TENTH EDITION

PRINCIPLES OF Operations Management

SUSTAINABILITY AND SUPPLY CHAIN MANAGEMENT

JAY HEIZER

BARRY RENDER

CHUCK MUNSON

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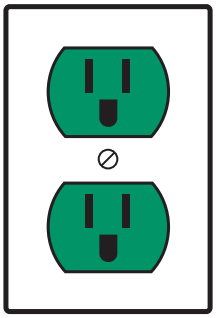

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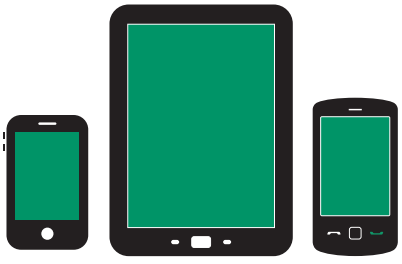

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PRINCIPLES OF OPERATIONS MANAGEMENT

Sustainability and Supply Chain Management

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PRINCIPLES OF OPERATIONS MANAGEMENT

Sustainability and Supply Chain Management

JAY
HEIZER
Jesse H. Jones Professor of Business Administration
Texas Lutheran University

BARRY
RENDER
Charles Harwood Professor of Operations Management
Graduate School of Business
Rollins College

CHUCK
MUNSON
Professor of Operations Management
Carson College of Business
Washington State University

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To Karen Heizer Herrmann, all a sister could ever be

J.H.

To Donna, Charlie, and Jesse

B.R.

To Kim, Christopher, and Mark Munson for their unwavering support, and to Bentonville High School teachers Velma Reed and Cheryl Gregory, who instilled in me the importance of detail and a love of learning

C.M.

ABOUT THE AUTHORS

JAY HEIZER

Professor Emeritus, the Jesse H. Jones Chair of Business Administration, Texas Lutheran University, Seguin, Texas. He received his B.B.A. and M.B.A. from the University of North Texas and his Ph.D. in Management and Statistics from Arizona State University. He was previously a member of the faculty at the University of Memphis, the University of Oklahoma, Virginia Commonwealth University, and the University of Richmond. He has also held visiting positions at Boston University, George Mason University, the Czech Management Center, and the Otto-Von-Guericke University, Magdeburg.

Dr. Heizer's industrial experience is extensive. He learned the practical side of operations management as a machinist apprentice at Foringer and Company, as a production planner for Westinghouse Airbrake, and at General Dynamics, where he worked in engineering administration. In addition, he has been actively involved in consulting in the OM and MIS areas for a variety of organizations, including Philip Morris, Firestone, Dixie Container Corporation, Columbia Industries, and Tenneco. He holds the CPIM certification from APICS—the Association for Operations Management.

Professor Heizer has co-authored 5 books and has published more than 30 articles on a variety of management topics. His papers have appeared in the *Academy of Management Journal*, *Journal of Purchasing*, *Personnel Psychology*, *Production & Inventory Control Management*, *APICS—The Performance Advantage*, *Journal of Management History*, *IIE Solutions,* and *Engineering Management*, among others. He has taught operations management courses in undergraduate, graduate, and executive programs.

BARRY RENDER

Professor Emeritus, the Charles Harwood Professor of Operations Management, Crummer Graduate School of Business, Rollins College, Winter Park, Florida. He received his B.S. in Mathematics and Physics at Roosevelt University, and his M.S. in Operations Research and Ph.D. in Quantitative Analysis at the University of Cincinnati. He previously taught at George Washington University, University of New Orleans, Boston University, and George Mason University, where he held the Mason Foundation Professorship in Decision Sciences and was Chair of the Decision Sciences Department. Dr. Render has also worked in the aerospace industry for General Electric, McDonnell Douglas, and NASA.

Professor Render has co-authored 10 textbooks for Pearson, including *Managerial Decision Modeling with Spreadsheets*, *Quantitative Analysis for Management*, *Service Management*, *Introduction to Management Science*, and *Cases and Readings in Management Science*. *Quantitative Analysis for Management,* now in its 13th edition, is a leading text in that discipline in the United States and globally. Dr. Render's more than 100 articles on a variety of management topics have appeared in *Decision Sciences*, *Production and Operations Management*, *Interfaces*, *Information and Management*, *Journal of Management Information Systems*, *Socio-Economic Planning Sciences*, *IIE Solutions*, and *Operations Management Review*, among others.

Dr. Render has been honored as an AACSB Fellow and was twice named a Senior Fulbright Scholar. He was Vice President of the Decision Science Institute Southeast Region and served as Software Review Editor for *Decision Line* for six years and as Editor of the *New York Times* Operations Management special issues for five years. For nine years, Dr. Render was President of Management Service Associates of Virginia, Inc., whose technology clients included the FBI, NASA, the U.S. Navy, Fairfax County, Virginia, and C&P Telephone. He is currently Consulting Editor to *Pearson Press*.

Dr. Render has received Rollins College's Welsh Award as leading Professor and was selected by Roosevelt University as the recipient of the St. Claire Drake Award for Outstanding Scholarship. Dr. Render also received the Rollins College MBA Student Award for Best Overall Course, and was named Professor of the Year by full-time MBA students.

CHUCK MUNSON

Professor of Operations Management, Carson College of Business, Washington State University, Pullman, Washington. He received his BSBA *summa cum laude* in finance, along with his MSBA and Ph.D. in operations management, from Washington University in St. Louis. For two years, he served as Associate Dean for Graduate Programs in Business at Washington State. He also worked for three years as a financial analyst for Contel Telephone Corporation.

Professor Munson serves as a senior editor for *Production and Operations Management*, and he serves on the editorial review board of four other journals. He has published more than 25 articles in such journals as *Production and Operations Management*, *IIE Transactions, Decision Sciences*, *Naval Research Logistics*, *European Journal of Operational Research*, *Journal of the Operational Research Society*, and *Annals of Operations Research.* He is editor of the book *The Supply Chain Management Casebook: Comprehensive Coverage and Best Practices in SCM*, and he has co-authored the research monograph *Quantity Discounts: An Overview and Practical Guide for Buyers and Sellers*. He is also coauthor of *Managerial Decision Modeling with Spreadsheets* (4th edition), published by Pearson.

Dr. Munson has taught operations management core and elective courses at the undergraduate, MBA, and Ph.D. levels at Washington State University. He has also conducted several teaching workshops at international conferences and for Ph.D. students at Washington State University. His major awards include being a Founding Board Member of the Washington State University President's Teaching Academy (2004); winning the WSU College of Business Outstanding Teaching Award (2001 and 2015), Research Award (2004), and Service Award (2009 and 2013); and being named the WSU MBA Professor of the Year (2000 and 2008).

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Brief Table of Contents

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Table of Contents

ONLINE TUTORIALS

Preface

Welcome to your operations management (OM) course. In this book, we present a state-of-the-art view of the operations function. Operations is an exciting area of management that has a profound effect on productivity. Indeed, few other activities have as much impact on the quality of our lives. The goal of this text is to present a broad introduction to the field of operations in a realistic, practical manner. Even if you are not planning on a career in the operations area, you will likely be working with people in operations. Therefore, having a solid understanding of the role of operations in an organization will be of substantial benefit to you. This book will also help you understand how OM affects society and your life. Certainly, you will better understand what goes on behind the scenes when you attend a concert or major sports event; purchase a bag of Frito-Lay potato chips; buy a meal at an Olive Garden or a Hard Rock Cafe; place an order through Amazon.com; board a flight on Alaska Airlines; or enter a hospital for medical care. More than one and a half million readers of our earlier editions seem to have endorsed this premise.

