



Operations and Supply Chain Management

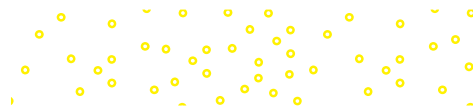
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OPERATIONS AND SUPPLY CHAIN MANAGEMENT, SEVENTEENTH EDITION

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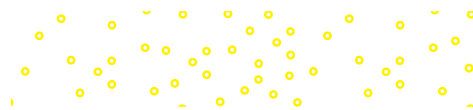
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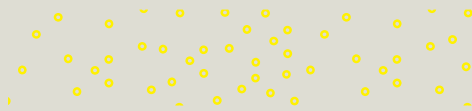
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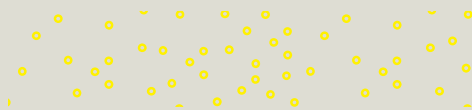
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To my wife, Rhonda, and our children Jenny, Suzy, and Jess

*To my wife, Harriet, and to our children
Laurie, Andy, Glenn, Robb, and Christine*



Section One

STRATEGY, PRODUCTS, AND CAPACITY

- 1 Introduction 2
- 2 Strategy 20
- 3 Design of Products and Services 41
- 4 Projects 73
- 5 Strategic Capacity Management 110
- 5s Investment Analysis 130
- 6 Learning Curves 146

Section Two

MANUFACTURING AND SERVICE PROCESSES

- 7 Manufacturing Processes 166
- 7S Manufacturing Technology 186
- 8 Facility Layout 193
- 9 Service Processes 227
- 9S Health Care 248
- 10 Waiting Line Analysis and Simulation 262
- 11 Process Design and Analysis 305
- 11S Operations Consulting 338
- 12 Quality Management 348
- 13 Statistical Quality Control 367

Section Three

SUPPLY CHAIN PROCESSES

- 14 Lean Supply Chains 398
- 15 Logistics and Distribution Management 426
- 16 Global Sourcing and Procurement 451

Section Four

SUPPLY AND DEMAND PLANNING AND CONTROL

- 17 The Internet of Things and ERP 474
- 18 Forecasting 487
- 19 Sales and Operations Planning 529
- 19S Linear Programming Using the Excel Solver 553
- 20 Inventory Management 567
- 21 Material Requirements Planning 612
- 22 Workcenter Scheduling 643
- 22S Theory of Constraints 676

APPENDICES

- A Interest Tables 707
- B Negative Exponential Distribution: Values of e^{-x} 711
- C Areas of the Cumulative Standard Normal Distribution 712
- D Uniformly Distributed Random Digits 713
- E Answers to Selected Objective Questions 714

INDEX 717

Section One

STRATEGY, PRODUCTS, AND CAPACITY

1 INTRODUCTION 2

- Introduction—The Elements of OSCM 3
 - What Is Operations and Supply Chain Management?* 3
 - Distinguishing Operations versus Supply Chain Processes* 5
 - Categorizing Operations and Supply Chain Processes* 6
 - Differences between Services and Goods* 7
 - The Goods–Services Continuum* 8
 - Product–Service Bundling* 9
- Careers in OSCM 9
- The Major Concepts that Define the OSCM Field 10
 - Current Issues in Operations and Supply Chain Management* 13
- Efficiency, Effectiveness, and Value 13
- Concept Connections 14
- Discussion Questions 15
- Objective Questions 16
- Analytics Exercise: Comparing Companies Using Wall Street Efficiency Measures 16
- Practice Exam 19

2 STRATEGY 20

- What Is Operations and Supply Chain Strategy? 21
 - Competitive Dimensions* 22
 - The Notion of Trade-Offs* 24
 - Order Winners and Order Qualifiers: The Marketing–Operations Link* 24
- Strategies Are Implemented Using Operations and Supply Chain Activities—IKEA’s Strategy 25
- Assessing the Risk Associated with Operations and Supply Chain Strategies 25
 - Risk Management Framework* 27
- Productivity Measurement 28

- A Sustainable Operations and Supply Chain Strategy 31
- Concept Connections 32
- Solved Problem 34
- Discussion Questions 34
- Objective Questions 35
- Case: The Tao of Timbuk2 37
- Analytics Exercise: The Carbon Footprint Quiz (LO2-5) 38
- Practice Exam 40

3 DESIGN OF PRODUCTS AND SERVICES 41

- Product Design 42
 - Product Development Process* 43
- Product Design Criteria 48
 - Designing for the Customer* 49
 - Value Analysis/Value Engineering* 50
 - Designing Products for Manufacture and Assembly* 51
- Designing Service Products 55
- Economic Analysis of Product Development Projects 56
 - Build a Base-Case Financial Model* 57
 - Sensitivity Analysis to Understand Project Trade-Offs* 59
- Measuring Product Development Performance 60
- Concept Connections 61
- Solved Problem 62
- Discussion Questions 65
- Objective Questions 65
- Case: IKEA: Design and Pricing 68
- Case: Comparison of Competing Products 70
- Practice Exam 72

4 PROJECTS 73

- What Is Project Management? 74
 - Organizing the Project Team* 75
 - Pure Project* 75
 - Functional Project* 75
 - Matrix Project* 76
 - Organizing Project Tasks* 77
- Managing Projects 78
 - Earned Value Management (EVM)* 80

Network-Planning Models 83
Critical Path Method (CPM) 84
CPM with Three Activity Time Estimates 88
Time–Cost Models and Project Crashing 90
 Project Management Information Systems 94
 Concept Connections 95
 Solved Problems 97
 Discussion Questions 101
 Objective Questions 101
 Analytics Exercise: Product Design Project 107
 Practice Exam 109

5 STRATEGIC CAPACITY MANAGEMENT 110

Capacity Management in Operations and Supply Chain Management 111
Capacity Planning Concepts 112
Economies and Diseconomies of Scale 112
Capacity Focus 113
Capacity Flexibility 113
 Capacity Planning 114
Considerations in Changing Capacity 114
Determining Capacity Requirements 115
 Using Decision Trees to Evaluate Capacity Alternatives 117
 Planning Service Capacity 120
Capacity Planning in Services versus Manufacturing 120
Capacity Utilization and Service Quality 121
 Concept Connections 122
 Solved Problem 123
 Discussion Questions 125
 Objective Questions 125
 Case: Shouldice Hospital—A Cut Above 127
 Practice Exam 129

5S INVESTMENT ANALYSIS 130

Investment Analysis 130
Concepts and Definitions 130
Activity-Based Costing 133
The Effects of Taxes 134
Choosing among Investment Proposals 135
Methods of Ranking Investments 141
Sample Problems: Investment Decisions 142
 Concept Connections 145

