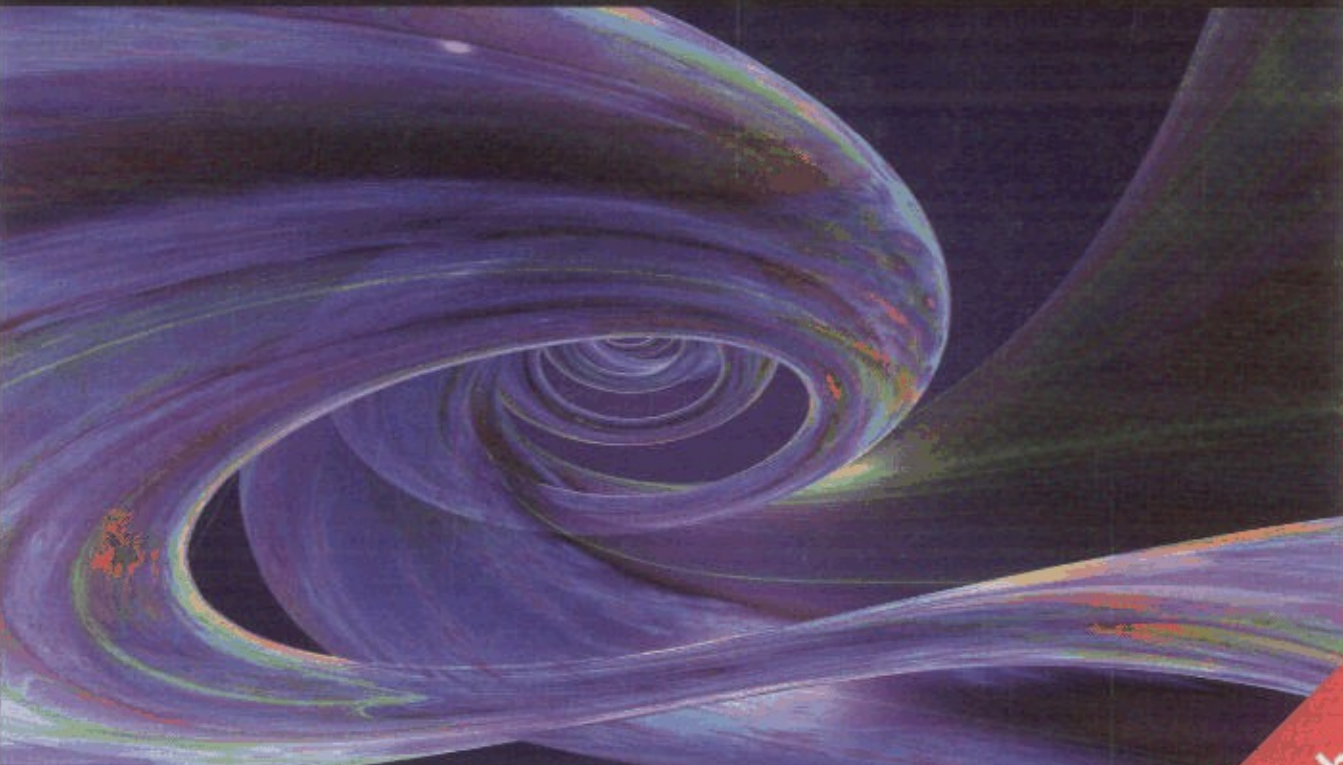


INTERNATIONAL STUDENT EDITION

AN INTRODUCTION TO MANAGEMENT SCIENCE

*QUANTITATIVE APPROACHES
TO DECISION MAKING*

Twelfth Edition

An abstract painting featuring a large, swirling vortex of purple and blue hues, with some green and yellow streaks, set against a dark background. The swirls create a sense of depth and movement, resembling a tunnel or a galaxy.

