

Jacobs • Chase • Aquilano

Operations & Supply Management

Twelfth Edition

**This
International
Student Edition
is for use
outside of
the U.S.**

McGraw-Hill International Edition



FOR SALE IN THE PHILIPPINES ONLY

OPERATIONS AND SUPPLY MANAGEMENT

twelfth edition

F. ROBERT JACOBS


Indiana University

RICHARD B. CHASE

University of Southern California

NICHOLAS J. AQUILANO

University of Arizona

 **McGraw-Hill
Irwin**

Boston Burr Ridge, IL Dubuque, IA Madison, WI New York San Francisco St. Louis
Bangkok Bogotá Caracas Kuala Lumpur Lisbon London Madrid Mexico City
Milan Montreal New Delhi Santiago Seoul Singapore Sydney Taipei Toronto

SECTION ONE

STRATEGY

- 1 Introduction to the Field 2
- 2 Operations and Supply Strategy 20
- 2A Linear Programming Using the Excel Solver 36
- 3 Project Management 56
- 4 Product and Service Design 90

SECTION TWO

PROCESSES

- 5 Strategic Capacity Management 120
- 5A Learning Curves 142
- 6 Process Analysis 158
- 6A Job Design and Work Measurement 186
- 7 Manufacturing Processes 204
- 7A Facility Layout 220
- 8 Service Processes 254
- 8A Waiting Line Analysis 276
- 9 Six-Sigma Quality 306
- 9A Process Capability and SPC 328

SECTION THREE

SUPPLY CHAIN DESIGN

- 10 Supply Chain Strategy 356
- 11 Logistics and Facility Location 382
- 12 Lean Manufacturing 402

- 13 Operations Consulting and Reengineering 424

SECTION FOUR

PLANNING AND CONTROLLING THE SUPPLY CHAIN

- 14 Enterprise Resource Planning Systems 454
- 15 Demand Management and Forecasting 466
- 16 Aggregate Sales and Operations Planning 514
- 17 Inventory Control 544
- 18 Material Requirements Planning 588

SECTION FIVE

SCHEDULING

- 19 Scheduling 622
- 19A Simulation 652
- 20 Constraint Management 678

SUPPLEMENTS

- A Financial Analysis 713
- B Operations Technology 730

APPENDICES

- A Answers to Selected Problems 738
- B Learning Curve Tables 741
- C Present Value Table 743

D Negative Exponential Distribution:
Values of e^{-x} 744

E Areas of the Cumulative Standard
Normal Distribution 745

F Uniformly Distributed Random Digit 746

G Interest Tables 747

PHOTO CREDITS 751

NAME INDEX 753

SUBJECT INDEX 755

SECTION ONE

STRATEGY

1 INTRODUCTION TO THE FIELD 2

- How IKEA Designs Its Sexy Prices 3
- Operations and Supply Management: A Critical Responsibility of Every Manager 4
 - Case: Progressive Insurance 5
 - Efficiency, Effectiveness, and Value 6
- What Is OSM? 7
- Supply Chain Transformation Processes 8
- Differences between Services and Goods 10
 - The Goods–Services Continuum 11
 - Growth of Services 11
- Careers in OSM 12
 - Chief Operating Officer 13
- Historical Development of OSM 14
 - Lean Manufacturing, JIT, and TQC 16
 - Manufacturing Strategy Paradigm 16
 - Service Quality and Productivity 16
 - Total Quality Management and Quality Certification 16
 - Business Process Reengineering 17
 - Six-Sigma Quality 17
 - Supply Chain Management 17
 - Electronic Commerce 17
 - Service Science 17
- Current Issues in OSM 18
- Key Terms 18
- Review and Discussion Questions 19
- Case: Fast-Food Feast 19
- Selected Bibliography 19
- Footnotes 19

2 OPERATIONS AND SUPPLY STRATEGY 20

- The Tao of Timbuk2 21
- What Is Operations and Supply Strategy? 22
 - Competitive Dimensions 22
 - The Notion of Trade-Offs 24
 - Order Winners and Order Qualifiers: The Marketing–Operations Link 25
- Strategic Fit: Fitting Operational Activities to Strategy 25
- A Framework for Operations and Supply Strategy 27

- Productivity Measurement 28
- How Does Wall Street Evaluate Operations Performance? 30
- Conclusion 31
- Key Terms 31
- Solved Problem 31
- Review and Discussion Questions 31
- Problems 32
- Internet Enrichment Exercise: Harley-Davidson Motorcycles 33
- Case: Timbuk2 34
- Selected Bibliography 35

2A LINEAR PROGRAMMING USING THE EXCEL SOLVER 36

- Introduction 37
- The Linear Programming Model 38
- Graphical Linear Programming 39
- Linear Programming Using Microsoft Excel 41
- Key Terms 45
- Solved Problems 45
- Problems 53
- Selected Bibliography 55
- Footnote 55

3 PROJECT MANAGEMENT 56

- Apple's iPod Has Its Own Product Development Team 57
- What Is Project Management? 59
- Structuring Projects 59
 - Pure Project 59
 - Functional Project 60
 - Matrix Project 61
- Work Breakdown Structure 62
- Project Control Charts 63
- Network-Planning Models 65
 - Critical Path Method (CPM) 65
 - CPM with Three Activity Time Estimates 70
 - Time–Cost Models 72
- Managing Resources 76
- Conclusion 77
- Key Terms 77
- Formula Review 78
- Solved Problems 78
- Review and Discussion Questions 81
- Problems 81

- Advanced Problem 87
- Case: The Campus Wedding (A) 87
- Case: The Campus Wedding (B) 88
- Case: Cell Phone Design Project 89
- Selected Bibliography 89

4 PRODUCT AND SERVICE DESIGN 90

- IDEO Product Development—Can You Learn Creativity? 91
- The Product Design Process 93
- The Product Development Process 94
- Economic Analysis of Product Development Projects 99
 - Build a Base-Case Financial Model* 99
 - Sensitivity Analysis to Understand Project Trade-Offs* 102
- Designing for the Customer 103
 - Quality Function Deployment* 103
 - Value Analysis/Value Engineering* 104
- Designing Products for Manufacture and Assembly 105
 - How Does Design for Manufacturing and Assembly (DFMA) Work?* 105
- Designing Service Products 108
- Measuring Product Development Performance 109
- Conclusion 110
- Key Terms 110
- Solved Problem 111
- Review and Discussion Questions 113
- Internet Enrichment Exercise 113
- Problems 113
 - Case: IKEA: Design and Pricing 116
 - Case: Dental Spa 118
- Selected Bibliography 118
- Footnotes 118

SECTION TWO

PROCESSES

5 STRATEGIC CAPACITY MANAGEMENT 120

- Pharmaceuticals Have Challenging Capacity Decisions 121
- Capacity Management in Operations 122
- Capacity Planning Concepts 124
 - Economies and Diseconomies of Scale* 124
 - The Learning Curve* 125
 - Where Economies of Scale Meet the Learning Curve* 125
 - Capacity Focus* 125
 - Capacity Flexibility* 126
- Capacity Planning 127
 - Considerations in Adding Capacity* 127
 - Determining Capacity Requirements* 128
 - Using Decision Trees to Evaluate Capacity Alternatives* 130
- Planning Service Capacity 133
 - Capacity Planning in Service versus Manufacturing* 133
 - Capacity Utilization and Service Quality* 133

- Conclusion 134
- Key Terms 135
- Solved Problem 135
- Review and Discussion Questions 136
- Problems 137
 - Case: Shouldice Hospital—A Cut Above 139
- Selected Bibliography 140
- Footnotes 141

5A LEARNING CURVES 142

- Application of Learning Curves 143
- Plotting Learning Curves 144
 - Logarithmic Analysis* 145
 - Learning Curve Tables* 145
 - Estimating the Learning Percentage* 148
 - How Long Does Learning Go On?* 149
- General Guidelines for Learning 149
 - Individual Learning* 149
 - Organizational Learning* 150
- Learning Curves Applied to Heart Transplant Mortality 151
- Key Terms 153
- Formula Review 153
- Solved Problems 153
- Review and Discussion Questions 154
- Problems 154
- Selected Bibliography 157
- Footnotes 157

6 PROCESS ANALYSIS 158

- Customer-Driven Service for McDonald's 159
 - Self-Ordering Kiosks and Environment* 159
- Process Analysis 160
 - Analyzing a Las Vegas Slot Machine* 161
- Process Flowcharting 162
- Types of Processes 164
 - Buffering, Blocking, and Starving* 164
 - Make-to-Stock versus Make-to-Order* 165
- Measuring Process Performance 168
- Process Analysis Examples 170
 - A Bread-Making Operation* 170
 - A Restaurant Operation* 172
 - Planning a Transit Bus Operation* 173
- Process Throughput Time Reduction 175
- Conclusion 177
- Key Terms 178
- Solved Problem 179
- Review and Discussion Questions 180
- Problems 180
 - Advanced Problem 183
 - Case: Analyzing Casino Money-Handling Processes 183
 - Case: Kristen's Cookie Company (A) 184
- Selected Bibliography 185
- Footnotes 185

6A JOB DESIGN AND WORK MEASUREMENT 186

- Job Design Decisions 187
- Behavioral Considerations in Job Design 188
 - Degree of Labor Specialization* 188

- Job Enrichment* 189
Sociotechnical Systems 189
 Work Measurement and Standards 190
Work Measurement Techniques 190
Time Study 192
Work Sampling 194
Work Sampling Compared to Time Study 198
 Conclusion 200
 Key Terms 200
 Formula Review 200
 Solved Problems 200
 Review and Discussion Questions 201
 Problems 202
 Selected Bibliography 203
 Footnotes 203
- 7 MANUFACTURING PROCESSES 204**
 Toshiba: Producer of the First Notebook Computer 205
 How Production Processes Are Organized 206
 Break-Even Analysis 207
 Manufacturing Process Flow Design 208
 Conclusion 213
 Key Terms 213
 Solved Problems 214
 Review and Discussion Questions 215
 Problems 215
 Case: Circuit Board Fabricators, Inc. 218
 Selected Bibliography 219
 Footnotes 219
- 7A FACILITY LAYOUT 220**
 Basic Production Layout Formats 221
 Workcenters 222
Systematic Layout Planning 226
 Assembly Lines 227
Assembly-Line Balancing 227
Splitting Tasks 230
Flexible and U-Shaped Line Layouts 232
Mixed-Model Line Balancing 232
Current Thoughts on Assembly Lines 234
 Cells 235
Developing a Manufacturing Cell 235
Virtual Manufacturing Cells 235
 Project Layouts 235
 Retail Service Layout 237
Servicescapes 238
Signs, Symbols, and Artifacts 240
 Office Layout 240
 Conclusion 240
 Key Terms 241
 Solved Problems 241
 Review and Discussion Questions 245
 Problems 245
 Advanced Problem 250
 Case: Soteriou's Souvlaki 251
 Case: State Automobile License Renewals 252
 Selected Bibliography 253
 Footnotes 253
- 8 SERVICE PROCESSES 254**
 My Week as a Room-Service Waiter at the Ritz 255
 The Nature of Services 256
 An Operational Classification of Services 257
 Designing Service Organizations 258
 Structuring the Service Encounter: Service-System Design Matrix 259
Strategic Uses of the Matrix 261
 Service Blueprinting and Fail-Safing 261
 Three Contrasting Service Designs 263
The Production-Line Approach 264
The Self-Service Approach 264
The Personal-Attention Approach 265
 Managing Customer-Introduced Variability 268
 Applying Behavioral Science to Service Encounters 269
 Service Guarantees as Design Drivers 270
 Conclusion 271
 Key Terms 271
 Review and Discussion Questions 272
 Problems 272
 Case: Pizza USA: An Exercise in Translating Customer Requirements into Process Design Requirements 273
 Case: Contact Centers Should Take a Lesson from Local Businesses 274
 Selected Bibliography 274
 Footnotes 275
- 8A WAITING LINE ANALYSIS 276**
 Economics of the Waiting Line Problem 277
The Practical View of Waiting Lines 277
 The Queuing System 278
Customer Arrivals 279
Distribution of Arrivals 280
The Queuing System: Factors 282
Exiting the Queuing System 285
 Waiting Line Models 285
 Approximating Customer Waiting Time 294
 Computer Simulation of Waiting Lines 296
 Conclusion 296
 Key Terms 296
 Formula Review 297
 Solved Problems 298
 Review and Discussion Questions 300
 Problems 300
 Case: Community Hospital Evening Operating Room 304
 Selected Bibliography 305
 Footnotes 305
- 9 SIX-SIGMA QUALITY 306**
 Total Quality Management 308
 Quality Specification and Quality Costs 310
Developing Quality Specifications 310
Cost of Quality 311
Functions of the QC Department 312
 Six-Sigma Quality 313
Six-Sigma Methodology 314

- Analytical Tools for Six Sigma and Continuous Improvement* 315
- Six-Sigma Roles and Responsibilities* 318
- The Shingo System: Fail-Safe Design 319
- ISO 9000 and 14000 320
- External Benchmarking for Quality Improvement 322
- Conclusion 322
- Key Terms 322
- Review and Discussion Questions 323
- Problems 323
- Internet Enrichment Exercises 324
- Case: Hank Kolb, Director of Quality Assurance 324
- Case: Appreciative Inquiry—A Different Kind of Fishbone 326
- Selected Bibliography 327
- Footnotes 327

9A PROCESS CAPABILITY AND SPC 328

- Variation Around Us 330
- Process Capability 331
 - Capability Index (C_{pk})* 332
- Process Control Procedures 336
 - Process Control with Attribute Measurements: Using p Charts* 336
 - Process Control with Variable Measurements: Using \bar{X} and R Charts* 338
 - How to Construct \bar{X} and R Charts* 340
- Acceptance Sampling 343
 - Design of a Single Sampling Plan for Attributes* 343
 - Operating Characteristic Curves* 344
- Conclusion 345
- Key Terms 346
- Formula Review 346
- Solved Problems 347
- Review and Discussion Questions 348
- Problems 348
- Advanced Problem 353
- Case: Hot Shot Plastics Company 353
- Selected Bibliography 354
- Footnotes 354

SECTION THREE

SUPPLY CHAIN DESIGN

10 SUPPLY CHAIN STRATEGY 356

- The World Is Flat 357
- Supply Chain Strategy 358
- Measuring Supply Chain Performance 359
- Supply Chain Design Strategy 361
- Service Supply Chains 365
- Outsourcing 366
- Design for Logistics 370
- Value Density (Value per Unit of Weight) 370
- Global Sourcing 373

- Sourcing/Purchasing—System Design Matrix 374
- Mass Customization 375
- Conclusion 377
- Key Terms 377
- Formula Review 378
- Review and Discussion Questions 378
- Problems 378
- Internet Enrichment Exercises 380
- Case: Pepe Jeans 380
- Selected Bibliography 381
- Footnotes 381

11 LOGISTICS AND FACILITY LOCATION 382

- FedEx: A Leading Global Logistics Company 383
- Logistics 384
- Decisions Related to Logistics 384
- Issues in Facility Location 387
- Plant Location Methods 389
 - Factor-Rating Systems* 389
 - Transportation Method of Linear Programming* 390
 - Centroid Method* 393
- Locating Service Facilities 394
- Conclusion 397
- Key Terms 397
- Formula Review 397
- Solved Problem 397
- Review and Discussion Questions 398
- Problems 398
- Case: Applichem—The Transportation Problem 400
- Selected Bibliography 401
- Footnote 401

12 LEAN MANUFACTURING 402

- Lean Six Sigma at Solectron 403
- Lean Logic 404
- The Toyota Production System 405
 - Elimination of Waste* 405
 - Respect for People* 412
- Lean Implementation Requirements 412
 - Lean Layouts and Design Flows* 412
 - Lean Applications for Line Flows* 413
 - Lean Applications for Workcenter Shops* 414
 - Six-Sigma Quality* 414
 - A Stable Schedule* 415
 - Work with Suppliers* 416
- Lean Services 417
- Conclusion 418
- Key Terms 419
- Formula Review 419
- Solved Problem 419
- Review and Discussion Questions 419
- Problems 420
- Case: Quality Parts Company 420
- Case: Value Chain Mapping Approach 422
- Selected Bibliography 423
- Footnotes 423

13 OPERATIONS CONSULTING AND REENGINEERING 424

- Pittiglio Rabin Todd & McGrath (PRTM)—A Leading Operations Consulting Company 425
- What Is Operations Consulting? 426
- The Nature of the Management Consulting Industry 427
- Economics of Consulting Firms 428
- When Operations Consulting Is Needed 429
 - When Are Operations Consultants Needed?* 430
- The Operations Consulting Process 431
- Operations Consulting Tool Kit 432
 - Problem Definition Tools* 432
 - Data Gathering* 435
 - Data Analysis and Solution Development* 438
 - Cost Impact and Payoff Analysis* 439
 - Implementation* 440
- Business Process
- Reengineering (BPR) 440
- Principles of Reengineering 441
- Guidelines for Implementation 442
- Conclusion 443
- Key Terms 443
- Review and Discussion Questions 443
- Problems 444
- Case: A California Auto Club Reengineers Customer Service 444
- Selected Bibliography 446
- Footnotes 446
- Appendix A: Systems Thinking 446
- Appendix B: RPA Questionnaire and Rating Sheet 451

15 DEMAND MANAGEMENT AND FORECASTING 466

- Wal-Mart's Data Warehouse 467
- Demand Management 468
- Types of Forecasting 469
- Components of Demand 469
- Qualitative Techniques in Forecasting 472
 - Grass Roots* 472
 - Market Research* 472
 - Panel Consensus* 472
 - Historical Analogy* 473
 - Delphi Method* 473
- Time Series Analysis 473
 - Simple Moving Average* 474
 - Weighted Moving Average* 476
 - Exponential Smoothing* 477
 - Forecast Errors* 480
 - Sources of Error* 480
 - Measurement of Error* 481
 - Linear Regression Analysis* 483
 - Decomposition of a Time Series* 487
- Causal Relationship Forecasting 493
 - Multiple Regression Analysis* 495
- Focus Forecasting 495
 - Methodology of Focus Forecasting* 496
- Web-Based Forecasting: Collaborative Planning, Forecasting, and Replenishment (CPFR) 497
- Conclusion 499
- Key Terms 499
- Formula Review 500
- Solved Problems 501
- Review and Discussion Questions 505
- Problems 505
- Case: Altavox Electronics 512
- Selected Bibliography 513
- Footnotes 513

SECTION FOUR**PLANNING AND CONTROLLING THE SUPPLY CHAIN****14 ENTERPRISE RESOURCE PLANNING SYSTEMS 454**

- Information Crisis—The Missing Desk 455
- SAP 457
- SAP Application Modules 458
 - Financials* 459
 - Human Capital Management* 460
 - Operations* 460
 - Corporate Services* 461
- mySAP.com and SAP NetWeaver—Integrated E-Business Applications 461
- Implementing ERP Systems 463
- Conclusion 464
- Key Terms 465
- Review and Discussion Questions 465
- Selected Bibliography 465
- Footnote 465

16 AGGREGATE SALES AND OPERATIONS PLANNING 514

- What Is Sales and Operations Planning? 516
- Overview of Sales and Operations Planning Activities 516
- The Aggregate Operations Plan 518
 - Production Planning Environment* 519
 - Relevant Costs* 520
- Aggregate Planning Techniques 522
 - A Cut-and-Try Example: The JC Company* 522
 - Aggregate Planning Applied to Services: Tucson Parks and Recreation Department* 527
 - Level Scheduling* 529
 - Mathematical Techniques* 531
- Yield Management 532
 - Operating Yield Management Systems* 533
- Conclusion 534
- Key Terms 535
- Solved Problem 535
- Review and Discussion Questions 537
- Problems 538
- Case: Bradford Manufacturing—Planning Plant Production 541

