

GLOBAL  
EDITION



# 13<sup>e</sup> OPERATIONS MANAGEMENT

## Sustainability and Supply Chain Management

Jay Heizer • Barry Render • Chuck Munson



THIRTEENTH EDITION  
GLOBAL EDITION

# 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



Pearson

Microsoft and/or its respective suppliers make no representations about the suitability of the information contained in the documents and related graphics published as part of the services for any purpose. All such documents and related graphics are provided “as is” without warranty of any kind. Microsoft and/or its respective suppliers hereby disclaim all warranties and conditions with regard to this information, including all warranties and conditions of merchantability, whether express, implied or statutory, fitness for a particular purpose, title and non-infringement. In no event shall Microsoft and/or its respective suppliers be liable for any special, indirect or consequential damages or any damages whatsoever resulting from loss of use, data or profits, whether in an action of contract, negligence or other tortious action, arising out of or in connection with the use or performance of information available from the services.

The documents and related graphics contained herein could include technical inaccuracies or typographical errors. Changes are periodically added to the information herein. Microsoft and/or its respective suppliers may make improvements and/or changes in the product(s) and/or the program(s) described herein at any time. Partial screen shots may be viewed in full within the software version specified. Microsoft® and Windows® are registered trademarks of the Microsoft Corporation in the U.S.A. and other countries. This book is not sponsored or endorsed by or affiliated with the Microsoft Corporation.

---

Pearson Education Limited  
KAO Two  
KAO Park  
Harlow  
CM17 9SR  
United Kingdom

and Associated Companies throughout the world

Visit us on the World Wide Web at: [www.pearsonglobaleditions.com](http://www.pearsonglobaleditions.com)

© Pearson Education Limited, 2020

The rights of Jay Heizer, Barry Render, and Chuck Munson to be identified as the authors of this work have been asserted by them in accordance with the Copyright, Designs and Patents Act 1988.

*Authorized adaptation from the United States edition, entitled Operations Management: Sustainability and Supply Chain Management, 13th Edition, ISBN 978-0-135-17362-6 by Jay Heizer, Barry Render, and Chuck Munson, published by Pearson Education © 2020.*

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without either the prior written permission of the publisher or a license permitting restricted copying in the United Kingdom issued by the Copyright Licensing Agency Ltd, Saffron House, 6–10 Kirby Street, London EC1N 8TS.

All trademarks used herein are the property of their respective owners. The use of any trademark in this text does not vest in the author or publisher any trademark ownership rights in such trademarks, nor does the use of such trademarks imply any affiliation with or endorsement of this book by such owners. For information regarding permissions, request forms, and the appropriate contacts within the Pearson Education Global Rights and Permissions department, please visit [www.pearsoned.com/permissions](http://www.pearsoned.com/permissions).

This eBook is a standalone product and may or may not include all assets that were part of the print version. It also does not provide access to other Pearson digital products like MyLab and Mastering. The publisher reserves the right to remove any material in this eBook at any time.

**British Library Cataloguing-in-Publication Data**

A catalogue record for this book is available from the British Library

**ISBN 10:** 1-292-29503-1

**ISBN 13:** 978-1-292-29503-9

**eBook ISBN 13:** 978-1-292-29510-7

eBook formatted by Integra Software Services Pvt Ltd.

---

**To Kay Heizer, always at my side**

J.H.

---

**To Horace Dawson and David Greenberg**

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.

---

*This page intentionally left blank*

# Brief Table of Contents

## **PART ONE Introduction to Operations Management 33**

- Chapter 1 Operations and Productivity 33**
- Chapter 2 Operations Strategy in a Global Environment 61**
- Chapter 3 Project Management 91**
- Chapter 4 Forecasting 137**

## **PART TWO Designing Operations 191**

- Chapter 5 Design of Goods and Services 191**
  - ◆ Supplement 5 Sustainability in the Supply Chain 225
- Chapter 6 Managing Quality 245**
  - ◆ Supplement 6 Statistical Process Control 277
- Chapter 7 Process Strategies 311**
  - ◆ Supplement 7 Capacity and Constraint Management 339
- Chapter 8 Location Strategies 369**
- Chapter 9 Layout Strategies 399**
- Chapter 10 Human Resources, Job Design, and Work Measurement 439**

## **PART THREE Managing Operations 473**

- Chapter 11 Supply Chain Management 473**
  - ◆ Supplement 11 Supply Chain Management Analytics 503
- Chapter 12 Inventory Management 519**
- Chapter 13 Aggregate Planning and S&OP 563**
- Chapter 14 Material Requirements Planning (MRP) and ERP 597**
- Chapter 15 Short-Term Scheduling 635**
- Chapter 16 Lean Operations 673**
- Chapter 17 Maintenance and Reliability 697**

## **PART FOUR Business Analytics Modules 715**

- Module A Decision-Making Tools 715**
- Module B Linear Programming 735**
- Module C Transportation Models 765**
- Module D Waiting-Line Models 783**
- Module E Learning Curves 811**
- Module F Simulation 827**
- Module G Applying Analytics to Big Data in Operations Management 845**

## **APPENDIXES**

- Appendix I Normal Curve Areas A2**
- Appendix II Using Excel OM and POM for Windows A4**
- Appendix III Solutions to Even-Numbered Problems A8**

**ONLINE TUTORIALS (located at [MyLab Operations Management](#))**

- 1. Statistical Tools for Managers T1-1**
- 2. Acceptance Sampling T2-1**
- 3. The Simplex Method of Linear Programming T3-1**
- 4. The MODI and VAM Methods of Solving Transportation Problems T4-1**
- 5. Vehicle Routing and Scheduling T5-1**

# Table of Contents

Preface	19
About the Authors	26

## PART ONE Introduction to Operations Management

33

### Chapter 1 Operations and Productivity 33

<b>GLOBAL COMPANY PROFILE: <i>Hard Rock Cafe: Operations Management at Hard Rock Cafe</i></b>	<b>34</b>
What Is Operations Management?	36
Organizing to Produce Goods and Services	36
The Supply Chain	38
Why Study OM?	38
What Operations Managers Do	39
The Heritage of Operations Management	40
Operations for Goods and Services	43
<i>Growth of Services</i>	43
<i>Service Pay</i>	44
The Productivity Challenge	45
<b>OM in Action: <i>Improving Productivity at Starbucks</i></b>	<b>46</b>
<i>Productivity Measurement</i>	46
<i>Productivity Variables</i>	47
<i>Productivity and the Service Sector</i>	49
<b>OM in Action: <i>Taco Bell Improves Productivity and Goes Green to Lower Costs</i></b>	<b>50</b>
Current Challenges in Operations Management	50
Ethics, Social Responsibility, and Sustainability	51
Summary	52
Key Terms	52
Ethical Dilemma	52
Discussion Questions	52
Using Software for Productivity Analysis	53
Solved Problems	53
Problems	54
<b>CASE STUDY</b>	<b>56</b>
<i>Aldi: Changing the Landscape of Grocery Shopping</i>	56
<b>VIDEO CASE STUDIES</b>	<b>56</b>
<i>Frito-Lay: Operations Management in Manufacturing</i>	56
<i>Hard Rock Cafe: Operations Management in Services</i>	57
<i>Celebrity Cruises: Operations Management at Sea</i>	58
Endnotes	58
Bibliography	58
Chapter 1 Rapid Review	59
Self Test	60

### Chapter 2 Operations Strategy in a Global Environment 61

<b>GLOBAL COMPANY PROFILE: <i>Boeing: Boeing's Global Supply-Chain Strategy Yields Competitive Advantage</i></b>	<b>62</b>
A Global View of Operations and Supply Chains	64
<i>Cultural and Ethical Issues</i>	67
Determining Missions and Strategies	67
<i>Mission</i>	67
<i>Strategy</i>	67
Achieving Competitive Advantage Through Operations	68
<i>Competing on Differentiation</i>	68
<i>Competing on Cost</i>	70
<i>Competing on Response</i>	70
Issues in Operations Strategy	72
Strategy Development and Implementation	73
<b>OM in Action: <i>Amazon Updates Sears' Strategy</i></b>	<b>73</b>
<i>Key Success Factors and Core Competencies</i>	74
<i>Integrating OM with Other Activities</i>	75
<i>Building and Staffing the Organization</i>	75
<i>Implementing the 10 Strategic OM Decisions</i>	76
Strategic Planning, Core Competencies, and Outsourcing	76
<i>The Theory of Comparative Advantage</i>	78
<i>Risks of Outsourcing</i>	78
<b>OM in Action: <i>China Outsources Too—to Ethiopia</i></b>	<b>78</b>
<i>Rating Outsource Providers</i>	79
Global Operations Strategy Options	80
Summary	82
Key Terms	82
Ethical Dilemma	82
Discussion Questions	82
Using Software to Solve Outsourcing Problems	83
Solved Problems	84
Problems	85