Anderson / Sweeney / Williams / Martin

Not for Sale in the
United States

Contents

| | |
|--------------------------|-------------|
| Preface | xvii |
| About the Authors | xxv |

Chapter 1 Introduction 1

| | |
|--|-----------|
| 1.1 Problem Solving and Decision Making | 3 |
| 1.2 Quantitative Analysis and Decision Making | 4 |
| 1.3 Quantitative Analysis | 6 |
| Model Development | 7 |
| Data Preparation | 10 |
| Model Solution | 11 |
| Report Generation | 12 |
| A Note Regarding Implementation | 12 |
| 1.4 Models of Cost, Revenue, and Profit | 14 |
| Cost and Volume Models | 14 |
| Revenue and Volume Models | 15 |
| Profit and Volume Models | 15 |
| Breakeven Analysis | 16 |
| 1.5 Management Science Techniques | 16 |
| Methods Used Most Frequently | 18 |
| Summary | 19 |
| Glossary | 19 |
| Problems | 20 |
| <i>Case Problem</i> Scheduling a Golf League | 24 |
| Appendix 1.1 The Management Scientist Software | 24 |
| Appendix 1.2 Using Excel for Breakeven Analysis | 27 |

Chapter 2 An Introduction to Linear Programming 31

| | |
|---|-----------|
| 2.1 A Simple Maximization Problem | 33 |
| Problem Formulation | 34 |
| Mathematical Statement of the Par, Inc., Problem | 36 |
| 2.2 Graphical Solution Procedure | 38 |
| A Note on Graphing Lines | 47 |
| Summary of the Graphical Solution Procedure for Maximization Problems | 49 |
| Slack Variables | 50 |
| 2.3 Extreme Points and the Optimal Solution | 51 |
| 2.4 Computer Solution of the Par, Inc., Problem | 53 |
| Interpretation of Computer Output | 54 |
| 2.5 A Simple Minimization Problem | 56 |
| Summary of the Graphical Solution Procedure for Minimization Problems | 58 |
| Surplus Variables | 59 |
| Computer Solution of the M&D Chemicals Problem | 60 |

- 2.6 Special Cases 61**
 - Alternative Optimal Solutions 61
 - Infeasibility 63
 - Unbounded 64
- 2.7 General Linear Programming Notation 66**
 - Summary 67**
 - Glossary 69**
 - Problems 70**
 - Case Problem 1 Workload Balancing 83*
 - Case Problem 2 Production Strategy 84*
 - Case Problem 3 Hart Venture Capital 85*
 - Appendix 2.1 Solving Linear Programs with the Management Scientist 86**
 - Appendix 2.2 Solving Linear Programs with LINDO 87**
 - Appendix 2.3 Solving Linear Programs with Excel 88**

Chapter 3 Linear Programming: Sensitivity Analysis and Interpretation of Solution 94

- 3.1 Introduction to Sensitivity Analysis 96**
- 3.2 Graphical Sensitivity Analysis 97**
 - Objective Function Coefficients 97
 - Right-Hand Sides 102
- 3.3 Sensitivity Analysis: Computer Solution 105**
 - Interpretation of Computer Output 105
 - Simultaneous Changes 108
 - Interpretation of Computer Output—A Second Example 110
 - Cautionary Note on the Interpretation of Dual Prices 112
- 3.4 More than Two Decision Variables 113**
 - The Modified Par, Inc., Problem 113
 - The Bluegrass Farms Problem 118
 - Formulation of the Bluegrass Farms Problem 119
 - Computer Solution and Interpretation for the Bluegrass Farms Problem 120
- 3.5 The Electronic Communications Problem 122**
 - Problem Formulation 123
 - Computer Solution and Interpretation 125
- Summary 128**
- Glossary 129**
- Problems 129**
 - Case Problem 1 Product Mix 147*
 - Case Problem 2 Investment Strategy 148*
 - Case Problem 3 Truck Leasing Strategy 149*
- Appendix 3.1 Sensitivity Analysis with Excel 150**

