requires safe working conditions and the right to unionize. All of the by-laws and employee regulations guaranteed by SA8000 are even included on Girlfriend Collective’s website.

Conclusion

From start to finish, Girlfriend Collective raises the bar on what sustainability really means and sets best practices for the garment industry.

Questions

1. What operations strategies are important at Girlfriend Collective?
2. In what ways do these strategies put Girlfriend Collective at a competitive advantage or disadvantage?
3. What short- and long-term impacts do Girlfriend Collective’s business practices have on the garment industry? On recyclers? On communities? On profits?
4. How might sustainability measures for people and production processes impact productivity? How can companies balance a desire for ethics with productivity concerns?

Based on: “About Girlfriend Collective,” https://www.girlfriend.com/pages/about

OPERATIONS TOUR

THE U.S. POSTAL SERVICE

"Neither rain, nor snow . . ."

The U.S. Postal Service (USPS) is the largest postal service in the world, handling about 47 percent (630 million pieces a day) of the world's mail volume. The second largest is Japan's, which handles only about 6 percent of the world's mail. The USPS is huge by any standard. It employs over 635,000 workers, making it the largest civilian employer in the United States. It has over 300,000 mail collection boxes, 38,000 post offices, 130 million mail delivery points, more than 300 processing plants to sort and ship mail, and more than 75,000 pieces of mail processing equipment. It handles over 100 billion pieces of first-class mail a year, and ships about 3 billion pounds of mail on commercial airline flights, making it the airlines' largest shipper.

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Processing First-Class Mail

The essence of processing the mail is sorting, which means organizing the mail into smaller and smaller subgroups to facilitate its timely delivery. Sorting involves a combination of manual and automatic operations. Much of the mail that is processed is first-class mail.

Most first-class mail is handled using automated equipment. A small portion that cannot be handled by automated equipment must be sorted by hand, just the way it was done in colonial times.

The majority of first-class mail begins at the advanced facer canceling system. This system positions each letter so that it is face up, with the stamp in the upper corner, checks to see if the address is handwritten, and pulls the hand-addressed letters off the line. It also rejects letters that have the stamp covered by tape, have no postage, are third-class mail, or have meter impressions that are too light to read. The rejects are handled manually. The remaining letters are canceled and date stamped, and then sorted to one of seven stackers.

Next, the letters go to the multiline optical character readers, which can handle both printed and pre–bar-coded mail, but not hand-addressed mail. The optical reader sprays a bar code on the mail that hasn't been pre–bar-coded, which represents up to an 11-digit zip code. For hand-addressed mail, a camera focuses on the front of the letter, and the image is displayed on a remote terminal, often in another city, where an operator views the image and provides the information that the optical readers could not determine so that a bar code can be added.

Bar-code readers then sort the mail into one of 96 stackers, doing this at a rate of more than 500 a minute. The mail goes through another sort using manually controlled mechanical equipment. At that point, the mail is separated according to whether it is local or out-of-town mail. The out-of-town mail is placed into appropriate sacks according to its destination, and moved to the outgoing send area where it will be loaded on trucks.

The local mail is moved to another machine that not only sorts the mail into local carrier delivery routes, it sorts it according to delivery walk sequence!

Small parcels, bundles of letters, and bundles of flats are sorted by a bundle-sorting machine.

Productivity

Over the years, the USPS has experienced an ever-increasing volume of mail. Productivity has been an important factor for the USPS in keeping postal rates low and maintaining rapid delivery service. Two key factors in improved productivity have been the increased use of automation and the introduction of zip codes.

Mail processing underwent a major shift to mechanization during the 1950s and 1960s, which led to more rapid processing and higher productivity. In 1978, an expanded zip code was introduced. That was followed in 1983 by a four-digit expansion in zip codes. These changes required new, automated processing equipment, and the use of bar codes and optical readers. All of these changes added greatly to productivity. But even with these improvements, the USPS faced increasing competitive pressures.

Competition

In the late 1980s, the USPS experienced a slowdown in the volume of mail. Some of this was due to a slowing of the economy, but most of it was the result of increasing competition. Delivery giants FedEx and UPS, as well as other companies that offer speedy delivery and package tracking, gave businesses and the general public convenient alternatives for some mail services. At the same time, there was a growing use of fax machines and electronic communications and increased use of alternate forms of advertising such as cable TV, all of which cut into the volume of mail. Early in this century, e-mail and automated bill paying also cut into mail volume.

Strategies and Tactics Used to Make the Postal Service More Competitive

To meet these challenges, the USPS developed several strategies to become more competitive. These included reorganizing, continuing to seek ways to keep costs down, increasing productivity, and emphasizing quality and customer service. Here is an overview of the situation and the strategies and tactics used by the USPS.

The USPS began working more closely with customers to identify better ways to meet their needs and expanded customer conveniences such as stamps on consignment. With the help of business mailers, the USPS continued support for rates reflecting customer work-sharing features, many tied to automation, to give customers more flexibility. At the same time, the USPS began forming Customer Advisory Councils—groups of citizens who volunteered to work with local postal management on postal issues of interest to the community. In 1990, the USPS awarded two contracts to private firms to measure first-class mail service and customer satisfaction. In 1992, the USPS stepped up its quest to become more competitive by reducing bureaucracy and overhead in order to improve service and customer satisfaction, and to reduce the need to increase postage rates.

To help accomplish these goals, the USPS underwent a reorganization. Layers of management were eliminated and overhead positions were cut by about 30,000. Five regions and 73 field divisions were replaced by 10 areas, each with a manager for customer services and a manager for processing and distribution. Ten customer service areas were established, with managers for customer service and processing and distribution in each area, as well as a marketing and sales office. The new structure allowed postal managers to be focused, improved communications, and empowered employees to meet customer needs. The USPS also took other steps to improve service. In 1993, it implemented improvements in processing and mail delivery at major postal facilities, expanded retail hours, and developed a more user-friendly Domestic Mail Manual. In cooperation with business customers, the USPS began to develop new services to meet specific mailer needs and to overhaul and simplify its complex rate structure. It also awarded contracts for two more external tracking systems, one to measure satisfaction levels of business mailers, and the other to measure service performance of third-class mail.

The reorganization eliminated some programs, cut costs, attracted new business, and reduced the USPS’s projected deficit.

The postal services’ sustainability scorecard for 2015 is shown as follows.

United States Postal Service

January 2015 OMB Scorecard on **Sustainability/Energy**

Scope 1&2 GHG Emission Reduction Target For Scope 1&2 GHG Reduction Target of 20% by 2020: 17% reduction in 2014 and on track	Score: **GREEN**
Scope 3GHG Emission Reduction Target For Scope 3GHG Reduction Target of 20% by 2020: 24% reduction in 2014 and on track	Score: **GREEN**
Reduction in Energy Intensity Reduction in energy intensity in goal-subject facilities compared with 2003: 32% and on track for 30% by 2015	Score: **GREEN**
Use of Renewable Energy Not applicable	Score: **N/A**
Reduction in Potable Water Intensity Reduction in potable water intensity compared with 2007: 30% and on track for 26% in 2020	Score: **GREEN**
Reduction in Fleet Petroleum Use Reduction in fleet petroleum use compared to 2005: 10.1% increase and not on track	Score: **RED**
Green Buildings Not applicable	Score: **N/A**

Questions

1. Why is it important for the USPS to have a high volume of mail to process?
2. What caused productivity to increase?
3. What impact did competitive pressures have on the USPS?

4. What measures did the USPS adopt to increase competitiveness?
5. What results were achieved by the USPS's changes?
6. What effect does the increased use of e-mail have on postal productivity?
7. How does the use of standard shipping containers and flat-rate mailers help competitiveness?

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Standards for Success — *Red Standard, Yellow Standard, Green Standard*

Scope 1&2 GHG Emission Reduction Target	**GREEN: On track to achieve agency's proposed 2020 GHG Scopes 1&2 emissions reduction target.** **YELLOW:** Less than a year behind glide path to achieve agency's 2020 target for GHG Scopes 1&2. **RED:** More than a year behind glide path to achieve agency's 2020 target for GHG Scopes 1&2.
Scope 3 GHG Emission Reduction Target	**GREEN: On track to achieve agency's proposed 2020 GHG Scope 3 emissions reduction target.** **YELLOW:** Less than a year behind glide path to achieve agency's 2020 target for GHG Scope 3. **RED:** More than a year behind glide path to achieve agency's 2020 target for GHG Scope 3.
Reduction in Energy Intensity	**GREEN:** Reduced energy intensity (Btu/GSF*) in EISA goal-subject facilities by at least 27 percent compared with 2003 and is on track for 30 percent reduction by 2015.

	YELLOW: Reduced energy intensity (Btu/GSF) in EISA goal-subject facilities by at least 24 percent compared with 2003. **RED:** Did not reduce energy intensity (Btu/GSF) in EISA goal-subject facilities by at least 24 percent compared with 2003.
Use of Renewable Energy	**GREEN:** Uses at least 7.5 percent electricity from renewable sources as a percentage of facility electricity use and at least 3.75 percent of facility electricity use comes from new sources (post-1999). (Thermal and mechanical renewable can be included in the 3.75 percent new requirement, but not the 7.5 percent goal; i.e., an agency meets all new sources requirement with thermal or mechanical energy (3.75 percent) but would still need an additional 7.5 percent from renewable electricity sources.) **YELLOW:** Uses at least 7.5 percent renewable energy from electric, thermal, or mechanical sources to power facilities and equipment; but less than half was obtained from new sources (post-1999) or part of the requirement was met with thermal and mechanical renewable energy. **RED:** Did not use at least 7.5 percent renewable energy from electric, thermal, or mechanical sources to power facilities and equipment.
Reduction in Potable Water Intensity	**GREEN:** Reduced water intensity by at least 14 percent from final approved 2007 baseline and is on track for 26 percent reduction by 2020. **YELLOW:** Reduced water intensity by at least 12 percent from final approved 2007 baseline. **RED:** Did not reduce water intensity by at least 12 percent from final approved 2007 baseline.

Reduction in Fleet Petroleum Use	**GREEN:** Achieved an 18 percent reduction in petroleum use in its entire vehicle fleet compared to 2005 and is on track for 20 percent reduction by 2015. **YELLOW:** Achieved at least 16 percent reduction in petroleum use in the entire vehicle fleet compared to 2005. **RED:** Did not achieve at least 16 percent reduction in petroleum use in its entire vehicle fleet since 2005.
Green Buildings	**GREEN:** Demonstrates implementation of Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings (GP) for new, existing and leased buildings; and is on track to meet 15% goal by 2015 by reporting that at least 13 percent of buildings over 5,000 GSF meet GP as reported in the Federal Real Property Profi (FRPP). **YELLOW:** Incorporates Guiding Principles into all new design contracts for construction, major renovations, and leases and at least 13 percent of GSF of its building inventory over 5,000 GSF meets GP as reported in FRPP. **RED:** Cannot demonstrate compliance with GP on new construction, major renovations, or leases; and/or less than 13 percent of building inventory, either by number of buildings or GSF, over 5,000 GSF meets GP as reported in FRPP.

*GSF = Gross Square Footage

Source: United States Postal Service

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CHAPTER 3 Forecasting

LEARNING OBJECTIVES

After completing this chapter, you should be able to:

LO3.1 List features common to all forecasts.

LO3.2 Explain why forecasts are generally wrong.

LO3.3 List the elements of a good forecast.

LO3.4 Outline the steps in the forecasting process.

LO3.5 Describe four qualitative forecasting techniques.

LO3.6 Use a naive method to make a forecast.

LO3.7 Prepare a moving average forecast.

LO3.8 Prepare a weighted-average forecast.

LO3.9 Prepare an exponential smoothing forecast.

LO3.10 Prepare a linear trend forecast.

LO3.11 Prepare a trend-adjusted exponential smoothing forecast.

LO3.12 Compute and use seasonal relatives.

LO3.13 Compute and use regression and correlation coefficients.

LO3.14 Summarize forecast errors and use summaries to make decisions.

LO3.15 Construct control charts and use them to monitor forecast errors.

LO3.16 Describe the key factors and trade-offs to consider when choosing a forecasting technique.

CHAPTER OUTLINE

Photodisc/Getty Images

Weather forecasts are one of the many types of forecasts used by some business organizations. Although some businesses simply rely on publicly available weather forecasts, others turn to firms that specialize in weather-related forecasts. For example, Home Depot, Gap, and JCPenney use such firms to help them take weather factors into account for estimating demand.

Many new car buyers have a thing or two in common. Once they make the decision to buy a new car, they want it as soon as possible. They usually don't want to order it and then have to wait six weeks or more for delivery. If the car dealer they visit doesn't have the car they want, they'll look elsewhere. Hence, it is important for a dealer to *anticipate* buyer wants and to have those models, with the necessary options, in stock. The dealer who can correctly forecast buyer wants, and have those cars available, is going to be much more successful than a competitor who guesses instead of forecasting—and guesses wrong—and gets stuck with cars customers don't want. So how does the dealer know how many cars of each type to stock? The answer is, the dealer *doesn't* know for sure, but by analyzing previous buying patterns, and perhaps making allowances for current conditions, the dealer can come up with a reasonable *approximation* of what buyers will want.

Planning is an integral part of a manager's job. If uncertainties cloud the planning horizon, managers will find it difficult to plan effectively. Forecasts help managers by reducing some of the uncertainty, thereby enabling them to develop more

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meaningful plans. A **forecast** is an estimate about the future value of a variable such as demand. The better the estimate, the more informed decisions can be. Some forecasts are long range, covering several years or more. Long-range forecasts are especially important for decisions that will have long-term consequences for an organization or for a town, city, country, state, or nation. One example is deciding on the right capacity for a planned power plant that will operate for the next 40 years. Other forecasts are used to determine if there is a profit potential for a new service or a new product: Will there be sufficient demand to make the innovation worthwhile? Many forecasts are short term, covering a day or week. They are especially helpful in planning and scheduling day-to-day operations. This chapter provides a survey of business forecasting. It describes the elements of good forecasts, the necessary steps in preparing a forecast, basic forecasting techniques, and how to monitor a forecast.

Forecast A statement about the future value of a variable of interest.

3.1 INTRODUCTION

Forecasts are a basic input in the decision processes of operations management because they provide information on future demand. The importance of forecasting to operations management cannot be overstated. The primary goal of operations management is to match supply to demand. Having a forecast of demand is essential for determining how much capacity or supply will be needed to meet demand. For instance, operations needs to know what capacity will be needed to make staffing and equipment decisions, budgets must be prepared, purchasing needs information for ordering from suppliers, and supply chain partners need to make their plans.

Businesses make plans for future operations based on anticipated future demand. Anticipated demand is derived from two possible sources, actual customer orders and forecasts. For businesses where customer orders make up most or all of anticipated demand, planning is straightforward, and little or no forecasting is needed. However, for many businesses, most or all of anticipated demand is derived from forecasts.

Two aspects of forecasts are important. One is the expected level of demand; the other is the degree of accuracy that can be assigned to a forecast (i.e., the potential size of forecast error). The expected level of demand can be a function of some structural variation, such as a trend or seasonal variation. Forecast accuracy is a function of the ability of forecasters to correctly model demand, random variation, and sometimes unforeseen events.

Forecasts are made with reference to a specific time horizon. The time horizon may be fairly short (e.g., an hour, day, week, or month), or somewhat longer (e.g., the next six months, the next year, the next five years, or the life of a product or service). Short-term forecasts pertain to ongoing operations. Long-range forecasts can be an important strategic planning tool. Long-term forecasts pertain to new products or services, new equipment, new facilities, or something else that will require a somewhat long lead time to develop, construct, or otherwise implement.

Forecasts are the basis for budgeting, planning capacity, sales, production and inventory, personnel, purchasing, and more. Forecasts play an important role in the planning process because they enable managers to anticipate the future so they can plan accordingly.

Forecasts affect decisions and activities throughout an organization, in accounting, finance, human resources, marketing, and management information systems (MIS), as well as in operations and other parts of an organization. Here are some examples of uses of forecasts in business organizations:

Accounting. New product/process cost estimates, profit projections, cash management.

Finance. Equipment/equipment replacement needs, timing and amount of funding/borrowing needs.

Human resources. Hiring activities, including recruitment, interviewing, and training; layoff planning, including outplacement counseling.

Marketing. Pricing and promotion, e-business strategies, global competition strategies.

MIS. New/revised information systems, internet services.

Operations. Schedules, capacity planning, work assignments and workloads, inventory planning, make-or-buy decisions, outsourcing, project management.

Product/service design. Revision of current features, design of new products or services.

In most of these uses of forecasts, decisions in one area have consequences in other areas. Therefore, it is very important for all affected areas to agree on a common forecast. However, this may not be easy to accomplish. Different departments often have very different perspectives on a forecast, making a consensus forecast difficult to achieve. For example, salespeople, by their very nature, may be overly optimistic with their forecasts, and may want to “reserve” capacity for their customers. This can result in excess costs for operations and inventory storage. Conversely, if demand exceeds forecasts, operations and the supply chain may not be able to meet demand, which would mean lost business and dissatisfied customers.

Forecasting is also an important component of yield management, which relates to the percentage of capacity being used. Accurate forecasts can help managers plan tactics (e.g., offer discounts, don’t offer discounts) to match capacity with demand, thereby achieving high-yield levels.

There are two uses for forecasts. One is to help managers plan the system, and the other is to help them plan the use of the system. Planning the system generally involves long-range plans about the types of products and services to offer, what facilities and equipment to have, where to locate, and so on. Planning the use of the system refers to short-range and intermediate-range planning, which involve tasks such as planning inventory and workforce levels, planning purchasing and production, budgeting, and scheduling.

Business forecasting pertains to more than predicting demand. Forecasts are also used to predict profits, revenues, costs, productivity changes, prices and availability of energy and raw materials, interest rates, movements of key economic indicators (e.g., gross domestic product, inflation, government borrowing), and prices of stocks and bonds. For the sake of simplicity, this chapter will focus on the forecasting of demand. Keep in mind, however, that the concepts and techniques apply equally well to the other variables.

The Walt Disney World forecasting department has 20 employees who formulate forecasts on volume and revenue for the theme parks, water parks, resort hotels, as well as merchandise, food, and beverage revenue by location.

Peter Cosgrove/AP Images

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Despite of its use of computers and sophisticated mathematical models, forecasting is not an exact science. Instead, successful forecasting often requires a skillful blending of science and intuition. Experience, judgment, and technical expertise all play a role in developing useful forecasts. Along with these, a certain amount of luck and a dash of humility can be helpful, because the worst forecasters occasionally produce a very good forecast, and even the best forecasters sometimes miss completely. Current forecasting techniques range from the mundane to the exotic. Some work better than others, but no single technique works all the time.

3.2 FEATURES COMMON TO ALL FORECASTS

LO3.1 List features common to all forecasts.

LO3.2 Explain why forecasts are generally wrong.

A wide variety of forecasting techniques are in use. In many respects, they are quite different from each other, as you shall soon discover. Nonetheless, certain features are common to all, and it is important to recognize them.

- Forecasting techniques generally assume that the same underlying causal system that existed in the past will continue to exist in the future.

Comment A manager cannot simply delegate forecasting to models or computers and then forget about it, because unplanned occurrences can wreak havoc with forecasts. For instance, weather-related events, tax increases or decreases, and changes in features or prices of competing products or services can have a major impact on demand. Consequently, a manager must be alert to such occurrences and be ready to override forecasts, which assume a stable causal system.

- Forecasts are not perfect; actual results usually differ from predicted values; the presence of randomness precludes a perfect forecast. Allowances should be made for forecast errors.
- Forecasts for groups of items tend to be more accurate than forecasts for individual items because forecasting errors among items in a group usually have a canceling effect. Opportunities for grouping may arise if

parts or raw materials are used for multiple products or if a product or service is demanded by a number of independent sources.

- Forecast accuracy decreases as the time period covered by the forecast—the *time horizon*—increases. Generally speaking, short-range forecasts must contend with fewer uncertainties than longer-range forecasts, so they tend to be more accurate.

An important consequence of the last point is that flexible business organizations—those that can respond quickly to changes in demand—require a shorter forecasting horizon and, hence, benefit from more accurate short-range forecasts than competitors who are less flexible and who must therefore use longer forecast horizons.

3.3 ELEMENTS OF A GOOD FORECAST

LO3.3 List the elements of a good forecast.

A properly prepared forecast should fulfill certain requirements:

- The forecast should be **timely.** Usually, a certain amount of time is needed to respond to the information contained in a forecast. For example, capacity cannot be expanded overnight, nor can inventory levels be changed immediately. Hence, the forecasting horizon must cover the time necessary to implement possible changes.
- The forecast should be **accurate,** and the degree of accuracy should be stated. This will enable users to plan for possible errors and will provide a basis for comparing alternative forecasts.
- The forecast should be **reliable;** it should work consistently. A technique that sometimes provides a good forecast and sometimes a poor one will leave users with the uneasy feeling that they may get burned every time a new forecast is issued.
- The forecast should be expressed in **meaningful units.** Financial planners need to know how many *dollars* will be needed, production planners need to know how many *units* will be needed, and

schedulers need to know what *machines* and *skills* will be required. The choice of units depends on user needs.

- The forecast should be **in writing.** Although this will not guarantee that all concerned are using the same information, it will at least increase the likelihood of it. In addition, a written forecast will permit an objective basis for evaluating the forecast once actual results are in.
- The forecasting technique should be **simple to understand and use.** Users often lack confidence in forecasts based on sophisticated techniques; they do not understand either the circumstances in which the techniques are appropriate or the limitations of the techniques. Misuse of techniques is an obvious consequence. Not surprisingly, fairly simple forecasting techniques enjoy widespread popularity because users are more comfortable working with them.
- The forecast should be **cost-effective:** The benefits should outweigh the costs.

3.4 FORECASTING AND THE SUPPLY CHAIN

Accurate forecasts are very important for the supply chain. Inaccurate forecasts can lead to shortages and excesses throughout the supply chain. Shortages of materials, parts, and services can lead to missed deliveries, work disruption, and poor customer service. Conversely, overly optimistic forecasts can lead to excesses of materials and/or capacity, which increase costs. Both shortages and excesses in the supply chain have a negative impact not only on customer service but also on profits. Furthermore, inaccurate forecasts can result in temporary increases and decreases in orders to the supply chain, which can be misinterpreted by the supply chain.

Organizations can reduce the likelihood of such occurrences in a number of ways. One, obviously, is by striving to develop the best possible forecasts. Another is through collaborative planning and forecasting with major supply chain partners. Yet another way is through information sharing among partners and perhaps increasing supply chain visibility by allowing supply chain partners to have real-time access to sales and inventory information. Also important is rapid communication about poor forecasts, as well as about unplanned events that disrupt operations (e.g., flooding, work stoppages), and changes in plans.

3.5 STEPS IN THE FORECASTING PROCESS

LO3.4 Outline the steps in the forecasting process.

There are six basic steps in the forecasting process:

1. **Determine the purpose of the forecast.** How will it be used and when will it be needed? This step will provide an indication of the level of detail required in the forecast, the amount of resources (personnel, computer time, dollars) that can be justified, and the level of accuracy necessary.
2. **Establish a time horizon.** The forecast must indicate a time interval, keeping in mind that accuracy decreases as the time horizon increases.
3. **Obtain, clean, and analyze appropriate data.** Obtaining the data can involve significant effort. Once obtained, the data may need to be "cleaned" to get rid of outliers and obviously incorrect data before analysis.
4. **Select a forecasting technique.**
5. **Make the forecast.**
6. **Monitor the forecast errors.** The forecast errors should be monitored to determine if the forecast is performing in a satisfactory manner. If it is not, reexamine the method, assumptions, the validity of data, and so on; modify as needed; and prepare a revised forecast.

Once the process has been set up, it may only be necessary to repeat steps 3 and 6 as new data become available.

Note, too, that additional action may be necessary. For example, if demand was much less than the forecast, an action such as a price reduction or a promotion may be needed. Conversely, if demand was much more than predicted, increased output may be advantageous. That may involve working overtime, outsourcing, or taking other measures.

3.6 APPROACHES TO FORECASTING

There are two general approaches to forecasting: qualitative and quantitative. Qualitative methods consist mainly of subjective inputs, which often defy precise numerical description. Quantitative methods involve either the projection of historical data or the development of associative models that attempt to utilize *causal (explanatory) variables* to make a forecast.

Qualitative techniques permit inclusion of *soft* information (e.g., human factors, personal opinions, hunches) in the forecasting process. Those factors are often omitted or downplayed when quantitative techniques are used because they are difficult or impossible to quantify. Quantitative techniques consist mainly of analyzing objective, or *hard,* data. They usually avoid personal biases that sometimes contaminate qualitative methods. In practice, either approach, or a combination of both approaches, might be used to develop a forecast.

The following pages present a variety of forecasting techniques that are classified as judgmental, time-series, or associative.

Judgmental forecasts rely on analysis of subjective inputs obtained from various sources, such as consumer surveys, the sales staff, managers and executives, and panels of experts. Quite frequently, these sources provide insights that are not otherwise available.

Judgmental forecasts Forecasts that use subjective inputs such as opinions from consumer surveys, sales staff, managers, executives, and experts.

Time-series forecasts simply attempt to project past experience into the future. These techniques use historical data with the assumption that the future will be like the past. Some models merely attempt to smooth out random variations in historical data; others attempt to identify specific patterns in the data and project or extrapolate those patterns into the future, without trying to identify causes of the patterns.

Time-series forecasts Forecasts that project patterns identified in recent time-series observations.

Associative models use equations that consist of one or more *explanatory* variables that can be used to predict demand. For example, demand for paint might be related to variables such as the price per gallon and the amount spent on advertising, as well as to specific characteristics of the paint (e.g., drying time, ease of cleanup).

Associative model Forecasting technique that uses explanatory variables to predict future demand.

3.7 QUALITATIVE FORECASTS

LO3.5
Describe four qualitative forecasting techniques.

In some situations, forecasters rely solely on judgment and opinion to make forecasts. If management must have a forecast quickly, there may not be enough time to gather and analyze quantitative data. At other times, especially when political and economic conditions are changing, available data may be obsolete, and more up-to-date information might not yet be available. Similarly, the introduction of new products and the redesign of existing products or packaging suffer from the absence of historical data that would be useful in forecasting. In such instances, forecasts are based on executive opinions, consumer surveys, opinions of the sales staff, and opinions of experts.

Executive Opinions

A small group of upper-level managers (e.g., in marketing, operations, and finance) may meet and collectively develop a forecast. This approach is often used as a part of long-range planning and new product development. It has the advantage of bringing together the considerable knowledge and talents of various managers. However, there is the risk that the view of one person will prevail, and the possibility that diffusing responsibility for the forecast over the entire group may result in less pressure to produce a good forecast.

Salesforce Opinions

Members of the sales staff or the customer service staff are often good sources of information because of their direct contact with consumers. They are often aware of any plans the customers may be considering for the future. There are, however, several drawbacks to using salesforce opinions. One is that staff members may be unable to distinguish between what customers would *like* to do and what they actually *will* do. Another is that these people are sometimes overly influenced by recent experiences. Thus, after several periods of low sales, their estimates may tend to become pessimistic. After several periods of good sales, they may tend to be too optimistic. In addition, if forecasts are used to establish sales quotas, there will be a conflict of interest because it is to the salesperson's advantage to provide low sales estimates.

Consumer Surveys

Because it is the consumers who ultimately determine demand, it seems natural to solicit input from them. In some instances, every customer or potential customer can be contacted. However, usually there are too many customers or there is no way to identify all potential customers. Therefore, organizations seeking consumer input usually resort to consumer surveys, which enable them to *sample* consumer opinions. The obvious advantage of consumer surveys is that they can tap information that might not be available elsewhere. On the other hand, a considerable amount of knowledge and skill is required to construct a survey, administer it, and correctly interpret the results for valid information. Surveys can be expensive and time-consuming. In addition, even under the best conditions, surveys of the general public must contend with the possibility of irrational behavior patterns. For example, much of the consumer's thoughtful information gathering before purchasing a new car is often undermined by the glitter of a new car showroom or a high-pressure sales pitch. Along the same lines, low response rates to a mail survey should—but often don't—make the results suspect.

If these and similar pitfalls can be avoided, surveys can produce useful information.

Other Approaches

A manager may solicit opinions from a number of other managers and staff people. Occasionally, outside experts are needed to help with a forecast. Advice may be needed on political or economic conditions in the United States or a foreign country, or some other aspect of importance with which an organization lacks familiarity.

Another approach is the **Delphi method**, an iterative process intended to achieve a consensus forecast. This method involves circulating a series of questionnaires among individuals who possess the knowledge and ability to contribute meaningfully. Responses are kept anonymous, which tends to encourage honest responses and reduces the risk that one person's opinion will prevail. Each new questionnaire is developed using the information extracted from the previous one, thus enlarging the scope of information on which participants can base their judgments.

Delphi method An iterative process in which managers and staff complete a series of questionnaires, each developed from the previous one, to achieve a consensus forecast.

The Delphi method has been applied to a variety of situations, not all of which involve forecasting. The discussion here is limited to its use as a forecasting tool.

As a forecasting tool, the Delphi method is useful for *technological* forecasting; that is, for assessing changes in technology and their impact on an organization. Often, the goal is to predict *when* a certain event will occur. For instance, the goal of a Delphi forecast might be to predict when video telephones might be installed in at least 50 percent of residential homes or when a vaccine for a disease might be developed and ready for mass distribution. For the most part, these are long-term, single-time forecasts, which usually have very little hard information to go by or data that are costly to obtain, so the problem does not lend itself to analytical techniques. Rather, judgments of experts or others who possess sufficient knowledge to make predictions are used.

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3.8 FORECASTS BASED ON TIME-SERIES DATA

A **time series** is a time-ordered sequence of observations taken at regular intervals (e.g., hourly, daily, weekly, monthly, quarterly, annually). The data may be measurements of demand, sales, earnings, profits, shipments, accidents, output, precipitation, productivity, or the consumer price index. Note that forecasts based on sales will understate demand when demand exceeds sales, causing shortages (stockouts) to occur. Forecasting techniques based on time-series data are made on the assumption that future values of the series can be estimated from past values. Although no attempt is made to identify variables that influence the series, these methods are widely used, often with quite satisfactory results.

Time series A time-ordered sequence of observations taken at regular intervals.

Analysis of time-series data requires the analyst to identify the underlying behavior of the series. This can often be accomplished by merely *plotting the data* and visually examining the plot. One or more patterns might appear: trends, seasonal variations, cycles, or variations around an average. In addition, there will be random and perhaps irregular variations. These behaviors can be described as follows:

. **Trend** refers to a long-term upward or downward movement in the data. Population shifts, changing incomes, and cultural changes often account for such movements.

Trend A long-term upward or downward movement in data.

. **Seasonality** refers to short-term, fairly regular variations generally related to factors such as the calendar or time of day. Restaurants, supermarkets, and theaters experience weekly and even daily "seasonal" variations.

Seasonality Short-term regular variations related to the calendar or time of day.

. **Cycles** are wavelike variations of more than one year's duration. These are often related to a variety of economic, political, and even agricultural conditions.

Cycle Wavelike variations lasting more than one year.

. **Irregular variations** are due to unusual circumstances such as severe weather conditions, strikes, or a major change in a product or service. They do not reflect typical behavior, and their inclusion in the series can distort the overall picture. Whenever possible, these should be identified and removed from the data.

Irregular variation Caused by unusual circumstances, not reflective of typical behavior.

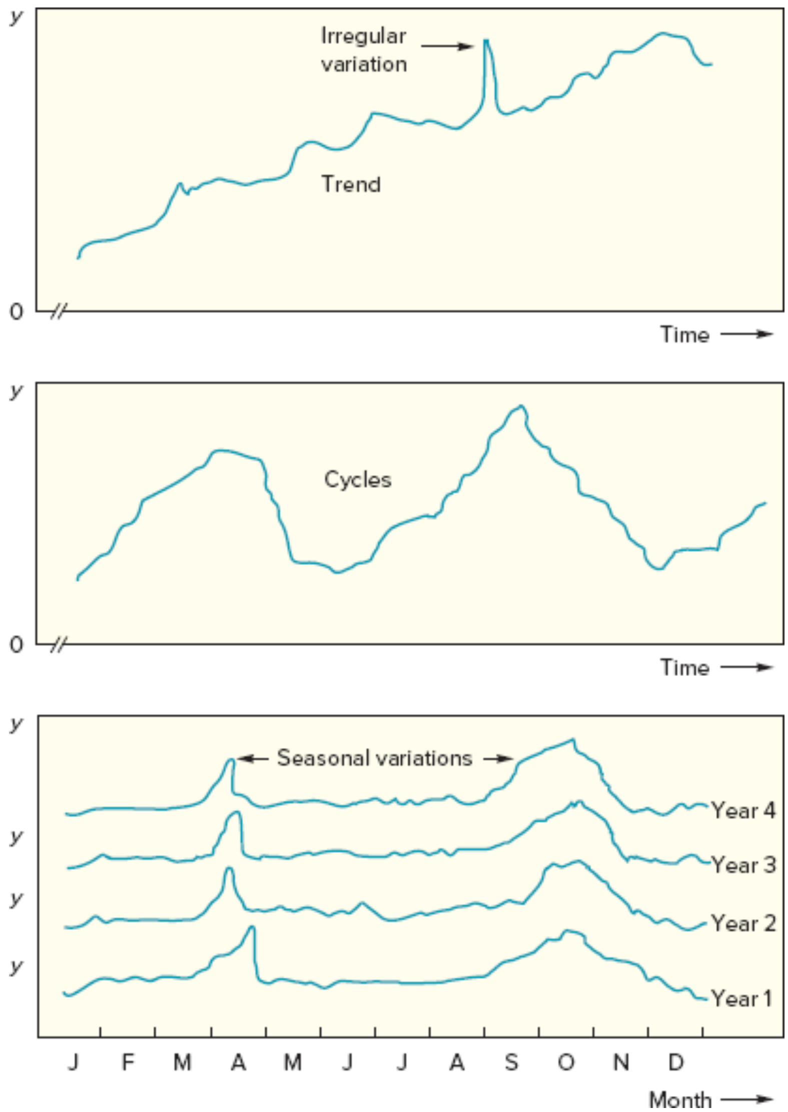
. **Random variations** are residual variations that remain after all other behaviors have been accounted for.

Random variations Residual variations after all other behaviors are accounted for.

These behaviors are illustrated in Figure 3.1. The small "bumps" in the plots represent random variability.

FIGURE 3.1

Trend, cyclical, and seasonal data plots, with random and irregular variations



The remainder of this section describes the various approaches to the analysis of time-series data. Before turning to those discussions, one point should be emphasized: A demand forecast should be based on a time series of past *demand* rather than unit sales. Sales would not truly reflect demand if one or more *stockouts* occurred.

Naive Methods

LO3.6 Use a naive method

to make a forecast.

A simple but widely used approach to forecasting is the naive approach. A **naive forecast** uses a single previous value of a time series as the basis of a forecast. The naive approach can be used with a stable series (variations around an average), with seasonal variations, or with trend. With a stable series, the last data point becomes the forecast for the next period. Thus, if demand for a product last week was 20 cases, the forecast for this week is 20 cases. With seasonal variations, the forecast for this "season" is equal to the value of the series last "season." For example, the forecast for demand for turkeys this Thanksgiving season is equal to demand for turkeys last Thanksgiving; the forecast of the number of checks cashed at a bank on the first day of the month next month is equal to the number of checks cashed on the first day of this month; and the forecast for highway traffic volume this Friday is equal to the highway traffic volume last Friday. For data with trend, the forecast is equal to the last value of the series plus or minus the difference between the last two values of the series. For example, suppose the last two values were 50 and 53. The next forecast would be 56:

Naive forecast A forecast for any period that equals the previous period's actual value.

Period	Actual	Change from Previous Value	Forecast
1	50		
2	53	+3	
3			53 + 3 = 56

Although at first glance the naive approach may appear *too* simplistic, it is nonetheless a legitimate forecasting tool. Consider the advantages: It has virtually no cost, it is quick and easy to prepare because data analysis is nonexistent, and it is easily understandable. The main objection to this method is its inability to provide highly accurate forecasts. However, if resulting accuracy is acceptable, this approach deserves serious consideration. Moreover, even if other forecasting techniques offer better accuracy, they will almost always involve a greater cost. The accuracy of a naive forecast can serve as a standard of comparison against which to judge the cost and accuracy of other techniques. Thus, managers must answer the question: Is the increased accuracy of another method worth the additional resources required to achieve that accuracy?

Techniques for Averaging

Historical data typically contain a certain amount of random variation, or *white noise,* that tends to obscure systematic movements in the data. This randomness arises from the combined influence of many—perhaps a great many—relatively unimportant factors, and it cannot be reliably predicted. Averaging techniques smooth variations in the data. Ideally, it would be desirable to completely remove any randomness from the data and leave only "real" variations, such as changes in the demand. As a practical matter, however, it is usually impossible to distinguish between these two kinds of variations, so the best one can hope for is that the small variations are random and the large variations are "real."

Averaging techniques smooth fluctuations in a time series because the individual highs and lows in the data offset each other when they are combined into an average. A forecast based on an average thus tends to exhibit less variability than the original data (see Figure 3.2). This can be advantageous because many of these movements merely reflect random variability rather than a true change in the series. Moreover, because responding to changes in expected demand often entails considerable cost (e.g., changes in production rate, changes in the size of a workforce, inventory changes), it is desirable to avoid reacting to minor variations. Thus, minor variations are treated as random variations, whereas larger variations are viewed as more likely to reflect "real" changes, although these, too, are smoothed to a certain degree.

FIGURE 3.2

Averaging applied to three possible patterns

Averaging techniques generate forecasts that reflect recent values of a time series (e.g., the average value over the last several periods). These techniques work best when a series tends to vary around an average, although they also can handle step changes or gradual changes in the level of the series. Three techniques for averaging are described in this section:

- Moving average
- Weighted moving average
- Exponential smoothing

Moving Average One weakness of the naive method is that the forecast just *traces* the actual data, with a lag of one period; it does not smooth at all. But by expanding the amount of historical data a forecast is based on, this difficulty can be overcome. A **moving average** forecast uses a *number* of the most recent actual data values in generating a forecast. The moving average forecast can be computed using the following equation:

Moving average Technique that averages a number of recent actual values, updated as new values become available.

LO3.7
Prepare a moving average forecast.

$$F_t = \mathrm{MA}_n = \frac{\sum_{i=1}^{n} A^{t-i}}{n} = \frac{A_{t-n} + \cdots + A_{t-2} + A_{t-1}}{n} \qquad (3\text{–}1)$$

where

F_t = Forecast for time period t
MA_n = n period moving average
A_{t-i} = Actual value in period $t - i$
n = Number of periods (data points) in the moving average

For example, MA_3 would refer to a three-period moving average forecast, and MA_5 would refer to a five-period moving average forecast.

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EXAMPLE 1 Computing a Moving Average

eXcel

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Compute a three-period moving average forecast given demand for shopping carts for the last five periods.

Period	Demand	
1	42	
2	40	
3	43	
4	40	the 3 most recent demands
5	41	

SOLUTION

$$F_6 = \frac{43 + 40 + 41}{3} = 41.33$$

If actual demand in period 6 turns out to be 38, the moving average forecast for period 7 would be

$$F_7 = \frac{40 + 41 + 38}{3} = 39.67$$

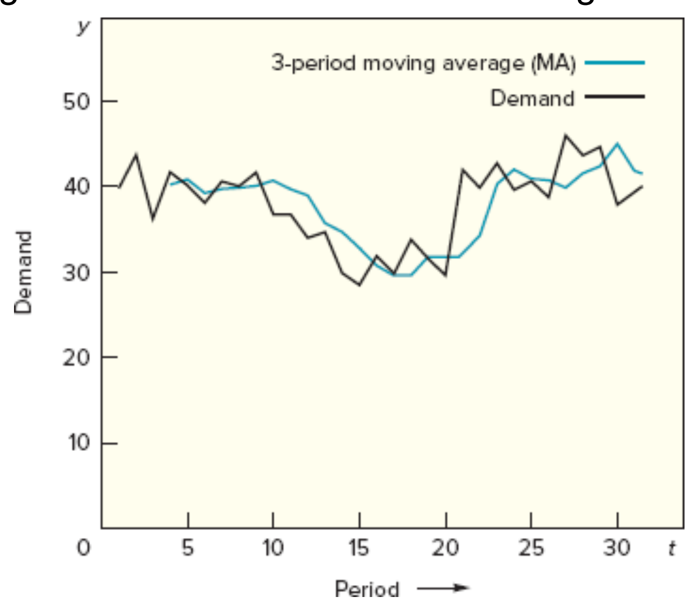
Note that in a moving average, as each new actual value becomes available, the forecast is updated by adding the newest value and dropping the oldest and then recomputing the average. Consequently, the forecast "moves" by reflecting only the most recent values.

In computing a moving average, including a *moving total* column—which gives the sum of the *n* most current values from which the average will be computed—aids computations. To update the moving total: Subtract the oldest value from the newest value and add that amount to the moving total for each update.

Figure 3.3 illustrates a three-period moving average forecast plotted against actual demand over 31 periods. Note how the moving average forecast *lags* the actual values and how *smooth* the forecasted values are compared with the actual values.

FIGURE 3.3

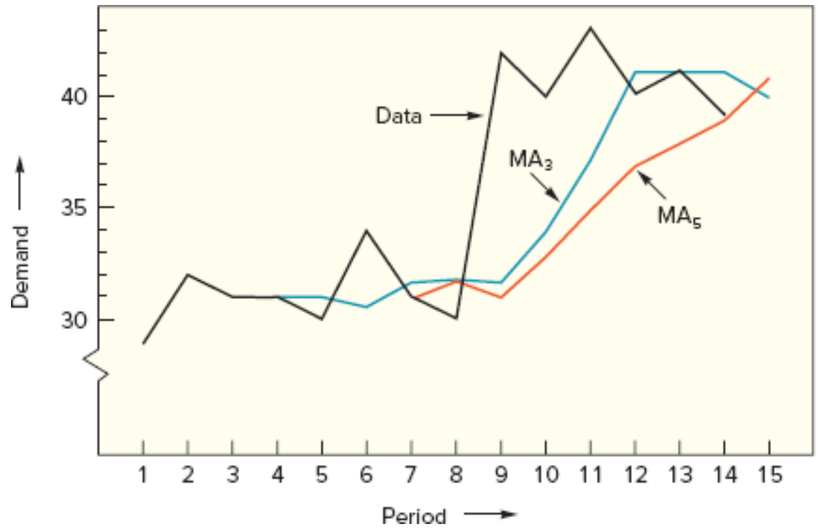
A moving average forecast tends to smooth and lag changes in the data



The moving average can incorporate as many data points as desired. In selecting the number of periods to include, the decision maker must take into account that the number of data points in the average determines its sensitivity to each new data point: The fewer the data points in an average, the more sensitive (responsive) the average tends to be. (See Figure 3.4A.)