**CASE STUDY 86***Outsourcing: Ethiopia 86***VIDEO CASE STUDIES 87***Strategy at Regal Marine 87**Hard Rock Cafe's Global Strategy 87**Outsourcing Offshore at Darden 88*

Endnotes 88

Bibliography 88

Chapter 2 Rapid Review 89

Self Test 90

**Chapter 3 Project Management 91****GLOBAL COMPANY PROFILE: Bechtel Group: Project Management Provides a Competitive Advantage for Bechtel 92**

The Importance of Project Management 94

Project Planning 94

*The Project Manager 95**Work Breakdown Structure 96*

Project Scheduling 97

*OM in Action: Delta's Ground Crew Orchestrates a Smooth Takeoff 98*

Project Controlling 98

Project Management Techniques: PERT and CPM 99

*The Framework of PERT and CPM 99**Network Diagrams and Approaches 100**Activity-on-Node Example 101**Activity-on-Arrow Example 103*

Determining the Project Schedule 103

*Forward Pass 104**Backward Pass 106**Calculating Slack Time and Identifying the Critical Path(s) 107*

Variability in Activity Times 109

*Three Time Estimates in PERT 109**Probability of Project Completion 111*

Cost-Time Trade-Offs and Project Crashing 114

A Critique of PERT and CPM 117

*OM in Action: Behind the Tour de France 117*

Using Microsoft Project to Manage Projects 118

Summary 120

Key Terms 121

Ethical Dilemma 121

Discussion Questions 121

Using Software to Solve Project Management Problems 122

Solved Problems 123

Problems 126

**VIDEO CASE STUDIES 132***Project Management at Arnold Palmer Hospital 132**Managing Hard Rock's Rockfest 133*

Endnotes 134

Bibliography 134

Chapter 3 Rapid Review 135

Self Test 136

**Chapter 4 Forecasting 137****GLOBAL COMPANY PROFILE: Walt Disney Parks & Resorts: Forecasting Provides a Competitive Advantage for Disney 138**

What Is Forecasting? 140

*Forecasting Time Horizons 140**Types of Forecasts 141*

The Strategic Importance of Forecasting 141

*Supply Chain Management 141**Human Resources 142**Capacity 142*

Seven Steps in the Forecasting System 142

Forecasting Approaches 143

*Overview of Qualitative Methods 143**Overview of Quantitative Methods 144*

Time-Series Forecasting 144

*Decomposition of a Time Series 144**OM in Action: Forecasting at Olive Garden 145**Naive Approach 145**Moving Averages 146**Exponential Smoothing 148**Measuring Forecast Error 149**Exponential Smoothing with Trend Adjustment 152**Trend Projections 156**Seasonal Variations in Data 158**Cyclical Variations in Data 163*

Associative Forecasting Methods: Regression and Correlation Analysis 163

*Using Regression Analysis for Forecasting 163**Standard Error of the Estimate 165**Correlation Coefficients for Regression Lines 166**Multiple Regression Analysis 168**OM in Action: NYC's Potholes and Regression Analysis 169*

Monitoring and Controlling Forecasts 170

*Adaptive Smoothing 171**Focus Forecasting 171*

Forecasting in the Service Sector 172

Summary 173

Key Terms 173

Ethical Dilemma 173

Discussion Questions 174

Using Software in Forecasting 174

Solved Problems 176

Problems 178

<b>CASE STUDY</b>	<b>185</b>
<i>Southwestern University: (B)</i>	185
<b>VIDEO CASE STUDIES</b>	<b>186</b>
<i>Forecasting Ticket Revenue for Orlando Magic Basketball Games</i>	186
<i>Forecasting at Hard Rock Cafe</i>	187

Endnotes	188
Bibliography	188
Chapter 4 Rapid Review	189
Self Test	190

## **PART TWO Designing Operations**

191

### **Chapter 5 Design of Goods and Services 191**

<b>GLOBAL COMPANY PROFILE: <i>Regal Marine: Product Strategy Provides Competitive Advantage at Regal Marine</i></b>	<b>192</b>
Goods and Services Selection	194
<i>Product Strategy Options Support Competitive Advantage</i>	195
<i>Product Life Cycles</i>	196
<i>Life Cycle and Strategy</i>	196
<i>Product-by-Value Analysis</i>	197
Generating New Products	197
Product Development	198
<i>Product Development System</i>	198
<i>Quality Function Deployment (QFD)</i>	198
<i>Organizing for Product Development</i>	201
<i>Manufacturability and Value Engineering</i>	202
Issues for Product Design	202
<i>Robust Design</i>	202
<i>Modular Design</i>	203
<i>Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM)</i>	203
<i>Virtual Reality Technology</i>	204
<i>Value Analysis</i>	205
<i>Sustainability and Life Cycle Assessment (LCA)</i>	205
Product Development Continuum	205
<i>OM in Action: Product Design at McDonald's</i>	206
<i>Purchasing Technology by Acquiring a Firm</i>	207
<i>Joint Ventures</i>	207
<i>Alliances</i>	207
Defining a Product	207
<i>Make-or-Buy Decisions</i>	208
<i>Group Technology</i>	209
Documents for Production	210
<i>Product Life-Cycle Management (PLM)</i>	210
Service Design	211
<i>Designing More Efficient Services</i>	212
<i>OM in Action: Amazon Pushes Product Design</i>	212
<i>Documents for Services</i>	213
Application of Decision Trees to Product Design	214
Transition to Production	215
Summary	216
Key Terms	216

Ethical Dilemma	217
Discussion Questions	217
Solved Problem	217
Problems	218
<b>CASE STUDY</b>	<b>220</b>
<i>Product Design at McDonald's: Standardization vs. Localization</i>	220
<b>VIDEO CASE STUDIES</b>	<b>221</b>
<i>Product Design at Regal Marine</i>	221
<i>Celebrity Cruises Designs a New Ship</i>	221
Endnotes	222
Bibliography	222
Chapter 5 Rapid Review	223
Self Test	224
<b>Supplement 5 Sustainability in the Supply Chain</b>	<b>225</b>
Corporate Social Responsibility	226
Sustainability	226
<i>Systems View</i>	226
<i>Commons</i>	226
<i>Triple Bottom Line</i>	227
<i>OM in Action: Blue Jeans and Sustainability</i>	228
Design and Production for Sustainability	229
<i>Product Design</i>	229
<i>Production Process</i>	232
<i>Logistics</i>	232
<i>End-of-Life Phase</i>	234
Regulations and Industry Standards	234
<i>OM in Action: Designing for End of Life</i>	235
<i>International Environmental Policies and Standards</i>	235
<i>OM in Action: Subaru's Clean, Green Set of Wheels with ISO 14001 and ISO 50001</i>	236
Summary	237
Key Terms	237
Discussion Questions	237
Solved Problems	237
Problems	238
<b>VIDEO CASE STUDIES</b>	<b>240</b>
<i>Building Sustainability at the Orlando Magic's Amway Center</i>	240
<i>Green Manufacturing and Sustainability at Frito-Lay</i>	241

“Saving the Waves” at Celebrity Cruises	241
Endnotes	242
Bibliography	242
Supplement 5 Rapid Review	243
Self Test	244
<b>Chapter 6 Managing Quality</b>	<b>245</b>
<b>GLOBAL COMPANY PROFILE: Arnold Palmer Hospital: Managing Quality Provides a Competitive Advantage at Arnold Palmer Hospital</b>	<b>246</b>
Quality and Strategy	248
Defining Quality	249
Implications of Quality	249
Malcolm Baldrige National Quality Award	250
ISO 9000 International Quality Standards	250
Cost of Quality (COQ)	250
Ethics and Quality Management	251
Total Quality Management	251
Continuous Improvement	252
Six Sigma	252
Employee Empowerment	253
Benchmarking	254
Just-in-Time (JIT)	255
Taguchi Concepts	255
OM in Action: A Hospital Benchmarks Against the Ferrari Racing Team?	255
Knowledge of TQM Tools	256
Tools of TQM	257
Check Sheets	257
Scatter Diagrams	258
Cause-and-Effect Diagrams	258
Pareto Charts	258
Flowcharts	259
Histograms	260
Statistical Process Control (SPC)	260
The Role of Inspection	261
When and Where to Inspect	261
OM in Action: Inspecting the Boeing 787	262
Source Inspection	263
Service Industry Inspection	263
Inspection of Attributes Versus Variables	263
OM in Action: Safe Patients, Smart Hospitals	263
TQM in Services	264
OM in Action: Richey International’s Spies	266
Summary	266
Key Terms	266
Ethical Dilemma	267
Discussion Questions	267
Solved Problems	267
Problems	268
<b>CASE STUDY</b>	<b>270</b>
Southwestern University: (C)	270
<b>VIDEO CASE STUDIES</b>	<b>271</b>
The Culture of Quality at Arnold Palmer Hospital	271
Quality Counts at Alaska Airlines	272
Celebrity Cruises: A Premium Experience	273
Endnote	274
Bibliography	274
Chapter 6 Rapid Review	275
Self Test	276
<b>Supplement 6 Statistical Process Control</b>	<b>277</b>
Statistical Process Control (SPC)	278
Control Charts for Variables	279
The Central Limit Theorem	279
Setting Mean Chart Limits ( $\bar{x}$ -Charts)	281
Setting Range Chart Limits (R-Charts)	284
Using Mean and Range Charts	285
Control Charts for Attributes	287
OM in Action: Trying to Land a Seat with Frequent Flyer Miles	289
Managerial Issues and Control Charts	290
Process Capability	291
Process Capability Ratio ( $C_p$ )	291
Process Capability Index ( $C_{pk}$ )	292
Acceptance Sampling	293
Operating Characteristic Curve	294
Average Outgoing Quality	295
Summary	296
Key Terms	296
Discussion Questions	296
Using Software for SPC	297
Solved Problems	298
Problems	299
<b>CASE STUDY</b>	<b>305</b>
Bayfield Mud Company	305
<b>VIDEO CASE STUDIES</b>	<b>306</b>
Frito-Lay’s Quality-Controlled Potato Chips	306
Farm to Fork: Quality at Darden Restaurants	307
Endnotes	307
Bibliography	308
Supplement 6 Rapid Review	309
Self Test	310
<b>Chapter 7 Process Strategies</b>	<b>311</b>
<b>GLOBAL COMPANY PROFILE: Harley-Davidson: Repetitive Manufacturing Works at Harley-Davidson</b>	<b>312</b>
Four Process Strategies	314
Process Focus	314
Repetitive Focus	315
Product Focus	316
Mass Customization Focus	316