Chapter 4 Linear Programming Applications 153

- 4.1 Marketing Applications 154**
 - Media Selection 155
 - Marketing Research 158

| | |
|------------|---|
| 4.2 | Financial Applications 161 |
| | Portfolio Selection 161 |
| | Financial Planning 164 |
| 4.3 | Production Management Applications 168 |
| | A Make-or-Buy Decision 169 |
| | Production Scheduling 173 |
| | Workforce Assignment 180 |
| 4.4 | Blending Problems 183 |
| 4.5 | Data Envelopment Analysis 189 |
| | Evaluating the Performance of Hospitals 190 |
| | Overview of the DEA Approach 190 |
| | DEA Linear Programming Model 191 |
| | Summary of the DEA Approach 196 |
| 4.6 | Revenue Management 197 |
| | Summary 203 |
| | Glossary 203 |
| | Problems 204 |
| | <i>Case Problem 1</i> Planning an Advertising Campaign 221 |
| | <i>Case Problem 2</i> Phoenix Computer 222 |
| | <i>Case Problem 3</i> Textile Mill Scheduling 223 |
| | <i>Case Problem 4</i> Workforce Scheduling 224 |
| | <i>Case Problem 5</i> Cinergy Coal Allocation 226 |
| | Appendix 4.1 Excel Solution of Hewlett Corporation Financial Planning Problem 228 |

Chapter 5 Linear Programming: The Simplex Method 233

| | |
|------------|--|
| 5.1 | An Algebraic Overview of the Simplex Method 234 |
| | Algebraic Properties of the Simplex Method 235 |
| | Determining a Basic Solution 235 |
| | Basic Feasible Solution 236 |
| 5.2 | Tableau Form 237 |
| 5.3 | Setting Up the Initial Simplex Tableau 239 |
| 5.4 | Improving the Solution 242 |
| 5.5 | Calculating the Next Tableau 244 |
| | Interpreting the Results of an Iteration 247 |
| | Moving Toward a Better Solution 247 |
| | Interpreting the Optimal Solution 250 |
| | Summary of the Simplex Method 251 |
| 5.6 | Tableau Form: The General Case 252 |
| | Greater-Than-or-Equal-to Constraints 252 |
| | Equality Constraints 256 |
| | Eliminating Negative Right-Hand-Side Values 257 |
| | Summary of the Steps to Create Tableau Form 258 |
| 5.7 | Solving a Minimization Problem 259 |
| 5.8 | Special Cases 261 |
| | Infeasibility 261 |
| | Unboundedness 263 |
| | Alternative Optimal Solutions 264 |
| | Degeneracy 265 |

Summary 267

Glossary 268

Problems 269

Chapter 6 Simplex-Based Sensitivity Analysis and Duality 278

6.1 Sensitivity Analysis with the Simplex Tableau 279

Objective Function Coefficients 279

Right-Hand-Side Values 283

Simultaneous Changes 290

6.2 Duality 291

Economic Interpretation of the Dual Variables 293

Using the Dual to Identify the Primal Solution 295

Finding the Dual of Any Primal Problem 295

Summary 297

Glossary 298

Problems 298

Chapter 7 Transportation, Assignment, and Transshipment Problems 306

7.1 Transportation Problem: The Network Model and a Linear Programming Formulation 307

Problem Variations 310

A General Linear Programming Model of the Transportation Problem 313

7.2 Assignment Problem: The Network Model and a Linear Programming Formulation 314

Problem Variations 318

A General Linear Programming Model of the Assignment Problem 318

Multiple Assignments 318

7.3 Transshipment Problem: The Network Model and a Linear Programming Formulation 320

Problem Variations 325

A General Linear Programming Model of the Transshipment Problem 326

7.4 A Production and Inventory Application 327

7.5 Transportation Simplex Method: A Special-Purpose Solution Procedure (Optional) 330

Phase I: Finding an Initial Feasible Solution 332

Phase II: Iterating to the Optimal Solution 335

Summary of the Transportation Simplex Method 344

Problem Variations 346

7.6 Assignment Problem: A Special-Purpose Solution Procedure (Optional) 347

Finding the Minimum Number of Lines 350

Problem Variations 350

Summary 353

Glossary 354

Problems 355

Case Problem Distribution System Design 372

Appendix 7.1 Excel Solution of Transportation, Assignment, and Transshipment Problems 374

