TABLE OF CONTENTS

PREFACE xxiii

CHAPTER 1 Introduction 1

- 1.1 The Origins of Operations Research 1
- 1.2 The Nature of Operations Research 2
- 1.3 The Impact of Operations Research 3

1.4 Algorithms and OR Courseware 5 Problems 6

Problems

CHAPTER 2

Overview of the Operations Research Modeling Approach 7

- 2.1 Defining the Problem and Gathering Data 7
- 2.2 Formulating a Mathematical Model 10
- 2.3 Deriving Solutions from the Model 14
- 2.4 Testing the Model 16
- 2.5 Preparing to Apply the Model 18
- 2.6 Implementation 20
- 2.7 Conclusions 21
- Selected References 22
- Problems 22

CHAPTER 3

Introduction to Linear Programming 24

- 3.1 Prototype Example 25
- 3.2 The Linear Programming Model 31
- 3.3 Assumptions of Linear Programming 36
- 3.4 Additional Examples 44
- 3.5 Some Case Studies 61
- 3.6 Displaying and Solving Linear Programming Models on a Spreadsheet 67
- 3.7 Formulating Very Large Linear Programming Models 73
- 3.8 Conclusions 79
- Appendix 3.1 The LINGO Modeling Language 79

Selected References 89 Learning Aids for This Chapter in Your OR Courseware 90 Problems 90 Case 3.1 Auto Assembly 103 Case 3.2 Cutting Cafeteria Costs 104 Case 3.3 Staffing a Call Center 106

CHAPTER 4

Solving Linear Programming Problems: The Simplex Method 109

- 4.1 The Essence of the Simplex Method 109
- 4.2 Setting Up the Simplex Method 114
- 4.3 The Algebra of the Simplex Method 118
- 4.4 The Simplex Method in Tabular Form 123
- 4.5 Tie Breaking in the Simplex Method 128
- 4.6 Adapting to Other Model Forms 132
- 4.7 Postoptimality Analysis 152
- 4.8 Computer Implementation 160
- 4.9 The Interior-Point Approach to Solving Linear Programming Problems 163
- 4.10 Conclusions 168

Appendix 4.1 An Introduction to Using LINDO 169

Selected References 171

Learning Aids for This Chapter in Your OR Courseware 172

- Problems 172
- Case 4.1 Fabrics and Fall Fashions 182
- Case 4.2 New Frontiers 185
- Case 4.3 Assigning Students to Schools 188

CHAPTER 5

The Theory of the Simplex Method 190

5.1 Foundations of the Simplex Method 190
5.2 The Revised Simplex Method 202
5.3 A Fundamental Insight 212
5.4 Conclusions 220
Selected References 220
Learning Aids for This Chapter in Your OR Courseware 221
Problems 221

CHAPTER 6

Duality Theory and Sensitivity Analysis 230

- 6.1 The Essence of Duality Theory 231
- 6.2 Economic Interpretation of Duality 239
- 6.3 Primal-Dual Relationships 242
- 6.4 Adapting to Other Primal Forms 247
- 6.5 The Role of Duality Theory in Sensitivity Analysis 252
- 6.6 The Essence of Sensitivity Analysis 254

- 6.7 Applying Sensitivity Analysis 262
- 6.8 Conclusions 284
- Selected References 284

Learning Aids for This Chapter in Your OR Courseware 285

Problems 285

- Case 6.1 Controlling Air Pollution 302
- Case 6.2 Farm Management 304
- Case 6.3 Assigning Students to Schools (Revisited) 307

CHAPTER 7

Other Algorithms for Linear Programming 309

- 7.1 The Dual Simplex Method 309
- 7.2 Parametric Linear Programming 312
- 7.3 The Upper Bound Technique 317
- 7.4 An Interior-Point Algorithm 320
- 7.5 Linear Goal Programming and Its Solution Procedures 332
- 7.6 Conclusions 339
- Selected References 340
- Learning Aids for This Chapter in Your OR Courseware 340 Problems 341

Case 7.1 A Cure for Cuba 347

CHAPTER 8

The Transportation and Assignment Problems 350

8.1 The Transportation Problem 351
8.2 A Streamlined Simplex Method for the Transportation Problem 365
8.3 The Assignment Problem 381
8.4 Conclusions 391
Selected References 391
Learning Aids for This Chapter in Your OR Courseware 392
Problems 392
Case 8.1 Shipping Wood to Market 401
Case 8.2 Project Pickings 402