FIGURE 3.4A

The more periods in a moving average, the greater the forecast will lag changes in the data



If responsiveness is important, a moving average with relatively few data points should be used. This will permit quick adjustment to, say, a step change in the data, but it also will cause the forecast to page 86 be somewhat responsive even to random variations. Conversely, moving averages based on more data points will smooth more but be less responsive to "real" changes. Hence, the decision maker must weigh the cost of responding more slowly to changes in the data against the cost of responding to what might simply be random variations. A review of forecast errors can help in this decision.

The advantages of a moving average forecast are that it is easy to compute and easy to understand. A possible disadvantage is that all values in the average are weighted equally. For instance, in a 10-period moving average, each value has a weight of 1/10. Hence, the oldest value has the *same weight* as the most recent value. If a change occurs in the series, a moving average forecast can be slow to react, especially if there are a large number of values in the average. Decreasing the number of values in the average increases the weight of more recent values, but it does so at the expense of losing potential information from less recent values.

Weighted Moving Average A **weighted average** is similar to a moving average, except that it typically assigns more weight to the most recent values in a time series. For instance, the most recent value might be assigned a weight of .40, the next most recent value a weight of .30, the next after that a weight of .20, and the next after that a weight of .10.

Note that the weights must sum to 1.00, and that the heaviest weights are assigned to the most recent values.

LO3.8 Prepare a weighted-average forecast.

Weighted average More recent values in a series are given more weight in computing a forecast.

$$F_t = w_{t-n}A_{t-n} + w_{t-n+1}A_{t-n+1} + \cdots + w_{t-2}A_{t-2} + w_{t-1}A_{t-1} \quad (3\text{–}2)$$

where

w_{t-1} = Weight for period $t - 1$, etc.
A_{t-1} = Actual value for period $t - 1$, etc.

EXAMPLE 2 Computing a Weighted Moving Average

excel

mhhe.com/stevenson14e

Given the following demand data,

a. Compute a weighted average forecast using a weight of .40 for the most recent period, .30 for the next most recent, .20 for the next, and .10 for the next.
b. If the actual demand for period 6 is 39, forecast demand for period 7 using the same weights as in part *a.*

Period	Demand
1	42
2	40
3	43

Period	Demand
4	40
5	41

SOLUTION

a. F_6 = .10(40) + .20(43) + .30(40) + .40(41) = 41.0

b. F_7 = .10(43) + .20(40) + .30(41) + .40(39) = 40.2

Note that if four weights are used, only the *four most recent* demands are used to prepare the forecast.

The advantage of a weighted average over a simple moving average is that the weighted average is more reflective of the most recent occurrences. However, the choice of weights is somewhat arbitrary and generally involves the use of trial and error to find a suitable weighting scheme.

Exponential Smoothing **Exponential smoothing** is a sophisticated weighted averaging method that is still relatively easy to use and understand. Each new forecast is based on the previous forecast plus a percentage of the difference between that forecast and the actual value of the series at that point. That is:

Exponential smoothing A weighted averaging method based on the previous forecast plus a percentage of the forecast error.

$$\text{Next forecast} = \text{Previous forecast} + \alpha(\text{Actual} - \text{Previous forecast})$$

where (Actual − Previous forecast) represents the forecast error and α is a percentage of the error. More concisely,

LO3.9 Prepare an exponential

smoothing forecast.

$$F_t = F_{t-1} + \alpha(A_{t-1} - F_{t-1}) \tag{3–3a}$$

where

$$\begin{aligned} F_t &= \text{Forecast for period } t \\ F_{t-1} &= \text{Forecast for the previous period (i.e., period } t-1) \\ \alpha &= \text{Smoothing constant (percentage, usually less than 50\%)} \\ A_{t-1} &= \text{Actual demand or sales for the previous period} \end{aligned}$$

The smoothing constant α represents a percentage of the forecast error. Each new forecast is equal to the previous forecast plus a percentage of the previous error. For example, suppose the previous forecast was 42 units, actual demand was 40 units, and α = .10. The new forecast would be computed as follows:

$$F_t = 42 + .10(40 - 42) = 41.8$$

Then, if the actual demand turns out to be 43, the next forecast would be

$$F_t = 41.8 + .10(43 - 41.8) = 41.92$$

An alternate form of Formula 3–3a reveals the weighting of the previous forecast and the latest actual demand:

$$F_t = (1 - \alpha)F_{t-1} + \alpha A_{t-1} \tag{3–3b}$$

For example, if α = .10, this would be

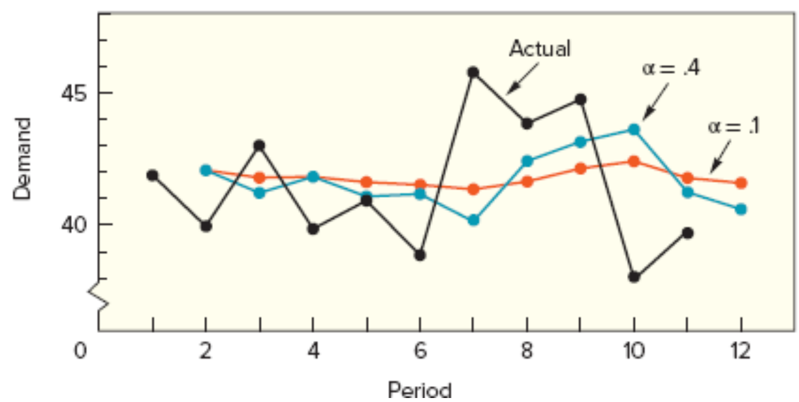
$$F_t = .90F_{t-1} + .10A_{t-1}$$

The quickness of forecast adjustment to error is determined by the smoothing constant, α. The closer its value is to zero, the slower the forecast will be to adjust to forecast errors (i.e., the greater the smoothing). Conversely, the closer the value of α is to 1.00, the greater the responsiveness and the less the smoothing. This is illustrated in Figure 3.4B.

FIGURE 3.4B

The closer α is to zero, the greater the smoothing

Period (t)	Actual Demand	$\alpha = .10$ Forecast	$\alpha = .40$ Forecast
1	42 starting forecast	—	—
2	40	42	42
3	43	41.8	41.2
4	40	41.92	41.92
5	41	41.73	41.15
6	39	41.66	41.09
7	46	41.39	40.25
8	44	41.85	42.55
9	45	42.07	43.13
10	38	42.35	43.88
11	40	41.92	41.53
12		41.73	40.92



Selecting a smoothing constant is basically a matter of judgment or trial and error, using forecast errors to guide the decision. The goal is to select a smoothing constant that balances the benefits of smoothing random variations with the benefits of responding to real changes if and when they occur. Commonly used values of α range from .05 to .50. Low values of α are used when the underlying average tends to be stable; higher values are used when the underlying average is susceptible to change.

Some computer packages include a feature that permits automatic modification of the smoothing constant if the forecast errors become unacceptably large.

Exponential smoothing is one of the most widely used techniques in forecasting, partly because of its ease of calculation and partly because of the ease with which the weighting scheme can be altered—simply by changing the value of α.

Note: Exponential smoothing should begin several periods back to enable forecasts to adjust to the data, instead of starting one period back. A number of different approaches can be used to obtain a *starting forecast,* such as the average of the first several periods, a subjective estimate, or the first actual value as the forecast for period 2 (i.e., the naive approach). For simplicity, the naive approach is used in this book. In practice, using an average of, say, the first three values as a forecast for period 4 would provide a better starting forecast because that would tend to be more representative.

Other Forecasting Methods

You may find two other approaches to forecasting interesting. They are briefly described in this section.

Focus Forecasting Some companies use forecasts based on a "best recent performance" basis. This approach, called **focus forecasting**, was developed by Bernard T. Smith, and is described in several

of his books.[1] It involves the use of several forecasting methods (e.g., moving average, weighted average, and exponential smoothing) all being applied to the last few months of historical data after any irregular variations have been removed. The method that has the highest accuracy is then used to make the forecast for the next month. This process is used for each product or service, and is repeated monthly.

Focus forecasting Using the forecasting method that demonstrates the best recent success.

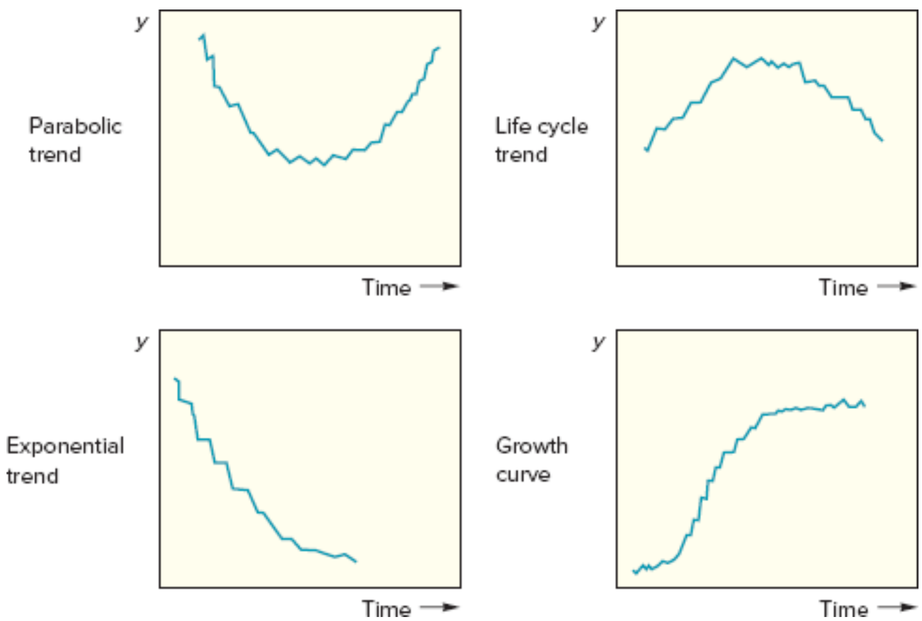
Diffusion Models When new products or services are introduced, historical data are not generally available on which to base forecasts. Instead, predictions are based on rates of product adoption and usage spread from other established products, using mathematical diffusion models. These models take into account such factors as market potential, attention from mass media, and word of mouth. Although the details are beyond the scope of this text, it is important to point out that diffusion models are widely used in marketing and to assess the merits of investing in new technologies.

Techniques for Trend

Analysis of trend involves developing an equation that will suitably describe trend (assuming that trend is present in the data). The trend component may be linear, or it may not. Some commonly encountered nonlinear trend types are illustrated in Figure 3.5. A simple plot of the data often can reveal the existence and nature of a trend. The discussion here focuses exclusively on *linear* trends because these are fairly common.

FIGURE 3.5

Graphs of some nonlinear trends



There are two important techniques that can be used to develop forecasts when trend is present. One involves use of a trend equation; the other is an extension of exponential smoothing.

Trend Equation A **linear trend equation** has the form

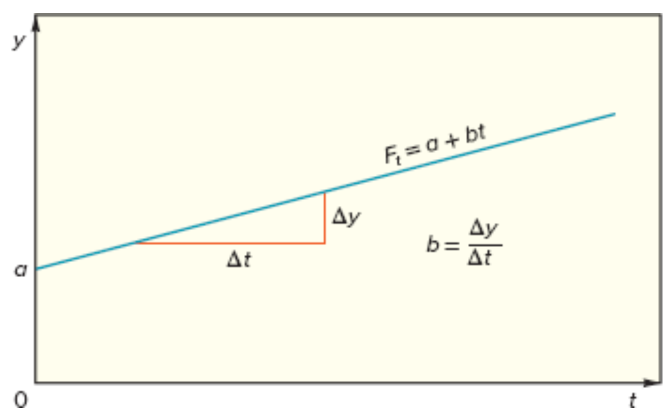
Linear trend equation $F_t = a + bt$, used to develop forecasts when trend is present.

$$F_t = a + bt \tag{3–4}$$

where

F_t = Forecast for period t
a = Value of F_t at $t = 0$, which is the y intercept
b = Slope of the line
t = Specified number of time periods from $t = 0$

LO3.10
Prepare a linear trend forecast.



For example, consider the trend equation $F_t = 45 + 5t$. The value of F_t when $t = 0$ is 45, and the slope of the line is 5, which means that, on average, the value of F_t will increase by five units for each time period. If $t = 10$, the forecast, F_t, is $45 + 5(10) = 95$ units. The equation can be plotted by finding two points on the line. One can be found by substituting some value of t into the equation (e.g., $t = 10$) and then solving for F_t. The other point is a (i.e., F_t at $t = 0$). Plotting those two points and drawing a line through them yields a graph of the linear trend line.

The coefficients of the line, *a* and *b,* are based on the following two equations:

$$b = \frac{n\sum ty - \sum t \sum y}{n\sum t^2 - (\sum t)^2} \qquad (3–5)$$

$$a = \frac{\sum y - b\sum t}{n} \text{ or } \bar{y} - b\bar{t} \qquad (3–6)$$

where

n = Number of periods
y = Value of the time series

Note that these two equations are identical to those used for computing a linear regression line, except that *t* replaces *x* in the equations. Values for the trend equation can be obtained easily by using the Excel template.

EXAMPLE 3

Obtaining and Using a Trend Equation

eXcel
mhhe.com/stevenson14e

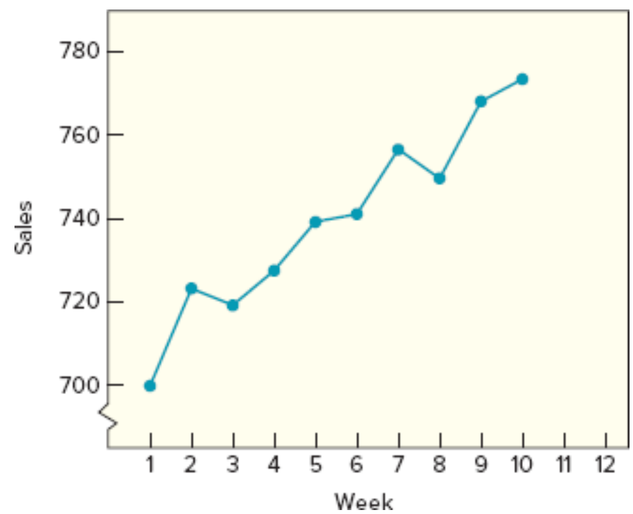
Cell phone sales for a California-based firm over the last 10 weeks are shown in the following table. Plot the data and visually check to see if a linear trend line would be appropriate. Then, determine the equation of the trend line, and predict sales for weeks 11 and 12.

Week	Unit Sales
1	700
2	724
3	720
4	728
5	740

Week	Unit Sales
6	742
7	758
8	750
9	770
10	775

SOLUTION

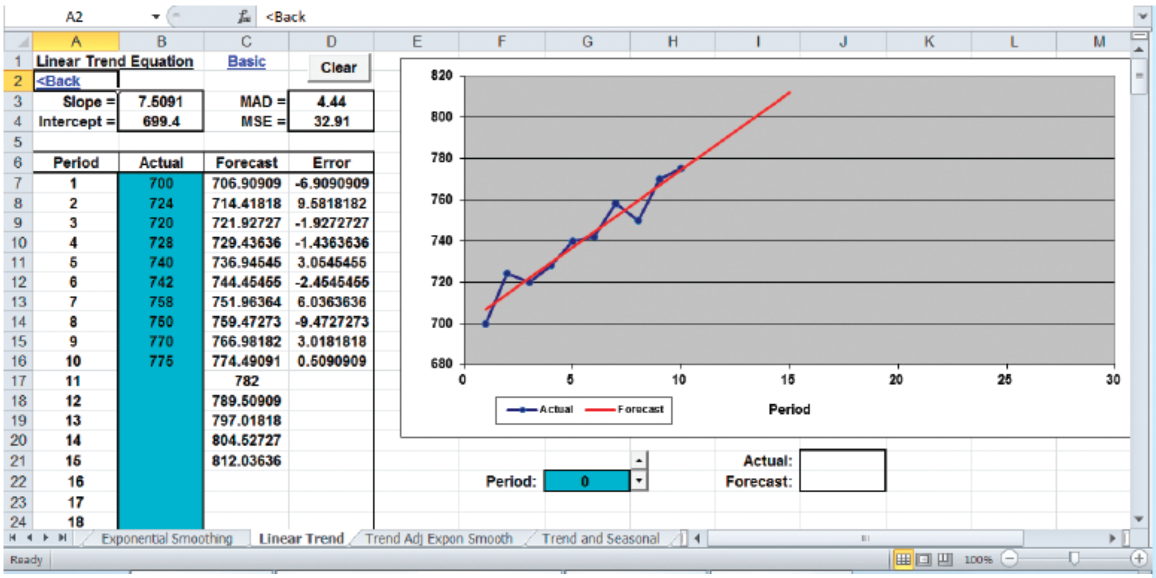
a. A plot suggests that a linear trend line would be appropriate:



b. The solution obtained by using the Excel template for linear trend is shown in Table 3.1.

TABLE 3.1

Excel solution for Example 3



Linear Trend Equation		Basic	Clear
<Back			
Slope =	7.5091	MAD =	4.44
Intercept =	699.4	MSE =	32.91
Period	Actual	Forecast	Error
1	700	706.90909	-6.9090909
2	724	714.41818	9.5818182
3	720	721.92727	-1.9272727
4	728	729.43636	-1.4363636
5	740	736.94545	3.0545455
6	742	744.45455	-2.4545455
7	758	751.96364	6.0363636
8	750	759.47273	-9.4727273
9	770	766.98182	3.0181818
10	775	774.49091	0.5090909
11		782	
12		789.50909	
13		797.01818	
14		804.52727	
15		812.03636	
16			
17			
18			

Source: Microsoft

$b = 7.51$ and $a = 699.40$

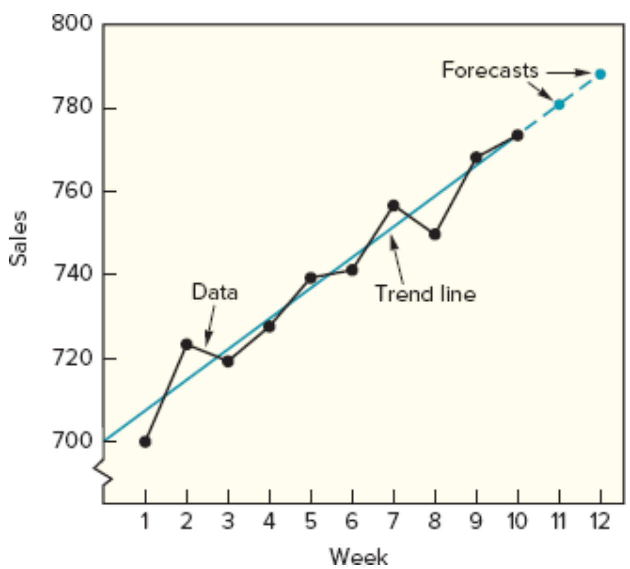
The trend line is $F_t = 699.40 + 7.51t$, where $t = 0$ for period 0.

c. Substituting values of t into this equation, the forecasts for the next two periods (i.e., $t = 11$ and $t = 12$) are:

$$F_{11} = 699.40 + 7.51(11) = 782.01$$

$$F_{12} = 699.40 + 7.51(12) = 789.52$$

d. For purposes of illustration, the original data, the trend line, and the two projections (forecasts) are shown on the following graph:



Trend-Adjusted Exponential Smoothing

LO3.11
Prepare a trend-adjusted exponential smoothing forecast.

A variation of simple exponential smoothing can be used when a time series exhibits a *linear* trend. It is called **trend-adjusted exponential smoothing**, or sometimes *double smoothing,* to differentiate it from simple exponential smoothing, which is appropriate only when data vary around an average or have step or gradual changes. If a series exhibits a trend, and simple smoothing is used on it, the forecasts will all lag the trend: If the data are increasing, each forecast will be too low; if decreasing, each forecast will be too high.

Trend-adjusted exponential smoothing Variation of exponential smoothing used when a time series exhibits a linear trend.

The trend-adjusted forecast (TAF) is composed of two elements—a smoothed error and a trend factor.

$$\text{TAF}_{t+1} = S_t + T_t \tag{3–7}$$

where

S_t = Previous forecast plus smoothed error
T_t = Current trend estimate

and

$$\begin{aligned} S_t &= \text{TAF}_t + \alpha(A_t - \text{TAF}_t) \\ T_t &= T_{t-1} + \beta(\text{TAF}_t - \text{TAF}_{t-1} - T_{t-1}) \end{aligned} \tag{3–8}$$

where

α = Smoothing constant for average
β = Smoothing constant for trend

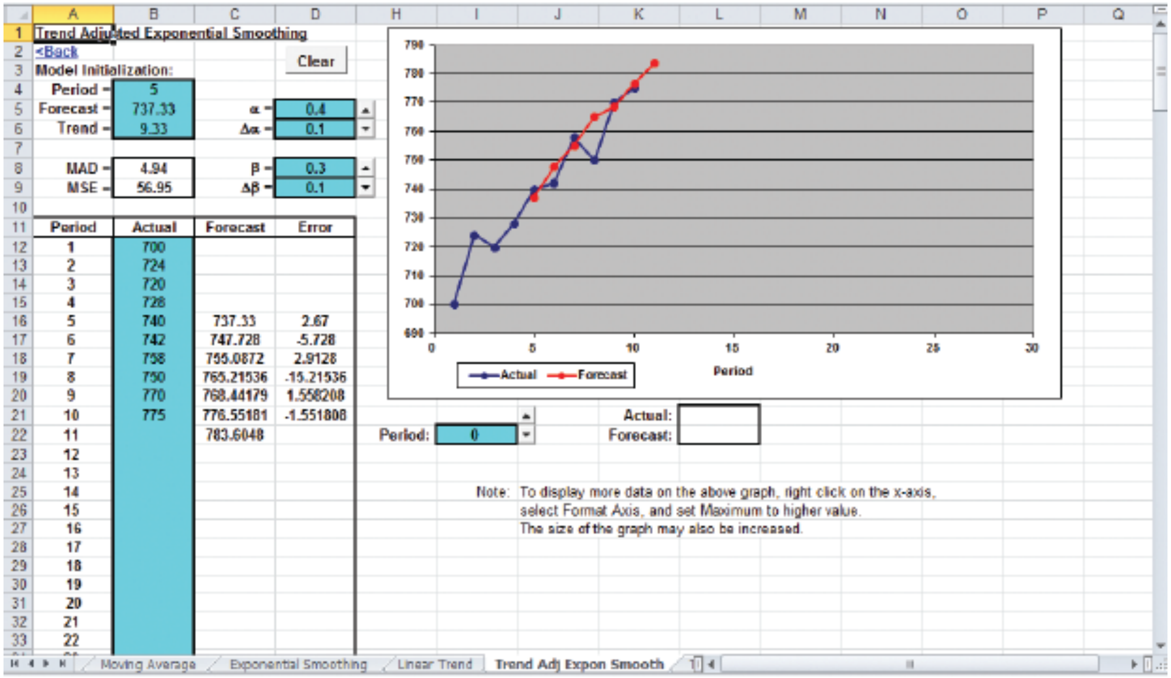
In order to use this method, one must select values of α and β (usually through trial and error) and make a starting forecast and an estimate of trend.

Using the cell phone data from the previous example (where it was concluded that the data exhibited a linear trend), use trend-adjusted exponential smoothing to obtain forecasts for periods 6 through 11, with α = .40 and β = .30.

The initial estimate of trend is based on the net change of 28 for the *three changes* from period 1 to period 4, for an average of 9.33. The Excel spreadsheet is shown in Table 3.2. Notice that an initial estimate of trend is estimated from the first four values and that the starting forecast (period 5) is developed using the previous (period 4) value of 728 plus the initial trend estimate:

TABLE 3.2

Using the Excel template for trend-adjusted smoothing



Source: Microsoft

$$\text{Starting forecast} = 728 + 9.33 = 737.33$$

Unlike a linear trend line, trend-adjusted smoothing has the ability to adjust to *changes* in trend. Of course, trend projections are much simpler with a trend line than with trend-adjusted forecasts, so a manager must decide which benefits are most important when choosing between these two techniques for trend.

Techniques for Seasonality

Seasonal variations in time-series data are regularly repeating upward or downward movements in series values that can be tied to recurring events. *Seasonality* may refer to regular annual variations. Familiar examples of seasonality are weather variations (e.g., sales of winter and summer sports equipment) and vacations or holidays (e.g., airline travel, greeting card sales, visitors at tourist and resort centers). The term *seasonal variation* is also applied to daily, weekly, monthly, and other regularly recurring patterns in data. For example, rush hour traffic occurs twice a day—incoming in the morning and outgoing in the late afternoon. Theaters and restaurants often experience weekly demand patterns, with demand higher later in the week. Banks may experience daily seasonal variations (heavier traffic during the noon hour and just before closing), weekly variations (heavier toward the end of the week), and monthly variations (heaviest around the beginning of the month because of Social Security, payroll, and welfare checks being cashed or deposited). Mail volume; sales of toys, beer, automobiles, and turkeys; highway usage; hotel registrations; and gardening also exhibit seasonal variations.

Seasonal variations Regularly repeating movements in series values that can be tied to recurring events.

Punchstock/Getty Images

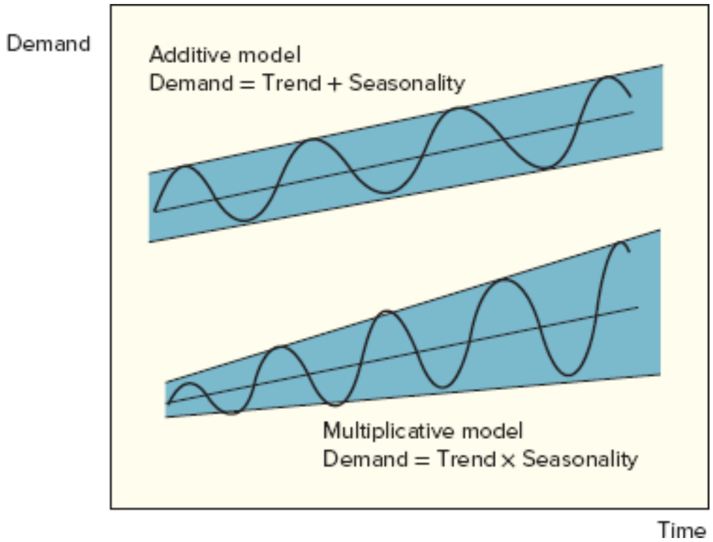
Steve Mason/Getty Images

Seasonality in a time series is expressed in terms of the amount that actual values deviate from the *average* value of a series. If the series tends to vary around an average value, then seasonality is expressed in terms of that average (or a moving average); if trend is present, seasonality is expressed in terms of the trend value.

There are two different models of seasonality: additive and multiplicative. In the *additive* model, seasonality is expressed as a *quantity* (e.g., 20 units), which is added to or subtracted from the series average in order to incorporate seasonality. In the *multiplicative* model, seasonality is expressed as a *percentage* of the average (or trend) amount (e.g., 1.10), which is then used to multiply the value of a series to incorporate seasonality. Figure 3.6 illustrates the two models for a linear trend line. In practice, businesses use the multiplicative model much more widely than the additive model, because it tends to be more representative of actual experience, so we will focus exclusively on the multiplicative model.

FIGURE 3.6

Seasonality: the additive and multiplicative models compared using a linear trend



The seasonal percentages in the multiplicative model are referred to as **seasonal relatives** or *seasonal indexes.* Suppose that the seasonal relative for the quantity of toys sold in May at a store is 1.20. This indicates that toy sales for that month are 20 percent above the monthly average. A seasonal relative of .90 for July indicates that July sales are 90 percent of the monthly average.

Seasonal relative Percentage of average or trend.

Knowledge of seasonal variations is an important factor in retail planning and scheduling. Moreover, seasonality can be an important factor in capacity planning for systems that must be designed to handle peak loads (e.g., public transportation, electric power plants, highways, and bridges). Knowledge of the extent of seasonality in a time series can enable one to *remove* seasonality from the data (i.e., to seasonally adjust data) in order to discern other patterns or the lack of patterns in the series. Thus, one frequently reads or hears about "seasonally adjusted unemployment" and "seasonally adjusted personal income."

The next section briefly describes how seasonal relatives are used.

Using Seasonal Relatives Seasonal relatives are used in two different ways in forecasting. One way is to *deseasonalize data;* the other way is to *incorporate seasonality in a forecast.*

LO3.12
Compute and use seasonal relatives.

To deseasonalize data is to remove the seasonal component from the data in order to get a clearer picture of the nonseasonal (e.g., trend) components. Deseasonalizing data is accomplished by *dividing* each data point by its corresponding seasonal relative (e.g., divide November demand by the November relative, divide December demand by the December relative, and so on).

Incorporating seasonality in a forecast is useful when demand has both trend (or average) and seasonal components. Incorporating seasonality can be accomplished in this way:

. Obtain trend estimates for desired periods using a trend equation.

. Add seasonality to the trend estimates by *multiplying* (assuming a multiplicative model is appropriate) these trend estimates by the corresponding seasonal relative (e.g., multiply the November trend estimate by the November seasonal relative, multiply the December trend estimate by the December seasonal relative, and so on).

Example 4 illustrates these two techniques.

EXAMPLE 4

a. Deseasonalizing Data and b. Using Trend and Seasonal Relatives to make a Forecast

eXcel
mhhe.com/stevenson14e

A coffee shop owner wants to estimate demand for the next two quarters for hot chocolate. Sales data consist of trend and seasonality.

a. Quarter relatives are 1.20 for the first quarter, 1.10 for the second quarter, 0.75 for the third quarter, and 0.95 for the fourth quarter. Use this information to deseasonalize sales for quarters 1 through 8.

b. Using the appropriate values of quarter relatives and the equation $F_t = 124 + 7.5t$ for the trend component, estimate demand for periods 9 and 10.

SOLUTION

a.

Period	Quarter	Sales (gal.)	÷	Quarter Relative	=	Deseasonalized Sales
1	1	158.4	÷	1.20	=	132.0
2	2	153.0	÷	1.10	=	139.1
3	3	110.0	÷	0.75	=	146.7
4	4	146.3	÷	0.95	=	154.0
5	1	192.0	÷	1.20	=	160.0
6	2	187.0	÷	1.10	=	170.0
7	3	132.0	÷	0.75	=	176.0
8	4	173.8	÷	0.95	=	182.9

b. The trend values are:

Period 9: $F_t = 124 + 7.5(9) = 191.5$

Period 10: $F_t = 124 + 7.5(10) = 199.0$

Period 9 is a first quarter and period 10 is a second quarter. Multiplying each trend value by the appropriate quarter relative results in:

Period 9: 191.5(1.20) = 229.8

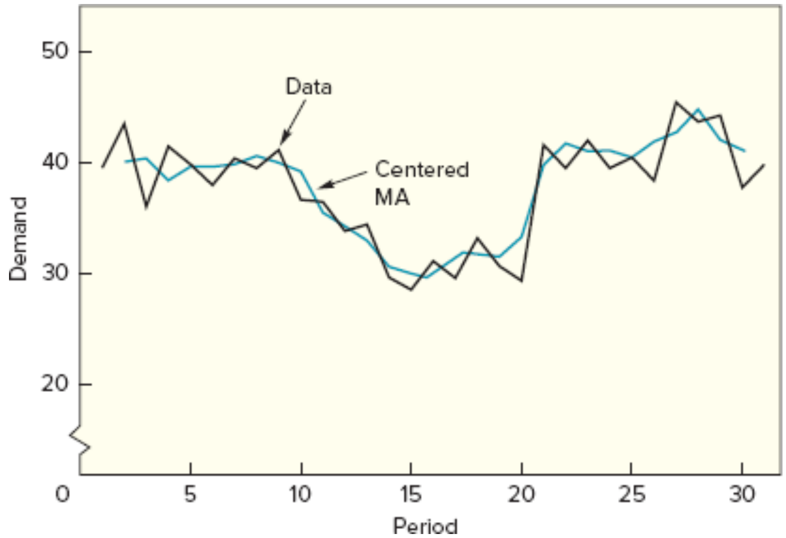
Period 10: 199.0(1.10) = 218.9

Computing Seasonal Relatives A widely used method for computing seasonal relatives involves the use of a **centered moving average**. This approach effectively accounts for any trend (linear or curvilinear) that might be present in the data. For example, Figure 3.7 illustrates how a three-period centered moving average closely tracks the data originally shown in Figure 3.3.

Centered moving average A moving average positioned at the center of the data that were used to compute it.

FIGURE 3.7

A centered moving average closely tracks the data



Manual computation of seasonal relatives using the centered moving average method is a bit cumbersome, so the use of software is recommended. Manual computation is illustrated in Solved Problem 4 at the end of the chapter. The Excel template (on the website) is a simple and convenient way to obtain values of seasonal relatives (indexes). Example 5 illustrates this approach.

For practical purposes, you can round the relatives to two decimal places. Thus, the seasonal (standard) index values are:

Day	Index
Tues	0.87
Wed	1.05
Thurs	1.20
Fri	1.37
Sat	1.24
Sun	0.53
Mon	0.75

Computing Seasonal Relatives Using the Simple Average Method

The simple average (SA) method is an alternative way to compute seasonal relatives. Each seasonal relative is the average for that season divided by the average of all seasons. This method is illustrated in Example 5, where the seasons are days. Note that there is no need to standardize the relatives when using the SA method.

EXAMPLE 5 **Computing Seasonal Relatives**

eXcel

mhhe.com/stevenson14e

The manager of a call center recorded the volume of calls received between 9 and 10 a.m. for 21 days and wants to obtain a seasonal index for each day for that hour.

Day	Volume	Day	Volume	Day	Volume
Tues	67	Tues	60	Tues	64
Wed	75	Wed	73	Wed	76
Thurs	82	Thurs	85	Thurs	87
Fri	98	Fri	99	Fri	96
Sat	90	Sat	86	Sat	88
Sun	36	Sun	40	Sun	44
Mon	55	Mon	52	Mon	50

SOLUTION

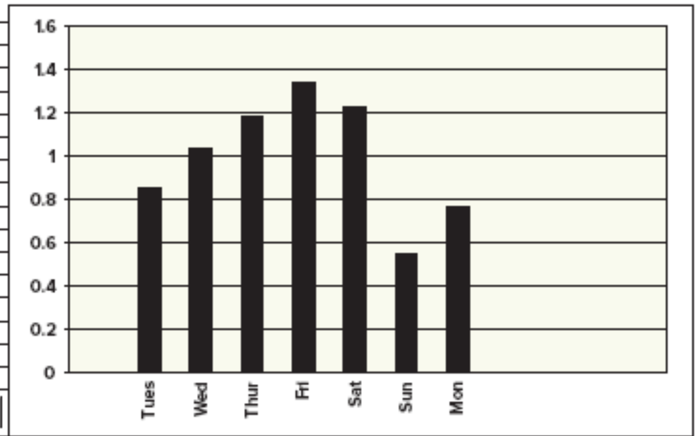
Compute Seasonal Indexes

<Back

Number of "seasons" = 7

Season	Average Index	Standard Index
Tues	0.8688	0.8690
Wed	1.0460	1.0463
Thur	1.1980	1.1983
Fri	1.3648	1.3652
Sat	1.2383	1.2386
Sun	0.5339	0.5341
Mon	0.7484	0.7486

Clear



Period	Season	Actual	MA	Center	Index
1	Tues	67			
2	Wed	75			
3	Thur	82			
4	Fri	98		71.857143	1.3638171
5	Sat	90		70.857143	1.2701613
6	Sun	38		70.571429	0.5101215
7	Mon	55	71.857143	71	0.7746479
8	Tues	60	70.857143	71.142857	0.8433735
9	Wed	73	70.571429	70.571429	1.034413
10	Thur	85	71	71.142857	1.1947791
11	Fri	99	71.142857	70.714286	1.4
12	Sat	86	70.571429	71.285714	1.2064128
13	Sun	40	71.142857	71.714286	0.5577689
14	Mon	62	70.714286	72	0.7222222
15	Tues	64	71.285714	71.571429	0.8942116
16	Wed	76	71.714286	71.857143	1.0576541
17	Thur	87	72	72.428571	1.2011834
18	Fri	96	71.571429	72.142857	1.3306931
19	Sat	88	71.857143		
20	Sun	44	72.428571		
21	Mon	50	72.142857		

Source: Microsoft

EXAMPLE 6 Computing Seasonal Relatives Using the Simple Averaging Method

This example illustrates the steps needed to compute seasonal relatives using the SA method.

SOLUTION

eXcel

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Step 1: Compute the season averages

Step 3: Compute the SA relatives

Quarter	Year 1	Year 2	Year 3	Quarter Total	Quarter Average	Quarter Relative
1	20	23	17	60	20	20/20 = 1.00
2	10	12	8	30	10	10/20 = 0.50
3	25	17	22	66	22	22/20 = 1.10
4	28	26	30	84	28	28/20 = 1.40
					80	4.00

Average of quarter averages = 80/4 = 20

Step 2: Compute the overall average

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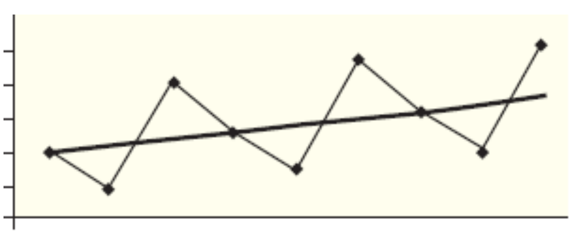
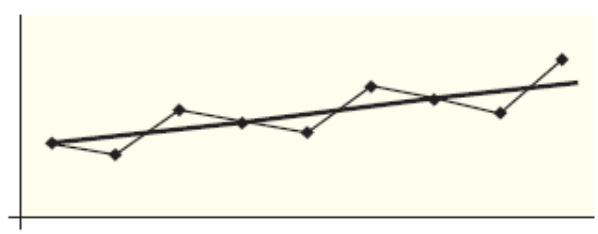
The obvious advantage of the SA method compared to the centered MA method is the simplicity of computations. When the data have a stationary mean (i.e., variation around an average), the SA method works quite well, providing values of relatives that are quite close to those obtained using the centered MA method, which is generally accepted as accurate. Conventional wisdom is that the SA method should not be used when linear trend is present in the data. However, it can be used to obtain fairly good values of seasonal relatives as long as the ratio of the intercept to the slope is large, or when variations are large relative to the slope, shown as follows. Also, the larger the ratio, the smaller the error. The general relationship is illustrated in the following figure.



Variations are large relative to the slope of the line, so it is okay to use the SA method.



Variations are small relative to the slope of the line, so it is not okay to use the SA method.

Techniques for Cycles

Cycles are up-and-down movements similar to seasonal variations but of longer duration—say, two to six years between peaks. When cycles occur in time-series data, their frequent irregularity makes it difficult or impossible to project them from past data because turning points are difficult to identify. A short moving average or a naive approach may be of some value, although both will produce forecasts that lag cyclical movements by one or several periods.

The most commonly used approach is explanatory: Search for another variable that relates to, and *leads,* the variable of interest. For example, the number of housing starts (i.e., permits to build houses) in a given month often is an indicator of demand a few months later for products and services directly tied to construction of new homes (landscaping; sales of washers and dryers, carpeting, and furniture; new demands for shopping, transportation, schools). Thus, if an organization is able to establish a high correlation with such a *leading variable* (i.e., changes in the variable precede changes in the variable of interest), it can develop an equation that describes the relationship, enabling forecasts to be made. It is important that a persistent relationship exists between the two variables. Moreover, the higher the correlation, the better the chances that the forecast will be on target.

3.9 ASSOCIATIVE FORECASTING TECHNIQUES

Associative techniques rely on identification of related variables that can be used to predict values of the variable of interest. For example, sales of beef may be related to the price per pound charged for beef and the prices of substitutes such as chicken, pork, and lamb; real estate prices are usually related to property location and square footage; and crop yields are related to soil conditions and the amounts and timing of water and fertilizer applications.

The essence of associative techniques is the development of an equation that summarizes the effects of **predictor variables**. The primary method of analysis is known as **regression**. A brief overview of regression should suffice to place this approach into perspective relative to the other forecasting approaches described in this chapter.

Predictor variables Variables that can be used to predict values of the variable of interest.

Regression Technique for fitting a line to a set of points.

LO3.13 Compute and use regression and correlation coefficients.

Simple Linear Regression

The simplest and most widely used form of regression involves a linear relationship between two variables. A plot of the values might appear like that in Figure 3.8. The object in linear regression is to obtain an equation of a straight line that minimizes the sum of squared vertical deviations of data points from the line (i.e., the *least squares criterion*). This **least squares line** has the equation

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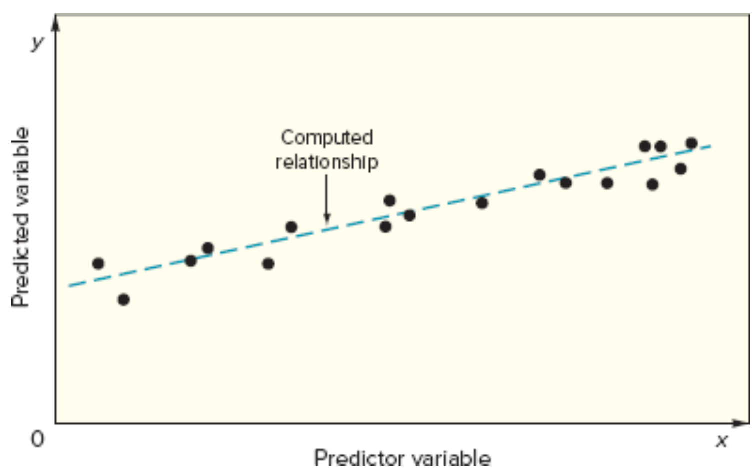
Least squares line Minimizes the sum of the squared vertical deviations around the line.