6 LEARNING CURVES 146

What Are Learning Curves? 147
 How Are Learning Curves Modeled? 148
Logarithmic Analysis 149
Learning Curve Tables 149
Estimating the Learning Percentage 153
How Long Does Learning Go On? 153

In Practice, How much Learning Occurs? 153
Individual Learning 153
Organizational Learning 154
 Concept Connections 156
 Solved Problems 156
 Discussion Questions 157
 Objective Questions 158
 Analytics Exercise: Tesla's Model 3 Learning Curve 160
 Practice Exam 163

Section Two

MANUFACTURING AND SERVICE PROCESSES

7 MANUFACTURING PROCESSES 166

Manufacturing Technology plus AI = Innovation 166
 What Are Manufacturing Processes? 167
 How Manufacturing Processes Are Organized 169
Break-Even Analysis 171
 Manufacturing Process Flow Design 173
 Concept Connections 178
 Solved Problems 179
 Discussion Questions 180
 Objective Questions 181
 Case: Circuit Board Fabricators, Inc. 183
 Practice Exam 185

7S MANUFACTURING TECHNOLOGY 186

Manufacturing Technology 186
Technologies in Manufacturing 186
Computer-Integrated Manufacturing 189
 Concept Connections 191
 Discussion Questions 192

8 FACILITY LAYOUT 193

Facility Layout 194
 Analyzing the Four Most Common Layout Formats 195
Workcenters (Job Shops) 195
Systematic Layout Planning 199
Assembly Lines 199
Assembly-Line Design 199
Splitting Tasks 203
Flexible and U-Shaped Line Layouts 204
Mixed-Model Line Balancing 204
Cells 206
Project Layouts 206
 Retail Service Layout 208
Servicescapes 208
Signs, Symbols, and Artifacts 210
Office Layout 210

- Concept Connections 211
 Solved Problems 212
 Discussion Questions 217
 Objective Questions 217
 Advanced Problems 223
 Analytics Exercise: Designing a
 Manufacturing Process 224
 Practice Exam 226
- 9 SERVICE PROCESSES 227**
- The Nature of Services 228
*An Operational Classification of
 Services 228*
 Designing Service
 Organizations 229
*Structuring the Service Encounter: The
 Service-System Design Matrix 231*
Web Platform Businesses 232
*Managing Customer-Introduced
 Variability 234*
*Applying Behavioral Science to Service
 Encounters 234*
 Service Blueprinting and
 Fail-Safing 237
 Three Contrasting Service
 Designs 238
The Production-Line Approach 239
The Self-Service Approach 240
*The Personal-Attention
 Approach 240*
*Seven Characteristics of a Well-Designed
 Service System 241*
 Concept Connections 243
 Discussion Questions 244
 Objective Questions 245
 Case: South Beach Pizza: An Exercise
 in Translating Customer Requirements
 into Process Design Requirements 245
 Practice Exam 247
- 9S HEALTH CARE 248**
- The Nature of Health Care
 Operations 248
Classification of Hospitals 249
*Hospital Layout and Care
 Chains 250*
Capacity Planning 251
Workforce Scheduling 252
*Quality Management and Process
 Improvement 252*
Health Care Supply Chains 253
Inventory Management 255
 Performance Measures 255
Performance Dashboards 256
 Trends in Health Care 256
 Concept Connections 257
 Discussion Questions 258
 Objective Questions 259
 Case: Managing Patient Wait Times at a
 Family Clinic 259
 Practice Exam 261
- 10 WAITING LINE ANALYSIS AND
 SIMULATION 262**
- The Waiting Line Problem 263
The Practical View of Waiting Lines 263
The Queuing System 264
 Waiting Line Models 271
*Approximating Customer Waiting
 Time 277*
 Simulating Waiting Lines 280
*Example: A Two-Stage Assembly
 Line 280*
Spreadsheet Simulation 283
Simulation Programs and Languages 285
 Concept Connections 287
 Solved Problems 289
 Discussion Questions 292
 Objective Questions 292
 Case: Community Hospital Evening
 Operating Room 297
 Analytics Exercise: Processing Customer
 Orders 297
 Practice Exam 300
- 11 PROCESS DESIGN AND
 ANALYSIS 305**
- Process Analysis 306
*Example: Analyzing a Las Vegas Slot
 Machine 306*
Process Flowcharting 308
 Understanding Processes 309
Buffering, Blocking, and Starving 309
Make to Stock vs. Make to Order 310
Measuring Process Performance 313
*Production Process Mapping and Little's
 Law 315*
 Job Design Decisions 317
*Behavioral Considerations in Job
 Design 318*
Work Measurement and Standards 318
 Process Analysis Examples 319
A Bread-Making Operation 319
A Restaurant Operation 320
Planning a Transit Bus Operation 322
Process Flow Time Reduction 324
 Concept Connections 326
 Solved Problems 328
 Discussion Questions 330
 Objective Questions 331
 Case: Runners Edge—Call Center
 Process Analysis 335
 Practice Exam 337
- 11S OPERATIONS CONSULTING 338**
- What is Operations Consulting? 338
*The Management Consulting
 Industry 338*
Economics of Consulting Firms 339
*When Operations Consulting is
 Needed 340*
 The Operations Consulting
 Process 341

Operations Consulting Tool Kit 342
Problem Definition Tools 342
Data Gathering 344
Data Analysis and Solution Development 345
Cost Impact and Payoff Analysis 345
Implementation 346
 Concept Connections 346
 Discussion Questions 347
 Objective Questions 347
 Practice Exam 347

12 QUALITY MANAGEMENT 348

Total Quality Management 349
 Quality Specifications and Quality Costs 350
 Developing Quality Specifications 350
 Cost of Quality 351
 Six Sigma Quality 353
 Six Sigma Methodology 354
 Analytical Tools for Six Sigma 355
 Six Sigma Roles and Responsibilities 358
 The Shingo System: Fail-Safe Design 359
 ISO 9000 and ISO 14000 360
 External Benchmarking for Quality Improvement 361
 Concept Connections 362
 Discussion Questions 363
 Objective Questions 364
 Case: Tesla's Quality Challenge 365
 Practice Exam 366