CHAPTER 9

Network Optimization Models 405

- 9.1 Prototype Example 406
- 9.2 The Terminology of Networks 407
- 9.3 The Shortest-Path Problem 411
- 9.4 The Minimum Spanning Tree Problem 415
- 9.5 The Maximum Flow Problem 420
- 9.6 The Minimum Cost Flow Problem 429
- 9.7 The Network Simplex Method 438
- 9.8 Conclusions 448
- Selected References 449

Learning Aids for This Chapter in Your OR Courseware 449 Problems 450 Case 9.1 Aiding Allies 458 Case 9.2 Money in Motion 464

CHAPTER 10

Project Management with PERT/CPM 468

10.1 A Prototype Example—The Reliable Construction Co. Project 469

10.2 Using a Network to Visually Display a Project 470

10.3 Scheduling a Project with PERT/CPM 475

10.4 Dealing with Uncertain Activity Durations 485

10.5 Considering Time-Cost Trade-Offs 492

10.6 Scheduling and Controlling Project Costs 502

10.7 An Evaluation of PERT/CPM 508

10.8 Conclusions 512

Selected References 513

Learning Aids for This Chapter in Your OR Courseware 514

Problems 514

Case 10.1 Steps to Success 524

Case 10.2 "School's out forever . . ." 527

CHAPTER 11

Dynamic Programming 533

11.1 A Prototype Example for Dynamic Programming 533

11.2 Characteristics of Dynamic Programming Problems 538

11.3 Deterministic Dynamic Programming 541

- 11.4 Probabilistic Dynamic Programming 562
- 11.5 Conclusions 568

Selected References 568

Learning Aids for This Chapter in Your OR Courseware 568 Problems 569

CHAPTER 12

Integer Programming 576

- 12.1 Prototype Example 577
- 12.2 Some BIP Applications 580
- 12.3 Innovative Uses of Binary Variables in Model Formulation 585
- 12.4 Some Formulation Examples 591
- 12.5 Some Perspectives on Solving Integer Programming Problems 600
- 12.6 The Branch-and-Bound Technique and Its Application to Binary Integer Programming 604
- 12.7 A Branch-and-Bound Algorithm for Mixed Integer Programming 616
- 12.8 Other Developments in Solving BIP Problems 622
- 12.9 Conclusions 630
- Selected References 631

Learning Aids for This Chapter in Your OR Courseware631Problems632Case 12.1Capacity Concerns642645

Case 12.3 Stocking Sets 649

Case 12.4 Assigning Students to Schools (Revisited Again) 653

CHAPTER 13

Nonlinear Programming 654

- 13.1 Sample Applications 655
- 13.2 Graphical Illustration of Nonlinear Programming Problems 659
- 13.3 Types of Nonlinear Programming Problems 664
- 13.4 One-Variable Unconstrained Optimization 670
- 13.5 Multivariable Unconstrained Optimization 673
- 13.6 The Karush-Kuhn-Tucker (KKT) Conditions for Constrained Optimization 679
- 13.7 Quadratic Programming 683

13.8 Separable Programming 690

- 13.9 Convex Programming 697
- 13.10 Nonconvex Programming 702

13.11 Conclusions 706

Selected References 706

Learning Aids for This Chapter in Your OR Courseware 707

Problems 708

Case 13.1 Savvy Stock Selection 720

CHAPTER 14

Game Theory 726

- 14.1 The Formulation of Two-Person, Zero-Sum Games 726
- 14.2 Solving Simple Games—A Prototype Example 728
- 14.3 Games with Mixed Strategies 733
- 14.4 Graphical Solution Procedure 735
- 14.5 Solving by Linear Programming 738
- 14.6 Extensions 741
- 14.7 Conclusions 742
- Selected References 743

Learning Aids for This Chapter in Your OR Courseware 743 Problems 743

CHAPTER 15

Decision Analysis 749

- 15.1 A Prototype Example 750
- 15.2 Decision Making without Experimentation 751
- 15.3 Decision Making with Experimentation 758
- 15.4 Decision Trees 764
- 15.5 Utility Theory 770

15.6 The Practical Application of Decision Analysis 778
15.7 Conclusions 781
Selected References 781
Learning Aids for This Chapter in Your OR Courseware 782
Problems 782
Case 15.1 Brainy Business 795
Case 15.2 Smart Steering Support 798

CHAPTER 16

Markov Chains 802

- 16.1 Stochastic Processes 802
- 16.2 Markov Chains 803
- 16.3 Chapman-Kolmogorov Equations 808
- 16.4 Classification of States of a Markov Chain 810
- 16.5 Long-Run Properties of Markov Chains 812
- 16.6 First Passage Times 818
- 16.7 Absorbing States 820
- 16.8 Continuous Time Markov Chains 822
- Selected References 827