- Selected Bibliography 543
Footnotes 543
- 17 INVENTORY CONTROL 544**
Hospitals Hope to Save by Supply Management 545
Definition of Inventory 547
Purposes of Inventory 548
Inventory Costs 549
Independent versus Dependent Demand 549
Inventory Systems 550
 A Single-Period Inventory Model 551
 Multiperiod Inventory Systems 553
Fixed-Order Quantity Models 555
 Establishing Safety Stock Levels 558
 Fixed-Order Quantity Model with Safety Stock 559
Fixed-Time Period Models 562
 Fixed-Time Period Model with Safety Stock 563
Inventory Control and Supply Chain Management 564
Price-Break Models 565
Miscellaneous Systems and Issues 568
 Three Simple Inventory Systems 568
 ABC Inventory Planning 569
 Inventory Accuracy and Cycle Counting 570
 Inventory Control in Services 572
Conclusion 574
Key Terms 574
Formula Review 575
Solved Problems 576
Review and Discussion Questions 578
Problems 578
Case: Hewlett-Packard—Supplying the DeskJet Printer in Europe 584
Selected Bibliography 586
Footnotes 587
- 18 MATERIAL REQUIREMENTS PLANNING 588**
From Push to Pull 589
Master Production Scheduling 590
 Time Fences 591
Where MRP Can Be Used 592
Material Requirements Planning System Structure 593
 Demand for Products 593
 Bill of Materials 593
 Inventory Records 596
 MRP Computer Program 597
An Example Using MRP 598
 Forecasting Demand 598
 Developing a Master Production Schedule 598
 Bill of Materials (Product Structure) 599
 Inventory Records 599
 Performing the MRP Calculations 600
Improvements in the MRP System 603
 Computing Work Center Load 603
 Closed-Loop MRP 605
 MRP II (Manufacturing Resource Planning) 605
Flow Manufacturing: Embedding JIT into MRP 606
- Lot Sizing in MRP Systems 607
 Lot-for-Lot 608
 Economic Order Quantity 608
 Least Total Cost 609
 Least Unit Cost 610
 Choosing the Best Lot Size 610
Conclusion 611
Key Terms 612
Solved Problems 612
Review and Discussion Questions 614
Problems 614
Case: Brunswick Motors, Inc.—An Introductory Case for MRP 619
Selected Bibliography 620
Footnotes 620

SECTION FIVE

SCHEDULING

- 19 SCHEDULING 622**
Hospitals Cut ER Waits—New “Fast Track” Units, High-Tech IDs Speed Visits; See a Doctor in 17 Minutes 623
Manufacturing Execution Systems 624
The Nature and Importance of Work Centers 624
 Typical Scheduling and Control Functions 625
 Objectives of Work-Center Scheduling 626
 Job Sequencing 627
Priority Rules and Techniques 628
 Scheduling n Jobs on One Machine 628
 Comparison of Priority Rules 630
 Scheduling n Jobs on Two Machines 630
 Scheduling a Set Number of Jobs on the Same Number of Machines 632
 Scheduling n Jobs on m Machines 634
Shop-Floor Control 634
 Gantt Charts 634
 Tools of Shop-Floor Control 635
 Input/Output Control 635
 Data Integrity 636
 Principles of Work-Center Scheduling 638
Personnel Scheduling in Services 638
 Scheduling Consecutive Days Off 638
 Scheduling Daily Work Times 640
 Scheduling Hourly Work Times 640
Conclusion 642
Key Terms 642
Solved Problem 643
Review and Discussion Questions 643
Problems 644
Case: Keep Patients Waiting? Not in My Office 649
Selected Bibliography 650
Footnotes 651
- 19A SIMULATION 652**
Definition of Simulation 653
Simulation Methodology 653
 Problem Definition 654
 Constructing a Simulation Model 654

<i>Specifying Values of Variables and Parameters</i>	656
<i>Evaluating Results</i>	656
<i>Validation</i>	657
<i>Proposing a New Experiment</i>	657
<i>Computerization</i>	657
Simulating Waiting Lines	658
<i>Example: A Two-Stage Assembly Line</i>	658
Spreadsheet Simulation	661
Simulation Programs and Languages	663
<i>Desirable Features of Simulation</i>	
<i>Software</i>	666
Advantages and Disadvantages of Simulation	666
Conclusion	667
Key Terms	667
Solved Problems	667
Review and Discussion Questions	669
Problems	669
Advanced Case: Understanding the Impact of Variability on the Capacity of a Production System	676
Selected Bibliography	677
Footnotes	677
20 CONSTRAINT MANAGEMENT	678
Goal of the Firm	682
Performance Measurements	682
<i>Financial Measurements</i>	682
<i>Operational Measurements</i>	682
<i>Productivity</i>	683
Unbalanced Capacity	684
<i>Dependent Events and Statistical Fluctuations</i>	684
Bottlenecks and Capacity-Constrained Resources	686
Basic Manufacturing Building Blocks	686
Methods for Control	687
<i>Time Components</i>	688
<i>Finding the Bottleneck</i>	689
<i>Saving Time</i>	689
<i>Avoid Changing a Nonbottleneck into a Bottleneck</i>	690
<i>Drum, Buffer, Rope</i>	690
<i>Importance of Quality</i>	693
<i>Batch Sizes</i>	694
<i>How to Treat Inventory</i>	695
Comparing Synchronous Manufacturing to MRP and JIT	697
Relationship With Other Functional Areas	697
<i>Accounting's Influence</i>	697
<i>Marketing and Production</i>	698
Conclusion	705
Key Terms	706
Solved Problem	706
Review and Discussion Questions	707
Problems	708

Case: Solve the OPT Quiz—A Challenge in Scheduling	712
Selected Bibliography	712
Footnotes	712

S U P P L E M E N T S

SUPPLEMENT A 713

Financial Analysis	713
<i>Concepts and Definitions</i>	713
<i>Activity-Based Costing</i>	716
<i>The Effects of Taxes</i>	718
<i>Choosing among Investment Proposals</i>	718
<i>Determining the Cost of Capital</i>	718
<i>Interest Rate Effects</i>	721
<i>Methods of Ranking Investments</i>	724
<i>Sample Problems: Investment Decisions</i>	725
Selected Bibliography	729
Footnotes	729

SUPPLEMENT B 730

Operations Technology	730
<i>Technologies in Manufacturing</i>	730
<i>Computer-Integrated Manufacturing (CIM)</i>	734
<i>Evaluation of Technology Investments</i>	734
Benefits of Technology Investments	735
Conclusion	736
Review and Discussion Questions	736
Selected Bibliography	737

A P P E N D I C E S

A	Answers to Selected Problems	738
B	Learning Curve Tables	741
C	Present Value Table	743
D	Negative Exponential Distribution: Values of e^{-x}	744
E	Areas of the Cumulative Standard Normal Distribution	745
F	Uniformly Distributed Random Digit	746
G	Interest Tables	747

PHOTO CREDITS 751

NAME INDEX 753

SUBJECT INDEX 755

SUBJECT INDEX

Note: Page numbers followed by *n* indicate material in footnotes or chapter endnotes.

A

- A. T. Kearney, 428
- ABC inventory planning, 569–570, 574
- Absolute error, 195, 196
- Accenture, 355, 368, 428, 429, 443
- Acceptable limits for tracking signal, 482
- Acceptable quality level (AQL), 343, 344, 354ⁿ
- Acceptance number (*c*), 343, 344–345
- Acceptance sampling, 313, 343–345
 - operating characteristic curves, 344–345
 - single sampling plan, 343–344
- Access to help, 150
- Accommodation strategies, 268, 269
- Accounting, 697–698
- Accuracy of inventory count, 570–572
- Accurate response, 519
- Activities, 63
 - allocation of overhead by, 717
 - changing sequence of, 175
 - of consumer groups, 25
 - job design principles in, 189–190
 - least-cost activities, 74
 - parallel activities, 165, 175, 177, 441–442
 - in S&OP, 516–518
 - unnecessary, eliminating, 418
 - in value chain mapping, 406
- Activity-based costing, 716–718
- Activity direct costs, 73
- Activity identification, 66, 68, 70
- Activity inspection, 15
- Activity relationship diagrams, 226
- Activity scheduling charts, 15
- Activity-system maps, 26, 27
- Activity time independence, 72
- Activity time variances, 70, 71
- Adaptive control, 730
- Additive seasonal variation, 487, 488
- Adjacency patterns, 226
- Advanced Optical Components, 521
- Advanced Planner and Optimizer (APO)
 - software, 463
- Advanced planning option, 37
- Aesthetics, 310, 311
- After-sale support, 24
- Aggregate operations plan, 516, 517, 518–521, 534
 - production planning environment, 519–520
 - relevant costs, 520–521
- Aggregate planning techniques, 522–532
 - applied to services, 527–529
 - cut-and-try example, 522–527, 531
 - level scheduling, 529–530
 - mathematical techniques, 531–532
- Aggregate sales and operations planning. *See* Sales and operations planning
- Agile supply chains, 364, 376
- AGV (automated guided vehicle) systems, 732, 733
- Airbus, 7
- Airline industry
 - improvement in boarding times, 7
 - scheduling in, 621
 - service utilization in, 134
 - single-period inventory model, 553
 - transformation processes in, 9
 - See also specific airlines*
- Air transportation, 371, 385
- Aisle characteristics, 238
- Alcoa Inc., 343, 387
- Alliance and partnership projects, 58
- α (Alpha)
 - producer's risk, 343, 344
 - smoothing constant, 477, 480
- Alternative path structures, 284, 285
- "Alternative workplaces," 188
- Amazon.com, 15, 17
- Ambient conditions, 238
- AMD, 370
- American Airlines, 532
- American Express, 188, 369, 432
- American Hardware Supply Company, 513ⁿ
- American Management Association
 - International, 367ⁿ
- American Production and Inventory Control Society, 513ⁿ
- American Society of Quality Control, 15
- America Online, 15
- America West, 7
- AMH (automated materials handling) system, 730, 732
- Amortization, 714
- Analysis for Production and Operations Management* (Bowman & Fetter), 14
- Analytical thinking, 7
- Analytical tools of Six Sigma, 315–317
- Andon system, 408
- Anheuser-Busch, 369
- Annuity
 - compound value of, 721–722, App–8
 - present value of, 723–724, App–10
 - present value of annuity of \$1, App–10
 - sum of annuity table, App–8
- ANSI/ASQ Z1.4-2003 standards, 321
- ANSI/ASQ Z1.9-2003 standards, 321
- Answer Report, 44
- Anticipated delay report, 635, 636
- APICS Dictionary, 634
- APO (Advanced Planner and Optimizer)
 - software, 463
- Apple Computer Corp., 13, 14, 57–58, 60
- Appraisal costs (COQ), 311, 312
- AQL (acceptable quality level), 343, 344, 354ⁿ
- Archetypes, 448–449
- Area of feasibility, 39, 40
- Arm's-length relationships, 368
- ARPANET, 17
- Arrival(s), 279
 - distribution of, 280–282
 - exponential distribution, 280
 - Poisson distribution, 281–282, 287, 290
 - waiting lines and, 277–278
- Arrival patterns, 281–282
- Arrival rate, 280
- Arrival variability, 268
- Artifacts, 240
- AS/RS (automated storage and retrieval systems), 732
- Assemble-to-order operations, 593
- Assemble-to-stock operations, 593
- Assembly (gozinto) charts, 208–209, 219ⁿ
- Assembly drawings, 208–209
- Assembly line(s), 206, 624
 - basic format of, 221
 - development of, 16
 - facility layout of, 227–234
 - balancing, 227–230
 - current thinking on, 234
 - examples of, 228, 234
 - flexible or U-shaped, 232
 - mixed-model line balancing, 232–234
 - splitting tasks on, 230–231
 - information assembly line, 264
 - moving, 15
 - pacing, 167–168
 - two-stage, simulating, 658–661
- Assembly-line balancing, 227–230
- Assembly-line balancing problem, 228
- Assembly operations, 592
- Assignable variation, 329
- Assignment method of job scheduling, 632–634
- Association for Operations Management, 384
- "Assortment packing," 372–373
- Asymptotic trend in forecasting, 471, 472
- @RISK simulation program, 664
- AT&T, 188
- Attributes (quality characteristics), 336
 - attribute measurements, 336–338, 346
 - sampling by attributes, 336–338
 - single sampling plan for, 343–344
- Automated guided vehicle (AGV) systems, 732, 733
- Automated manufacturing planning and control systems (MP&CS), 734

- Automated materials handling (AMH) system, 730, 732
- Automated storage and retrieval systems (AS/RIS), 732
- Automated systems, 149
- Automation of manual work, 15, 188
- Automotive industry
 contract manufacturers in, 93
 International Automotive Task Force, 321
 inventory control in, 573
 system dynamics models of, 450
- "Autonomous work groups," 189
- Available space, 223
- Available to promise, 592
- Average(s)
 moving averages, 500
 simple, 470, 474-476
 weighted, 470, 476-477
 smoothed average, 513n
- Average aggregate inventory value, 360
- Average daily demand, 560-562, 575
- Average demand, 469, 471
- Average inventory value, 564, 565, 576
- Avoidable costs, 714
- Avraham Y. Goldratt Institute, 712n
- B**
- B (balancing loops), 438, 447, 448
- Backflush, 415
- Back-office operations, 240-241
- Backordering, 531, 532
- Backordering costs, 520
- Backward scheduling, 625, 697
- Balanced scorecard, 439
- Balancing loops (B), 438, 447, 448
- "Balancing the Professional Service Firm" (Maister), 428
- Baldrige National Quality Award, 15, 16, 266-267, 308-309, 366
- Balking, 282
- Banking
 bank loan as short-term debt, 718-719
 personnel scheduling in, 640, 641
 service contact in, 257, 258
 Theory of Constraints applied to, 681, 703-704, 705
- Bank of Montreal, 439
- Bar chart, 63-65
- Bar-coding technology, 625
- Bar/milestone chart, 64, 65
- Base-case financial model, 99-102
- Basic production costs, 520
- Batch arrival, 282
- Batch operations, 213, 592
- Batch order processing, 460-461
- Batch sizes, 694-695
- Behavioral factors in servicescape layout, 240
- Behavioral science, 269-270
- Benchmarking, 168, 190, 322, 432-433
- Best Buy Co., Inc., 13
- Best Buy International, 13
- Best-known alternative, 714
- Best operating level, 124
- Best practices, 9-10, 320
- β (consumer's risk), 343, 344
- Bias errors, 480
- Bidirectional service supply chain, 365-366
- Bill of materials (BOM) file, 593, 595-596, 599, 600, 611
- Birdcaging, 232
- "Black Belt Program," 17
- Black belts, in Six Sigma, 319
- Black & Decker, 93, 425
- Blame, in service process, 270
- Blaupunkt, 370
- Blockbuster, 269
- Blocking, 164
- BMW AG, 23, 124, 322, 387
- Boeing Co., 7
- BOM (bill of materials) file, 593, 595-596, 599, 600, 611
- Bonds, as long-term debt, 719-720, 722
- Book value, 714
- Booz Allen Hamilton, 370
- Borderless manufacturing, 373
- Boston Consulting Group, 428
- Bottleneck(s), 164-165, 705
 adding, 127
 avoiding creation of, 690
 defined, 690-691
 finding, 689
 input reduction at, 635
 maximizing use of, 702-703
 in multi-step processes, 170-171
 product flow through, 686-688, 695
 saving time at, 689-690
- Bottleneck analysis, 15, 438
- Box Jenkins technique (forecasting), 470
- Boy Scouts, 679-680, 684
- BP Amoco, 265
- BPR. *See* Business process reengineering
- BPR Capture software, 436, 438
- Brainstorming, 92, 105
- Brain surgery projects, 428
- Break-even analysis, 207-208
- Break-even chart, 208
- Breakthrough projects, 58, 60
- Bristol-Myers Squibb, 463
- Buddy system, 234
- Budgets, 521
- Buffer burn rate, 696
- Buffered core, 259, 260
- Buffering
 buffer inventory, 164-165, 359, 360-361, 691
 in service system design, 259-260, 271
 time buffers, 691-692, 696
 variability of cycle times and, 169-170
- Buffer inventory, 164-165, 359, 360-361, 691
- Buffer management, 696
- Building design, 240
- Build-to-order model, 589
- Build-to-stock model, 589
- Bullwhip effect, 361, 362
- Bureaucracy, avoiding, 102
- Bureau of Economic Analysis, U.S., 123, 141n
- Burger King, 166, 167
- Burnout loop, 447, 448
- Business climate, facility location and, 387
- Business One software (SAP AG), 463, 464
- Business process reengineering (BPR), 15, 17, 440-441
 guidelines for implementation, 442-443
 principles of reengineering, 441-442
 in "reinventing government," 6
- C**
- c (acceptance number), 343, 344-345
- Cable News Network (CNN), 17
- CAD (computer-aided design), 105, 730, 734
- CAD/CAM systems, 15, 735
- CAE (computer-aided engineering), 734
- CAFTA (Central America Free Trade Agreement), 389
- Caging, 232
- Call centers, 664
- CAM (computer-aided manufacturing), 734
- Campbell Soup Company, 358-359, 361-362
- Cannondale Bicycle Corp., 548
- Canon, 97
- Capability index (C_{pk}), 332-336, 346
- Capability sourcing, 369
- Capability variability, 268
- Capacity, 122, 686
 addition of, 127, 128, 173, 178
 analyzing capabilities in, 213, 271
 as consideration in MRP, 603-605
 determining (examples of), 172-173, 212
 effects on firm, 123
 finite/infinite loading systems, 624-625
 limited line capacity, 282-283
 planning (*See* Capacity planning; Service capacity planning; Strategic capacity management)
 shop capacity control load flow, 635, 637
 unbalanced, 684-685
 underutilization/overutilization of, 415-416
- Capacity allocation, 190
- Capacity-constrained resource (CCR), 686, 691, 692, 695, 705
- Capacity cushion, 128
- Capacity flexibility, 126-127, 135
 flexible plants, 126
 flexible processes, 127
 flexible workers, 127, 211
- Capacity focus, 125-126, 135
- Capacity loop, 447, 448
- Capacity planning, 123, 127-132, 517
 addition of capacity, 127, 128
 considerations in, 127, 128
 decision trees used in, 130-132
 degree of customer contact and, 258
 determining requirements, 128-129
 long-range, 122, 134
 resource inputs and product outputs in, 122-123
 in services (*See* Service capacity planning)
 short-range, 122, 625
See also Strategic capacity management
- Capacity requirements planning
 master scheduling, 519
 in MRP, 604-605
- Capacity requirements planning (CRP) program, 695
- Capacity resource profile, 689, 692
- Capacity sharing, 127
- Capacity utilization, in service capacity planning, 133-134, 135, 173-175
- Capacity utilization rate, 124
- Capital, cost of, 718-721
 internal rate of return compared, 725
 weighted average cost, 720-721
- Capital asset pricing model (CAPM), 720

