

TABLE OF CONTENTS

PREFACE xx

CHAPTER 1

Introduction 1

- 1.1 The Origins of Operations Research 1
- 1.2 The Nature of Operations Research 3
- 1.3 The Relationship between Analytics and Operations Research 4
- 1.4 The Impact of Operations Research 8
- 1.5 Some Trends that Should Further Increase the Future Impact
of Operations Research 11
- 1.6 Algorithms and OR Courseware 12
- Selected References 14
- Problems 14

CHAPTER 2

Overview of How Operations Research and Analytics Professionals Analyze Problems 15

- 2.1 Defining the Problem 16
- 2.2 Gathering and Organizing Relevant Data 17
- 2.3 Using Descriptive Analytics to Analyze Big Data 18
- 2.4 Using Predictive Analytics to Analyze Big Data 19
- 2.5 Formulating a Mathematical Model to Begin Applying Prescriptive Analytics 23
- 2.6 Learning How to Derive Solutions from the Model 25
- 2.7 Testing the Model 28
- 2.8 Preparing to Apply the Model 29
- 2.9 Implementation 29
- 2.10 Conclusions 30
- Selected References 30
- Problems 31

CHAPTER 3

Introduction to Linear Programming 32

- 3.1 Prototype Example 33
- 3.2 The Linear Programming Model 40
- 3.3 Assumptions of Linear Programming 45
- 3.4 Additional Examples 52
- 3.5 Formulating and Solving Linear Programming Models on a Spreadsheet 61
- 3.6 Formulating Very Large Linear Programming Models 69
- 3.7 Conclusions 77
- Selected References 77
- Learning Aids for this Chapter on Our Website 77
- Problems 78

Case 3.1 Reclaiming Solid Wastes 89

Previews of Added Cases on Our Website 89

Case 3.2 Cutting Cafeteria Costs 89

Case 3.3 Staffing a Call Center 89

Case 3.4 Promoting a Breakfast Cereal 90

Case 3.5 Auto Assembly 90

CHAPTER 4

Solving Linear Programming Problems: The Simplex Method 91

4.1 The Essence of the Simplex Method 92

4.2 Setting Up the Simplex Method 96

4.3 The Algebra of the Simplex Method 100

4.4 The Simplex Method in Tabular Form 106

4.5 Tie Breaking in the Simplex Method 111

4.6 Reformulating Nonstandard Models to Prepare for Applying the Simplex Method 114

4.7 The Big M Method for Helping to Solve Reformulated Models 122

4.8 The Two-Phase Method is an Alternative to the Big M Method 129

4.9 Postoptimality Analysis 135

4.10 Computer Implementation 143

4.11 The Interior-Point Approach to Solving Linear Programming Problems 146

4.12 Conclusions 149

Appendix 4.1: An Introduction to Using LINDO and LINGO 149

Selected References 153

Learning Aids for this Chapter on Our Website 153

Problems 154

Case 4.1 Fabrics and Fall Fashions 163

Previews of Added Cases on Our Website 165

Case 4.2 New Frontiers 165

Case 4.3 Assigning Students to Schools 165

CHAPTER 5

The Theory of the Simplex Method 166

5.1 Foundations of the Simplex Method 166

5.2 The Simplex Method in Matrix Form 177

5.3 A Fundamental Insight 186

5.4 The Revised Simplex Method 189

5.5 Conclusions 192

Selected References 192

Learning Aids for this Chapter on Our Website 193

Problems 193

CHAPTER 6

Duality Theory 200

6.1 The Essence of Duality Theory 200

6.2 Primal-Dual Relationships 208

6.3 Adapting to Other Primal Forms 213

6.4 The Role of Duality Theory in Sensitivity Analysis 217

6.5 Conclusions 220

Selected References	220
Learning Aids for this Chapter on Our Website	220
Problems	221

CHAPTER 7

Linear Programming under Uncertainty 225

7.1 The Essence of Sensitivity Analysis	226
7.2 Applying Sensitivity Analysis	233
7.3 Performing Sensitivity Analysis on a Spreadsheet	250
7.4 Robust Optimization	259
7.5 Chance Constraints	263
7.6 Stochastic Programming with Recourse	266
7.7 Conclusions	271
Selected References	271
Learning Aids for this Chapter on Our Website	272
Problems	273
Case 7.1 Controlling Air Pollution	281
Previews of Added Cases on Our Website	282
Case 7.2 Farm Management	282
Case 7.3 Assigning Students to Schools, Revisited	282
Case 7.4 Writing a Nontechnical Memo	282