Learning Aids for This Chapter in Your OR Courseware 828 Problems 828

CHAPTER 17

Queueing Theory 834

- 17.1 Prototype Example 835
- 17.2 Basic Structure of Queueing Models 835
- 17.3 Examples of Real Queueing Systems 840
- 17.4 The Role of the Exponential Distribution 841
- 17.5 The Birth-and-Death Process 848
- 17.6 Queueing Models Based on the Birth-and-Death Process 852
- 17.7 Queueing Models Involving Nonexponential Distributions 871
- 17.8 Priority-Discipline Queueing Models 879
- 17.9 Queueing Networks 885
- 17.10 Conclusions 889
- Selected References 890
- Learning Aids for This Chapter in Your OR Courseware 890
- Problems 891
- Case 17.1 Reducing In-Process Inventory 905

CHAPTER 18 The Application of Queueing Theory 907

- 18.1 Examples 907
- 18.2 Decision Making 909
- 18.3 Formulation of Waiting-Cost Functions 912

18.4 Decision Models 917
18.5 Some Award-Winning Applications of Queueing Theory 923
18.6 Conclusions 926
Selected References 926
Learning Aids for This Chapter in Your OR Courseware 926
Problems 927
Case 18.1 Queueing Quandary 932

CHAPTER 19 Inventory Theory 935

- 19.1 Examples 936
- 19.2 Components of Inventory Models 938
- 19.3 Deterministic Continuous-Review Models 941
- 19.4 A Deterministic Periodic-Review Model 951
- 19.5 A Stochastic Continuous-Review Model 956
- 19.6 A Stochastic Single-Period Model for Perishable Products 961
- 19.7 Stochastic Periodic-Review Models 975
- 19.8 Larger Inventory Systems in Practice 983
- 19.9 Conclusions 987
- Selected References 987

Learning Aids for This Chapter in Your OR Courseware 987 Problems 988

- Case 19.1 Brushing Up on Inventory Control 1000
- Case 19.2 TNT: Tackling Newsboy's Teachings 1002
- Case 19.3 Jettisoning Surplus Stock 1004

CHAPTER 20

Forecasting 1009

- 20.1 Some Applications of Forecasting 1010
- 20.2 Judgmental Forecasting Methods 1013
- 20.3 Time Series 1014
- 20.4 Forecasting Methods for a Constant-Level Model 1016
- 20.5 Incorporating Seasonal Effects into Forecasting Methods 1018
- 20.6 An Exponential Smoothing Method for a Linear Trend Model 1021
- 20.7 Forecasting Errors 1025
- 20.8 Box-Jenkins Method 1026
- 20.9 Causal Forecasting with Linear Regression 1028
- 20.10 Forecasting in Practice 1036
- 20.11 Conclusions 1038
- Selected References 1038
- Learning Aids for This Chapter in Your OR Courseware 1038 Problems 1039
- Case 20.1 Finagling the Forecasts 1048

CHAPTER 21

Markov Decision Processes 1053

- 21.1 A Prototype Example 1053
- 21.2 A Model for Markov Decision Processes 1056
- 21.3 Linear Programming and Optimal Policies 1059
- 21.4 Policy Improvement Algorithm for Finding Optimal Policies 1064
- 21.5 Discounted Cost Criterion 1069
- 21.6 Conclusions
- Selected References 1077
- Learning Aids for This Chapter in Your OR Courseware 1078 Problems 1078

CHAPTER 22

Simulation 1084

- 22.1 The Essence of Simulation 1084
- 22.2 Some Common Types of Applications of Simulation 1097
- 22.3 Generation of Random Numbers 1101
- 22.4 Generation of Random Observations from a Probability Distribution 1105
- 22.5 Outline of a Major Simulation Study 1110
- 22.6 Performing Simulations on Spreadsheets 1115
- 22.7 Variance-Reducing Techniques 1126
- 22.8 Regenerative Method of Statistical Analysis 1131
- 22.9 Conclusions 1138
- Selected References 1140
- Learning Aids for This Chapter in Your OR Courseware 1140
- Problems 1141
- Case 22.1 Planning Planers 1151
- Case 22.2 Pricing under Pressure 1153

APPENDIXES

- 1. Documentation for the OR Courseware 1156
- 2. Convexity 1159
- 3. Classical Optimization Methods 1165
- 4. Matrices and Matrix Operations 1169
- 5. Tables 1174

PARTIAL ANSWERS TO SELECTED PROBLEMS 1176

INDEXES

Author Index 1195 Subject Index 1199