<i>OM in Action: Mass Customization for Straight Teeth</i>	317	<i>OM in Action: Matching Airline Capacity to Demand</i>	344
<i>Process Comparison</i>	318	<i>Service-Sector Demand and Capacity Management</i>	345
Selection of Equipment	320	Bottleneck Analysis and the Theory of Constraints	345
Process Analysis and Design	321	<i>Theory of Constraints</i>	348
<i>Flowchart</i>	321	<i>Bottleneck Management</i>	349
<i>Time-Function Mapping</i>	321	Break-Even Analysis	349
<i>Process Charts</i>	322	<i>Single-Product Case</i>	350
<i>Value-Stream Mapping</i>	322	<i>Multiproduct Case</i>	351
<i>Service Blueprinting</i>	324	Reducing Risk with Incremental Changes	353
Special Considerations for Service Process Strategies	325	Applying Expected Monetary Value (EMV) to Capacity Decisions	354
Production Technology	326	Applying Investment Analysis to Strategy-Driven Investments	355
<i>Machine Technology</i>	326	<i>Investment, Variable Cost, and Cash Flow</i>	355
<i>Automatic Identification Systems (AISs) and RFID</i>	327	<i>Net Present Value</i>	355
<i>Process Control</i>	327	Summary	357
<i>OM in Action: 500,000 Tons of Steel; 14 Jobs</i>	328	Key Terms	358
<i>Vision Systems</i>	328	Discussion Questions	358
<i>Robots</i>	328	Using Software for Break-Even Analysis	358
<i>Automated Storage and Retrieval Systems (ASRSs)</i>	328	Solved Problems	359
<i>Automated Guided Vehicles (AGVs)</i>	328	Problems	361
<i>Flexible Manufacturing Systems (FMSs)</i>	329	<b>VIDEO CASE STUDY</b>	<b>365</b>
<i>Computer-Integrated Manufacturing (CIM)</i>	329	<i>Capacity Planning at Arnold Palmer Hospital</i>	365
<i>OM in Action: Technology Changes the Hotel Industry</i>	330	Bibliography	366
Technology in Services	330	Supplement 7 Rapid Review	367
Process Redesign	330	Self Test	368
Summary	331	<b>Chapter 8 Location Strategies</b>	<b>369</b>
Key Terms	331	<b>GLOBAL COMPANY PROFILE: FedEx: Location Provides Competitive Advantage for FedEx</b>	<b>370</b>
Ethical Dilemma	332	The Strategic Importance of Location	372
Discussion Questions	332	Factors That Affect Location Decisions	373
Solved Problem	332	<i>Labor Productivity</i>	374
Problems	333	<i>Exchange Rates and Currency Risk</i>	374
<b>CASE STUDY</b>	<b>334</b>	<i>Costs</i>	374
<i>Rochester Manufacturing's Process Decision</i>	334	<i>OM in Action: Iowa—Home of Corn and Facebook</i>	375
<b>VIDEO CASE STUDIES</b>	<b>334</b>	<i>Political Risk, Values, and Culture</i>	375
<i>Process Strategy at Wheeled Coach</i>	334	<i>Proximity to Markets</i>	375
<i>Alaska Airlines: 20-Minute Baggage Process—Guaranteed!</i>	335	<i>Proximity to Suppliers</i>	376
<i>Process Analysis at Arnold Palmer Hospital</i>	335	<i>Proximity to Competitors (Clustering)</i>	376
Endnotes	336	Methods of Evaluating Location Alternatives	376
Bibliography	336	<i>OM in Action: Denmark's Meat Cluster</i>	377
Chapter 7 Rapid Review	337	<i>The Factor-Rating Method</i>	377
Self Test	338	<i>Locational Cost-Volume Analysis</i>	378
<b>Supplement 7 Capacity and Constraint Management</b>	<b>339</b>	<i>Center-of-Gravity Method</i>	380
Capacity	340	<i>Transportation Model</i>	381
<i>Design and Effective Capacity</i>	340	Service Location Strategy	382
<i>Capacity and Strategy</i>	342	<i>OM in Action: How La Quinta Selects Profitable Hotel Sites</i>	383
<i>Capacity Considerations</i>	343	Geographic Information Systems	383
<i>Managing Demand</i>	343	Summary	385

Key Terms 385  
 Ethical Dilemma 386  
 Discussion Questions 386  
 Using Software to Solve Location Problems 386  
 Solved Problems 387  
 Problems 389  
**CASE STUDY 394**  
*Southern Recreational Vehicle Company 394*  
**VIDEO CASE STUDIES 395**  
*Locating the Next Red Lobster Restaurant 395*  
*Where to Place the Hard Rock Cafe 395*  
 Endnote 396  
 Bibliography 396  
 Chapter 8 Rapid Review 397  
 Self Test 398

**Chapter 9 Layout Strategies 399**

**GLOBAL COMPANY PROFILE: McDonald's: McDonald's Looks for Competitive Advantage Through Layout 400**  
 The Strategic Importance of Layout Decisions 402  
 Types of Layout 402  
 Office Layout 403  
 Retail Layout 404  
*Servicescapes 407*  
 Warehouse and Storage Layouts 407  
*OM in Action: Amazon Warehouses Are Full of Robots 408*  
*Cross-Docking 408*  
*Random Stocking 409*  
*Customizing 409*  
 Fixed-Position Layout 409  
 Process-Oriented Layout 410  
*Computer Software for Process-Oriented Layouts 414*  
 Focused Facilities 415  
*Work Cells 415*  
*Focused Work Center 417*  
*Focused Factory 417*  
 Repetitive and Product-Oriented Layout 417  
*Assembly-Line Balancing 418*  
 Summary 423  
 Key Terms 423  
 Ethical Dilemma 423  
 Discussion Questions 423  
 Using Software to Solve Layout Problems 424  
 Solved Problems 425  
 Problems 427  
**CASE STUDY 433**  
*State Automobile License Renewals 433*  
**VIDEO CASE STUDIES 434**  
*Laying Out Arnold Palmer Hospital's New Facility 434*  
*Facility Layout at Wheeled Coach 435*

Bibliography 436  
 Chapter 9 Rapid Review 437  
 Self Test 438

**Chapter 10 Human Resources, Job Design, and Work Measurement 439**

**GLOBAL COMPANY PROFILE: NASCAR's Racing Teams: High-Performance Teamwork Makes the Difference Between Winning and Losing 440**  
 Human Resource Strategy for Competitive Advantage 442  
*Constraints on Human Resource Strategy 442*  
 Labor Planning 443  
*Employment-Stability Policies 443*  
*Work Schedules 443*  
*Job Classifications and Work Rules 444*  
 Job Design 444  
*Labor Specialization 444*  
*Job Expansion 445*  
*Psychological Components of Job Design 445*  
*Self-Directed Teams 446*  
*OM in Action: Using Incentives to Unsnarl Traffic Jams in the OR 447*  
*Motivation and Incentive Systems 447*  
 Ergonomics and the Work Environment 447  
*OM in Action: The Missing Perfect Chair 448*  
 Methods Analysis 449  
 The Visual Workplace 452  
 Labor Standards 452  
*Historical Experience 453*  
*Time Studies 453*  
*Predetermined Time Standards 457*  
*OM in Action: UPS: The Tightest Ship in the Shipping Business 458*  
*Work Sampling 459*  
 Ethics 462  
 Summary 462  
 Key Terms 462  
 Ethical Dilemma 463  
 Discussion Questions 463  
 Solved Problems 464  
 Problems 466  
**CASE STUDY 469**  
*Fast & Fresh Pastry 469*  
**VIDEO CASE STUDIES 469**  
*The "People" Focus: Human Resources at Alaska Airlines 470*  
*Hard Rock's Human Resource Strategy 470*  
 Bibliography 470  
 Chapter 10 Rapid Review 471  
 Self Test 472