FIGURE 3.8

A straight line is fitted to a set of sample points



$$y_c = a + bx \quad (3\text{–}9)$$

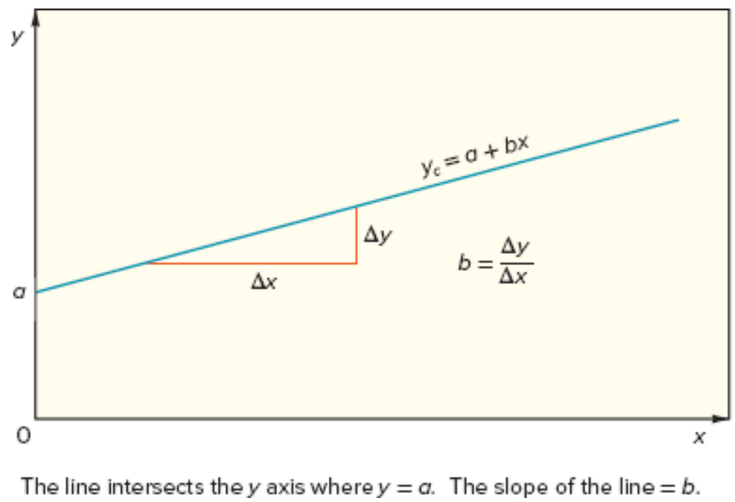
where

y_c = Predicted (dependent) variable
x = Predictor (independent) variable
b = Slope of the line
a = Value of y_c when $x = 0$ (i.e., the height of the line at the y intercept)

(*Note:* It is conventional to represent values of the predicted variable on the *y* axis and values of the predictor variable on the *x* axis.) Figure 3.9 is a general graph of a linear regression line.

FIGURE 3.9

Equation of a straight line: The line represents the average (expected) values of variable *y* given values of variable *x*



The coefficients *a* and *b* of the line are based on the following two equations:

$$b = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2} \quad (3\text{–}10)$$

$$a = \frac{\sum y - b\sum x}{n} \text{ or } \bar{y} - b\bar{x} \quad (3\text{–}11)$$

where

n = Number of paired observations

EXAMPLE 7 Determining a Regression Equation

eXcel

mhhe.com/stevenson14e

Healthy Hamburgers has a chain of 12 stores in northern Illinois. Sales figures and profits for the stores are given in the following table. Obtain a regression equation for the data, and predict profit for a store assuming sales of $10 million.

Unit Sales, x (in $ millions)	Profits, y (in $ millions)
$7	$0.15
2	0.10
6	0.13
4	0.15
14	0.25
15	0.27
16	0.24
12	0.20
14	0.27
20	0.44
15	0.34
7	0.17

SOLUTION

First, plot the data and decide if a linear model is reasonable. (That is, do the points seem to scatter around a straight line? Figure 3.10 suggests they do.) Next, using the appropriate Excel template on the text website, obtain the regression equation $y_c = 0.0506 + 0.0159x$ (see Table 3.3). For sales of $x = 10$ (i.e., 10 million), estimated profit is y_c =

0.0506 + 0.0159(10) = .2099, or $209,900. (Substituting x = 0 into the equation to produce a predicted profit of $50,600 may appear strange because it seems to suggest that amount of profit will occur with no sales. However, the value of x = 0 is *outside the range of observed values.* The regression line should be used only for the range of values from which it was developed; the relationship may be nonlinear outside that range. The purpose of the a value is simply to establish the height of the line where it crosses the y axis.)

FIGURE 3.10

A linear model seems reasonable

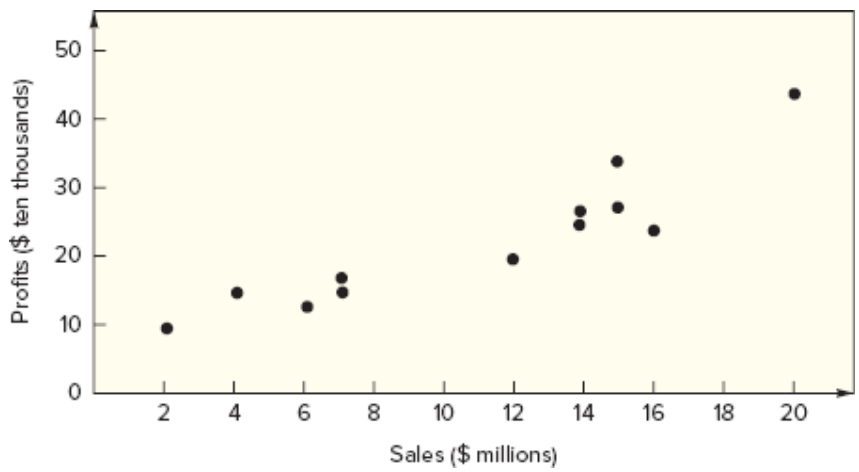
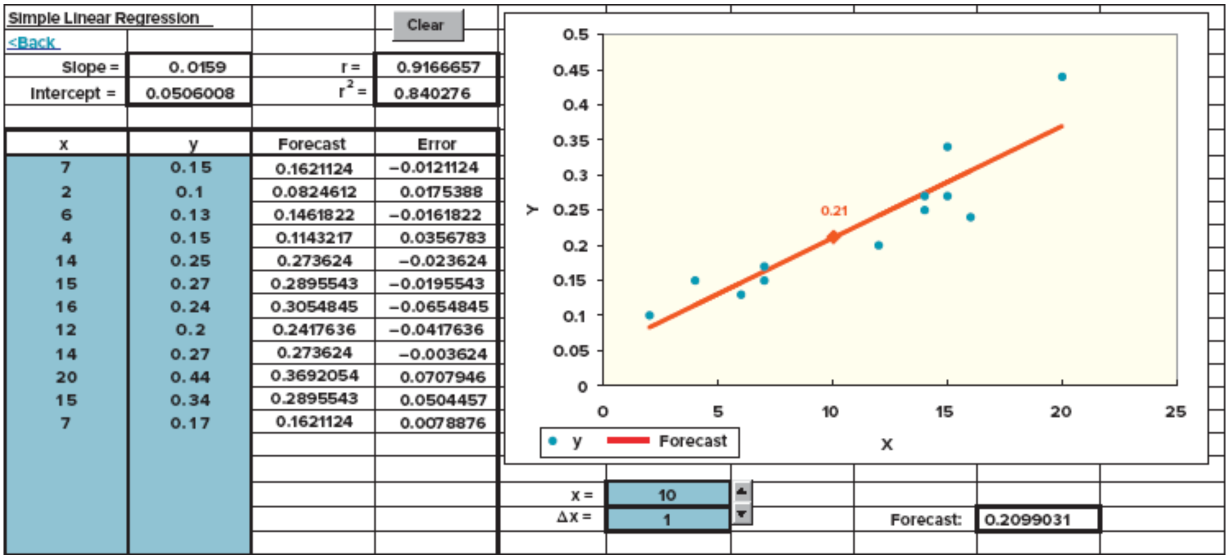


TABLE 3.3

Using the Excel template for linear regression



Simple Linear Regression			Clear
<Back			
Slope =	0.0159	r =	0.9166657
Intercept =	0.0506008	r^2 =	0.840276
x	y	Forecast	Error
7	0.15	0.1621124	−0.0121124
2	0.1	0.0824612	0.0175388
6	0.13	0.1461822	−0.0161822
4	0.15	0.1143217	0.0356783
14	0.25	0.273624	−0.023624
15	0.27	0.2895543	−0.0195543
16	0.24	0.3054845	−0.0654845
12	0.2	0.2417636	−0.0417636
14	0.27	0.273624	−0.003624
20	0.44	0.3692054	0.0707946
15	0.34	0.2895543	0.0504457
7	0.17	0.1621124	0.0078876

Source: Microsoft

One indication of how accurate a prediction might be for a linear regression line is the amount of scatter of the data points around the line. If the data points tend to be relatively close to the line, predictions using the linear equation will tend to be more accurate than if the data points are widely scattered. The scatter can be summarized using the **standard error of estimate**. It can be computed by finding the vertical difference between each data point and the computed value of the regression equation for that value of *x*, squaring each difference, adding the squared differences, dividing by *n* − 2, and then finding the square root of that value.

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Standard error of estimate A measure of the scatter of points around a regression line.

$$S_e = \sqrt{\frac{\sum (y - y_c)^2}{n-2}} \tag{3–12}$$

where

S_e = Standard error of estimate
y = y value of each data point and y_c is the computed value at that point.
n = Number of data points

For the data given in Table 3.3, the error column shows the $y - y_c$ differences. Squaring each error and summing the squares yields .01659. Hence, the standard error of estimate is

$$S_e = \sqrt{\frac{.01659}{12-2}} = .0407 \text{ million}$$

One application of regression in forecasting relates to the use of indicators. These are uncontrollable variables that tend to lead or precede changes in a variable of interest. For example, changes in the Federal Reserve Board's discount rate may influence certain business activities. Similarly, an increase in energy costs can lead to price increases for a wide range of products and services. Careful identification and analysis of indicators may yield insight into possible future demand in some situations. There are numerous published indexes and websites from which to choose.[2] These include:

Net change in inventories on hand and on order

Interest rates for commercial loans

Industrial output

Consumer price index (CPI)

The wholesale price index

Stock market prices

Other potential indicators are population shifts, local political climates, and activities of other firms (e.g., the opening of a shopping center may result in increased sales for nearby businesses). Three conditions are required for an indicator to be valid:

- The relationship between movements of an indicator and movements of the variable should have a logical explanation.
- Movements of the indicator must precede movements of the dependent variable by enough time so that the forecast isn't outdated before it can be acted upon.
- A fairly high correlation should exist between the two variables.

Correlation A measure of the strength and direction of relationship between two variables.

Correlation measures the strength and direction of relationship between two variables. Correlation can range from −1.00 to +1.00. A correlation of +1.00 indicates that changes in one variable are always matched by changes in the other; a correlation of −1.00 indicates that increases in one variable are matched by decreases in the other; and a correlation close to zero indicates little *linear* relationship between two variables. The correlation between two variables can be computed using the equation

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{n(\sum x^2) - (\sum x)^2}\sqrt{n(\sum y^2) - (\sum y)^2} \qquad (3\text{–}13)$$

The square of the correlation coefficient, r^2, provides a measure of the percentage of variability in the values of y that is "explained" by the independent variable. The possible values of r^2 range from 0 to 1.00. The closer r^2 is to 1.00, the greater the percentage of explained variation. A high value of r^2, say .80 or more, would indicate that the independent variable is a good predictor of values of the dependent variable. A low value, say .25 or less, would indicate a poor predictor, and a value between .25 and .80 would indicate a moderate predictor.

Comments on the Use of Linear Regression Analysis

Use of simple regression analysis implies that certain assumptions have been satisfied. Basically, these are as follows:

- Variations around the line are random. If they are random, no patterns such as cycles or trends should be apparent when the line and data are plotted.
- Deviations around the average value (i.e., the line) should be normally distributed. A concentration of values close to the line with a small proportion of larger deviations supports the assumption of normality.
- Predictions are being made only within the range of observed values.

If the assumptions are satisfied, regression analysis can be a powerful tool. To obtain the best results, observe the following:

- Always plot the data to verify that a linear relationship is appropriate.
- The data may be time-dependent. Check this by plotting the dependent variable versus time; if patterns appear, use analysis of time series instead of regression, or use time as an independent variable as part of a *multiple regression analysis.*
- A small correlation may imply that other variables are important.

In addition, note these weaknesses of regression:

- Simple linear regression applies only to linear relationships with *one* independent variable.
- One needs a considerable amount of data to establish the relationship—in practice, 20 or more observations.
- All observations are weighted equally.

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EXAMPLE 8 **Determining a Regression Equation**

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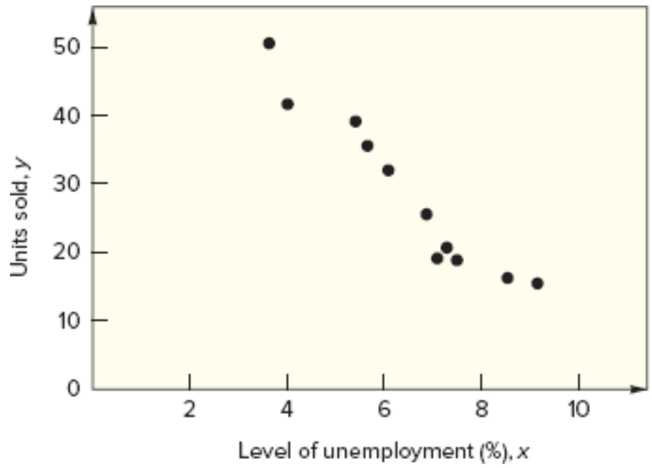
Sales of new houses and three-month lagged unemployment are shown in the following table. Determine if unemployment levels can be used to predict demand for new houses and, if so, derive a predictive equation.

Period	1	2	3	4	5	6	7	8	9	10	11
Units sold	20	41	17	35	25	31	38	50	15	19	14
Unemployment % (three-month lag)	7.2	4.0	7.3	5.5	6.8	6.0	5.4	3.6	8.4	7.0	9.0

SOLUTION

1. Plot the data to see if a *linear* model seems reasonable. In this case, a linear model seems appropriate *for the range of the data.*



2. Check the correlation coefficient to confirm that it is not close to zero using the website template, and then obtain the regression equation:

$r = -.966$

This is a fairly high negative correlation. The regression equation is

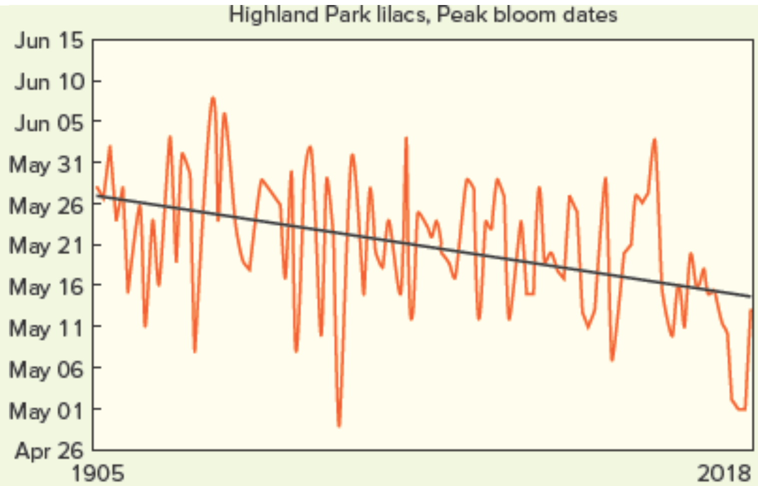
$y = 71.85 - 6.91x$

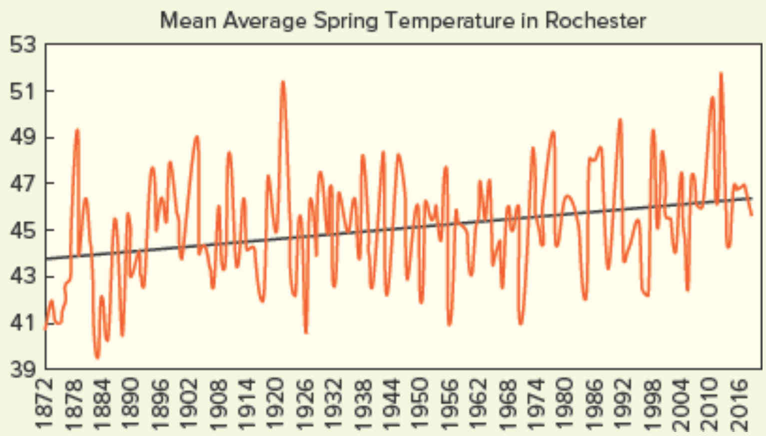
Note that the equation pertains only to unemployment levels in the range 3.6 to 9.0, because sample observations covered only that range.

J Edwards Photography/Shutterstock

READING LILACS

Rochester, New York's Highland Park is home to the largest collection of lilacs in the United States, with over 1,200 plants. About a half million visitors now come to the park each spring to enjoy the lilacs and other plants, as well as the Lilac Festival. It is interesting to note that over the years the lilacs have been trending toward earlier blooming, as shown in the graphs, perhaps due to global warming.





Source: *Rochester Democrat and Chronicle,* Dec. 21, 2018, p.1, p.11.

Questions

1. Do you think there is a correlation between blooming date and temperature?
2. Although each graph shows a definite linear trend, based on the data in the graphs, the trend lines probably shouldn't be used to predict when the blooms will occur in any given year. Explain the reason for not doing that.
3. Park employees make their prediction each year a few months ahead of when they think the plants will bloom, and when the festival should occur. However, a bout of unusually warm or cold weather can alter the actual blooming times. What businesses are likely to be impacted by the festival, and what affect might a change in bloom time have on some of them?

zatvornik/Shutterstock

Nonlinear and Multiple Regression Analysis

Simple linear regression may prove inadequate to handle certain problems because a linear model is inappropriate or because more than one predictor variable is involved. When nonlinear relationships are present, you should employ nonlinear regression; models that involve more than one predictor require the use of multiple regression analysis. While these analyses are beyond the scope of this text, you should be aware that they are often used. Multiple regression forecasting substantially increases data requirements.

3.10 FORECAST ACCURACY

Accuracy and control of forecasts is a vital aspect of forecasting, so forecasters want to minimize forecast errors. However, the complex nature of most real-world variables makes it almost impossible to correctly predict future values of those variables on a regular basis. Moreover, because random variation is always present, there will always be some residual error, even if all other factors have been accounted for. Consequently, it is important to include an indication of the extent to which the forecast might deviate from the value of the variable that actually occurs. This will provide the forecast user with a better perspective on how far off a forecast might be.

Decision makers will want to include accuracy as a factor when choosing among different techniques, along with cost. Accurate forecasts are necessary for the success of daily activities of every business organization. Forecasts are the basis for an organization's schedules, and unless the forecasts are accurate, schedules will be generated that may provide for too few or too many resources, too little or too much output, the wrong output, or the wrong timing of output, all of which can lead to additional costs, dissatisfied customers, and headaches for managers.

Some forecasting applications involve a series of forecasts (e.g., weekly revenues), whereas others involve a single forecast that will be used for a one-time decision (e.g., the size of a power plant). When making periodic forecasts, it is important to monitor forecast errors to determine if the errors are within reasonable bounds. If they are not, it will be necessary to take corrective action.

"I recommend our 'wild' expectations be downgraded to 'great.'"

Mike Baldwin/Cornered

Forecast **error** is the difference between the value that occurs and the value that was predicted for a given time period. Hence, Error = Actual −

Forecast:

Error Difference between the actual value and the value that was predicted for a given period.

$$e_t = A_t - F_t \tag{3–14}$$

where

t = Any given time period

Positive errors result when the forecast is too low, while negative errors occur when the forecast is too high. For example, if actual demand for a week is 100 units, and forecast demand was 90 units, the forecast was too low. The error is 100 − 90 = +10.

Forecast errors influence decisions in two somewhat different ways. One is in making a choice between various forecasting alternatives, and the other is in evaluating the success or failure of a technique in use. We shall begin by examining ways to summarize forecast error over time, and see how that information can be applied to compare forecasting alternatives.

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READING 

HIGH FORECASTS CAN BE BAD NEWS

Overly optimistic forecasts by retail store buyers can easily lead retailers to overorder, resulting in bloated inventories. When that happens, there is pressure on stores to cut prices in order to move the excess merchandise. Although customers delight in these markdowns, retailer profits generally suffer. Furthermore, retailers will naturally cut back on new orders while they work off their inventories, creating a ripple effect that hits the entire supply chain, from shippers, to producers, to suppliers of raw materials. Moreover, the cutbacks to the supply chain could be misinterpreted. The message is clear: Overly optimistic forecasts can be bad news.

Summarizing Forecast Accuracy

LO3.14
Summarize forecast errors and use summaries to make decisions.

Forecast accuracy is a significant factor when deciding among forecasting alternatives. Accuracy is based on the historical error performance of a forecast.

Three commonly used measures for summarizing historical errors are the **mean absolute deviation (MAD)**, the **mean squared error (MSE)**, and the **mean absolute percent error (MAPE)**. MAD is the average absolute error, MSE is the average of squared errors, and MAPE is the average absolute percent error. The formulas used to compute MAD,[3] MSE, and MAPE are as follows:

Mean absolute deviation (MAD) The average absolute forecast error.

Mean squared error (MSE) The average of squared forecast errors.

Mean absolute percent error (MAPE) The average absolute percent error.

$$\text{MAD} = \frac{\sum |\text{Actual}_t - \text{Forecast}_t|}{n} \tag{3–15}$$

$$\text{MSE} = \frac{\sum (\text{Actual}_t - \text{Forecast}_t)^2}{n - 1} \tag{3–16}$$

$$MAPE = \frac{\sum \frac{|Actual_t - Forecast_t|}{Actual_t} \times 100}{n}$$ (3–17)

Example 9 illustrates the computation of MAD, MSE, and MAPE.

EXAMPLE 9 Computing MAD, MSE, and MAPE

eXcel

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Compute MAD, MSE, and MAPE for the following data, showing actual and forecasted numbers of accounts serviced.

Period	Actual	Forecast	$A - F$ (Error)	|Error|	Error^2	[|Error| ÷ Actual] × 100
1	217	215	2	2	4	.92%
2	213	216	−3	3	9	1.41
3	216	215	1	1	1	.46
4	210	214	−4	4	16	1.90
5	213	211	2	2	4	.94
6	219	214	5	5	25	2.28
7	216	217	−1	1	1	.46
8	212	216	−4	4	16	1.89
			−2	22	76	10.26%

SOLUTION

Using the figures shown in the table,

$$MAD = \frac{\sum |e|}{n} = \frac{22}{8} = 2.75$$

$$MSE = \frac{\sum e^2}{n-1} = \frac{76}{8-1} = 10.86$$

$$MAPE = \frac{\sum \left[\frac{|e|}{Actual} \times 100\right]}{n} = \frac{10.26\%}{8} = 1.28\%$$

From a computational standpoint, the difference between these measures is that MAD weights all errors evenly, MSE weights errors according to their *squared* values, and MAPE weights according to *relative* error.

One use for these measures is to compare the accuracy of alternative forecasting methods. For instance, a manager could compare the results to determine which one yields the *lowest* MAD, MSE, or MAPE for a given set of data. Another use is to track error performance over time to decide if attention is needed. Is error performance getting better or worse, or is it staying about the same?

In some instances, historical error performance is secondary to the ability of a forecast to respond to changes in data patterns. Choice among alternative methods would then focus on the cost of not responding quickly to a change relative to the cost of responding to changes that are not really there (i.e., random fluctuations).

Overall, the operations manager must settle on the relative importance of historical performance versus responsiveness and whether to use MAD, MSE, or MAPE to measure historical performance. MAD is the easiest to compute, but weights errors linearly. MSE squares errors, thereby giving more weight to larger errors, which typically cause more problems. MAPE should be used when there is a need to put errors in perspective. For example, an error of 10 in a forecast of 15 is huge. Conversely, an error of 10 in a forecast of 10,000 is insignificant. Hence, to put large errors in perspective, MAPE would be used. Another use of MAPE is when there is a need to compare forecast errors for *different* products or services. One example would be forecasts for store brands versus national brands.

3.11 MONITORING FORECAST ERROR

LO3.15 Construct control charts and use them to monitor forecast errors.

Many forecasts are made at regular intervals (e.g., weekly, monthly, quarterly). Because forecast errors are the rule rather than the exception, there will be a succession of forecast errors. Tracking the forecast errors and analyzing them can provide useful insight on whether forecasts are performing satisfactorily.

There are a variety of possible sources of forecast errors, including the following:

. The model may be inadequate due to (*a*) the omission of an important variable, (*b*) a change or shift in the variable that the model cannot deal with (e.g., the sudden appearance of a trend or cycle), or (*c*) the appearance of a new variable (e.g., new competitor).

. Irregular variations may occur due to severe weather or other natural phenomena, temporary shortages or breakdowns, catastrophes, or similar events.

. Random variations. Randomness is the inherent variation that remains in the data after all causes of variation have been accounted for. There are always random variations.

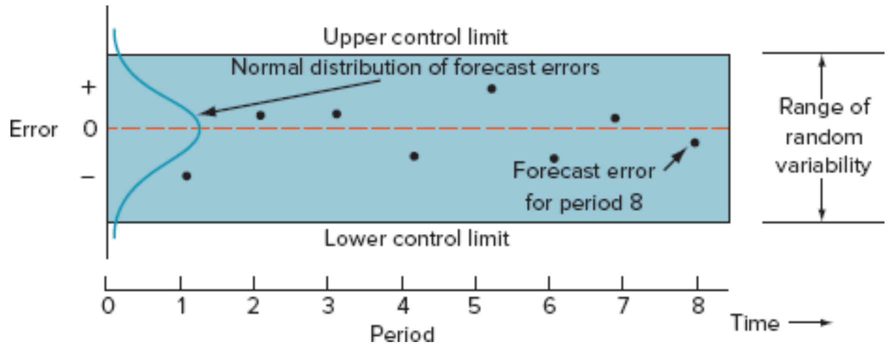
A forecast is generally deemed to perform adequately when the errors exhibit only random variations. Hence, the key to judging when to reexamine the validity of a particular forecasting technique is whether forecast errors are random. If they are not random, it is necessary to investigate to determine which of the other sources is present and how to correct the problem.

A very useful tool for detecting nonrandomness in errors is a **control chart**. Errors are plotted on a control chart in the order that they occur, such as the one depicted in Figure 3.11. The center line of the chart represents an error of zero. Note the two other lines, one above and one below the center line. They are called the upper and lower control limits because they represent the upper and lower ends of the range of acceptable variation for the errors.

Control chart A visual tool for monitoring forecast errors.

FIGURE 3.11

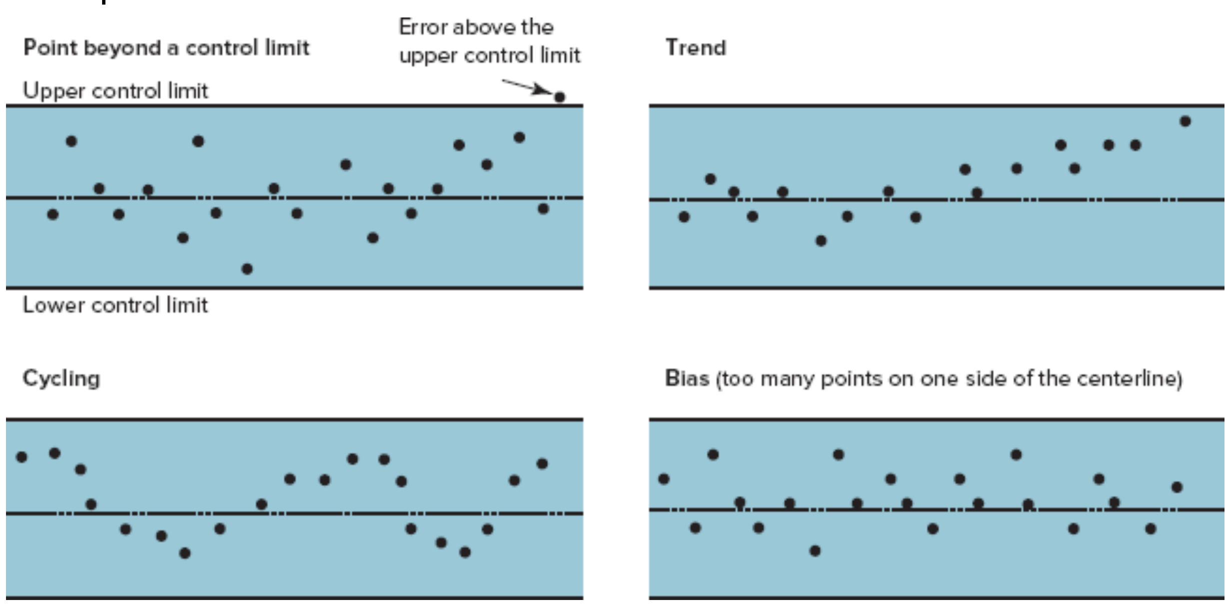
Conceptual representation of a control chart



In order for the forecast errors to be judged “in control” (i.e., random), two things are necessary. One is that all errors are within the control limits. The other is that no patterns (e.g., trends, cycles, noncentered data) are present. Both can be accomplished by inspection. Figure 3.12 illustrates some examples of nonrandom errors.

FIGURE 3.12

Examples of nonrandomness



Technically speaking, one could determine if any values exceeded either control limit without actually plotting the errors, but the visual detection of patterns generally requires plotting the errors, so it is best to construct a control chart and plot the errors on the chart.

To construct a control chart, first compute the MSE. The square root of MSE is used in practice as an estimate of the standard deviation of the distribution of errors.[4] That is,

$$s = \sqrt{\text{MSE}} \tag{3–18}$$

Control charts are based on the assumption that when errors are random, they will be distributed according to a normal distribution around a mean of zero. Recall that for a normal distribution, approximately 95.5 percent of the values (errors in this case) can be expected to fall within limits of 0 ± 2*S* (i.e., 0 ± 2 standard deviations), and approximately 99.7 percent of the values can be expected to fall within ± 3*s* of zero. With that in mind, the following formulas can be used to obtain the upper control limit (UCL) and the lower control limit (LCL):

$$\text{UCL}: 0 + z\sqrt{\text{MSE}}$$
$$\text{LCL}: 0 - z\sqrt{\text{MSE}}$$

where

$$z = \text{Number of standard deviations from the mean}$$

Combining these two formulas, we obtain the following expression for the control limits:

$$\text{Control limits}: 0 \pm z\sqrt{\text{MSE}} \tag{3–19}$$

EXAMPLE 10

Computing Control Limits for Errors

Compute 2*s* control limits for forecast errors when the MSE is 9.0.

SOLUTION

eXcel

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$$s = \sqrt{\text{MSE}} = 3.0$$
$$\text{UCL} = 0 + 2(3.0) = +6.0$$
$$\text{LCL} = 0 - 2(3.0) = -6.0$$

Another method is the **tracking signal**. It relates the cumulative forecast error to the average absolute error (i.e., MAD). The intent is to detect any **bias** in errors over time (i.e., a tendency for a sequence of errors to be positive or negative). The tracking signal is computed period by period using the following formula:

Tracking signal The ratio of cumulative forecast error to the corresponding value of MAD, used to monitor a forecast.

Bias Persistent tendency for forecasts to be greater or less than the actual values of a time series.

$$\text{Tracking signal}_t = \frac{\sum(\text{Actual}_t - \text{Forecast}_t)}{\text{MAD}_t} \tag{3–20}$$

Values can be positive or negative. A value of zero would be ideal; limits of ± 4 or ± 5 are often used for a range of acceptable values of the tracking signal. If a value outside the acceptable range occurs, that would be taken as a signal that there is bias in the forecast, and that corrective action is needed.

After an initial value of MAD has been determined, the value of MAD can be updated and smoothed (SMAD) using exponential smoothing:

$$\text{SMAD}_t = \text{MAD}_{t-1} + \alpha(|\text{Actual} - \text{Forecast}|_t - \text{MAD}_{t-1}) \tag{3–21}$$

EXAMPLE 11

a. Computing a Tracking Signal and b. Computing Control Limits

eXcel

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Monthly attendance at financial planning seminars for the past 24 months, and forecasts and errors for those months, are shown in the following table. Determine if the forecast is working using these approaches:

1. A tracking signal, beginning with month 10, updating MAD with exponential smoothing. Use limits of ± 4 and α = .2.
2. A control chart with 2*s* limits. Use data from the first eight months to develop the control chart, and then evaluate the remaining data with the control chart.

Month	*A* (Attendance)	*F* (Forecast)	*A* − *F* (Error)	|e|	Cumulative |e|
1	47	43	4	4	4
2	51	44	7	7	11
3	54	50	4	4	15
4	55	51	4	4	19
5	49	54	−5	5	24
6	46	48	−2	2	26
7	38	46	−8	8	34
8	32	44	−12	12	46
9	25	35	−10	10	56
10	24	26	−2	2	58
11	30	25	5	5	
12	35	32	3	3	
13	44	34	10	10	
14	57	50	7	7	
15	60	51	9	9	
16	55	54	1	1	
17	51	55	−4	4	
18	48	51	−3	3	
19	42	50	−8	8	
20	30	43	−13	13	
21	28	38	−10	10	
22	25	27	−2	2	
23	35	27	8	8	
24	38	32	6	6	
			−11		

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SOLUTION

1. The sum of absolute errors through the 10th month is 58. Hence, the initial MAD is 58/10 = 5.8. The subsequent MADs are updated using

the formula $MAD_{new} = MAD_{old} + \alpha(|e| - MAD_{old})$. The results are shown in the following table.

The tracking signal for any month is

$$\frac{\text{Cumulative error at that month}}{\text{Updated MAD at that month}}$$

t (Month)	|e|	$MAD_t = MAD_{t-1} + .2(\|e\| - MAD_{t-1})$	Cumulative Error	Tracking Signal = Cumulative Error ÷ MAD*t*
10			−20	−20/5.800 = −3.45
11	5	5.640 = 5.8 + .2(5 − 5.8)	−15	−15/5.640 = −2.66
12	3	5.112 = 5.640 + .2(3 − 5.64)	−12	−12/5.112 = −2.35
13	10	6.090 = 5.112 + .2(10 − 5.112)	−2	−2/6.090 = −0.33
14	7	6.272 = 6.090 + .2(7 − 6.090)	5	5/6.272 = 0.80
15	9	6.818 = 6.272 + .2(9 − 6.272)	14	14/6.818 = 2.05
16	1	5.654 = 6.818 + .2(1 − 6.818)	15	15/5.654 = 2.65
17	4	5.323 = 5.654 + .2(4 − 5.654)	11	11/5.323 = 2.07
18	3	4.858 = 5.323 + .2(3 − 5.323)	8	8/4.858 = 1.65
19	8	5.486 = 4.858 + .2(8 − 4.858)	0	0/5.486 = 0.00
20	13	6.989 = 5.486 + .2(13 − 5.486)	−13	−13/6.989 = −1.86
21	10	7.591 = 6.989 + .2(10 − 6.989)	−23	−23/7.591 = −3.03
22	2	6.473 = 7.591 + .2(2 − 7.591)	−25	−25/6.473 = −3.86
23	8	6.778 = 6.473 + .2(8 − 6.473)	−17	−17/6.778 = −2.51
24	6	6.622 = 6.778 + .2(6 − 6.778)	−11	−11/6.622 = −1.66

Because the tracking signal is within ± 4 every month, there is no evidence of a problem.

2a. Make sure that the average error is approximately zero, because a large average would suggest a biased forecast.

$$\text{Average error} = \frac{\sum \text{errors}}{n} = \frac{-11}{24} = -46$$

b. Compute the standard deviation:

$$s = \sqrt{\text{MSE}} = \sqrt{\frac{\sum e^2}{n-1}}$$

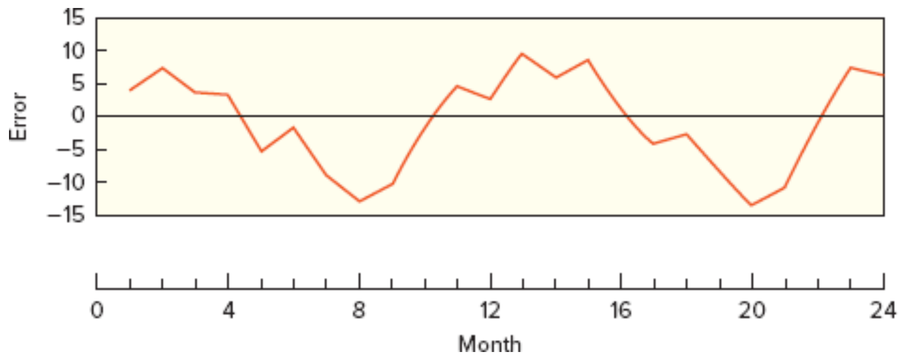
$$= \sqrt{\frac{4^2 + 7^2 + 4^2 + 4^2 + (-5)^2 + (-2)^2 + (-8)^2 + (-12)^2}{8-1}} = 6.91$$

c. Determine 2*s* control limits:

$$0 \pm 2s = 0 \pm 2(6.91) = -13.82 \text{ to } +13.82$$

d.(1) Check that all errors are within the limits. (They are.)

(2) Plot the data (see the following graph), and check for nonrandom patterns. Note the strings of positive and negative errors. This suggests nonrandomness (and that an improved forecast is possible). The tracking signal did not reveal this.



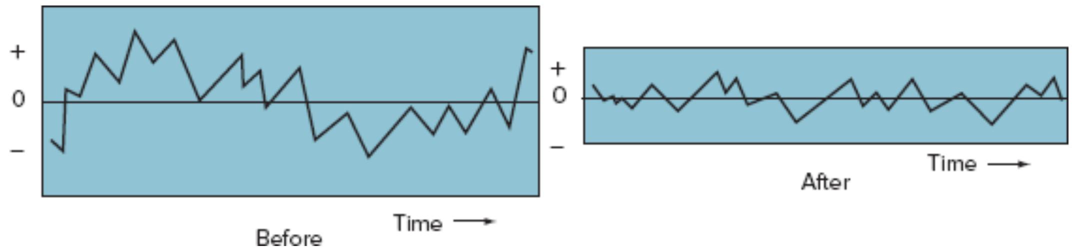
A plot helps you to visualize the process and enables you to check for possible patterns (i.e., nonrandomness) within the limits that suggest an improved forecast is possible.[5]

Like the tracking signal, a control chart focuses attention on deviations that lie outside predetermined limits. With either approach, however, it is desirable to check for possible patterns in the errors, even if all errors are within the limits.

If nonrandomness is found, corrective action is needed. That will result in less variability in forecast errors, and, thus, in narrower control limits. (Revised control limits must be computed using the resulting forecast errors.) Figure 3.13 illustrates the impact on control limits due to decreased error variability.

FIGURE 3.13

Removal of a pattern usually results in less variability, and, hence, narrower control limits



Comment The control chart approach is generally superior to the tracking signal approach. A major weakness of the tracking signal approach is its use of cumulative errors: Individual errors can be obscured so that large positive and negative values cancel each other. Conversely, with control charts, every error is judged individually. Thus, it can be misleading to rely on a tracking signal approach to monitor errors. In fact, the historical roots of the tracking signal approach date from before the first use of computers in business. At that time, it was much more difficult to compute standard deviations than to compute average deviations; for that reason, the concept of a tracking signal was developed. Now computers and calculators can easily provide standard deviations. Nonetheless, the use of tracking signals has persisted, probably because users are unaware of the superiority of the control chart approach.

3.12 CHOOSING A FORECASTING TECHNIQUE

LO3.16 Describe the key factors and trade-offs to consider when choosing a forecasting technique.

Many different kinds of forecasting techniques are available, and no single technique works best in every situation. When selecting a technique, the manager or analyst must take a number of factors into consideration.

The two most important factors are *cost* and *accuracy.* How much money is budgeted for generating the forecast? What are the possible costs of errors, and what are the benefits that might accrue from an accurate forecast? Generally speaking, the higher the accuracy, the higher the cost, so it is important to weigh cost–accuracy trade-offs carefully. The best forecast is not necessarily the most accurate or the least costly; rather, it is some combination of accuracy and cost deemed best by management.

Other factors to consider in selecting a forecasting technique include the availability of historical data; the availability of computer software; and the time needed to gather and analyze data and to prepare the forecast. The forecast horizon is important because some techniques are more suited to long-range forecasts while others work best for the short range. For example, moving averages and exponential smoothing are essentially short-range techniques, because they produce forecasts for the *next* period. Trend equations can be used to project over much longer time periods. When using time-series data, *plotting the data* can be very helpful in choosing an appropriate method. Several of the qualitative techniques are well-suited to long-range forecasts because they do not require historical data. The Delphi method and executive opinion methods are often used for long-range planning. New products and services lack historical data, so forecasts for them must be based on subjective estimates. In many cases, experience with similar page 112 items is relevant. Table 3.4 provides a guide for selecting a forecasting method. Table 3.5 provides additional perspectives on forecasts in terms of the time horizon.

TABLE 3.4

A guide to selecting an appropriate forecasting method

Forecasting Method	Amount of Historical Data	Data Pattern	Forecast Horizon	Preparation Time	Personnel Background
Moving average	2 to 30 observations	Variation around an average	Short	Short	Little sophistication
Simple exponential smoothing	5 to 10 observations	Variation around an average	Short	Short	Little sophistication
Trend-adjusted exponential smoothing	10 to 15 observations	Trend	Short to medium	Short	Moderate sophistication
Trend models	10 to 20; for seasonality at least 5 per season	Trend	Short to medium	Short	Moderate sophistication
Seasonal	Enough to see 2 peaks and troughs	Handles cyclical and seasonal patterns	Short to medium	Short to moderate	Little sophistication
Causal regression models	10 observations per independent variable	Can handle complex patterns	Short, medium, or long	Long development time, short time for implementation	Considerable sophistication

Source: Adapted from J. Holton Wilson and Deborah Allison-Koerber, "Combining Subjective and Objective Forecasts Improves Results," *Journal of Business Forecasting,* Fall 1992, p. 4. Institute of Business Forecasting.