13 STATISTICAL QUALITY CONTROL 367

Statistical Quality Control 368
 Understanding and Measuring Process Variation 369
 Measuring Process Capability 371
 Statistical Process Control
 Procedures 375
 Process Control with Attribute Measurements: Using p-Charts 376
 Process Control with Attribute Measurements: Using c-Charts 378
 Process Control with Variable Measurements: Using \bar{X} - and R-Charts 379
 How to Construct \bar{X} - and R-Charts 380
 Acceptance Sampling 383
 Design of a Single Sampling Plan for Attributes 383
 Operating Characteristic Curves 384
 Concept Connections 386
 Solved Problems 387
 Discussion Questions 390
 Objective Questions 390
 Analytics Exercise: Hot Shot Plastics Company 394
 Analytics Exercise: Quality Management—Toyota 395
 Practice Exam 395

Section Three

SUPPLY CHAIN PROCESSES

14 LEAN SUPPLY CHAINS 398

Lean Manufacturing Practices and the COVID-19 Pandemic 398
 Lean Production 399
 The Toyota Production System 400
 Lean Supply Chains 401
 Value Stream Mapping 403
 Lean Supply Chain Design
 Principles 405
 Lean Concepts 406
 Lean Production Schedules 407
 Lean Supply Chains 411
 Lean Services 412
 Concept Connections 414
 Solved Problems 416
 Discussion Questions 420
 Objective Questions 420
 Case: Quality Parts Company 421
 Case: Value Stream Mapping 423
 Case: Pro Fishing Boats—A Value Stream Mapping Exercise 424
 Practice Exam 425

15 LOGISTICS AND DISTRIBUTION MANAGEMENT 426

Logistics 427
 Decisions Related to Logistics 428
 Transportation Modes 428
 Distribution Facilities 429
 Distribution Facility Processes 429
 Locating Logistics Facilities 430
 Plant Location Methods 432
 Centroid Method 436
 Locating Service Facilities 437
 Concept Connections 440
 Solved Problems 441
 Discussion Questions 445
 Objective Questions 445
 Analytics Exercise: Distribution Center Location 448
 Practice Exam 450

16 GLOBAL SOURCING AND PROCUREMENT 451

Strategic Sourcing 452
 The Bullwhip Effect 453
 Supply Chain Uncertainty Framework 454
 Outsourcing 457
 Logistics Outsourcing 457
 Framework for Supplier Relationships 458
 Green Sourcing 459
 Total Cost of Ownership 462
 Measuring Sourcing Performance 463

Concept Connections 466
 Discussion Questions 467
 Objective Questions 468
 Analytics Exercise: Global Sourcing
 Decisions—Grainger: Reengineering the
 China/U.S. Supply Chain 470
 Practice Exam 472

Section Four

SUPPLY AND DEMAND PLANNING AND CONTROL

17 THE INTERNET OF THINGS AND ERP 474

*Intelligent Devices Connected through the
 Internet* 475
 What Is ERP? 475
 Consistent Numbers 476
 Software Imperatives 476
 Routine Decision Making 476
 How ERP Connects the Functional
 Units 477
 Finance 477
 Manufacturing and Logistics 478
 Sales and Marketing 478
 Human Resources 479
 Customized Software 479
 Data Integration 479
 How Supply Chain Planning and Control
 Fits within ERP 480
 Simplified Example 480
 SAP Supply Chain Management 481
 SAP Supply Chain Execution 482
 SAP Supply Chain Collaboration 482
 SAP Supply Chain Coordination 483
 Performance Metrics to Evaluate
 Integrated System Effectiveness 483
 The “Functional Silo” Approach 484
 Concept Connections 485
 Discussion Questions 486
 Objective Questions 486
 Practice Exam 486

18 FORECASTING 487

Forecasting in Operations and Supply
 Chain Management 488
 Quantitative Forecasting Models 489
 Components of Demand 489
 Time Series Analysis 490
 Forecast Errors 503
 Causal Relationship Forecasting 506
 Qualitative Techniques in
 Forecasting 508
 Market Research 509
 Panel Consensus 509
 Historical Analogy 509
 Delphi Method 510

Web-Based Forecasting: Collaborative
 Planning, Forecasting, and Replenish-
 ment (CPFR) 510
 Concept Connections 512
 Solved Problems 513
 Discussion Questions 517
 Objective Questions 518
 Analytics Exercise: Forecasting Supply
 Chain Demand—Starbucks Corporation
 (LO18-2) 526
 Analytics Exercise: Forecasting Demand
 at Sebastian River Farms (LO18-2) 527
 Practice Exam 528

19 SALES AND OPERATIONS PLANNING 529

What Is Sales and Operations
 Planning? 530
 *An Overview of Sales and Operations
 Planning Activities* 530
 The Aggregate Operations Plan 532
 Aggregate Planning Techniques 535
 *A Cut-and-Try Example: The JC
 Company* 535
 *Aggregate Planning Applied to Ser-
 vices: Tucson Parks and Recreation
 Department* 540
 Yield Management 542
 *Operating Yield Management
 Systems* 543
 Concept Connections 544
 Solved Problem 545
 Discussion Questions 548
 Objective Questions 548
 Analytics Exercise: The Pudding
 Manufacturing Aggregate Plan 551
 Practice Exam 552

19S LINEAR PROGRAMMING USING THE EXCEL SOLVER 553

Linear Programming 553
 The Linear Programming Model 554
 *Linear Programming Using Microsoft
 Excel* 555
 Concept Connections 558
 Solved Problem 558
 Objective Questions 565

20 INVENTORY MANAGEMENT 567

Understanding Inventory
 Management 568
 Purposes of Inventory 570
 Inventory Costs 571
 *Independent versus Dependent
 Demand* 571
 Inventory Control Systems 572
 A Single-Period Inventory Model 573
 Multiperiod Inventory Systems 574
 Fixed-Order Quantity Models 577
 Fixed-Time Period Models 583

Inventory Turn Calculation 585
Price-Break Model 586
 Inventory Planning and Accuracy 589
 ABC Classification 589
 Inventory Accuracy and Cycle Counting 590
 Concept Connections 592
 Solved Problems 594
 Discussion Questions 597
 Objective Questions 597
 Analytics Exercise: Inventory Management at Big10Sweaters.com 606
 Analytics Exercise: Inventory Control at Sebastian River Farms 608
 Practice Exam 610

21 MATERIAL REQUIREMENTS PLANNING 612

Understanding Material Requirements Planning 613
 Where MRP Can Be Used 613
 Master Production Scheduling 613
 Material Requirements Planning System Structure 616
 Demand for Products 616
 Bill-of-Materials 617
 Inventory Records 619
 MRP Computer Program 620
 An Example Using MRP 621
 Forecasting Demand 621
 Developing a Master Production Schedule 621
 Bill-of-Materials (Product Structure) 622
 Inventory Records 622
 Performing the MRP Calculations 622
 Lot Sizing in MRP Systems 625
 Lot-for-Lot 626
 Economic Order Quantity 626
 Least Total Cost 627
 Least Unit Cost 628
 Choosing the Best Lot Size 628
 Concept Connections 629
 Solved Problems 631
 Discussion Questions 636
 Objective Questions 636
 Analytics Exercise: An MRP Explosion—Brunswick Motors 640
 Practice Exam 642