We welcome comments by email from our North American readers and from students using the International edition, the Indian edition, the Arabic edition, and our editions in Portuguese, Spanish, Turkish, Indonesian, and Chinese. Hopefully, you will find this material useful, interesting, and even exciting.

New to This Edition

We've made significant revisions to this edition, and want to share some of the changes with you.

Four New *Video Case Studies* Featuring Alaska Airlines

In this edition, we take you behind the scenes of Alaska Airlines, consistently rated as one of the top carriers in the country. This fascinating organization opened its doors—and planes—so we could examine leading edge OM in the airlines industry. We observe: the quality program at Alaska Air (Chapter 6); the process analysis behind the airline's 20-minute baggage retrieval guarantee (Chapter 7); how Alaska empowers its employees (Chapter 10); and the airline's use of Lean, 5s, kaizen, and Gemba walks (Chapter 16).

Our prior editions focused on integrated *Video Case Studies* for the Orlando Magic basketball team, Frito-Lay, Darden Restaurants, Hard Rock Cafe, Arnold Palmer Hospital, Wheeled Coach Ambulances, and Regal Marine. These *Video Case Studies* appear in this edition as well, along with the five new ones for Alaska Airlines. All of our videos are created by the authors, with the outstanding coauthorship of Beverly Amer at Northern Arizona University, to explicitly match with text content and terminology.

Alaska Airlines: 20-Minute Baggage Process—Guaranteed! Video Case

Alaska Airlines is unique among the nine major U.S. carriers not only for its extensive flight coverage of remote towns throughout Alaska (it also covers the U.S., Hawaii, and Mexico from its primary hub in Seattle). It is also one of the smallest independent airlines, with 10,300 employees, including 3,000 flight attendants and 1,500 pilots. What makes it really unique, though, is its ability to build state-of-the-art processes, using the latest technology, that yield high customer satisfaction. Indeed, J. D. Power and Associates has ranked Alaska Airlines highest in North America for seven years in a row for customer satisfaction.

Alaska Airlines was the first to sell tickets via the Internet, first to offer Web check-in and print boarding passes online, and first with kiosk check-in. As Wayne Newton, Director of System Operation Control, states, "We are passionate about our processes. If it's not measured, it's not managed."

One of the processes Alaska is most proud of is its baggage handling system. Passengers can check in at kiosks, tag their own bags with bar code stickers, and deliver them to a customer service agent at the carousel, which carries the bags through the vast underground system that eventually delivers the bags to a baggage handler. En route, each bag passes through TSA automated screening and is manually opened or inspected if it appears suspicious. With the help of bar code readers, conveyer belts automatically sort and transfer bags to their location (called a "pier") at the tarmac level. A baggage handler then loads the bags onto a cart and takes it to

Alaska Airlines

Creating Your Own Excel Spreadsheets

We continue to provide two free decision support software programs, Excel OM for Windows and Mac and POM for Windows, to help you and your students solve homework problems and case studies. These excellent packages are found in MyOMLab and at our text's Student Download Page.

Many instructors also encourage students to develop their own Excel spreadsheet models to tackle OM issues. With this edition, we provide numerous examples at chapter end on how to do so. "Creating Your Own Excel Spreadsheets" examples now appear in Chapters 1, 2, 4, 8, 12 (2 examples), and 13, Supplement 6, and Supplement 7. We hope these nine samples will help expand students' spreadsheet capabilities.

Using Software for Productivity Analysis

This section presents three ways to solve productivity problems with computer software. First, you can create your own Excel spreadsheets to conduct productivity analysis. Second, you can use the Excel OM software that comes with this text. Third, POM for Windows is another program that is available with this text.

CREATING YOUR OWN EXCEL SPREADSHEETS

Program 1.1 illustrates how to build an Excel spreadsheet for the data in Example 2.

	A	B	C	D	E
1	Collins Title Insurance Ltd.	Enter the values for the old system in column B and the new system in Column C.			
2	Productivity Increase Computations				
3					
4	Parameters	Old System	New System		
5	Length of Workday (hours)	8	8		
6	Number of Workers	4	4		
7	Labor Hours per Day	32	32	=C5*C6	
8	Payroll Cost per Day	$640	$640		
9	Overhead Expenses	$400	$800		
10	Output (Titles per Day)	8	14		
11		=B10/B7		Productivity = Output/Input	
12					
13	Solutions	Old System	New System	% Increase	
14	Labor Productivity (Titles per Labor-Hour)	0.25	0.4375	75.00%	
15	Multifactor Productivity (Titles per Dollar)	0.0077	0.0097	26.39%	
16		=C10/(C8+C9)		=(C14-B14)/B14	

Actions
Copy C7 to B7, Copy B14 to C14, Copy C15 to B15, and Copy D14 to D15

Create a row for each of the inputs used for the productivity measure. Put the output in the last row.

Program 1.1

USING EXCEL OM

Excel OM is an Excel "add-in" with 24 Operations Management decision support "Templates." To access the templates, double-click on the *Excel OM* tab at the top of the page, then in the menu bar choose the appropriate chapter (in this case Chapter 1), from either the "Chapter" or "Alphabetic" tab on the left. Each of Excel OM's 24 modules includes instructions for that particular module. The instructions can be turned on or off via the "instruction" tab in the menu bar.

USING POM FOR WINDOWS

POM for Windows is decision support software that includes 24 Operations Management modules. The modules are accessed by double-clicking on *Module* in the menu bar, and then double-clicking on the appropriate (in this case *Productivity*) item. Instructions are provided for each module just below the menu bar.

Expanding and Reordering Our Set of Homework Problems

We believe that a vast selection of quality homework problems, ranging from easy to challenging (denoted by one to four dots), is critical for both instructors and students. Instructors need a broad selection of problems to choose from for homework, quizzes, and exams—without reusing the same set from semester to semester. We take pride in having more problems—by far, with 618—than any other OM text. We added dozens of new problems this edition. The following table illustrates the selection by chapter.

Chapter	Number of Problems	Chapter	Number of Problems	Chapter	Number of Problems
1	18	Supplement 6	55	Supplement 11	20
2	12	7	17	12	53
3	33	Supplement 7	45	13	26
4	59	8	34	14	32
5	28	9	27	15	27
Supplement 5	19	10	46	16	12
6	21	11	8	17	24

Further, with the majority of our adopters now using the MyOMLab learning system in their classes, we have reorganized all the homework problems—both those appearing in the printed text, as well as the Additional Homework Problems that are available in MyOMLab—by topic heading. We are identifying all problems by topic (see the following example).

The list of all problems by topic also appears at the end of each boxed example, as well as in the Rapid Review that closes each chapter. These handy references should make it easier to assign problems for homework, quizzes, and exams. A rich set of assignable problems and cases makes the learning experience more complete and pedagogically sound.

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

Problems 5.4–5.8 relate to Product Development

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

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

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

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

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

Problems 5.9–5.17 relate to Defining a Product

•• **5.9** Prepare a bill of material for (a) a pair of eyeglasses and its case or (b) a fast-food sandwich (visit a local sandwich

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

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

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

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

•• **5.22** MacDonald Products, Inc., of Clarkson, New York, has the option of (a) proceeding immediately with production of

Jay, Barry, and Chuck's OM Blog

As a complement to this text, we have created a companion blog, with coordinated features to help teach the OM course. There are teaching tips, highlights of OM items in the news (along with class discussion questions and links), video tips, guest posts by instructors using our text, sample OM syllabi from dozens of colleges, and much more—all arranged by chapter. To learn more about any chapter topics, visit *www.heizerrenderOM.wordpress.com*. As you prepare your lectures and syllabus, scan our blog for discussion ideas, teaching tips, and classroom exercises.