TABLE 3.5

Forecast factors, by range of forecast

Factor	Short Range	Intermediate Range	Long Range
1. Frequency	Often	Occasional	Infrequent
2. Level of aggregation	Item	Product family	Total output Type of product/service
3. Type of model	Smoothing Projection Regression	Projection Seasonal Regression	Managerial judgment
4. Degree of management involvement	Low	Moderate	High

Factor	Short Range	Intermediate Range	Long Range
5. Cost per forecast	Low	Moderate	High

In some instances, a manager might use more than one forecasting technique to obtain independent forecasts. If the different techniques produced approximately the same predictions, that would give increased confidence in the results; disagreement among the forecasts would indicate that additional analysis may be needed. Another possibility is combining the results of two techniques. Still another possibility is to use several techniques on recent data and then use the one with the least error to make the actual forecast, but keep the others, and then use the one with the least error to make the next forecast, and so on. Then, if one technique consistently performs better than the others, that technique would emerge as the favorite.

3.13 USING FORECAST INFORMATION

A manager can take a *reactive* or a *proactive* approach to a forecast. A reactive approach views forecasts as probable future demand, and a manager reacts to meet that demand (e.g., adjusts production rates, inventories, the workforce). Conversely, a proactive approach seeks to actively influence demand (e.g., by means of advertising, pricing, or product/service changes).

Generally speaking, a proactive approach requires either an explanatory model (e.g., regression) or a subjective assessment of the influence on demand. A manager might make two forecasts—one to predict what will happen under the status quo and a second one based on a "what if clear" approach, if the results of the status quo forecast are unacceptable.

3.14 COMPUTER SOFTWARE IN FORECASTING

eXcel

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Computers play an important role in preparing forecasts based on quantitative data. Their use allows managers to develop and revise forecasts quickly, and without the burden of manual computations. There is a wide range of software packages available for forecasting. The Excel templates on the text website are an example of a spreadsheet approach. There are templates for moving averages, exponential smoothing, linear trend equation, trend-adjusted exponential smoothing, and simple linear regression. Some templates are illustrated in the Solved Problems section at the end of the chapter.

3.15 OPERATIONS STRATEGY

Forecasts are the basis for many decisions and an essential input for matching supply and demand. Clearly, the more accurate an organization's forecasts, the better prepared it will be to take advantage of future opportunities and reduce potential risks. A worthwhile strategy can be to work to improve short-term forecasts. Better short-term forecasts will not only enhance profits through lower inventory levels, fewer shortages, and improved customer service, they also will enhance forecasting *credibility* throughout the organization: If short-term forecasts are inaccurate, why should other areas of the organization put faith in long-term forecasts? Also, the sense of confidence that accurate short-term forecasts would generate would allow allocating more resources to strategic and medium- to longer-term planning and less on short-term, tactical activities.

Maintaining accurate, up-to-date information on prices, demand, and other variables can have a significant impact on forecast accuracy. An organization also can do other things to improve forecasts. These do not involve searching for improved techniques but relate to the inverse relation of accuracy to the forecast horizon: Forecasts that cover shorter time frames tend to be more accurate than longer-term forecasts. Recognizing this, management might choose to devote efforts to *shortening the time horizon that forecasts must cover.* Essentially, this means shortening the *lead time* needed to respond to a forecast. This might involve building *flexibility* into operations to permit rapid response to changing demands for products and services, or to changing volumes in quantities demanded; shortening the lead time required to obtain supplies, equipment, and raw materials, or the time needed to train or retrain employees; or shortening the time needed to *develop* new products and services.

Lean systems are demand driven; goods are produced to fulfill orders rather than to hold in inventory until demand arises. Consequently, they are far less dependent on short-term forecasts than more traditional systems.

In certain situations, forecasting can be very difficult when orders have to be placed far in advance. This is the case, for example, when demand is sensitive to weather conditions, such as the arrival of spring, and there is a narrow window for demand. Orders for products or services that relate to this (e.g., garden materials, advertising space) often have to be placed many months in advance—far beyond the ability of forecasters to accurately predict weather conditions and, hence, the timing of demand. In such cases, there may be pressures from salespeople who want low quotas and from financial people who don't want to have to deal with the cost of excess inventory to have conservative forecasts. Conversely, operations people may want more optimistic forecasts to reduce the risk of being blamed for possible shortages.

Sharing forecasts or demand data throughout the supply chain can improve forecast quality in the supply chain, resulting in lower costs and shorter lead times. For example, both Hewlett-Packard and IBM require resellers to include such information in their contracts.

The following reading provides additional insights on forecasting and supply chains.

READING  GAZING AT THE CRYSTAL BALL

BY RAM REDDY

Disregarding Demand Forecasting Technologies during Tough Economic Times Can Be a Costly Mistake

Caught up in the general disillusionment with IT in a downturn has been demand forecasting (DF) technologies. Many companies blame DF technologies for supply chain problems such as excess inventory. Pinning the blame on and discontinuing DF technologies is the equivalent of throwing out the baby with the bathwater. The DF misunderstanding stems from the fact that, despite sophisticated mathematical models and underlying technologies, the output from these systems is, at best, an educated guess about the future.

A forecast from these systems is only as good as the assumptions and data used to build the forecast. Even the best forecast fails when an unexpected event—such as a recession—clobbers the underlying assumptions. However, this doesn’t imply that DF technologies aren’t delivering the goods. But, unfortunately, many DF and supply chain technology implementations have recently fallen victim to this mindset. DF is part science and part art (or intuition)—having the potential to significantly impact a company’s bottom line. In this column, you’ll find an overview of how DF is supposed to work, which you can compare with how most companies actually practice it. I’ll conclude with suggestions on how to avoid common mistakes when implementing and using this particular class of technologies.

The Need for DF Systems

DF is crucial to minimizing working capital and associated expenses and extracting maximum value from a company's capital investments in property, plant, and equipment (PPE). It takes a manufacturing company a lot of lead time to assemble and stage the raw materials and components to manufacture a given number of products per day. The manufacturing company, in turn, generates its sales forecast numbers using data from a variety of sources such as distribution channels, factory outlets, value-added resellers, historical sales data, and general macroeconomic data. Manufacturing companies can't operate without a demand forecast because they won't know the quantities of finished goods to produce. The manufacturing company wants to make sure all or much of its finished product moves off the store shelves or dealer lots as quickly as possible. Unsold products represent millions of dollars tied up in inventory.

The flip side of this equation is the millions of dollars invested in PPE to manufacture the finished products. The company and its supporting supply chain must utilize as close to 100 percent of its PPE investments. Some manufacturing plants make products in lots of 100 or 1,000. Generally, it's cost prohibitive to have production runs of one unit. So how do you extract maximum value from your investments and avoid having money tied up in unsold inventory?

DF and supply chain management (SCM) technologies try to solve this problem by generating a production plan to meet forecasted demand and extract maximum value from PPE, while reducing the amount of capital tied up in inventory. Usually, the demand forecast is pretty close to the actual outcomes, but there are times when demand forecasts don't match the outcomes. In addition to unforeseen economic events, a new product introduction may be a stellar success or an abysmal failure. In the case of a phenomenal success, the manufacturing plant may not be able to meet demand for its product.

Consider the case of the Chrysler PT Cruiser. It succeeded way beyond the demand forecast's projections. Should it have started with manufacturing capacity to fulfill the runaway demand? Absolutely not. Given the additional millions of dollars of investment in PPE necessary to add that capacity, it would've backfired if the

PT Cruiser had been a flop. The value provided by DF and supporting SCM technologies in this instance was the ability to add capacity to meet the amended forecast based on actual events. Demand forecasts can and do frequently miss their targets. The point to underscore here is that the underlying DF and supporting SCM technologies are critical to a company's ability to react and respond in a coordinated manner when market conditions change.

The manufacturing company and its supply chain are able to benefit from sharing information about the changed market conditions and responding to them in a coordinated manner. Despite best practices embedded in DF and SCM technologies to support this manner of collaboration, it plays out differently in the real world.

How It Works in Real Life—Worst Practices

A company prepares its forecast by taking into account data about past sales, feedback from distribution channels, qualitative assessments from field sales managers, and macroeconomic data. DF and SCM technologies take these inputs and add existing capacities within the company and across the supply chain to generate a production plan for optimum financial performance.

There's been incredible pressure on executives of publicly traded companies to keep up stock prices. This pressure, among other reasons, may cause manufacturing company executives to make bold projections to external financial analysts (or Wall Street) about future sales without using the demand forecast generated from the bottom up. When the company realizes this disparity between the initial projection and the forecast, the forecast is changed to reflect the projections made by the company's officers, negating its accuracy.

The company arbitrarily sets sales targets for various regions to meet Wall Street numbers that are totally out of sync with input provided by the regional sales managers for the DF process. Even though the regional sales managers' input may have a qualitative element (art), they tend to be more accurate, given their proximity to the customers in the region. Unfortunately, the arbitrary sales targets make their way back to the supply chain, and the result is often excessive inventory buildup starting at the distribution channels to the upstream suppliers.

Seeing the inventory pile up, the manufacturing company may decide to shut down a production line. This action affects upstream suppliers who had procured raw materials and components to meet the executive-mandated production numbers, which may cause them to treat any future forecasted numbers with suspicion. Most cost efficiencies that could be obtained through planned procurement of raw materials and components go out the window. It’s very likely that the companies try to blame DF and SCM technologies for failing to provide a responsive and efficient supply chain, even though the fault may lie in the company’s misuse of the technologies and not the technologies themselves.

Guarding against the Extremes

Earlier in this column, I said that DF is part art or intuition and part science. The art/intuition part comes in when subject-matter experts (SMEs) make educated estimates about future sales. These SMEs could range from distribution outlet owners to sales and marketing gurus and economists. Their intuition is typically combined with data (such as historical sales figures) to generate the forecast for the next quarter or year. During a recession, the SMEs tend to get overly pessimistic. The demand forecasts generated from this mindset lead to inventory shortages when the economy recovers. Similarly, during an economic expansion, the SMEs tend to have an overly rosy picture of the future. This optimism leads to inventory gluts when the economy starts to slow down. In both instances, blaming and invalidating DF and SCM technologies is counterproductive in the long run.

It’s very rare that a demand forecast and the actual outcome match 100 percent. If it’s close enough to avoid lost sales or create an excess inventory situation, it’s deemed a success. DF and supporting SCM technologies are supposed to form a closed loop, with actual sales at the cash register providing a feedback mechanism. This feedback is especially essential during economic upturns or downturns. It provides the necessary information to a company and its supply chain to react in a coordinated and efficient manner.

Don't let the current disillusionment with DF and SCM technologies impede the decision-making process within your company. The intelligent enterprise needs these technologies to effectively utilize its capital resources and efficiently produce to meet its sales forecasts.

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Questions

1. What is DF and why is it important?
2. Why might a company executive make bold predictions about future demand to Wall Street analysts?
3. How might an executive's comments to Wall Street analysts affect demand forecasts, and what are the consequences of doing so?

Source: Ram Reddy, "Gazing at the Crystal Ball," *Intelligent Enterprise,* June 13, 2002.

SUMMARY

Forecasts are vital inputs for the design and the operation of the productive systems because they help managers anticipate the future.

Forecasting techniques can be classified as qualitative or quantitative. Qualitative techniques rely on judgment, experience, and expertise to formulate forecasts; quantitative techniques rely on the use of historical data or associations among variables to develop forecasts. Some of the techniques are simple, and others are complex. Some work better than others, but no technique works all the time. Moreover, all forecasts include a certain degree of inaccuracy, and allowance should be made for this. The techniques generally assume that the same underlying causal system that existed in the past will continue to exist in the future.

The qualitative techniques described in this chapter include consumer surveys, salesforce estimates, executive opinions, and manager and staff opinions. Two major quantitative approaches are described: analysis of time-series data and associative techniques. The time-series techniques rely strictly on the examination of historical data; predictions are made by projecting past movements of a variable into the future without considering specific factors that might influence the variable. Associative techniques attempt to explicitly identify influencing factors and to incorporate that information into equations that can be used for predictive purposes.

All forecasts tend to be inaccurate; therefore, it is important to provide a measure of accuracy. It is possible to compute several measures of forecast accuracy that help managers to evaluate the performance of a given technique and to choose among alternative forecasting techniques. Control of forecasts involves deciding whether a forecast is performing adequately, typically using a control chart.

When selecting a forecasting technique, a manager must choose a technique that will serve the intended purpose at an acceptable level of cost and accuracy.

The various forecasting techniques are summarized in Table 3.6. Table 3.7 lists the formulas used in the forecasting techniques and in the methods of measuring their accuracy. Note that the Excel templates on the text website that accompanies this book are especially useful for tedious calculations.

TABLE 3.6

Forecasting approaches

	Approaches	Brief Description
Judgment/opinion:	Consumer surveys	Questioning consumers on future plans
	Direct-contact composites	Joint estimates obtained from salespeople or customer service people
	Executive opinion	Finance, marketing, and manufacturing managers join to prepare forecast

	Approaches	Brief Description
	Delphi technique	Series of questionnaires answered anonymously by knowledgeable people; successive questionnaires are based on information obtained from previous surveys
	Outside opinion	Consultants or other outside experts prepare the forecast
Statistical:	Time series:	
	Naive	Next value in a series will equal the previous value in a comparable period
	Moving averages	Forecast is based on an average of recent values

Approaches	Brief Description
Exponential smoothing	Sophisticated form of weighted moving average
Associative models:	
Simple regression	Values of one variable are used to predict values of a dependent variable
Multiple regression	Two or more variables are used to predict values of a dependent variable

TABLE 3.7

Summary of formulas

Technique	Formula	Definitions
MAD	$\text{MAD} = \frac{\sum^{n} \lvert e \rvert}{n}$	MAD = Mean absolute deviation e = Error, $A - F$ n = Number of errors
MSE	$\text{MSE} = \frac{\sum^{n} e^2}{n - 1}$	MSE = Mean square error n = Number of errors
MAPE	$\text{MAPE} = \frac{\sum^{n} \left[\frac{\lvert e_t \rvert}{\text{Actual}_t} \times 100 \right]}{n}$	MAPE = Mean absolute percent error n = Number of errors

Technique	Formula	Definitions
Moving average forecast	$F_t = \dfrac{\sum_{i=1}^{n} A_{t-i}}{n}$	$A =$ Demand in period $t - i$ $n =$ Number of periods
Weighted average	$F_t = w_{t-n}A_{t-n} + w_{t-n+1}A_{t-n+1} + \cdots + w_{t-2}A_{t-2} + w_{t-1}A_{t-1}$	$w_t =$ Weight for the period t $A_t =$ Actual value in period t
Exponential smoothing forecast	$F_t = F_{t-1} + \alpha(A_{t-1} - F_{t-1})$	$\alpha =$ Smoothing factor
Linear trend forecast	$F_t = a + b_t$ where $b = \dfrac{n\sum ty - \sum t \sum y}{n\sum t^2 - (\sum t^2)}$ $a = \dfrac{\sum y - b\sum t}{n}$ or $\bar{y} - b\bar{t}$	$a = y$ intercept $b =$ Slope
Trend-adjusted forecast	$TAF_{t+1} = S_t + T_t$ where $S_t = TAF_t + \alpha(A_t - TAF_t)$ $T_t = T_{t-1} + \beta(TAF_t - TAF_{t-1} - T_{t-1})$	$t =$ Current period $TAF_{t+1} =$ Trend-adjusted forecast for next period $S =$ Previous forecast plus smoothed error $T =$ Trend component
Linear regression forecast	$Y_c = a + bx$ where $b = \dfrac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x^2)}$ $a = \dfrac{\sum y - b\sum x}{n}$ or $\bar{y} - b\bar{x}$	$y_c =$ Computed value of dependent variable $x =$ Predictor (independent) variable $b =$ Slope of the line $a =$ Value of y_c when $x = 0$
Standard error of estimate	$S_e = \sqrt{\dfrac{\sum(y - y_c)^2}{n - 2}}$	$S_e =$ Standard error of estimate $y =$ y value of each data point $n =$ Number of data points
Tracking signal	$TS_t = \dfrac{\sum^{t} e}{MAD_t}$	
Control limits	$UCL = 0 + z\sqrt{MSE}$ $LCL = 0 - z\sqrt{MSE}$	$\sqrt{MSE} =$ standard deviation $z =$ Number of standard deviations; 2 and 3 are typical values

Microsoft

KEY POINTS

1. Demand forecasts are essential inputs for many business decisions. They help managers decide how much supply or capacity will be needed to match expected demand, both within the organization and in the supply chain.
2. Because of random variations in demand, it is likely that the forecast will not be perfect, so managers need to be prepared to deal with forecast errors.
3. Other, nonrandom factors might also be present, so it is necessary to monitor forecast errors to check for nonrandom patterns in forecast errors.
4. It is important to choose a forecasting technique that is cost-effective and one that minimizes forecast error.

KEY TERMS

SOLVED PROBLEMS

Problem 1

Forecasts based on averages. Given the following data:

Period	Number of Complaints
1	60
2	65
3	55
4	58
5	64

Prepare a forecast for period 6 using each of these approaches:

a. The appropriate naive approach.
b. A three-period moving average.
c. A weighted average using weights of .50 (most recent), .30, and .20.
d. Exponential smoothing with a smoothing constant of .40.

Solution

Step by step

a. Plot the data to see if there is a pattern. Here, we have only variations around an average (i.e., no trend or cycles). Therefore, the most recent value of the series becomes the next forecast: 64.
b. Use the latest values. $\text{MA}_3 = \frac{55 + 58 + 64}{3} = 59$
c. $F = .20(55) + .30(58) + .50(64) = 60.4$
d. Start with period 2. Use the data in period 1 as the forecast for period 2, and then use exponential smoothing for successive forecasts.

Period	Number of Complaints	Forecast	Calculations
1	60		[The previous value of the series is used
2	65	60	as the starting forecast.]
3	55	62	$60 + .40(65 - 60) = 62$
4	58	59.2	$62 + .40(55 - 62) = 59.2$
5	64	58.72	$59.2 + .40(58 - 59.2) = 58.72$
6		60.83	$58.72 + .40(64 - 58.72) = 60.83$

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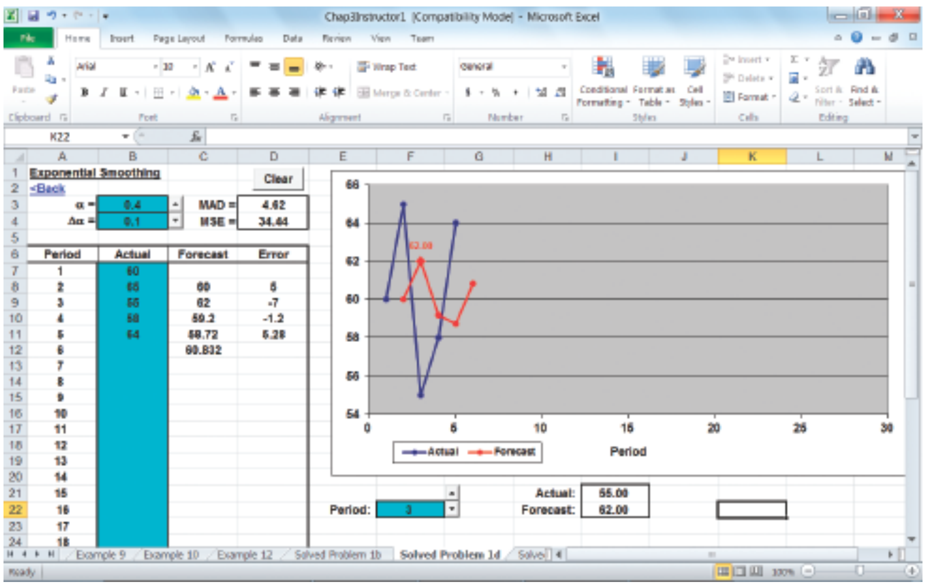
You also can obtain the forecasts and a plot using an Excel template, as shown:



Source: Microsoft

Problem 2

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Using seasonal relatives. Apple's Citrus Fruit Farm ships boxed fruit to anywhere in the world. Using the following information, a manager wants to forecast shipments for the first four months of next year.

Month	Seasonal Relative	Month	Seasonal Relative
Jan.	1.2	Jul.	0.8
Feb.	1.3	Aug.	0.6
Mar.	1.3	Sep.	0.7
Apr.	1.1	Oct.	1.0
May.	0.8	Nov.	1.1
Jun.	0.7	Dec.	1.4

The monthly forecast equation being used is:

$$F_t = 402 + 3t$$

where

t_0 = January of *last* year
F_t = Forecast of shipments for month t

Solution

a. Determine trend amounts for the first four months of *next* year: January, t = 24; February, t = 25; etc. Thus,

$$F_{\text{Jan}} = 402 + 3(24) = 474$$
$$F_{\text{Feb}} = 402 + 3(25) = 477$$
$$F_{\text{Mar}} = 402 + 3(26) = 480$$
$$F_{\text{Apr}} = 402 + 3(27) = 483$$

b. Multiply each monthly trend by the corresponding seasonal relative for that month.

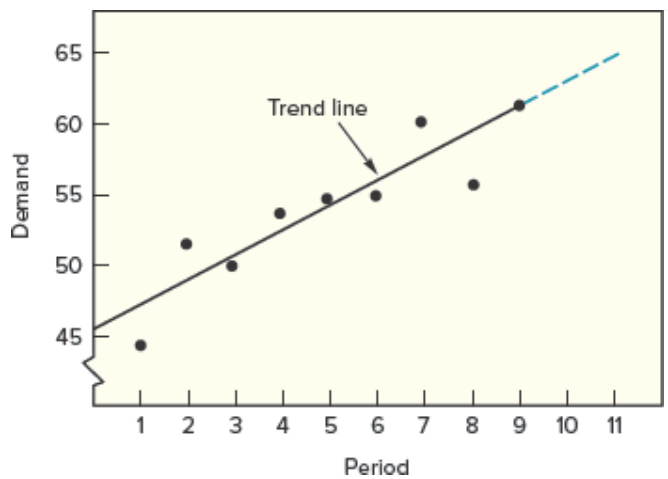
Month	Seasonal Relative	Forecast
Jan.	1.2	474(1.2) = 568.8
Feb.	1.3	477(1.3) = 620.1
Mar.	1.3	480(1.3) = 624.0
Apr.	1.1	483(1.1) = 531.3

Problem 3

Linear trend line. Plot the data on a graph, and verify visually that a linear trend line is appropriate. Develop a linear trend equation for the following data. Then, use the equation to predict the next two values of the series.

Period	Demand
1	44
2	52
3	50
4	54
5	55
6	55
7	60
8	56
9	62

A plot of the data indicates that a linear trend line is appropriate:



Period, t	t^2	Demand, y	ty
1	1	44	44
2	4	52	104
3	9	50	150
4	16	54	216
5	25	55	275
6	36	55	330
7	49	60	420
8	64	56	448
9	81	62	558
45	285	488	2,545

$\sum t = 45$ and $\sum t^2 = 285$

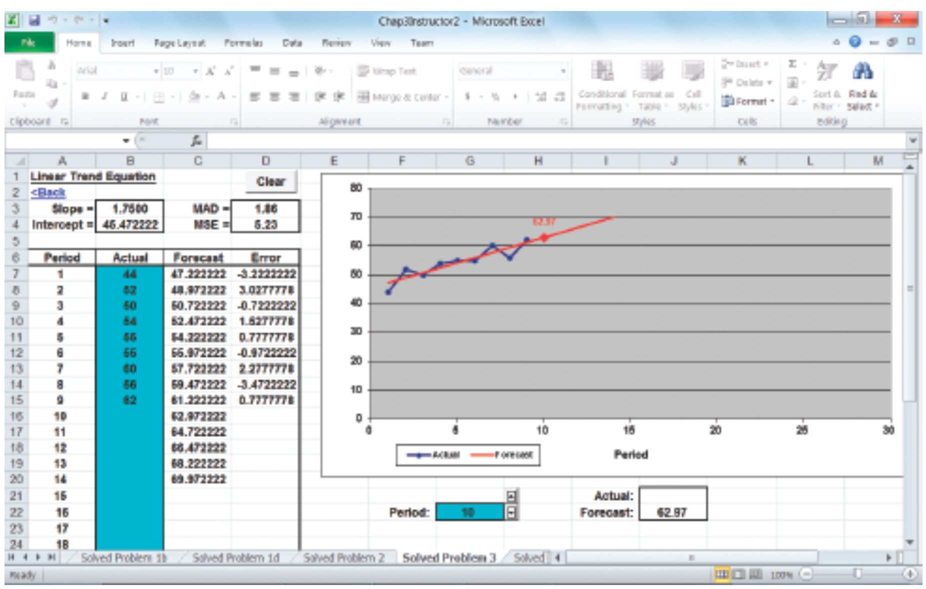
$$b = \frac{n\sum ty - \sum t \sum y}{n\sum t^2 - (\sum t)^2} = \frac{9(2,545) - 45(488)}{9(285) - 45(45)} = 1.75$$

$$a = \frac{\sum y - b\sum t}{n} = \frac{488 - 1.75(45)}{9} = 45.47$$

Thus, the trend equation is $F_t = 45.47 + 1.75t$. The next two forecasts are:

$$F_{10} = 45.47 + 1.75(10) = 62.97$$
$$F_{11} = 45.47 + 1.75(11) = 64.72$$

You also can use an Excel template to obtain the coefficients and a plot. Simply replace the existing data in the template with your data.



Source: Microsoft

Problem 4

Seasonal relatives. Obtain estimates of quarter relatives for these data using the centered moving average method:

	YEAR												
	1				2				3				4
Quarter:	1	2	3	4	1	2	3	4	1	2	3	4	1
Demand:	14	18	35	46	28	36	60	71	45	54	84	88	58

Solution

Note that each season has an *even* number of data points. When an even-numbered moving average is used (in this case, a four-period moving average), the "centered value" will not correspond to an actual data point; the center of 4 is *between* the second and third data points. To correct for this, a *second* set of moving averages must be computed using the MA_4 values. The MA_2 values are centered between the MA_4 and "line up" with actual data points. For example, the first MA_4 value is 28.25. It is centered between 18 and 35 (i.e., between quarter 2 and quarter 3). When the average of the first two MA_4 values is taken (i.e., MA_2) and centered, it lines up with the 35 and, hence, with quarter 3.

So, whenever an even-numbered moving average is used as a centered moving average (e.g., MA_4, MA_{12}), a second moving average, a two-period moving average, is used to achieve correspondence with periods. This procedure is not needed when the number of periods in the centered moving average is odd.

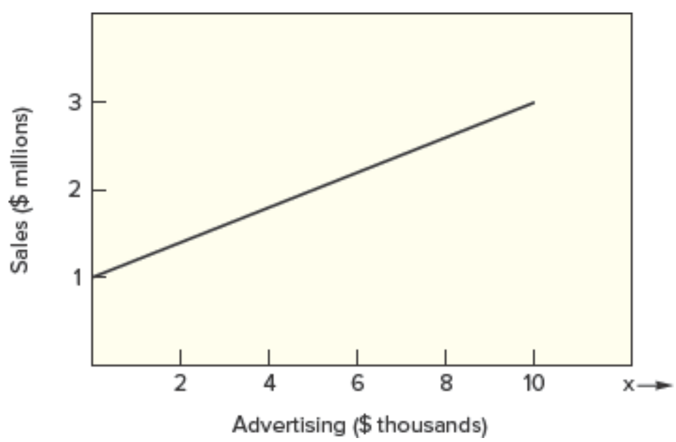
Year	Quarter	Demand	MA_4	MA_2	Demand/MA_2
1	1	14			
	2	18	28.25		
	3	35	31.75	30.00	1.17
	4	46	36.25	34.00	1.35
2	1	28	42.50	39.38	0.71
	2	36	48.75	45.63	0.79
	3	60	53.00	50.88	1.18
	4	71	57.50	55.25	1.29
3	1	45	63.50	60.50	0.74
	2	54	67.75	65.63	0.82
	3	84	71.00	69.38	1.21
	4	88			
4	1	58			

	QUARTER			
	1	2	3	4
	0.71	0.79	1.17	1.35
	0.74	0.82	1.18	1.29
	1.45	1.61	1.21	2.64
			3.56	
Average for the quarter:	0.725	0.805	1.187	1.320

The sum of these relatives is 4.037. Multiplying each by 4.00/4.037 will standardize the relatives, making their total equal 4.00. The resulting relatives are quarter 1, .718; quarter 2, .798; quarter 3, 1.176; quarter 4, 1.308.

Problem 5

Regression line. A large Midwestern retailer has developed a graph that summarizes the effect of advertising expenditures on sales volume. Using the graph, determine an equation of the form $y = a + bx$ that describes this relationship.



Solution

The linear equation has the form $y = a + bx$, where a is the value of y when $x = 0$ (i.e., where the line intersects the y axis) and b is the slope of the line (the amount by which y changes for a one-unit change in x).

Accordingly, $a = 1$ and $b = (3 - 1)/(10 - 0) = .2$, so $y = a + bx$ becomes $y = 1 + .2x$. [*Note:* $(3 - 1)$ is the change in y, and $(10 - 0)$ is the change in x.]

Problem 6

Regression analysis. The owner of a small hardware store has noted a sales pattern for window locks that seems to parallel the number of break-ins reported each week in the newspaper. The data are:

Sales:	46	18	20	22	27	34	14	37	30
Break-ins:	9	3	3	5	4	7	2	6	4

a. Plot the data to determine which type of equation, linear or nonlinear, is appropriate.

b. Obtain a regression equation for the data.

c. Estimate average sales when the number of break-ins is five.

Solution

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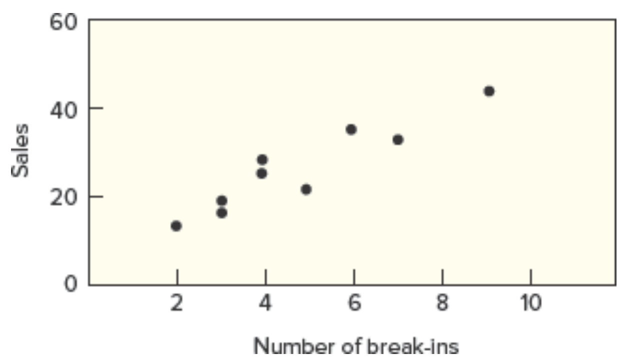
a.



The graph supports a linear relationship.

b. You can obtain the regression coefficients using the appropriate Excel template. Simply replace the existing data for x and y with your data. *Note:* Be careful to enter the values for the variable you want to predict as y values. In this problem, the objective is to predict sales, so the sales values are entered in the y column. The equation is $y_C = 7.129 + 4.275x$.

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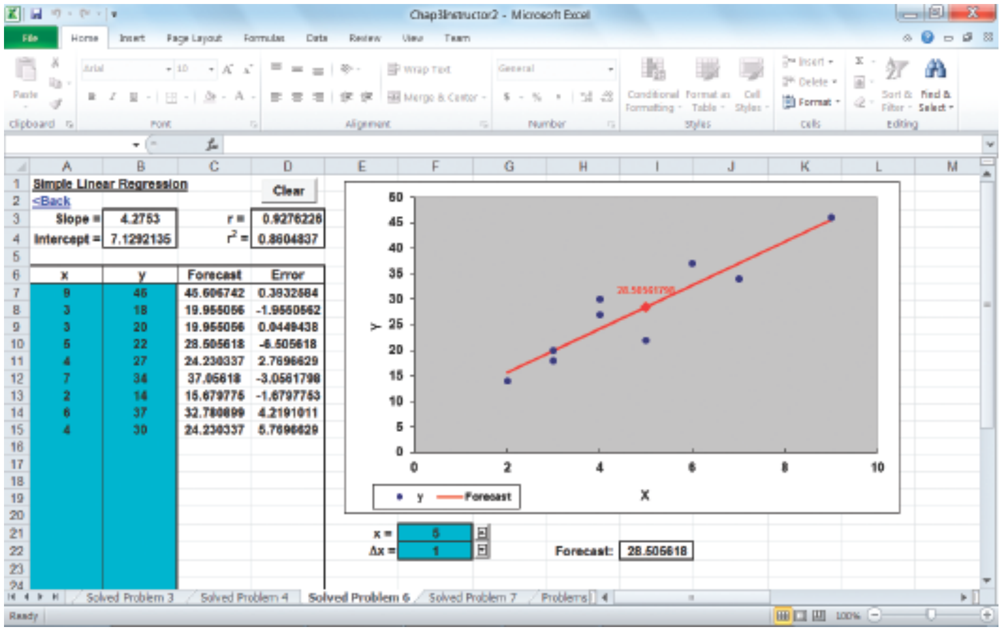

Source: Microsoft

c. For $x = 5$, $y_c = 7.129 + 4.275(5) = 28.50$.

Problem 7

eXcel

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Accuracy of forecasts. The manager of a large manufacturer of industrial pumps must choose between two alternative forecasting techniques. Both techniques have been used to prepare forecasts for a six-month period. Using MAD as a criterion, which technique has the better performance record?

		FORECAST	
Month	**Demand**	**Technique 1**	**Technique 2**
1	492	488	495
2	470	484	482
3	485	480	478
4	493	490	488
5	498	497	492
6	492	493	493

Solution

Check that each forecast has an average error of approximately zero. (See computations that follow.)

Month	Demand	Technique 1	e	$\|e\|$	Technique 2	e	$\|e\|$
1	492	488	4	4	495	−3	3
2	470	484	−14	14	482	−12	12
3	485	480	5	5	478	7	7
4	493	490	3	3	488	5	5
5	498	497	1	1	492	6	6
6	492	493	−1	1	493	−1	1
			−2	28		+2	34

$$MAD_1 = \frac{\sum |e|}{n} = \frac{28}{6} = 4.67$$

$$MAD_2 = \frac{\sum |e|}{n} = \frac{34}{6} = 5.67$$

Technique 1 is superior in this comparison because its MAD is smaller, although six observations would generally be too few on which to base a realistic comparison.

Problem 8

Control chart. Given the demand data that follow, prepare a naive forecast for periods 2 through 10. Then, determine each forecast error, and use those values to obtain 2*s* control limits. If demand in the next two periods turns out to be 125 and 130, can you conclude that the forecasts are in control?

Period:	1	2	3	4	5	6	7	8	9	10
Demand:	118	117	120	119	126	122	117	123	121	124

Solution

For a naive forecast, each period's demand becomes the forecast for the next period. Hence, the forecasts and errors are:

Period	Demand	Forecast	Error	Error^2
1	118	—	—	—
2	117	118	−1	1
3	120	117	3	9
4	119	120	−1	1
5	126	119	7	49
6	122	126	−4	16
7	117	122	−5	25
8	123	117	6	36
9	121	123	−2	4
10	124	121	3	9
			+6	150

$$s = \sqrt{\frac{\sum \text{Error}^2}{n-1}} = \sqrt{\frac{150}{9-1}} = 4.33 \quad (n = \text{Number of errors})$$

The control limits are 2(4.33) = ± 8.66.

The forecast for period 11 was 124. Demand turned out to be 125, for an error of 125 − 124 = +1. This is within the limits of ± 8.66. If the next demand is 130 and the naive forecast is 125 (based on the period 11 demand of 125), the error is + 5. Again, this is within the limits, so you cannot conclude the forecast is not working properly. With more values—at least five or six—you could plot the errors to see whether you could detect any patterns suggesting the presence of nonrandomness.

DISCUSSION AND REVIEW QUESTIONS

1. What are the main advantages that quantitative techniques for forecasting have over qualitative techniques? What limitations do quantitative techniques have?
2. What are some of the consequences of poor forecasts? Explain.
3. List the specific weaknesses of each of the following approaches to developing a forecast.
   a. Consumer surveys
   b. Salesforce composite
   c. Committee of managers or executives
4. Forecasts are generally wrong.
   a. Why are forecasts generally wrong?
   b. Explain the term “wrong” as it pertains to a good forecast.
5. What is the purpose of establishing control limits for forecast errors?
6. What factors would you consider in deciding whether to use wide or narrow control limits for forecasts?
7. Contrast the use of MAD and MSE in evaluating forecasts.
8. What advantages as a forecasting tool does exponential smoothing have over moving averages?

9. How does the number of periods in a moving average affect the responsiveness of the forecast?

10. What factors enter into the choice of a value for the smoothing constant in exponential smoothing?
11. How accurate is your local five-day weather forecast? Support your answer with actual data.
12. Explain how using a centered moving average with a length equal to the length of a season eliminates seasonality from a time series.
13. Contrast the terms *sales* and *demand.*
14. Contrast the reactive and proactive approaches to forecasting. Give several examples of types of organizations or situations in which each type is used.
15. Explain how flexibility in production systems relates to the forecast horizon and forecast accuracy.
16. How is forecasting in the context of a supply chain different from forecasting for just a single organization? List possible supply chain benefits and discuss potential difficulties in doing supply chain forecasting.
17. Which type of forecasting approach, qualitative or quantitative, is better?
18. Suppose a software producer is about to release a new version of its popular software. What information do you think it would take into account in forecasting initial sales?
19. Choose the type of forecasting technique (survey, Delphi, averaging, seasonal, naive, trend, or associative) that would be most appropriate for predicting the:
    a. Demand for Mother's Day greeting cards.
    b. Popularity of a new television series.
    c. Demand for vacations on the moon.
    d. Impact a price increase of 10 percent would have on sales of orange marmalade.
    e. Demand for toothpaste in a particular supermarket.

TAKING STOCK

1. Explain the trade-off between responsiveness and stability in a forecasting system that uses time-series data.
2. Who needs to be involved in preparing forecasts?
3. How has technology had an impact on forecasting?

CRITICAL THINKING EXERCISES

1. It has been said that forecasting using exponential smoothing is like driving a car by looking in the rear-view mirror. What are the conditions that would have to exist for driving a car that are analogous to the assumptions made when using exponential smoothing?
2. What capability would an organization have to have to not need forecasts?
3. When a new business is started, or a patent idea needs funding, venture capitalists or investment bankers will want to see a business plan that includes forecast information

related to a profit and loss statement. What type of forecasting information do you suppose would be required?

4. Discuss how you would manage a poor forecast.
5. Omar has heard from some of his customers that they will probably cut back on order sizes in the next quarter. The company he works for has been reducing its salesforce due to falling demand, and he worries that he could be next if his sales begin to fall off. Believing that he may be able to convince his customers not to cut back on orders, he turns in an optimistic forecast of his next quarter sales to his manager. What are the pros and cons of doing that?
6. Give three examples of unethical conduct involving forecasting and the ethical principle each violates.

PROBLEMS

1. A commercial bakery has recorded sales (in dozens) for three products, shown as follows:

Day	Blueberry Muffins	Cinnamon Buns	Cupcakes
1	30	18	45
2	34	17	26
3	32	19	27
4	34	19	23
5	35	22	22
6	30	23	48
7	34	23	29
8	36	25	20
9	29	24	14
10	31	26	18
11	35	27	47
12	31	28	26
13	37	29	27
14	34	31	24
15	33	33	22

a. Predict orders for the following day for each of the products using an appropriate naive method. *Hint:* Plot each data set.

b. What should the use of *sales* data instead of *demand* imply?

2. National Scan, Inc., sells radio frequency inventory tags. Monthly sales for a seven-month period were as follows:

Month	Sales (000 units)
Feb.	19
Mar.	18
Apr.	15
May	20
Jun.	18
Jul.	22
Aug.	20

a. Plot the monthly data on a sheet of graph paper.

b. Forecast September sales volume using each of the following:

(1) The naive approach

(2) A five-month moving average

(3) A weighted average using .60 for August, .30 for July, and .10 for June

(4) Exponential smoothing with a smoothing constant equal to .20, assuming a a March forecast of 19(000)

(5) A linear trend equation

c. Which method seems least appropriate? Why? (*Hint:* Refer to your plot from part *a.*)

d. What does use of the term *sales* rather than *demand* presume?

3. A dry cleaner uses exponential smoothing to forecast equipment usage at its main plant. August usage was forecasted to be 88 percent of capacity; actual usage was 89.6 percent of capacity. A smoothing constant of .1 is used.

a. Prepare a forecast for September.

b. Assuming actual September usage of 92 percent, prepare a forecast for October usage.

4. An electrical contractor's records during the last five weeks indicate the number of job requests:

Week	1	2	3	4	5
Requests	20	22	18	21	22

Predict the number of requests for week 6 using each of these methods:

a. Naive

b. A four-period moving average

c. Exponential smoothing with α = .30; use 20 for week 2 forecast

5. A cosmetics manufacturer's marketing department has developed a linear trend equation that can be used to predict annual sales of its popular Hand

& Foot Cream.

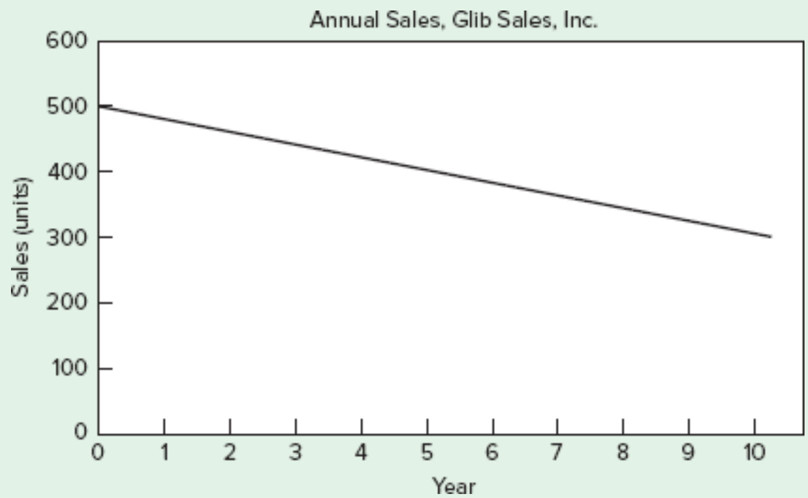
$F_t = 80 + 15t$

where

F_t = Annual sales (000 bottles)
t is in years

a. Are annual sales increasing or decreasing? By how much?
b. Predict annual sales for year 6 using the equation.

6. From the following graph, determine the equation of the linear trend line for time-share sales for Glib Marketing, Inc.



7. Freight car loadings over a 12-year period at a busy port are as follows:

Week	Number	Week	Number	Week	Number
1	220	7	350	13	460
2	245	8	360	14	475
3	280	9	400	15	500
4	275	10	380	16	510
5	300	11	420	17	525
6	310	12	450	18	541

a. Determine a linear trend line for expected freight car loadings.
b. Use the trend equation to predict expected loadings for weeks 20 and 21.
c. The manager intends to install new equipment when the volume exceeds 800 loadings per week. Assuming the current trend continues, the loading volume will reach that level in approximately what week?