22 WORKCENTER SCHEDULING 643

Workcenter Scheduling 644
 The Nature and Importance of Workcenters 644
 Typical Scheduling and Control Functions 646
 Objectives of Workcenter Scheduling 647
 Job Sequencing 647
 Priority Rules and Techniques 648
 Scheduling n Jobs on One Machine 648
 Scheduling n Jobs on Two Machines 651

Scheduling a Set Number of Jobs on the Same Number of Machines 652
 Scheduling n Jobs on m Machines 654
 Shop-Floor Control 654
 Gantt Charts 654
 Tools of Shop-Floor Control 655
 Principles of Workcenter Scheduling 657
 Personnel Scheduling in Services 658
 Scheduling Daily Work Times 658
 Scheduling Hourly Work Times 659
 Concept Connections 660
 Solved Problems 662
 Discussion Questions 667
 Objective Questions 667
 Case: Keep Patients Waiting? Not in My Office 672
 Practice Exam 674

22S THEORY OF CONSTRAINTS 676

Eli Goldratt's Theory of Constraints 676
 The Goal of the Firm 677
 Performance Measurements 677
 Unbalanced Capacity 679
 Bottlenecks, Capacity-Constrained Resources, and Synchronous Manufacturing 680
 Basic Manufacturing Building Blocks 681
 Methods for Synchronous Control 681
 Comparing Synchronous Manufacturing (TOC) to Traditional Approaches 690
 MRP and JIT 690
 Relationship with Other Functional Areas 691
 Theory of Constraints—Problems About What to Produce 692
 Concept Connections 699
 Solved Problem 700
 Discussion Questions 702
 Objective Questions 702
 Practice Exam 706

APPENDICES

A Interest Tables 707

B Negative Exponential Distribution: Values of e^{-x} 711

C Areas of the Cumulative Standard Normal Distribution 712

D Uniformly Distributed Random Digits 713

E Answers to Selected Objective Questions 714

INDEX 717

Operations and supply chain management (OSCM) is a key element in the improvement in productivity in business around the world. Establishing a *competitive advantage* through operations requires an understanding of how the operations and supply chain functions contribute to productivity growth. However, our intent in this book is to do more than just show you what companies are doing to create a competitive advantage in the marketplace by conveying to you a set of skills and tools that you can actually apply.

Hot topics in business today that relate to operations and supply chain management are mitigating the risk of disruptions while reducing the cost of supply chain processes, integration and collaboration with customers and suppliers, sustainability and minimizing the long-term cost of products and processes. These topics are studied in the book with up-to-date, high-level managerial material to clarify the “big picture” of what these topics are and why they are so important to business today.

A significant feature of this book is the organization of each chapter by concise learning objectives. Each objective relates to a block of knowledge that should be studied as a unit. The objectives are carried through the end-of-chapter material that includes Concept Connections, Discussion Questions, Objective Questions, and a Practice Exam. The material is organized to ease understanding of each topic.

Success in OSCM requires a data-driven view of a firm’s business. Every chapter in the book has *analytic* content that ties decisions to relevant data. Mathematical models are used to structure the data for making decisions. Given the facts that are supported by data, success in OSCM requires using a *strategy* that is consistent with the operations-related priorities of a firm. Different approaches can often be used, and usually trade-offs related to cost and other flexibility-related criteria exist. Strategies are implemented through *processes* that define exactly how things are done. Processes are executed over and over again as the firm conducts business, so they must be designed to operate efficiently to minimize cost while meeting quality-related standards. Great managers are analytic in their approach to decision making; they understand and select the appropriate strategy, and then execute the strategy through great processes. We develop this pattern throughout the topics in this book.

The reality of global customers, global suppliers, and global supply chains has made the global firm recognize the importance of being both lean and green to ensure competitiveness. Applications that range from high-tech manufacturing to high-touch service are used in the balanced treatment of the traditional topics of the field. Success for companies today requires successfully managing the entire supply flow, from the sources of the firm, through the value-added process of the firm, and on to the customers of the firm.

Each chapter includes information about how operations and supply chain–related problems are solved. There are concise treatments of the many decisions that need to be made in designing, planning, and managing the operations of a business. Many spreadsheets are available from the book website to help clarify how these problems are quickly solved.

OSCM should appeal to individuals who want to be directly involved in making products or providing services. The entry-level operations specialist is the person who determines how best to design, supply, and run the processes. Senior operations managers are responsible for setting the strategic direction of the company from an operations and supply chain standpoint, deciding what technologies should be used and where facilities should be located, purchasing the resources needed, and managing the facilities that make the products or provide the services. OSCM is an interesting mix of managing people and applying sophisticated technology. The goal is to efficiently create wealth by supplying quality goods and services.

Features to aid in your understanding of the material include the following:

- Chapter supplements provide additional material for students that relate to the chapter. In some cases analytical tools are discussed, such as financial present value analysis and linear programming. In other cases, specialized applications such as health care and consulting are discussed.
- OSCM at Work boxes provide short overviews of how leading-edge companies are applying OSCM concepts today.
- Solved problems at the end of chapters serve as models that can be reviewed prior to attempting problems.
- The Concept Connections section in each chapter summarizes the concepts in each learning objective, has definitions of the key terms, and lists the equations where appropriate.
- Discussion questions are designed to review concepts and show their applicability in real-world settings. These are included in each chapter and organized by learning objectives.
- Objective questions at the end of chapters cover each concept and problem. These are organized by the chapter learning objectives.
- Practice exam questions at the end of each chapter are special questions designed to require a deeper understanding of the material in the chapter. They are similar to the type of short-answer questions that might be given on a test.
- Answers to selected problems are in Appendix E.
- The seventeenth edition is supported by a wealth of content in McGraw-Hill's Connect homework management system, including the adaptive SmartBook eBook, assignable and autogradable problems and exercises from the text, autogradable Interactive Excel exercises, Test Bank questions, and concept videos. Instructors can access additional resources through the Connect library, including PowerPoint slide outlines of each chapter, Excel spreadsheets for the solved problems and other examples, practice quizzes, Excel tutorials and Step-by-Step Example videos, Internet links, and video segments that illustrate the application of operations concepts in companies such as Apple, Amazon, Tesla, Honda, Disney, Ford, and many others. Additional student resources are also available in Connect.