Chapter 8 Integer Linear Programming 380

- 8.1 Types of Integer Linear Programming Models 382**
- 8.2 Graphical and Computer Solutions for an All-Integer Linear Program 384**
 - Graphical Solution of the LP Relaxation 385
 - Rounding to Obtain an Integer Solution 386
 - Graphical Solution of the All-Integer Problem 386
 - Using the LP Relaxation to Establish Bounds 386
 - Computer Solution 388
- 8.3 Applications Involving 0-1 Variables 388**
 - Capital Budgeting 389
 - Fixed Cost 390
 - Distribution System Design 392
 - Bank Location 396
 - Product Design and Market Share Optimization 400
- 8.4 Modeling Flexibility Provided by 0-1 Integer Variables 405**
 - Multiple-Choice and Mutually Exclusive Constraints 405
 - k Out of n Alternatives Constraint 406
 - Conditional and Corequisite Constraints 406
 - A Cautionary Note About Sensitivity Analysis 408
- Summary 408**
- Glossary 409**
- Problems 410**
 - Case Problem 1 Textbook Publishing 421*
 - Case Problem 2 Yeager National Bank 422*
 - Case Problem 3 Production Scheduling with Changeover Costs 423*
- Appendix 8.1 Excel Solution of Integer Linear Programs 424**

Chapter 9 Network Models 428

- 9.1 Shortest-Route Problem 429**
 - A Shortest-Route Algorithm 430
- 9.2 Minimal Spanning Tree Problem 438**
 - A Minimal Spanning Tree Algorithm 439
- 9.3 Maximal Flow Problem 442**
 - Summary 446**
 - Glossary 446**
 - Problems 446**
 - Case Problem Ambulance Routing 455*

Chapter 10 Project Scheduling: PERT/CPM 457

- 10.1 Project Scheduling with Known Activity Times 458**
 - The Concept of a Critical Path 459
 - Determining the Critical Path 461
 - Contributions of PERT/CPM 465
 - Summary of the PERT/CPM Critical Path Procedure 466
- 10.2 Project Scheduling with Uncertain Activity Times 468**
 - The Daugherty Porta-Vac Project 468
 - Uncertain Activity Times 469

- The Critical Path 471
- Variability in Project Completion Time 474
- 10.3 Considering Time-Cost Trade-Offs 476**
 - Crashing Activity Times 477
 - Linear Programming Model for Crashing 479
- Summary 482**
- Glossary 482**
- Problems 483**
- Case Problem R. C. Coleman 493*

Chapter 11 Inventory Models 495

- 11.1 Economic Order Quantity (EOQ) Model 496**
 - The How-Much-to-Order Decision 501
 - The When-to-Order Decision 502
 - Sensitivity Analysis for the EOQ Model 503
 - Excel Solution of the EOQ Model 504
 - Summary of the EOQ Model Assumptions 505
- 11.2 Economic Production Lot Size Model 506**
 - Total Cost Model 507
 - Economic Production Lot Size 509
- 11.3 Inventory Model with Planned Shortages 509**
- 11.4 Quantity Discounts for the EOQ Model 514**
- 11.5 Single-Period Inventory Model with Probabilistic Demand 516**
 - Johnson Shoe Company 517
 - Nationwide Car Rental 521
- 11.6 Order-Quantity, Reorder Point Model with Probabilistic Demand 522**
 - The How-Much-to-Order Decision 523
 - The When-to-Order Decision 524
- 11.7 Periodic Review Model with Probabilistic Demand 526**
 - More Complex Periodic Review Models 529
- Summary 530**
- Glossary 531**
- Problems 532**
- Case Problem 1 Wagner Fabricating Company 540*
- Case Problem 2 River City Fire Department 541*
- Appendix 11.1 Development of the Optimal Order Quantity (Q) Formula for the EOQ Model 542**
- Appendix 11.2 Development of the Optimal Lot Size (Q^*) Formula for the Production Lot Size Model 543**