8. Air travel on Mountain Airlines for the past 18 weeks was:

Week	Passengers

Week	Passengers
1	405
2	410
3	420
4	415
5	412
6	420
7	424
8	433
9	438
10	440
11	446
12	451
13	455
14	464
15	466
16	474
17	476
18	482

a. Explain why an averaging technique would not be appropriate for forecasting.

b. Use an appropriate technique to develop a forecast for the expected number of passengers for the next three weeks.

9. a. Obtain the linear trend equation for the following data on new checking accounts at Fair Savings Bank and use it to predict expected new checking accounts for periods 16 through 19.

Period	New Accounts	Period	New Accounts	Period	New Accounts
1	200	6	232	11	281
2	214	7	248	12	275
3	211	8	250	13	280
4	228	9	253	14	288
5	235	10	267	15	310

b. Use trend-adjusted smoothing with $\alpha = .3$ and $\beta = .2$ to smooth the new account data in part *a.* What is the forecast for period 16?

10. After plotting demand for four periods, an emergency room manager has concluded that a trend-adjusted exponential smoothing model is appropriate to predict future demand. The initial estimate of trend is based on the net change of 30 for the *three* periods from 1

to 4, for an average of +10 units. Use α = .5 and β = .4, and TAF of 250 for period 5. Obtain forecasts for periods 6 through 10.

Period	Actual	Period	Actual
1	210	6	265
2	224	7	272
3	229	8	285
4	240	9	294
5	255	10	

11. A manager of a store that sells and installs spas wants to prepare a forecast for January, February, and March of next year. Her forecasts are a combination of trend and seasonality. She uses the following equation to estimate the trend component of monthly demand: $F_t = 70 + 5t$, where $t = 0$ in June of last year. Seasonal relatives are 1.10 for January, 1.02 for February, and .95 for March. What demands should she predict?
12. The following equation summarizes the trend portion of quarterly sales of condominiums over a long cycle. Sales also exhibit seasonal variations. Using the information given, prepare a forecast of sales for each quarter of next year (not this year), and the first quarter of the year following that.

$$F_t = 40 - 6.5t + 2t^2$$

where

F_t = Unit Sales
t = 0 at the first quarter of last year

Quarter	Relative
1	1.1
2	1.0
3	.6
4	1.3

13. Compute seasonal relatives for this data using the SA method:

Quarter	Year 1	Year 2	Year 3	Year 4
1	2	3	7	4
2	6	10	18	14
3	2	6	8	8
4	5	9	15	11

14. A tourist center is open on weekends (Friday, Saturday, and Sunday). The owner-manager hopes to improve scheduling of part-time employees by determining seasonal

relatives for each of these days. Data on recent traffic at the center have been tabulated and are shown in the following table:

	WEEK					
	1	2	3	4	5	6
Friday	149	154	152	150	159	163
Saturday	250	255	260	268	273	276
Sunday	166	162	171	173	176	183

a. Develop seasonal relatives for the shop using the centered moving average method.

b. Develop seasonal relatives for the shop using the SA method (see Example 8B).

c. Explain why the results of the two methods correlate the way they do.

15. The manager of a fashionable restaurant open Wednesday through Saturday says that the restaurant does about 35 percent of its business on Friday night, 30 percent on Saturday night, and 20 percent on Thursday night. Which seasonal relatives would describe this situation?

16. Obtain estimates of daily relatives for the number of customers at a restaurant for the evening meal, given the following data.

a. Use the centered moving average method. (*Hint:* Use a seven-day moving average.)

b. Use the SA method.

Day	Number Served
1	80
2	75
3	78
4	95
5	130
6	136
7	40
8	82
9	77
10	80
11	94
12	131
13	137
14	42
15	84
16	78
17	83

Day	Number Served
18	96
19	135
20	140
21	44
22	87
23	82
24	88
25	99
26	144
27	144
28	48

17. A pharmacist has been monitoring sales of a certain over-the-counter pain reliever. Daily sales during the last 15 days were as follows:

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Day	1	2	3	4	5	6	7	8	9
Number sold	36	38	42	44	48	49	50	49	52
Day	10	11	12	13	14	15			
Number sold	48	52	55	54	56	57			

a. Which method would you suggest using to predict future sales—a linear trend equation or trend-adjusted exponential smoothing? Why?

b. If you learn that on some days the store ran out of the specific pain reliever, would that knowledge cause you any concern? Explain.

c. Assume that the data refer to demand rather than sales. Using trend-adjusted smoothing with an initial forecast of 50 for day 8, an initial trend estimate of 2, and $\alpha = \beta = .3$, develop forecasts for days 9 through 16. What is the MSE for the eight forecasts for which there are actual data?

18. New car sales for a dealer in Cook County, Illinois, for the past year are shown in the following table, along with monthly indexes (seasonal relatives), which are supplied to the dealer by the regional distributor.

Month	Units Sold	Index
Jan.	640	0.80
Feb.	648	0.80
Mar.	630	0.70
Apr.	761	0.94
May.	735	0.89

Month	Units Sold	Index
Jun.	850	1.00
Jul.	765	0.90
Aug.	805	1.15
Sept.	840	1.20
Oct.	828	1.20
Nov.	840	1.25
Dec.	800	1.25

a. Plot the data. Does there seem to be a trend?
b. Deseasonalize car sales.
c. Plot the deseasonalized data on the same graph as the original data. Comment on the two graphs.
d. Assuming no proactive approach on the part of management, discuss (no calculations necessary) how you would forecast sales for the first three months of the next year.
e. What action might management consider based on your findings in part *b*?

19. The following table shows a tool and die company's quarterly sales for the current year. What sales would you predict for the first quarter of next year? Quarter relatives are $SR_1 = 1.10$, $SR_2 = .99$, $SR_3 = .90$, and $SR_4 = 1.01$.

Quarter	1	2	3	4
Sales	88	99	108	141.4

20. An analyst must decide between two different forecasting techniques for weekly sales of roller blades: a linear trend equation and the naive approach. The linear trend equation is = 124 + 2*t*, and it was developed using data from periods 1 through 10. Based on data for periods 11 through 20 as shown in the table, which of these two methods has the greater accuracy if MAD and MSE are used?

t	Units Sold
11	147
12	148
13	151
14	145
15	155
16	152
17	155
18	157
19	160

t	Units Sold
20	165

21. Two different forecasting techniques (F1 and F2) were used to forecast demand for cases of bottled water. Actual demand and the two sets of forecasts are as follows:

		PREDICTED DEMAND	
Period	**Demand**	**F1**	**F2**
1	68	66	66
2	75	68	68
3	70	72	70
4	74	71	72
5	69	72	74
6	72	70	76
7	80	71	78
8	78	74	80

a. Compute MAD for each set of forecasts. Given your results, which forecast appears to be more accurate? Explain.
b. Compute the MSE for each set of forecasts. Given your results, which forecast appears to be more accurate?
c. In practice, *either* MAD *or* MSE would be employed to compute forecast errors. What factors might lead a manager to choose one rather than the other?
d. Compute MAPE for each data set. Which forecast appears to be more accurate?

22. Two independent methods of forecasting based on judgment and experience have been prepared each month for the past 10 months. The forecasts and actual sales are as follows:

Month	Sales	Forecast 1	Forecast 2
1	770	771	769
2	789	785	787
3	794	790	792
4	780	784	798
5	768	770	774
6	772	768	770

Month	Sales	Forecast 1	Forecast 2
7	760	761	759
8	775	771	775
9	786	784	788
10	790	788	788

a. Compute the MSE and MAD for each forecast. Does either forecast seem superior? Explain.

b. Compute MAPE for each forecast.

c. Prepare a naive forecast for periods 2 through 11 using the given sales data. Compute each of the following: (1) MSE, (2) MAD, (3) tracking signal at month 10, and (4) 2*s* control limits. How do the naive results compare with the other two forecasts?

23. Long-Life Insurance has developed a linear model that it uses to determine the amount of term life insurance a family of four should have, based on the current age of the head of the household. The equation is:

$$y = 850 - .1x$$

where

y = Insurance needed ($000)
x = Current age of head of household

a. Plot the relationship on a graph.

b. Use the equation to determine the amount of term life insurance to recommend for a family of four if the head of the household is 30 years old.

24. Timely Transport provides local delivery service for a number of downtown and suburban businesses. Delivery charges are based on distance and weight involved for each delivery: 10 cents per pound and 15 cents per mile. Also, there is a $10 handling fee per parcel.

a. Develop an expression that summarizes delivery charges.

b. Determine the delivery charge for transporting a 40-pound parcel 26 miles.

25. The manager of a seafood restaurant was asked to establish a pricing policy on lobster dinners. Experimenting with prices produced the following data:

Average Number Sold per Day, *y*	Price, *x*	Average Number Sold per Day, *y*	Price, *x*
200	$6.00	155	$8.25
190	6.50	156	8.50
188	6.75	148	8.75
180	7.00	140	9.00

Average Number Sold per Day, *y*	Price, *x*	Average Number Sold per Day, *y*	Price, *x*
170	7.25	133	9.25
162	7.50		
160	8.00		

a. Plot the data and a regression line on the same graph.
b. Determine the correlation coefficient and interpret it.

26. The following data were collected during a study of consumer buying patterns:

Observation	*x*	*y*
1	15	74
2	25	80
3	40	84
4	32	81
5	51	96
6	47	95
7	30	83
8	18	78
9	14	70
10	15	72
11	22	85
12	24	88
13	33	90

1. Plot the data.
2. Obtain a linear regression line for the data.
3. What percentage of the variation is explained by the regression line?
4. Use the equation determined in part *b* to predict the expected value of *y* for *x* = 41.

27. Lovely Lawns, Inc., intends to use sales of lawn fertilizer to predict lawn mower sales. The store manager estimates a probable six-week lag between fertilizer sales and mower sales. The pertinent data are:

Period	Fertilizer Sales (tons)	Number of Mowers Sold (six-week lag)
1	1.6	10
2	1.3	8
3	1.8	11
4	2.0	12
5	2.2	12
6	1.6	9
7	1.5	8
8	1.3	7
9	1.7	10
10	1.2	6
11	1.9	11
12	1.4	8
13	1.7	10
14	1.6	9

a. Determine the correlation between the two variables. Does it appear that a relationship between these variables will yield reasonable predictions? Explain.

b. Obtain a linear regression line for the data.

c. Predict expected lawn mower sales for the first week in August, given fertilizer sales six weeks earlier of 2 tons.

28. The manager of a travel agency has been using a seasonally adjusted forecast to predict demand for packaged tours. The actual and predicted values are as follows:

Period	Demand	Predicted
1	129	124
2	194	200
3	156	150
4	91	94
5	85	80
6	132	140
7	126	128
8	126	124
9	95	100

Period	Demand	Predicted
10	149	150
11	98	94
12	85	80
13	137	140
14	134	128

a. Compute MAD for the fifth period, and then update it period by period using exponential smoothing with $\alpha = .3$.

b. Compute a tracking signal for periods 5 through 14 using the initial and updated MADs. If limits of ± 4 are used, what can you conclude?

29. Refer to the data in problem 22.

a. Compute a tracking signal for the 10th month for each forecast using the cumulative error for months 1 to 10. Use action limits of ± 4. Is there bias present? Explain.

b. Compute 2*s* control limits for each forecast.

30. The classified department of a monthly magazine has used a combination of quantitative and qualitative methods to forecast sales of advertising space. Results over a 20-month period are as follows:

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Month	Error
1	−8
2	−2
3	4
4	7
5	9
6	5
7	0
8	−3
9	−9
10	−4
11	1
12	6
13	8
14	4
15	1
16	−2

Month	Error
17	−4
18	−8
19	−5
20	−1

a. Compute a tracking signal for months 11 through 20. Compute an initial value of MAD for month 11, and then update it for each month using exponential smoothing with α = .1. What can you conclude? Assume limits of ± 4.

b. Using the first half of the data, construct a control chart with 2*s* limits. What can you conclude?

c. Plot the last 10 errors on the control chart. Are the errors random? What is the implication of this?

31. A textbook publishing company has compiled data on total annual sales of its business texts for the preceding nine years:

Year	1	2	3	4	5	6	7	8	9
Sales (000)	40.2	44.5	48.0	52.3	55.8	57.1	62.4	69.0	73.7

a. Using an appropriate model, forecast textbook sales for each of the next five years.

b. Prepare a control chart for the forecast errors using the original data. Use 2*s* limits.

c. Suppose actual sales for the next five years turn out as follows:

Year	10	11	12	13	14
Sales (000)	77.2	82.1	87.8	90.6	98.9

Is the forecast performing adequately? Explain.

32. A manager has just received an evaluation from an analyst on two potential forecasting alternatives. The analyst is indifferent between the two alternatives, saying that they should be equally effective.

Period	1	2	3	4	5	6	7	8	9	10
Data	37	39	37	39	45	49	47	49	51	54
Alt. 1	36	38	40	42	46	46	46	48	52	55
Alt. 2	36	37	38	38	41	52	47	48	52	53

a. What would cause the analyst to reach this conclusion?

b. What information can you add to enhance the analysis?

33. A manager uses this equation to predict demand for landscaping services: $F_t = 10 + 5t$. Over the past eight periods, demand has been as follows:

Period, *t*	1	2	3	4	5	6	7	8
Demand	15	21	23	30	32	38	42	47

Is the forecast performing adequately? Explain.

34. A manager uses a trend equation plus quarter relatives to predict demand. Quarter relatives are $SR_1 = .90$, $SR_2 = .95$, $SR_3 = 1.05$, and $SR_4 = 1.10$. The trend equation is: $F_t = 10 + 5t$. Over the past nine quarters, demand has been as follows:

Period, t	1	2	3	4	5	6	7	8	9
Demand	14	20	24	31	31	37	43	48	52

Is the forecast performing adequately? Explain.

CASE M&L MANUFACTURING

M&L Manufacturing makes various components for printers and copiers. In addition to supplying these items to a major manufacturer, the company distributes these and similar items to office supply stores and computer stores as replacement parts for printers and desktop copiers. In all, the company makes about 20 different items. The two markets (the major manufacturer and the replacement market) require somewhat different handling. For example, replacement products must be packaged individually, whereas products are shipped in bulk to the major manufacturer.

The company does not use forecasts for production planning. Instead, the operations manager decides which items to produce and the batch size, based on orders and the amounts in inventory. The products that have the fewest amounts in inventory get the highest priority. Demand is uneven, and the company has experienced being overstocked on some items and out of others. Being understocked has occasionally created tensions with the managers of retail outlets. Another problem is that prices of raw materials have been creeping up, although the operations manager thinks that this might be a temporary condition.

Because of competitive pressures and falling profits, the manager has decided to undertake a number of changes. One change is to introduce more formal forecasting procedures in order to improve production planning and inventory management.

With that in mind, the manager wants to begin forecasting for two products. These products are important for several reasons. First, they account for a disproportionately large share of the company's profits. Second, the manager believes that one of these products will become increasingly important to future growth plans; and third, the other product has experienced periodic out-of-stock instances.

The manager has compiled data on product demand for the two products from order records for the previous 14 weeks. These are shown in the following table.

Week	Product 1	Product 2
1	50	40
2	54	38
3	57	41
4	60	46
5	64	42
6	67	41
7	90*	41
8	76	47
9	79	42
10	82	43
11	85	42
12	87	49
13	92	43
14	96	44

*Unusual order due to flooding of customer's warehouse.

QUESTIONS

1. What are some of the potential benefits of a more formalized approach to forecasting?
2. Prepare a weekly forecast for the next four weeks for each product. Briefly explain why you chose the methods you used. (*Hint:* For

product 2, a simple approach, possibly some sort of naive/intuitive approach, would be preferable to a technical approach in view of the manager's disdain of more technical methods.)

CASE HIGHLINE FINANCIAL SERVICES, LTD.

Highline Financial Services provides three categories of service to its clients. Managing partner Freddie Mack is getting ready to prepare financial and personnel hiring (or layoff) plans for the coming year. He is a bit perplexed by the following printout he obtained, which seems to show oscillating demand for the three categories of services over the past eight quarters:

		Service		
Year	Quarter	A	B	C
1	1	60	95	93
	2	45	85	90
	3	100	92	110
	4	75	65	90

Examine the demand that this company has experienced for the three categories of service it offers over the preceding two years. Assuming nothing changes in terms of advertising or promotion, and competition doesn't change, predict demand for the services the company offers for the next four quarters. Note that there are not enough data to develop seasonal relatives. Nonetheless, you should be able to make reasonably good, approximate *intuitive* estimates of demand. What general observations can you make regarding demand? Should Freddie have any concerns? Explain.

Year	Quarter	Service A	Service B	Service C
2	1	72	85	102
	2	51	75	75
	3	112	85	110
	4	85	50	100

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[1] See, for example, Bernard T. Smith and Virginia Brice, *Focus Forecasting: Computer Techniques for Inventory Control Revised for the Twenty-First Century* (Essex Junction, VT: Oliver Wight, 1984).

[2] See, for example, *The National Bureau of Economic Research, The Survey of Current Business, The Monthly Labor Review,* and *Business Conditions Digest.*

[3] The absolute value, represented by the two vertical lines in Formula 3–2, ignores minus signs; all data are treated as positive values. For example, −2 becomes +2.

[4] The actual value could be computed as $s = \sqrt{\frac{\sum(e - \bar{e})^2}{n-1}}$..

[5] The theory and application of control charts and the various methods for detecting patterns in the data are covered in more detail in Chapter 10, on quality control.

CHAPTER 4

Product and Service Design

LEARNING OBJECTIVES

After completing this chapter, you should be able to:

LO4.1 Explain the strategic importance of product and service design.

LO4.2 Describe what product and service design does.

LO4.3 Name the key questions of product and service design.

LO4.4 Identify some reasons for design or redesign.

LO4.5 List some of the main sources of design ideas.

LO4.6 Discuss the importance of legal, ethical, and sustainability considerations in product and service design.

LO4.7 Explain the purpose and goal of life-cycle assessment.

LO4.8 Explain the phrase "the 3 Rs."

LO4.9 Briefly describe the phases in product design and development.

LO4.10 Discuss several key issues in product or service design.

LO4.11 Discuss the two key issues in service design.

LO4.12 List the characteristics of well-designed service systems.

LO4.13 List some guidelines for successful service design.

CHAPTER OUTLINE

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Mark Lennihan/AP Images

LO4.1 Explain the strategic importance of product and service design.

The essence of a business organization is the products and services it offers, and every aspect of the organization and its supply chain are structured around those products and services. Organizations that have well-designed products or services are more likely to realize their goals than those with poorly designed products or services. Hence, organizations have a strategic interest in product and service design. Product or service design should be closely tied to an organization's strategy. It is a major factor in cost, quality, time-to-market, customer satisfaction, and competitive advantage. Consequently, marketing, finance, operations, accounting, IT, and HR need to be involved. Demand forecasts and projected costs are important, as is the expected impact on the supply chain. It is significant to note that an important cause of operations failures can be traced to faulty design. Designs that have not been well thought out, or are incorrectly implemented, or instructions for assembly or usage that are wrong or unclear, can be the cause of product and service failures, leading to lawsuits, injuries and deaths, product recalls, and damaged reputations.

The introduction of new products or services, or changes to product or service designs, can have impacts throughout the organization and the entire supply chain. Some processes may change very little, while others may have to change considerably in terms of what they do or how and when they do it. New processes may have to be added, and some current ones may be eliminated. New suppliers and distributors may need to be found and integrated into the system, and some current suppliers and distributors may no longer be an appropriate fit. Moreover, it is necessary to take into account the projected impact on demand, as well as the financial, marketing, and distribution implications. Because of the potential for widespread effects, taking a "big picture" systems approach early and throughout the design or redesign process is imperative to reduce the chance of missing some implications and costs, and to understand the time it will take. Likewise, input from engineering, operations, marketing, finance, accounting, and supply chains is crucial.

In this chapter, you will discover insights into the design process that apply to both product and service design.

READING

DESIGN AS A BUSINESS STRATEGY

As businesses continue to reduce costs to achieve competitive advantage, design issues are becoming increasingly important aspects of business strategy. Because product and service design touches every part of a business organization, from operations and supply chains to finance, marketing, accounting, and information systems, design decisions have far-reaching implications for the organization and its success in the marketplace. Product and service innovation is becoming a key avenue in pursuing a competitive edge, and sustainability issues are being given increasing importance in business decisions.

Some companies, such as Steelcase, Inc., have adopted "design thinking" to integrate design strategy throughout the company. The idea is to predicate design on insights into user wants and needs—and thus put forth a concept that then becomes the focal point of how the company makes design decisions.

Source: "Product Redesign, Not Offshoring, Holds Cost Advantage for U.S. Manufacturers," *Supply & Demand Chain Executive,* September 8, 2004. Cygnus Business Media.

4.1 INTRODUCTION

LO4.2 Describe what product and service design does.

This section discusses what product and service designers do, the reasons for design (or redesign), and key questions that management must address.

What Does Product and Service Design Do?

The primary focus of product or service design should be on customer satisfaction. The various activities and responsibilities of product and service design include the following (functional interactions are shown in parentheses):

- Translate customer wants and needs into product and service requirements (marketing, operations)
- Refine existing products and services (marketing)
- Develop new products and/or services (marketing, operations)
- Formulate quality goals (marketing, operations)
- Formulate cost targets (accounting, finance, operations)
- Construct and test prototypes (operations, marketing, engineering)
- Document specifications
- Translate product and service specifications into *process* specifications (engineering, operations)

Product and service design involves or affects nearly every functional area of an organization. However, marketing and operations have major involvement.

Objectives of Product and Service Design

Primary consideration: Customer satisfaction.

Secondary considerations: Cost or profit, quality, ability to produce a product or service, ethics/safety, and sustainability.

Key Questions

LO4.3 Name the key questions of product and service design.

From a buyer's standpoint, most purchasing decisions entail two fundamental considerations; one is cost and the other is quality or performance. From the organization's standpoint, the key questions are:

- **Is there demand for it?** What is the potential size of the market, and what is the expected demand profile (will demand be long term or short term, will it grow slowly or quickly)?
- **Can we do it?** Do we have the necessary knowledge, skills, equipment, capacity, and supply chain capability? For products, this is known as **manufacturability**; for services, this is known as **serviceability**. Also, is outsourcing some or all of the work an option?

Manufacturability The capability of an organization to produce an item at an acceptable profit.

Serviceability The capability of an organization to provide a service at an acceptable cost or profit.

- **What level of quality is appropriate?** What do customers expect? What level of quality do competitors provide for similar items? How would it fit with our current offerings?
- **Does it make sense from an economic standpoint?** What are the potential liability issues, ethical considerations, sustainability issues, costs, and profits? For nonprofits, is the cost within budget?

Reasons for Product and Service Design or Redesign

LO4.4
Identify some reasons for design or redesign.

Product and service design typically has *strategic* implications for the success and prosperity of an organization. Consequently, decisions in this area are some of the most fundamental that managers must make. Product and service design or redesign should be closely tied to an organization's strategy.

Organizations become involved in product and service design or redesign for a variety of reasons. The main forces that initiate design or redesign are market opportunities and threats. The factors that give rise to market opportunities and threats can be one or more *changes:*

- **Economic** (e.g., low demand, excessive warranty claims, the need to reduce costs)
- **Social and demographic** (e.g., aging baby boomers, population shifts)
- **Political, liability, or legal** (e.g., government changes, safety issues, new regulations)
- **Competitive** (e.g., new or changed products or services, new advertising/promotions)
- **Cost or availability** (e.g., of raw materials, components, labor, water, energy)
- **Technological** (e.g., in product components, processes)

While each of these factors may seem obvious, let's reflect a bit on technological changes, which can create a need for product or service design changes in several different ways. An obvious way is new technology that can be used directly in a product or service (e.g., a faster, smaller microprocessor that spawns a new generation of smartphones). Technology also can indirectly affect product and service design: Advances in processing technology may require altering an existing design to make it compatible with the new processing technology. Still another way that technology can impact product design is illustrated by digital recording technology that allows television viewers to skip commercials when they view a recorded program. This means that advertisers (who support a television program) can't get their message to viewers. To overcome this, some advertisers have adopted a strategy of making their products an integral part of a television program, say by having their products prominently displayed and/or mentioned by the actors as a way to call viewers' attention to their products without the need for commercials.

The following reading suggests another potential benefit of product redesign.

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READING

DUTCH BOY BRUSHES UP ITS PAINTS

Sherwin-Williams' Dutch Boy Group put a revolutionary spin on paint cans with its innovative square-shaped Twist & PourTM paint-delivery container for the Dirt Fighter interior latex paint line. The four-piece square container could be the first major change in how house paint is packaged in decades. Lightweight but sturdy, the Twist & Pour "bucket" is packed with so many conveniences, it is next to impossible to mess up a painting project.

Winning Best of Show in an AmeriStar packaging competition sponsored by the Institute of Packaging Professionals, the exclusive, all-plastic paint container stands almost 7½ in. tall and holds 126 oz., a bit less than 1 gal. Rust-resistant and moisture-resistant, the plastic bucket gives users a new way to mix, brush, and store paint.

A hollow handle on one side makes it comfortable to pour and carry. A convenient, snap-in pour spout neatly pours paint into a tray with no dripping but can be removed if desired, to allow a wide brush to be dipped into the 5¾-in.-diameter mouth. Capping the container is a large, twist-off lid that requires no tools to open or close. Molded with two lugs for a snug-finger-tight closing, the threaded cap provides a tight seal to extend the shelf life of unused paint.

While the lid requires no tools to access, the snap-off carry bail is assembled on the container in a “locked-down position” and can be pulled up after purchase for toting or hanging on a ladder. Large, nearly 4½-inch-tall label panels allow glossy front and back labels printed and UV-coated to wrap around the can’s rounded corners, for an impressive display.

Jim MacDonald, co-designer of the Twist & Pour and a packaging engineer at Cleveland-based Sherwin-Williams, tells *Packaging Digest* that the space-efficient, square shape is easier to ship and easier to stack in stores. It can also be nested, courtesy of a recess in the bottom that mates with the lid’s top ring. “The new design allows for one additional shelf facing on an eight-foot rack or shelf area.”

Jerry Simon

The labels are applied automatically, quite a feat, considering their complexity, size, and the hollow handle they likely encounter during application. MacDonald admits, “Label application was a challenge. We had to modify the bottle several times to accommodate the labeling machinery available.”

Source: “Dutch Boy Brushes Up Its Paints,” *Packaging Digest,* October 2002.

4.2 IDEA GENERATION

LO4.5 List some of the main sources of design ideas.

Ideas for new or redesigned products or services can come from a variety of sources, including customers, the supply chain, competitors, employees, and research. Customer input can come from surveys, focus groups, complaints, and unsolicited suggestions for improvement. Input from suppliers, distributors, and employees can be obtained from interviews, direct or indirect suggestions, and complaints.

One of the strongest motivators for new and improved products or services is competitors' products and services. By studying a competitor's products or services and how the competitor operates (pricing policies, return policies, warranties, location strategies, etc.), an organization can glean many ideas. Beyond that, some companies purchase a competitor's product and then carefully dismantle and inspect it, searching for ways to improve their own product. This is called **reverse engineering**. Automotive companies use this tactic in developing new models. They examine competitors' vehicles, searching for best-in-class components (e.g., best hood release, best dashboard display, best door handle). Sometimes, reverse engineering can enable a company to leapfrog the competition by developing an even better product. However, some forms of reverse engineering are illegal under the *Digital Millennium Copyright Act.*

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

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READING

VLASIC'S BIG PICKLE SLICES

The folks at Vlasic Pickles, a popular brand of all kinds of pickles, decided there was a market for large pickle slices. Pickles, of course, are made from brining cucumbers. The problem was, in order to get large slices, they needed large cucumbers, which didn't exist at the time.

AN NGUYEN/Shutterstock

So Vlasic had to first come up with large cucumbers. Think Botany 101. They crossed a variety of cucumber types, and then had to wait about 10 weeks, the time needed for the cucumber plants to mature, to see what developed. After several attempts, they finally developed a strain of large cucumbers. But those cucumbers didn't taste quite right, so it was back to the drawing board, or, in this case, more crossing of different cucumber varieties, and then waiting another 10 weeks for the results. Eventually, they got it right: large cucumbers that had the taste they wanted.

End of story? Not quite. The pickle-slicing equipment in the factory wasn't able to handle the large pickles, and it broke down when trying to slice the larger pickles. That meant that new equipment had to be designed and installed that was able to slice the large pickles.

Questions

1. What are some reasons consumers would be interested in large pickle slices? Name two reasons.
2. What lesson about new product development does this story tell?

Suppliers are still another source of ideas, and with increased emphasis on supply chains and supplier partnerships, suppliers are becoming an important source of ideas.

Research is another source of ideas for new or improved products or services. **Research and development (R&D)** refers to organized efforts that are directed toward increasing scientific knowledge and product or process innovation. Most of the advances in semiconductors, medicine, communications, and space technology can be attributed to R&D efforts at colleges and universities, research foundations, government agencies, and private enterprises.

Research and development (R&D) Organized efforts to increase scientific knowledge or product innovation.

R&D efforts may involve *basic research, applied research,* or *development.*

Basic research has the objective of advancing the state of knowledge about a subject, without any near-term expectation of commercial applications.

Applied research has the objective of achieving commercial applications.

Development converts the results of applied research into useful commercial applications.

Basic research, because it does not lead to near-term commercial applications, is generally underwritten by the government and large corporations. Conversely, applied research and development, because of the potential for commercial applications, appeals to a wide spectrum of business organizations.

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

The costs of R&D can be high. Some companies spend more than $1 million *a day* on R&D. Large companies in the automotive, computer, communications, and pharmaceutical industries spend even more. For example, IBM spends about $6 billion a year, and Hewlett-Packard Enterprises about $2 billion a year. Even so, critics say that many U.S. companies spend too little on R&D, a factor often cited in the loss of competitive advantage.

It is interesting to note that some companies are now shifting from a focus primarily on *products* to a more balanced approach that explores both product and *process* R&D. Also, there is

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increasing recognition that technologies often go through life cycles, the same way that many products do. This can impact R&D efforts on two fronts. Sustained economic growth requires constant attention to competitive factors over a life cycle, and it also requires planning to be able to participate in the next-generation technology.

In certain instances, however, research may not be the best approach. The preceding reading illustrates a research success.

4.3 LEGAL AND ETHICAL CONSIDERATIONS

LO4.6
Discuss the importance of legal, ethical, and sustainability considerations in product and service design.

Designers must be careful to take into account a wide array of legal and ethical considerations. Generally, they are mandatory. Moreover, if there is a potential to harm the environment, then those issues also become important. Most organizations are subject to numerous government agencies that regulate them. Among the more familiar federal agencies are the Food and Drug Administration, the Occupational Health and Safety Administration, the Environmental Protection Agency, and various state and local agencies. Bans on cyclamates, red food dye, phosphates, and asbestos have sent designers scurrying back to their drawing boards to find alternative designs that were acceptable to both government regulators and customers. Similarly, automobile pollution standards and safety features, such as seat belts, air bags, safety glass, and energy-absorbing bumpers and frames, have had a substantial impact on automotive design. Much attention also has been directed toward toy design to remove sharp edges, small pieces that can cause choking, and toxic materials. The government further regulates construction, requiring the use of lead-free paint, safety glass in entranceways, access to public buildings for individuals with disabilities, and standards for insulation, electrical wiring, and plumbing.

Product liability can be a strong incentive for design improvements. **Product liability** is the responsibility of a manufacturer for any injuries or damages caused by a faulty product because of poor workmanship or design. Many business firms have faced lawsuits related to their products, including Firestone Tire & Rubber, Ford Motor Company, General Motors, tobacco companies, and toy manufacturers. Manufacturers also are faced with the implied warranties created by state laws under the **Uniform Commercial Code**, which says that products carry an implication of *merchantability* and *fitness;* that is, a product must be usable for its intended purposes.

Product liability The responsibility of a manufacturer for any injuries or damages caused by a faulty product.

Uniform Commercial Code A product must be suitable for its intended purpose.

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

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

Ethical issues often arise in the design of products and services; it is important for managers to be aware of these issues and for designers to adhere to ethical standards. Designers are often under pressure to speed up the design process and to cut costs. These pressures often require them to make trade-off decisions, many of which involve ethical considerations. One example of what can happen is “vaporware,” when a software company doesn’t issue a release of software as scheduled because it is struggling with production problems or bugs in the software. The company faces the dilemma of releasing the software right away or waiting until most of the bugs have been removed—knowing that the longer it waits, the more time will be needed before it receives revenues and the greater the risk of damage to its reputation.

Organizations generally want designers to adhere to guidelines such as the following:

- Produce designs that are consistent with the goals of the organization. For instance, if the company has a goal of high quality, don’t cut corners to save on costs, even in areas where it won’t be apparent to the customer.

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The much anticipated Boeing 787 Dreamliner aircraft resumed flights after being grounded for more than three months for a battery defect. Aviation safety depends on well-maintained equipment and an expert flight crew who can handle emergencies as they come up.

TOM MARESCHAL/Alamy Stock Photo

- Give customers the value they expect.
- Make health and safety a primary concern. At risk are employees who will produce goods or deliver services, workers who will transport the products, customers who will use the products or receive the services, and the general public, which might be endangered by the products or services.

4.4 HUMAN FACTORS

Human factor issues often arise in the design of consumer products. Safety and liability are two critical issues in many instances, and they must be carefully considered. For example, the crashworthiness of vehicles is of much interest to consumers, insurance companies, automobile producers, and the government.

Another issue for designers to take into account is adding new features to their products or services. Companies in certain businesses may seek a competitive edge by adding new features. Although this can have obvious benefits, it can sometimes be "too much of a good thing," and be a source of customer dissatisfaction. This "creeping featurism" is particularly evident in electronic products such as handheld devices that continue to offer new features, and more complexity, even while they are shrinking in size. This may result in low consumer ratings in terms of "ease of use."

4.5 CULTURAL FACTORS

Product designers in companies that operate globally also must take into account any cultural differences of different countries or regions related to the product. This can result in different designs for different countries or regions, as illustrated by the following reading.

READING

GREEN TEA ICE CREAM? KALE SOUP?

In order to be successful around the globe, McDonald's has regionalized its menu items to conform to local culinary preferences, laws, and religious traditions. Below are a sample of items that appear on McDonald's menus in various countries.

Canada: Poutine (french fries and cheese curds with brown gravy).

China: Chicken nuggets with chili garlic sauce, green tea ice cream.

Chile: Cheese empanadas.

Finland: Hamburgers with salsa and sour cream.

France: Beer for breakfast, burgers containing crispy peppers for lunch.

India: Spicy chicken wrap, rice bowls, masola wedges, tikki burgers.

Israel: Burgers are cooked over charcoal instead of fried.

Malaysia: Chicken porridge.

Netherlands: Fried chicken with peanut sauce.

Norway: Deep-fried fish, chicken salsa.

Philippines: Spaghetti, cheesy butter french fries.

Portugal: Kale soup, cream of carrot, bean and spinach soup.

Singapore: Salted egg yolk chicken burgers, curry sauce dip for chicken nuggets.

South Korea: Shrimp burger, pork burger, affogata (vanilla gelato with a shot of hot espresso).

Taiwan. Corn soup, rice patties.

Turkey: Spiced mincemeat patty, cold savory yogurt beverage mixed with salt.

Questions

1. What effects do cultural differences have on the design of fast-food offerings in this reading?
2. What functions in the organization are impacted by the differences in product offerings among different countries?

4.6 GLOBAL PRODUCT AND SERVICE DESIGN

Traditionally, product design has been conducted by members of the design team who are located in one facility or a few nearby facilities. However, organizations that operate globally are discovering advantages in global product design, which uses the combined efforts of a team of designers who work in different countries and even on different continents. Such *virtual teams* can provide a range of comparative advantages over traditional teams such as engaging the best human resources from around the world without the need to assemble them all in one place, and operating on a 24-hour basis, thereby decreasing the time-to-market. The use of global teams also allows for customer needs assessment to be done in more than one country with local resources, opportunities, and constraints to be taken into account. Global product design can provide design outcomes that increase the marketability and utility of a product. The diversity of an international team may yield different points of view and also ideas and information to enrich the design process. However, care must be taken in managing the diversity, because if it is mismanaged, it can lead to conflicts and miscommunications.

Advances in information technology have played a key role in the viability of global product design teams by enabling team members to maintain continual contact with each other and to instantaneously share designs and progress, and to transmit engineering changes and other necessary information.

4.7 ENVIRONMENTAL FACTORS: SUSTAINABILITY

LO4.7 Explain the purpose and goal of life-cycle assessment.

Product and service design is a focal point in the quest for sustainability. Key aspects include cradle-to-grave assessment, end-of-life programs, reduction of costs and materials used, reuse of parts of returned products, and recycling.

Cradle-to-Grave Assessment

Cradle-to-grave assessment, also known as life cycle analysis, is the assessment of the environmental impact of a product or service throughout its useful life, focusing on such factors as global warming (the amount of carbon dioxide released into the atmosphere), smog formation, oxygen depletion, and solid waste generation. For products, cradle-to-grave analysis takes into account impacts in every phase of a product's life cycle, from raw material extraction from the earth, or the growing and harvesting of plant materials, through fabrication of parts and assembly operations, or other processes used to create products, as well as the use or consumption of the product, and final disposal at the end of a product's useful life. It also considers energy consumption, pollution and waste, and transportation in all phases. Although services generally involve less use of materials, cradle-to-grave assessment of services is nonetheless important, because services consume energy and involve many of the same or similar processes that products involve.

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Cradle-to-grave assessment The assessment of the environmental impact of a product or service throughout its useful life.

The goal of cradle-to-grave assessment is to choose products and services that have the least environmental impact, while still taking into account economic considerations. The procedures of cradle-to-grave assessment are part of the ISO 14000 environmental management standards, which are discussed in Chapter 9.

End-of-Life Programs

End-of-life (EOL) programs deal with products that have reached the end of their useful lives. The products include both consumer products and business equipment. The purpose of these programs is to reduce the dumping of products, particularly electronic equipment, in landfills or third-world countries, as has been the common practice, or incineration, which converts materials into hazardous air and water emissions and generates toxic ash. Although the programs are not limited to electronic equipment, that equipment poses problems because it typically contains toxic materials such as lead, cadmium, chromium, and other heavy metals. IBM provides a good example of the potential of EOL programs. Over the last 15 years, it has collected about 2 billion pounds of product and product waste.

The Three Rs: Reduce, Reuse, and Recycle

LO4.8
Explain the phrase “the 3 Rs.”

Designers often reflect on three particular aspects of potential cost savings and reducing environmental impact: reducing the use of materials through value analysis; refurbishing and then reselling returned goods that are deemed to have additional useful life, which is referred to as remanufacturing; and reclaiming parts of unusable products for recycling.

Reduce: Value Analysis

Value analysis refers to an examination of the *function* of parts and materials in an effort to reduce the cost and/or improve the performance of a product. Typical questions that would be asked as part of the analysis include: Could a cheaper part or material be used? Is the function necessary? Can the function of two or more parts or components be performed by a single part for a lower cost? Can a part be simplified? Could product specifications be relaxed, and would this result in a lower price? Could standard parts be substituted for nonstandard parts? Table 4.1 provides a checklist of questions that can guide a value analysis.

Value analysis Examination of the function of parts and materials in an effort to reduce cost and/or improve product performance.

TABLE 4.1

Overview of value analysis

1. Select an item that has a high annual dollar volume. This can be material, a purchased item, or a service.
2. Identify the function of the item.
3. Obtain answers to these kinds of questions:
   a. Is the item necessary and have value, or can it be eliminated?
   b. Are there alternative sources for the item?
   c. Can the item be provided internally?
   d. What are the advantages of the present arrangement?
   e. What are the disadvantages of the present arrangement?
   f. Could another material, part, or service be used instead?
   g. Can specifications be less stringent to save cost or time?
   h. Can two or more parts be combined?
   i. Can more/less processing be done on the item to save cost or time?
   j. Do suppliers/providers have suggestions for improvements?
   k. Do employees have suggestions for improvements?
   l. Can packaging be improved or made less costly?
4. Analyze the answers obtained above, as well as the answers to other questions that arise, and then make recommendations.

The following reading describes how Kraft Foods is working to reduce water and energy use, CO_2 and plant waste, and packaging.

READING 

KRAFT FOODS' RECIPE FOR SUSTAINABILITY

The threat of global warming and the desire to protect the environment has many companies embracing sustainability initiatives. Along the way, they are finding that, in many instances, there are cost savings in doing so.

Among them was the Kraft Foods Company prior to the spin off of its North American grocery business, known as Mondelez, and its merger with the H.J. Heinz Company. The Kraft Heinz Company is now one of the largest food and beverage companies in the world. Its brands include *Kraft, Heinz, ABC, Capri Sun, Jell-O, Kool-Aid, Lunchables, Maxwell House, Ore-Ida, Oscar Mayer, Philadelphia, Planters, Quero, Weight Watchers Smart Ones,* and *Velveeta.* According to the company's website, it "is dedicated to the sustainable health of our people, our planet and our Company" (kraftheinzcompany.com).

Prior to the merger of the two companies, both Kraft Foods and the H.J. Heinz Company were recognized for their sustainability efforts. Here, the focus is on some of Kraft's accomplishments prior to the merger. They provide insight into some of the cost savings that can stem from sustainability efforts, and serve as examples that others might wish to follow.

Some of Kraft's successes came from redesigned packaging. The goal was ambitious. It required more efficient packaging and a reduction in the amount of packaging material used. Kraft believed that the greatest opportunity to reduce the environmental impact of a package is early in the design phase. Their packaging designers worldwide critically considered the amount of packaging used, how much post-consumer material could be used, how much energy was used to create the packaging materials, how much CO_2 was generated as the materials were created and formed, and how well the package fit the product physically. According to Kraft's press releases at the time, examples and benefits of some packaging redesigns included:

- DiGiorno and California Pizza Kitchen pizzas: Using slimmer cartons that allow shipment of two extra pizza boxes per case and 14 percent more pizzas per pallet. This led to a savings of approximately 1.4 million pounds of packaging per year, and the ability to load more pizzas on each truck meant there were fewer trucks on the road and less fuel consumed.
- Oscar Mayer Deli Creations: Using 30 percent less paperboard than the previous design resulted in 1.2 million fewer pounds of packaging going to landfills.
- Kraft salad dressing: Using 19 percent less plastic per bottle translated to 3 million pounds fewer annually. Additionally, the new design allowed more bottles to be shipped per truckload, leading to an increase in transportation efficiency of 18 percent.