- Capital investment decision, 718
 CAPM (capital asset pricing model), 720
 CAPP (computer-aided process planning), 730
 Cardinal Health, 546
 Cards, in kanban pull system, 409, 410, 411
 Career opportunities, 7, 12-14
 Carrying (holding) costs, 414n, 549, 557, 567
 Cash flow(s)
 company performance measured by, 682
 determining present value of, 726
 discounted, 724
 future cash flows, 99-100
 organizing with spreadsheets, 100
 period cash flow, 101
 replacement decision and, 727-728
 work flow and, 624
 Cash flow report, 101
 CashWorks, 369
 Caterpillar, 606
 Causal forecasting, 469
 Causal loop analysis, 438, 439
 Causal loop diagramming, 447, 448
 Causal loop diagrams, 450
 Causal relationship(s), 473, 513n
 Causal relationship forecasting, 493-495
 dynamic models, 469, 470
 linear regression in, 484
 Cause-and-effect diagrams, 315, 317, 438
 CCR (capacity-constrained resource), 686, 691, 692, 695, 705
 CCR (critical customer requirement), 314
 CDC (E.A. Sween: Combined Distribution Centers), 369
 Central America Free Trade Agreement (CAFTA), 389
 Central limit theorem, 72
 Central scheduling systems, 436
 Centroid method of plant location, 389, 393-394
 CEO (chief executive officer), 13
 Certification
 first-, second-, and third-party, 321-322
 ISO 9000 quality certification, 15, 16, 430
 Champions, in Six Sigma, 318, 319
 Channel switching, 285
 Charles Schwab, 15, 17
 Charting, 63, 64, 432
 Charts and graphs
 bar charts, 63-65
 computer graphics, 734
 constructing \bar{X} and R charts, 340-342
 cut-and-try graphic methods, 522-527, 531
 flowcharts (See Flowchart(s); Flowcharting)
 Gantt charts (See Gantt charts)
 graphic project reports, 64
 organization charts, 438
 Pareto charts, 315, 316, 587n
 p charts, 336-338
 three-dimensional graphing, 39
 See also specific kinds of charts and graphs
 Chase strategy, 520
 Checksheets, 315, 316
 Chevron Corp., 463
 Chicago Tribune, 388
 Chief executive officer (CEO), 13
 Chief operating officer (COO), 13-14
 China, offshoring in, 357
 Chi-square tests, 439
 Chrysler, 25
 CIM (computer-integrated manufacturing), 15, 734, 736
 Cincinnati Milacron, 732, 733
 Circulation paths, 238, 239
 Cisco Systems, 366, 594
 Citgo, 369
 Classic accommodation strategy, 268, 269
 Classic reduction strategy, 268, 269
 Client/server software, 15
 Clocks, 167-168
 Closed-loop MRP, 605, 606
 CNN (Cable News Network), 17
 Coaching, 199
 Coca-Cola Corporation, 370
 Codification of reengineering, 442
 Coding, in simulation, 658
 The Coffee Bean, 13
 Collaborative planning, forecasting, and replenishment (CPFR), 497-499
 Colored golf balls, 410
 Combination facility layouts, 222
 Combined ratio, 5
 Commitment to quality, 437
 Common stock, 720
 Common variation, 329
 Community issues, facility location and, 389
 Compaq Computer Corporation, 14
 Competitive advantage
 facility location and, 389
 manufacturing as competitive weapon, 15
 market forces and, 425
 reducing service costs and, 5-6
 Competitiveness, 22
 Competitive position of firm
 facility location and, 387-389
 operations and supply strategy and, 22-24, 31
 reducing service costs and, 5-6
 role of process analysis in, 160
 Complementary products, 513n, 519
 Complexity
 assessing management of, 437
 defined, 109
 in designing service products, 108-109
 of operations, systems thinking and, 446-450
 Complex systems
 development of, 98-99
 kinds of products developed in, 96, 97, 98
 Component parts inventory, 547
 Compound interest table, App-7
 Compound value(s), 722
 Compound value of annuity, 721-722, App-8
 Compound value of single amount, 721, 722, App-7
 Computer(s)
 computerized conveyers, 732
 for cycle counting, 571
 manufacturers of, 205
 MRP "explosion" process, 597-598, 602, 611
 in simulation (See Computer simulation)
 software packages (See Computer software)
 technologies in manufacturing, 730-734
 tracking technology in logistics outsourcing, 366-367
 widespread use of, 15
 See also Internet
 Computer-aided design (CAD), 105, 730, 734
 Computer-aided engineering (CAE), 734
 Computer-aided manufacturing (CAM), 734
 Computer-aided process planning (CAPP), 730
 Computer graphics, 734
 Computer-integrated manufacturing (CIM), 15, 734, 736
 Computerized systems, 234, 573
 Computer Sciences Corporation (CSC), 428
 Computer simulation, 15
 computer languages for, 657, 658, 663-666
 in data analysis and solution development, 438, 439
 dynamic models in forecasting, 469, 470
 in focus forecasting, 496-497
 interactive simulation games, 450
 Microsoft® Excel® used in, 438, 661-663, 664
 models for, 657-658, 661
 in scheduling, 652-667
 simulation methodology, 657-658
 software for, 438, 450, 664, 667
 of waiting lines, 296
 See also Simulation
 Computer software
 applications for e-commerce, 461-463
 sales and operations planning, 462-463
 supply chain management, 462
 client/server software, 15
 corporate governance programs, 459-460
 corporate services software, 461
 decision trees, 130-132
 for lean manufacturing, 416
 manufacturing systems, 730, 734
 in material requirements planning, 597-598
 multiple uses of, 464
 for personnel scheduling, 639
 in sales and distribution, 460-461
 simulation software, 438, 450, 664, 667
 talent management software, 460
 workflow software, 436, 438
 See also specific software packages
 Concept development phase, 94, 95, 96, 99
 Concurrent engineering, 15, 99, 175, 259
 Confidence levels, in work sampling, 194, 195
 Conformance quality, 310
 Consecutive days off, scheduling, 638-640
 Consistency, 310
 Constant arrival distribution, 280
 Constraint equations, 39, 40
 Constraint management, 678-705
 bottlenecks and (See Bottleneck(s))
 building blocks of manufacturing, 686-687
 capacity-constrained resources, 686
 example of, 679-681
 goal of firm and, 682, 683, 705
 methods for control, 687-696
 avoiding creation of bottlenecks, 690
 batch sizes, 694-695
 Critical Chain Project Management, 696
 drums, buffers, and ropes, 690-693
 finding bottlenecks, 689
 importance of quality, 693
 saving time, 689-690
 time components, 688-689
 treatment of inventory, 695-696

- Constraint management (Cont.)
 performance measurements
 financial, 682
 operational, 682-683
 productivity, 683
 relationship with other functional areas,
 697-705
 accounting, 697-698
 five-step focusing process, 681,
 703-704, 705
 marketing and production, 698-704
 synchronous manufacturing, 697
 unbalanced capacity and, 684-685
- Consumer electronics, 57-58
 Consumer groups, 25
 Consumer's risk (β), 343, 344
 Consumption coefficients, 152
 Container system, 410
 Context of service utilization rates, 134
 Continental Airlines, 25
 Continuous improvement/*kaizen*, 187,
 314, 403
 Continuous improvement paradigm, 15
 Continuous process, 206
 Continuous process manufacturing, 626
 Continuous reinforcement, 319
 Continuous replenishment, 361-362
 Continuous simulation models, 663
 Contract manufacturers, 18, 93, 122
 Control charts, 331, 438
 as analytical tools, 315, 317
 designing, example of, 337-338
 preoccupation with, 320
 Control limits
 in constructing range charts, 340-341
 in sampling by variables, 339
 Control point (drum), 690-691, 692
 Convenience, facility location and, 388
 Convexity, 39, 40
 Conveyers, computerized, 732
 COO (chief operating officer), 13-14
 Co-production of goods and services, 18
 COQ (cost of quality), 311-312
 Core activities, 370
 Core competencies, 28, 93, 366, 368, 369
 Core goods, 11
 Core services, 11
 Corner points, 40
 Corporate annual plan, 518
 Corporate culture, 698
 Corporate goals, 176
 Corporate governance software, 459-460
 Corporate services software, 461
 Corporations
 annual plan, 518
 differences in corporate culture, 698
 global, 8, 25, 384
 goal of firm, 176, 682, 683, 705
 Correlation analysis, 439
 Cost(s)
 associated with changes in production, 520
 avoidable costs, 714
 competitive position of firm and, 22, 23
 facility location and, 387
 factor-rating systems and, 390
 fixed, 713
 outsourcing and, 367
 reducing
 in service companies, 5-6
 shipping costs, 3
 technology investments and, 735
 using DFMA, 106
 in work center design, 224
 relevant to S&OP, 520-521
 variable, 533, 713
See also specific kinds of costs
 Cost accounting measurements, 698
 Cost activity pools, 716
 Cost avoidance, 104-105
 Cost distortion, 716, 718
 Cost drivers, 716
 Cost impact and payoff analysis tools, 432,
 439-440
 balanced scorecard, 439
 decision trees, 439
 process dashboards, 440
 stakeholder analysis, 439
 Cost matrix, 224, 225
 Cost of capital, 718-721
 internal rate of return compared, 725
 weighted average, 720-721
 Cost of goods sold, 360
 Cost of manufacture, 728
 Cost-of-poor-quality loop, 447, 448
 Cost of quality (COQ), 311-312
 Cost of revenue, 360
 Cost per day, in time-cost models, 74
 Cost/performance tracking schedule, 64
 Cost per unit, learning curve and, 125
 Cost per unit of time, in time-cost models, 73-74
 Cost per unit output, determining, 212-213
 Cost reduction. *See* Cost(s)
 Cost savings, 3, 4
 Cost schedule status report (CSSR), 65
 Cost targets, 416
 Cost trade-off decision, 277, 296
 CPFR (collaborative planning, forecasting, and
 replenishment), 497-499
 C_p (capability index), 332-336, 346
 CPM. *See* Critical path method
 CPM/PERT techniques, 440
 "Crash costs," 73, 77
 "Crash times," 73, 77
 Creation of service, 257
 Creative Output, 681
 Creativity, in product design, 91-92, 102
 Critical Chain Project Management, 696
 Critical customer requirement (CCR), 314
 Critical path, 65
 calculating, 58, 67, 68, 70, 74
 shortening at least cost, 74-75
 Critical path method (CPM), 65-69
 early-start and late-start schedules, 67-69
 examples of, 68, 69, 70-71
 probability analysis and, 72
 steps in, 66-68
 with three time estimates, 70-72
 Critical ratio (CR) rule, 627
 Critical to quality concept, 307
 Critical zone, in waiting lines, 133, 134
 Cross-docking, 386
 Cross-functional uses of OSM, 7, 25
 Cross-training, job design and, 187
 CRP (capacity requirements planning)
 program, 695
 CR (critical ratio) rule, 627
 Crystal Ball (computer simulation
 software), 438
 CSC (Computer Sciences Corporation), 428
 CSSR (cost schedule status report), 65
 Cumulative average time, 143-144
 Cumulative Standard Normal Distribution table,
 551, 559, App-5
 Customer(s)
 aggregate planning and, 516
 control of service process, 270
 interactions (contact) with, 10, 18, 257-261
 management of, 22, 278
 needs of, 22, 27, 103, 125, 314
 proximity to, 387
 role in product design, 103-105
 quality function deployment, 103-104
 value analysis/value engineering, 104-105
 services and
 customer as focal point of service
 organization, 256-257
 involvement in service design, 108,
 133, 265
 role in service supply chains, 365, 366
 suppliers as, 365-366
 views of variability, 330
 workers and, 260, 261, 436
See also Waiting line(s)
 Customer contact, 10, 18, 257-261
 Customer-driven scheduling, 418
 Customer-induced variability, 268-269
 Customer loyalty analysis, 432
 Customer Relationship Management Suite
 (software), 459
 Customer requirements, 103, 314
 Customer retention, 448
 Customer satisfaction, 436
 Customer/server contact, 259, 260
 Customer service analysis software, 464
 Customer specifications, 234
 Customer surveys, 432, 436
 Customer touch points, 18
 Customization
 competitive position of firm and, 24
 face-to-face total customization
 personal-attention approach as, 265-266
 in service-system design matrix, 260-261
 mass customization, 17, 375-377
 Customized products, 96, 97, 98
 Cut-and-try graphic methods, 522-527, 531
 Cycle counting, 571-572
 Cycle mix, 233
 Cycles of study, 194
 Cycle time(s)
 long, 191, 548
 model of, computing, 409
 in process performance metrics,
 168, 169, 173
 reducing, 546, 735
 of repetitive process, 161, 165
 short (high-volume production), 144, 199
 throughput time differentiated from, 185n
 time components of, 688-689
 variability in, 169-170, 174
 workstation cycle time, 227, 228, 229

- Cyclical, 488
Cyclical factors in demand, 469, 519
- D**
Daily dispatch list, 635, 636
Daily work times, 640, 641
DaimlerChrysler, 25, 30, 321
- Data**
elemental, 191
generation of, in simulation, 658
"hard" or "soft," 698
inaccuracies in, 637-638
performance data, 199
used in decision support, 467
- Data analysis**
computer software for, 486, 487, 495
data envelopment analysis (DEA), 439
in external benchmarking, 322
tools of, 432
- Data analysis and solution development,**
438-439
bottleneck analysis, 438
computer simulation, 438, 439
problem analysis (SPC tools), 438
statistical tools, 439
- Data envelopment analysis (DEA),** 439
- Data gathering, 435-438**
data mining, 467
flowcharts, 436, 438
organization charts, 438
plant tours/audits, 435-437
in simulation studies, 659-661
tools of, 432
work sampling, 436
- Data integrity, 636-638**
- Data mining, 467**
- DATA program (TreeAge Software),**
130-132
- Data responsibility, 636-637**
- Data warehouses, 458, 467**
- Days off, scheduling, 638-640**
- DEA (data envelopment analysis), 439**
- Decision making**
capital investment decision, 718
cost trade-off decision, 277
data used in decision support, 467
expansion decision, 725-727
facilities location decisions, 394-395, 396
inputs to layout decision, 221
in job design, 187-188
lease-or-buy decision, 718
make-or-buy decision, 207-208, 718, 728
market selection decision, 394-395
operational design decisions, 99
plant abandonment decision, 718
related to logistics, 384-386
replacement decision, 718, 727-728
- Decision points, 162, 442**
- Decision rules, 228, 230, 654**
- Decision support, 467**
- Decision theory, 15**
- Decision trees, 130-132, 439**
- Declining-balance depreciation method, 715**
- Decomposition of time series, 470,**
487-493
additive seasonal variation, 487, 488
error range in, 493
multiplicative seasonal variation, 487, 488
seasonal factor (index), 488-490
using least squares regression, 490-493
- Defects**
probability of producing, 334, 335
zero defects, 307
- Defects per million opportunities (DPMO),**
313-314
- Defense Department, U.S., 17**
- Define, measure, analyze, improve, and control**
(DMAIC) cycle, 314-315
- Degree of completion, 64, 65**
- Degree of patience, 282**
- Delay, in feedback loops, 447**
- Delivery**
hand delivery, 386
just-in-time delivery, 6
of raw materials, 548
reliability and speed of, 23
service delivery, 261, 264
- Dell Computer Corporation, 18, 24, 94, 205, 234,**
358, 360-361, 377
- Deloitte & Touche Consulting Group, 426, 434n**
- Delphi method of forecasting, 470, 472, 473**
- Demand**
average daily demand, 560-562, 575
average demand, 469, 471
certainty of, 559-560, 562
changes in, 23-24
components of, 469, 471, 472
cyclical factors in, 469, 519
dependent, 468, 549-550, 574, 590
deseasonalized, 491-492
economies of scale and, 125
marginal cost of overestimating, 551-552
product demand, 548, 593
random variations in, 469
retail-level demand forecast, 498
role of accurate response in controlling, 519
seasonal, 528
trend projections in, 469, 471, 472
uncertainty in, 363, 364
volatility of, 133
- Demand distribution, 654, 655**
- Demand forecasts**
in CPMR, 498
in MRP, 598
in yield management, 533, 534
- Demand management. See Forecasting**
- Demand planning software, 462**
- Demand-pull scheduling, 418**
- Demand stabilization, 414**
- Departmental staffing plans, 640, 641**
- Department of Commerce, U.S., 308**
- Department of Defense, U.S., 63**
- Dependent demand, 468, 574**
independent demand compared, 549-550
MRP based on, 590
- Dependent events, 684, 685**
- Depreciation, 714-716, 728**
declining-balance method, 715
depreciation-by-use method, 715-716
double-declining-balance method, 715
effects of taxes on, 718
straight-line method, 715
sum-of-the-year's-digits method, 715, 726
- Depreciation of knowledge, 151**
- Derivative projects, 58**
- Deseasonalized demand, 491-492**
- Design**
of jobs (See Job design)
meanings of, 105
of products (See Product design)
quality of, 23, 310
of services (See Service design; Service
system design)
- Design drivers, 270-271**
- Design flows, 412-413, 414**
- Design for logistics, 370**
- Design for manufacture and assembly (DFMA),**
105-108, 259
- Design of experiments (DOE) methods,**
314, 318
- Detail design phase, 95, 96**
- Detailed complexity, 446**
- Detection, in FMEA, 318**
- Development cost, 102**
- Development cost sensitivity, 101**
- Deviate values, 655**
- DFMA (design for manufacture and assembly),**
105-108, 259
- Dimensions of quality, 310, 311**
- Directional flow requirements, 285**
- Direct labor, 716**
- Direct observation, 190-191**
- Discounted cash flow, 724**
- Discounted loans, 719**
- Discrete distribution, 281**
- Discrete simulation models, 663**
- Diseconomies of scale, 124, 125**
- Disneyland, 108, 260, 270, 417**
- Dispatching, 625, 626**
- "Dispersed manufacturing," 373**
- Distribution**
role in mass customization, 376, 377
service time distribution, 283, 294
in simulation model, 654, 655
use of linear programming in scheduling, 37
use of software in, 460-461
- Distribution(s), mathematical**
Cumulative standard normal distribution
table, 551, 559, App-5
distribution of arrivals, 280-282
exponential distribution, 280
Poisson distribution, 281-282, 287, 290
empirical frequency distributions, 654, 655
exponential distribution, 280, 290, 297
negative exponential distribution table,
App-4
Poisson distribution, 281-282, 287, 290,
297, 654
probability distributions, 654, 655
standard distribution
in forecasting, 472
relating random numbers to, 654-656
in simulation, 654, 655
uniformly distributed random digit table,
App-6
- Distribution centers, 376, 383**
- Distribution processes, 9, 10**
- Distributors, 572**
- Divergence, 108-109, 109**
- Dividends, 720**

- Divisibility, 38, 39
 Divisional breakdown of costs and labor hours, 64
 DMAIC cycle, 314-315
 Document retention, 150, 151
 DOE (design of experiments) methods, 314, 318
 Dollar days, 696
 Dollar volume, 569
 Double-declining-balance depreciation method, 715
 Dow Chemical Company, 331
 Dow Jones Industrial Average, 5
 DPMO (defects per million opportunities), 313-314
 "Drilling down," 459
 Drum (control point), 690-691, 692
 Dynamic complexity, 446
 Dynamic design chain, 57-58
 Dynamic (simulation) models, 469, 470
 Dynamic programming, 38
- E**
- E.A. Sween: Combined Distribution Centers (CDC), 369
 Earliest due date first (EDD) rule, 627, 629, 630
 Early adopters of new technology, 735
 Early start schedule, 67-68
 eBay, 15, 17
 E-commerce, 15, 17
 software applications for, 461-463
 sales and operations planning, 462-463
 supply chain management, 462
 Econometric models, in forecasting, 470
 Economic analysis, 99-102
 Economic life, 714
 Economic lot size, 15
 Economic order quantity (EOQ), 554
 applied to inventory control, 15
 computing, 561, 575
 in MRP, 608-609
 in price-break models, 565-567
 in retailing, 572
 Economic order size, 567
 Economic purchase order size, 548
 Economics of waiting lines, 277-278
 Economies of scale, 124, 125, 134
 Economies of scope, 127
 EDD (earliest due date first) rule, 627, 629, 630
 EDI (electronic data interchange), 361-362
 EDS (Electronic Data Systems), 369, 428
 Effective interest rate, 719
 Effectiveness, 6
 Efficiency, 6, 7
 customer contact and, 259,
 in MRP, 603, 604
 as process performance metric, 168, 169
 Efficient supply chains, 364
 Effort variability, 268-269
 80-20 rule, 431
 EI (employee involvement) teams, 189
 Electronic catalogue, 375
 Electronic data interchange (EDI), 361-362
 Electronic Data Systems (EDS), 369, 428
 Electronic enterprise. *See* E-commerce
 Elemental data, 191
 Elements, at workstations, 227
- Elevator test, 432
 Eli Lilly, 361
 Elimination of waste, 405-412
 Empirical frequency distributions, 654, 655
 Employee involvement in job design, 187
 Employee involvement (EI) teams, 189
 Employees. *See* Workers
 Empowerment, 187
 End items, in MRP, 597, 600
 Engineered labor standards, 199
 Enterprise asset management, 464
 Enterprise resource planning (ERP), 430, 489
 Enterprise resource planning (ERP) systems, 454-465
 developers of, 454, 457
 global, 18
 implementing, 463
 linear programming used with, 37
 in pharmaceutical industry, 590
 software by SAP AG, 457-458
 application modules, 458-461
 integrated e-business applications, 461-463
 open information warehouse, 459
 SAP Business One, 464
 Environmental management, 321
 Environmental regulation, 389
 Environmental risks in adopting technology, 736
 E-operations, 430
 EOQ. *See* Economic order quantity
 Equal contribution line, 40
 Equipment
 calculating availability and requirements, 128, 129
 determining equipment capacity, 212
 general- or special-purpose, 207
 individual learning and, 150
 minimizing downtime, 124
 original equipment manufacturers, 8
 selection problem (illustration), 287, 289, 297
 Equity securities (stocks), 720
 Ericsson, 134, 366
 ERP. *See* Enterprise resource planning;
 Enterprise resource planning systems
- Error**
- absolute error, 195, 196
 forecast errors, 480
 inaccuracies in data, 637-638
 mean squared error, 481
 measurement of, 481-482, 483
 sources of, 480
 standard error, 481, 486, 513n
 task or treatment errors, 270
 tolerable, in inventory control, 571-572
 Error range, 493
 Estimated activity time, 70
 ET (expected time) for activities, 70
 Ethical issues, 6, 271
 European Union, 321-322
 Evaluation of results in simulation, 656-657
 Event simulation, 663
 Eveready Batteries, 625
 Evolutionary changes, 261
 Evolve Software, 440
 Evolving supply process, 363
 Excel. *See* Microsoft® Excel®
 Exchange transformation processes, 8
- Execution, commitment to, 426
 Executive leaders. *See* Senior executives
 Exit from queuing system, 285
 Expansion decision, 725-727
 Expected completion time, 71
 Expected time (ET) for activities, 70
 Expected value costs, 714
 Expeditors, 651n
 Experience curves. *See* Learning curves
 ExPlan software, 450
 Explicit objective, 38, 39
 Explicit services, 10
 "Explosion" process, 597-598, 602, 611
 Exponential distribution, 280, 290, 297
 Exponential learning curve, 144-149
 arithmetic analysis of, 144, 145
 continual improvement, 149
 estimating learning percentage, 148-149
 learning curve tables, 145-148
 logarithmic analysis of, 144, 145
 Exponential service, 287-288
 Exponential smoothing, 470, 477-480, 513n
 choosing appropriate value for alpha, 480
 in computerized inventory systems, 573
 single, 478-479, 500
 trend effects in, 479-480, 500
 Exponential trend in forecasting, 471, 472
 Extend (computer simulation software), 438, 664, 667
 Extent of contact, 257
 External benchmarking, 322
 External failure costs (COQ), 312
 External setups, 412
 External sources of capacity, 127
 E-Z Pass, 277
- F**
- Fabricate-to-order operations, 593
 Fabricate-to-stock operations, 593
 Face-to-face loose specs, 260, 261, 265
 Face-to-face services, 241
 Face-to-face tight specs, 260, 261
 Face-to-face total customization
 personal-attention approach as, 265-266
 in service-system design matrix, 260-261
 Face (par) value of bond, 719
 Face (simple) yield, 719
 Facilitating goods, in services, 10
 Facilities
 audit of service facilities, 436
 level facility load in lean services, 418
 supporting facility for services, 10
 Facility layout, 220-241
 assembly lines (*See* Assembly line(s))
 basic layout formats, 221-222
 cells, 235, 236
 degree of customer contact and, 258
 office layout, 240
 project layouts, 235, 237
 retail service layout, 237-240
 systematic layout planning (SLP), 226
 work centers, 222-226
 See also Manufacturing
 Facility location
 degree of customer contact and, 258
 issues in, 387-389