**PART THREE Managing Operations****473****Chapter 11 Supply Chain Management 473**

**GLOBAL COMPANY PROFILE: Red Lobster: Red Lobster's Supply Chain Yields a Competitive Advantage 474**

The Supply Chain's Strategic Importance 476

*OM in Action: A Rose Is a Rose, but Only If It Is Fresh 478*

Sourcing Issues: Make-or-Buy and Outsourcing 478

*Make-or-Buy Decisions 479*

*Outsourcing 479*

Six Sourcing Strategies 479

*Many Suppliers 479*

*Few Suppliers 479*

*OM in Action: The Complex Supply Chain for Apple and Samsung 480*

*Vertical Integration 480*

*Joint Ventures 481*

*Keiretsu Networks 481*

*Virtual Companies 481*

Supply Chain Risk 481

*Risks and Mitigation Tactics 482*

*Security and JIT 483*

Managing the Integrated Supply Chain 483

*Issues in Managing the Integrated Supply Chain 483*

*Opportunities in Managing the Integrated Supply Chain 484*

Building the Supply Base 485

*Supplier Evaluation 486*

*Supplier Development 486*

*Negotiations 486*

*Contracting 487*

*Centralized Purchasing 487*

*E-Procurement 487*

Logistics Management 488

*Shipping Systems 488*

*Warehousing 489*

*Third-Party Logistics (3PL) 489*

*OM in Action: DHL's Role in the Supply Chain 490*

Distribution Management 490

Ethics and Sustainable Supply Chain Management 491

*Supply Chain Management Ethics 491*

*Establishing Sustainability in Supply Chains 492*

Measuring Supply Chain Performance 492

*Assets Committed to Inventory 492*

*Benchmarking the Supply Chain 494*

*The SCOR Model 495*

Summary 496

Key Terms 496

Ethical Dilemma 496

Discussion Questions 496

Solved Problem 497

Problems 497

**VIDEO CASE STUDIES 499**

*Darden's Global Supply Chains 499*

*Supply Chain Management at Regal Marine 499*

*Arnold Palmer Hospital's Supply Chain 500*

Bibliography 500

Chapter 11 Rapid Review 501

Self Test 502

**Supplement 11 Supply Chain Management Analytics 503**

Techniques for Evaluating Supply Chains 504

Evaluating Disaster Risk in the Supply Chain 504

Managing the Bullwhip Effect 505

*A Bullwhip Effect Measure 506*

*OM in Action: RFID Helps Control the Bullwhip 507*

Supplier Selection Analysis 508

Transportation Mode Analysis 509

Warehouse Storage 509

Summary 511

Discussion Questions 511

Solved Problems 511

Problems 513

Bibliography 516

Supplement 11 Rapid Review 517

Self Test 518

**Chapter 12 Inventory Management 519**

**GLOBAL COMPANY PROFILE: Amazon.com: Inventory Management Provides Competitive Advantage at Amazon.com 520**

The Importance of Inventory 522

*Functions of Inventory 522*

*Types of Inventory 522*

Managing Inventory 523

*ABC Analysis 523*

*OM in Action: Inventory Accuracy at Milton Bradley 525*

*Record Accuracy 525*

*Cycle Counting 525*

*Control of Service Inventories 526*

*OM in Action: Retail's Last 10 Yards 527*

Inventory Models 527

*Independent vs. Dependent Demand 527*

*Holding, Ordering, and Setup Costs 527*

Inventory Models for Independent Demand 528  
*The Basic Economic Order Quantity (EOQ) Model* 528  
*Minimizing Costs* 529  
*Reorder Points* 533  
*Production Order Quantity Model* 534  
*Quantity Discount Models* 537  
 Probabilistic Models and Safety Stock 540  
*Other Probabilistic Models* 543  
 Single-Period Model 545  
 Fixed-Period (*P*) Systems 546  
 Summary 547  
 Key Terms 547  
 Ethical Dilemma 547  
 Discussion Questions 547  
 Using Software to Solve Inventory Problems 548  
 Solved Problems 549  
 Problems 552  
**CASE STUDY 557**  
*Zhou Bicycle Company* 557  
**VIDEO CASE STUDIES 558**  
*Managing Inventory at Frito-Lay* 558  
*Inventory Management at Celebrity Cruises* 558  
*Inventory Control at Wheeled Coach* 559  
 Endnotes 560  
 Bibliography 560  
 Chapter 12 Rapid Review 561  
 Self Test 562

**Chapter 13 Aggregate Planning and S&OP 563**

**GLOBAL COMPANY PROFILE: Frito-Lay: Aggregate Planning Provides a Competitive Advantage at Frito-Lay 564**  
 The Planning Process 566  
 Sales and Operations Planning 567  
 The Nature of Aggregate Planning 568  
*OM in Action: Building the Plan at Snapper* 569  
 Aggregate Planning Strategies 569  
*Capacity Options* 569  
*Demand Options* 570  
*Mixing Options to Develop a Plan* 571  
 Methods for Aggregate Planning 572  
*Graphical Methods* 572  
*Mathematical Approaches* 577  
 Aggregate Planning in Services 579  
*Restaurants* 580  
*Hospitals* 580  
*National Chains of Small Service Firms* 580  
*Miscellaneous Services* 580  
*Airline Industry* 581  
 Revenue Management 581  
*OM in Action: Revenue Management Makes Disney the “King” of the Broadway Jungle* 582

Summary 584  
 Key Terms 584  
 Ethical Dilemma 585  
 Discussion Questions 585  
 Using Software for Aggregate Planning 586  
 Solved Problems 588  
 Problems 589  
**CASE STUDY 593**  
*Andrew-Carter, Inc.* 593  
**VIDEO CASE STUDY 594**  
*Using Revenue Management to Set Orlando Magic Ticket Prices* 594  
 Bibliography 594  
 Chapter 13 Rapid Review 595  
 Self Test 596

**Chapter 14 Material Requirements Planning (MRP) and ERP 597**

**GLOBAL COMPANY PROFILE: Wheeled Coach: MRP Provides a Competitive Advantage for Wheeled Coach 598**  
 Dependent Demand 600  
 Dependent Inventory Model Requirements 600  
*Master Production Schedule* 601  
*Bills of Material* 602  
*Accurate Inventory Records* 604  
*Purchase Orders Outstanding* 604  
*Lead Times for Components* 604  
 MRP Structure 605  
 MRP Management 609  
*MRP Dynamics* 609  
*MRP Limitations* 610  
 Lot-Sizing Techniques 610  
 Extensions of MRP 614  
*Material Requirements Planning II (MRP II)* 614  
*Closed-Loop MRP* 615  
*Capacity Planning* 615  
 MRP in Services 617  
*Distribution Resource Planning (DRP)* 618  
 Enterprise Resource Planning (ERP) 618  
*OM in Action: Managing Benetton with ERP Software* 619  
*ERP in the Service Sector* 621  
 Summary 621  
 Key Terms 621  
 Ethical Dilemma 621  
 Discussion Questions 622  
 Using Software to Solve MRP Problems 622  
 Solved Problems 623  
 Problems 626

**CASE STUDY 630***Hill's Automotive, Inc.* 630**VIDEO CASE STUDIES 630***When 18,500 Orlando Magic Fans Come to Dinner* 630*MRP at Wheeled Coach* 631

Endnotes 631

Bibliography 632

Chapter 14 Rapid Review 633

Self Test 634

**Chapter 15 Short-Term Scheduling 635****GLOBAL COMPANY PROFILE: Alaska Airlines: Scheduling Flights When Weather Is the Enemy 636**

The Importance of Short-Term Scheduling 638

Scheduling Issues 638

*Forward and Backward Scheduling* 639*OM in Action: Prepping for the Orlando Magic Basketball Game* 640*Finite and Infinite Loading* 640*Scheduling Criteria* 640

Scheduling Process-Focused Facilities 641

Loading Jobs 641

*Input-Output Control* 642*Gantt Charts* 643*Assignment Method* 644

Sequencing Jobs 647

*Priority Rules for Sequencing Jobs* 647*Critical Ratio* 650*Sequencing N Jobs on Two Machines: Johnson's Rule* 651*Limitations of Rule-Based Sequencing Systems* 652