Our aim is to cover the latest and the most important issues facing OSCM managers, as well as basic tools and techniques. We supply many examples of leading-edge companies and practices and have done our best to make the book an interesting read and give you a competitive advantage in your career.

We hope you enjoy it.

Plan of the Book

This book is about methods to effectively produce and distribute the goods and services sold by a company. To develop a better understanding of the field, this book is organized into four major sections: Strategy, Products, and Capacity; Manufacturing and Service Processes; Supply Chain Processes; and Supply and Demand Planning and Control. In the following paragraphs, we quickly describe the major topics in the book.

Strategy and sustainability are important and recurring topics in the book. Any company must have a comprehensive business plan that is supported by a marketing strategy, operations strategy, and financial strategy. It is essential for a company to ensure that the three strategies support each other. Strategy is covered from a high-level view in Chapter 2 (Strategy), and more details that relate to economies of scale and learning are covered in Strategic Capacity Management (Chapter 5), and Learning Curves (Chapter 6). Because the company strategy must be supported financially, financial tools that are commonly used are reviewed in the supplement to Chapter 5 (Investment Analysis).

The lifeline of the company is a steady stream of innovative products that are offered to the marketplace at the lowest cost possible. Design of Products and Services (Chapter 3) includes a view of how products are designed in the context of having to actually produce and distribute the product over its life cycle. The chapter includes material on how to manage and analyze the economic impact of a stream of products that are developed over time. Projects (Chapter 4) are used to implement change in a firm, be it a change in strategy, a new product introduction, or a new process.

The second section of the book, titled Manufacturing and Service Processes, focuses on the design of internal processes. Chapters 7 and 9 cover the unique characteristics of production and service processes. The supplement to Chapter 9 discusses health care services, an industry of interest to many students taking the course. Important technical material that relates to design activities is covered in Chapters 8 (Facility Layout) and 10 (Waiting Line Analysis and Simulation).

Chapter 11, Process Design and Analysis, is a nuts-and-bolts chapter on process flow charting and static process analysis using some easily understood real-life examples. The supplement to Chapter 11 discusses how these techniques are used in consulting businesses, another industry of interest to many students taking the course.

An essential element of process design is quality. Quality Management is the topic of Chapter 12. Here we cover total quality management concepts, quality analysis tools, and ISO 9000 and 14000. Technical details covering all the statistical aspects of quality are in Chapter 13 (Statistical Quality Control).

The third section of the book, titled Supply Chain Processes, expands our focus to the entire distribution system from the sourcing of material and other resources to the distribution of products and services. We discuss the concepts behind lean manufacturing and just-in-time processes in Chapter 14. These are ideas used by companies throughout the world and are key drivers for efficient and quick-responding supply systems. Many different transformation processes are needed to put together a supply chain. There are critical decisions such as: Where should we locate our facility? What equipment should we buy or lease? Should we outsource work or do it in-house? These are the topics of Chapters 15 and 16 that relate to logistics, distribution, location of facilities, sourcing, and procurement. All of these decisions have a direct financial impact on the firm.

Section Four, titled Supply and Demand Planning and Control, covers the techniques required to actually run the system. This is at the heart of OSCM. The Internet of Things (Chapter 17) is a term used to describe the connection of intelligent devices through the Internet. This technology combined with the use of enterprise resource planning systems has rapidly changed the way business is done today. The basic building blocks are Forecasting (Chapter 18), Sales and Operations Planning (Chapter 19), Inventory Management (Chapter 20), Material Requirements Planning (Chapter 21), and Workcenter Scheduling (Chapter 22). These daily processes are often partially automated with computer information systems.

Making fact-based decisions is what OSCM is all about, so this book features extensive coverage of decision-making approaches and tools. One useful way to categorize decisions is by the length of the planning horizon, or the period of time that the decision maker must consider. For example, building a new plant would be a long-term decision that a firm would need to be happy with for 10 to 15 years into the future. At the other extreme, a decision about how much inventory for a particular item should be ordered for tomorrow typically has a much shorter planning horizon of a few months or, in many cases, only a few days. Such short-term decisions are usually automated using computer programs. In the intermediate term are decisions that a company needs to live with for only 3 to 12 months. Often these decisions correspond to yearly model changes and seasonal business cycles.

As you can see from this discussion, this material is all interrelated. A company's strategy dictates how operations are designed. The design of the operation dictates how it needs to be managed. Finally, because businesses are constantly being presented with new opportunities through new markets, products, and technologies, a business needs to be very good at managing change.

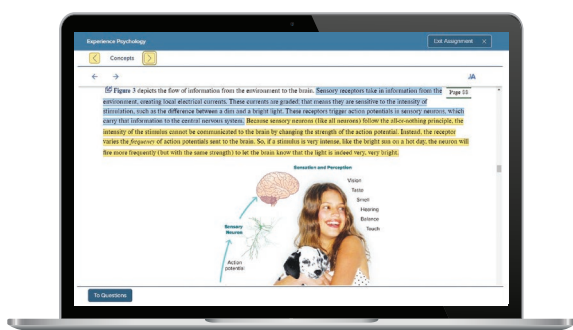
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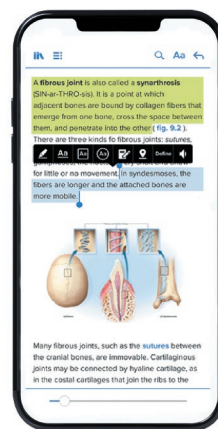
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“I really liked this app—it made it easy to study when you don't have your textbook in front of you.”

- Jordan Cunningham,
Eastern Washington University

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Many very talented scholars have made major contributions to specific chapters in this edition of the book. We are pleased to thank the following individuals:

Ronny Richardson of Kennesaw State University and Emily Bello of University of Louisville, who spent countless hours checking problems and improving Connect.

Supplements are a great deal of work to write, and we appreciate the efforts that make teaching the course easier for everyone who uses the text. Emily Bello of University of Louisville updated the test bank and created the Connect guided examples. Ronny Richardson of Kennesaw State University updated the PowerPoint decks.

We also want to thank the following individuals for their thoughtful reviews of the previous edition and their suggestions for this text: Dr. Richard Dawe, Golden Gate University; Robert G. Stoll, Ashland University; Janaina Siegler, Butler University; Jennifer Flanagan, Texas Woman's University; Drew Stapleton, University of Wisconsin La Crosse; Henry Aigbedo, Oakland University; Olga Pak, Penn State University; Iddrisu Awudu, Quinnipiac University; Art Hudson, Villanova University; Vinay Gonela, Texas A&M University; Stanislaus Solomon, Southern Illinois University Edwardsville; Kaan Kuzu, University of Wisconsin Milwaukee; Ana L. Rosado Feger, Ohio University; Jeffrey D. Vondy, University of Mary; Jan Zantinga, University of Georgia; Dr. Cristiane Biazzin, Northern Kentucky University; Dr. Balaji Janamanchi, Texas A&M International University; Robert Myers, Georgia Tech University; Steve Lundregan, Ohio State University; Mark Hanna, Georgia Southern University.