- manufacturing facilities, 395
- plant location methods, 389–394
 - centroid method, 389, 393–394
 - factor-rating systems, 389–390
 - transportation method, 389, 390–393
- service facilities, 394–396, 397
- Factor-rating systems, 389–390
- Factory automation
 - automation of heavy manual work, 188
 - total factory automation, in CIM, 15, 734, 736
- Factory focus, 16
- Factory of the future (CIM), 15, 734, 736
- Fail-safe procedures, 320
- Fail-safing, in service processes, 261–263
- Failure mode and effect (FMEA) analysis, 315, 318
- Fair Labor Standards Act, 638
- Fast-food restaurants, 159–160, 165–168
- FCFS (first come, first served), 283
- FCFS (first-come, first-served) rule, 627, 628–629, 630
- Features, dimensions of quality for, 310, 311
- Federal Express (FedEx) Corporation, 13, 15, 17, 23, 417
 - logistics outsourcing to, 367
 - logistics solutions by, 383–384
 - supply chain strategy, 371–372
- Feedback, 190, 442–443
- Feedback loops, 447
- The Fifth Discipline* (Senge), 446
- Finance, in mass customization, 376
- Financial analysis, 713–728
 - activity-based costing, 716–718
 - capital investment decision, 718
 - concepts and definitions, 713–716
 - cost of capital, 718–721
 - effects of taxes, 718
 - interest rate effects, 721–724
 - compound value of annuity, 721–722, App-8
 - compound value of single amount, 721, 722, App-7
 - discounted cash flow, 724
 - present value of annuity, 723–724, App-10
 - present value of future single payment, 722–723, App-9
 - methods of ranking investments
 - internal rate of return, 725, App-10
 - investments with uneven lives, 725
 - net present value, 724
 - payback period, 724–725
 - sample problems, 725–728
 - expansion decision, 725–727
 - make-or-buy decision, 728
 - replacement decision, 727–728
- Financial impact of outsourcing, 108
- Financial modeling, 99–100, 102
- Financial performance measurements, 5, 682
- Financial services, 430
- "Finders," 428
- Finisar, 521
- Finished goods inventory, 683, 687–688
 - focus forecasting in, 495–497
 - in make-to-stock process, 165, 167
- Finished products, 547
- Finite forward scheduling, 626
- Finite loading system, 625
- Finite population, arrivals from, 279
- Finite queuing
 - equations, 286
 - problem (illustration), 287, 290, 292, 293, 297
 - tables, 292
- First Bank/Dallas, 417
- First come, first served (FCFS), 283
- First-come, first-served (FCFS) rule, 627, 628–629, 630
- "First-hour" principle, 640–641
- First-party certification, 321
- Fishbone diagrams, 315, 317, 438
- FIT (forecast including trend), 479–480
- Fitness for use, 310
- FITS (forecast including trend and seasonal factors), 479–480
- Five forces model, 433, 435
- Five-step focusing process, 681, 703–704, 705
- Fixed costs, 713
- Fixed-order interval system. *See* Fixed-time period models
- Fixed-order quantity models (Q-model), 555–562, 574, 575
 - constructing model, 556–557
 - "event triggered," 554, 555
 - for multiperiod inventory systems, 553–554
 - with safety stock, 559–562
 - safety stock levels in, 558–559
- Fixed-time increment method, 656
- Fixed-time period models (P-model), 562–564, 574
 - for multiperiod inventory systems, 553–554
 - with safety stock, 563–564, 575
 - "time triggered," 554, 555
- Flexibility
 - capacity flexibility, 126–127, 135, 211
 - competitive position of firm and, 24
 - limited, in JIT, 697
 - in service system design, 271
- Flexible assembly line layouts, 232
- Flexible manufacturing systems (FMS), 15, 730, 732–733, 736
- Flexible plants, 126
- Flexible processes, 127
- Flexible workers, 127, 211
- Flextronics, 366
- Flotation costs, 720
- Flow(s)
 - design flows, in lean layout, 412–413, 414
 - directional flow requirements, 285
 - in flowcharting, 162, 211
 - in lean manufacturing, 403
 - in manufacturing processes, 208–213
- Flowchart(s)
 - as analytical tools, 315, 316
 - in data gathering, 436, 438
 - process flowcharts, 209–211
- Flowcharting
 - in eliminating redundancy, 177
 - flows in, 162, 211
 - in process analysis, 162–164
 - process flowcharting, 162–164
 - in service process design, 261, 262, 271
 - in simulation, 657
- Flow management, 589
- Flow manufacturing, 606, 607
- Flow of production
 - balancing, 684, 685
 - smoothing, 408–409
 - through bottlenecks, 686–688, 695
- Flow of service experience, 269
- Flow of time, 269
- Flow patterns, 235
- Flow-shop layout, 221, 624
- FMEA (failure mode and effect) analysis, 315, 318
- FMS (flexible manufacturing systems), 15, 730, 732–733, 736
- Focal points in servicescapes, 238
- Focused factory, 125–126
- Focused factory networks, 405, 407
- Focus forecasting, 495–497
- Ford Motor Company, 25, 30, 124, 321, 339, 437, 450, 556
- Ford Motor Company of the Americas, 13
- Forecast demand, 593
- Forecast errors, 480
- Forecast including trend (FIT), 479–480
- Forecast including trend and seasonal factors (FITS), 490
- Forecasting, 15, 439, 499
 - accuracy of, 546
 - causal relationship forecasting, 469, 470, 484, 493–495
 - demand forecasts, 498, 533, 534, 598
 - demand management and, 466, 469, 471, 472
 - focus forecasting, 495–497
 - as intermediate-term activity, 517
 - of production capacity, 521
 - qualitative techniques, 469, 470, 472–473
 - Delphi method, 473
 - grass roots, 472
 - historical analogy, 473
 - market research, 472
 - panel consensus, 472
 - reliance on sales forecasts, 589
 - techniques of, 128–129
 - time series analysis, 470, 473–493
 - decomposition of time series, 487–493
 - exponential smoothing, 470, 477–480, 500, 513n, 573
 - forecast errors, 480
 - linear regression analysis, 483–486, 487
 - measurement of error, 481–482, 483
 - simple moving average, 474–476
 - weighted moving average, 476–477
 - web-based (CPFR), 497–499
- Forecast sharing, in CPFR, 498
- Formulas
 - for calculating mean, 329, 346
 - capability index (C_{pk}), 334, 346
 - payback formula, 732
 - for range charts, 346–347
 - for standard deviation, 330, 346, 557n
 - used in SQC, 346–347
 - using attribute measurements, 346
 - for waiting line problems, 277, 285, 286
- Fortune magazine, 188
- Forward buying, 361
- Forward scheduling, 625, 697
- Fractional options, 596
- Free trade zones, 388
- Freeze window, 415
- Frequency of capacity additions, 127, 128
- Frequency of samples, 339
- Frito-Lay, 369, 734

- Front-end partnership agreement, 498, 499
 FTE (full-time-equivalent) employees, 527-529
 Fujitsu, 368
 Full-time-equivalent (FTE) employees, 527-529
 Functional layout, 221
 Functional products, 362-363, 364
 Functional projects, 60-61
 "Functional silo" syndrome, 435
 Fundamental manufacturing equation, 606
 Funnel, process as, 177-178
 Furniture industry, 25-27
 Future cash flows, 99-100
 Future value, calculating, 722
- G**
- Gantt charts, 63-65, 440
 project timing information, 100
 in shop-floor control, 634-635
 tracking Gantt charts, 77
 The Gap, Inc., 192, 199
 Gap analysis, 432-433, 434
 GATT (General Agreement on Tariffs and Trade), 373
 GDP (gross domestic product), 5
 GE (General Electric), 15, 307, 313, 314, 319
 Gemini Consulting, 428
 General Agreement on Tariffs and Trade (GATT), 373
 General Electric (GE), 15, 307, 313, 314, 319
 General Motors Corporation (GM), 25, 30, 228, 321, 361, 450, 518
 General-purpose equipment, 207
 General-purpose simulation software, 664
 The Gilmore Research Group, 472
 Global corporations, 8, 25, 384
 Global cost accounting measurements, 698
 Global economy, 11, 12, 373
 Global enterprise resource planning systems, 18
 Globalization, job design and, 200
 Global sourcing, 373-374
 Global strategy, 426
 GM (General Motors), 25, 30, 228
 GMSI (GM Strategic Initiatives), 450
 GM Strategic Initiatives (GMSI), 450
 GNM (Guardian News & Media), 13
 Goal(s)
 constraint management and, 682, 683, 705
 explicit, linear planning and, 38, 39
 process improvement and, 176
 in reengineering, 442-443
 of simulation studies, 659
 stretch objectives, 319
 of work center scheduling, 626
 The Goal (Goldratt), 681-682
 Goal programming, 38
 Goldratt's Theory of Constraints (TOC), 681-682, 703-704, 705
 Golf balls (colored), 410
 Go/no-go milestones, 99
 Goods
 co-production of goods and services, 18
 cost of goods sold, 360
 finished goods inventory, 683, 687-688
 focus forecasting in, 495-497
 in make-to-stock process, 165, 167
 services contrasted, 10-12
 Goods-services comparison, 10-12
 Goods-services continuum, 11
 Goodwill, 265-266
 Goodyear, 311
 Google, 17
 Government, barriers created by, 389
 Gozinto (assembly) charts, 208-209, 219n
 GPSS/H simulation software, 664
 GPSS/PC simulation software, 664
 GRANET software, 469
 Graphical linear programming, 39-41
 Graphic project reports, 64
 Graphics. *See* Charts and graphs
 Grass roots forecasting, 470, 472
 Gray hair projects, 428
 Great America amusement park, 77
 "Green Belt Program," 17
 Green belts, in Six Sigma, 319
 Grid map, 393
 "Grinders," 428
 Gross domestic product (GDP), 5
 Gross profit, maximizing, 700, 702
 Gross requirements, in MRP, 597, 600, 602, 603
 Grouping by association, 239
 Group technology (GT), 222, 407
 Group technology cell (GT cell)
 configuration, 624
 GT (group technology), 222, 407
 GT cell (group technology cell)
 configuration, 624
 GTE Laboratories, 469
 Guardian News & Media (GNM), 13
- H**
- Hand delivery, 386
 Hand-fit straight line, 489-490, 494
 "Hard" (quantitative) data, 698
 Hardware systems, 730-733
 Hardware technologies, 730
Harvard Business Review, 17, 264
 Harvard Business School, 15, 16, 463
 Hawthorne studies of worker motivation, 15
 H.B. Maynard Co., 192, 199
 Health care industry (hospitals)
 example of learning curves in, 151-153
 inventory control in, 545-546
 operations consulting in, 430
 processes in, 160
 scheduling in, 623-624, 664
 system dynamics consulting in, 450
 transformation processes in, 8, 9
 use of simulation in, 665
 workcenter layouts in, 221
 work sampling applied to nursing, 195-198
 Heart transplant procedures, 151-153
Heijunka (uniform plant loading), 408-409
 Heineken, 546
 Hershey, 369
 Heterogeneity of services, 10
 Hewlett-Packard, 344, 361, 366, 367, 375-376, 413n
 Hidden costs, 387
 High-contact systems, 257, 258
 High-risk products, 96, 97, 98
 High-volume manufacturing, 626
 High-volume processes, 165-166
 Highway transportation (trucking), 371, 385
 "Hijacking" capacity, 121
 Hillerich and Bradsby, 460
 Histograms, 315, 316
 Historical analogy, 470, 471, 473
 Hitachi, 368
 Holding (carrying) costs, 414n, 549, 557, 567
 Home Depot, 238
 Homogeneity, 38, 39
 Honda Motors, 93, 124, 160, 233, 388
 Honeywell, 417
 HOPS inventory control system (Heineken), 546
 Horizontal job enlargement, 189
 Hospitality (hotel) industry
 inventory control problem in (reservations), 552-553
 operations consulting in, 430
 service facility location, 395
 service processes in, 255-256
 Hotel Monaco, 269
 Hourly work times, 640-642
 Housekeeping upgrade, 417
 House of quality matrix, 103-104
 Hub-and-spoke systems, 386
 Human capital management, 460
 Human relations, 235
 Human resource renaissance, 200
 Hybrid production process, 165, 167, 606, 607
 Hypothesis testing, 314, 439
- I**
- IBM, 14, 15, 17, 188, 361, 366, 428
 IBM Personal Computer Company, 14
 ICL, 322
 IDA, 457
 IDEO Product Development, 91-92, 103, 159
 Idle time, in production cycle, 688
 IE (industrial engineering), 7-8
 IKEA, 3, 4, 25-27, 31, 238
 Illegal acts, 6
I Love Lucy, 227
 Imagine That! Inc., 664
 Immediate predecessors, 66
 Impatient arrival, 282
 Implementation tools, 432, 440
 Implicit services, 11
 "Inbound logistics," 10
 Indented structure of BOM file, 595, 599, 600
 Independence of operations, 548
 Independent demand, 468, 549-550, 574
 Independent modules, 375-376
 Indianapolis 500, 388
 Indirect observation, 190, 191
 Individual learning, 143, 149-150
 Industrial design, 103
 Industrial engineering (IE), 7-8
 Industrial psychology, 15
 Industrial robots, 15, 730, 731, 732
 Industry guidelines, 149
 Industry learning, 143, 144, 152
 Infinite backward scheduling system, 625
 Infinite forward scheduling, 626
 Infinite loading, 624-625
 Infinite population, arrivals from, 279
 Infinite potential line length, 282
 Infinite queuing equations, 286

- "Informating," 187-188
 Information, 455-456
 Informational transformation processes, 8
 Information assembly line, 264
 Information capture, 442
 Information flow, 240, 377
 Information-processing work, 441
 Information systems, 76, 77, 384
 Information technology (IT)
 applied to service productivity, 15
 in-store systems, 369
 in management consulting industry, 428
 use in reengineering, 441
 INFOR/SSA Global, 457
 Infosys Technology, 428
 Infrastructure, 386, 388
 Innovation(s), 426
 degree of customer/service contact and,
 260, 261
 product innovation, 22, 362, 363, 364
 Input/output control (shop-floor), 635, 636, 637
 Input/output control reports, 635, 636
 Input/output models, 470
 INSEAD, 355
 Institute for Strategic Change (Accenture), 368
 Institute for Supply Management (ISM), 5
 Insurance industry, 5-6
 Intangible assets, 714
 Intangible processes, 10
 Integer programming, 38
 Integrated teams, 175
 Integration of inventory systems, 549
 Intel Corporation, 368-370
 Intellectual property, 368
 Intelligent Electronics, 14
 Intelligent conveyors, 234
 Intelligent Instrumentation, 625
 Interactive simulation games, 450
 Interarrival time, 294
 Interest rate, real or effective, 719
 Interest rate effects, 721-724
 compound value of annuity, 721-722, App-8
 compound value of single amount, 721, 722,
 App-7
 discounted cash flow, 724
 present value of annuity, 723-724, App-10
 present value of future single payment,
 722-723, App-9
 Interest tables, App-7-App-10
 compound sum of \$1, App-7
 present value of \$1, App-3, App-9
 present value of annuity of \$1, App-10
 sum of annuity of \$1, App-8
 Intermediary(ies), 358-359
 Intermediate-range planning, 122, 517-518, 521
 Internal failure costs (COQ), 312
 Internal rate of return, 722, 725, App-10
 Internal Revenue Service, 715
 Internal setups, 412
 International Automotive Task Force, 321
 International logistics, 384
 International Organization for Standardization,
 15, 16
 Internet, 15
 as buffer in service-system design matrix,
 259-260, 271
 co-production of goods and services, 18
 e-commerce, 15, 17, 461-463
 integrated e-business applications, 461-463
 use by manufacturers, 358
 using to inform workers, 187-188
 Interruptions, reducing, 175-177
 Interworkcenter flow, 223
 Interworkcenter flow graph, 224, 225
 Inventory, 547, 574, 682, 683
 accuracy of, 570-572
 assessing, in RPA, 437
 average aggregate value of, 360
 buffer inventory, 164-165, 359, 360-361, 691
 definition of, 547
 economic benefits of reducing, 546
 finished goods inventory, 683, 687-688
 focus forecasting in, 495-497
 in make-to-stock process, 165, 167
 "just-in-case," 415
 in make-to-order process, 165
 measurement of, 696
 problems hidden by, 407-408
 purposes of, 548
 replenishment of, in CPFR, 498-499
 supply chain inventories, 547
 vendor-managed, 375
 work-in-process inventory, 211, 233, 683
 assessing, in RPA, 437
 manufacturing cells and, 235
 negative impact of, 695
 Inventory buffer, 164-165, 359, 360-361, 691
 Inventory control, 15, 544-574
 constraint management and, 695-696
 fixed-order quantity models, 555-562
 with safety stock, 559-562
 safety stock levels in, 558-559
 fixed-time period models, 562-564
 in health care industry, 545-546
 independent v. dependent demand, 549-550
 inventory costs and, 549
 inventory systems (See Inventory systems)
 price-break models, 565-567, 574
 purposes of inventory, 548
 supply chain management and, 564-565
 use of linear programming in, 37
 Inventory control logic, 550
 Inventory Control-System Design Matrix, 550
 Inventory costs
 holding (carrying) costs, 414n, 439, 447, 567
 inventory control and, 549
 reducing, 3, 735
 Inventory management, 464, 589
 Inventory on hand, 518
 Inventory order cycle time, 546
 Inventory position, 555
 Inventory records, 596, 597, 599-600
 Inventory systems, 547, 550-554
 miscellaneous systems and issues, 568-573
 ABC inventory planning, 569-570
 cycle counting, 571-572
 inventory accuracy, 570-572
 one-bin system, 554, 569
 optional replenishment system, 554, 568
 services, 572-573
 two-bin system, 554, 568
 multiperiod systems, 550, 553-554, 555
 single-period inventory model, 550, 551-553,
 574, 575
 Inventory transactions file, 596
 Inventory turnover
 calculating, 359, 360-361, 378, 576
 company performance and, 564
 Investment(s)
 capital investment decision, 718
 in industrial robots, 732
 methods of ranking
 internal rate of return, 725, App-10
 investments with uneven lives, 725
 net present value, 724
 payback period, 724-725
 return on investment, 121, 682
 in technology
 benefits of, 735-736
 evaluation of, 734-735
 IRI, 369
isee systems, 450
 ISM (Institute for Supply Management), 5
 ISO 9000, 320-322
 ISO 9000 quality certification, 15, 16, 430
 ISO 9001 specifications, 460
 ISO 14000, 320-322
 ISO 14001 standards, 321
 Iso-profit line, 40, 41
 ISO/TS 16949 standards, 321
 Issue trees, 432, 434
 IT (information technology), 15, 369, 428, 441
 ithink software, 450
 i2 Technologies, 416, 457, 463, 464, 589
- J**
 J. D. Power and Associates, 313
 Jaguar, 124
 Japanese Railways, 433
 "Japanese-style work groups," 189
 Jelly Belly Candy Company, 123
 JIT. See Just-in-time (JIT) production
 JIT kanban logic, 589, 697
 Job characteristics, 150
 Job design, 200
 behavioral considerations in, 188-190
 degree of labor specialization, 188-189
 job enrichment, 189
 sociotechnical systems, 189-190
 decisions in, 187-188
 See also Work measurement
 Job enlargement, 189
 Job enrichment, 189
 Job priorities, 625
 Job redesign, 150
 Job scheduling, 621, 632-634
 Job sequencing
 priority rules for, 627, 628-634
 critical ratio rule, 627
 earliest due date first, 629, 630
 first-come, first-served, 628-629, 630
 Johnson's rule (method), 630-632
 last-come, first-served, 629-630
 least-slack rule, 627
 random order (whim), 629-630
 shortest operating time, 629, 630
 shortest processing time, 627
 slack time remaining, 629-630
 slack time remaining per operation, 627
 in work centers, 627-628