Finite Capacity Scheduling (FCS) 653

Scheduling Services 654

*OM in Action: Starbucks' Controversial Scheduling Software* 655*Scheduling Service Employees with Cyclical Scheduling* 655

Summary 657

Key Terms 657

Ethical Dilemma 657

Discussion Questions 657

Using Software for Short-Term Scheduling 658

Solved Problems 660

Problems 662

**CASE STUDY 666***Old Oregon Wood Store* 666**VIDEO CASE STUDIES 667***From the Eagles to the Magic: Converting the Amway Center* 667*Scheduling at Hard Rock Cafe* 669

Endnotes 670

Bibliography 670

Chapter 15 Rapid Review 671

Self Test 672

**Chapter 16 Lean Operations 673****GLOBAL COMPANY PROFILE: Toyota Motor Corporation: Achieving Competitive Advantage with Lean Operations at Toyota Motor Corporation 674**

Lean Operations 676

*Eliminate Waste* 676*OM in Action: Toyota's New Challenge* 677*Remove Variability* 678*Improve Throughput* 678

Lean and Just-in-Time 678

*Supplier Partnerships* 679*Lean Layout* 680*Lean Inventory* 681*Lean Scheduling* 684*Lean Quality* 687

Lean and the Toyota Production System 687

*Continuous Improvement* 687*Respect for People* 687*OM in Action: Dr Pepper's Move to Kaizen* 687*Processes and Standard Work Practice* 688

Lean Organizations 688

*Building a Lean Organization* 688*OM in Action: Lean Delivers the Medicine* 689*Lean Sustainability* 689

Lean in Services 689

Summary 690

Key Terms 690

Ethical Dilemma 691

Discussion Questions 691

Solved Problem 691

Problems 692

**VIDEO CASE STUDIES 693***Lean Operations at Alaska Airlines* 693*JIT at Arnold Palmer Hospital* 693

Endnote 694

Bibliography 694

Chapter 16 Rapid Review 695

Self Test 696

**Chapter 17 Maintenance and Reliability 697****GLOBAL COMPANY PROFILE: Orlando Utilities Commission: Maintenance Provides a Competitive Advantage for the Orlando Utilities Commission 698**

The Strategic Importance of Maintenance and Reliability 700

Reliability 701



System Reliability	701
Providing Redundancy	703
Maintenance	705
Implementing Preventive Maintenance	705
Increasing Repair Capabilities	708
Autonomous Maintenance	708
Total Productive Maintenance	709
Summary	709
Key Terms	709
Ethical Dilemma	709

Discussion Questions	709
Using Software to Solve Reliability Problems	710
Solved Problems	710
Problems	710
<b>VIDEO CASE STUDY</b>	<b>712</b>
Maintenance Drives Profits at Frito-Lay	712
Bibliography	712
Chapter 17 Rapid Review	713
Self Test	714

## PART FOUR Business Analytics Modules

715

### Module A Decision-Making Tools 715

The Decision Process in Operations	716
Fundamentals of Decision Making	716
Decision Tables	717
Types of Decision-Making Environments	718
Decision Making Under Uncertainty	718
Decision Making Under Risk	719
Decision Making Under Certainty	720
Expected Value of Perfect Information (EVPI)	720
Decision Trees	722
A More Complex Decision Tree	723
Summary	725
Key Terms	725
Discussion Questions	725
Using Software for Decision Models	725
Solved Problems	727
Problems	728
<b>CASE STUDY</b>	<b>732</b>
Festival App	732
Endnote	732
Bibliography	732
Module A Rapid Review	733
Self Test	734

Sensitivity Analysis	741
Sensitivity Report	742
Changes in the Resources or Right-Hand-Side Values	742
Changes in the Objective Function Coefficient	743
Solving Minimization Problems	744
OM in Action: LP at UPS	745
Linear Programming Applications	746
Production-Mix Example	746
Diet Problem Example	747
Labor Scheduling Example	748
The Simplex Method of LP	749
Integer and Binary Variables	749
Creating Integer and Binary Variables	749
Linear Programming Applications with Binary Variables	750
A Fixed-Charge Integer Programming Problem	751
Summary	752
Key Terms	752
Discussion Questions	752
Using Software to Solve LP Problems	752
Solved Problems	754
Problems	756
<b>CASE STUDY</b>	<b>761</b>
GuitarsToday: Assembly	761

### VIDEO CASE STUDY 761

Scheduling Challenges at Alaska Airlines 761

Endnotes	762
Bibliography	762
Module B Rapid Review	763
Self Test	764

### Module B Linear Programming 735

Why Use Linear Programming?	736
Requirements of a Linear Programming Problem	736
Formulating Linear Programming Problems	736
Glickman Electronics Example	737
Graphical Solution to a Linear Programming Problem	738
Graphical Representation of Constraints	738
Iso-Profit Line Solution Method	739
Corner-Point Solution Method	741

### Module C Transportation Models 765

Transportation Modeling	766
Developing an Initial Solution	767
The Northwest-Corner Rule	767
The Intuitive Lowest-Cost Method	769

The Stepping-Stone Method	770
Special Issues in Modeling	773
<i>Demand Not Equal to Supply</i>	773
<i>Degeneracy</i>	773
Summary	774
Key Terms	774
Discussion Questions	774
Using Software to Solve Transportation Problems	774
Solved Problems	776
Problems	777
<b>CASE STUDY</b>	<b>779</b>
<i>Custom Vans, Inc.</i>	779
Bibliography	780
Module C Rapid Review	781
Self Test	782

## Module D Waiting-Line Models 783

Queuing Theory	784
Characteristics of a Waiting-Line System	784
<i>Arrival Characteristics</i>	784
<i>Waiting-Line Characteristics</i>	786
<i>Service Characteristics</i>	786
<i>Measuring a Queue's Performance</i>	788
<i>OM in Action: Zero Wait Time Guarantee at This Michigan Hospital's ER</i>	788
Queuing Costs	789
The Variety of Queuing Models	789
<i>Model A (M/M/1): Single-Server Queuing Model with Poisson Arrivals and Exponential Service Times</i>	790
<i>Model B (M/M/S): Multiple-Server Queuing Model</i>	792
<i>Model C (M/D/1): Constant-Service-Time Model</i>	797
<i>Little's Law</i>	798
<i>Model D (M/M/1 with Finite Source): Finite-Population Model</i>	798
Other Queuing Approaches	800
Summary	800
Key Terms	800
Discussion Questions	801
Using Software to Solve Queuing Problems	801
Solved Problems	802
Problems	803
<b>CASE STUDY</b>	<b>807</b>
<i>New England Foundry</i>	807
<i>Waiting in line: QuickMart Grocery</i>	808
Endnotes	808
Bibliography	808
Module D Rapid Review	809
Self Test	810

## Module E Learning Curves 811

What Is a Learning Curve?	812
Learning Curves in Services and Manufacturing	813
Applying the Learning Curve	814
<i>Doubling Approach</i>	814
<i>Formula Approach</i>	814
<i>Learning-Curve Table Approach</i>	815
Strategic Implications of Learning Curves	818
Limitations of Learning Curves	819
Summary	819
Key Term	819
Discussion Questions	819
Using Software for Learning Curves	820
Solved Problems	820
Problems	821
<b>CASE STUDY</b>	<b>823</b>
<i>SMT's Negotiation with IBM</i>	823
Bibliography	824
Module E Rapid Review	825
Self Test	826

## Module F Simulation 827

What Is Simulation?	828
Advantages and Disadvantages of Simulation	829
Monte Carlo Simulation	830
<i>OM in Action: Simulation Takes the Kinks Out of Starbucks' Lines</i>	833
Simulation with Two Decision Variables: An Inventory Example	833
Summary	835
Key Terms	835
Discussion Questions	835
Using Software in Simulation	836
Solved Problems	837
Problems	838
<b>CASE STUDY</b>	<b>841</b>
<i>Alabama Airlines' Call Center</i>	841
Endnote	842
Bibliography	842
Module F Rapid Review	843
Self Test	844

## Module G Applying Analytics to Big Data in Operations Management 845

Introduction to Big Data and Business Analytics	846
<i>OM in Action: UPS Forecasting Improves Logistics Planning Through Predictive Analysis</i>	847
Data Management	847
<i>Graphical Techniques for Cleaning Data</i>	848
<i>Excel Techniques for Cleaning Data</i>	847
<i>Using Excel's PivotTable Tool</i>	850

Data Visualization	852
<i>Using Excel's Visualization Tools</i>	852
Predictive and Prescriptive Business Analytics Tools	854
<i>Other Business Analytics Tools Not Covered in This Text</i>	854
Summary	855
Key Terms	855
Discussion Questions	855
Solved Problems	856
Problems	857