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Finally, I want to thank my past coauthors Dick Chase and Nick Aquilano for giving me the opportunity to work with them on their book for the past 25 years. I had the opportunity to work with Nick Aquilano on two editions of the book and with Dick Chase on six editions. They have been an inspiration to me and wonderful colleagues.

F. Robert Jacobs

NOTE TO INSTRUCTORS

Discussion of Seventeenth Edition Revisions

The revisions to the seventeenth edition are a reflection of how the field is changing and an intent to make the material relevant to students. Each chapter is organized around a short set of learning objectives. These learning objectives define the major sections of each chapter. A complete set of Discussion Questions together with Objective Questions, which include concepts and problems, are included.

The many questions now included in each chapter are all available for use in Connect, the automated assignment grading system available to adopters of the book. In addition, Interactive Excel exercises are now available in Connect.

Much work has been put into Connect to make it an easy to use and reliable tool. The Objective Question problems are available and many have both static versions (these are identical to the problem in the book) and scenario versions. In the scenario versions of the problem, the parameters have been changed, but the problem is essentially the same, thus allowing students to see different examples of the same problem. The instructor can select predefined or set up custom problem sets that students can complete. These are automatically graded with the results available in a spreadsheet that can be easily downloaded by the instructor. There are many options for how these problem sets can be used, such as allowing the students multiple tries, giving the students help, and timed exams.

In this edition, we have continued to focus on supply chain analytics, while featuring material on more specialized applications such as health care, consulting, investment analysis, and optimization. Supply chain analytics involve the analysis of data to better solve business problems. We recognize that this is not really a new concept because data have always been used to solve business problems. But what is new is the reality that there are so much more data now available for decision making.

In the past, most analysis involved the generation of standard and ad hoc reports that summarized the current state of the firm. Software allowed query and “drill down” analysis to the level of the individual transaction, useful features for understanding what happened in the past. Decision making was typically left to the decision makers, based on their judgment or simply because they were aware of the rules. The new “analytics” movement takes this to a new level using statistical analysis, forecasting to extrapolate what to expect in the future, and even optimization, possibly in real time, to support decisions.

In this edition, our goal is to capture this spirit of using integrated analytic and strategic criteria in making operations and supply chain decisions. We have done this in two major ways. First, we have organized the material in the book by integrating the strategic and analytic material. Next, we have added 4 new Analytics Exercises (we now have 15 in total) spread throughout the chapters. In this edition, many small changes designed to increase clarity, simplify assumptions, and make the exercises better learning tools have been made.

These Analytics Exercises use settings that are modern and familiar to students taking the course. They include Starbucks, cell phones, notebook computers, a wholesale tree farm company, Taco Bell Restaurant, Toyota, a retail website-based company, and industrial products that are sourced from China/Taiwan and sold globally. The book has been reorganized into four major sections: Strategy, Products, and Capacity; Manufacturing and Service Processes; Supply Chain Processes; and Supply and Demand Planning and Control. Our strategy is to weave analytics into the managerial material so students see the important role of data analysis in making operations and supply chain management decisions.

In the first section, Strategy, Products, and Capacity, our chapters cover Strategy, Design of Products and Services, Projects, Strategic Capacity Management, Investment Analysis, and Learning Curves. The key themes of operations strategy, product design to support the strategy, and strategic capacity are a good foundation for learning about operations and supply chain management. Because most strategic plans are implemented using projects, we include this topic in the first section as well. In the projects chapter, we introduce a good amount of

material on product design through examples and exercises, emphasizing the strategic importance of these projects to the success of the firm.

The second section, Manufacturing and Service Processes, gets into the nuts and bolts of operations management. The section introduces the ways manufacturing and service systems are organized. The Quality Management and Statistical Quality Control chapters cover topics that would be appropriate for a green-belt program and include good coverage of the popular value-stream mapping technique.

The third section, Supply Chain Processes, discusses processes that source material for internal operations and then distribute products to the customers. The analytic models involved with location/transportation are included here. The topics are tied together in the Lean Supply Chain chapter, which now stresses the cost versus disruption risk trade-offs that are involved in such tactics as single sourcing and just-in-time inventory.

The fourth section, Supply and Demand Planning and Control, covers the techniques typically implemented in Enterprise Resource Planning Systems. These include Forecasting, Sales and Operations Planning, Inventory Management, Material Requirements Planning, and Workcenter Scheduling. We also include supplements on Linear Programming Using the Excel Solver and the Theory of Constraints, a set of thought-provoking concepts.

The following is a list of the major revisions in selected chapters:

- *Chapter 1 Introduction*—The initial example was changed and now relates to making three types of jeans using a combination of domestic and global suppliers. Insight from the impact of supply chain disruptions has been added to current OSCM issues. The Analytics Exercise using efficiency measures was updated, and it is now easier to obtain the comparison data.
- *Chapter 2 Strategy*—The opening vignette now features Moderna, the innovative COVID-19 vaccine provider. The Activity-System-Map was updated. The section on risk was rewritten to reflect current thought. The new Analytics Exercise “Carbon Footprint Quiz,” was added. This is an exercise requiring CO₂ emissions calculations.
- *Chapter 3 Design of Products and Services*—A new opening vignette that features the All-Electric Chevy Silverado RST pickup truck was written for this chapter. There are also many updates to examples in the chapter.
- *Chapter 4 Projects*—The new opening vignette features Starlink, the innovative Elon Musk project that provides broadband Internet using a constellation of satellites in low-Earth orbit. Many other edits were made to the chapter to clarify notation.
- *Chapter 5 Strategic Capacity Management*—The opening vignette featuring the Tesla Model 3 was updated. Objective Question 9 was updated to make it easier to understand. The Shouldice Hospital case was updated.
- *Chapter 5S Investment Analysis*—Only minor changes were made.
- *Chapter 6 Learning Curves*—A new Tesla’s Model 3 Learning Curve Analytics Exercise was added. New material was added to the chapter showing how to fit a power function to historical production data to obtain learning curve parameters using Excel. The new Analytics Exercise uses the technique.
- *Chapter 7 Manufacturing Processes*—A new AI Manufacturing Technology opening vignette was written. The vignette discusses the use of vision technology for monitoring manufacturing processes.
- *Chapter 7S Manufacturing Technology*—Only minor changes were made.
- *Chapter 8 Facility Layout*—The pictures were changed to better correspond to the different types of layouts described in the chapter. Objective Question 8 was updated to clarify what is meant by *rectilinearly*.
- *Chapter 9 Service Processes*—A new opening vignette featuring Orlando Universal Studios was added. Material on platform services was updated, and many other changes were made to better reflect the impact the Internet has had on services.
- *Chapter 9S Health Care*—Changes were made to the capacity metrics to reflect what is currently used by health care providers.