- Job shops, 213, 221, 415, 428, 653
 John Deere, 518
 Johnson's rule (method), 627, 630-632
 Joint business planning, 498
 Judging encounter performance, 269
 "Just-in-case" inventory, 415
 Just-in-time delivery, 6
 Just-in-time (JIT) production, 15, 16, 404, 693
 embedding into MRP (flow manufacturing), 606, 607
 mixed-model line balancing in, 232-234
 synchronous manufacturing compared, 697
 in Toyota Production System, 407-408
 See also Lean manufacturing
 Just-in-time (JIT) systems, 143, 319, 430
- K**
Kaizen, 190, 191, 314
Kaizen/continuous improvement, 187, 314, 403
 Kanban card sets, 409, 410, 411
 Kanban production control systems, 15, 409-411, 413
 Kanban squares, 410
 Kawasaki Motors, U.S.A., 408, 410
 Kennedy Information, 427
 Kevin Kennedy and Associates Inc., 431
 Key performance indicators (KPIs), 464
 Kiva Systems, Inc., 572
 Kmart, 238
 KPIs (key performance indicators), 464
- L**
 Labor, quality of, 388
 Labor capacity, 212
 Labor costs, reducing, 730, 731, 735
 Labor-limited process, 625
 Labor standards, 199
 Labor unions, 190, 367, 412
 Lahey Clinic, 545-546
 Land Rover, 375
 Largest-number-of-following-tasks rule, 231
 Last-come, first-served (LCFS) rule, 627, 629-630
 Late start schedule, 67-68, 69
 Layoffs due to outsourcing, 367-368
 Layout decision, 221
 LCFS (last-come, first-served) rule, 627, 629-630
 LCL (lower control limit), 336
 Leading indicators, 470, 493
 Lead time, in inventory restocking, 572
 Leaning process, 404
 Lean manufacturing, 15, 16, 318, 402-417, 418
 implementation requirements for, 412-417
 applications for line flows, 413, 414
 applications for work center shops, 414, 415
 layouts and design flows, 412-413, 414
 Six-Sigma quality, 414-415
 stable schedule, 415-416
 work with suppliers, 416-417
 logic behind, 404-405
 RPA questionnaire and rating sheet, 451-452
 Six Sigma and, 403-404
 software for, 416
 Theory of Constraints compared, 681-682
 Toyota Production System, 405-412
See also Just-in-time (JIT) production
- Lean production pull system, 403, 404-405
 Lean services, 417-418
 Lean Six Sigma, 403-404
 reducing variability in, 318
 Six-Sigma quality, 414-415
 Lean supply chain, 416-417
Lean Thinking (Womack and Jones), 416
 Learning curve equation, 145
 Learning curves, 125, 134, 142-153
 application of, 143-144
 applications of (examples)
 heart transplant mortality, 151-153
 production problem, 148
 general learning guidelines, 149-151
 individual learning, 149-150
 organizational learning, 150-151
 improvement in, 199
 plotting, 144-149
 continual improvement, 149
 estimating learning percentage, 148-149
 learning curve tables, 145-148
 logarithmic analysis, 145
 Learning curve tables, App-1, App-2
 Learning curve theory, 143
 Learning percentage, 148-149
 Lease-or-buy decision, 718
 Least-cost activities, 74
 Least-slack rule, 627
 Least squares regression
 in decomposition of time series, 490-493, 500
 linear regression analysis, 484-486, 487
 Least-total-cost (LTC) method, 609-610
 Least unit cost method, 610, 611
 Legal issues, 6, 259, 387
 Length of lines, 282-283
 Level facility load, 418
 "Leveling" feature in PMIS, 77
 Level-loaded schedules, 696
 Level schedule, 415
 Level scheduling, 529-530
 Level strategy, 520
 L4L (lot-for-lot) order quantity, 601, 608, 610
 Life cycle changes, 261
 Lifetime employment, 412
 Li & Fung, 372
 The Limited, 373
 Limited line capacity, 282-283
 Limited resources, 38, 39
 Limits-to-growth archetype, 448, 449
 Linearity, 38, 39
 Linear programming (LP), 36-44
 applications of, 37
 data envelopment analysis (DEA), 439
 graphical, 39-41
 model of, 38-39, 654
 simplex method of, 15
 transportation method, 389, 390-393, 397, 531, 532
 using Microsoft® Excel®, 41-44
 Linear regression, 483
 Linear regression analysis, 484-486, 487
 Linear regression forecasting, 470, 483-486, 487
 Linear Technologies, Inc., 57
 Linear trend in forecasting, 471
 Line configuration, 227
- Line flows, 413, 414
 Line length
 on assembly lines, 227
 problem (illustration), 286, 287-288, 297
 Line management, 7
 Line of visibility, 261, 262
 Line structures, 283-285
 mixed, 284-285
 multichannel, multiphase, 284
 multichannel, single phase, 284
 single channel, multiphase, 284
 single channel, single phase, 283, 284
 Little's Law, 170, 181
 L.L. Bean, 322, 433
 Loads, in work centers, 223
 Local cost accounting measurements, 698
 Localization, 358
 Location, in service capacity planning, 133
 Location transformation processes, 8
 Lockheed, 151
 Logistics, 383-384
 decisions related to, 384-386
 cross-docking, 386
 Logistics-System Design Matrix, 385-386
 outsourcing, 366-367
 process analysis in, 173-175
 supply chain planning, 517
 Logistics processes, 9, 10
 Logistics-System Design Matrix, 385-386
 Long lead procurement, 63, 64
 Long-range capacity planning, 122, 134
 Long-range planning, 517
 Long-term debt, 719-720
 Long-term models, in forecasting, 473, 483-484
 Loss curve, 330-331
 Lost sales, 532
 Lot-for-lot order quantity (L4L), 601, 608, 610
 Lot size
 determining in MRP systems, 607-610, 611
 economic order quantity (EOQ), 608-609
 least-total-cost (LTC) method, 609-610
 least unit cost, 610, 611
 lot-for-lot (L4L), 601, 608, 610
 setup costs and, 413, 414
 Lot tolerance percent defective (LTPD), 343, 344
 Lotus, 222
 Low-contact systems, 257, 258
 Low-cost accommodation, 268, 269
 Low-cost producers, 23, 30
 Lower control limit (LCL), 336
 Low-level coding, 596
 Low prices, 22, 23
 Low-volume manufacturing, 626
 LP. *See* Linear programming
 LTC (least-total-cost) method, 609-610
 LTPD (lot tolerance percent defective), 343, 344
- M**
 Machine-limited process, 625
 Machining centers, 730, 731
 MAD (mean absolute deviation), 481-482, 483
 Maintenance costs, 735
 Maintenance issues, 412, 437

- Major League Baseball, 369
- Make-or-buy decision, 207-208, 718, 728
- Make-to-order operating strategy, 94
- Make-to-order process, 165-166
- Make-to-stock process, 165-166, 167
- Malaysian Airlines, 269
- Malcolm Baldrige National Quality Award, 15, 16, 266-267, 308-309, 366
- Mall of America, 395
- Management
- company unions and, 412
 - human capital management, 430
 - line management, 7
 - people management skills, 187, 443
 - scientific, 15
 - top management (See Senior executives)
- Management by exception, 77
- Management consulting industry, 427-428
- Management flight simulators (MFSs), 450
- Managers
- OSM as critical responsibility, 4-7
 - purchasing managers index, 5
 - role of project manager in matrix projects, 61
- Manpower, 188
- Manual inventory systems, 549
- Manufacturers, 8, 18, 93, 122, 205
- Manufacture-to-order operations, 593
- Manufacturing
- automation in, 15, 188, 734
 - borderless, 373
 - break-even analysis in, 207-208
 - building blocks of, 686-687
 - as competitive weapon, 15
 - computer-integrated manufacturing (CIM), 15, 734, 736
 - computer technology in, 358, 730-734
 - concurrent engineering in, 175
 - continuous process manufacturing, 626
 - design for manufacture and assembly, 105-108, 259
 - "dispersed," 373
 - distribution and, in mass customization, 376, 377
 - dollar day measurements in, 696
 - facilities location decisions in, 395
 - flexible manufacturing systems, 15, 730, 732-733, 736
 - flow manufacturing, 606, 607
 - high- and low-volume, 626
 - lean manufacturing (See Lean manufacturing)
 - light, in distribution centers, 376
 - marks of good layout for, 240-241
 - MRP II, 489, 605-606
 - need for operations consulting in, 429-430
 - operational classification of, 257
 - operations technology in, 730-734
 - hardware systems, 730-733
 - software systems, 734
 - process analysis in, 170-172
 - processes, 9, 10, 204-213
 - break-even analysis of, 207-208
 - example of: Toshiba, 205
 - facility layout in (See Facility layout)
 - flow design, 208-213
 - organization of, 206, 207
 - process analysis, 170-172
 - transformation processes in, 8, 9
 - purchasing managers index, 5
 - quality specifications for, 310
 - similarity of service businesses to, 271
 - supply chains for, 358
 - synchronous manufacturing, 15, 682, 684, 697
 - trade-offs in, 16
 - typical supply chain, 365
 - See also Just-in-time production
- Manufacturing cells, 206, 732-733
- basic format of, 222
 - developing, 235, 236
 - in direct build-to-order model, 234
 - virtual, 235
- Manufacturing Execution Systems (MES), 624
- Manufacturing inventory, 547
- Manufacturing productivity analysis, 37
- Manufacturing programs, 373
- Manufacturing reporting, 464
- Manufacturing resource planning (MRP II), 489, 605-606
- Manufacturing schedules, charting, 63, 64
- Manufacturing strategy paradigm, 15, 16
- Marginal analysis, 533
- Marginal cost, 718
- Marginal cost of overestimating demand, 551-552
- Market(s), 28, 93
- Market-basket analysis, 467
- Market coup, 370
- Market forces, 425
- Marketing
- dollar day measurements in, 696
 - link with operations, 25
 - planning retail servicescapes and, 239
 - relationship with constraint management, 698-704
 - role in mass customization, 376-377
 - in service capacity planning, 258-259
 - "soft" (qualitative) data in, 698
- Market-pull products, 96, 97
- Market research, 470, 472
- Market risks, 736
- Market selection decision, 394-395
- Marks and Spencer, 322
- Marriott Corporation, 259
- Massachusetts Institute of Technology (MIT), 450
- Mass customization, 17, 375-377
- Mass production, 15
- Master black belts, 319
- Master production schedule (MPS), 591, 598-599, 600, 611
- Master production scheduling, 590-592
- in aggregate planning, 517-518, 519
 - planned order releases, 590-591
 - time fences in, 591-592
- Master scheduler, 590-591, 626, 688-689
- Material(s)
- automated materials handling systems, 730, 732
 - bill of materials file, 593, 595-596, 599, 600, 611
 - delivery of raw materials, 548
 - quality specifications for, 310
 - raw materials inventory, 547
- Material costs, 735
- Material flow, 240
- Material handling, 37, 225-226, 227, 235
- Material requirements planning (MRP), 15, 464, 517-518, 588-611
- example of, 598-603
 - bill of materials, 599, 600
 - developing master production schedule, 598-599
 - forecasting demand, 598
 - inventory records, 599-600
 - performing calculations, 600-603
 - flow management, 589
 - flow manufacturing, 606, 607
 - improvements in system, 603-606
 - closed-loop MRP, 605
 - computing workcenter load, 603-605
 - MRP II, 605-606
 - as infinite, backward scheduling system, 625
 - lot sizing in, 607-610, 611
 - choosing best lot size, 610
 - economic order quantity, 608-609
 - least total cost, 609-610
 - least unit cost, 610, 611
 - lot-for-lot, 601, 608, 610
 - master production scheduling, 590-592
 - planned order releases, 590-591
 - time fences, 591-592
 - need for operations consulting in
 - developing, 430
 - synchronous manufacturing compared, 697
 - system structure, 593-598, 693, 695
 - bill of materials, 593, 595-596
 - demand for products and, 593
 - inventory records, 596, 597
 - MRP computer program, 597-598
 - venues for, 592, 593
- Mathematical programming, 15
- Mathematical techniques
- in aggregate planning, 531-532
 - linear programming, 36-44
 - simulation compared, 667
- Matrix projects, 61-62, 77
- Maximum practical capacity, 123
- McDonald's Corporation, 106, 389
- lean services, 417, 418
 - make-to-order process, 159-160, 166-167
 - quality control, 15, 16
 - service design, 263, 264
- McKinsey & Company, 322, 428, 431, 432, 443
- Mean
- formula for, 329, 346
 - in process capability, 331, 332-334
 - in size of samples, 339
- Mean absolute deviation (MAD), 481-482, 483, 500
- Mean squared error, 481
- Mean time between repair (MTBR) analysis, 464
- Mean time to repair (MTTR) analysis, 464
- Measurement(s)
- attribute measurements, 336-338, 346
 - cost accounting measurements, 698
 - dollar day measurements, 696
 - of error, 481-482, 483
 - inventory measurement, 696
 - of performance (See Performance measurement)
 - of product development performance, 109-110
 - productivity measurement, 28-29

- Measurement(s) (Cont.)
 variable measurements, 338–339
See also Work measurement
- Medium-term models, 473, 499
- MedModel (computer simulation software), 438
- Merchandise groupings, 238–239
- Merck, 30
- Merge-in-transit service, 384
- Meridian Energy Company, 65
- MES (Manufacturing Execution Systems), 624
- Methods Time Measurement (MTM), 191
- MFSs (management flight simulators), 450
- Microsoft Corporation, 15, 72, 76, 97, 366, 450
- Microsoft® Excel®
 for computer simulation, 438, 661–663, 664
 cut-and-try costs estimates, 527, 531
 Data Analysis ToolPak, 486, 487, 495
 financial functions in, 722, App–3–App–5
 logarithmic analysis, 144, 145
 NORMSDIST (Z) function in, 72, 334, 335, 559
 NORMSINV (probability) function in, 551, 552, 561, 563
 process flowcharting with, 164
 QueueModel spreadsheet, 285, 295–296
 @RISK simulation program, 664
 Solver function, 36
 in job scheduling, 632–633
 linear programming with, 41–44, 531
 logistics problems, 391–393, 394
 in sales and operations planning, 463
- Microsoft Office Suite, 76, 164
- Microsoft Project, 76, 440
- Mid-volume manufacturing, 626
- Milestone/bar chart, 64, 65
- Miller Brewing Company, 417
- "Minders," 428
- Minimized setup times, 412
- Minimum-cost schedule, 75–76
- Minimum-cost scheduling, 73–76
- MIT (Massachusetts Institute of Technology), 450
- Mixed line structures, 284–285
- Mixed-model line balancing, 232–234, 530
- Mixed-model production cycle, 409
- Mixed strategy, 520, 527
- M&M Mars, 124
- Modeling
 in economic analysis, 99–102
 in forecasting
 dynamic models, 469, 470
 long-term models, 473, 483–484
 medium-term models, 473, 499
 short-term models, 473, 499
 model of linear programming, 38–39, 654
 network-planning models, 65–76
 P-model (*See* Fixed-time period models)
 price-break models, 565–567, 574
 Q-model (*See* Fixed-order quantity models)
 regression modeling, 395
 self-service model, 25–27, 159–160
 simulation model, 657–658, 661
 constructing, 653, 654–656
 continuous or discrete, 663
 dynamic models, 469, 470
 in systems thinking, 449–450
 system dynamics models, 449–450
 time-cost models, 72–76
- Modern Production Management (Buffa), 14
- Modular bill of materials, 595–596
- Moore's Law, 264
- MOST (Most Work Measurement System), 191, 192, 199
- Most Work Measurement System (MOST), 191, 192, 199
- Motion studies, 15
- Motion-time analysis, 227
- Motivation, 150, 187, 190, 437
- Motorola Corp., 15, 60, 313, 331, 336, 354n, 361, 366
- Moving averages
 simple, 470, 474–476
 weighted, 470, 476–477
- MP&CS (automated manufacturing planning and control systems), 730
- MPS (master production schedule), 591, 598–599, 600, 611
- MRP. *See* Material requirements planning
- MRP II (manufacturing resource planning), 489, 605–606
- MTBR (mean time between repair) analysis, 464
- MTM (Methods Time Measurement), 191
- MTTR (mean time to repair) analysis, 464
- Muda (waste), elimination of, 405–412, 416
- Multichannel, multiphase line structure, 284
- Multichannel, single-phase line structure, 284
- Multidisciplinary teams, 15
- Multifactor productivity measure, 28, 29
- Multiperiod inventory systems, 550, 553–554, 555
- Multiple lines, 283
- Multiple machine centers, 634
- Multiple regression analysis, 495
- Multiple-stage processes, 164, 170–172
- Multiple-to-single channel structure, 284–285
- Multiplicative seasonal variation, 487, 488
- Multiproduct production, 532
- Multiskilled workers, 187
- Multivariate testing, 318
- N**
- n* (number of units in sample), 343, 344–345
 "n/1," priority rules for, 628–630
 "n/2 flow-shop case," 630–632
- NAFTA (North American Free Trade Agreement), 373, 389
- NASCAR, 369
- National Institute of Standards and Technology, 15, 16
- Navy, U.S., 65
- NC (numerically controlled) machines, 730
- NEC, 368
- Negative exponential distribution table, App–4
- Negative values, 722
- Nestlé, 450
- Net change systems, in MRP, 598
- Netflix, 269
- Net present value (NPV)
 in base-case model, 99, 100–102
 calculating with spreadsheet, 722
 expansion decision and, 725–727
 internal rate of return compared, 725
 of investments, 724
 replacement decision and, 727–728
 sensitivity analysis and, 102
- Net profits, 682
- Net requirements, in MRP, 597, 600, 602, 603
- Net return, 718
- Netscape Communications Corporation, 15
- NetWeaver software, 461–462
- Network diagrams, 66, 68, 69, 73
- Network-planning models, 65–76
 CPM with three time estimates, 70–72
 critical path method (CPM), 65–69, 70–72
 time-cost models, 72–76
- New product introduction, 24
- "Newsperson" problem, 551, 552
- New York Stock Exchange (NYSE), 282
- Nike, 373
- Nissan, 124
- "n job—two-machines problem," 630–632
- Nokia, 8, 221
- Nonbottlenecks
 product flow through, 686–688
 saving time at, 689–690
- Nonlinear problems, 43
- Nonlinear programming, 38
- Nonpaced production process, 167
- Non-steady state processes, 172
- Non-value-added activities, 406
- Nordstrom Department Stores, 263, 265
- Norm(s), 270
- Normal time, in time study, 192
- NORMSDIST (Z) function, 72, 334, 335, 559
- NORMSINV (probability) function, 551, 552, 561, 563
- Nortel Networks, 366
- North American Free Trade Agreement (NAFTA), 373, 389
- Northeast Utilities, 188
- Nper, in present value calculations, 722
- NPV. *See* Net present value
- NTN Drive Shafts, 387
- Number of lines, 283
- Number of samples, 339
- Number of servers problem (illustration), 286, 287, 290, 291, 297
- Number of units in sample (*n*), 343, 344–345
- Numerically controlled (NC) machines, 730
- NYSE (New York Stock Exchange), 282
- O**
- Oakmont Country Club, 551
- Oakwood Healthcare System, 623
- Oakwood Hospital and Medical Center, 623
- Objective(s). *See* Goal(s)
- Objective function, 40, 41
- Observations, 196
- Obsolescence, 549, 683, 714, 735
- Occurrence, in FMEA, 318
- OC (operating characteristic) curves, 344–345
- OEM (original equipment manufacturer), 8
- Office layout, 240
- Offshoring, 357
- OID (original issue discount), 719
- OLM Consulting, 450
- One-bin system, 554, 569
- "100 Best Companies to Work For" (*Fortune*), 188
- 100 percent testing, 330–331, 332, 343