Endnote	857
Bibliography	858
Module G Rapid Review	859
Self Test	860

<b>Appendix I</b>	<b>Normal Curve Areas</b>	<b>A2</b>
<b>Appendix II</b>	<b>Using Excel OM and POM for Windows</b>	<b>A4</b>
<b>Appendix III</b>	<b>Solutions to Even-Numbered Problems</b>	<b>A8</b>
<b>Name Index</b>	<b>I1</b>	
<b>General Index</b>	<b>I4</b>	

## ONLINE TUTORIALS (located at MyLab Operations Management)

### 1. Statistical Tools for Managers T1-1

Discrete Probability Distributions	T1-2
<i>Expected Value of a Discrete Probability Distribution</i>	T1-3
<i>Variance of a Discrete Probability Distribution</i>	T1-3
Continuous Probability Distributions	T1-4
<i>The Normal Distribution</i>	T1-4
Summary	T1-7
Key Terms	T1-7
Discussion Questions	T1-7
Problems	T1-7
Bibliography	T1-7

### 2. Acceptance Sampling T2-1

Sampling Plans	T2-2
<i>Single Sampling</i>	T2-2
<i>Double Sampling</i>	T2-2
<i>Sequential Sampling</i>	T2-2
Operating Characteristic (OC) Curves	T2-2
Producer's and Consumer's Risk	T2-3
Average Outgoing Quality	T2-5
Summary	T2-6
Key Terms	T2-6
Solved Problem	T2-7
Discussion Questions	T2-7
Problems	T2-7

### 3. The Simplex Method of Linear Programming T3-1

Converting the Constraints to Equations	T3-2
Setting Up the First Simplex Tableau	T3-2
Simplex Solution Procedures	T3-4
Summary of Simplex Steps for Maximization Problems	T3-6
Artificial and Surplus Variables	T3-7
Solving Minimization Problems	T3-7
Summary	T3-8
Key Terms	T3-8
Solved Problem	T3-8

Discussion Questions	T3-8
Problems	T3-9

### 4. The MODI and VAM Methods of Solving Transportation Problems T4-1

MODI Method	T4-2
<i>How to Use the MODI Method</i>	T4-2
<i>Solving the Arizona Plumbing Problem with MODI</i>	T4-2
Vogel's Approximation Method: Another Way to Find an Initial Solution	T4-4
Discussion Questions	T4-8
Problems	T4-8

### 5. Vehicle Routing and Scheduling T5-1

Introduction	T5-2
<i>Service Delivery Example: Meals-for-ME</i>	T5-2
Objectives of Routing and Scheduling Problems	T5-2
Characteristics of Routing and Scheduling Problems	T5-3
<i>Classifying Routing and Scheduling Problems</i>	T5-3
<i>Solving Routing and Scheduling Problems</i>	T5-4
Routing Service Vehicles	T5-5
<i>The Traveling Salesman Problem</i>	T5-5
<i>Multiple Traveling Salesman Problem</i>	T5-8
<i>The Vehicle Routing Problem</i>	T5-9
<i>Cluster First, Route Second Approach</i>	T5-10
Scheduling Service Vehicles	T5-11
<i>The Concurrent Scheduler Approach</i>	T5-13
Other Routing and Scheduling Problems	T5-13
Summary	T5-14
Key Terms	T5-15
Discussion Questions	T5-15
Problems	T5-15
<b>CASE STUDY</b>	<b>T5-17</b>
<i>Routing and Scheduling of Phlebotomists</i>	T5-17
Bibliography	T5-17

## New to This Edition

Operations is an exciting area of management that has a profound effect on productivity. The goal of this text and **MyLab Operations Management** is to present students a broad introduction to the field of operations in a realistic, practical, and applied manner. We want students to understand how operations work within an organization by seeing first-hand what goes on behind the scenes at a concert or major sports event; place an order through Amazon.com; board a flight on Alaska Airlines; or take a cruise with Celebrity Cruises. This text and **MyLab Operations Management** offer behind the scenes views that no other product on the market provides and one that students tell us they value because they gain a true understanding of operations.

With each edition, we work to gather feedback from instructors and students to enhance our text and MyLab. Based on that feedback, we have added the following new features and improvements.

### Video Cases – Celebrity Cruise Line

With each edition, we offer in **MyLab Operations Management** integrated Video Cases as a valuable teaching tool for students. These short videos help readers see and understand operations in action within a variety of industries. With this edition, we are pleased to take you behind the scenes of Celebrity Cruises, one of the world's premier cruise lines. This fascinating organization opened its doors—and ships—for us to examine and share with you leading-edge OM in the cruise line industry.

The videos provide an inside look at:

- the 10 operations decisions at Celebrity Cruises (Chapter 1);
- how Celebrity Cruises designs a new product (Chapter 5);
- Celebrity's "Save-the-Waves" sustainability program (Supplement 5);
- how Celebrity Cruises treats quality as the heartbeat of the company (Chapter 6); and
- inventory management at Celebrity Cruises (Chapter 12).

#### Celebrity Cruises: Operations Management at Sea

Video Case 

On any given day, Celebrity Cruises, Inc. has tens of thousands of passengers at sea on more than a dozen spectacular ships, spanning 7 continents and 75 countries. With this level of capital investment along with the responsibility for the happiness and safety of so many passengers, excellence in operations is required. To make it all work, the 10 operations management decisions must be executed flawlessly. From product design (which encompasses the ship's layout, the food, and 300 destinations), to scheduling, supply chain, inventory, personnel, maintenance, and the processes that hold them together, OM is critical.

Cruise lines require precise scheduling of ships, with down-to-the-minute docking and departure times. In addition to ship and port scheduling, some 2,000 plus crew members must be scheduled. And there are many schedule variations. Entertainers may arrive and leave at each port, while officers may have a schedule of 10 weeks on and 10 weeks off. Other crew members have onboard commitments varying from 4 to 9 months.

With \$400 million invested in a ship and more than 5,000 lives involved in a cruise, detailed processes to ensure maintenance and reliability are vital. The modern ship is a technological marvel with hundreds of electronic monitors operating 24/7 to track everything from ship speed and location, to sea depth, to shipboard power demand and cabin temperature.

Celebrity's ship layout, destinations, and routing are adjusted to meet seasonal demands and the expectations of its premium market segment. With destinations from Alaska to Europe to Asia, crews are recruited worldwide, with as many as 70 nationalities represented. Instilling a quality culture requires an aggressive quality service orientation and, of course, meticulous cleanliness

and attention to detail. Processes for food preparation, laundry, quality, and maintenance are complete and detailed.

A cruise ship, as a moving city, requires a comprehensive and precise supply chain that replenishes everything from food to fuel to soap and water. Land-based buyers support Celebrity's annual food and beverage purchases that exceed \$110 million. Included in these expenditures are weekly shipments of 6 to 10 containers from the Miami headquarters destined for ships in European ports. An onboard staff organizes inventories to support this massive operation. The logistics effort includes hedging the weekly use of 24,000 gallons of fuel per ship with purchases 6 years into the future. Reliable global supply chains have been developed that deliver the required inventory on a tight time frame.

These crucial shipboard systems typically represent the best of operations management. Such is the case at Celebrity Cruises.

#### Discussion Questions\*

1. Describe how the 10 OM decisions are implemented at Celebrity Cruises, Inc.
2. Identify how the 10 OM decisions at Celebrity Cruises differ from those decisions at a manufacturing firm.
3. Identify how the 10 OM decisions at Celebrity Cruises differ from those decisions at a retail store.
4. How are hotel operations on a ship different from those at a land-based hotel?

\*You may wish to view the video that accompanies this case before addressing these questions.

**In addition, we continue to offer our previous Video Cases that cover:** Alaska Airlines, Orlando Magic basketball team, Frito-Lay, Darden/Red Lobster Restaurants, Hard Rock Cafe, Arnold Palmer Hospital, Wheeled Coach Ambulances, and Regal Marine.

We take the integration of our video case studies seriously, and for this reason, all of our videos are **created by the authors**, with the outstanding coauthorship of Beverly Amer at Northern Arizona University, to explicitly match text content and terminology.

#### **46 Video Cases Listed by Chapter (new videos in bold)**

- ◆ Frito-Lay: Operations Management in Manufacturing (Chapter 1)
- ◆ **Celebrity Cruises: Operations Management at Sea (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)
- ◆ **Celebrity Cruises Designs a New Ship (Chapter 5)**
- ◆ Product Design at Regal Marine (Chapter 5)
- ◆ Building Sustainability at the Orlando Magic’s Amway Center (Supplement 5)
- ◆ **“Saving the Waves” at Celebrity Cruises (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)
- ◆ **Celebrity Cruises: A Premium Experience (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)
- ◆ **Inventory Management at Celebrity Cruises (Chapter 12)**
- ◆ 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)
- ◆ Scheduling Challenges at Alaska Airlines (Module B)

## Videos from Recent Graduates for Students

Located in [MyLab Operations Management](#) are brief videos of many recent grads who now work in some aspect of operations management. These 2- to 4-minute video clips feature young professionals talking about their jobs in the gamut of OM functions—each tied to a specific chapter and accompanied by multiple-choice quizzes that may be assigned. Each recent grad also talks about tips for success in the job market. This is sure to be a popular feature to engage students!