The company also worked to reduce water pollution/soil erosion and support biodiversity. Considering those successes, Kraft's recipe for sustainability is one that other companies should emulate.

Kraft Natural Cheese packaging zipper eliminates more than one million pounds of packaging per year.

James F. Quinn KRT/Newscom

Reuse: Remanufacturing

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

Remanufacturing Refurbishing used products by replacing worn-out or defective components.

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

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READING

CHINA CLAMPS DOWN ON RECYCLABLES

BY LISA SPENCER

Trash piles up around the world as China's "National Sword" policy cuts off much of global recycling. Ships that brought Chinese goods to the United States used to return home full of America's recyclables to feed a booming recycling industry in China. The recycled metals, plastic pellets, glass, and paper were gobbled up by Chinese manufacturers in need of raw materials. However, corruption and environmental pollution by some of China's recycling operators led its government to shut the door on most of the world's scrap beginning in 2018 (Hook and Reed, 2018).

Whereas China and Hong Kong bought 60 percent of the G7's plastic waste in the first half of 2017, they took only 10 percent in the first half of 2018. Bales of plastic that U.S.

recyclers previously sold for $20 per ton may now instead cost cities $10 per ton to dispose. While China still accepts some cardboard, plastic, glass, and scrap metal, it needs to be "ready to use" without much further cleaning or processing. The new standard is an impurity level of only 0.5 percent, something most U.S. recyclers cannot achieve. Furthermore, China no longer wants plastic water bottles. Now it wants plastic pellets, ready to use in its own manufacturing processes to make packaging, toys, and other goods (Hook and Reed, 2018). Recyclable scrap was America's biggest export to China by volume, and China bought 31 percent of U.S. scrap commodity exports. Municipalities now struggle with mountains of trash, which used to generate income but now do not (Phillips, 2018).

Where will the world's trash go? More than 270 million tons of global waste is recycled each year, much of it in China. Some now flows to other Southeast Asian countries such as Malaysia, Thailand, Vietnam, and Indonesia. Many new recycling businesses have sprung up to process shipments of recyclables, but local residents worry about the lack of regulation and the air and water pollution generated by these factories. These governments are now erecting barriers of their own to curb the recent influx of scrap coming into their countries. Shipping costs to these alternate countries are much higher as well, because they lack the steady flow of empty returning containers and ships that enabled the cheap transport to China. Interestingly, some Chinese companies are now investing in American paper mills or plastic facilities to transfer their operations to the United States (Hook and Reed, 2018).

Recyclers, governments, and consumers around the world are being forced to rethink their use of plastics, paper waste, and e-waste. Some consumers in California, France, and Italy are looking to the past for alternatives to some of today's one-time-use packages and wasteful use of plastics. They bring their own multi-use bottles and bags to stores that sell items in bulk. Some municipalities are already changing rules about what can go into recycling bins, and many may be forced to charge customers more for weekly trash pickups. Cutting back on the creation of waste products may become more important to consumers and businesses who do not want to pay more and more for waste removal (Hook and Reed, 2018).

Questions

1. How have China's own sustainability issues and policies affected sustainability concerns worldwide?
2. What changes are being seen in the supply chain for recyclers of waste products?
3. What types of package design changes might be envisioned in the future to help reduce the amount of waste that is created?

Based on: Leslie Hook and John Reed, "The $280 B Crisis Sparked by China Calling Time on Taking in 'Foreign Trash.'" *Financial Review,* October 31, 2018. https://www.afr.com/news/the-280-billion-crisis-caused-when-china-called-time-on-foreign-trash-20181031-h17cfw

Erica E. Phillips, "U.S. Recycling Companies Face Upheaval from China Scrap Ban." *The Wall Street Journal,* August 2, 2018. https://www.wsj.com/articles/u-s-recycling-companies-face-upheaval-from-china-scrap-ban-1533231057

Designing products so they can be more easily taken apart has given rise to yet another design consideration: **Design for disassembly (DFD)**.

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

Recycle

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

Recycling Recovering materials for future use.

Companies recycle for a variety of reasons, including

- Cost savings
- Environment concerns
- Environmental regulations

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

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

Design for recycling (DFR) Design that facilitates the recovery of materials and components in used products for reuse.

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READING

RECYCLE CITY: MARIA'S MARKET

Maria's Market is the main supermarket in Recycle City. Maria tries to stock items and provide services in her store that reduce the amount of material going into the waste stream and encourage reuse and recycling.

Maria realized that the first and best thing she should do was to reduce the amount of waste her customers had to throw away after they bought products at her market.

Maria

To reduce the amount of waste and its impact on the environment, Maria began to stock items in the store that contained fewer harmful ingredients and used less packaging. To reduce packaging and wasted food, she created a section in the store where shoppers could buy food in bulk, measuring out the exact amounts they needed.

Maria also set up a program to reuse those things that could be reused, such as cardboard boxes that shoppers could use to carry their purchases and bring back to the store on their next visit. She also gave customers discounts for returning their plastic bags the next time they shopped and for bringing their own cloth sacks to carry groceries home.

Finally, Maria made sure that many of the items in the store could be easily recycled. She set up well-marked collection containers to make it easy for shoppers to participate in the market's recycling program. Maria knows that recycling keeps useful materials from going into landfills, helping to preserve the land in and around Recycle City for other uses, like parks and schools.

Paper or Plastic?

Should you ask for a paper or plastic bag at the checkout counter? There's no easy answer. The materials needed to make either bag come from our natural resources.

- Paper comes from wood, which comes from trees, which grow in the earth's soil.
- Plastic is made from petroleum, also known as fossil fuel. Petroleum is made by the decomposition (breaking down) of ancient plants and animals inside the earth.

The trees needed to make paper are considered renewable resources. That means more trees can be planted to take the place of trees that are cut down to make paper and other products. However, trees take many years to replace because they grow slowly. Once paper is made, it can be recycled and used to create more paper goods. Making it into new paper, though, uses water and energy.

Petroleum needed to make plastic is considered a non-renewable resource. Like aluminum, tin, and steel, petroleum is not renewable because it is the result of geological processes that take millions of years to complete. When used up, the earth's petroleum reserves will be gone for a long, long time. While plastic bags are easy to reuse, they're seldom recycled, and lots and lots of them get dumped into landfills.

Oscar Knott/Fogstock Images/Media Bakery

The best solution is to use a cloth bag or knapsack for grocery shopping, or to bring your old plastic or paper bag back to the store when you shop again. (Some stores, like Maria's Market in Recycle City, credit your grocery bill for reusing old bags because they don't have to buy as many new ones.) If you only purchase one or two items, you might not need a bag at all.

Recycling Igloos

In many parts of the country, supermarkets place recycling containers near the store to encourage their customers to recycle. (They can be any shape really, but Recycle City uses these brightly colored igloos because they're fun.)

These igloos are used to collect bottles, cans, and plastic from Maria's Market shoppers. Twice a week, trucks from the local Materials Recovery Facility come by to empty the igloos and take the items for recycling.

Cardboard Boxes

The cardboard boxes used to ship food to Maria's Market can be put to a variety of other uses once the food has been unpacked. The folks at the market let Recycle City residents come by and pick up cartons for storing things or moving to a new home. Any cartons that aren't claimed by the residents are broken down and put into a pile so they can be collected, recycled, and made into other things, such as new boxes, paper bags, building insulation, animal bedding, or packaging materials.

Reduced Packaging

When the buyers at Maria's Market place orders to restock the store, they try to order items with very little packaging, or that use ecological packaging (ones requiring as little energy and as few resources as possible to produce).

Maria's buyers also try to stock products that come in refillable containers. Products that don't harm the environment and come in ecologically friendly packages are called green products.

Packaging that isn't environmentally friendly includes products that are wrapped in several layers of plastic, use plastic foam, or have individually wrapped packages inside of a larger wrapped package.

Maria's buyers let the manufacturers who make products for the grocery shelves know that they and their Recycle City customers would rather buy products wrapped in environmentally friendly packages than ones that aren't. Using this kind of packaging is good for the manufacturer's business.

Bulk and Fresh Foods

Packaging materials make up more than 30 percent of all consumer waste. Maria's Market offers shoppers many fresh foods and bulk foods to help reduce the amount of waste from too much packaging.

Fresh foods, such as bananas, oranges, and nuts, come in their own natural packaging and are excellent sources of nutrition.

Bulk items and food purchased in bulk quantities allow Maria's shoppers to decide exactly how much they want to keep on hand. For small needs, folks measure out the exact quantity they want, helping to reduce food waste. For larger needs, they can buy bulk quantities, which usually use less packaging material and cost less.

When purchasing fresh foods or buying in bulk, shoppers can put their purchases into refillable containers they bring to the store or into the recyclable or reusable bags Maria provides.

Paper Towels and Other Paper Items

Many paper products on the shelves today have already been recycled. Buying recycled products saves valuable natural resources and helps to create a market for those materials. When manufacturers know that shoppers want recyclable goods, they will make more of them.

In Maria's Market, the popularity of paper towels and toilet paper made from recycled materials ensures that fewer new trees have to be cut down to produce new products.

Source: Excerpted from https://www3.epa.gov/recyclecity/market.htm

4.8 OTHER DESIGN CONSIDERATIONS

LO4.9 Briefly describe the phases in product design and development.

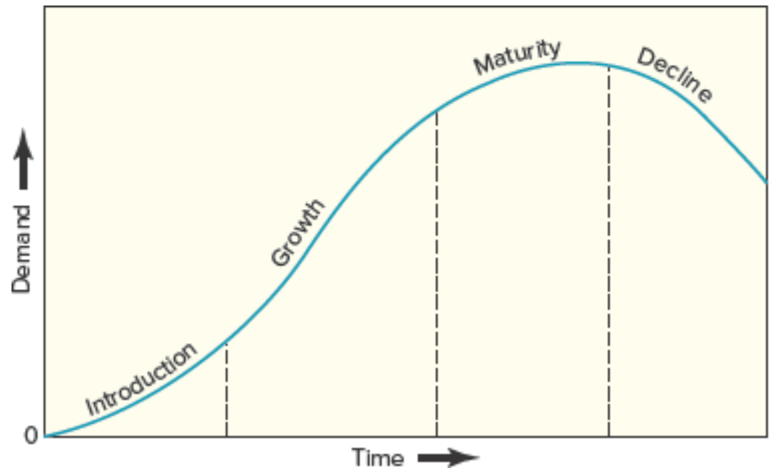
Aside from legal, ethical, environmental, and human considerations, designers must also take into account product or service life cycles, how much standardization to incorporate, product or service reliability, and the range of operating conditions under which a product or service must function. These topics are discussed in this section. We begin with life cycles.

Strategies for Product or Service Life Stages

Most, but not all, products and services go through a series of stages over their useful life, sometimes referred to as their life cycle, as shown in Figure 4.1. Demand typically varies by phase. Different phases call for different strategies. In every phase, forecasts of demand and cash flow are key inputs for strategy.

FIGURE 4.1

Products or services often go through stages over time



When a product or service is introduced, it may be treated as a curiosity item. Many potential buyers may suspect that all the bugs haven't been worked out and that the price may drop after the introductory period. Strategically, companies must carefully weigh the trade-offs in getting all the bugs out versus getting a leap on the competition, as well as getting to market at an advantageous time. For example, introducing new high-tech products or features during peak back-to-school buying periods or holiday buying periods can be highly desirable.

It is important to have a reasonable forecast of initial demand so an adequate supply of product or an adequate service capacity is in place.

Over time, design improvements and increasing demand yield higher reliability and lower costs, leading the growth in demand. In the growth phase, it is important to obtain accurate projections of the demand growth rate and how long that will persist, and then to ensure that capacity increases coincide with increasing demand.

In the next phase, the product or service reaches maturity, and demand levels off. Few, if any, design changes are needed.

Generally, costs are low and productivity is high. New uses for products or services can extend their life and increase the market size. Examples include baking soda, duct tape, and vinegar. The maker of LEGOs has found a way to grow its market, as described in the following reading.

In the decline phase, decisions must be made about whether to discontinue a product or service and replace it with new ones or abandon the market, or to attempt to find new uses or new users for the existing product or service. For example, duct tape and baking soda are two products that have been employed well beyond their original uses of taping heating and cooling ducts and cooking. The advantages of keeping existing products or services can be tremendous. The same workers can produce the product or provide the service using much of the same equipment, the same supply chain, and perhaps the same distribution channels. Consequently, costs tend to be very low, and additional resource needs and training needs are low.

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READING

LEGO A/S IN THE PINK

Lego A/S overcame the recent doldrums in the toy market, as well as new competition in the building-block segment to continue its market success, increasing revenues and achieving a close tie for the No. 2 slot in the global toy business.

“The Danish toy maker enjoyed sustained success for its popular LEGO City and LEGO Star Wars sets. Its new LEGO Friends theme, targeting girls, sold twice as well as initial expectations and helped triple sales to girls.”

Questions

Can you think of other companies that have used new colors to extend or grow the market for their products?

Source: “Lego Shrugs Off Toy-Market Blues,” *The Wall Street Journal,* February 21, 2013.

International Design Excellence Award Winner: The Technogym Recline Personal is a recumbent bike that integrates ergonomic design, cardiovascular exercise, and entertainment, making it suitable for the home or office.

A. Astes/Alamy Stock Photo

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

Some service life cycles are related to the life cycles of products. For example, as older products are phased out, services such as installation and repair of the older products also phase out.

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

Product Life Cycle Management

LO4.10
Discuss several key issues in product or service design.

Product life cycle management (PLM) is a systematic approach to managing the series of changes a product goes through, from its conception, design, and development, through production and any redesign, to its end of life. PLM incorporates everything related to a particular product. That includes data pertaining to production processes, business processes, people, and anything else related to the product.

Product life cycle management (PLM) A systematic approach to managing the series of changes a product goes through, from its conception to its end-of-life.

PLM software can be used to automate the management of product-related data and integrate the data with other business processes, such as enterprise resource planning (discussed in Chapter 12). A goal of PLM is to eliminate waste and improve efficiency. For example, PLM is considered to be an integral part of lean production (discussed in Chapter 14).

There are three phases of PLM application:

- Beginning of life, which involves design and development;
- Middle of life, which involves working with suppliers, managing product information and warranties; and
- End of life, which involves strategies for product discontinuance, disposal, or recycling.

Although PLM is generally associated with manufacturing, the same management structure can be applied to software development and services.

Degree of Standardization

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

Standardization Extent to which a product, service, or process lacks variety.

Standardization carries a number of important benefits, as well as certain disadvantages. Standardized products are immediately available to customers. Standardized products mean *interchangeable parts,* which greatly lower the cost of production while increasing productivity and making replacement or repair relatively easy compared with that of customized parts. Design costs are generally lower. For example, automobile producers standardize key components of automobiles across product lines; components such as brakes, electrical systems, and other “under-the-skin” parts would be the same for all car models. By reducing variety, companies save time and money while increasing the quality and reliability of their products.

Another benefit of standardization is reduced time and cost to train employees and reduced time to design jobs. Similarly, the scheduling of work, inventory handling, and purchasing and accounting activities become much more routine, and quality is more consistent.

Lack of standardization can at times lead to serious difficulties and competitive struggles. For example, the use of the English system of measurement by U.S. manufacturers, while most of the rest of the world’s manufacturers use the metric system, has led to problems in selling U.S. goods in foreign countries and

in buying foreign machines for use in the United States. This may make it more difficult for U.S. firms to compete in the European Union.

Standardization also has disadvantages. A major one relates to the reduction in variety. This can limit the range of customers to whom a product or service appeals. And that creates a risk that a competitor will introduce a better product or greater variety and realize a competitive advantage. Another disadvantage is that a manufacturer may freeze (standardize) a design prematurely and, once the design is frozen, find compelling reasons to resist modification.

Obviously, designers must consider important issues related to standardization when making choices. The major advantages and disadvantages of standardization are summarized in Table 4.2.

TABLE 4.2

Advantages and disadvantages of standardization

Advantages	1.	Fewer parts to deal with in inventory and in manufacturing.
	2.	Reduced training costs and time.
	3.	More routine purchasing, handling, and inspection procedures.
	4.	Orders fillable from inventory.
	5.	Opportunities for long production runs and automation.
	6.	Need for fewer parts justifies increased expenditures on perfecting designs and improving quality control procedures.
Disadvantages	1.	Designs may be frozen with too many imperfections remaining.
	2.	High cost of design changes increases resistance to improvements.
	3.	Decreased variety results in less consumer appeal.

Designing for Mass Customization

LO4.10
Discuss several key issues in product or service design.

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

Mass customization A strategy of producing basically standardized goods, but incorporating some degree of customization.

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

Delayed differentiation The process of producing, but not quite completing, a product or service until customer preferences are known.

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FAST-FOOD CHAINS ADOPT MASS CUSTOMIZATION

Pulled pork sandwiches are proving popular at many chain restaurants, including Wendy's, Buffalo Wild Wings, and Burger King. Because pulled pork typically takes about 4 hours to cook, it's not a food most folks are likely to cook at home. And once cooked, sandwiches can easily be assembled to order (i.e., delayed differentiation) using any of a large number of sauces or seasonings. Customer appeal is obvious. The advantages for fast-food restaurants include simplified menus, minimal training requirements, and little need for new equipment.

Questions

1. What two major benefits do customers get from delayed differentiation?
2. Can you think of another food product that might lend itself to delayed differentiation, and therefore end up as a popular fast-food item?

Source: Based on “Fast-Food Chains Are Pigging Out.” *Businessweek,* October 12–October 18, 2015, pp. 22–23.

Modular design is a form of standardization. Modules represent groupings of component parts into subassemblies, usually to the point where the individual parts lose their separate identity. One familiar example of modular design is computers, which have modular parts that can be replaced if they become defective. By arranging modules in different configurations, different computer capabilities can be obtained. For mass customization, modular design enables producers to quickly assemble products with modules to achieve a customized configuration for an individual customer, avoiding the long customer wait that would occur if individual parts had to be assembled. Dell Computers has successfully used this concept to become a dominant force in the PC industry by offering consumers the opportunity to configure modules according to their own specifications. Many other computer manufacturers now use a similar approach. Modular design also is found in the construction industry. One firm in Rochester, New York, makes prefabricated motel rooms complete with wiring, plumbing, and even room decorations in its factory and then moves the complete rooms by rail to the construction site, where they are integrated into the structure.

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

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

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Employees on the production line at the new Dell Global Operation Facility in China. With the capacity to produce up to seven million units a year, the site will manufacture electronics for the Chinese market as well as markets in Europe and the United States.

Liu Zheng/ColorChinaPhoto/AP Images

The main disadvantages of modular design stem from the decrease in variety: The number of possible configurations of modules is much less than the number of possible configurations based on individual components. Another disadvantage that is sometimes encountered is the inability to disassemble a module in order to replace a faulty part; the entire module must be scrapped—usually at a higher cost.

Reliability

LO4.10 Discuss several key issues in product or service design.

Reliability is a measure of the ability of a product, a part, a service, or an entire system to perform its intended function under a prescribed set of conditions. The importance of reliability is underscored by its use by prospective buyers in comparing alternatives, and by sellers as one determinant of price. Reliability also can have an impact on repeat sales, reflect on the product's image, and, if it is too low, create legal implications. Reliability is also a consideration for sustainability: The higher the reliability of a product, the fewer the resources that will be needed to maintain it, and the less frequently it will involve the three Rs.

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

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

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

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

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

Improving Reliability Reliability can be improved in a number of ways, some of which are listed in Table 4.3.

TABLE 4.3

Potential ways to improve reliability

1. Improve component design.
2. Improve production and/or assembly techniques.
3. Improve testing.
4. Use backups.
5. Improve preventive maintenance procedures.
6. Improve user education.
7. Improve system design.

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

A fundamental question concerning improving reliability is: How much reliability is needed? Obviously, the reliability needed for a household light bulb isn't in the same category as the

reliability needed for an airplane. So the answer to the question depends on the potential benefits of improvements and on the cost of those improvements. Generally speaking, reliability improvements become increasingly costly. Thus, although benefits initially may increase at a much faster rate than costs, the opposite eventually becomes true. The optimal level of reliability is the point where the incremental benefit received equals the incremental cost of obtaining it. In the short term, this trade-off is made in the context of relatively fixed parameters (e.g., costs). However, in the longer term, efforts to improve reliability and reduce costs can lead to higher optimal levels of reliability.

Robust Design

LO4.10 Discuss several key issues in product or service design.

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

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

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

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

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

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

The Taguchi approach modifies the conventional statistical methods of experimental design. Consider this example. Suppose a company will use 12 chemicals in a new product it intends to produce. There are two suppliers for these chemicals, but the chemical concentrations vary slightly between the two suppliers. Classical design of experiments would require $2^{12} = 4{,}096$ test runs to determine which combination of chemicals would be optimum. Taguchi's approach would involve only testing a portion of the possible combinations. Relying on experts to identify the variables that would be most likely to affect important performance, the number of combinations would be dramatically reduced, perhaps to, say, 32. Identifying the best combination in the smaller sample might be a near-optimal combination instead of the optimal combination. The value of this approach is its ability to achieve major advances in product or process design fairly quickly, using a relatively small number of experiments.

Critics charge that Taguchi's methods are inefficient and incorrect, and often lead to non-optimal solutions. Nonetheless, his methods are widely used and have been credited with helping to achieve major improvements in U.S. products and manufacturing processes.

Degree of Newness

LO4.10
Discuss several key issues in

product or
service
design.

Product or service design change can range from the modification of an existing product or service to an entirely new product or service:

1. Modification of an existing product or service
2. Expansion of an existing product line or service offering
3. Clone of a competitor's product or service
4. New product or service

The degree of change affects the newness to the organization and the newness to the market. For the organization, a low level of newness can mean a fairly quick and easy transition to producing the new product, while a high level of newness would likely mean a slower and more difficult, and therefore more costly, transition. For the market, a low level of newness would mean little difficulty with market acceptance, but possibly low profit potential. Even in instances of low profit potential, organizations might use this strategy to maintain market share. A high level of newness, on the other hand, might mean more difficulty with acceptance, or it might mean a rapid gain in market share with a high potential for profits. Unfortunately, there is no way around these issues. It is important to carefully assess the risks and potential benefits of any design change, taking into account clearly identified customer wants.

Quality Function Deployment

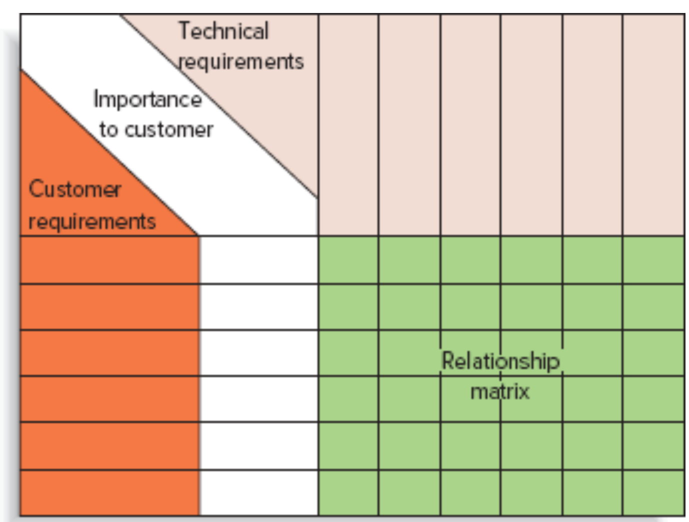
Obtaining input from customers is essential to assure that they will want what is offered for sale. Although obtaining input can be informal through discussions with customers, there is a formal way to document customer wants. **Quality function deployment (QFD)** is a structured approach for integrating the "voice of the customer" into both the product and service development process. The purpose is to ensure that customer requirements are factored into every aspect of the process. Listening to and understanding the customer is the central feature of QFD. Requirements often take the form of a general statement such as, “It should be easy to adjust the cutting height of the lawn mower.” Once the requirements are known, they must be translated into technical terms related to the product or service. For example, a statement about changing the height of the lawn mower may relate to the mechanism used to accomplish that, its position, instructions for use, tightness of the spring that controls the mechanism, or materials needed. For manufacturing purposes, these must be related to the materials, dimensions, and equipment used for processing.

Quality function deployment (QFD) An approach that integrates the “voice of the customer” into both product and service development.

The structure of QFD is based on a set of matrices. The main matrix relates customer requirements (what) and their corresponding technical requirements (how). This matrix is illustrated in Figure 4.2. The matrix provides a structure for data collection.

FIGURE 4.2

An example of the house of quality: the main QFD matrix

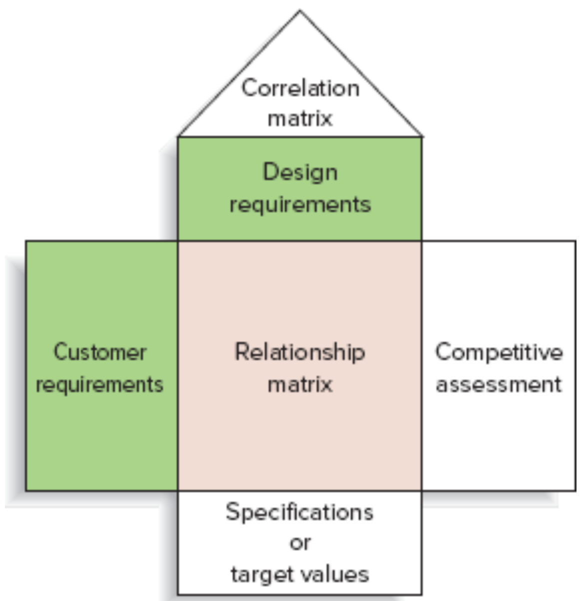


Source: Ernst and Young Consulting Group, *Total Quality* (Homewood, IL: Dow-Jones Irwin, 1991), p. 121.

Additional features are usually added to the basic matrix to broaden the scope of analysis. Typical additional features include importance weightings and competitive evaluations. A correlational matrix is usually constructed for technical requirements; this can reveal conflicting technical requirements. With these additional features, the set of matrices has the form illustrated in Figure 4.3. It is often referred to as the *house of quality* because of its house-like appearance.

FIGURE 4.3

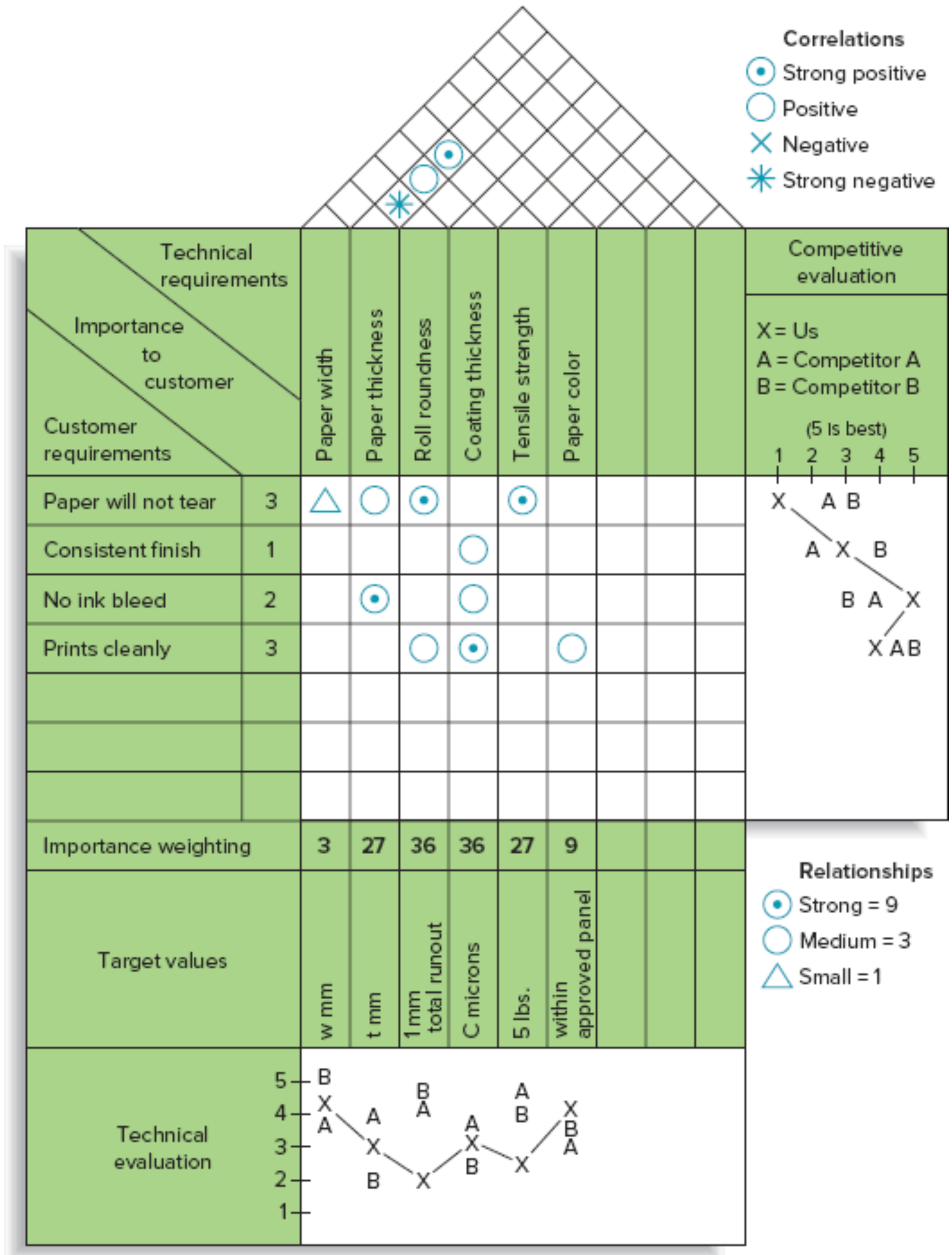
The house of quality



An analysis using this format is shown in Figure 4.4. The data relate to a commercial printer (customer) and the company that supplies the paper. At first glance, the display appears complex. It contains a considerable amount of information for product and process planning. Therefore, let's break it up into separate parts and consider them one at a time. To start, a key part is the list of customer requirements on the left side of the figure. Next, note the technical requirements, listed vertically near the top. The key relationships and their degree of importance are shown in the center of the figure. The circle with a dot inside indicates the strongest positive relationship; that is, it denotes the most important technical requirements for satisfying customer requirements. Now look at the “importance to customer” numbers that are shown next to each customer requirement (3 is the most important). Designers will take into account the importance values and the strength of correlation in determining where to focus the greatest effort.

FIGURE 4.4

An example of the house of quality



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

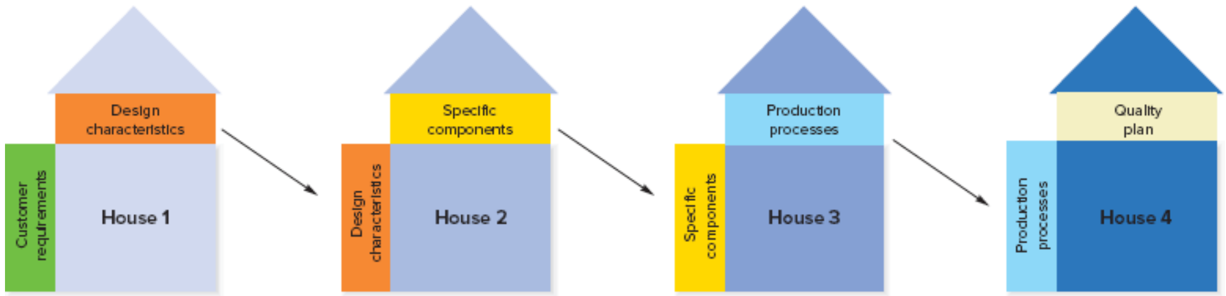
On the right side of the figure is a competitive evaluation comparing the supplier's performance on the customer requirements with each of the two key competitors (A and B). For example, the supplier (X) is worst on the first customer requirement and best on the third customer requirement. The line connects the X performances. Ideally, design will cause all of the Xs to be in the highest positions.

Across the bottom of Figure 4.4 are importance weightings, target values, and technical evaluations. The technical evaluations can be interpreted in a manner similar to that of the competitive evaluations (note the line connecting the Xs). The target values typically contain technical specifications, which we will not discuss. The importance weightings are the sums of values assigned to the relationships (see the lower right-hand key for relationship weights). The 3 in the first column is the product of the importance to the customer, 3, and the small (Δ) weight, 1. The importance weightings and target evaluations help designers focus on desired results. In this example, the first technical requirement has the lowest importance weighting, while the next four technical requirements all have relatively high importance weightings.

The house of quality approach involves a sequence of "houses," beginning with design characteristics, which leads to specific components, then production processes, and finally, a quality plan. The sequence is illustrated in Figure 4.5. Although the details of each house are beyond the scope of this text, Figure 4.5 provides a conceptual understanding of the progression involved.

FIGURE 4.5

The house of quality sequence



The Kano Model

LO4.10 Discuss several key issues in product or service design.

The *Kano model* is a theory of product and service design developed by Dr. Noriaki Kano, a Japanese professor, who offered a perspective on customer perceptions of quality different from the traditional view that "more is better." Instead, he proposed different categories of quality and posited that understanding them would better position designers to assess and address quality needs. His model provides insights into the attributes that are perceived to be important to customers. The model employs three page 161 definitions of quality: basic, performance, and excitement.

Basic quality refers to customer requirements that have only a limited effect on customer satisfaction if present, but lead to dissatisfaction if not present. For example, putting a very short cord on an electrical appliance will likely result in customer dissatisfaction, but beyond a certain length (e.g., 4 feet), adding more cord will not lead to increased levels of customer satisfaction. Performance quality refers to customer requirements that generate satisfaction or dissatisfaction in proportion to their level of functionality and appeal. For example, increasing the tread life of a tire or the amount of time house paint will last will add to customer satisfaction. Excitement quality refers to a feature or attribute that was unexpected by the customer and causes excitement (the "wow" factor), such as a voucher for dinner for two at the hotel restaurant when checking in. Figure 4.6A portrays how the three definitions of quality influence customer satisfaction or dissatisfaction relative to the degree of implementation. Note that features that are perceived by customers as basic quality result in dissatisfaction if they are missing or at low levels, but do not result in customer satisfaction if they are present, even at high levels. Performance factors can result in satisfaction or dissatisfaction, depending on the degree to which they are present. Excitement factors, because they are unexpected, do not result in dissatisfaction when they are absent or at low levels, but have the potential for disproportionate levels of satisfaction if they are present.

FIGURE 4.6A

The Kano model

Over time, features that excited become performance features, and performance features soon become basic quality features, as illustrated in Figure 4.6B. The rates at which various design elements are migrating is an important input from marketing that will enable designers to continue to satisfy and delight customers and not waste efforts on improving what have become basic quality features.

FIGURE 4.6B

As time passes, excitement factors become performance factors, and performance factors become basic factors

The lesson of the Kano model is that design elements that fall into each aspect of quality must first be determined. Once basic needs have been met, additional efforts in those areas should not be pursued. For performance features, cost–benefit analysis comes into play, and these features should be included as long as the benefit exceeds the cost. Excitement features pose somewhat of a challenge. Customers are not likely to indicate excitement factors in surveys because they don't know that they want them. However, small increases in such factors produce disproportional increases in customer satisfaction and generally increase brand loyalty, so it is important for companies to strive to identify and include these features when economically feasible.

The Kano model can be used in conjunction with QFD, as well as in Six Sigma projects (see Chapter 9 for a discussion of Six Sigma).

4.9 PHASES IN PRODUCT DESIGN AND DEVELOPMENT

Product design and development generally proceeds in a series of phases (see Table 4.4).

TABLE 4.4

Phases in the product development process

1. Feasibility analysis
2. Product specifications
3. Process specifications
4. Prototype development
5. Design review
6. Market test
7. Product introduction
8. Follow-up evaluation

Feasibility analysis. Feasibility analysis entails market analysis (demand), economic analysis (development cost and production cost, profit potential), and technical analysis (capacity requirements and availability, and the skills needed). Also, it is necessary to answer the question: Does it fit with the mission? It requires collaboration among marketing, finance, accounting, engineering, and operations.

Product specifications. This involves detailed descriptions of what is needed to meet (or exceed) customer wants, and requires collaboration between legal, marketing, and operations.

Process specifications. Once product specifications have been set, attention turns to specifications for the process that will be needed to produce the product. Alternatives must be weighed in terms of cost, availability of resources, profit potential, and quality. This involves collaboration between accounting and operations.

Prototype development. With product and process specifications complete, one (or a few) units are made to see if there are any problems with the product or process specifications.

Design review. At this stage, any necessary changes are made or the project is abandoned. Marketing, finance, engineering, design, and operations collaborate to determine whether to proceed or abandon.

Market test. A market test is used to determine the extent of consumer acceptance. If unsuccessful, the product returns to the design review phase. This phase is handled by marketing.

Product introduction. The new product is promoted. This phase is handled by marketing.

Follow-up evaluation. Based on user feedback, changes may be made or forecasts refined. This phase is handled by marketing.

4.10 DESIGNING FOR PRODUCTION

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

Concurrent Engineering

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

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

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

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

. Manufacturing personnel are able to identify production capabilities and capacities. Very often, they have some latitude in design in terms of selecting suitable materials and processes. Knowledge of production capabilities can help in the selection process. In addition, cost and quality considerations can be greatly influenced by design, and conflicts during production can be greatly reduced.

- Design or procurement of critical tooling, some of which might have long lead times, can occur early in the process. This can result in a major shortening of the product development process, which could be a key competitive advantage.
- The technical feasibility of a particular design or a portion of a design can be assessed early on. Again, this can avoid serious problems during production.
- The emphasis can be on *problem* resolution instead of *conflict* resolution.

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However, despite the advantages of concurrent engineering, a number of potential difficulties exist in this co-development approach. Two key ones are the following:

- Long-standing boundaries between design and manufacturing can be difficult to overcome. Simply bringing a group of people together and thinking they will be able to work together effectively is probably naive.
- There must be extra communication and flexibility if the process is to work, and these can be difficult to achieve.

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

Computer-Aided Design (CAD)

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

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

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

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

An architect is using an iPad CAD (computer-aided design) application to model a 3D layout design of a new house.
Iain Masterton/Alamy Stock Photo

Some CAD systems allow the designer to perform engineering and cost analyses on proposed designs. For instance, the computer can determine the weight and volume of a part and do stress analysis as well. When there are a number of alternative designs, the computer can quickly go through the possibilities and identify the best one, given the designer's criteria. CAD that includes finite element analysis (FEA) capability can greatly shorten the time to market of new products. It enables developers to perform simulations that aid in the design, analysis, and commercialization of new products. Designers in industries such as aeronautics, biomechanics, and automotives use FEA.

Production Requirements

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

Forecasts of future demand can be very useful, supplying information on the timing and volume of demand, and information on demands for new products and services.

Manufacturability is a key concern for manufactured goods: Ease of fabrication and/or assembly is important for cost, productivity, and quality. With services, ease of providing the service, cost, productivity, and quality are of great concern.

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

Design for manufacturing (DFM) The designing of products that are compatible with an organization's capabilities.

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

Manufacturability The capability of an organization to produce an item at an acceptable profit.

Component Commonality

Companies often have multiple products or services to offer customers. Often, these products or services have a high degree of similarity of features and components. This is particularly true of *product families,* but it is also true of many services. Companies can realize significant benefits when a part can be used in multiple products. For example, car manufacturers employ this tactic by using internal components such as water pumps, engines, and transmissions on several automobile nameplates. In addition to the savings in design time, companies reap benefits through standard training for assembly and installation, increased opportunities for savings by buying in bulk from suppliers, and commonality of parts for repair, which reduces the inventory that dealers and auto parts stores must carry. Similar benefits accrue in services. For example, in automobile repair, component commonality means less training is needed because the variety of jobs is reduced. The same applies to appliance repair, where commonality and *substitutability* of parts are typical. Multiple-use forms in financial and medical services are other examples. Computer software often comprises a number of modules that are commonly used for similar applications, thereby saving the time and cost to write the code for major portions of the software. Tool manufacturers use a design that allows tool users to attach different power tools to a common power source. Similarly, HP has a universal power source that can be used with a variety of computer hardware.

4.11 SERVICE DESIGN

There are many similarities between product and service design. However, there are some important differences as well, owing to the nature of services. One major difference is that unlike manufacturing, where production and delivery are usually separated in time, services are usually created and delivered *simultaneously.*

Service refers to an *act,* something that is done to or for a customer (client, patient, etc.). It is provided by a **service delivery system**, which includes the facilities, processes, and skills needed to provide the service. Many services are not pure services, but part of a **product bundle**—the combination of goods and services provided to a customer. The service component in products is increasing. The ability to create and deliver reliable customer-oriented service is often a key competitive differentiator. Successful companies combine customer-oriented service with their products.

Service Something that is done to or for a customer.

Service delivery system The facilities, processes, and skills needed to provide a service.

Product bundle The combination of goods and services provided to a customer.

System design involves development or refinement of the overall **service package**:[1]

- The physical resources needed.
- The accompanying goods that are purchased or consumed by the customer, or provided with the service.
- Explicit services (the essential/core features of a service, such as tax preparation).
- Implicit services (ancillary/extra features, such as friendliness, courtesy).

Service package The physical resources needed to perform the service, the accompanying goods, and the explicit and implicit services included.

Overview of Service Design

LO4.11 Discuss the two key issues in service design.

Service design begins with the choice of a service strategy, which determines the nature and focus of the service, and the target market. This requires an assessment by top management of the potential market and profitability (or need, in the case of a nonprofit organization) of a particular service, and an assessment of the organization's ability to provide the service. Once decisions on the focus of the service and the target market have been made, the customer requirements and expectations of the target market must be determined.