- One-time orders, 553
 Open build cells, 234
 Open information warehouse, 459
 "Open-to-buy" figure, 573
 Operating characteristic (OC) curves, 344-345
 Operating differences, 149
 Operating expenses, 682, 683
 Operating rules, 654
 Operating yield management systems, 533-534
 Operational design decisions, 99
 Operational fit, 108, 110
 Operational performance measurements, 682-683
 Operational risks, 736
 Operation and route sheet, 208-209, 210
 Operations, 4
 aggregate operations plan, 516, 517, 518-521, 534
 production planning environment, 519-520
 relevant costs, 520-521
 complexity of, 446-450
 degree of customer/service contact and, 260, 261
 ERP software for, 460-461
 evaluation of performance, 30, 31
 independence of, 548
 marketing-operations link, 25
 role in service triangle, 257
 stable, 307, 697
 strategic capacity management in, 122-123
 yield management in, 532-534
 See also *specific kinds of operations*
 Operations and supply management (OSM), 1, 2-18
 careers in, 7, 12-14
 current issues in, 14-17
 example: Ikea, 3
 example: Progressive Insurance, 5-6
 historical development, 14-17
 managers' responsibility for, 4-7
 nature of field, 7-8
 purchasing managers index (PMI), 5
 services and goods contrasted, 10-12
 goods-services continuum, 11
 growth of service sector, 11, 12
 supply chain transformation processes, 8-10
 Operations and supply strategy, 20-31
 competitive dimensions of, 22-24
 framework for, 27-28
 marketing-operations link, 25
 productivity measurement, 28-29
 strategic fit in, 25-27
 trade-offs in, 24-25
 Wall Street's evaluation of, 30
 Operations consulting, 424-440
 economics of consulting firms, 428-429
 example of, 425-426
 guidelines for, 431-432
 management consulting industry, 427-428
 nature of, 426
 need for, 429-430
 tool kit for, 432-440
 cost impact and payoff analysis, 439-440
 data analysis and solution development, 438-439
 data gathering, 435-438
 implementation, 440
 problem definition tools, 432-435
 Operations effectiveness, 22
 Operations focus, 24-25
 Operations model, 426
 Operations perspective, 30
 Operations plan, 517
 Operations research and management science (OR/MS), 7-8
 Operations research tools, 15
 Operations technology, 730-735
 computer-integrated manufacturing, 15, 734, 736
 in manufacturing, 730-734
 hardware systems, 730-733
 software systems, 734
 technology investments
 benefits of, 735-736
 evolution of, 734-735
 Operation time, 168, 169
 Opportunities, in DPMO, 314
 Opportunity costs, 633-634, 714
 Opportunity flow diagrams, 315, 317
 OPT (optimized production technology), 15, 681
 Optimal order quantity, 562, 575
 Optimal stocking level, 551-552
 Optima! simulation software, 436, 438, 667
 Optimized production technology (OPT), 15, 681
 Optimizing process, 38
 Optimum point, 40-41
 Optional replenishment system, 554, 568
 Oracle, 15, 457, 463, 532, 589
 Order fulfillment analysis, 464
 Ordering costs, 549, 557, 568
 Order lead time, reducing, 176-177
 Order qualifier, 25
 Order quantities
 accuracy in, 549
 calculating, 601, 608-611
 computing, 562, 575
 EOQ (See Economic order quantity)
 in fixed-order quantity models, 555-556, 558
 in fixed-time period model, 563-565
 in price-break models, 566-567
 Order winner, 25
 Organizational learning, 143, 150-151
 Organizational risks, 736
 Organization charts, 438
 Original equipment manufacturer (OEM), 8
 Original issue discount (OID), 719
 OR/MS (operations research and management science), 7-8
 OSM. See Operations and supply management
 "Outbound logistics," 10
 Outcomes, in reengineering, 441
 Output
 attainable rate of (See Capacity)
 productivity measurements, 28
 Output reports, 658
 Output requirements, 518
 Outsourcing
 in adding capacity, 127
 capability sourcing, 369
 coordination of, 18
 of product design, 93, 94
 in supply chain strategy, 357, 366-370
 Overall allocation of resources, 77
 Overhead, allocation of, 717
 Overhead rate, 716
 Overtime, 231, 638
 Overutilization of capacity, 415-416
 P
 Paced production process, 167
 Pacing, 167-168, 227
 "Pacing process," scheduling as, 436
 Package of features, services as, 10-11
 Panasonic, 370
 Panel consensus, 470, 472
 Parallel activities, 165, 175, 177, 441-442
 Parallel workstations, 231
 Parameters, 654, 656
 Paramount, 77
 Pareto analysis, 438
 Pareto charts, 315, 316, 587n
 Pareto principle, 569, 587n
 Part families, 236
 Partial factor productivity, 169
 Partial productivity measure, 28, 29
 Par (face) value of bond, 719
 Patient arrival, 282
 Payback formula, 732
 Payback period, 724-725
p charts, 336-338
 PC-MODEL simulation software, 664
 PDCA cycle, 314
 Peg record file, 596
 People, respect for, 412
 People Express MFS, 450
 People management skills, 187, 443
 Peoples' Express, 532
 PeopleSoft, 463
 Perceived quality, 310, 311
 Percentage learning rate, 143, 144, 145
 Performance
 dimensions of quality for, 310, 311
 improving, outsourcing and, 367
 key performance indicators (KPIs), 464
 performance data, 199
 service encounter performance, 269
 Performance data, 199
 Performance evaluation, 190, 194
 Performance index, 194
 Performance measurement
 in constraint management, 682-683
 financial performance, 5, 682-683
 in process analysis, 168-170
 process performance metrics, 168-170, 173
 in product development process, 109-110
 rating, in time study, 192
 in supply chain strategy, 359-361
 work sampling applied to, 195
 Performance summary report, 635
 Period cash flow, 101
 Periodic review system. See Fixed-time period models
 Periodic system. See Fixed-time period models
 Period model, 531
 Perishability, 531, 532
 Perishability of services, 10
 Permeable system, 259, 260

- Perpetual system. *See* Fixed-order quantity models
- Personal-attention approach, 263, 265–268
- Personal needs allowance, 192–193
- Personnel practices, in Six Sigma, 318–319
- PERT (Program Evaluation and Review Technique), 65, 70
- Per unit gross profit, 700, 702
- Pfizer, 30
- Pharmaceutical industry
 contract manufacturers in, 93, 94
 ERP systems used in, 590
 plant location in, 390–393
 strategic capacity management in, 121–122
- Physical constraints, 705
- Physical contact methods. *See* Poka-yokes
- Physical environment, 436
- Physical transformation processes, 8
- Physiological transformation processes, 8
- “Pick to light” computerized system, 234
- “Pipelined” projects, 696
- Pipeline transportation, 371, 385, 386
- Pittiglio Rabin Todd & McGrath (PRTM) Consultants, 425–426
- Plan, do, check, and act (PDCA) cycle, 314
- Planned order receipts, in MRP, 597, 600, 602
- Planned order releases, 590–591, 600, 602
- Planning concepts, 124–127
 capacity flexibility, 126–127, 135, 211
 capacity focus, 125–126, 135
 economies and diseconomies of scale, 124, 125
 learning curve, 125
- Planning phase, 94–95, 96
- Plant(s)
 flexible, 126
 influences on size of, 124
 specialized, elimination of waste and, 405, 407
- Plant abandonment decision, 718
- Plant location methods, 389–394
 centroid method, 389, 393–394
 factor-rating systems, 389–390
 transportation method, 389, 390–393
- Plant location studies, 37
- Plants within plants (PWWPs), 126
- Plant tours/audits, 435–437, 451, 452
- Platform products, 96, 97–98
- Platform projects, 58
- PM (project manager), 61
- PMI (purchasing managers index), 5
- PMIS (project management information systems), 76, 77
- P-model. *See* Fixed-time period models
- Pmt (payment), 722
- PMTS (predetermined motion-time data systems), 191
- Poisson distribution, 281–282, 287, 290, 297, 654
- Poka-yokes, 15
 examples of, 262–263, 264
 in service operations, 261–262, 264
- Poka-yoke system, 319, 320
- Polaroid Corporation, 99, 100, 102
- Policy constraints, 705
- Political risk, 388
- PortalPlayer, 57
- Positive values, 722
- Powersim Solutions, 450
- Precedence diagram, 229, 231
- Precedence relationship, 228
- Precedence relationship networks, 66, 68, 69
- Predetermined motion-time data systems (PMTS), 191
- Present value
 of annuity, 723–724, App–10
 calculating with spreadsheet, 722
 of future single payment, 722–723, App–9
 present value (PV) procedures, 722–723
 present value tables, App–3, App–9
- Prevention costs (COQ), 311–312
- Preventive maintenance, 412
- Price-break models, 565–567, 574
- Price promotions, 361
- Price/service duration matrix, 534
- Primavera, 76
- Primavera Project Planner, 76, 440
- The Principles of Scientific Management* (Taylor), 427
- Priority rules and techniques, 627, 628–634
 assignment method, 632–634
 comparison of, 630
 jobs on two machines, 630–632
 multiple machine centers, 634
- Probability analysis, 72
- Probability approach, 559
- Probability distributions, 654, 655
- Probability function, 551, 552, 561, 563
- Probability of completion, 70–71
- Probability of producing defect, 334, 335
- Probability of reservice, 285
- Problem(s)
 in cost accounting measurement, 698
 economics of, 515
 in financial analysis, 725–728
 hidden by inventory, 407–408
 illustrations (*See specific problems*)
 multidisciplinary team approach to, 15
 shortage problems, 515
 use of LP in problem situations, 38
 waiting line problems, 277, 285, 286
- Problem analysis (SPC tools), 438
- Problem definition, in simulation, 653, 654
- Problem definition tools, 432–435
 customer surveys, 432
 employee surveys, 433
 five forces model, 433, 435
 gap analysis, 432–433, 434
 issue trees, 432, 434
- Problem-solving groups
 in lean services, 417
 multidisciplinary teams, 15
 work groups as, 189
- Procedural differences, 149
- Procedures projects, 428
- Process(es), 119
 alignment with strategy, 426
 consistency of, 331
 defined, 160
 design of, 22, 258
 flexible, 127
 as funnel, 177–178
 manufacturing (*See Manufacturing*)
 multi-step, 164, 170–172
 process analysis (*See Process analysis*)
- quality of
 competitive position of firm and, 23
 Six-Sigma quality, 15, 17, 414–415
 services (*See Service processes*)
 single-stage, 164
 speed of, 162, 172
 strategic capacity management (*See Strategic capacity management*)
 types of, 164–168
 buffering, blocking, and starving, 164–165
 make-to-stock v. make-to-order, 165–168
- Process analysis, 158–178
 example: slot machine, 161–162
 examples of, 170–175
 logistics, 173–175
 manufacturing, 170–172
 services, 172–173
 flowcharting, 162–164
 performance measurement, 168–170
 process improvement v. corporate goals, 176
 in restaurant industry, 159–160
 throughput time reduction, 175–177
 types of processes, 164–168
- Process batch, 694, 695
- Process capability, 307, 331–336
- Process capability index, 332–336
- Process change projects, 58
- Process control, 37, 270, 313
- Process control charts, 346–347
- Process control procedures, 336–342
 with attribute measurements, 336–338
 constructing \bar{X} and R charts, 340–342
 with variable measurements, 338–339
- Process dashboards, 440
- Process flowcharting, 162–164
- Process flowcharts, 209–211
- Process flow clarification, 417
- Process identification, 322
- Process improvement, 176, 426, 430
- Processing time, 688
- Process-intensive products, 96, 97, 98
- Process Model simulation software, 667
- Process operations, MRP used in, 593
- Process optimization, 37
- Process performance metrics, 168–170, 173
- Process planning, 517, 734
- Process postponement, 376
- Process selection, 206
- Process throughput time. *See* Throughput time
- Process velocity, 170
- Procter & Gamble, 322, 361
- “Procurement and logistics” software, 460
- Procurement monitoring, 464
- Producer’s risk (α), 343, 344
- Product(s)
 addition or elimination of, 718
 complementary products, 513n, 519
 customized, 96, 97, 98
 demand for, 593
 designed for markets, 93
 dimensions of quality for, 310, 311
 finished products, 547
 functional, 362–363, 364
 market-pull products, 96, 97
 outputs, 122–123, 735
 platform products, 96, 97–98
 postponing differentiation of, 375–377

- product families, 516
 redesign, 231
 service product design, 108-109
 technology investments and, 735
 technology-push products, 96-97, 98
 value of, 121
- Product change projects, 58
- Product concepts (prototypes), 373
- Product consistency, 167
- Product cost, 102
- Product demand, 548, 593
- Product design, 90-110
 creativity in, 91-92, 102
 degree of customer contact and, 258
 as foundation of quality, 415
 lowered costs and, 3, 4
 for manufacture and assembly (DFMA), 105-108
 process of, 93-94
 redesign, 231
 role of customer in, 103-105
 quality function deployment, 103-104
 value analysis/value engineering, 104-105
 role of product development process in
 (See Product development process)
 service products, 108-109
- Product development process, 94-99
 brainstorming in, 92, 105
 complex systems, 98-99
 in consumer electronics, 57-58
 customized products, 98
 economic analysis of
 base-case financial model, 99-102
 sensitivity analysis, 102
 high-risk products, 96, 97, 98
 operations consulting in, 430
 performance measurement in, 109-110
 platform products, 97-98
 process-intensive products, 98
 quality measurement in, 110
 quick-build products, 98
 rapid prototyping in, 177
 technology-push products, 96-97
- Product innovation, 22, 362, 363, 364
- Production
 change (setup) costs (See Setup costs)
 JIT (See Just-in-time (JIT) production)
 relationship with constraint management,
 698-704
 Toyota system (See Toyota Production
 System)
- Production activity control. See Shop-floor
 control
- Production capacity, 521
- Production cycle, 688-689
- Production decisions
 differing objectives and, 698-700
 quantity to produce, 700-703
- Production flow. See Flow of production
- Production history, 148-149
- Production-line approach, 263, 264
- Production planning
 alternative plans, 523
 calculating costs, 523-525
 degree of customer contact and, 258
 environment of
 aggregate operations plan and,
 519-520
 strategies, 520
 subcontracting, 520
 strategies, 520
- Production ramp-up phase, 95, 96
- Production rate, 518
- Production requirements, 523
- Production scheduling, 548
- Production setup, 235
- Production smoothing, 530
- Productivity, 28
 constraint management and, 683
 cost of quality and, 312
 job enrichment and, 189
 as performance metric, 168-169
 service productivity, 15, 16, 37
- Productivity analysis, 37
- Productivity loop, 447, 448
- Productivity measurement, 28-29
 in constraint management, 683
 in product development, 110
- Product launch, 95, 96
- Product learning, 143, 144
- Product life cycles, 364
- Product mix, 24, 122, 227
- Product planning, 37
- Product-process matrix, 206, 206n, 207
- Product routing, 37
- Product-specific criteria, 24
- Product tree (BOM file), 593, 595-596, 599,
 600, 611
- Professional service organizations (PSOs),
 259, 270
- Profit
 equipment selection and, 287, 289
 per square foot, 237-240
- Program Evaluation and Review Technique
 (PERT), 65, 70
- Program management, software for, 464
- Progress curves, 143, 144
- Progressive-build approach, 234
- Progressive Insurance, 4, 5-6, 425
- Project, defined, 59
- Project control charts, 63-65
- Project development time, 102
- Project direct costs, 75-76
- Projected available balance, 600, 601, 602
- Project indirect costs, 73, 75-76
- Project layouts, 206, 222, 235, 237
- Project management, 15, 56-77
 defined, 59
 dollar day measurements in, 696
 network-planning models, 65-76
 CPM with three time estimates, 70-72
 critical path method (CPM), 65-69, 70-72
 time-cost models, 72-76
 product development and, 57-58
 project control charts, 63-65
 project management information systems,
 76, 77
 resource management, 76-77
 software for, 464
 structuring projects in, 59-62
 functional projects, 60-61
 matrix projects, 61-62
 pure projects, 59-60
 techniques in, 440
 work breakdown structure, 61-63
- Project management information systems
 (PMIS), 76, 77
- Project Management Institute, 76
- Project manager (PM), 61
- Project milestones, 62
- Project mix, 58
- Project networks, 58
- Project scheduling techniques, 15
- Project structuring, 59-62
 functional projects, 60-61
 matrix projects, 61-62
 pure projects, 59-60
- Project total costs, 75-76
- ProModel (computer simulation software), 438
- PRTM (Pittiglio Rabin Todd & McGrath)
 Consultants, 425-426
- PSOs (professional service organizations),
 259, 270
- Pull process, 403, 404-405
- Pull system
 assessing, in RPA, 437
 kanban pull system, 409-410
 in lean production, 403, 404-405
 in simple line flow, 413, 414
- Purchase decision, 718
- Purchasing, 696
- Purchasing managers index (PMI), 5
- Pure goods, 11
- Pure projects, 59-60
- Pure services, 11
- Pure strategy, 520, 523-525
- PV (present value) procedures, 722-723
- PWPs (plants within plants), 126
- Q
 "Q-Bot" device, 279
 QC (quality control) departments, 312-313
 QFD (quality function deployment),
 103-104, 118n
 Q-model. See Fixed-order quantity models
 QS-9000 standards, 321
 Quadratic programming, 38
 Qualitative forecasting techniques, 469, 470,
 472-473
 Delphi method, 473
 grass roots, 472
 historical analogy, 473
 market research, 470, 472
 panel consensus, 472
- Quality
 acceptable quality level (AQL), 343,
 344, 354n
 assessing commitment to, 437
 attributes (quality characteristics), 338
 attribute measurements, 336-338, 346
 sampling by attributes, 336-338
 single sampling plan for, 343-344
 competitive position of firm and, 23
 conformance quality, 310
 of design, 23, 310
 dimensions of, 310, 311
 house of quality matrix, 303-304
 importance in constraint management, 691
 job enrichment and, 189
 measurement of, 110
 product design and, 415