Lean Operations

In previous editions, we sought to explicitly differentiate the concepts of just-in-time, Lean, and Toyota Production System in Chapter 16. However, there is significant overlap and interchangeability among those three concepts, so we have revised Chapter 16 to incorporate the three concepts into an overall concept of "Lean." The chapter suggests that students view Lean as a comprehensive integrated operations strategy that sustains competitive advantage and results in increased returns to all stakeholders.

Chapter-by-Chapter Changes

To highlight the extent of the revisions in this edition, here are a few of the changes, on a chapter-by-chapter basis.

Chapter 1: Operations and Productivity

We updated Table 1.4 to reflect employment in various sectors and expanded our discussion of Lean operations. Our new case, Uber Technologies, introduces productivity by discussing the disruptive nature of the Uber business model. In addition, there is a new "Creating Your Own Excel Spreadsheets" example for both labor productivity and multifactor productivity.

Chapter 2: Operations Strategy in a Global Environment

We have updated Figure 2.1 to better reflect changes in the growth of world trade and Figure 2.5 to reflect product life cycle changes. The Minute Lube case has been revised as Rapid Lube. Example 1 (National Architects) has been expanded to clarify factor rating calculations and is also demonstrated with a "Creating Your Own Excel Spreadsheets" presentation.

Chapter 3: Project Management

We rewrote and updated the Bechtel Global Company Profile and added a new section on well-defined projects with the "agile" and "waterfall" approaches. There are two new OM in Action boxes: "Agile Project Management at Mastek," and "Behind the Tour de France."

Chapter 4: Forecasting

We created a new table comparing the MAD, MSE, and MAPE forecasting error measures. There is also a new OM in Action box called "NYC's Potholes and Regression Analysis."

Chapter 5: Design of Goods and Services

We expanded our treatment of *concurrent engineering* and added two new discussion questions. Solved Problem 5.1 has been revised.

Supplement 5: Sustainability in the Supply Chain

We wrote a new introductory section on Corporate Social Responsibility. There is also a new OM in Action box called "Blue Jeans and Sustainability" and 10 new homework problems.

Chapter 6: Managing Quality

We added new material to expand our discussion of Taguchi's quality loss function. There is a new section on SERVQUAL, and a new video case study, "Quality Counts at Alaska Airlines," appears here.

Supplement 6: Statistical Process Control

We added a figure on the relationship between sample size and sampling distribution. We also added raw data to Examples S2 and S3 to illustrate how ranges are computed. There is a new Excel spreadsheet to show students how to make their own *c*-chart, and we have added three new homework problems.

Chapter 7: Process Strategy

We wrote a new section on machine technology and additive manufacturing. There are two new discussion questions and three new homework problems. Our second new video case study is called "Alaska Airlines: 20-Minute Baggage Process—Guaranteed!"

Supplement 7: Capacity and Constraint Management

We added a new Table S7.1, which compares and clarifies three capacity measurements, with an example of each. There is a new treatment of expected output and actual output in Example S2. The discussion of bottleneck time versus throughput time has also been expanded. Example S3, capacity analysis with parallel processes, has been revised. We have also added a new "Creating Your Own Excel Spreadsheets" example for a break-even model. Finally, we updated the Arnold Palmer Hospital capacity planning case with recent data.

Chapter 8: Location Strategies

We added two new OM in Action boxes: "Iowa—Home of Corn and Facebook" and "Denmark's Meat Cluster." We changed the notation for the center-of-gravity model to simplify the equation and provided a new "Creating Your Own Excel Spreadsheets" presentation for the center-of-gravity example.

Chapter 9: Layout Strategies

We created a new Muther grid for office relationship charting and added a spread of five layouts showing how offices have evolved over time. There is a new OM in Action box called "Amazon Lets Loose the Robots," and there is a new graphic example of Proplanner's Flow Path Calculator. We have included a formula for idle time as a second measure of balance assignment efficiency and added new technology issues to the Arnold Palmer Hospital video case.

Chapter 10: Human Resources, Job Design, and Work Measurement

We added a new OM in Action box, "The Missing Perfect Chair," and revised the Operations Chart as a service example. Our third new video case study is "The 'People' Focus: Human Resources at Alaska Airlines."

Chapter 11: Supply Chain Management

We added "outsourcing" as a supply chain risk in Table 11.3.

Supplement 11: Supply Chain Management Analytics

We added a major section on the topic of Warehouse Storage, with a new model for allocating inventory to storage locations. There is a new discussion question and three new homework problems.

Chapter 12: Inventory Management

New Programs 12.1 and 12.2 illustrate "Creating Your Own Excel Spreadsheets" for both the production run model and the single-period inventory model. The Excel function NORMSINV is introduced throughout the chapter. The Quantity Discount Model section is totally rewritten to illustrate the *feasible solution* shortcut. Solved Problem 12.5 is likewise redone with the new approach.

Chapter 13: Aggregate Planning and S&OP

We added a new OM in Action box, "Revenue Management Makes Disney the 'King' of the Broadway Jungle." We also provided a new "Creating Your Own Excel Spreadsheets" example for the transportation method for aggregate planning, using the Solver approach.

Chapter 14: Material Requirements Planning (MRP) and ERP

The MRP II example now includes greenhouse gasses.

Chapter 15: Short-Term Scheduling

We begin this chapter with a new Global Company Profile featuring Alaska Airlines and the scheduling issues it faces in its northern climate. We have added two new graphics to help illustrate Forward and Backward Scheduling. There is also a new section called Performance Criteria, detailing how the choice of priority rule depends on four quantifiable criteria. We now explicitly define the performance criteria for sequencing jobs as separate numbered equations. Also, we provide an explicit formula for job lateness. There is a new OM in Action box called "Starbucks' Controversial Scheduling Software."

Chapter 16: Lean Operations

This chapter saw a major reorganization and rewrite with an enhanced focus on Lean operations. There is more material on supplier partnerships and building lean organizations. A new OM in Action box describes the use of kaizen at San Francisco General Hospital, and we have added a new video case study called "Lean Operations at Alaska Airlines."

Chapter 17: Maintenance and Reliability

There are no major changes in this chapter.

Student Resources

To liven up the course and help students learn the content material, we have made available the following resources:

- *Forty-one exciting Video Case Studies (videos located at MyOMLab):* These *Video Case Studies* feature real companies (Alaska Airlines, The Orlando Magic, Frito-Lay, Darden Restaurants, Regal Marine, Hard Rock Cafe, Ritz-Carlton, Wheeled Coach, and Arnold Palmer Hospital) and allow students to watch short videos, read about the key topics, and answer questions. These case studies can also be assigned without using class time to show the videos. Each of them was developed and written by the text authors to specifically supplement the book's content. Instructors who wish to use these in class, and who don't have access to MyOMLab, should contact their Pearson Publishing Representative for access to the MyOMLab materials.
- *POM for Windows software (located at MyOMLab and at the Student Download Page, www.pearsonhighered.com/heizer):* POM for Windows is a powerful tool for easily solving OM problems. Its 24 modules can be used to solve most of the homework problems in the text.
- *Excel OM problem-solving software (located at MyOMLab and at the Student Download Page, www.pearsonhighered.com/heizer):* Excel OM is our exclusive user-friendly Excel add-in. Excel OM automatically creates worksheets to model and solve problems. Users select a topic from the pull-down menu and fill in the data, and then Excel will display and graph (where appropriate) the results. This software is great for student homework, what-if analysis, and classroom demonstrations. This edition includes a new version of Excel OM that is compatible with Microsoft Excel 2013 for Windows, Excel 2011 and 2016 for Mac, and earlier versions of Excel. Professor Howard Weiss, Temple University, developed both Excel OM for Windows and Mac, and POM for Windows to accompany our text and its problem set.
- *Excel OM data files (located at MyOMLab and at the Student Download Page, www.pearsonhighered.com/heizer):* These data files are prepared for specific examples and allow users to solve all the marked text examples without reentering any data.
- *Active Models (located at MyOMLab and at the Student Download Page, www.pearsonhighered.com/heizer):* These 28 Active Models are Excel-based OM simulations, designed to help students understand the quantitative methods shown in the textbook examples. Students may change the data in order to see how the changes affect the answers.