Chapter 12 Waiting Line Models 544

- 12.1 Structure of a Waiting Line System 546**
 - Single-Channel Waiting Line 546
 - Distribution of Arrivals 546
 - Distribution of Service Times 548
 - Queue Discipline 549
 - Steady-State Operation 550

| | |
|--|------------|
| 12.2 Single-Channel Waiting Line Model with Poisson Arrivals and Exponential Service Times | 550 |
| Operating Characteristics | 550 |
| Operating Characteristics for the Burger Dome Problem | 551 |
| Managers' Use of Waiting Line Models | 552 |
| Improving the Waiting Line Operation | 552 |
| Excel Solution of Waiting Line Model | 554 |
| 12.3 Multiple-Channel Waiting Line Model with Poisson Arrivals and Exponential Service Times | 555 |
| Operating Characteristics | 555 |
| Operating Characteristics for the Burger Dome Problem | 557 |
| 12.4 Some General Relationships for Waiting Line Models | 560 |
| 12.5 Economic Analysis of Waiting Lines | 561 |
| 12.6 Other Waiting Line Models | 563 |
| 12.7 Single-Channel Waiting Line Model with Poisson Arrivals and Arbitrary Service Times | 564 |
| Operating Characteristics for the $M/G/1$ Model | 564 |
| Constant Service Times | 566 |
| 12.8 Multiple-Channel Model with Poisson Arrivals, Arbitrary Service Times, and No Waiting Line | 566 |
| Operating Characteristics for the $M/G/k$ Model with Blocked Customers Cleared | 567 |
| 12.9 Waiting Line Models with Finite Calling Populations | 569 |
| Operating Characteristics for the $M/M/1$ Model with a Finite Calling Population | 570 |
| Summary | 573 |
| Glossary | 574 |
| Problems | 574 |
| <i>Case Problem 1 Regional Airlines</i> | 582 |
| <i>Case Problem 2 Office Equipment, Inc.</i> | 583 |

Chapter 13 Simulation 585

| | |
|---|------------|
| 13.1 Risk Analysis | 588 |
| PortaCom Project | 588 |
| What-If Analysis | 588 |
| Simulation | 590 |
| Simulation of the PortaCom Problem | 598 |
| 13.2 Inventory Simulation | 601 |
| Simulation of the Butler Inventory Problem | 604 |
| 13.3 Waiting Line Simulation | 607 |
| Hammondsport Savings Bank ATM Waiting Line | 607 |
| Customer Arrival Times | 607 |
| Customer Service Times | 609 |
| Simulation Model | 609 |
| Simulation of the Hammondsport Savings Bank ATM Problem | 613 |
| Simulation with Two ATMs | 614 |
| Simulation Results with Two ATMs | 616 |
| 13.4 Other Simulation Issues | 618 |
| Computer Implementation | 618 |