CHAPTER 8

Other Algorithms for Linear Programming 283

8.1 The Dual Simplex Method	283
8.2 Parametric Linear Programming	287
8.3 The Upper Bound Technique	293
8.4 An Interior-Point Algorithm	295
8.5 Conclusions	306
Selected References	307
Learning Aids for this Chapter on Our Website	307
Problems	307

CHAPTER 9

The Transportation and Assignment Problems 312

9.1 The Transportation Problem	313
9.2 A Streamlined Simplex Method for the Transportation Problem	326
9.3 The Assignment Problem	338
9.4 A Special Algorithm for the Assignment Problem	346
9.5 Conclusions	351
Selected References	351
Learning Aids for this Chapter on Our Website	352
Problems	352
Case 9.1 Shipping Wood to Market	358
Previews of Added Cases on Our Website	359
Case 9.2 Continuation of the Texago Case Study	359
Case 9.3 Project Pickings	359

CHAPTER 10

Network Optimization Models 360

- 10.1 Prototype Example 361
- 10.2 The Terminology of Networks 362
- 10.3 The Shortest-Path Problem 365
- 10.4 The Minimum Spanning Tree Problem 370
- 10.5 The Maximum Flow Problem 375
- 10.6 The Minimum Cost Flow Problem 383
- 10.7 The Network Simplex Method 391
- 10.8 A Network Model for Optimizing a Project's Time-Cost Trade-Off 401
- 10.9 Conclusions 413
- Selected References 413
- Learning Aids for this Chapter on Our Website 413
- Problems 414
- Case 10.1 Money in Motion 422
- Previews of Added Cases on Our Website 424
 - Case 10.2 Aiding Allies 424
 - Case 10.3 Steps to Success 424

CHAPTER 11

Dynamic Programming 425

- 11.1 A Prototype Example for Dynamic Programming 425
- 11.2 Characteristics of Dynamic Programming Problems 430
- 11.3 Deterministic Dynamic Programming 432
- 11.4 Probabilistic Dynamic Programming 448
- 11.5 Conclusions 454
- Selected References 454
- Learning Aids for this Chapter on Our Website 454
- Problems 455

CHAPTER 12

Integer Programming 460

- 12.1 Prototype Example 461
- 12.2 Some BIP Applications 464
- 12.3 Using Binary Variables to Deal with Fixed Charges 470
- 12.4 A Binary Representation of General Integer Variables 472
- 12.5 Some Perspectives on Solving Integer Programming Problems 473
- 12.6 The Branch-and-Bound Technique and its Application to Binary Integer Programming 477
- 12.7 A Branch-and-Bound Algorithm for Mixed Integer Programming 489
- 12.8 The Branch-and-Cut Approach to Solving BIP Problems 495
- 12.9 The Incorporation of Constraint Programming 502
- 12.10 Conclusions 506
- Selected References 507
- Learning Aids for this Chapter on Our Website 508
- Problems 508
- Case 12.1 Capacity Concerns 516

Previews of Added Cases on Our Website	518
Case 12.2 Assigning Art	518
Case 12.3 Stocking Sets	518
Case 12.4 Assigning Students to Schools, Revisited Again	519

CHAPTER 13

Nonlinear Programming 520

13.1 Sample Applications	521
13.2 Graphical Illustration of Nonlinear Programming Problems	525
13.3 Types of Nonlinear Programming Problems	529
13.4 One-Variable Unconstrained Optimization	535
13.5 Multivariable Unconstrained Optimization	540
13.6 The Karush-Kuhn-Tucker (KKT) Conditions for Constrained Optimization	546
13.7 Quadratic Programming	550
13.8 Separable Programming	556
13.9 Convex Programming	563
13.10 Nonconvex Programming (with Spreadsheets)	571
13.11 Conclusions	575
Selected References	576
Learning Aids for this Chapter on Our Website	576
Problems	577
Case 13.1 Savvy Stock Selection	588
Previews of Added Cases on Our Website	589
Case 13.2 International Investments	589
Case 13.3 Promoting a Breakfast Cereal, Revisited	589

CHAPTER 14

Metaheuristics 590

14.1 The Nature of Metaheuristics	591
14.2 Tabu Search	598
14.3 Simulated Annealing	608
14.4 Genetic Algorithms	618
14.5 Conclusions	628
Selected References	629
Learning Aids for this Chapter on Our Website	630
Problems	630