- *Virtual tours (located at MyOMLab):* These company tours provide direct links to companies—ranging from a hospital to an auto manufacturer—that practice key OM concepts. After touring each Web site, students are asked questions directly related to the concepts discussed in the chapter.
- *Online Tutorial Chapters (located at MyOMLab and at the Student Download Page, www.pearsonhighered.com/heizer):* "Statistical Tools for Managers," "Acceptance Sampling," "The Simplex Method of Linear Programming," "The MODI and VAM Methods of Solving Transportation Problems," and "Vehicle Routing and Scheduling" are provided as additional material.
- *Additional practice problems (located at MyOMLab):* These problems provide problem-solving experience. They supplement the examples and solved problems found in each chapter.
- *Additional case studies (located at MyOMLab and at the Student Download Page, www.pearsonhighered.com/heizer):* Over two dozen additional case studies supplement the ones in the text. Detailed solutions appear in the Solutions Manual.
- *Virtual office hours (located at MyOMLab):* Professors Heizer, Render, and Munson walk students through all 73 Solved Problems in a series of 5- to 20-minute explanations. These have been updated with this new edition.

Instructor Resources

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

The following supplements are available with this text:

Instructor's Resource Manual

The Instructor's Resource Manual, updated by co-author Chuck Munson, contains many useful resources for instructors—PowerPoint presentations with annotated notes, course outlines, video notes, blog highlights, learning techniques, Internet exercises and sample answers, case analysis ideas, additional teaching resources, and faculty notes.

Instructor's Solutions Manual

The Instructor's Solutions Manual, written by the authors, contains the answers to all of the discussion questions, *Ethical Dilemmas*, Active Models, and cases in the text, as well as worked-out solutions to all the end-of-chapter problems, additional homework problems, and additional case studies.

PowerPoint Presentations

An extensive set of PowerPoint presentations, created by Professor Jeff Heyl of Lincoln University, is available for each chapter. With well over 2,000 slides, this set has excellent color and clarity.

Test Bank/TestGen® Computerized Test Bank

The test bank, updated by James Roh, contains a variety of true/false, multiple-choice, short-answer, and essay questions, along with a selection of written problems, for each chapter. Test questions are annotated with the following information:

- Difficulty level
- Type: multiple-choice, true/false, short-answer, essay, problem
- Learning objective
- AACSB (see the description that follows)

TestGen®, Pearson Education's test-generating software, is PC/MAC compatible and preloaded with all the test bank questions. The test program permits instructors to edit, add, and delete questions from the test bank to create customized tests.

AACSB

The Association to Advance Collegiate Schools of Business (AACSB)

The test bank has connected select questions to the general knowledge and skill guidelines found in the AACSB Assurance of Learning standards.

AACSB is a not-for-profit corporation of educational institutions, corporations, and other organizations devoted to the promotion and improvement of higher education in business administration and accounting. A collegiate institution offering degrees in business administration or accounting may volunteer for AACSB accreditation review. The AACSB makes initial accreditation decisions and conducts periodic reviews to promote continuous quality improvement in management education. Pearson Education is a proud member of the AACSB and is pleased to provide advice to help you apply AACSB assurance of learning standards.

What are AACSB assurance of learning standards? One of the criteria for AACSB accreditation is quality of the curricula. Although no specific courses are required, the AACSB expects a curriculum to include learning experiences in the following areas:

- Written and oral communication
- Ethical understanding and reasoning
- Analytical thinking
- Information technology
- Interpersonal relations and teamwork
- Diverse and multicultural work environments
- Reflective thinking
- Application of knowledge

Questions that test skills relevant to these guidelines are appropriately tagged. For example, a question regarding clothing manufactured for U.S. firms by 10-year olds in Asia would receive the Ethical understanding and reasoning tag.

Tagged questions help you measure whether students are grasping the course content that aligns with the AACSB guidelines noted. In addition, the tagged questions may help instructors identify potential applications of these skills. This in turn may suggest enrichment activities or other educational experiences to help students achieve these skills.

Video Package

Designed and created by the authors specifically for their Heizer/Render/Munson texts, the video package contains the following 41 videos:

- Frito-Lay: Operations Management in Manufacturing (Chapter 1)
- Hard Rock Cafe: Operations Management in Services (Chapter 1)
- Strategy at Regal Marine (Chapter 2)
- Hard Rock Cafe's Global Strategy (Chapter 2)
- Outsourcing Offshore at Darden (Chapter 2)
- Project Management at Arnold Palmer Hospital (Chapter 3)
- Managing Hard Rock's Rockfest (Chapter 3)
- Forecasting Ticket Revenue for Orlando Magic Basketball Games (Chapter 4)
- Forecasting at Hard Rock Cafe (Chapter 4)
- Product Design at Regal Marine (Chapter 5)
- Building Sustainability at the Orlando Magic's Amway Center (Supplement 5)
- Green Manufacturing and Sustainability at Frito-Lay (Supplement 5)
- Quality Counts at Alaska Airlines (Chapter 6)
- The Culture of Quality at Arnold Palmer Hospital (Chapter 6)
- Quality at the Ritz-Carlton Hotel Company (Chapter 6)
- Frito-Lay's Quality-Controlled Potato Chips (Supplement 6)

- Farm to Fork: Quality at Darden Restaurants (Supplement 6)
- Alaska Airlines: 20-Minute Baggage Process—Guaranteed! (Chapter 7)
- Process Strategy at Wheeled Coach (Chapter 7)
- Process Analysis at Arnold Palmer Hospital (Chapter 7)
- Capacity Planning at Arnold Palmer Hospital (Supplement 7)
- Locating the Next Red Lobster Restaurant (Chapter 8)
- Where to Place the Hard Rock Cafe (Chapter 8)
- Facility Layout at Wheeled Coach (Chapter 9)
- Laying Out Arnold Palmer Hospital's New Facility (Chapter 9)
- The "People" Focus: Human Resources at Alaska Airlines (Chapter 10)
- Hard Rock's Human Resource Strategy (Chapter 10)
- Darden's Global Supply Chains (Chapter 11)
- Supply Chain Management at Regal Marine (Chapter 11)
- Arnold Palmer Hospital's Supply Chain (Chapter 11)
- Managing Inventory at Frito-Lay (Chapter 12)
- Inventory Control at Wheeled Coach (Chapter 12)
- Using Revenue Management to Set Orlando Magic Ticket Prices (Chapter 13)
- When 18,500 Orlando Magic Fans Come to Dinner (Chapter 14)
- MRP at Wheeled Coach (Chapter 14)
- From the Eagles to the Magic: Converting the Amway Center (Chapter 15)
- Scheduling at Hard Rock Cafe (Chapter 15)
- Lean Operations at Alaska Airlines (Chapter 16)
- JIT at Arnold Palmer Hospital (Chapter 16)
- Maintenance Drives Profits at Frito-Lay (Chapter 17)