- *Chapter 10 Waiting Line Analysis and Simulation*—Objective Question 18 was updated to make it clearer.
- *Chapter 11 Process Design and Analysis*—When Little’s Law is appropriate for use was clarified. The Runner Edge case was rewritten to remove reference to queuing models.
- *Chapter 11S Operations Consulting*—This was updated to focus on Operating Consulting. Terminology was updated to remove *reengineering*. Other updates reflect current companies.
- *Chapter 12 Quality Management*—The title of the chapter to better reflect current thought. The Baldrige Award criteria were revised, and Tesla’s Quality Challenge case was updated to reflect new global activity of the company.
- *Chapter 13 Statistical Quality Control*—Terminology in the opening vignette was revised to reduce confusion. The standard deviation formula was fixed, the solution to Solved Problem 3 was rewritten, and previous edition Objective Questions 11 and 12 were deleted.
- *Chapter 14 Lean Supply Chains*—The opening vignette on the hazards of lean manufacturing practices learned during the COVID-19 Pandemic is new. The term *muda* as often used to refer to elimination of waste in supply chains was added, and the Value Stream Mapping presentation was updated.
- *Chapter 15 Logistics and Distribution Management*—The name of chapter was changed to better reflect the topics in it, and the section on Distribution Facilities was rewritten to reflect refinements in the use of the terms *warehouse*, *distribution center*, and *fulfillment center*. Two OSCM at Work boxes were added; one describes Amazon’s supply chain, and the other features self-driving truck technology.
- *Chapter 16 Global Sourcing and Procurement*—The new opening vignette How the COVID-19 Pandemic Led to Empty Shelves introduces the bullwhip effect in the context of shortages in toilet paper. The new OSCM at Work box titled SpaceX—Orbit Freight Carrier was included. The impact of reusable rockets on the ability to place satellites in Earth orbit is described. Examples in the chapter were also updated.
- *Chapter 17 The Internet of Things and ERP*—A new opening vignette titled The World of Connected Assets was added.
- *Chapter 18 Forecasting*—The Starbucks opening vignette was updated. A new OSCM at Work that describes the use of Artificial Intelligence (AI) in Demand Forecasting was added. Finally, the new Analytics Exercise Forecasting Demand at Sebastian River Farms uses regression to find a trend line. It then moves to the calculation of multiplicative season indexes to forecast future demand.
- *Chapter 19 Sales and Operations Planning*—The costs in the examples were updated to better reflect current values. The name of Bradford Manufacturing in the Analytics Exercise was changed, and the data in it were updated.
- *Chapter 19S Linear Programming Using the Excel Solver*—Only minor edits were made.
- *Chapter 20 Inventory Management*—The new Analytics Exercise Inventory Control at Sebastian River Farms was added. The exercise involves setting reorder points and tree-planting decisions at a tree farm.
- *Chapter 21 Material Requirements Planning*—The description of MRP and the Least Unit Cost section were updated.
- *Chapter 22 Workcenter Scheduling*—The new opening vignette that describes the scheduling of Major League Baseball teams was added.
- *Chapter 22S Theory of Constraints*—The five-step focusing process for bank loans was updated.

F. Robert Jacobs
June 2022

Walkthrough

The following section highlights the key features developed to provide you with the best overall text available. We hope these features give you maximum support to learn, understand, and apply operations concepts.

Chapter Opener

Opening Vignettes

Each chapter opens with a short vignette to set the stage and help pique students' interest in the material about to be studied. A few examples include

- Tesla, Chapter 5
- Disney, Chapter 12
- Amazon, Chapter 20

Facility Layout

8

Learning Objectives

- LO8-1** Analyze the common types of manufacturing layouts.
- LO8-2** Illustrate layouts used in nonmanufacturing settings.

Amazon Go—The Cashierless Grocery Store

The Amazon Go stores are built around a new technology so you can walk in the store, take what ever you want from the shelves, and then just walk out. You are automatically charged for whatever you took.

Amazon envisions all types of Go stores: grocery stores where you get some food items, lunchtime spots that sell prepared foods like sandwiches and salads, or stores that sell refrigerated food kits with different ingredients for cooking a full meal.

The new stores are loaded with technology, with hundreds of sensors and cameras monitoring everything the customer does. The normal retail store pay areas with checkout stands and cashiers are not needed in a Go store. The stores rely on image recognition software and artificial intelligence to make the magic happen. Amazon has developed

a proprietary code that uses circles and diamonds to identify things in the stores. They use weight sensors to know when something has been removed or placed back on a shelf.

On leaving the store, the customer is given a precise list of what was bought. Think of the data that Amazon collects about each customer. They know precisely the path you took through the store, what products you picked up and considered, and exactly how much time you spent in the store. This data can be used to improve the selection offered in the store and optimize the layout of shopping areas.



THE AMAZON GO STOREFRONT.
Rocky Gimes/Shutterstock

193

From Bean to Cup: Starbucks Global Supply Chain Challenge

Starbucks Corporation is the largest coffeehouse company in the world, with over 34,000 stores in more than 84 countries. The company serves over 140 million customers each week.

Forecasting demand for a Starbucks is an amazing challenge. The product line goes well beyond drip-brewed coffee sold on demand in the stores. It includes espresso-based hot drinks, other hot and cold drinks, coffee beans, salads, hot and cold sandwiches and paninis, pastries, snacks, and items such as mugs and tumblers. Many of the company's products are seasonal or specific to the locality of the store.

Starbucks-branded ice cream and coffee are also offered at grocery stores around the world.

The creation of a single, global logistics system was important for Starbucks because of its far-flung supply chain. The company generally brings coffee beans from Latin America, Africa, and Asia to the United States and Europe in ocean containers. From the port of entry, the "green" (unroasted) beans are trucked to storage sites, either at a roasting plant or nearby. After the beans are roasted and packaged, the finished product is trucked to regional distribution centers, which range from 200,000 to 300,000 square feet in size. Coffee, however, is only one of the many products held at these distribution centers. They also handle other items required by Starbucks retail outlets, everything from furniture to cappuccino mix.