CHAPTER 15

Game Theory 634

15.1 The Formulation of Two-Person, Zero-Sum Games	634
15.2 Solving Simple Games—A Prototype Example	636
15.3 Games with Mixed Strategies	641
15.4 Graphical Solution Procedure	643
15.5 Solving by Linear Programming	645
15.6 Extensions	649
15.7 Conclusions	650
Selected References	650
Learning Aids for this Chapter on Our Website	650
Problems	651

CHAPTER 16**Decision Analysis 655**

- 16.1 A Prototype Example 656
- 16.2 Decision Making without Experimentation 657
- 16.3 Decision Making with Experimentation 662
- 16.4 Decision Trees 668
- 16.5 Utility Theory 673
- 16.6 The Practical Application of Decision Analysis 680
- 16.7 Multiple Criteria Decision Analysis, Including Goal Programming 682
- 16.8 Conclusions 686
- Selected References 687
- Learning Aids for this Chapter on Our Website 688
- Problems 688
- Case 16.1 Brainy Business 698
- Preview of Added Cases on Our Website 700
 - Case 16.2 Smart Steering Support 700
 - Case 16.3 Who Wants to Be a Millionaire? 700
 - Case 16.4 University Toys and the Engineering Professor Action Figures 700

CHAPTER 17**Queueing Theory 701**

- 17.1 Prototype Example 702
- 17.2 Basic Structure of Queueing Models 702
- 17.3 Some Common Types of Real Queueing Systems 707
- 17.4 The Role of the Exponential Distribution 708
- 17.5 The Birth-and-Death Process 714
- 17.6 Queueing Models Based on the Birth-and-Death Process 719
- 17.7 Queueing Models Involving Nonexponential Distributions 731
- 17.8 Priority-Discipline Queueing Models 739
- 17.9 Queueing Networks 744
- 17.10 The Application of Queueing Theory 748
- 17.11 Behavioral Queueing Theory 753
- 17.12 Conclusions 754
- Selected References 755
- Learning Aids for this Chapter on Our Website 756
- Problems 757
- Case 17.1 Reducing In-Process Inventory 769
- Preview of an Added Case on Our Website 770
 - Case 17.2 Queueing Quandary 770

CHAPTER 18**Inventory Theory 771**

- 18.1 Examples 772
- 18.2 Components of Inventory Models 774
- 18.3 Deterministic Continuous-Review Models 776
- 18.4 A Deterministic Periodic-Review Model 786
- 18.5 Deterministic Multiechelon Inventory Models for Supply Chain Management 791
- 18.6 A Stochastic Continuous-Review Model 810

18.7 A Stochastic Single-Period Model for Perishable Products	814
18.8 Revenue Management	826
18.9 Conclusions	834
Selected References	834
Learning Aids for this Chapter on Our Website	835
Problems	836
Case 18.1 Brushing Up on Inventory Control	846
Previews of Added Cases on Our Website	848
Case 18.2 TNT: Tackling Newsboy's Teaching	848
Case 18.3 Jettisoning Surplus Stock	848

CHAPTER 19

Markov Decision Processes 849

19.1 A Prototype Example	850
19.2 A Model for Markov Decision Processes	852
19.3 Linear Programming and Optimal Policies	855
19.4 Markov Decision Processes in Practice	859
19.5 Conclusions	861
Selected References	862
Learning Aids for this Chapter on Our Website	862
Problems	863

CHAPTER 20

Simulation 866

20.1 The Essence of Simulation	866
20.2 Some Common Types of Applications of Simulation	878
20.3 Generation of Random Numbers	882
20.4 Generation of Random Observations from a Probability Distribution	886
20.5 Simulation Optimization	891
20.6 Outline of a Major Simulation Study	900
20.7 Conclusions	904
Selected References	905
Learning Aids for this Chapter on Our Website	906
Problems	907
Case 20.1 Reducing In-Process Inventory, Revisted	912
Previews of Added Cases on Our Website	912
Case 20.2 Planning Planers	912
Case 20.3 Pricing under Pressure	912

APPENDIXES

1. Documentation for the OR Courseware	913
2. Convexity	915
3. Classical Optimization Methods	920
4. Matrices and Matrix Operations	923
5. Table for a Normal Distribution	928

PARTIAL ANSWERS TO SELECTED PROBLEMS 930

INDEXES

Author Index	942
Subject Index	949