Two key issues in service design are the degree of variation in service requirements and the degree of customer contact and customer involvement in the delivery system. These have an impact on the degree to which service can be standardized or must be customized. The lower the degree of customer contact and service requirement variability, the more standardized the service can be. Service design with no contact and little or no processing variability is very much like product design. Conversely, high variability and high customer contact generally mean the service must be highly customized. A related consideration in service design is the opportunity for selling: The greater the degree of customer contact, the greater the opportunities for selling.

Differences between Service Design and Product Design

Service operations managers must contend with issues that may be insignificant or nonexistent for managers in a production setting. These include the following:

. Products are generally tangible; services are generally intangible. Consequently, service design often focuses more on intangible factors (e.g., peace of mind, ambiance) than does product design.

. In many instances, services are created and delivered at the same time (e.g., a haircut, a car wash). In such instances, there is less latitude in finding and correcting errors *before* the customer has a chance to discover them. Consequently, training, process design, and customer relations are particularly important.

. Services cannot be inventoried. This poses restrictions on flexibility and makes capacity issues very important.

. Services that are highly visible to consumers and must be designed with that in mind; this adds an extra dimension to process design, one that usually is not present in product design.

. Some services have low barriers to entry and exit. This places additional pressures on service design to be innovative and cost-effective.

. Location is often important to service design, with convenience as a major factor. Hence, design of services and choice of location are often closely linked.

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. Service systems range from those with little or no customer contact to those that have a very high degree of customer contact. Here are some examples of those different types:

Insulated technical core; little or no customer contact (e.g., software development)

Production line; little or no customer contact (e.g., automatic car wash)

Personalized service (e.g., haircut, medical service)

Consumer participation (e.g., diet program, dance lessons)

Self-service (e.g., supermarket)

If there is little or no customer contact, service system design is like product system design.

. Demand variability alternately creates customer waiting times, which sometimes leads to lost sales, or idle service resources.

When demand variability is a factor, designers may approach service design from one of two perspectives. One is a cost and efficiency perspective, and the other is a customer perspective.

Waiting line analysis (see Chapter 18) can be especially useful in this regard.

Basing design objectives on cost and efficiency is essentially a “product design approach” to service design. Because customer participation makes both quality and demand variability more difficult to manage, designers may opt to limit customer participation in the process where possible. Alternatively, designers may use staff flexibility as a means of dealing with demand variability.

In services, a significant aspect of perceived quality relates to the intangibles that are part of the service package. Designers must proceed with caution because attempts to achieve a high level of efficiency tend to depersonalize service and to create the risk of negatively altering the customer’s perception of quality. Such attempts may involve the following:

- Reducing consumer choices makes service more efficient, but it can be both frustrating and irritating for the customer. An example would be a cable company that bundles channels, rather than allowing customers to pick only the channels they want.
- Standardizing or simplifying certain elements of service can reduce the cost of providing a service, but it risks eliminating features that some customers value, such as personal attention.
- Incorporating flexibility in capacity management by employing part-time or temporary staff may involve the use of less-skilled or less-interested people, and service quality may suffer.

Design objectives based on customer perspective require understanding the customer experience, and focusing on how to maintain control over service delivery to achieve customer satisfaction. The customer-oriented approach involves determining consumer wants and needs in order to understand relationships between service delivery and perceived quality. This enables designers to make enlightened choices in designing the delivery system.

Of course, designers must keep in mind that while depersonalizing service delivery for the sake of efficiency can negatively impact perceived quality, customers may not want or be willing to pay for highly personalized service either, so trade-offs may have to be made.

Phases in the Service Design Process

Table 4.5 lists the phases in the service design process. As you can see, they are quite similar to the phases of product design, except that the delivery system also must be designed.

TABLE 4.5

Phases in service design process

1. Conceptualize.
    - Idea generation
    - Assessment of customer wants/needs (marketing)
    - Assessment of demand potential (marketing)
2. Identify service package components needed (operations and marketing).
3. Determine performance specifications (operations and marketing).
4. Translate performance specifications into design specifications.
5. Translate design specifications into delivery specifications.

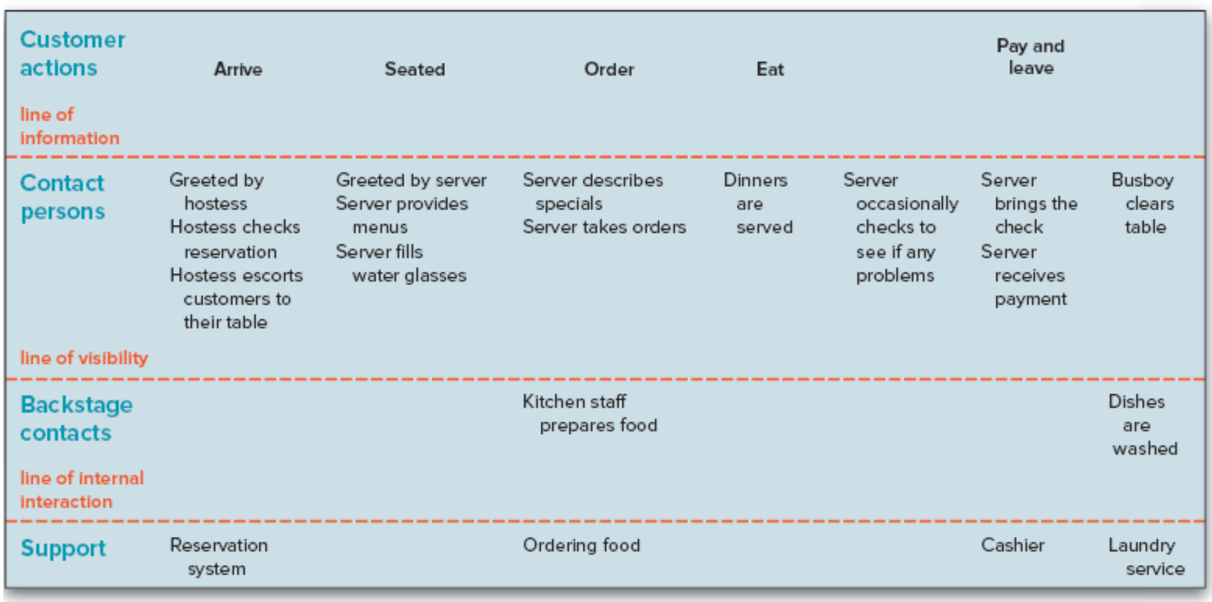
Service Blueprinting

A useful tool for conceptualizing a service delivery system is the **service blueprint**, which is a method for describing and analyzing a service process. A service blueprint is much like an architectural drawing, but instead of showing building dimensions and other construction features, a service blueprint shows the basic customer and service actions involved in a service operation. Figure 4.7 illustrates a simple service blueprint for a restaurant. At the top of the figure are the customer actions, and just below are the related actions of the direct contact service people. Next are what are sometimes referred to as “backstage contacts”—in this example, the kitchen staff—and below those are the support, or “backroom,” operations. In this example, support operations include the reservation system, ordering of food and supplies, cashier, and the outsourcing of laundry service. Figure 4.7 is a simplified illustration—typically, time estimates for actions and operations would be included.

Service blueprint A method used in service design to describe and analyze a proposed service.

FIGURE 4.7

A simple service blueprint for a restaurant



The major steps in service blueprinting are as follows:

. Establish boundaries for the service and decide on the level of detail needed.

. Identify and determine the sequence of customer and service actions and interactions. A flowchart can be a useful tool for this.

. Develop time estimates for each phase of the process, as well as time variability.

. Identify potential failure points and develop a plan to prevent or minimize them, as well as a plan to respond to service errors.

Characteristics of Well-Designed Service Systems

LO4.12 List the characteristics of well-designed service systems.

There are a number of characteristics of well-designed service systems. They can serve as guidelines in developing a service system. They include the following:

- Being consistent with the organization's mission.
- Being user-friendly.
- Being robust if variability is a factor.

- Being easy to sustain.
- Being cost-effective.
- Having value that is obvious to customers.
- Having effective linkages between back-of-the-house operations (i.e., no contact with the customer) and front-of-the-house operations (i.e., direct contact with customers). Front operations

should focus on customer service, while back operations should focus on speed and efficiency.

- Having a single, unifying theme, such as convenience or speed.
- Having design features and checks that will ensure service that is reliable and of high quality.

READING

THE CHALLENGES OF MANAGING SERVICES

Services can pose a variety of managerial challenges for managers—challenges that in manufacturing are either much less or nonexistent. And because services represent an increasing share of the economy, this places added importance on understanding and dealing with the challenges of managing services. Here are some of the main factors:

- Jobs in service environments are often less structured than in manufacturing environments.
- Customer contact is usually much higher in services.
- In many services, worker skill levels are low compared to those of manufacturing workers.
- Services are adding many new workers in low-skill, entry-level positions.
- Employee turnover is often higher, especially in the low-skill jobs.
- Input variability tends to be higher in many service environments than in manufacturing.

- Service performance can be adversely affected by workers' emotions, distractions, customers' attitudes, and other factors, many of which are beyond managers' control.

Because of these factors, quality and costs are more difficult to control, productivity tends to be lower, the risk of customer dissatisfaction is greater, and employee motivation is more difficult.

Questions

1. What managerial challenges do services present that manufacturing does not?
2. Why does service management present more challenges than manufacturing?

Challenges of Service Design

Variability is a major concern in most aspects of business operations, and it is particularly so in the design of service systems. Requirements tend to be variable, both in terms of differences in what customers want or need, and in terms of the timing of customer requests. Because services generally cannot be stored, there is the additional challenge of balancing supply and demand. This is less of a problem for systems in which the timing of services can be scheduled (e.g., doctor's appointment), but not so in others (e.g., emergency room visit).

Another challenge is that services can be difficult to describe precisely and are dynamic in nature, especially when there is a direct encounter with the customer (e.g., personal services), due to the large number of variables.

Guidelines for Successful Service Design

LO4.13 List some guidelines for successful service design.

- Define the service package in detail. A service blueprint may be helpful for this.
- Focus on the operation from the customer's perspective. Consider how customer expectations and perceptions are managed during and after the service.
- Consider the image that the service package will present both to customers and to prospective customers.
- Recognize that designers' familiarity with the system may give them quite a different perspective than that of the customer, and take steps to overcome this.
- Make sure that managers are involved and will support the design once it is implemented.
- Define quality for both tangibles and intangibles. Intangible standards are more difficult to define, but they must be addressed.
- Make sure that recruitment, training, and reward policies are consistent with service expectations.

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- Establish procedures to handle both predictable and unpredictable events.
- Establish systems to monitor, maintain, and improve service.

4.12 OPERATIONS STRATEGY

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

- Packaging products and ancillary services to increase sales. Examples include selling laptops at a reduced cost with a two-year internet access sign-up agreement, offering extended warranties on products, offering installation and service, and offering training with computer software.
- Using multiple-use platforms. Auto manufacturers use the same platform (basic chassis, say) for several nameplates (e.g., Jaguar S type, Lincoln LS, and Ford Thunderbird have shared the same platform). There are two basic computer platforms, PC and Mac, with many variations of computers using a particular platform.
- Implementing tactics that will achieve the benefits of high volume while satisfying customer needs for variety, such as mass customization.
- Continually monitoring products and services for small improvements rather than the “big bang” approach. Often, the “little” things can have a positive, long-lasting effect on consumer attitudes and buying behavior.
- Shortening the time it takes to get new or redesigned goods and services to market.

A key competitive advantage of some companies is their ability to bring new products to market more quickly than their competitors. Companies using this “first-to-market” approach are able to enter markets ahead of their competitors, allowing them to set higher selling prices than otherwise due to absence of competition. Such a strategy is also a defense against competition from cheaper “clones” because the competitors always have to play “catch up.”

From a design standpoint, reducing the time to market involves:

- Using standardized components to create new but reliable products.
- Using technology such as computer-aided design (CAD) equipment to rapidly design new or modified products.
- Concurrent engineering to shorten engineering time.

SUMMARY

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

The design process involves motivation, ideas for improvement, organizational capabilities, and forecasting. In addition to product life cycles, legal, environmental, and ethical considerations influence design choices. What degree of standardization designers should incorporate into designs is also an important consideration. A key objective for designers is to achieve a product or service design that will meet or exceed customer expectations, within cost or budget and taking into account the capabilities of operations. Although product design and service design are similar in some respects, a number of key differences exist between products and services that influence the way they are designed.

Successful design often incorporates many of these basic principles: Determine what customers want as a starting point; minimize the number of parts needed to manufacture an item or the number of steps to provide a service; simplify assembly or service, standardize as much as possible; and make the design robust. Trade-off decisions are common in design, and they involve such things as development time and cost, product or service cost, special features/performance, and product or service complexity.

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Research and development efforts can play a significant role in product and process innovations, although these are sometimes so costly that only large companies or governments can afford to underwrite them.

Reliability of a product or service is often a key dimension in the eyes of the customer. Measuring and improving reliability are important aspects of product and service design, although other areas of the organization also have an influence on reliability.

Quality function deployment is one approach for getting customer input for product or service design.

KEY POINTS

1. A range of factors can cause an organization to design or redesign a product or service, including economic, legal, political, social, technological, and competitive pressures. Furthermore, an important cause of operations failures can be traced to faulty design.
2. Every area of a business organization and its supply chain is connected to, and influenced by, its products and/or services, so the potential impact on each area must be taken into account when products or services are redesigned or new products or services are to be designed.

3. Central issues relate to the actual or expected demand for a product or service, the organization's capabilities, the cost to produce or provide, the desired quality level, and the cost and availability of necessary resources.
4. Among considerations that are generally important are legal, ethical, and environmental.
5. Although there are some basic differences between product design and service design, there are many similarities between the two.

KEY TERMS

computer-aided design (CAD), 164
concurrent engineering, 163
cradle-to-grave assessment, 146
delayed differentiation, 154
design for assembly (DFA), 165
design for disassembly (DFD), 149
design for manufacturing (DFM), 165
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DISCUSSION AND REVIEW QUESTIONS

1. What are some of the factors that cause organizations to redesign their products or services?
2. Contrast applied research with basic research.
3. What is CAD? Describe some of the ways a product designer can use it.
4. Name some of the main advantages and disadvantages of standardization.
5. What is modular design? What are its main advantages and disadvantages?
6. Explain the term *design for manufacturing* and briefly explain why it is important.
7. What are some of the competitive advantages of concurrent engineering?
8. Explain the term *remanufacturing.*
9. a. What is meant by the term *life cycle*?
   b. Why would this be a consideration in product or service design?
   c. Name three ways that each of these products has found new uses: baking soda, duct tape, and vinegar.
10. Why is R&D a key factor in productivity improvement? Name some ways R&D contributes to productivity improvements.
11. What is *mass customization*?
12. Name two factors that could make service design much different from product design.

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13. Explain the term *robust design.*
14. Explain what *quality function deployment* is and how it can be useful.
15. What is reverse engineering? Do you feel this is unethical?
16. What is the purpose of value analysis?
17. What is life cycle assessment, and what is its overall goal?
18. Explain the term “three Rs” and how the three Rs relate to sustainability.
19. a. Select an electronic device you are familiar with. What standard feature does it have that was once a “wow” feature? What “wow” feature does it have that you think will soon be a standard feature on new versions?
    b. Answer part *a* for a service you are familiar with.

TAKING STOCK

1. Describe some of the trade-offs that are encountered in product and service design.
2. Who needs to be involved in the design of products and services?
3. How has technology had an impact on product and service design?

CRITICAL THINKING EXERCISES

1. A number of fast-food chains, after their success with offering their customers fresh salads, and in an effort to downplay the image of selling unhealthy food, began adding fresh fruit plates to their menus. At about the same time, and seemingly in direct conflict with this “healthy” strategy, several other fast-food chains began offering fat- and calorie-laden items to their menus. Compare these two widely different approaches, and predict the chances of each one’s success. Name some other products that are popular, despite known health risks.
2. In wintry conditions, highway safety is improved by treating road surfaces with substances that will provide traction and/or melt snow and ice. Sand and rock salt are two widely used substances. Recently, a combination of beet juice and rock salt is being used in some parts of the country to treat road surfaces. Suppose you have been asked to provide a list of factors to consider for a switch from rock salt alone to using a combination of beet juice and rock salt. Name the major considerations you would take into account in making a decision in the following categories: cost considerations, environmental considerations, both positive and negative, and other considerations.
3. How were food producers impacted by the U.S. government’s requirement to identify the trans fat content on product labels?
4. Suppose a company intends to offer a new service to some of its internal customers. Briefly discuss how the fact that the customers are internal would change the process of managing the four phases of the service life cycle.
5. A few days before the end of the term of a two-year NDA (nondisclosure agreement) he signed with a start-up company related to a possible patent, Frank interviewed with another start-up and divulged information covered by the agreement. The interview had been scheduled for a week later, in which case it wouldn’t have been an issue, but had been moved up when another job applicant dropped out and the company had an opening for an earlier interview. Frank reasoned that he had met the spirit of the NDA, and a few days early wouldn’t really matter. Besides, as it turned out, the company he interviewed with wasn’t interested in that information, although they did hire him. What would you have done if you were Frank?
6. Give two examples of unethical conduct involving product or service design and the ethical principles (see Chapter 1) that are violated.

PROBLEMS

1. Examine and compare one of the following product sets. Base your comparison on such factors as features, costs, convenience, ease of use, and value.
   a. GPS versus maps
   b. Cell phones versus landlines
   c. Online shopping versus “bricks and mortar” shopping
   d. Standard gasoline automobile engines versus hybrids

e. Online course versus classroom
f. Satellite television versus cable

2. Use the internet to obtain recent crash-safety ratings for passenger vehicles. Then, answer these questions:
   a. Which vehicles received the highest ratings? The lowest ratings?
   b. How important are crash-safety ratings to new car buyers? Does the degree of importance depend on the circumstances of the buyer?
   c. Which types of buyers would you expect to be the most concerned with crash-safety ratings?
   d. Are there other features of a new car that might sway a buyer from focusing solely on crash safety? If so, what might they be?
3. Prepare a service blueprint for each of these banking transactions:
   a. Make a savings deposit using a teller
   b. Apply for a home equity loan
4. Prepare a service blueprint for each of these post office transactions:
   a. Buy stamps from a machine
   b. Buy stamps from a postal clerk
5. List the steps involved in getting gasoline into your car for full service and for self-service. Assume that paying cash is the only means of payment. For each list, identify the potential trouble points and indicate a likely problem.
6. Construct a list of steps for making a cash withdrawal from an automated teller machine (ATM). Assume that the process begins at the ATM with your bank card in hand. Then, identify the potential failure points (i.e., where problems might arise in the process). For each failure point, state one potential problem.
7. a. Refer to Figure 4.4. What two technical requirements have the highest impact on the customer requirement that the paper not tear?
   b. The following table presents technical requirements and customer requirements for the output of a laser printer. First, decide if any of the technical requirements relate to each customer requirement. Decide which technical requirement, if any, has the greatest impact on that customer requirement.

	TECHNICAL REQUIREMENTS		
Customer Requirements	**Type of Paper**	**Internal Paper Feed**	**Print Element**
Paper doesn't wrinkle			
Prints clearly			
Easy to use			

8. Prepare a table similar to that shown in problem 7*b* for cookies sold in a bakery. List what you believe are the three most important customer requirements (not including cost) and the three most relevant technical requirements (not including sanitary conditions). Next, indicate using a checkmark which customer requirements and which technical requirements are related.

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OPERATIONS TOUR

HIGH ACRES LANDFILL

The High Acres Landfill is located on a 218-acre site outside Fairport, New York. Opened in 1971, it is licensed to handle residential, commercial, and industrial nonhazardous waste. The landfill has 27 employees, and it receives approximately 3,000 tons of waste per day.

The public often has certain preconceived notions about a landfill, chief among them that landfills are dirty and unpleasant. However, a visit to the landfill by citizens dispelled some of those misconceptions. The entrance is nicely landscaped, and most of the site is planted with grass and a few trees. Although unpleasant odors can emanate from arriving trucks or at the dump site, the remainder of the landfill is relatively free of noxious smells.

A major portion of the landfill consists of a large hill, within which the waste is buried. Initially, the landfill began not as a hill but as a large hole in the ground. After a number of years of depositing waste, the hole eventually was filled. From that point on, as additional layers were added, the landfill began to take the shape of a flattop hill. Each layer was a little narrower than the preceding one, giving the hill a slope. The sides of the hill were planted with grass, and only the "working face" along the top currently remains unplanted. When the designated capacity is exhausted (this may take another 10 years), the landfill will be closed to further waste disposal. The site will be converted into a public park with hiking trails and picnic and recreation areas, and then given to the town.

The construction and operation of landfills are subject to numerous state and federal regulations. For example, nonpermeable liners must be placed on the bottom and sides of the landfill to prevent leakage of liquids into the groundwater. (Independent firms monitor groundwater to determine if there is any leakage into wells placed around the perimeter of the hill.) Mindful of public opinion, every effort is made to minimize the amount of time that waste is left exposed. At the end of each day, the waste that has been deposited in the landfill is compacted and covered with six inches of soil.

The primary source of income for the landfill is the fees it charges users. The landfill also generates income from methane gas, a by-product of organic waste decomposition, that accumulates within the landfill. A collection system is in place to capture and extract the gas from the landfill, and it is then sold to the local power company. Also, the landfill has a composting operation in which leaves and other yard wastes are converted into mulch.

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SUPPLEMENT 4 Reliability

LEARNING OBJECTIVES

After completing this chapter, you should be able to:

LO4S.1 Define *reliability*

LO4S.2 Perform simple reliability computations.

LO4S.3 Explain the term *availability* and perform simple calculations.

SUPPLEMENT OUTLINE

4S.1 INTRODUCTION

LO4S.1
Define *reliability.*

Reliability is a measure of the ability of a product, service, part, or system to perform its intended function under a prescribed set of conditions, and often over a designated time interval or life span. In effect, reliability is a *probability.*

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

Suppose that an item has a reliability of .90. This means it has a 90 percent probability of functioning as intended, either when needed (e.g., a security warning system) or over its life span (e.g., a vehicle). The probability it will fail is 1 − .90 = .10, or 10 percent. Hence, it is expected that, on average, 1 in every 10 such items will fail or, equivalently, that the item will fail, on average, once in every 10 trials. Similarly, a reliability of .985 implies 15 failures per 1,000 parts or trials.

4S.2 QUANTIFYING RELIABILITY

Engineers and designers have a number of techniques at their disposal for assessing reliability. A discussion of those techniques is not within the scope of this text. Instead, let us turn to the issue of quantifying overall product or system reliability. Probability is used in two ways:

. The probability that the product or system will function when activated.
. The probability that the product or system will function for a given length of time.

The first of these focuses on *one point in time* and is often used when a system must operate for one time or a relatively few number of times. The second of these focuses on the *length of service.* The distinction will become more apparent as each of these approaches is described in more detail.

Finding the Probability of Functioning When Activated

LO4S.2 Perform simple reliability computations.

The probability that a system or a product will operate as planned is an important concept in system and product design. Determining that probability when the product or system consists of a number of *independent* components requires the use of the rules of probability for independent events. **Independent events** have no relation to the occurrence or nonoccurrence of each other. What follows are three examples illustrating the use of probability rules to determine whether a given system will operate successfully.

Independent events Events whose occurrence or nonoccurrence does not influence each other.

Rule 1. If two or more events are independent and *success* is defined as the probability that all of the events occur, then the probability of success is equal to the product of the probabilities of the events.

Example Suppose a room has two lamps, but to have adequate light both lamps must work (success) when turned on. One lamp has a probability of working of .90, and the other has a probability of working of .80. The probability that both will work is .90 × .80 = .72. Note that the order of multiplication is unimportant: .80 × .90 = .72. Also note that if the room had three lamps, three probabilities would have been multiplied.

This system can be represented by the following diagram:

Even though the individual components of a system might have high reliabilities, the system as a whole can have considerably less reliability because all components that are in series (as are the ones in the preceding example) must function. As the number of components in a series increases, the system reliability decreases. For example, a system that has eight components in a series, each with a reliability of .99, has a reliability of only $.99^8 = .923$.

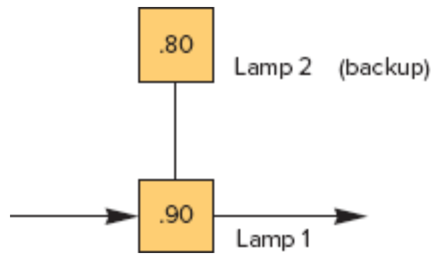
Obviously, many products and systems have a large number of component parts that must all operate, and some way to increase overall reliability is needed. One approach is to use **redundancy** in the design. This involves providing backup parts for some items.

Redundancy The use of backup components to increase reliability.

Rule 2. If two events are independent and *success* is defined as the probability that *at least one* of the events will occur, the probability of success is equal to the probability of either one plus 1.00 minus that probability multiplied by the other probability.

Example There are two lamps in a room. When turned on, one has a probability of working of .90 and the other has a probability of working of .80. Only a single lamp is needed to light for success. If one fails to light when turned on, the other lamp is turned on. Hence, one of the lamps is a backup in case the other one fails. Either lamp can be treated as the backup; the probability of success will be the same. The probability of success is $.90 + (1 - .90) \times .80 = .98$. If the .80 light is first, the computation would be $.80 + (1 - .80) \times .90 = .98$.

This system can be represented by the following diagram:



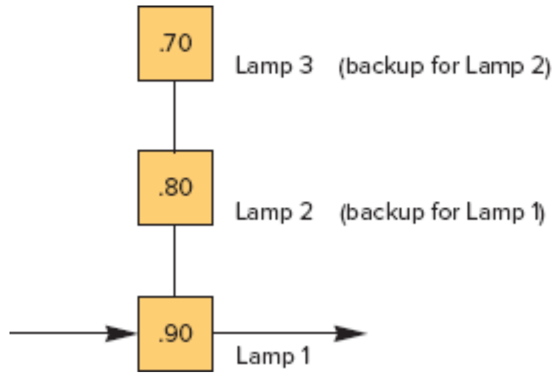
Rule 3. If two or more events are involved and success is defined as the probability that at least one of them occurs, the probability of success is $1 - p$ (all fail).

Example Three lamps have probabilities of .90, .80, and .70 of lighting when turned on. Only one lighted lamp is needed for success; hence, two of the lamps are considered to be backups. The probability of success is

$$1 - [(1 - .90) \times (1 - .80) \times (1 - .70)] = .994$$

Note: It is assumed that the switch that activates each lamp has a reliability of 100%. To see how to incorporate a switch with less than 100% reliability, consider that the second "lamp" is actually a switch with a probability of operating equal to .80, and the third lamp is the only backup (i.e., the second lamp). Thus, the problem would be solved in exactly the same way.

This system can be represented by the following diagram:



EXAMPLE 4S–1 **Computing Reliability**

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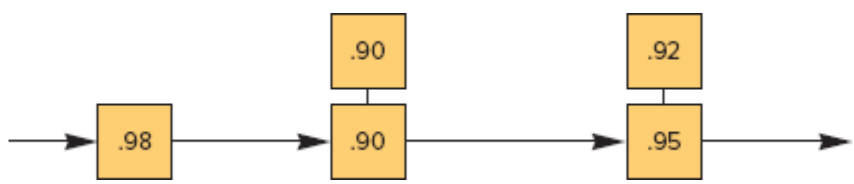
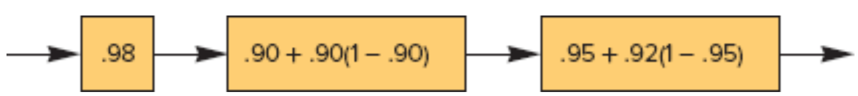
Determine the reliability of the following system.



SOLUTION

The system can be reduced to a series of three components:



The system reliability is, then, the product of these:

$.98 \times .99 \times .996 = .966$

Finding the Probability of Functioning for a Specified Length of Time

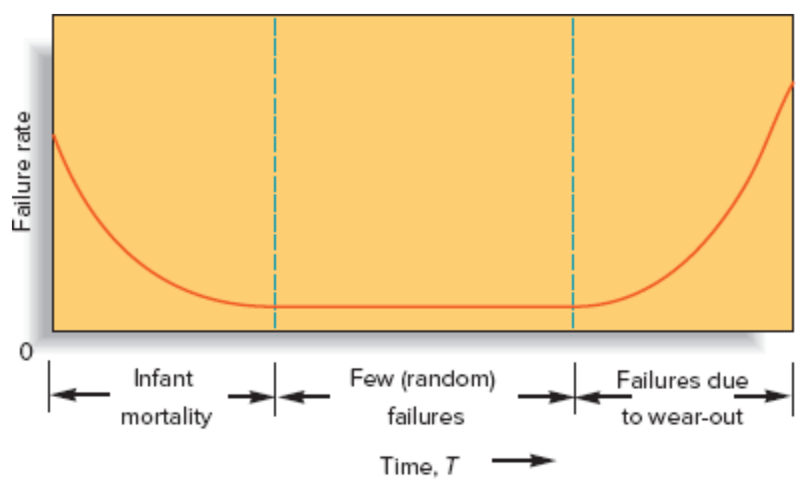
LO4S.2 Perform simple reliability computations.

The second way of looking at reliability considers the incorporation of a time dimension: Probabilities are determined relative to a specified length of time. This approach is commonly used in product warranties, which pertain to a given period of time after purchase of a product.

A typical profile of product failure rate over time is illustrated in Figure 4S.1. Because of its shape, it is sometimes referred to as a bathtub curve. Frequently, a number of products fail shortly after they are put into service, not because they wear out, but because they are defective to begin with. The rate of failures decreases rapidly once the truly defective items are weeded out. During the second phase, there are fewer failures because most of the defective items have been eliminated, and it is too soon to encounter items that fail because they have worn out. In some cases, this phase covers a relatively long time. In the third phase, failures occur because the products are worn out, and the failure rate increases.

FIGURE 4S.1

Failure rate is a function of time

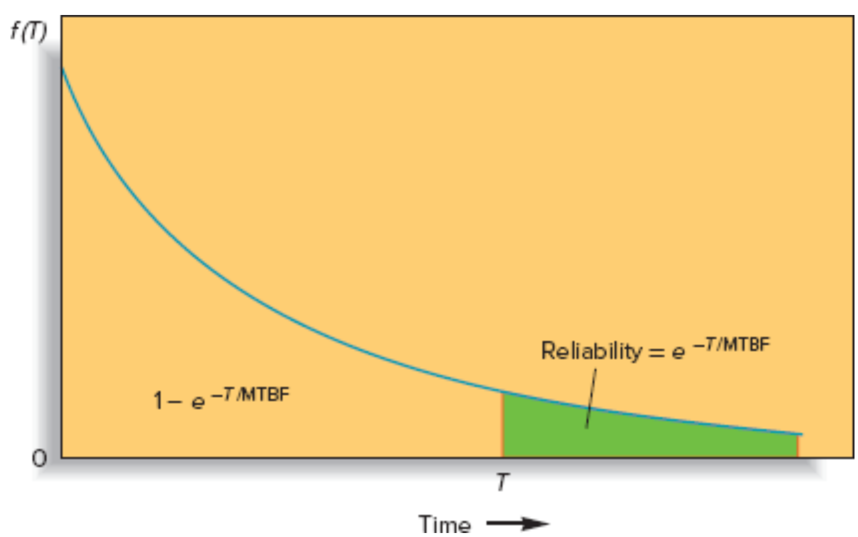


Information on the distribution and length of each phase requires the collection of historical data and analysis of those data. It often turns out that the **mean time between failures (MTBF)** page 179 in the infant mortality phase can be modeled by a negative exponential distribution, such as that depicted in Figure 4S.2. Equipment failures, as well as product failures, may occur in this pattern. In such cases, the exponential distribution can be used to determine various probabilities of interest. The probability that equipment or a product put into service at time 0 will fail *before* some specified time, *T,* is equal to the area under the curve between 0 and *T.* Reliability is specified as the probability that a product will last *at least until* time *T;* reliability is equal to the area under the curve *beyond T.* (Note that the total area under the curve in each phase is treated as 100 percent for computational purposes.) Observe that, as the specified length of service increases, the area under the curve to the right of that point (i.e., the reliability) decreases.

Mean time between failures (MTBF) The average length of time between failures of a product or component.

FIGURE 4S.2

An exponential distribution



Determining values for the area under a curve to the right of a given point, *T,* becomes a relatively simple matter using a table of exponential values. An exponential distribution is completely described using a single parameter, the distribution mean, which reliability engineers often refer to as the mean time between failures. Using the symbol T to represent length of service, the probability that failure will *not* occur before time T (i.e., the area in the right tail) is easily determined:

$$P(\text{no failure before } T) = e^{-T/\text{MTBF}}$$

where

e = 2.7183. . .
T = Length of service before failure
MTBF = Mean time between failures

The probability that failure will occur before time T is:

$$P(\text{failure before } T) = 1 - e^{-T/\text{MTBF}}$$

Selected values of $e^{-T/\text{MTBF}}$ are listed in Table 4S.1.

TABLE 4S.1

Values of $e^{-T/\text{MTBF}}$

T/MTBF	$e^{-T/MTBF}$	T/MTBF	$e^{-T/MTBF}$	T/MTBF	$e^{-T/MTBF}$
0.10	.9048	2.60	.0743	5.10	.0061
0.20	.8187	2.70	.0672	5.20	.0055
0.30	.7408	2.80	.0608	5.30	.0050
0.40	.6703	2.90	.0550	5.40	.0045
0.50	.6065	3.00	.0498	5.50	.0041
0.60	.5488	3.10	.0450	5.60	.0037
0.70	.4966	3.20	.0408	5.70	.0033
0.80	.4493	3.30	.0369	5.80	.0030
0.90	.4066	3.40	.0334	5.90	.0027
1.00	.3679	3.50	.0302	6.00	.0025
1.10	.3329	3.60	.0273	6.10	.0022
1.20	.3012	3.70	.0247	6.20	.0020
1.30	.2725	3.80	.0224	6.30	.0018
1.40	.2466	3.90	.0202	6.40	.0017
1.50	.2231	4.00	.0183	6.50	.0015
1.60	.2019	4.10	.0166	6.60	.0014
1.70	.1827	4.20	.0150	6.70	.0012
1.80	.1653	4.30	.0136	6.80	.0011
1.90	.1496	4.40	.0123	6.90	.0010
2.00	.1353	4.50	.0111	7.00	.0009
2.10	.1255	4.60	.0101		
2.20	.1108	4.70	.0091		
2.30	.1003	4.80	.0082		
2.40	.0907	4.90	.0074		
2.50	.0821	5.00	.0067		

EXAMPLE 4S–2

Computing Product Life Probability

eXcel

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By means of extensive testing, a manufacturer has determined that its Super Sucker Vacuum Cleaner models have an expected life that is exponential, with a mean of four years. Find the probability that one of these cleaners will have a life that ends

a. after the initial four years of service.

b. before four years of service are completed.

c. not before six years of service.

SOLUTION

MTBF = 4 years

a. T = 4 years:

$$T/\text{MTBF} = \frac{4 \text{ years}}{4 \text{ years}} = 1.0$$

From Table 4S.1, $e^{-1.0}$ =.3679

b. The probability of failure before T = 4 years is 1− e^{-1}, or 1 − .3679 = .6321.

c. T = 6 years:

$$T/\text{MTBF} = \frac{6 \text{ years}}{4 \text{ years}} = 1.50$$

From Table 4S.1, $e^{-1.5}$ = .2231

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READING 

SHOULD YOU BUY AN EXTENDED WARRANTY?

BY LISA SPENCER

From cars to computers to kitchen appliances, consumers are bombarded with offers for extended warranties. Are they worth the investment? According to *Consumer Reports,* the answer is usually "No" (Gauntt, 2019). Then why do people buy them?

Some buy for the peace of mind of knowing that if something goes wrong during the warranty period, they are covered and won't experience additional out-of-pocket costs. Others don't want to worry about figuring out where to take the product for a repair, or they like knowing that it will be replaced if it can't be fixed. Still others recall events in the past when they did not have an extended warranty and wished they did.

What factors do people weigh when making the decision to buy or not to buy? Reasons include:

The cost of the item itself. If it's a big ticket item and expensive to replace, the extended warranty becomes more attractive. A car, for instance, may seem more important to protect than an inexpensive printer.

Past history with a similar product or the particular brand being purchased. If a person had good luck in the past with a certain brand, he may figure the warranty is unnecessary. Conversely, a bad experience with the product type or brand may make someone more likely to buy the warranty (or perhaps simply choose a different brand!).

Who will be using the product or how heavily it will be used. If the product will be used by children versus adults, or if a person tends to be rough on things, the warranty may seem more worthwhile.

The reputation of the warranty company. If a company has a good customer service record, customers may be more likely to buy the warranty. Apple Care, for instance, tends to be highly rated and is often purchased.

What the warranty will cover. Some warranties are very extensive, while others are limited by a lot of fine print.

Warranties that offer a lot of protection may entice someone to purchase. Conversely, policies that have many coverage limitations or require routine maintenance to avoid nullifying the warranty may seem less desirable.

The length of the regular warranty. If the customer feels that the regular warranty is generous, or if the product type tends to have a long life, the extended warranty may seem less important.

How long the user plans to keep the product and how long the product life cycle is. If a user plans to keep the product, for instance a phone, for a short period of time, the normal warranty may already be long enough. Similarly, if the technology of the product becomes quickly obsolete, the customer may prefer upgrading to a newer model over opting for a repair.

Is the extended warranty a "good buy"?

Extended warranties can be very expensive, and some experts suggest the consumer is better off putting the cost of the warranty into a savings account where it is available if needed (Gauntt, 2019). Additionally, many credit card companies offer extended warranty protection if the purchase is made on that account, which is a simple and free way to avoid paying for extra coverage for some types of products.

The odds of actually needing the warranty are slim; thus, they are huge money makers for the companies that sell them. This is mainly because the extended warranty covers the product during its normal useful life, when most of the products should still be functioning properly. Dave Ramsey, a personal finance guru and popular public speaker states, "Extended warranties are a really horrible set of mathematics, and the reason people sell them is because they make a bundle on them in commissions" (*Consumer Reports,* 2018).

Many appliances, for instance, last so long that the extended warranty will expire long before they will. The typical refrigerator lasts 14 to 27 years, and even a microwave oven can last seven to nine years. “Most of the things we buy today are reliable: They come with warranties that protect us and last the amount of time we expect them to,” explains Richard M. Alderman, head of the Consumer Law Center of the University of Houston (Williams, 2018).

Of course, if a person happens to get one of the few products that does fail during the time of the extended warranty, having an extended warranty would be a good thing. However, most extended warranty purchasers will not need the service, similar to how most people who purchase term life insurance do not end up needing the coverage. A *Consumer Reports* member survey indicated that most car owners spent more on the extended warranty than the value of the services they got back in return (*Consumer Reports,* 2018).

Ultimately, each person has to decide for themselves whether the peace of mind and convenience of an extended warranty offer enough value to justify the cost.

1. How do warranties or extended warranties affect a company’s costs and reputation?
2. What strategic considerations should be taken into account when deciding how long a warranty to offer?

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“Are Extended Warranties Worth It?” Joshua Gauntt, WBRC, January 2, 2019. http://www.wbrc.com/2019/01/02/are-extended-warranties-worth-it/

“How Long Do Refrigerators Last? The Life Span of Kitchen Appliances.” Terri Williams, *Home Improvement,* April 9, 2018. https:///www.realtor.com/advice/home-improvement/how-long-do-refrigerators-last-kitchen-appliances-life-spans/

"Should You Get an Extended Warranty for Your Car?" *Consumer Reports,* December 27, 2018. https://www.yahoo.com/news/extended-warranty-car-110009647.html

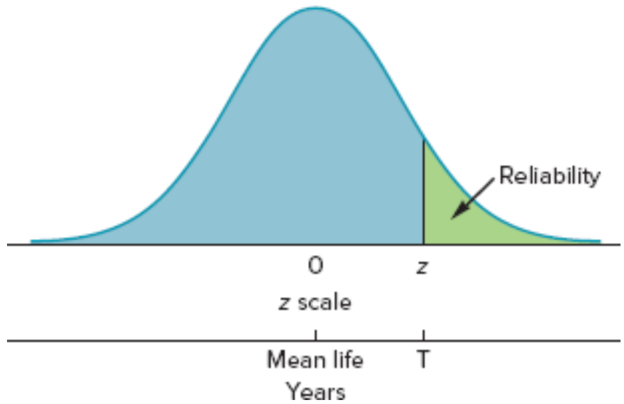
Product failure due to wear-out can sometimes be modeled by a normal distribution. Obtaining probabilities involves the use of a table (refer to Appendix Table B.2). The table provides areas under a normal curve from (essentially) the left end of the curve to a specified point *z* , where *z* is a *standardized* value computed using the formula

$$z = \frac{T - \text{Mean wear-out time}}{\text{Standard deviation of wear-out time}}$$

Thus, to work with the normal distribution, it is necessary to know the mean of the distribution and its standard deviation. A normal distribution is illustrated in Figure 4S.3. Appendix Table B.2 contains normal probabilities (i.e., the area that lies to the left of *z*). To obtain a probability that service life will not exceed some value *T,* compute *z* and refer to the table. To find the reliability for time *T,* subtract this probability from 100 percent. To obtain the value of *T* that will provide a given probability, locate the nearest probability under the curve *to the left* in Appendix Table B.2. Then, use the corresponding *z* in the preceding formula and solve for *T.*

FIGURE 4S.3

A normal curve



EXAMPLE 4S–3

Computing Life Probability and Service Life

eXcel

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The mean life of a certain ball bearing can be modeled using a normal distribution with a mean of six years and a standard deviation of one year. Determine each of the following:

a. The probability that a ball bearing will wear out *before* seven years of service.

b. The probability that a ball bearing will wear out *after* seven years of service (i.e., find its reliability).

c. The service life that will provide a wear-out probability of 10 percent.