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California State University–Hayward

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San Francisco State University

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Colorado State University–Pueblo

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University of Colorado at Colorado Springs

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David Cadden
Quinnipiac University

Larry A. Flick
Norwalk Community Technical College

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Joseph P. Geunes
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Rita Gibson
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Jim Gilbert
Rollins College

Donald Hammond
University of South Florida

Wende Huehn-Brown
St. Petersburg College

Adam Munson
University of Florida

Ronald K. Satterfield
University of South Florida

Theresa A. Shotwell
Florida A&M University

Jeff Smith
Florida State University

GEORGIA

John H. Blackstone
University of Georgia

Johnny Ho
Columbus State University

John Hoft
Columbus State University

John Miller
Mercer University

Nikolay Osadchiy
Emory University

Spyros Reveliotis
Georgia Institute of Technology

ILLINOIS

Suad Alwan
Chicago State University

Lori Cook
DePaul University

Matt Liontine
University of Illinois–Chicago

Zafar Malik
Governors State University

INDIANA

Barbara Flynn
Indiana University

B.P. Lingeraj
Indiana University

Frank Pianki
Anderson University

Stan Stockton
Indiana University

Jerry Wei
University of Notre Dame

Jianghua Wu
Purdue University

Xin Zhai
Purdue University

IOWA

Debra Bishop
Drake University

Kevin Watson
Iowa State University

Lifang Wu
University of Iowa

KANSAS

William Barnes
Emporia State University

George Heinrich
Wichita State University

Sue Helms
Wichita State University

Hugh Leach
Washburn University

M.J. Riley
Kansas State University

Teresita S. Salinas
Washburn University

Avanti P. Sethi
Wichita State University

KENTUCKY

Wade Ferguson
Western Kentucky University

Kambiz Tabibzadeh
Eastern Kentucky University

LOUISIANA

Roy Clinton
University of Louisiana at Monroe

L. Wayne Shell (retired)
Nicholls State University

MARYLAND

Eugene Hahn
Salisbury University

Samuel Y. Smith, Jr.
University of Baltimore

MASSACHUSETTS

Peter Ittig
University of Massachusetts

Jean Pierre Kuilboer
University of Massachusetts–Boston

Dave Lewis
University of Massachusetts–Lowell

Mike Maggard (retired)
Northeastern University

Peter Rourke
Wentworth Institute of Technology

Daniel Shimshak
University of Massachusetts–Boston

Ernest Silver
Curry College

Yu Amy Xia
Northeastern University

MICHIGAN

Darlene Burk
Western Michigan University

Damodar Golhar
Western Michigan University

Dana Johnson
Michigan Technological University

Doug Moodie
Michigan Technological University

MINNESOTA

Rick Carlson
Metropolitan State University

John Nicolay
University of Minnesota

Michael Pesch
St. Cloud State University

Manus Rungtusanatham
University of Minnesota

Kingshuk Sinha
University of Minnesota

Peter Southard
University of St. Thomas

MISSOURI

Shahid Ali
Rockhurst University

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Truman State University

Sema Alptekin
University of Missouri–Rolla

Gregory L. Bier
University of Missouri–Columbia

James Campbell
University of Missouri–St. Louis

Wooseung Jang
University of Missouri–Columbia

Mary Marrs
University of Missouri–Columbia

A. Lawrence Summers
University of Missouri

NEBRASKA

Zialu Hug
University of Nebraska–Omaha

NEVADA

Joel D. Wisner
University of Nevada, Las Vegas

NEW JERSEY

Daniel Ball
Monmouth University

Leon Bazil
Stevens Institute of Technology

Mark Berenson
Montclair State University

Grace Greenberg
Rider University

Joao Neves
The College of New Jersey

Leonard Presby
William Paterson University

Faye Zhu
Rowan University

NEW MEXICO

William Kime
University of New Mexico

NEW YORK

Theodore Boreki
Hofstra University

John Drabouski
DeVry University

Richard E. Dulski
Daemen College

Jonatan Jelen
Baruch College

Beate Klingenberg
Marist College

Donna Mosier
SUNY Potsdam

Elizabeth Perry
SUNY Binghamton

William Reisel
St. John's University

Kaushik Sengupta
Hofstra University

Girish Shambu
Canisius College

Rajendra Tibrewala
New York Institute of Technology

NORTH CAROLINA

Coleman R. Rich
Elon University

Ray Walters
Fayetteville Technical Community College

OHIO

Victor Berardi
Kent State University

Andrew R. Thomas
University of Akron

OKLAHOMA

Wen-Chyuan Chiang
University of Tulsa

OREGON

Anne Deidrich
Warner Pacific College

Gordon Miller
Portland State University

John Sloan
Oregon State University

PENNSYLVANIA

Henry Crouch
Pittsburgh State University

Jeffrey D. Heim
Pennsylvania State University

James F. Kimpel
University of Pittsburgh

Ian M. Langella
Shippensburg University

Prafulla Oglekar
LaSalle University

David Pentico
Duquesne University

Stanford Rosenberg
LaRoche College

Edward Rosenthal
Temple University

Susan Sherer
Lehigh University

Howard Weiss
Temple University

RHODE ISLAND

Laurie E. Macdonald
Bryant College

John Swearingen
Bryant College

Susan Sweeney
Providence College

SOUTH CAROLINA

Jerry K. Bilbrey
Anderson University

Larry LaForge
Clemson University

Emma Jane Riddle
Winthrop University

TENNESSEE

Joseph Blackburn
Vanderbilt University

Hugh Daniel
Lipscomb University

Cliff Welborn
Middle Tennessee State University

TEXAS

Warren W. Fisher
Stephen F. Austin State University

Garland Hunnicutt
Texas State University

Gregg Lattier
Lee College

Henry S. Maddux III
Sam Houston State University

Arunachalam Narayanan
Texas A&M University

Ranga V. Ramasesh
Texas Christian University

Victor Sower
San Houston State University

Cecelia Temponi
Texas State University

John Visich-Disc
University of Houston

Dwayne Whitten
Texas A&M University

Bruce M. Woodworth
University of Texas–El Paso

UTAH

William Christensen
Dixie State College of Utah

Shane J. Schvaneveldt
Weber State University

Madeline Thimmes (retired)
Utah State University

VIRGINIA

Andy Litteral
University of Richmond

Arthur C. Meiners, Jr.
Marymount University

Michael Plumb
Tidewater Community College

WASHINGTON

Mark McKay
University of Washington

Chris Sandvig
Western Washington University

John Stec
Oregon Institute of Technology

WASHINGTON, DC

Narendrea K. Rustagi
Howard University

WEST VIRGINIA

Charles Englehardt
Salem International University

Daesung Ha
Marshall University

John Harpell
West Virginia University

James S. Hawkes
University of Charleston

WISCONSIN

James R. Gross
University of Wisconsin–Oshkosh

Marilyn K. Hart (retired)
University of Wisconsin–Oshkosh

Niranjan Pati
University of Wisconsin–La Crosse

X. M. Safford
Milwaukee Area Technical College

Rao J. Taikonda
University of Wisconsin–Oshkosh

WYOMING

Cliff Asay
University of Wyoming

INTERNATIONAL

Steven Harrod
Technical University of Denmark

Robert D. Klassen
University of Western Ontario

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Hong Kong University of Science and Technology

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We wish you a pleasant and productive introduction to operations management.