- "Quality at the source," 187, 310, 407
 Quality certification, 15, 16, 430
 Quality control and improvement, 15, 306-322
 degree of customer contact and, 258
 example of process, 307
 external benchmarking for, 322
 inspections by industrial robots, 730
 ISO 9000 and ISO 14000, 320-322
 job design and, 187
 Malcolm Baldrige Quality Award and, 15, 16, 266-267, 308-309, 366
 quality specification and cost
 cost of quality, 311-312
 developing quality specifications, 310, 311
 functions of QC department, 312-313
 Shingo system, 319-320
 Six Sigma, 313-319
 analytical tools for, 315-318
 methodology, 314-315
 roles and responsibilities, 318-319
 SQC (See Statistical quality control)
 TQM (See Total quality management)
 Quality control (QC) departments, 312-313
Quality Control Handbook (Juran), 311
 Quality costs, 311-312, 735
 Quality function deployment (QFD), 103-104, 118n
 Quality function development, 15
 "Quality gurus," 309
 Quality improvement tools, 15
 Quality management software, 460, 464
 Quality of design, 313
 Quality of production, 313
Quality Planning and Analysis (Juran & Gryna), 343
 Quality production reporting system, 267-268
 Quality specification and cost
 cost of quality, 311-312
 developing quality specifications, 310, 311
 functions of QC department, 312-313
 Quality upgrade, 417
 Quantitative layout techniques, 237
 Queue(s). See Waiting line(s); Waiting line analysis
 Queue discipline, 283
 QueueModel spreadsheet, 285, 295-296
 Queue time, 688
 Queuing systems, 278-285
 customer arrivals, 277-278, 279
 distribution of arrivals, 280-282
 exponential distribution, 280
 Poisson distribution, 281-282, 287, 290
 exiting queue, 285
 factors in, 282-285
 line structures and, 283-285
 service time distribution and, 283
 Queuing theory, 277, 439
 Quick-build products, 96, 97, 98
- R**
 R (reinforcing loop), 438, 447, 448
 Radical change paradigm, 15
 Rail transportation, 371, 385, 386
 Rand Corporation, 473
 Random errors, 480
 Random number(s), 654-656
 Random number intervals, 659, 660
 Random number tables, 197
 Random order (whim), 627, 629-630
 Random service times, 283
 Random variation, 329
 Random variations in demand, 469
 Range charts, 338-339, 340-342
 Rapid plant assessment (RPA) tour
 in data gathering, 435, 436-437
 RPA questionnaire, 451
 RPA rating sheet, 452
 Rapid prototyping, 92, 98, 105, 177
 Rate, 722
 Rate-based planning and execution, 416
 Rate cutting, 190
 Rate fences, 533
 Rate of return, 718
 Rath & Strong Consulting, 270, 318n
 Ratio delay, 194
 Raw materials, 547, 548
 R chart, 340-342
 Reactive system, 259, 260
 Real interest rate, 719
 Recordkeeping, 571
 Redo loops, 406
 Redundancy, eliminating, 177
 Reengineering. See Business process reengineering
 Regression, 483
 Regression analysis, 439, 470, 657
 Regression modeling, 395
 Reinforcing loop (R), 438, 447, 448
 Relative measures, 28
 Relevant costs, 520-521
 Relocation of work, 441
 "Remainder cells," 235
 Reneging, 282
 Reorder point
 certainty of demand and, 559-560, 562
 computing, 575
 in two-bin system, 568
 Repetitive work, 191, 407-408, 697
 Replacement decision, 718, 727-728
 Request for bid, 374-375
 Request for proposal, 374-375
 Request variability, 268
 Research and development (R&D), 58, 376
 Residuals, 480
 Resource(s), 625
 capacity-constrained (CCR), 686, 691, 692, 695, 705
 determining usage of, 41, 42
 limited, 38, 39
 manufacturing resource planning (MRP II), 489, 605-606
 See also Enterprise resource planning (ERP)
 Resource allocation, 534
 Resource inputs, 122-123
 Resource management, 76-77
 Respect for people, 412
 Responsibility charts, 440
 Responsive supply chains, 364
 RESQ simulation software, 664
 Restaurant industry
 determining capacity, 172-173
 fast food (See Fast-food restaurants)
 learning curve in, 125
 personnel scheduling in, 640
 service utilization in, 134
 Retailing
 growth of, 17
 inventory control policies, 572-573
 inventory ordering in, 553
 risk-hedging supply chains in, 364
 self-service model in, 25-27
 systematic layout planning, 226
 transformation processes in, 8; 9
 work measurement in, 192
 Retail-level demand forecast, 498
 Retail prices, 3
 Retail service layout, 237-240
 servicescapes, 238-239
 signs, symbols, and artifacts in, 240
 Return on investment, 121, 682
 Returns management, 383
 Revenue, 162
 Reverse auction, 374-375
 Review period, 562
 Rewards, 187, 319
 Rework report, 635
 RFID technology, 625
 Ringling Bros. and Barnum & Bailey Circus, 126
 "Risers," 733
 Risk(s)
 in adopting new technology, 735-736
 consumer's or producer's risk, 343, 344
 expected value and, 714
 facility location and, 388
 of obsolescence, 549, 735
 Risk-hedging supply chains, 364
 Risk priority number (RPN), 318
 @RISK simulation program, 664
 Rituals, in service process, 270
 Ritz-Carlton Hotel Company, 255-256, 263, 265-267
 Roadway Logistics, 367
 Robots, 15, 730, 731, 732
 Rope (communication), 691, 693
 Route sheets, 208-209, 210
 Routine service organizations (RSOs), 259
 Routing matrix, 236
 RPA (rapid plant assessment) tour, 435, 436-437, 451, 452
 RPN (risk priority number), 318
 RSFE (running sum of forecast errors), 481, 483
 RSOs (routine service organizations), 259
 R/3 software (SAP AG), 15, 457-458
 application modules, 458-461
 financial application, 459-460
 human capital management, 460
 operations applications, 460-461
 Rubbermaid, 734
 Run charts, 315, 316, 438
 Run length (run time), 169, 656
 Running sum of forecast errors (RSFE), 481, 483
 Run time (run length), 169, 656
 Ryder, 366
- S**
 SABRE reservations system, 532
 Safety stock, 364, 599, 608
 computing amounts necessary, 560-562, 575
 in fixed-order quantity models, 558-562

- in fixed-time period models, 563–564
- planning, 463, 522
- in retailing, 572
- See also Buffering
- Sales analysis software, 464
- Sales and distribution software, 460–461
- Sales and operations planning (S&OP), 514–534
 - aggregate operations plan, 517, 518–521
 - production planning environment, 519–520
 - relevant costs, 520–521
 - aggregate planning techniques, 522–532
 - applied to services, 527–529
 - cut-and-try example, 522–527, 531
 - level scheduling, 529–530
 - mathematical techniques, 531–532
 - overview of activities in, 516–518
 - shortage problems and, 515
 - use of linear programming in, 37
 - yield management, 532–534
- Sales and Operations Planning software, 462–463
- Sales forecasts, 589
- Sales planning software, 464
- Sales plans, 516, 517
- Sales price, 102
- Sales revenue, 699, 701–702
- Sales volume, 102
- Sample size, 336–337, 339
- Sampling
 - by attributes, 336–338
 - example of, 337–338
 - sampling plans for, 343–344
 - size of sample, 336–337
 - purpose of, 330
 - by variables, 336, 338–339
- Sampling inspection, 15
- Sampling plans, 197, 343–344, 345–346
- SAP, 589
- SAP AG, 15, 430, 456, 464, 532
 - ERP software by, 457–458
 - corporate services application, 461
 - financial application, 459–460
 - human capital management application, 460
 - integrated e-business applications, 461–463
 - open information warehouse, 459
 - operations applications, 460–461
 - SAP Business One, 464
- SAS (Scandinavian Airlines System), 240
- "Sawtooth effect," 556
- Scandinavian Airlines System (SAS), 240
- Scatter diagrams, 438
- Schedule(s)
 - activity scheduling charts, 15
 - cost/performance tracking schedule, 64
 - early-start and late-start, 68–69
 - level-loaded, 696
 - level schedule, 415
 - manufacturing schedules, 63, 64
 - master production schedule, 591, 598–599, 600, 611
 - minimum-cost schedule, 75–76
 - stability of, 415–416
- Scheduled receipts, in MRP, 600, 602
- ScheduleSource Inc., 639
- Scheduling, 15, 621, 622–642
 - assessing scheduling system, 436
 - central scheduling systems, 436
 - computer simulation in, 652–667
 - constraint management, 672–705, 678–705
 - degree of customer contact and, 258
 - flexibility in, 548
 - in health care industry, 623–624, 664
 - importance of, 621
 - in lean services, 418
 - level scheduling, 529–530
 - manufacturing execution systems, 624
 - master scheduling, 519
 - minimum-cost scheduling, 73–76
 - as "pacing process," 436
 - of personnel in services, 638–642
 - consecutive days off, 638–640
 - daily work times, 640, 641
 - hourly work times, 640–642
 - software for, 639
 - priority rules and techniques, 628–634
 - assignment method, 632–634
 - comparison of, 630
 - jobs on two machines, 630–632
 - multiple machine centers, 634
 - project scheduling techniques, 15
 - in service system design, 271
 - shop-floor control, 634–638
 - data integrity and, 636–638
 - Gantt charts, 634–635
 - input/output control, 635, 636, 637
 - principles of, 638
 - tools of, 635
 - simulation in, 642, 652–667
 - use of linear programming in, 37
 - work centers, 624–628
 - job sequencing in, 627–628
 - objectives of, 626
 - scheduling and control functions, 625–626, 627
 - work measurement in, 190
- Scientific management, 15
- Scientific method, 314
- SCLogix, 457
- SCM (Supply Chain Management) software, 462
- Scrap report, 635
- S-curve trend, 471, 472
- Seasonal demand, 528
- Seasonal factor (index), 488–490, 491
- Second-party certification, 321
- Security measures, 571
- Security technology, 545
- Segmentation, 569, 570
- Segmented service experience, 270
- Self-check, 319, 320
- Self-service approach, 263, 264–265
- Self-service model, 25–27, 159–160
- Senior executives
 - chief executive officer, 13
 - chief operating officer, 13–14
 - involvement in reengineering, 443
 - judgment in forecasting, 472
 - leaders in Six Sigma, 318
 - raising awareness of OSM, 18
 - strategic vision of, 27, 28
- Sensitivity analysis, 102
- Sensitivity Report, 44
- Sequencing. See Job sequencing
- Serial production line, 662–663
- Serial production process, 167
- Serviceability, 310, 311
- Service blueprinting, 261–263
- Service bookends, 269
- Service capacity planning
 - capacity utilization in, 133–134, 135, 173–175
 - manufacturing compared, 133
 - marketing considerations in, 258–259
 - role of waiting lines in, 133–134, 141n, 172–173
 - uses of service-system design matrix, 260, 261
 - See also Capacity planning; Strategic capacity management
- Service companies, 4, 5–6, 358
- Service costs, reducing, 5–6
- Service delivery, 261, 264
- Service design
 - customer involvement in, 108, 133, 265
 - "fit" in, 108
 - service processes, 258–268, 271
 - service products, 108–109
 - service systems, 259–260, 267, 271
- Service Execution System (SES), 624
- Service experience fit, 108
- Service facilities
 - complete audit of, 436
 - location of, 394–396, 397
 - retail service layout, 237–240
 - servicescapes, 238–239
 - signs, symbols, and artifacts in, 240
- Service guarantees, 270–271
- Service-Master, 240
- Service Model (computer simulation software), 438
- Service organizations
 - customer as focal point of, 256–257
 - designing, 258–259
 - PSOs, 259, 270
 - RSOs, 259
- Service processes, 9, 10, 254–271
 - behavioral science in, 269–270
 - customer-induced variability in, 268–269
 - designing
 - flowcharting in, 261, 262, 271
 - sample designs, 263–268
 - personal-attention approach, 265–268
 - production-line approach, 264
 - self-service approach, 264–265
 - service organization design, 258–259
 - example: room service waiter, 255–256
 - management of, 533
 - nature of services, 256–257
 - operational classification of, 257, 258
 - service blueprinting and fail-safing, 261–263
 - service guarantees, 270–271
 - service-system design matrix, 256, 259–261
 - SQC applied to, 329
- Service product design, 108–109
- Service productivity, 15
- Service productivity analysis, 37
- Service quality, 133–134
- Service rate, 283, 288
- Service recovery, 270
- Service requirements, 277–278
- Services, 10–12, 18
 - aggregate planning techniques applied to, 527–529

Services (Cont.)

- automation of heavy manual work, 188
- capacity planning in (See Service capacity planning)
- customer and
 - customer as focal point of service organization, 256–257
 - involvement in service design, 108, 133, 265
 - role in service supply chains, 365, 366
- design of (See Service design)
- dimensions of quality for, 311
- examples of process analysis, 172–173
- extent of contact in, 257
- face-to-face services, 241
- financial services, 430
- high-or low-contact systems, 257, 258
- inventory control in, 572–573
- inventory in, 547
- lean services, 417–418
- nature of, 256–257
- operational classification of, 257, 258
- operations consulting in, 430
- as output of processes, 160
- process analysis in, 172–173
- scheduling personnel in, 638–642
 - consecutive days off, 638–640
 - daily work times, 640, 641
 - hourly work times, 640–642
 - software for, 639
 - time in process, 175, 176
 - value-added, 18, 384, 386
- Servicescapes, 238–239
- Service science, 15, 17
- Service Science Management and Engineering (SSME), 17
- Service sector
 - growth of, 11, 12
 - mass production in, 15
 - quality and productivity in, 15, 16, 37
- Service supply chains, 365–366
- Service system design
 - buffering in, 259–260, 271
 - characteristics of well-designed systems, 267
 - design matrix, 256, 259–261, 265, 271
- Service-system design matrix, 256, 259–261, 265, 271
- Service time distribution, 283, 294
- Service triangle, 256–257
- Service utilization, 133–134
- SES (Service Execution System), 624
- Setup (production change) costs, 414*n*
 - inventory size and, 549
 - L4L order quantity and, 608
 - lot size and, 413, 414
 - splitting shifts, 642
- Setup times, 169, 412, 688–689
- 7-Eleven, 369
- Severity, in FMEA, 318
- Sharp Electronics Corp., 57
- Shibaura Seisaku-sho (Shibaura Engineering Works), 205
- Shifting-the-burden/addiction archetype, 448, 449
- Shingo system, 319–320
- Shipping costs, 3
- Shiskin time series (X-11) forecasting, 470
- Shop capacity control load flow, 635, 637
- Shop discipline, 636–637
- Shop-floor control, 625, 634–638
 - data integrity and, 636–638
 - Gantt charts, 634–635
 - input/output control, 635, 636, 637
 - principles of, 638
 - tools of, 635
- Shop scheduling, 15
- Shortages, 515, 549, 635
- Shortest operating time (SOT) rule, 627, 629, 630
- Shortest processing time (SPT) rule, 627
- Short-range capacity planning, 122, 625
- Short-range planning, 517, 518
- Short-term debt, 718–719
- Short-term models, 473, 499
- Sigma, 330
- Signs, in retail service layout, 240
- SIMAN simulation software, 664, 667
- SIMFACTORY simulation software, 438, 664, 667
- Simple moving average, 470, 474–476, 500
- Simple proportion, 488–489
- Simplex method of linear programming, 15
- Simple (face) yield, 719
- Simplification of product, 106
- SIMSCRIPT II.5 simulation software, 664
- Simulation, 642, 652–667
 - advantages and disadvantages of, 666–667
 - defined, 653
 - methodology of, 653–658
 - computerization, 657–658
 - constructing simulation model, 653, 654–656
 - evaluating results, 656–657
 - problem definition, 654
 - proposing new experiment in, 657
 - validation, 657, 658
 - values of variables and parameters, 656
 - programs and languages for, 663–666
 - by spreadsheet, 661–663, 664
 - in systems thinking, 450
 - of two-stage assembly lines, 658–661
 - use of computers in (See Computer simulation)
- Simulation model, constructing, 653, 654–656
 - decision rules, 654
 - probability distributions, 654, 655
 - time-incrementing procedure, 656
 - variables and parameters, 654
- Simulation study, steps in, 653
- Singapore Airlines, 433, 533
- Single-activity Gantt chart, 64
- Single arrival, 282
- Single channel, multiphase line structure, 284
- Single channel, single phase line structure, 283, 284
- Single exponential smoothing, 478–479, 500
- Single lines, 283
- Single-period inventory systems, 550, 551–553, 574, 575
- Single sampling plan, 343–344
- Single-stage processes, 164
- SIPOC analysis, 315, 316
- Six Flags, 279
- Six Sigma, 313–319
 - analytical tools for, 315–318
 - as approach to TQM, 309
 - example of, 307
 - lean, 403–404
 - reducing variability in, 318
 - Six-Sigma quality, 414–415
 - methodology, 314–315
 - process capability, 331, 332
 - roles and responsibilities, 318–319
 - Theory of Constraints compared, 681–682
 - Six-Sigma quality, 15, 17, 414–415
 - Six-Sigma training, 319, 430
 - Size of arrival units, 282
 - Skill variety, 190
 - SKU (stockkeeping unit), 572
 - Skunkworks projects, 59–60
 - Skype, 17
 - Slack time, 67
 - Slačk time remaining per operation (STR/OP) rule, 627
 - Slack time remaining (STR) rule, 627, 629–630
 - SLAM II simulation software, 664, 667
 - "Slice and dice," 459
 - "Slipping filters," 77
 - Slot machines, 161, 162–164
 - SLP (systematic layout planning), 226
 - Smoothed average, 513*n*
 - Smoothing
 - exponential (See Exponential smoothing)
 - flow of production, 408–409
 - production smoothing, 530
 - Smoothing constant alpha (α), 477, 480
 - Smoothing constant delta (δ), 479
 - Social security, 721
 - Sociotechnical systems, 189–190
 - "Soft" (qualitative) data, 698
 - Software. See Computer software
 - Solelectron, 366, 403–404
 - Solution development tools, 432
 - Solver function. See Microsoft® Excel®
 - Sony, 57, 366
 - S&OP. See Sales and operations planning
 - SOT (shortest operating time) rule, 627, 629, 630
 - Source inspection, 319–320, 320
 - Sources of error, 480
 - Sourcing processes, 9–10
 - Sourcing/Purchasing—System Design Matrix, 374–375
 - Southwest Airlines, 7, 18, 25
 - SOW (statement of work), 62
 - Space utilization, 436–437
 - Spatial layout and functionality, 238
 - SPC (statistical process control), 336, 345–346, 438
 - Specialization, 425
 - of labor, 188–189
 - in management consulting industry, 428
 - work specialization, 150
 - Specialized plants, 405, 407
 - Special-purpose equipment, 207
 - Special-purpose simulation software, 664
 - Specification limits, 330, 332
 - Speedi-Lube, 417, 418
 - Speed of processes, 162, 172
 - Splitting shifts, 642
 - Sports, service utilization in, 134
 - Spreadsheets
 - in computing interest rate effects, 721, 722
 - cut-and-try graphic methods, 522–527, 531