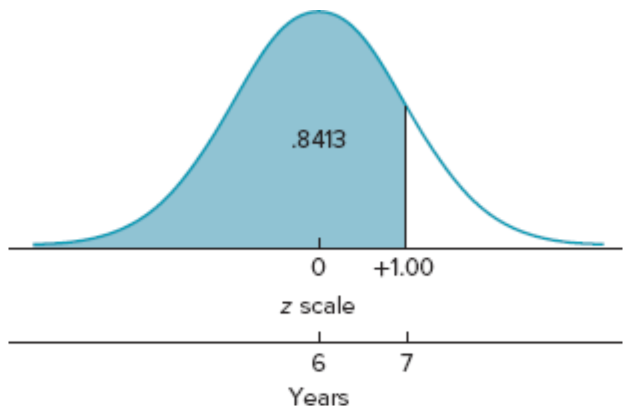
SOLUTION

Wear-out life mean = 6 years.

Wear out life standard deviation = 1 year.

Wear-out life is normally distributed.

a. Compute z and use it to obtain the probability directly from Appendix Table B.2 (see diagram).



$$z = \frac{7-6}{1} = +1.00$$

Thus, $P(T < 7) = .8413$

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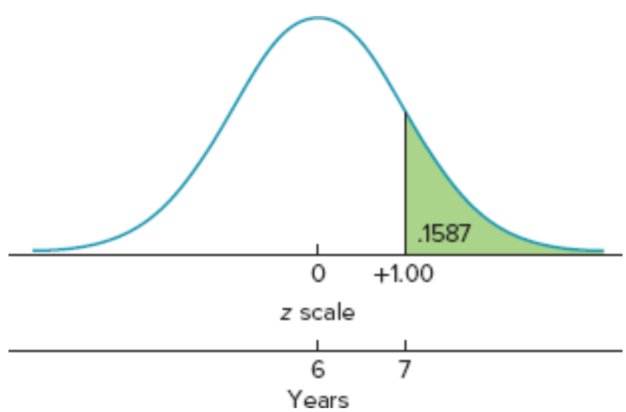
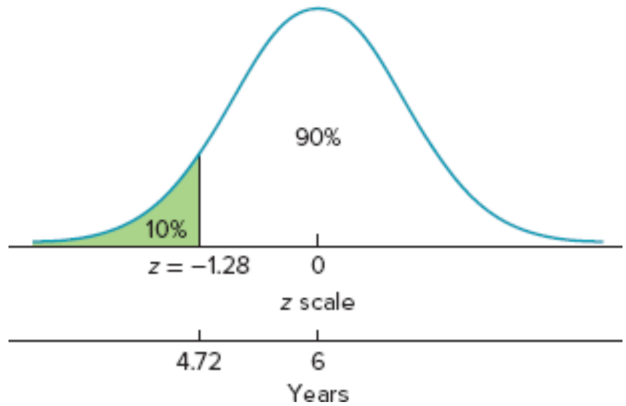
b. Subtract the probability determined in part *a* from 100 percent (see diagram).



$1.00 - .8413 = .1587$

c. Use the normal table and find the value of *z* that corresponds to an area under the curve of 10 percent (see diagram).



$$z = -1.28 = \frac{T-6}{1}$$

Solving for *T*, we find *T* = 4.72 years.

4S.3 AVAILABILITY

LO4S.3 Define the term *availability* and perform simple calculations.

A related measure of importance to customers, and hence to designers, is **availability**. It measures the fraction of time a piece of equipment is expected to be operational (as opposed to being down for repairs). Availability can range from zero (never available) to 1.00 (always available). Companies that can offer equipment with a high availability factor have a competitive advantage over companies that offer equipment with lower availability values. Availability is a function of both the mean time between failures and the mean time to repair. The availability factor can be computed using the following formula:

$$\text{Availability} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTR}}$$

Availability The fraction of time a piece of equipment is expected to be available for operation.

where

MTBF = Mean time between failures
MTR = Mean time to repair, including waiting time

EXAMPLE 4S–4 **Computing Availability**

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A copier is able to operate for an average of 200 hours between repairs, and the mean repair time is 2 hours. Determine the availability of the copier.

SOLUTION

MTBF = 200 hours and MTR = 2 hours

$$\text{MTBF} = 200 \text{ hours and MTR} = 2 \text{ hours}$$

Two implications for design are revealed by the availability formula. One is that availability increases as the mean time between failures increases. The other is that availability also increases as the mean repair time decreases. It would seem obvious that designers would want to design products that have a long time between failures. However, some design options enhance repairability, which can be incorporated into the product. Ink-jet printers, for example, are designed with print cartridges that can easily be replaced.

KEY TERMS

SOLVED PROBLEMS

Problem 1

A product design engineer must decide if a redundant component is cost-justified in a certain system. The system in question has a critical component with a probability of .98 of operating. System failure would involve a cost of \$20,000. For a cost of \$100, a switch could be added that would automatically transfer the system to the backup component in the event of a failure. Should the backup be added if the backup probability is also .98?

Solution

Because no probability is given for the switch, we will assume its probability of operating when needed is 100 percent. The expected cost of failure (i.e., without the backup) is $\$20{,}000 \times (1 - .98) = \$400$.

With the backup, the probability of *not* failing would be:

$$.98 + 0.2(.98) = .9996$$

Hence, the probability of failure would be $1 - .9996 = .0004$. The expected cost of failure with the backup would be the added cost of the backup component plus the failure cost:

$$\$100 + \$20{,}000(.0004) = \$108$$

Because this is less than the cost without the backup, it appears that adding the backup is definitely cost justifiable.

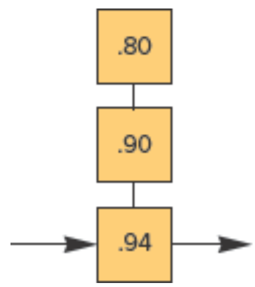
Problem 2

Due to the extreme cost of interrupting production, a firm has two standby machines available in case a particular machine breaks down. The machine in use has a reliability of .94, and the backups have reliabilities of .90 and .80. In the event of a failure, either backup can be pressed into service. If one fails, the other backup can be used. Compute the system reliability.

Solution

R_1 = .94, R_2 = .90, and R_3 = .80

The system can be depicted in this way:



$$R_{\text{system}} = R_1 + R_2(1 - R_1) + R_3(1 - R_2)(1 - R_1)$$
$$= .94 + .90(1 - .94) + .80(1 - .90)(1 - .94) = .9988$$

Problem 3

A hospital has three *independent* fire alarm systems, with reliabilities of .95, .97, and .99. In the event of a fire, what is the probability that a warning would be given?

Solution

A warning would *not* be given if all three alarms failed. The probability that at least one alarm would operate is 1 − *P* (none operate):

$$P(\text{none operate}) = (1 - .95)(1 - .97)(1 - .99) = .000015$$
$$P(\text{warning}) = 1 - .000015 = .999985$$

Problem 4

A weather satellite has an expected life of 10 years from the time it is placed into earth orbit. Determine its probability of no wear-out before each of the following lengths of service. Assume the exponential distribution is appropriate.

a. 5 years
b. 12 years
c. 20 years
d. 30 years

Solution

MTBF is 10 years. Compute the ratio *T*/MTBF for *T* = 5, 12, 20, and 30, and obtain the values of $e^{-T/\text{MTBF}}$ from Table 4S.1. The solutions are summarized in the following table.

T	MTBF	*T*/MTBF	$e^{-T/\text{MTBF}}$
a. 5	10	0.50	.6065
b. 12	10	1.20	.3012
c. 20	10	2.00	.1353
d. 30	10	3.00	.0498

Problem 5

What is the probability that the satellite described in Solved Problem 4 will fail between 5 and 12 years after being placed into earth orbit?

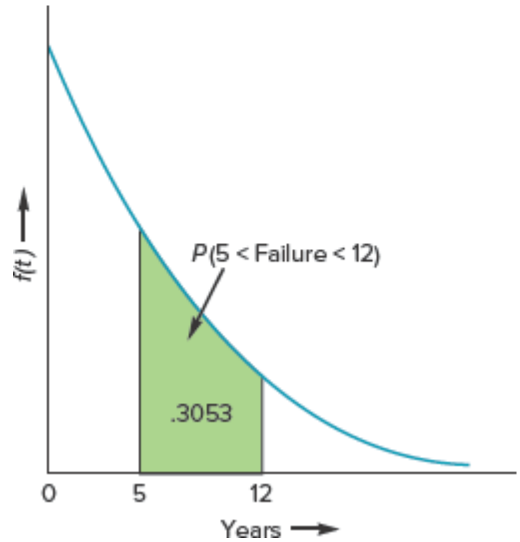
Solution

P(5 years < failure < 12 years) = *P*(failure after 5 years) − *P*(failure after 12 years)

Using the probabilities shown in the previous solution, you obtain:

$$\begin{array}{rr} P(\text{failure after} = \text{years}) = & .6065 \\ -P(\text{failure after 12 years}) = & \underline{.3012} \\ & .3053 \end{array}$$

The corresponding area under the curve is illustrated as follows.



Problem 6

One line of tires produced by a large company has a wear-out life that can be modeled using a normal distribution with a mean of 25,000 miles and a standard deviation of 2,000 miles. Determine each of the following:

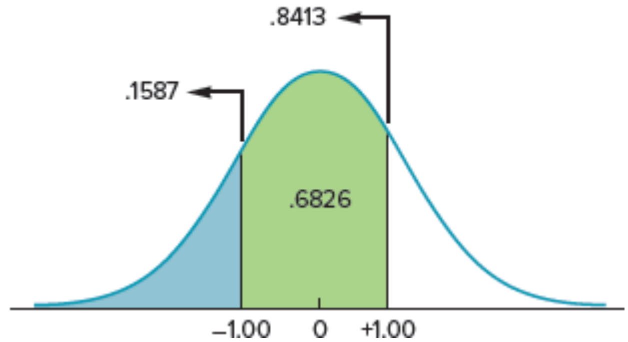
a. The percentage of tires that can be expected to wear out within ± 2,000 miles of the average (i.e., between 23,000 miles and 27,000 miles).
b. The percentage of tires that can be expected to fail between 26,000 miles and 29,000 miles.
c. For what tire life would you expect 4 percent of the tires to have worn out?

Solution

Notes: (1) Miles are analogous to time and are handled in exactly the same way; (2) the term *percentage* refers to a probability.

a. The phrase "within ± 2,000 miles of the average" translates to within one standard deviation of the mean because the standard deviation equals 2,000 miles. Therefore, the range of z is $z = -1.00$, to $z = +1.00$, and the area under the curve between those points is found as the difference between $P(z < +1.00)$ and $P(z < -1.00)$, using values obtained from Appendix Table B.2.

$$\begin{array}{r} P(z < +1.00) = .8413 \\ -P(z < -1.00) = .1587 \\ \hline P(-1.00 < z < +1.00) = .6826 \end{array}$$



b. Wear-out mean = 25,000 miles

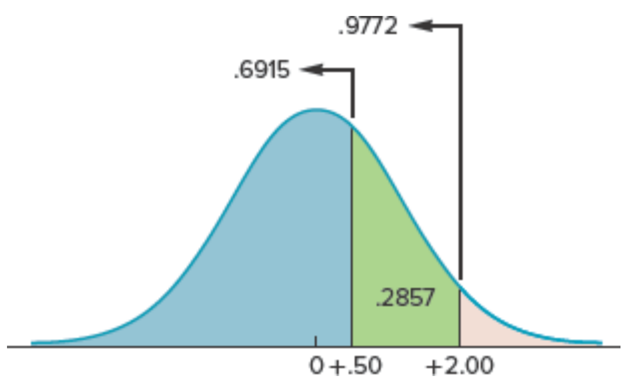
Wear-out standard deviation = 2,000 miles

$P(26{,}000 < \text{Wear-out} < 29{,}000) = P(z < z_{29{,}000}) - P(z < z_{26{,}000})$

$$z_{29{,}000} = \frac{29{,}000 - 25{,}000}{2{,}000} = +2.00 \quad \text{From Appendix Table B} \quad P = .9772$$

$$z_{26{,}000} = \frac{26{,}000 - 25{,}000}{2{,}000} = +.50 \quad \text{From Appendix Table B} \quad P = .6915$$

The difference is .9772 − .6915 = .2857, which is the expected percent of tires that will wear out between 26,000 miles and 29,000 miles.



c. Use Appendix Table B.1 to find z for 4 percent: $z = -1.75$.

Find tire life using $\mu + z\sigma$: 25,000 − 1.75(2,000) = 21,500 miles.

DISCUSSION AND REVIEW QUESTIONS

1. Define the term *reliability.*
2. Explain why a product or system might have an overall reliability that is low even though it is comprised of components that have fairly high reliabilities.
3. What is redundancy and how can it improve product design?

PROBLEMS

1. Consider the following system:

   Determine the probability that the system will operate under each of these conditions:

   a. The system as shown.
   b. Each system component has a backup with a probability of .90 and a switch that is 100 percent reliable.
   c. Backups with .90 probability and a switch that is 99 percent reliable.

2. A product is composed of four parts. In order for the product to function properly in a given situation, each of the parts must function. Two of the parts have a .96 probability of functioning, and two have a probability of .99. What is the overall probability that the product will function properly?
3. A system consists of three identical components. In order for the system to perform as intended, all of the components must perform. Each has the same probability of performance. If the system is to have a .92 probability of performing, what is the minimum probability of performing needed by each of the individual components?
4. A product engineer has developed the following equation for the cost of a system component: $C = (10P)^2$, where C is the cost in dollars and P is the probability that the component will operate as expected. The system is composed of two identical components, both of which must operate for the system to operate. The engineer can spend $173 for the two components. To the nearest two decimal places, what is the largest component probability that can be achieved?
5. The guidance system of a ship is controlled by a computer that has three major modules. In order for the computer to function properly, all three modules must function. Two of the modules have reliabilities of .97, and the other has a reliability of .99.

   a. What is the reliability of the computer?
   b. A backup computer identical to the one being used will be installed to improve overall reliability. Assuming the new computer automatically functions if the main one fails, determine the resulting reliability.
   c. If the backup computer must be activated by a switch in the event that the first computer fails, and the switch has a reliability of .98, what is the overall reliability

of the system? (*Both* the switch and the backup computer must function in order for the backup to take over.)

6. One of the industrial robots designed by a leading producer of servomechanisms has four major components. Components' reliabilities are .98, .95, .94, and .90. All of the components must function in order for the robot to operate effectively.
   a. Compute the reliability of the robot.
   b. Designers want to improve the reliability by adding a backup component. Due to space limitations, only one backup can be added. The backup for any component will have the same reliability as the unit for which it is the backup. Which component should get the backup in order to achieve the highest reliability?
   c. If one backup with a reliability of .92 can be added to any one of the main components, which component should get it to obtain the highest overall reliability?
7. A production line has three machines A, B, and C, with reliabilities of .99, .96, and .93, respectively. The machines are arranged so that if one breaks down, the others must shut down. Engineers are weighing two alternative designs for increasing the line's reliability. Plan 1 involves adding an identical backup *line,* and plan 2 involves providing a backup for each *machine.* In either case, three machines (A, B, and C) would be used with reliabilities equal to the original three.
   a. Which plan will provide the higher reliability?
   b. Explain why the two reliabilities are not the same.
   c. What other factors might enter into the decision of which plan to adopt?

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8. Refer to the previous problem.
   a. Assume that the single switch used in plan 1 is 98 percent reliable, while reliabilities of the machines remain the same. Recalculate the reliability of plan 1. Compare the reliability of this plan with the reliability of plan 1 calculated in solving the original problem. How much did the reliability of plan 1 decrease as a result of a 98 percent reliable switch?
   b. Assume that the three switches used in plan 2 are all 98 percent reliable, while reliabilities of the machines remain the same. Recalculate the reliability of plan 2. Compare the reliability of this plan with the reliability of plan 2 calculated in solving the original problem. How much did the reliability of plan 2 decrease?
9. A web server has five major components that must all function in order for it to operate as intended. Assuming that each component of the system has the same reliability, what is the minimum reliability each one must have in order for the overall system to have a reliability of .98?
10. Repeat Problem 9 using the condition that one of the components will have a backup with a reliability equal to that of any one of the other components.
11. Hoping to increase the chances of reaching a performance goal, the director of a research project has assigned three separate research teams the same task. The

director estimates that the team probabilities are .9, .8, and .7 for successfully completing the task in the allotted time. Assuming that the teams work independently, what is the probability that the task will *not* be completed in time?

12. An electronic chess game has a useful life that is exponential with a mean of 30 months. Determine each of the following:
    a. The probability that any given unit will operate for at least (1) 39 months, (2) 48 months, (3) 60 months.
    b. The probability that any given unit will fail sooner than (1) 33 months, (2) 15 months, (3) 6 months.
    c. The length of service time after which the percentage of failed units will approximately equal (1) 50 percent, (2) 85 percent, (3) 95 percent, (4) 99 percent.
13. A manufacturer of programmable calculators is attempting to determine a reasonable free-service period for a model it will introduce shortly. The manager of product testing has indicated that the calculators have an expected life of 30 months. Assume product life can be described by an exponential distribution.
    a. If service contracts are offered for the expected life of the calculator, what percentage of those sold would be expected to fail during the service period?
    b. What service period would result in a failure rate of approximately 10 percent?
14. Lucky Lumen light bulbs have an expected life that is exponentially distributed with a mean of 20,000 hours. Determine the probability that one of these light bulbs will last
    a. at least 24,000 hours.
    b. no longer than 4,000 hours.
    c. between 4,000 hours and 24,000 hours.
15. Planetary Communications, Inc., intends to launch a satellite that will enhance reception of television programs in Alaska. According to its designers, the satellite will have an expected life of six years. Assume the exponential distribution applies. Determine the probability that it will function for each of the following time periods:
    a. More than 9 years
    b. Less than 12 years
    c. More than 9 years but less than 12 years
    d. At least 21 years
16. An office manager has received a report from a consultant that includes a section on equipment replacement. The report indicates that scanners have a service life that is normally distributed with a mean of 41 months and a standard deviation of 4 months. On the basis of this information, determine the percentage of scanners that can be expected to fail in the following time periods:
    a. Before 38 months of service
    b. Between 40 and 45 months of service
    c. Within ±2 months of the mean life

17. A major television manufacturer has determined that its 50-inch LED televisions have a mean service life that can be modeled by a normal distribution with a mean of six years and a standard deviation of one-half year.
    a. What probability can you assign to service lives of at least (1) five years? (2) Six years? (3) Seven and one-half years?
    b. If the manufacturer offers service contracts of four years on these televisions, what percentage can be expected to fail from wear-out during the service period?
    c. What service period would achieve an expected wear-out rate of (1) 2 percent? (2) 5 percent?
18. A soon-to-be-introduced cell phone has an expected service life that can be modeled by a normal distribution with a mean of five years and a standard deviation of 0.6 year.
    a. If the company offers a warranty of four years, what percentage of cell phones can be expected to fail before that time?
    b. What probability can you assign to a service life of (1) 5.9 years? (2) 6.2 years?
19. Determine the availability for each of these cases:
    a. MTBF = 40 days, average repair time = 3 days
    b. MTBF = 300 hours, average repair time = 6 hours
20. A machine can operate for an average of 10 weeks before it needs to be overhauled, a process which takes two days. The machine is operated five days a week. Compute the availability of this machine. (*Hint:* All times must be in the same units.)
21. A manager must decide between two machines. The manager will take into account each machine's operating costs and initial costs, and its breakdown and repair times. Machine A has a projected average operating time of 142 hours and a projected average repair time of 7 hours. Projected times for machine B are an average operating time of 65 hours and a repair time of 2 hours. What are the projected availabilities of each machine?
22. A designer estimates that she can (*a*) increase the average time between failures of a part by 5 percent at a cost of $450, or (*b*) reduce the average repair time by 10 percent at a cost of $200. Which option would be more cost-effective? Currently, the average time between failures is 100 hours and the average repair time is 4 hours.
23. Auto batteries have an average life of 2.7 years. Battery life is normally distributed with a mean of 2.7 years and a standard deviation of .3 year. The batteries are warranted to operate for a minimum of 2 years. If a battery fails within the warranty period, it will be replaced with a new battery at no charge. The company sells and installs the batteries. Also, the usual $5 installation charge will be waived.
    a. What percentage of batteries would you expect to fail before the warranty period expires?

b. A competitor is offering a warranty of 30 months on its premium battery. The manager of this company is toying with the idea of using the same battery with a different exterior, labeling it as a premium battery, and offering a 30-month warranty on it. How much more would the company have to charge on its "premium" battery to offset the additional cost of replacing batteries?
c. What other factors would you take into consideration besides the price of the battery?

Design element: Operations Tour (city map icon): tovovan/Shutterstock

CHAPTER 5

Strategic Capacity Planning for Products and Services

LEARNING OBJECTIVES

After completing this chapter, you should be able to:

LO5.1 Name the three key questions in capacity planning.

LO5.2 Explain the importance of capacity planning.

LO5.3 Describe ways of defining and measuring capacity.

LO5.4 Name several determinants of effective capacity.

LO5.5 Discuss factors to consider when deciding whether to perform in-house or outsource.

LO5.6 Discuss the major considerations related to developing capacity alternatives.

LO5.7 Describe the steps used to resolve constraint issues.

LO5.8 Briefly describe approaches that are useful for evaluating capacity alternatives.

CHAPTER OUTLINE

Mark Peterson/Redux

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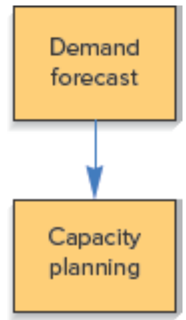
Capacity planning is a key strategic component in designing the system. It encompasses many basic decisions with long-term consequences for the organization. In this chapter, you will learn about the importance of capacity decisions, the measurement of capacity, how capacity requirements are determined, and the development and evaluation of capacity alternatives. Note that decisions made in the product or service design stage have major implications for capacity planning. Designs have processing requirements related to volume and degree of customization that affect capacity planning.



5.1 INTRODUCTION

Hospitals that not too long ago had what could be described as "facility oversupply" are now experiencing what might be called a "capacity crisis" in some areas. The way hospitals plan for capacity is critical to their future success. The same applies to all sorts of organizations, at all levels of these organizations. **Capacity** refers to an upper limit or ceiling on the load that an operating unit can handle. The load might be in terms of the number of physical units produced (e.g., bicycles assembled per hour) or the number of services performed (e.g., computers upgraded per hour). The operating unit might be a plant, department, machine, store, or worker. Capacity needs include equipment, space, and employee skills.

Capacity The upper limit or ceiling on the load that an operating unit can handle.

READING

EXCESS CAPACITY CAN BE BAD NEWS!

Today, huge gaps between supply and demand have many companies struggling. Excess capacity abounds in such major industries as telecom, airline, and auto manufacturing. The bad news is that some companies are losing millions of dollars a year because of this. In the telecom industry, the increasing reach of cellular technology and other kinds of wireless access is continuing to create more and more supply, requiring telecom companies to cut prices and offer incentives to increase demand.

As newer television models come onto the market, demand for older sets declines, leaving manufacturing companies that produce the older type of sets with excess capacity, and prices are greatly reduced.

Similarly, auto manufacturers have to reduce output or close factories for models where demand has fallen substantially (e.g., sedans being replaced by SUVs and pickup trucks).

The goal of strategic capacity planning is to achieve a match between the long-term supply capabilities of an organization and the predicted level of long-term demand. Organizations become involved in capacity planning for various reasons. Among the chief reasons are changes in demand, changes in technology, changes in the environment, and perceived threats or opportunities. A gap between current and desired capacity will result in capacity that is out of balance. Overcapacity (i.e., *excess* capacity) causes operating costs that are too high, while undercapacity (i.e., not enough capacity to meet demand) causes strained resources and a possible loss of customers.

LO5.1 Name the three key questions in capacity planning.

The key questions in capacity planning are the following:

1. What kind of capacity is needed?
2. How much is needed to match demand?
3. When is it needed?

The question of what kind of capacity is needed depends on the products and services that management intends to produce or provide. Hence, in a very real sense, capacity planning is governed by those choices.

Forecasts are key inputs used to answer the questions of how much capacity is needed and when is it needed.

Related questions include:

1. How much will it cost, how will it be funded, and what is the expected return?
2. What are the potential benefits and risks? These involve the degree of uncertainty related to forecasts of the amount of demand and the rate of change in demand, as well as costs, profits, and the time to implement capacity changes. The degree of accuracy that can be attached to forecasts is an important consideration. The likelihood and impact of wrong decisions also need to be assessed.

- Are there sustainability issues that need to be addressed?
- Should capacity be changed all at once, or through several (or more) small changes?
- Can the supply chain handle the necessary changes? Before an organization commits to ramping up its input, it is essential to confirm that its *supply chain* will be able to handle related requirements. And different issues occur for the supply chain when output decreases.

Because of uncertainties, some organizations prefer to delay capacity investment until demand materializes. However, such strategies often inhibit growth because adding capacity takes time and customers won't usually wait. Conversely, organizations that add capacity in anticipation of growth often discover that the new capacity actually attracts growth. Some organizations "hedge their bets" by making a series of small changes and then evaluating the results before committing to the next change.

In some instances, capacity choices are made very infrequently; in others, they are made regularly, as part of an ongoing process. Generally, the factors that influence this frequency are the stability of demand, the rate of technological change in equipment and product design, and competitive factors. Other factors relate to the type of product or service and whether style changes are important (e.g., automobiles and clothing). In any case, management must review product and service choices periodically to ensure that the company makes capacity changes when they are needed for cost, competitive effectiveness, or other reasons.

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5.2 CAPACITY DECISIONS ARE STRATEGIC

LO5.2
Explain the

importance of capacity planning.

For a number of reasons, capacity decisions are among the most fundamental of all the design decisions that managers must make. In fact, capacity decisions can be *critical* for an organization.

- Capacity decisions have a real impact on the ability of the organization to meet future demands for products and services; capacity essentially limits the rate of output possible. Having capacity to satisfy demand can often allow a company to take advantage of tremendous benefits. When Microsoft introduced its new Xbox, there were insufficient supplies, resulting in lost sales and unhappy customers. Similarly, shortages of flu vaccine in some years due to production problems affected capacity, limiting the availability of the vaccine.
- Capacity decisions affect operating costs. Ideally, capacity and demand requirements will be matched, which will tend to minimize operating costs. In practice, this is not always achieved because actual demand differs from expected demand or tends to vary (e.g., cyclically). In such cases, a decision might be made to attempt to balance the *costs* of over- and undercapacity.
- Capacity is usually a major determinant of initial cost. Typically, the greater the capacity of a productive unit, the greater its cost. This does not necessarily imply a one-for-one relationship; larger units tend to cost *proportionately* less than smaller units.
- Capacity decisions often involve a long-term commitment of resources, and once they are implemented, those decisions may be difficult or impossible to modify without incurring major costs.
- Capacity decisions can affect competitiveness. If a firm has excess capacity, or can quickly add capacity, that fact may serve as a barrier to entry by other firms. Then, too, capacity can affect *delivery speed,* which can be a competitive advantage.

- Capacity affects the ease of management; having appropriate capacity makes management easier than when capacity is mismatched.
- Globalization has increased the importance and the complexity of capacity decisions. Far-flung supply chains and distant markets add to the uncertainty about capacity needs.

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- Because capacity decisions often involve substantial financial and other resources, it is necessary to plan for them far in advance. For example, it may take years for a new power-generating plant to be constructed and become operational. However, this increases the risk that the designated amount of capacity will not match actual demand or reserve requirements when the capacity becomes available.

5.3 DEFINING AND MEASURING CAPACITY

LO5.3
Describe ways of defining and measuring capacity.

Capacity often refers to an upper limit on the *rate* of output. Even though this seems simple enough, there are subtle difficulties in actually measuring capacity in certain cases. These difficulties arise because of different interpretations of the term *capacity* and problems with identifying suitable measures for a specific situation.

In selecting a measure of capacity, it is important to choose one that does not require updating. For example, dollar amounts are often a poor measure of capacity (e.g., a capacity of $30 million a year), because price changes necessitate updating of that measure.

Where only one product or service is involved, the capacity of the productive unit may be expressed in terms of that item. However, when multiple products or services are involved, as is often the case, using a simple measure of capacity based on units of output can be misleading. An appliance manufacturer may produce both refrigerators and freezers. If the output rates for these two products are different, it would not make sense to simply state capacity in units without reference to either refrigerators or freezers. The problem is compounded if the firm has other products. One possible solution is to state capacities in terms of each product. Thus, the firm may be able to produce 100 refrigerators per day *or* 80 freezers per day. Sometimes this approach is helpful, sometimes not. For instance, if an organization has many different products or services, it may not be practical to list all of the relevant capacities. This is especially true if there are frequent changes in the mix of output, because this would necessitate a frequently changing composite index of capacity. The preferred alternative in such cases is to use a measure of capacity that refers to *availability of inputs.* Thus, a hospital has a certain number of beds, a factory has a certain number of machine hours available, and a bus has a certain number of seats and a certain amount of standing room.

No single measure of capacity will be appropriate in every situation. Rather, the measure of capacity must be tailored to the situation. Table 5.1 provides some examples of commonly used measures of capacity.

TABLE 5.1

Measures of capacity

Business	Inputs	Outputs
Auto manufacturing	Labor hours, machine hours	Number of cars per shift
Steel mill	Furnace size	Tons of steel per day
Oil refinery	Refinery size	Gallons of fuel per day
Farming	Number of acres, number of cows	Bushels of grain per acre per year, gallons of milk per day
Restaurant	Number of tables, seating capacity	Number of meals served per day
Theater	Number of seats	Number of tickets sold per performance

Business	Inputs	Outputs
Retail sales	Square feet of floor space	Revenue generated per day

Up to this point, we have been using a general definition of capacity. Although it is functional, it can be refined into two useful definitions of capacity:

- **Design capacity**: The maximum output rate or service capacity an operation, process, or facility is designed for.
- **Effective capacity**: Design capacity minus allowances such as personal time, and preventive maintenance.

Design capacity The maximum designed service capacity or output rate.

Effective capacity Design capacity minus allowances such as personal time, equipment maintenance, delays due to scheduling problems, and changing the mix of products.

Design capacity is the maximum rate of output achieved under ideal conditions. Effective capacity is always less than design capacity, owing to realities of changing product mix, the need for periodic maintenance of equipment, lunch breaks, coffee breaks, problems in scheduling and balancing operations, and similar circumstances. *Actual output* cannot exceed effective capacity and is often less because of machine breakdowns, absenteeism, shortages of materials, and quality problems, as well as factors that are outside the control of the operations managers.

These different measures of capacity are useful in defining two measures of system effectiveness: efficiency and utilization. *Efficiency* is the ratio of actual output to effective capacity. *Capacity utilization* is the ratio of actual output to design capacity.

$$\text{Efficiency} = \frac{\text{Actual output}}{\text{Effective capacity}} \times 100\% \qquad (5\text{–}1)$$

$$\text{Utilization} = \frac{\text{Actual output}}{\text{Design capacity}} \times 100\% \qquad (5\text{–}2)$$

Both measures are expressed as percentages.

It is not unusual for managers to focus exclusively on efficiency, but in many instances this emphasis can be misleading. This happens when effective capacity is low compared to design capacity. In those cases, high efficiency would seem to indicate an effective use of resources, when in fact it does not. The following example illustrates this point.

EXAMPLE 1

Computing Efficiency and Utilization

eXcel

mhhe.com/stevenson14e

Given the following information, compute the efficiency and the utilization of the vehicle repair department:

$$\begin{aligned} \text{Design capacity} &= 50 \text{ trucks per day} \\ \text{Effective capacity} &= 40 \text{ trucks per day} \\ \text{Actual output} &= 36 \text{ trucks per day} \end{aligned}$$

SOLUTION

$$\text{Efficiency} = \frac{\text{Actual output}}{\text{Effective capacity}} \times 100\% = \frac{36 \text{ trucks per day}}{40 \text{ trucks per day}} \times 100\% = 90\%$$

$$\text{Utilization} = \frac{\text{Actual output}}{\text{Design capacity}} \times 100\% = \frac{36 \text{ trucks per day}}{50 \text{ trucks per day}} \times 100\% = 72\%$$

Compared to the effective capacity of 40 units per day, 36 units per day looks pretty good. However, compared to the design capacity of 50 units per day, 36 units per day is much less impressive, although probably more meaningful.

Because effective capacity acts as a lid on actual output, the real key to improving capacity utilization is to increase effective capacity by correcting quality problems, maintaining equipment in good operating condition, fully training employees, and improving bottleneck operations that constrain output. Eliminating waste, which is a key aspect of lean operation (discussed in Chapter 14), can also help to improve effective capacity.

Hence, increasing utilization depends on being able to increase effective capacity, and this requires a knowledge of what is constraining effective capacity.

The following section explores some of the main determinants of effective capacity. It is important to recognize that the benefits of high utilization are realized only in instances where there is demand for the output. When demand is not there, focusing exclusively on utilization can be counterproductive, because the excess output not only results in additional variable costs but also generates the costs of having to carry the output as inventory. Another disadvantage of high utilization is that operating costs may increase because of increasing waiting time due to bottleneck conditions.

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5.4 DETERMINANTS OF EFFECTIVE CAPACITY

LO5.4 Name several determinants of effective capacity.

Many decisions about system design have an impact on capacity. The same is true for many operating decisions. This section briefly describes some of these factors, which are then elaborated on elsewhere in the book. The main factors relate to facilities, products or services, processes, human considerations, operational factors, the supply chain, and external forces.

Facilities The design of facilities, including size and provision for expansion, is key. Locational factors, such as transportation costs, distance to market, labor supply, energy sources, and room for expansion, are also important. Likewise, layout of the work area often determines how smoothly work can be performed, and environmental factors such as heating, lighting, and ventilation also play a significant role in determining whether personnel can perform effectively or whether they must struggle to overcome poor design characteristics.

Product and Service Factors Product or service design can have a tremendous influence on capacity. For example, when items are similar, the ability of the system to produce those items is generally much greater than when successive items differ. Thus, a restaurant that offers a limited menu can usually prepare and serve meals at a faster rate than a restaurant with an extensive menu. Generally speaking, the more uniform the output, the more opportunities there are for standardization of methods and materials, which leads to greater capacity. The particular mix of products or services rendered must also be considered, because different items will have different rates of output.

In only 48 hours, Solectron in San Jose, California, can build to order, ship, and install a complex computer system. Suppliers hold inventory until it is pulled, thereby increasing manufacturing flexibility.

Mark Richards/PhotoEdit

Making a violin requires precision and skill from an artisan. Capacity is highly limited when items are specialized and produced one at a time.

syolacan/Getty Images

Process Factors The quantity capability of a process is an obvious determinant of capacity. A more subtle determinant is the influence of output *quality.* For instance, if quality of output does not meet standards, the rate of output will be slowed by the need for inspection and rework activities. Productivity also affects capacity. Process improvements that increase quality and productivity can result in increased capacity. Also, if multiple products or multiple services are processed in batches, the time to change equipment settings must be taken into account.

Human Factors The tasks that make up a job, the variety of activities involved, and the training, skill, and experience required to perform a job all have an impact on the potential and actual output. In addition, employee motivation has a very basic relationship to capacity, as do absenteeism and labor turnover.

Policy Factors Management policy can affect capacity by allowing or not allowing capacity options such as overtime or second or third shifts.

Operational Factors Scheduling problems may occur when an organization has differences in equipment capabilities among alternative pieces of equipment or differences in job requirements. Inventory stocking decisions, late deliveries, purchasing requirements, acceptability of purchased materials and parts, and quality inspection and control procedures also can have an impact on effective capacity.

Inventory shortages of even one component of an assembled item (e.g., computers, refrigerators, automobiles) can cause a temporary halt to assembly operations until the components become available. This can have a major impact on effective capacity. Thus, insufficient capacity in one area can affect overall capacity.

Supply Chain Factors Supply chain factors must be taken into account in capacity planning if substantial capacity changes are involved. Key questions include: What impact will the changes have on suppliers, warehousing, transportation, and distributors? If capacity will be increased, will these elements of the supply chain be able to handle the increase? Conversely, if capacity is to be decreased, what impact will the loss of business have on these elements of the supply chain?

External Factors Product standards, especially minimum quality and performance standards, can restrict management's options for increasing and using capacity. Thus, pollution standards on products and equipment often reduce effective capacity, as does paperwork required by government regulatory agencies by engaging employees in nonproductive activities. A similar effect occurs when a union contract limits the number of hours and type of work an employee may do.

Table 5.2 summarizes these factors. In addition, *inadequate planning* can be a major limiting determinant of effective capacity.

TABLE 5.2

Factors that determine effective capacity

A. Facilities
  1. Design
  2. Location
  3. Layout
  4. Environment
B. Product/service
  1. Design
  2. Product or service mix
C. Process

1. Quantity capabilities
2. Quality capabilities

D. Human factors
   1. Job content
   2. Job design
   3. Training and experience
   4. Motivation
   5. Compensation
   6. Learning rates
   7. Absenteeism and labor turnover

E. Policy

F. Operational
   1. Scheduling
   2. Materials management
   3. Quality assurance
   4. Maintenance policies
   5. Equipment breakdowns

G. Supply chain

H. External factors
   1. Product standards
   2. Safety regulations
   3. Unions
   4. Pollution control standards

5.5 STRATEGY FORMULATION

The three primary strategies are leading, following, and tracking. A leading capacity strategy builds capacity in anticipation of future demand increases. If capacity increases involve a long lead time, this strategy may be the best option. A following strategy builds capacity when demand exceeds current capacity. A tracking strategy is similar to a following strategy, but it adds capacity in relatively small increments to keep pace with increasing demand.

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An organization typically bases its capacity strategy on assumptions and predictions about long-term demand patterns, technological changes, and the behavior of its competitors. These typically involve (1) the growth rate and variability of demand, (2) the costs of building and operating facilities of various sizes, (3) the rate and direction of technological innovation, (4) the likely behavior of competitors, and (5) availability of capital and other inputs.

In some instances, a decision may be made to incorporate a **capacity cushion**, which is an amount of capacity in excess of expected demand when there is some uncertainty about demand. Capacity cushion = capacity − expected demand. Typically, the greater the degree of demand uncertainty, the greater the amount of cushion used. Organizations that have standard products or services generally have smaller capacity cushions. Cost and competitive priorities are also key factors.

Capacity cushion Extra capacity used to offset demand uncertainty.

Steps in the Capacity Planning Process

1. Estimate future capacity requirements.
2. Evaluate existing capacity and facilities and identify gaps.
3. Identify alternatives for meeting requirements.
4. Conduct financial analyses of each alternative.
5. Assess key qualitative issues for each alternative.
6. Select the alternative to pursue that will be best in the long term.
7. Implement the selected alternative.

. Monitor results.

Capacity planning can be difficult at times due to the complex influence of market forces and technology.

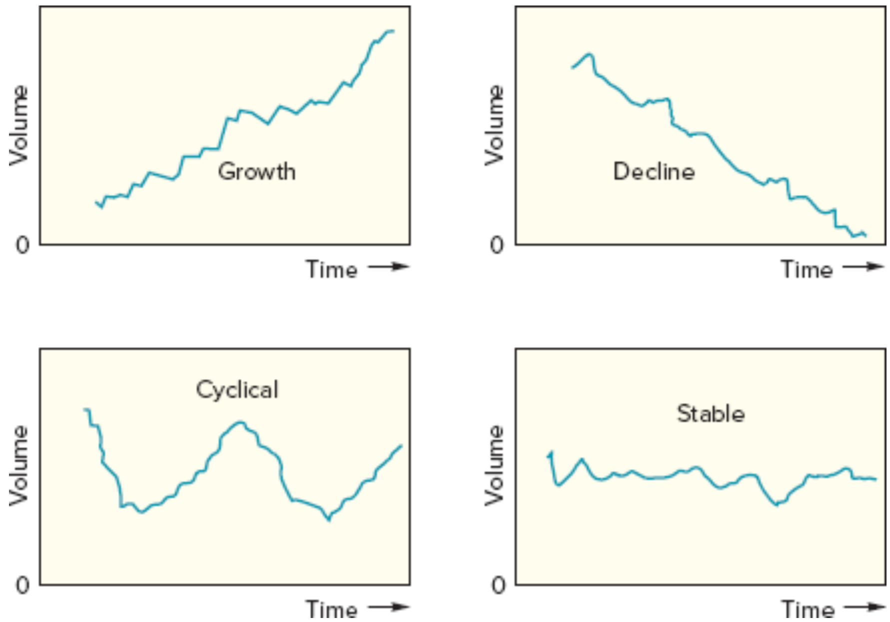
5.6 FORECASTING CAPACITY REQUIREMENTS

Capacity planning decisions involve both long-term and short-term considerations. Long-term considerations relate to overall *level* of capacity, such as facility size, whereas short-term considerations relate to probable *variations* in capacity requirements created by such things as seasonal, random, and irregular fluctuations in demand. Because the time intervals covered by each of these categories can vary significantly from industry to industry, it would be misleading to put times on the intervals. However, the distinction will serve as a framework within which to discuss capacity planning.

Long-term capacity needs require forecasting demand over a time horizon and then converting those forecasts into capacity requirements. Figure 5.1 illustrates some basic demand patterns that might be identified by a forecast. In addition to basic patterns, there are more complex patterns, such as a combination of cycles and trends.

FIGURE 5.1

Common demand patterns



When trends are identified, the fundamental issues are (1) how long the trend might persist, because few things last forever, and (2) the slope of the trend. If cycles are identified, interest focuses on (1) the approximate length of the cycles and (2) the amplitude of the cycles (i.e., deviation from average).

Short-term capacity needs are less concerned with cycles or trends than with seasonal variations and other variations from average. These deviations are particularly important because they can place a severe strain on a system's ability to satisfy demand at some times and yet result in idle capacity at other times.

An organization can identify seasonal patterns using standard forecasting techniques. Although commonly thought of as annual fluctuations, seasonal variations are also reflected in monthly, weekly, and even daily capacity requirements. Table 5.3 provides some examples of items that tend to exhibit seasonal demand patterns.

TABLE 5.3

Examples of seasonal demand patterns