## More Homework Problems—Quantity, Algorithmic, and Conceptual

We know 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 818—than any other OM text.

For this edition, we have added several **HUNDRED new algorithmic problems and concept questions in [MyLab Operations Management](#)!**

## New Module Called “Applying Analytics to Big Data in Operations Management”

The marriage of business analytics, big data, and operations/supply chain management is a revolutionary change in our field. We are the first text to include a chapter (Module G) on this subject, which includes sections on data management, data visualization, and predictive and prescriptive business analytics tools. The topics include heat maps, conditional formatting for cleaning data, and pivot tables. The module includes numerous exercises that will use students’ Excel skills and show them the power of Excel in Big Data.



Kimberly Gersh, Project Manager, Little Green River Software

# Detailed Chapter-by-Chapter Changes

## Chapter 1: Operations and Productivity

We introduced two new learning objectives for the chapter: “*Identify* the 10 strategic decisions of operations management” and “*Identify* career opportunities in operations management.” Our first new video case study is called “Celebrity Cruises: Operations Management at Sea.” We updated several entries for the Globalization Era in Figure 1.4. We updated Table 1.4 to reflect employment in various sectors. Finally, we added a new discussion question.

## Chapter 2: Operations Strategy in a Global Environment

We updated Figure 2.1 on the growth of world trade and added several key historical events to the graph. We added the new key term *operational hedging*. There are two new OM in Action boxes in this chapter: “Amazon Updates Sears’ Strategy” and “China Outsources Too—to Ethiopia.” Finally, we updated Figure 2.5 to reflect product life cycle changes.

## Chapter 3: Project Management

The Bechtel Global Profile has been rewritten and we have added four new homework problems.

## Chapter 4: Forecasting

There are eight new homework problems in this chapter.

## Chapter 5: Design of Goods and Services

We modified Figure 5.2 to present the cash flows more clearly. We introduced a discussion of *additive manufacturing* as a new key term to subsume 3-D printing. We added a new discussion of *augmented reality*. There are two new OM in Action boxes: “Product Design at McDonald’s” and “Amazon Pushes Product Design.” Our second new video case study is called “Celebrity Cruises

Designs a New Ship.” We replaced the section on PCN Analysis with a new discussion on service design. We added two discussion questions and have seven new homework problems in this chapter.

### Supplement 5: Sustainability in the Supply Chain

There is a new video case study called “Saving the Waves at Celebrity Cruises.” We’ve also added new material on the circular economy and on ISO 50001. There is also a new OM in Action box called “Designing for the End of Life.”

### Chapter 6: Managing Quality

Our new video case study is called “Celebrity Cruises: A Premium Experience.” There is also a new OM in Action box called “Inspecting the Boeing 787,” new material on testing Samsung smart phones, and four new homework problems.

### Supplement 6: Statistical Process Control

We have added 14 new homework problems and updated the OM in Action box called “Landing a Seat with Frequent Flyer Miles.”

### Chapter 7: Process Strategies

We updated Figure 7.8 to simplify the presentation of degree of customization and labor for services. We added an OM in Action box called “500,000 Tons of Steel; 14 Jobs.” Finally, we updated Table 7.4 to provide more examples of technology’s impact on services.

### Supplement 7: Capacity and Constraint Management

We modified the numbers used to compute actual output in Table S7.1. We modified Figure S7.6 to improve the exposition for the four approaches to capacity expansion. We added 10 new homework problems for this supplement. Finally, we updated the birth rates in Table S7.4 for the Arnold Palmer Hospital case.

### Chapter 8: Location Strategies

We have added seven new homework problems to this chapter.

### Chapter 9: Layout Strategies

There is a new OM in Action box called “Amazon Warehouses are Full of Robots,” and we have made major revisions to our coverage of Work Cells, Focused Facilities, Focused Work Centers, and Focused Factories. There are also four new homework problems.

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

We have added five new homework problems to this chapter.

### Chapter 11: Supply Chain Management

We begin the chapter with a new Global Company Profile featuring Red Lobster. We’ve added a new section on blockchain, a new OM in Action box called “Samsung and Apple’s Complex Supply Chain,” and updated our treatment of SCOR. We also added three new homework problems.

### Supplement 11: Supply Chain Management Analytics

There is a new discussion question and three new homework problems.

### Chapter 12: Inventory Management

There is a new video case study called “Inventory Management at Celebrity Cruises.” We have also revised the Amazon Global Company Profile and expanded coverage of the single period model. In addition, there are 13 new homework problems.

### Chapter 13: Aggregate Planning and S&OP

We’ve added three new homework problems to this chapter.

## Chapter 14: Material Requirements Planning (MRP) and ERP

We deleted Figure 14.6 and moved the presentation of *allocated items* into Example 3. Under *MRP Management*, we introduced a new section and key term for *demand-driven MRP*, along with a new associated Figure 14.6. A discussion of *blockchains* is introduced in the *Enterprise Resource Planning (ERP)* section. Finally, five new homework problems were added for this chapter.

## Chapter 15: Short-Term Scheduling

There are six new homework problems to this chapter.

## Chapter 16: Lean Operations

There is a new OM in Action box, “Dr. Pepper’s Move to Kaizen,” and two new homework problems.

## Chapter 17: Maintenance and Reliability

There is new coverage of predictive maintenance, and there are three new homework problems.

## Module A: Decision Making Tools

There is a new case study, “Festival App,” and seven new homework problems.

## Module B: Linear Programming

We have added seven new homework problems to this module.

## Module C: Transportation Models

We have added one new homework problem to this module.

## Module D: Waiting-Line Models

There are five new homework problems in this module.

## Module E: Learning Curves

We have revised Figure E.1, which deals with exponential and log-log learning graphs.

## Module F: Simulation

There are three new homework problems in this module.

## Module G: Applying Analytics to Big Data in Operations Management

This new module includes sections on big data and business analytics, data management, data visualization, and predictive and prescriptive business analytics tools. There are 10 homework problems, two solved problems, and eight discussion questions.

# Solving Teaching and Learning Challenges

Now in its 13th edition, the text and [MyLab Operations Management](#) provide an extremely comprehensive learning package. This robust program addresses teaching and learning challenges and affords the student with opportunities to learn and practice employable skills. Here are just a few of the key elements offered with this textbook and [MyLab Operations Management](#).



## MyLab Operations Management

**MyLab Operations Management** is the teaching and learning platform that empowers *every* student. When combined with educational content written by the authors, **MyLab Operations Management** helps deliver the learning outcomes to which students and instructors aspire.



## Operations Management Simulations

Five operations management simulations give students hands-on experience in real-world roles, helping them make decisions, think critically, and link course concepts to on-the-job application.

By receiving real-time, dynamic feedback from stakeholders, students see the impact of their choices and can gauge their performance against individual, peer, and system metrics. Results of these simulations are recorded in the MyLab Gradebook.

The five simulations are:

- ◆ Project Management (Chapter 3)
- ◆ Forecasting (Chapter 4)
- ◆ Quality Management (Chapter 6)
- ◆ Supply Chain Management (Chapter 11)
- ◆ Inventory Management (Chapter 12)

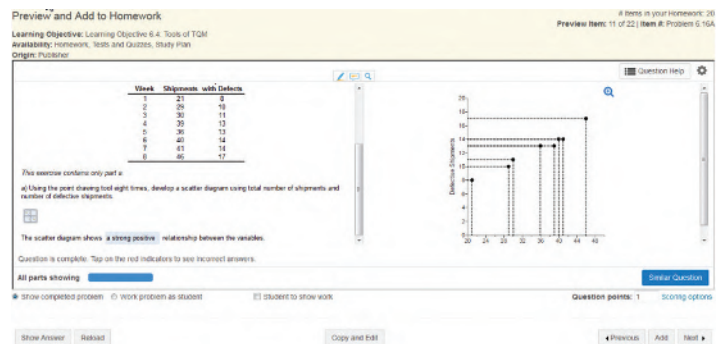
Students tell us that they enjoy learning OM through these simulations!

## A Powerful Homework and Test Manager

Problems from the textbook can be assigned to students via a robust platform. This allows instructors to manage, create, and import online homework assignments, quizzes, and tests that are automatically graded. Instructors can choose from a wide range of assignment options, including time limits, proctoring, and maximum number of attempts allowed. The bottom line: **MyLab Operations Management** means more learning and less time grading.

## Learning Aids

Right at the time of learning, students can access Learning Aids like Help Me Solve This, Videos from the authors of similar problems being solved, Ask My Instructor, and eText Pages. All of which provides the student feedback and assistance when they need it most.