JAY HEIZER
Texas Lutheran University
1000 W. Court Street
Seguin, TX 78155
Email: jheizer@tlu.edu

BARRY RENDER
Graduate School of Business
Rollins College
Winter Park, FL 32789
Email: brender@rollins.edu

CHUCK MUNSON
Carson College of Business
Washington State University
Pullman, WA 99164-4746
Email: munson@wsu.edu

TWO VERSIONS ARE AVAILABLE

This text is available in two versions: *Operations Management*, 12th edition, a hardcover, and *Principles of Operations Management*, 10th edition, a paperback. Both books include the identical core Chapters 1–17. However, *Operations Management*, 12th edition also includes six business analytics modules in Part IV.

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3. Project Management
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5. Design of Goods and Services
S5. Sustainability in the Supply Chain
6. Managing Quality
S6. Statistical Process Control
7. Process Strategy
S7. Capacity and Constraint Management
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PRINCIPLES OF OPERATIONS MANAGEMENT

Sustainability and Supply Chain Management

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Operations and Productivity

CHAPTER 1

CHAPTER OUTLINE

GLOBAL COMPANY PROFILE: *Hard Rock Cafe*

Alaska Airlines

10 OM STRATEGY DECISIONS

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

GLOBAL COMPANY PROFILE
Hard Rock Cafe

Operations Management at Hard Rock Cafe

Operations managers throughout the world are producing products every day to provide for the well-being of society. These products take on a multitude of forms. They may be washing machines at Whirlpool, motion pictures at DreamWorks, rides at Disney World, or food at Hard Rock Cafe. These firms produce thousands of complex products every day—to be delivered as the customer ordered them, when the customer wants them, and where the customer wants them. Hard Rock does this for over 35 million guests worldwide every year. This is a challenging task, and the operations manager's job, whether at Whirlpool, DreamWorks, Disney, or Hard Rock, is demanding.

Andre Jenny/Alamy

Hard Rock Cafe in Orlando, Florida, prepares over 3,500 meals each day. Seating more than 1,500 people, it is one of the largest restaurants in the world. But Hard Rock's operations managers serve the hot food hot and the cold food cold.

Demetrio Carrasco/Rough Guides/Dorling Kindersley, Ltd.

Operations managers are interested in the attractiveness of the layout, but they must be sure that the facility contributes to the efficient movement of people and material with the necessary controls to ensure that proper portions are served.

Presselect/Alamy

Lots of work goes into designing, testing, and costing meals. Then suppliers deliver quality products on time, every time, for well-trained cooks to prepare quality meals. But none of that matters unless an enthusiastic waitstaff, such as the one shown here, holding guitars previously owned by members of U2, is doing its job.

Efficient kitchen layouts, motivated personnel, tight schedules, and the right ingredients at the right place at the right time are required to delight the customer.

Jack Picone/Alamy

Orlando-based Hard Rock Cafe opened its first restaurant in London in 1971, making it over 45 years old and the granddaddy of theme restaurants. Although other theme restaurants have come and gone, Hard Rock is still going strong, with 150 restaurants in more than 53 countries—and new restaurants opening each year. Hard Rock made its name with rock music memorabilia, having started when Eric Clapton, a regular customer, marked his favorite bar stool by hanging his guitar on the wall in the London cafe. Now Hard Rock has 70,000 items and millions of dollars invested in memorabilia. To keep customers coming back time and again, Hard Rock creates value in the form of good food and entertainment.

The operations managers at Hard Rock Cafe at Universal Studios in Orlando provide more than 3,500 custom products—in this case meals—every day. These products are designed, tested, and then analyzed for cost of ingredients, labor requirements, and customer satisfaction. On approval, menu items are put into production—and then only if the ingredients are available from qualified suppliers. The production process, from receiving, to cold storage, to grilling or baking or frying, and a dozen other steps, is designed and maintained to yield a quality meal. Operations managers, using the best people they can recruit and train, also prepare effective employee schedules and design efficient layouts.

Managers who successfully design and deliver goods and services throughout the world understand operations. In this text, we look not only at how Hard Rock's managers create value but also how operations managers in other services, as well as in manufacturing, do so. Operations management is demanding, challenging, and exciting. It affects our lives every day. Ultimately, operations managers determine how well we live.

LEARNING OBJECTIVES

STUDENT TIP Let's begin by defining what this course is about.

What Is Operations Management?

LO 1.1 *Define* operations management

Operations management (OM) is a discipline that applies to restaurants like Hard Rock Cafe as well as to factories like Ford and Whirlpool. The techniques of OM apply throughout the world to virtually all productive enterprises. It doesn't matter if the application is in an office, a hospital, a restaurant, a department store, or a factory—the production of goods and services requires operations management. And the *efficient* production of goods and services requires effective applications of the concepts, tools, and techniques of OM that we introduce in this book.

As we progress through this text, we will discover how to manage operations in an economy in which both customers and suppliers are located throughout the world. An array of informative examples, charts, text discussions, and pictures illustrates concepts and provides information. We will see how operations managers create the goods and services that enrich our lives.

VIDEO 1.1 Operations Management at Hard Rock

VIDEO 1.2 Operations Management at Frito-Lay

In this chapter, we first define *operations management*, explaining its heritage and exploring the exciting role operations managers play in a huge variety of organizations. Then we discuss production and productivity in both goods- and service-producing firms. This is followed by a discussion of operations in the service sector and the challenge of managing an effective and efficient production system.

Production The creation of goods and services.

Operations management (OM) Activities that relate to the creation of goods and services through the transformation of inputs to outputs.

Production is the creation of goods and services. **Operations management (OM)** is the set of activities that creates value in the form of goods and services by transforming inputs into outputs. Activities creating goods and services take place in all organizations. In manufacturing firms, the production activities that create goods are usually quite obvious. In them, we can see the creation of a tangible product such as a Sony TV or a Harley-Davidson motorcycle.

In an organization that does not create a tangible good or product, the production function may be less obvious. We often call these activities *services*. The services may be "hidden" from the public and even from the customer. The product may take such forms as the transfer of funds from a savings account to a checking account, the transplant of a liver, the filling of an empty seat on an airplane, or the education of a student. Regardless of whether the end product is a good or service, the production activities that go on in the organization are often referred to as operations, or *operations management*.

STUDENT TIP Operations is one of the three functions that every organization performs.

Organizing to Produce Goods and Services

To create goods and services, all organizations perform three functions (see Figure 1.1). These functions are the necessary ingredients not only for production but also for an organization's survival. They are:

1. *Marketing*, which generates the demand, or at least takes the order for a product or service (nothing happens until there is a sale).
2. *Production/operations*, which creates, produces, and delivers the product.
3. *Finance/accounting*, which tracks how well the organization is doing, pays the bills, and collects the money.