In the first Analytics Exercise at the end of the chapter, we consider the challenging demand forecasting problem that Starbucks must solve to successfully run this complex supply chain.



STARBUCKS COFFEE IN BUR JUMAN CENTER SHOPPING MALL, DUBAI, UNITED ARAB EMIRATES.
Atkinson Phototravel/Getty Images

487

OSCM at Work—SpaceX—Orbit Freight Carrier

Elon Musk, the innovative billionaire who popularized the idea of the electric vehicle with Tesla Motors, recently announced the prices SpaceX charges to move satellites into orbit. Companies that operate communications satellites in orbit need to figure out some way to get these gadgets into space. In the early days, these companies hitched rides on NASA rockets, the Space Shuttle, and other government vehicles. Today there are more options including rockets launched by countries and private companies.

SpaceX has made the idea of putting a satellite into orbit much like sending a load of merchandise across the country in a truck. The company has two reusable vehicles, the Falcon 9 and the Falcon Heavy, each of which can carry many satellites into space on a single launch. There is now a price tag on carrying items into space, much as there is a price to ship goods on a truck across the country. Of course, it is a little more expensive. A slot on a Falcon 9 was listed as starting at \$1.1 million. A whole Falcon 9 can be reserved for \$67 million, and the larger Falcon Heavy goes for \$97 million—an amazing bargain compared to options available in the past.



Joseph Marino/Alamy Stock Photo

It will be interesting to track what SpaceX, led by Elon Musk, does in the future with the new Starship that is being developed. To give some perspective, the Falcon 9 carries 22,800 kgs in space, the Falcon Heavy carries 63,800 kgs, and the Starship will carry over 100,000 kgs. It is estimated that the Starship also can carry 100 people into space at a time.

OSCM at Work Boxes

The boxes provide examples or expansions of the topics presented by highlighting leading companies practicing new, breakthrough ways to run their operations. Examples include:

- “Inspire the World, Create the Future,” Chapter 3
- Animation and Simulation Software, Chapter 10
- Malcom Baldrige National Quality Award, Chapter 12
- Open Information Warehouse, Chapter 17

Key Ideas

Important points in the text are called out and summarized in the margins.

KEY IDEA



Companies are positioned in different places in the supply chain. Within the context of their position, they all require planning, sourcing, making, delivering, and returning processes.

Solved Problems

Representative problems are placed at the end of appropriate chapters. Each includes a worked-out solution, giving students a review before solving problems on their own.

Solved Problems

LO10-2 SOLVED PROBLEM 1

Quick Lube Inc. operates a fast lube and oil change garage. On a typical day, customers arrive at the rate of three per hour and lube jobs are performed at an average rate of one every 15 minutes. The mechanics operate as a team on one car at a time.

Assuming Poisson arrivals and exponential service, find

- Utilization of the lube team.
- The average number of cars in line.
- The average time a car waits before it is lubed.
- The total time it takes to go through the system (that is, waiting in line plus lube time).

Solution

$$\lambda = 3, \mu = 4$$

- Utilization $\rho = \frac{\lambda}{\mu} = \frac{3}{4} = 75\%$.
- $L_q = \frac{\lambda^2}{\mu(\mu - \lambda)} = \frac{3^2}{4(4 - 3)} = \frac{9}{4} = 2.25$ cars in line.
- $W_q = \frac{L_q}{\lambda} = \frac{2.25}{3} = 0.75$ hour, or 45 minutes.
- $W_s = \frac{L_s}{\lambda} = \frac{\lambda}{\mu - \lambda} / \lambda = \frac{3}{4 - 3} / 3 = 1$ hour (waiting + lube).

Concept Connections

The Concept Connections grid appears at the end of every chapter. This tool draws students' attention to the main points, key terms, and formulas for each learning objective. The organization of the Concept Connections gives students a quick and effective reference when applying the chapter content.

Concept Connections

LO10-1 Understand what a waiting line problem is.

Summary

- The study of waiting in line is the essence of this problem. Queuing theory is the mathematical analysis of the waiting line.
- A queuing (or waiting line) system is composed of three major parts: (1) the customers arriving to the system, (2) the servicing of the customers, and (3) how customers exit the system.
- Queuing theory assumes that customers arrive according to a Poisson arrival distribution and are served according to an exponential service time distribution. These are specific probability distributions that often match well with actual situations.

Key Terms

Queuing system A process where customers wait in line for service.

Arrival rate The expected number of customers that arrive each period.

Exponential distribution A probability distribution associated with the time between arrivals.

Poisson distribution Probability distribution for the number of arrivals during each time period.

Service rate The number of customers a server can handle during a given time period.

Practice Exams

The Practice Exams are designed to allow students to see how well they understand the material using a format that is similar to what they might see in an exam. This feature includes many straightforward review questions, but also has a selection that tests for mastery and integration/application level understanding, that is, the kind of questions that make an exam challenging. The practice exams include short answers at the bottom so students can see how well they have answered the questions.

Practice Exam

Answer the following questions. Answers are listed at the end of this section.

1. The queuing models assume that customers are served in what order?
2. Consider two identical queuing systems except for the service time distribution. In the first system, the service time is random and Poisson distributed. The service time is constant in the second system. How would the waiting time differ in the two systems?
3. What is the average utilization of the servers in a system that has three servers? On average, 15 customers arrive every 15 minutes. It takes a server exactly three minutes to wait on each customer.
4. What is the expected waiting time for the system described in question 3?
5. Firms that desire high service levels where customers have short wait times should target server utilization levels at no more than this percentage.
6. In most cases, if a firm increases its service capacity by 10 percent, it would expect waiting times to be reduced by what percentage? Assume customer arrivals and service times are random.
7. An ice cream stand has a single window and one employee to serve customers. During their busy season, 30 customers arrive each hour, on average. It takes 1.5 minutes, on average, to serve a customer. What is the utilization of the employee?
8. How long would customers have to wait in line, on average, at the ice cream shop discussed in question 7?
9. Random service times can be modeled by this.
10. A bank teller takes 2.4 minutes, on average, to serve a customer. What would be the hourly service rate used in the queuing formulas?
11. There are three teller windows in the bank described in the prior question. On average, 60 customers per hour arrive at the bank. What will be the average number of customers in line at the bank?

Answers to Practice Exam 1. First come, first served 2. Waiting time in the first system is two times the second. 3. 100% 4. Infinite 5. 70-80% 6. Greater than 10% 7. 75% 8. .075 hours, or 4.5 minutes 9. Exponential distribution 10. 25 customers per hour 11. 2.5888 (from Exhibit 10.9)