Verification and Validation 619

Advantages and Disadvantages of Using Simulation 619

Summary 620

Glossary 621

Problems 622

Case Problem 1 Tri-State Corporation 629

Case Problem 2 Harbor Dunes Golf Course 631

Case Problem 3 County Beverage Drive-Thru 632

Appendix 13.1 Simulation with Excel 634

Appendix 13.2 Simulation of the PortaCom Problem Using Crystal Ball 640

Chapter 14 Decision Analysis 645

14.1 Problem Formulation 647

Influence Diagrams 648

Payoff Tables 648

Decision Trees 649

14.2 Decision Making Without Probabilities 650

Optimistic Approach 650

Conservative Approach 650

Minimax Regret Approach 651

14.3 Decision Making with Probabilities 653

Expected Value of Perfect Information 655

14.4 Risk Analysis and Sensitivity Analysis 657

Risk Analysis 658

Sensitivity Analysis 658

14.5 Decision Analysis with Sample Information 663

Influence Diagram 663

Decision Tree 663

Decision Strategy 666

Risk Profile 670

Expected Value of Sample Information 673

Efficiency of Sample Information 673

14.6 Computing Branch Probabilities 674

14.7 Utility and Decision Making 677

The Meaning of Utility 678

Developing Utilities for Payoffs 679

Expected Utility Approach 682

Summary 683

Glossary 685

Problems 687

Case Problem 1 Property Purchase Strategy 703

Case Problem 2 Lawsuit Defense Strategy 705

Appendix 14.1 Decision Analysis with TreePlan 706

Chapter 15 Multicriteria Decisions 712

15.1 Goal Programming: Formulation and Graphical Solution 713

Developing the Constraints and the Goal Equations 714

| | |
|--|------------|
| Developing an Objective Function with Preemptive Priorities | 716 |
| Graphical Solution Procedure | 717 |
| Goal Programming Model | 720 |
| 15.2 Goal Programming: Solving More Complex Problems | 721 |
| Suncoast Office Supplies Problem | 721 |
| Formulating the Goal Equations | 722 |
| Formulating the Objective Function | 723 |
| Computer Solution | 724 |
| 15.3 Scoring Models | 727 |
| 15.4 Analytic Hierarchy Process | 732 |
| Developing the Hierarchy | 733 |
| 15.5 Establishing Priorities Using AHP | 734 |
| Pairwise Comparisons | 734 |
| Pairwise Comparison Matrix | 736 |
| Synthesization | 737 |
| Consistency | 738 |
| Other Pairwise Comparisons for the Car Selection Problem | 740 |
| 15.6 Using AHP to Develop an Overall Priority Ranking | 742 |
| Summary | 743 |
| Glossary | 744 |
| Problems | 745 |
| <i>Case Problem EZ Trailers, Inc.</i> | 754 |
| Appendix 15.1 Scoring Models with Excel | 755 |

Chapter 16 Forecasting 758

| | |
|--|------------|
| 16.1 Components of a Time Series | 760 |
| Trend Component | 760 |
| Cyclical Component | 760 |
| Seasonal Component | 761 |
| Irregular Component | 762 |
| 16.2 Smoothing Methods | 762 |
| Moving Averages | 763 |
| Weighted Moving Averages | 766 |
| Exponential Smoothing | 766 |
| 16.3 Trend Projection | 771 |
| 16.4 Trend and Seasonal Components | 774 |
| Multiplicative Model | 775 |
| Calculating the Seasonal Indexes | 777 |
| Deseasonalizing the Time Series | 780 |
| Using Deseasonalized Time Series to Identify Trend | 780 |
| Seasonal Adjustments | 783 |
| Models Based on Monthly Data | 783 |
| Cyclical Component | 784 |
| 16.5 Regression Analysis | 784 |
| Using Regression Analysis as a Causal Forecasting Method | 785 |
| Using Regression Analysis with Time Series Data | 790 |
| 16.6 Qualitative Approaches | 792 |
| Delphi Method | 792 |
| Expert Judgment | 792 |

| | |
|--|-----|
| Scenario Writing | 792 |
| Intuitive Approaches | 792 |
| Summary | 793 |
| Glossary | 793 |
| Problems | 794 |
| <i>Case Problem 1</i> Forecasting Sales | 804 |
| <i>Case Problem 2</i> Forecasting Lost Sales | 805 |
| Appendix 16.1 Using Excel for Forecasting | 806 |

Chapter 17 Markov Processes 808

| | |
|--|-----|
| 17.1 Market Share Analysis | 810 |
| 17.2 Accounts Receivable Analysis | 818 |
| Fundamental Matrix and Associated Calculations | 819 |
| Establishing the Allowance for Doubtful Accounts | 821 |
| Summary | 822 |
| Glossary | 823 |
| Problems | 824 |
| Appendix 17.1 Matrix Notation and Operations | 828 |

Chapter 18 Dynamic Programming 832

| | |
|---|-----|
| 18.1 A Shortest-Route Problem | 833 |
| 18.2 Dynamic Programming Notation | 837 |
| 18.3 The Knapsack Problem | 841 |
| 18.4 A Production and Inventory Control Problem | 847 |
| Summary | 851 |
| Glossary | 852 |
| Problems | 853 |
| <i>Case Problem</i> Process Design | 857 |

Appendixes 859

Appendix A Areas for the Standard Normal Distribution 860

Appendix B Values of $e^{-\lambda}$ 861

Appendix C References and Bibliography 862

Appendix D Self-Test Solutions and Answers to Even-Numbered Problems 864

Index 897