Universities, churches or synagogues, and businesses all perform these functions. Even a volunteer group such as the Boy Scouts of America is organized to perform these three basic

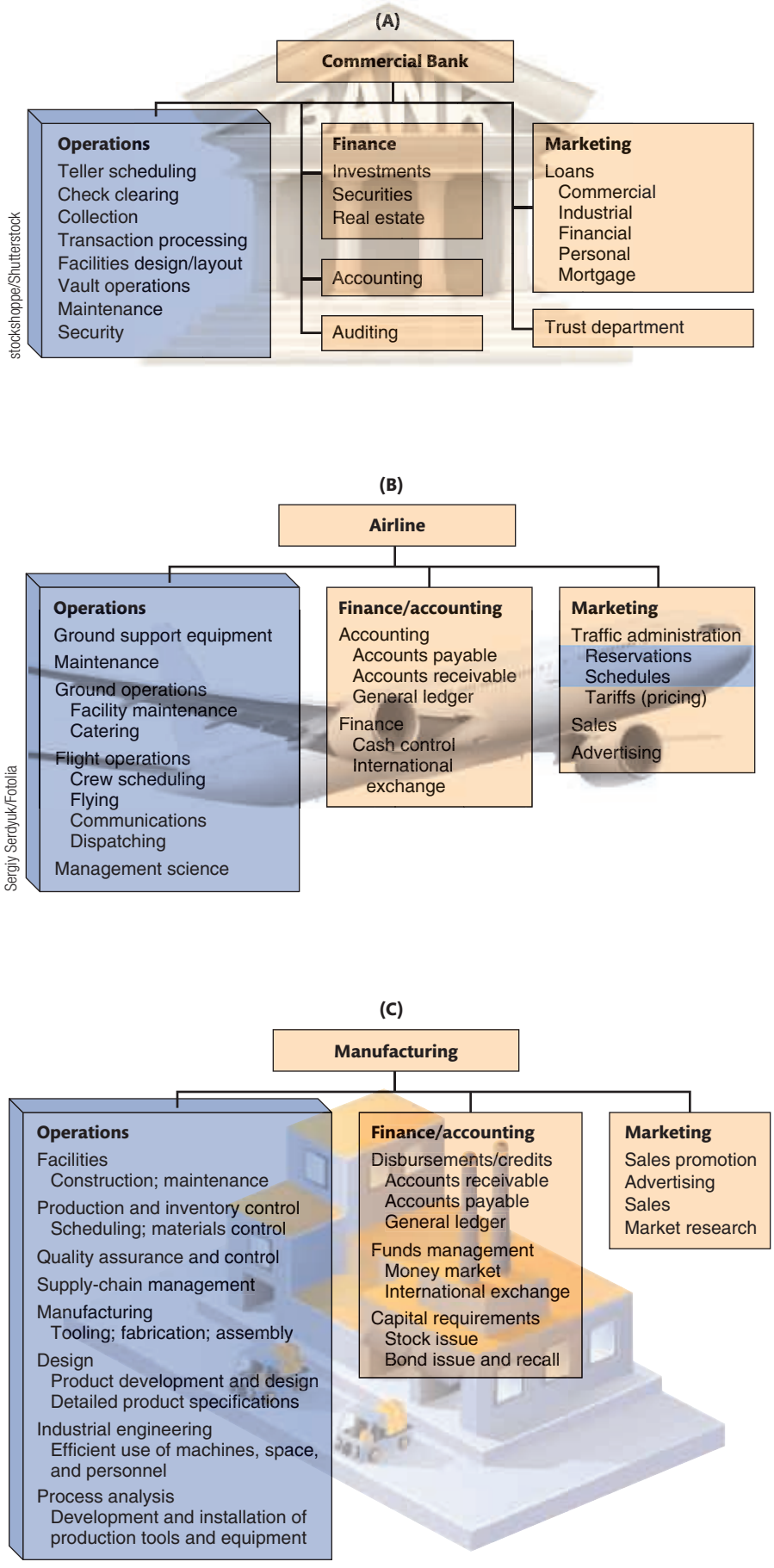

Figure **1.1**

Organization Charts for Two Service Organizations and One Manufacturing Organization

(A) a bank, (B) an airline, and (C) a manufacturing organization. The blue areas are OM activities.

STUDENT TIP

The areas in blue indicate the significant role that OM plays in both manufacturing and service firms.

Figure 1.2

Soft Drink Supply Chain

A supply chain for a bottle of Coke requires a beet or sugar cane farmer, a syrup producer, a bottler, a distributor, and a retailer, each adding value to satisfy a customer. Only with collaborations between all members of the supply chain can efficiency and customer satisfaction be maximized. The supply chain, in general, starts with the provider of basic raw materials and continues all the way to the final customer at the retail store.

functions. Figure 1.1 shows how a bank, an airline, and a manufacturing firm organize themselves to perform these functions. The blue-shaded areas show the operations functions in these firms.

The Supply Chain

Supply chain
A global network of organizations and activities that supplies a firm with goods and services.

Through the three functions—marketing, operations, and finance—value for the customer is created. However, firms seldom create this value by themselves. Instead, they rely on a variety of suppliers who provide everything from raw materials to accounting services. These suppliers, when taken together, can be thought of as a *supply chain.* A **supply chain** (see Figure 1.2) is a global network of organizations and activities that supply a firm with goods and services.

As our society becomes more technologically oriented, we see increasing specialization. Specialized expert knowledge, instant communication, and cheaper transportation also foster specialization and worldwide supply chains. It just does not pay for a firm to try to do everything itself. The expertise that comes with specialization exists up and down the supply chain, adding value at each step. When members of the supply chain collaborate to achieve high levels of customer satisfaction, we have a tremendous force for efficiency and competitive advantage. Competition in the 21st century is not between companies; it is between *supply chains.*

STUDENT TIP
Good OM managers are scarce and, as a result, career opportunities and pay are excellent.

Why Study OM?

We study OM for four reasons:

1. OM is one of the three major functions of any organization, and it is integrally related to all the other business functions. All organizations market (sell), finance (account), and produce (operate), and it is important to know how the OM activity functions. Therefore, we study *how people organize themselves for productive enterprise*.
2. We study OM because we want to know *how goods and services are produced*. The production function is the segment of our society that creates the products and services we use.
3. We study OM to *understand what operations managers do*. Regardless of your job in an organization, you can perform better if you understand what operations managers do. In addition, understanding OM will help you explore the numerous and lucrative career opportunities in the field.
4. We study OM *because it is such a costly part of an organization*. A large percentage of the revenue of most firms is spent in the OM function. Indeed, OM provides a major opportunity for an organization to improve its profitability and enhance its service to society. Example 1 considers how a firm might increase its profitability via the production function.

Example 1

EXAMINING THE OPTIONS FOR INCREASING CONTRIBUTION

Fisher Technologies is a small firm that must double its dollar contribution to fixed cost and profit in order to be profitable enough to purchase the next generation of production equipment. Management has determined that if the firm fails to increase contribution, its bank will not make the loan and the equipment cannot be purchased. If the firm cannot purchase the equipment, the limitations of the old equipment will force Fisher to go out of business and, in doing so, put its employees out of work and discontinue producing goods and services for its customers.

APPROACH ► Table 1.1 shows a simple profit-and-loss statement and three strategic options (marketing, finance/accounting, and operations) for the firm. The first option is a *marketing option*, where excellent marketing management may increase sales by 50%. By increasing sales by 50%, contribution will in turn increase 71%. But increasing sales 50% may be difficult; it may even be impossible.

TABLE 1.1 Options for Increasing Contribution

		MARKETING OPTION[a]	FINANCE/ ACCOUNTING OPTION[b]	OM OPTION[c]
	CURRENT	INCREASE SALES REVENUE 50%	REDUCE FINANCE COSTS 50%	REDUCE PRODUCTION COSTS 20%
Sales	$100,000	$150,000	$100,000	$100,000
Costs of goods	–80,000	–120,000	–80,000	–64,000
Gross margin	20,000	30,000	20,000	36,000
Finance costs	–6,000	–6,000	–3,000	–6,000
Subtotal	14,000	24,000	17,000	30,000
Taxes at 25%	–3,500	–6,000	–4,250	–7,500
Contribution[d]	$ 10,500	$ 18,000	$ 12,750	$ 22,500

[a]Increasing sales 50% increases contribution by $7,500, or 71% (7,500/10,500).
[b]Reducing finance costs 50% increases contribution by $2,250, or 21% (2,250/10,500).
[c]Reducing production costs 20% increases contribution by $12,000, or 114% (12,000/10,500).
[d]Contribution to fixed cost (excluding finance costs) and profit.