## Working with Excel Software

Excel use in the Operations Management course is becoming more important, and instructors often ask their students to develop their own Excel spreadsheet models. For this reason, we provide “Creating Your Own Excel Spreadsheets,” examples toward the end of numerous chapters.

## Decision Support Software

We also provide two decision support software programs, Excel OM for Windows and Mac, and POM for Windows, to help solve homework problems and case studies. More information on these packages can be found in [MyLab Operations Management](#) in the Download Center.

### Using Software to Solve Outsourcing Problems

Excel, Excel OM, and POM for Windows may be used to solve many of the problems in this chapter.

#### CREATING YOUR OWN EXCEL SPREADSHEETS

Program 2.1 illustrates how to build an Excel spreadsheet for the data in Example 1. In this example the factor rating method is used to compare National Architects’ three potential outsourcing providers.

This program provides the data inputs for seven important factors, including their weights (0.0–1.0) and ratings (1–5 scale where 5 is the highest rating) for each country. As we see, BIM is most highly rated, with a 3.9 score, versus 3.3 for S.P.C. and 3.8 for Telco.

FACTOR (CRITERION)	IMPORTANCE WEIGHT	OUTSOURCE PROVIDERS		
		BIM (U.S.)	S.P.C. (INDIA)	TELCO (ISRAEL)
1. Can reduce operating costs	0.2	3	1	5
2. Can reduce capital investment	0.2	4	1	3
3. Skilled personnel	0.2	5	4	3
4. Can improve quality	0.1	4	3	2
5. Can gain access to technology not in the company	0.1	5	1	5
6. Can create additional capacity	0.1	4	2	4
7. Aligns with policy/philosophy/culture	0.1	2	1	3
<b>Total Weighted Score</b>		<b>3.9</b>	<b>3.3</b>	<b>3.8</b>

Program 2.1

Using Excel to Develop a Factor Rating Analysis, With Data from Example 1

#### ✕ USING EXCEL OM

Excel OM (free with your text and also found in [MyLab Operations Management](#)) may be used to solve Example 1 (with the Factor Rating module).

#### ▶ USING POM FOR WINDOWS

POM for Windows also includes a factor rating module. For details, refer to Appendix II. POM for Windows is also found in [MyLab Operations Management](#) and can solve all problems labeled with a ▶.

## Jay, Barry, & 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, and much more—all arranged by chapter. To learn more about any chapter topics, visit [www.heizerrenderOM.wordpress.com](http://www.heizerrenderOM.wordpress.com). As instructors prepare their lectures and syllabus, they can scan our blog for discussion ideas, teaching tips, and classroom exercises.

## ABOUT THE AUTHORS

JAY HEIZER



The Jesse H. Jones Professor Emeritus 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, where he was department chair, 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 five 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



The Charles Harwood Professor Emeritus 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 14th 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. 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.

Professor of Operations Management and Carson College of Business Ph.D. Program Director, 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 three years, he worked 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: Business Analytics with Spreadsheets* (4th edition), published by deGruyter.

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 winning the Sahlin Faculty Excellence Award for Instruction (Washington State University's top teaching award, 2016); 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).

**CHUCK MUNSON**

# Instructor Teaching Resources

This teaching package comes with the following teaching resources.

Supplements available to instructors at <a href="http://www.pearsonglobaleditions.com/">http://www.pearsonglobaleditions.com/</a>	Features of the Supplement
<b>Instructor's Resource Manual</b> authored by Chuck Munson	<ul style="list-style-type: none"> <li>• Chapter summary</li> <li>• Class Discussion Ideas</li> <li>• Active Classroom Learning Exercises</li> <li>• Company Videos discussion</li> <li>• Cinematic Ticklers</li> <li>• Jay, Barry, and Chuck's OM Blog</li> <li>• Presentation Slides discussion</li> <li>• Additional Assignment Ideas</li> <li>• Internet Resources and Other Supplementary Materials</li> </ul>
<b>Instructor's Solutions Manual</b>	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.
<b>Test Bank</b> authored by Jianli Hu, Cerritos College	<ul style="list-style-type: none"> <li>• More than 1,500 multiple-choice, true-or-false, and essay questions</li> <li>• Keyed by learning objective</li> <li>• Classified according to difficulty level</li> <li>• AACSB learning standard identified (Ethical Understanding and Reasoning; Analytical Thinking Skills; Information Technology; Diverse and Multicultural Work; Reflective Thinking; Application of Knowledge)</li> </ul>
<b>Computerized TestGen</b>	TestGen allows instructors to <ul style="list-style-type: none"> <li>• customize, save, and generate classroom tests.</li> <li>• edit, add, or delete questions from the Test Item Files.</li> <li>• analyze test results.</li> <li>• organize a database of tests and student results.</li> </ul>
<b>PowerPoints</b> authored by Jeff Heyl, Lincoln University	An extensive set of PowerPoint presentations is available for each chapter. With well over 2,000 slides, this set has excellent color and clarity. A set of PowerPoints is also available as an ADA-compliant version that meet accessibility standards for students with disabilities. Features include: <ul style="list-style-type: none"> <li>• Keyboard and screen reader access</li> <li>• Alternative text for images</li> <li>• High contrast between background and foreground colors</li> </ul>
<b>Excel Data Files, Excel OM, POM for Windows, and Active Models</b> developed by Howard Weiss, Temple University	<ul style="list-style-type: none"> <li>• The data files are prepared for specific examples and allow users to solve all the marked text examples without reentering any data.</li> <li>• POM for Windows is a powerful tool for easily solving OM problems.</li> <li>• Excel OM is our exclusive user-friendly Excel add-in. Excel OM automatically creates worksheets to model and solve problems. This software is great for student homework, what-if analysis, and classroom demonstrations.</li> <li>• 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 to see how the changes affect the answers.</li> </ul>

# Acknowledgments

We thank the many individuals who were kind enough to assist us in this endeavor. The following professors provided insights that guided us in this edition (their names are in bold) and in prior editions:

## ALABAMA

John Mittenthal  
*University of Alabama*  
Philip F. Musa  
*University of Alabama at Birmingham*  
William Petty  
*University of Alabama*  
Doug Turner  
*Auburn University*

## ALASKA

Paul Jordan  
*University of Alaska*

## ARIZONA

Susan K. Norman  
*Northern Arizona University*  
Scott Roberts  
*Northern Arizona University*  
Vicki L. Smith-Daniels  
*Arizona State University*  
Susan K. Williams  
*Northern Arizona University*

## CALIFORNIA

Jean-Pierre Amor  
*University of San Diego*  
Moshen Attaran  
*California State University–Bakersfield*  
Ali Behnezhad  
*California State University–Northridge*  
Joe Biggs  
*California Polytechnic State University*  
Lesley Buehler  
*Ohlone College*  
**Manny Fernandez**  
*Bakersfield College*  
Rick Hesse  
*Pepperdine*  
**Jianli Hu**  
*Cerritos College*  
Ravi Kathuria  
*Chapman University*  
Richard Martin  
*California State University–Long Beach*

Ozgur Ozluk  
*San Francisco State University*  
Zinovy Radovilsky  
*California State University–Hayward*  
**Robert Saltzman**  
*San Francisco State University*  
Robert J. Schlesinger  
*San Diego State University*  
V. Udayabhanu  
*San Francisco State University*  
Rick Wing  
*San Francisco State University*

## COLORADO

Peter Billington  
*Colorado State University–Pueblo*  
Gregory Stock  
*University of Colorado at Colorado Springs*

## CONNECTICUT

David Cadden  
*Quinnipiac University*  
Larry A. Flick  
*Norwalk Community Technical College*

## FLORIDA

Joseph P. Geunes  
*University of Florida*  
Rita Gibson  
*Embry-Riddle Aeronautical University*  
Donald Hammond  
*University of South Florida*  
Wende Huehn–Brown  
*St. Petersburg College*  
**Andrew Johnson**  
*University of Central Florida*  
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 Osadchyi  
*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*

**MICHIGAN**

Darlene Burk  
*Western Michigan University*

Sima Fortsch  
*University of Michigan–Flint*

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*

Stephen Allen  
*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 HAMPSHIRE**

Dan Bouchard  
*Granite State College*

**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**

Michael Adams  
*SUNY Old Westbury*

Theodore Boreki  
*Hofstra University*

John Drabouski  
*DeVry University*

Richard E. Dulski  
*Daemen College*

Jonatan Jelen  
*Baruch College*

Beate Klingenberg  
*Marist College*

Purushottam Meena  
*New York Institute of  
Technology*

Donna Mosier  
*SUNY Potsdam*

Elizabeth Perry  
*SUNY Binghamton*

William Reisel  
*St. John's University*

Abraham Seidmann  
*University of Rochester*

Kaushik Sengupta  
*Hofstra University*

Girish Shambu  
*Canisius College*

Rajendra Tibrewala  
*New York Institute of  
Technology*