- Excel (See Microsoft® Excel®)
 - limitations of, 449–450
 - organizing project cash flows, 100
 - simulation, 661–663, 664
- SPT (shortest processing time) rule, 627
- SQC. See Statistical quality control
- SSME (Service Science Management and Engineering), 17
- Stable operations, 307, 697
- Stable supply process, 363
- Stable workforce—variable work hours, 520
- Staged projects, 696
- Stakeholder analysis, 439
- Standard deviation
 - formula for, 330, 346, 587*n*
 - in process capability, 331, 332
 - in time study, 192, 294
- Standard deviation of daily demand, 560–562, 575
- Standard distribution
 - in forecasting, 472
 - relating random numbers to, 654–656
 - in simulation, 654, 655
- Standard error, 481, 486, 513*n*
- Standardization, 206, 207, 546
- Standardized procedures, 150–151
- Standard Meat Company, 417
- Standard time, 192–193
- Standard transportation problem, 543*n*
- Stanford University, 355
- Staples, Inc., 361, 375, 572
- Starting conditions for variables, 656
- Starving, 164
- State Farm Insurance, 389
- Statement of work (SOW), 62
- Statistical fluctuation, 684, 685
- Statistical metrics, 404, 656–657
- Statistical process control (SPC), 336, 345–346, 438
- Statistical quality control (SQC), 313, 328–347
 - acceptance sampling, 343–345
 - operating characteristic curves, 344–345
 - single sampling plan, 343–344
 - capability index, 332–336
 - formulas used in, 346–347
 - overview of, 329–330
 - process capability, 331–336
 - process control procedures, 336–342
 - with attribute measurements, 336–338
 - constructing \bar{X} and R charts, 340–342
 - with variable measurements, 338–339
 - variation and, 330–331
- Statistical tools, 439
- Status and exception reports, 635
- Steady rate, 170
- Steady-state formulas, 277, 285, 286
- Steady-state processes, 172, 209, 277, 285, 286
- Steinway Piano Company, 151
- Stew Leonard's Dairy Store, 238, 239
- Stock-and-flow diagrams, 450
- "Stock chasers," 651*n*
- Stockkeeping unit (SKU), 572
- Stockout, 549, 558
- Stocks, 720
- Storage, in flowcharting, 162, 211
- Storage transformation processes, 8
- Straddling, 25
- Straight-line depreciation method, 715
- Strategic activities, 370
- Strategic capacity management, 120–135
 - capacity planning (See Capacity planning)
 - in operations, 122–123
 - in pharmaceutical industry, 121–122
 - planning concepts, 124–127
 - capacity flexibility, 126–127, 135, 211
 - capacity focus, 125–126, 135
 - economies and diseconomies of scale, 124, 125
 - learning curve, 125
 - service capacity planning (See Service capacity planning)
 - time horizons for, 122
- Strategic control, 368
- Strategic fit, 25–27
- Strategy, 1, 22
 - activity-system maps, 26, 27
 - alignment with process, 426
 - design (See Product design; Service processes)
 - global, 426
 - mixed, 520, 527
 - operations and supply (See Operations and supply strategy)
 - project management (See Project management)
 - pure strategy, 520, 523–525
 - in supply chain (See Supply chain strategy)
- Strategy development, 430
- Strategy framework, 27–28
- Stretch objectives, 319
- STR/OP (slack time remaining per operation) rule, 627
- STR (slack time remaining) rule, 627, 629–630
- Structure, organizational learning and, 150, 151
- Subcontracting, 412, 520, 531, 532
- Subjective preference variability, 268, 269
- Suboptimization, 62
- Subtask, 62
- Successive check inspection, 319–320
- Success-to-the-successful archetype, 449
- Sum of annuity table, App–8
- Sum-of-the-year's-digits (SYD) depreciation method, 715, 726
- Sunistanai*, 446
- Sunk costs, 713–714, 726
- Sun Microsystems, 94, 366
- Super bill of materials, 596
- Supermaids, 417
- Supplier(s)
 - as customers, 365–366
 - facility location and, 388
 - JIT systems and, 697
 - working with, 368, 416–417
- Supplier, input, process, output, customer (SIPOC) analysis, 315, 316
- Supplier networks, 418
- Supplies inventory, 547
- Supply, 4
- Supply chain(s), 358
 - agile, 364, 376
 - assessing integration of, 437
 - design of, 355
 - design strategy, 361–364
 - lean manufacturing, 402–417, 418
 - logistics and facility location, 383–397
 - operations consulting and reengineering, 424–443
 - Sourcing/Purchasing—System Design Matrix, 374–375
 - supply chain strategy, 356–377
 - lean, 416–417
 - managing (See Supply chain management)
 - measures of efficiency, 377
 - of original equipment manufacturer, 8
 - OSM in, 4
 - planning and controlling, 453
 - demand management and forecasting, 466–499, 500
 - ERP systems, 454–465
 - inventory control, 544–576
 - material requirements planning, 588–611
 - service supply chains, 365–366
 - strategy for (See Supply chain strategy)
 - transformation processes, 8–10
 - Supply chain inventories, 547
 - Supply chain management, 1, 15, 17, 372–373
 - inventory control and, 564–565
 - in mass customization, 376–377
 - rate-based planning and execution, 416
 - in "reinventing government," 6
 - Supply Chain Management (SCM) software, 462
 - Supply chain partnerships, 499
 - Supply chain planning, 517
 - Supply chain strategy, 356–377
 - design for logistics, 370
 - design strategy, 361–364
 - global sourcing, 373–374
 - mass customization, 375–377
 - offshoring, 357
 - outsourcing, 357, 366–370
 - overview, 358–359, 377
 - performance measurement, 359–361
 - service supply chains, 365–366
 - Sourcing/Purchasing—System Design Matrix, 374–375
 - value density, 370–372
 - Supply network. See Supply chain
 - Supply uncertainty, 363
 - Supporting facility for services, 10
 - SWOT analysis, 435
 - SYD (sum-of-the-year's-digits) depreciation method, 715, 726
 - Symbols, in retail service layout, 240
 - Synchronized planning, 37
 - Synchronous manufacturing, 15, 682, 684, 697
 - System(s)
 - defined, 446
 - kinds of
 - ERP systems (See Enterprise resource planning systems)
 - inventory systems (See Inventory systems)
 - just-in-time (JIT) systems, 143, 319, 430
 - Kanban production control systems, 15, 409–411, 413
 - MRP systems (See Material requirements planning)
 - pull system (See Pull system)
 - queuing system (See Queuing systems)
 - at Toyota (See Toyota Production System)
 - service system design (See Service system design)

- System(s) (*Cont.*)
 system design
 Inventory Control-System Design Matrix, 550
 Logistics-System Design Matrix, 385-386
 Sourcing/Purchasing-System Design Matrix, 374-375
See also specific named systems
 Systematic layout planning (SLP), 226
 System balance, 127
 System constraints, 703-704, 705
 System dynamics, 446-447
 analysis of, 438
 models, 449-450
 System-level design phase, 95, 96, 99
 Systems thinking, 446-450
 archetypes in, 448-449
 causal loop diagramming, 447, 448
 industry examples of, 450
 modeling and simulation in, 449-450
 in work-center scheduling, 626
- T**
 Table of cumulative values, 147, App-2
 Table of unit values, 146, App-1
 Taco Bell, 18
 "Talent management" software, 460
 Tangible assets, depreciation of, 714-716
 Target Cell, 41, 42
 Target market, choosing, 28
 Task(s), 62
 flowcharting, 162, 211
 at workstations, 227, 228, 230
 Task autonomy, 190
 Task errors, 270
 Task identity, 190
 Task sharing, 230
 Task splitting, 230-231
 Task time, 230, 231
 Task variety, 189-190
 Taxes, 718, 720, 721
 Teamwork
 assessing, in RPA, 437
 in CPM, 66
 in manufacturing process, 213
 in operations consulting, 431
 in project development, 59, 77
 skunkworks projects, 59-60
 TeamWork scheduling software, 639
 Te Aipiti Wind Farm Project, 65
 Technical obsolescence, 549
 Technical support, 24
 Technological risks, 735
 Technology
 group technology, 222, 407
 improvements in, 716
 information technology (IT), 15, 369, 428, 441
 investments in
 benefits of, 735-736
 evolution of, 734-735
 in logistics outsourcing, 366-367
 in manufacturing
 computer technology, 358, 730-734
 operations technology, 730-734
 optimized production technology, 15, 681
 in manufacturing processes, 213
 in operations (*See Operations technology*)
 organizational learning and, 150, 151
 in production-line approach to service delivery, 264
 revision of, in lean services, 417
 RFID technology, 625
 risks in adopting, 735-736
 security technology, 545
 Technology platforms, 97
 Technology-push products, 96-97, 98
 Telecommunications
 cellular phone customers, 448
 centroid method of plant location for, 389, 393-394
 transformation processes in, 8, 9
 Telecommuting, 188
 Temporary shutdown decision, 718
 Temporary workers, 188
 Testing and refinement phase, 95, 96
 Texas Instruments, 57, 442, 625
 Theatre, service utilization in, 134
 Theoretical minimum number of parts, 106
 Theory of Constraints (TOC), 15, 681-682, 703-704, 705
 Third-party certification, 321-322
 Third-party logistics company, 384
 30-Minute guarantee, 623
 3M, 387
 Three-dimensional graphing, 39
 Three-time-estimate approach to CPM, 70-72
 "Three T's" poka-yokes, 261
 Throughput, 682, 683
 Throughput rate, 168, 169
 Throughput ratio, 170
 Throughput time
 calculating, 171-172
 cycle time differentiated from, 185n
 as process performance metric, 168, 169-170
 reduction of, 175-177
 Timbuk2, 21
 Time
 activity time, 70, 71, 72
 cumulative average time, 143-144
 cycle time (*See Cycle time(s)*)
 decomposition of time series, 470, 487-493
 flow of, in service experience, 269
 in forecasting (*See Time series analysis*)
 as key resource, 58
 operation time, 168, 169
 reducing order lead time, 176-177
 run time, 169, 656
 saying at bottlenecks, 689-690
 in service capacity planning, 133
 slack time, 67
 standard time for tasks, 195
 task time, 230, 231
 throughput time (*See Throughput time*)
 value-added time, 170
 waiting time (*See Waiting times*)
 Time buckets, 596
 Time buffers, 691-692, 696
 Time components, 688-689
 Time-cost models, 72-76
 control of expenditures, 72
 minimum-cost scheduling, 73-76
 Time-cost trade-off, 73-76
 Time-dependence of services, 10
 Time estimates, in CPM, 70
 Time fences, 591-592
 Time horizons, 122
 Time incrementing, 656
 Time in process, 175, 176
 Time per unit, 143
 Time savings, 689-690
 Time series analysis (forecasting), 469, 470, 473-493, 500
 decomposition of time series, 487-493
 exponential smoothing (*See Exponential smoothing*)
 forecast errors, 480
 linear regression analysis, 483-486, 487
 measurement of error, 481-482, 483
 simple moving average, 474-476
 weighted moving average, 476-477
 Time series forecasting, 484
 Time standards, 195, 198, 258
 Time study, 191, 192-194, 199
 normal time, 192
 standard deviation in, 192, 294
 standard time, 192-193
 work sampling compared, 198-199
 Time-study concept, 15
 Time-study observation sheet, 193
 Time to market, 110
 TL 9000 standards, 321
 T-Mobile, 17
 TOC (Theory of Constraints), 15, 681-682, 703-704, 705
 Tokyo Electric Company, 205
 Tokyo Shibaura Denki (Tokyo Shibaura Electric Co. Ltd.), 205
 Tolerance limits, 330, 331
 Tom's of Maine, 360
 Toro, 488
 Toshiba, 57, 205, 206
 Total factor productivity, 169
 Total factory automation (CIM), 15, 734, 736
 Total gross profit, 700
 Total productivity measure, 28, 29
 Total profit (cost), 41, 42
 Total program cost breakdown, 64
 Total quality control (TQC), 15, 16
 Total quality management (TQM), 15, 16, 17, 308-309
 achieving, 322
 job design and, 187
 reengineering compared to, 440-441
 in "reinventing government," 6
 Toyota Motor Corporation, 15, 18, 30, 97, 103, 124, 190, 191, 232, 234, 319, 404, 437, 530, 545
 Toyota Production System, 191, 403, 418
 elimination of waste, 405-412
 focused factory networks, 405, 407
 group technology, 407
 JIT production, 407-408
 Kanban production control systems, 409-410
 minimized setup times, 412
 number of kanbans needed, 410-411
 quality at the source, 407
 uniform plant loading, 408-409
 respect for people, 412
 Toys "R" Us, 387

- TQC (total quality control), 15, 16
 TQM. *See* Total quality management
 Tracking Gantt charts, 77
 Tracking signal (TS), 481–482, 483, 500
 Trade-offs
 cost trade-off decision, 277
 customer-induced variability and, 268
 in logistics management, 384
 in operations and supply strategy, 24–25
 uses of service-system design matrix, 261
 value density and, 370–372
 Trading blocs, 389
 Training
 cross-training, 187
 employee involvement and, 437
 individual learning and, 150
 in service organizations, 259
 in Six Sigma, 319, 430
 for yield management, 534
 Transaction cost, factors in, 549
 Transaction (activity-based) costing, 716–718
 Transfer batch, 694–695
 Transformation processes, 4, 8–10
 Transportation (logistics), 8, 9, 360, 430
 Transportation matrix, 391
 Transportation method of linear programming, 389, 390–393, 397, 531, 532
 Transportation Security Administration (TSA), 639
 Treatment errors, 270
 TreeAge Software, 130–132, 439
 Trend projections (trend lines), 469, 470, 471, 472
 Trucking, 371, 385
 Truncated SOT rule, 630
 TS (tracking signal), 481–482, 483
 TSA (Transportation Security Administration), 639
 t-tests, 439, 657
 Tucson Parks and Recreation Department, 527–529
 Turnover loop, 447, 448
 Two-bin logic, 549
 Two-bin system, 554, 568
 Two-stage assembly lines, 658–661
- U**
 UCL (upper control limit), 336
 Unavoidable work delays, 192–193
 Unbalanced capacity, 684–685
 Uncertainty characteristics, 363
 Uncompromised reduction, 268, 269
 Unconditional service guarantees, 270–271
 Underutilization of capacity, 415–416
 Uneven life of investments, 725
 Uneven service times, 284
 Uniformly distributed random digit table, App-6
 Uniform plant loading (*heijunka*), 408–409
 Union contracts, 190
 United Parcel Service (UPS), 190, 371–372, 384
 Units of measure, 29
 Units of output per time period, 143, 144
 Unnecessary activities, 418
 Upgrading, cost and frequency of, 127, 128
 Upper and lower specification limits, 330, 332
 Upper and lower tolerance limits, 330, 331
- Upper control limit (UCL), 336
 UPS (United Parcel Service), 190, 371–372, 384
 U.S. Navy, 450
 U.S. Open golf tournament, 551
 U.S. Steel, 686
 USA Today, 30
 U-shaped line layout, 232
 Utilization, 295
 capacity utilization
 in service capacity planning, 133–134, 135, 173–175
 underutilization/overutilization, 415–416
 utilization rate, 124
 in MRP, 603, 604
 in process analysis, 162, 172, 173
 in process performance metrics, 168, 169
 space utilization, assessing, 436–437
- V**
 Validation, 657, 658
 Value, 6
 in financial analysis (*See* Financial analysis)
 future value, 722
 in lean manufacturing, 403, 416
 NPV (*See* Net present value)
 present value (*See* Present value)
 table of cumulative values, 147, App-2
 table of unit values, 146, App-1
 Value added, 683
 Value-added activities, 406
 Value-added analysis, 177
 Value-added services, 18, 384, 386
 Value-added time, 170
 Value analysis/value engineering (VA/VE), 15, 104–105
 Value chain, 403, 404, 433, 435
 Value chain mapping, 405, 406
 Value density, 370–372
 Value per share of stock, 720
 Value per unit of weight, 370–372
 Variability, 318, 437, 533
 Variability magnification, 361, 362
 Variable(s)
 in facilities location decision, 395, 396
 random, 72
 in simulation model, 654
 specifying values of, 656
 Variable arrival distribution, 280
 Variable costs, 533, 713
 Variables sampling, 336, 338–339
 Variable-time increment method, 656
 Variation, 307, 313, 330–331, 684
 VA/VE (value analysis/value engineering), 15, 104–105
 VCSEL, 521
 Vehicle or crew scheduling, 37
 Velocity, 168
 Vendor-managed inventory, 375
 Vensim PLE software, 450
 Vensim software, 450
 Ventana Systems, 450
 Vertical integration, 94, 368, 369
 Vertical job enlargement, 189
 Virtual manufacturing cells, 235
 Virtual office, 188
 Visual contact methods (*poka-yokes*), 261
- Visual management system, 436
 Volume of product, 206, 207
 Volume purchases, 567
 Volvo, 93, 124
- W**
 W. L. Gore Associates, 97
 Wage payment, 258
 Waiting, 406
 Waiting line(s) (queues)
 approximation of, 295–296
 computer simulation of, 296
 management of, 278
 models of, 259, 271, 285–293
 practical view of, 277–278
 in service capacity planning, 133–134, 141n, 172–173
 simulating two-stage assembly lines, 658–661
 See also Queuing systems
 Waiting line analysis, 276–298
 approximating waiting time, 294–296
 computer simulation in, 296
 economics of problem, 277–278
 queuing system, 278–285
 customer arrivals, 277–278, 279
 distribution of arrivals, 280–282, 287, 290
 exiting, 285
 factors in, 282–285
 in service system design, 271
 waiting line models, 259, 271, 285–293
 Waiting-line theory, 15
 Waiting times
 approximating, 294–296, 297–298
 calculating (example), 172–173
 eliminating, 177
 in production cycle, 688
 scheduling and, 623–624
 Wall Street analysts, 30, 31
 The Wall Street Journal, 5
 Wal-Mart, 238, 361, 425, 467, 545, 570
 Walt Disney Company, 387
 Warehouse management software, 464
 Warehousing, 8, 9, 386
 Warning methods (*poka-yokes*), 261
 Waste (*muda*), elimination of, 405–412, 416
 Water transportation (ship), 371, 385
 WBS (work breakdown structure), 62–63
 Web-based forecasting (CPFR), 497–499
 Weeks of supply, calculating, 359, 360, 361, 378
 Weighted average, 718–719
 Weighted average cost of capital, 720–721
 Weighted average inventory method, 573
 Weighted moving average, 470, 476–477, 500
 Weights, 476–477
 Wendy's, 166, 167, 418
 Western Union, 369
 Wildlife Habitat Enhancement Council, 387
 Wolfson Microelectronics Ltd., 57
 Work activities, 189–190
 Work area configurations, 418
 Work breakdown structure (WBS), 62–63
 Work centers, 206, 213
 basic format of, 221
 computing work center load, 603–605
 demand stabilization in, 414
 facility layout, 222–226

- Work centers (Cont.)
 organization of, 624
 scheduling in, 624-628
 job sequencing in, 627-628
 objectives of, 626
 scheduling and control functions,
 625-626, 627
- Workcenter shops, 414, 415
- Workers
 in alternative production plans, 523-525
 customers and, 258, 260, 261, 436
 expertise of, 235
 fatigue of, in time study, 192-193
 flexible, 127, 211
 full-time-equivalent (FTE) employees,
 527-529
 Hawthorne studies, 15
 individual learning, 150
 inventory cycle counting and, 571
 multiskilled, 187
 skill level of, task time and, 231
 surveys of, 433
 temporary, 188
 using Internet to inform, 187-188
- Work flow, 221, 624
- Work-flow diagrams, 436
- Work-flow software, 436, 438
- Work-flow structures, 221
- Workforce. *See* Workers
- "Workforce deployment" software, 460
- Workforce diversity, 187
- Workforce level, 518
- Work groups, 189
- Work-in-process, 171
- Work-in-process inventory, 211, 233, 547, 683
 assessing, in RPA, 437
 manufacturing cells and, 235
 negative impact of, 695
- Work measurement, 190-199
 in retailing, 192
 techniques, 190-192
 techniques in, 190-192
 time studies, 192-194, 199
 work sampling, 194-199
 work standards and, 190, 191
See also Job design
- Work package, 62
- Work sampling, 191, 192, 194-198
 in data gathering, 436
 example of, 195-198
 time study compared, 198-199
- Work scheduling, 190
- Work specialization, 150
- Workstation characteristics, 227
- Workstation cycle time, 227, 228, 229
- Work-study concept, 15
- Work units, 227
- World Bank, 450
- World Trade Organization (WTO), 357
- World Wide Web, 15, 17
- WTO (World Trade Organization), 357
- X
- X chart, construction of, 340-342
- X-11 forecasting (Shiskin time series), 470
- Xerox, 126
- Y
- Yahoo!, 15
- Yield management, 532-534
 characteristics of, 532-533
 operating yield management systems,
 533-534
- Yield to maturity, 719
- Z
- Zero-changeover-time plant, 126
- Zero conflict scheduling, 639
- Zero defects, 307
- Zero variability, 330
- Zero wait program, 623