The second option is a *finance/accounting option*, where finance costs are cut in half through good financial management. But even a reduction of 50% is still inadequate for generating the necessary increase in contribution. Contribution is increased by only 21%.

The third option is an *OM option*, where management reduces production costs by 20% and increases contribution by 114%.

SOLUTION ► Given the conditions of our brief example, Fisher Technologies has increased contribution from $10,500 to $22,500. It may now have a bank willing to lend it additional funds.

INSIGHT ► The OM option not only yields the greatest improvement in contribution but also may be the only feasible option. Increasing sales by 50% and decreasing finance cost by 50% may both be virtually impossible. Reducing operations cost by 20% may be difficult but feasible.

LEARNING EXERCISE ► What is the impact of only a 15% decrease in costs in the OM option? [Answer: A $19,500 contribution; an 86% increase.]

Example 1 underscores the importance of the effective operations activity of a firm. Development of increasingly effective operations is the approach taken by many companies as they face growing global competition.

What Operations Managers Do

All good managers perform the basic functions of the management process. The management process consists of *planning*, *organizing*, *staffing*, *leading*, and *controlling*. Operations managers apply this management process to the decisions they make in the OM function. The **10 strategic OM decisions** are introduced in Table 1.2. Successfully addressing each of these decisions requires planning, organizing, staffing, leading, and controlling.

10 Strategic OM Decisions
- Design of goods and services
- Managing quality
- Process strategy
- Location strategies
- Layout strategies
- Human resources
- Supply-chain management
- Inventory management
- Scheduling
- Maintenance

Where Are the OM Jobs? How does one get started on a career in operations? The 10 strategic OM decisions identified in Table 1.2 are made by individuals who work in the disciplines shown in the blue areas of Figure 1.1. Business students who know their accounting,

STUDENT TIP

An operations manager must successfully address the 10 decisions around which this text is organized.

TABLE 1.2 Ten Strategic Operations Management Decisions

DECISION	CHAPTER(S)
1. *Design of goods and services:* Defines much of what is required of operations in each of the other OM decisions. For instance, product design usually determines the lower limits of cost and the upper limits of quality, as well as major implications for sustainability and the human resources required.	5, Supplement 5
2. *Managing quality:* Determines the customer's quality expectations and establishes policies and procedures to identify and achieve that quality.	6, Supplement 6
3. *Process and capacity strategy:* Determines how a good or service is produced (i.e., the process for production) and commits management to specific technology, quality, human resources, and capital investments that determine much of the firm's basic cost structure.	7, Supplement 7
4. *Location strategy:* Requires judgments regarding nearness to customers, suppliers, and talent, while considering costs, infrastructure, logistics, and government.	8
5. *Layout strategy:* Requires integrating capacity needs, personnel levels, technology, and inventory requirements to determine the efficient flow of materials, people, and information.	9
6. *Human resources and job design:* Determines how to recruit, motivate, and retain personnel with the required talent and skills. People are an integral and expensive part of the total system design.	10
7. *Supply chain management:* Decides how to integrate the supply chain into the firm's strategy, including decisions that determine what is to be purchased, from whom, and under what conditions.	11, Supplement 11
8. *Inventory management:* Considers inventory ordering and holding decisions and how to optimize them as customer satisfaction, supplier capability, and production schedules are considered.	12, 14, 16
9. *Scheduling:* Determines and implements intermediate- and short-term schedules that effectively and efficiently utilize both personnel and facilities while meeting customer demands.	13, 15
10. *Maintenance:* Requires decisions that consider facility capacity, production demands, and personnel necessary to maintain a reliable and stable process.	17

statistics, finance, and OM have an opportunity to assume entry-level positions in all of these areas. As you read this text, identify disciplines that can assist you in making these decisions. Then take courses in those areas. The more background an OM student has in accounting, statistics, information systems, and mathematics, the more job opportunities will be available. About 40% of *all* jobs are in OM.

The following professional organizations provide various certifications that may enhance your education and be of help in your career:

- APICS, the Association for Operations Management (www.apics.org)
- American Society for Quality (ASQ) (www.asq.org)
- Institute for Supply Management (ISM) (www.ism.ws)
- Project Management Institute (PMI) (www.pmi.org)
- Council of Supply Chain Management Professionals (www.cscmp.org)

Figure 1.3 shows some recent job opportunities.

The Heritage of Operations Management

The field of OM is relatively young, but its history is rich and interesting. Our lives and the OM discipline have been enhanced by the innovations and contributions of numerous individuals. We now introduce a few of these people, and we provide a summary of significant events in operations management in Figure 1.4.

1/15 **Plant Manager**
Division of Fortune 1000 company seeks plant manager for plant located in the upper Hudson Valley area. This plant manufactures loading dock equipment for commercial markets. The candidate must be experienced in plant management including expertise in production planning, purchasing, and inventory management. Good written and oral communication skills are a must, along with excellent application of skills in managing people.

2/23 **Operations Analyst**
Expanding national coffee shop: top 10 "Best Places to Work" wants junior level systems analyst to join our excellent store improvement team. Business or I.E. degree, work methods, labor standards, ergonomics, cost accounting knowledge a plus. This is a hands-on job and excellent opportunity for a team player with good people skills. West Coast location. Some travel required.

3/18 **Quality Manager**
Several openings exist in our small package processing facilities in the Northeast, Florida, and Southern California for quality managers. These highly visible positions require extensive use of statistical tools to monitor all aspects of service, timeliness, and workload measurement. The work involves (1) a combination of hands-on applications and detailed analysis using databases and spreadsheets, (2) processing of audits to identify areas for improvement, and (3) management of implementation of changes. Positions involve night hours and weekends.

4/6 **Supply-Chain Manager and Planner**
Responsibilities entail negotiating contracts and establishing long-term relationships with suppliers. We will rely on the selected candidate to maintain accuracy in the purchasing system, invoices, and product returns. A bachelor's degree and up to 2 years related experience are required. Working knowledge of MRP, ability to use feedback to master scheduling and suppliers and consolidate orders for best price and delivery are necessary. Proficiency in all PC Windows applications, particularly Excel and Word, is essential. Effective verbal and written communication skills are essential.

5/14 **Process Improvement Consultants**
An expanding consulting firm is seeking consultants to design and implement lean production and cycle time reduction plans in both service and manufacturing processes. Our firm is currently working with an international bank to improve its back office operations, as well as with several manufacturing firms. A business degree required; APICS certification a plus.

Figure **1.3**

Many Opportunities Exist for Operations Managers

Eli Whitney (1800) is credited for the early popularization of interchangeable parts, which was achieved through standardization and quality control. Through a contract he signed with the U.S. government for 10,000 muskets, he was able to command a premium price because of their interchangeable parts.

Frederick W. Taylor (1881), known as the father of scientific management, contributed to personnel selection, planning and scheduling, motion study, and the now popular field of ergonomics. One of his major contributions was his belief that management should be much more resourceful and aggressive in the improvement of work methods. Taylor and his colleagues, Henry L. Gantt and Frank and Lillian Gilbreth, were among the first to systematically seek the best way to produce.

Another of Taylor's contributions was the belief that management should assume more responsibility for:

1. Matching employees to the right job.
2. Providing the proper training.
3. Providing proper work methods and tools.
4. Establishing legitimate incentives for work to be accomplished.