# Contents

About the Authors xiv Preface xvii

## Chapter 1 Introduction 1

- 1.1 Decision Making 4
- 1.2 Business Analytics Defined 5
- A Categorization of Analytical Methods and Models 5
   Descriptive Analytics 5
   Predictive Analytics 6
   Prescriptive Analytics 6

#### Analytics in Action: Procter & Gamble Uses Business Analytics to Redesign its Supply Chain 7

- 1.4 Big Data 8
- 1.5 Business Analytics in Practice 9
  - Financial Analytics 9 Human Resource (HR) Analytics 10 Marketing Analytics 10 Health Care Analytics 10 Supply Chain Analytics 11 Analytics for Government and Nonprofits 11 Sports Analytics 12 Web Analytics 12

## Summary 13

**Glossary** 13

## Chapter 2 Descriptive Statistics 15

#### Analytics in Action: U.S. Census Bureau 16

- 2.1 Overview of Using Data: Definitions and Goals 16
- 2.2 Types of Data 17

Population and Sample Data 17 Quantitative and Categorical Data 18 Cross-Sectional and Time Series Data 18 Sources of Data 18

## 2.3 Modifying Data in Excel 21

Sorting and Filtering Data in Excel 21 Conditional Formatting of Data in Excel 23

#### **Creating Distributions from Data 25** 2.4 Frequency Distributions for Categorical Data 25 Relative Frequency and Percent Frequency Distributions 27 Frequency Distributions for Quantitative Data 28 Histograms 31 Cumulative Distributions 34 2.5 Measures of Location 35 Mean (Arithmetic Mean) 35 Median 36 Mode 37 Geometric Mean 38 2.6 Measures of Variability 40 Range 41 Variance 41 Standard Deviation 43 Coefficient of Variation 44 2.7 **Analyzing Distributions** 44 Percentiles 44 **Quartiles** 45 z-scores 46 **Empirical Rule 48 Identifying Outliers** 48 Box Plots 49 2.8 Measures of Association Between Two Variables 51 Scatter Charts 51 Covariance 52 Correlation Coefficient 55 Summary 57 **Glossary 57** Problems 58 **Case: Heavenly Chocolates Web Site Transactions** 66 Appendix: Creating Box Plots in XLMiner 67 Chapter 3 **Data Visualization** -70

Analytics in Action: Cincinnati Zoo & Botanical Garden 71
3.1 Overview of Data Visualization 73

Effective Design Techniques 73

3.2 Tables 75

Table Design Principles 77
Crosstabulation 79
PivotTables in Excel 80

3.3 Charts 85

Scatter Charts 85
Line Charts 87

Bar Charts and Column Charts 90

A Note on Pie Charts and 3-D Charts 93
Bubble Charts 93
Heat Maps 95
Additional Charts for Multiple Variables 97
PivotCharts in Excel 101

3.4 Advanced Data Visualization 102

Advanced Charts 103
Geographic Information Systems Charts 104

#### 3.5 Data Dashboards 105

Principles of Effective Data Dashboards 106 Applications of Data Dashboards 106

Summary 108

Glossary 109 Problems 110

Problems 110

Case Problem: All-Time Movie Box Office Data 118

Appendix: Creating a Scatter Chart Matrix and a Parallel Coordinates Plot with XLMiner 119

## Chapter 4 Linear Regression 123

#### Analytics in Action: Alliance Data Systems 124

#### 4.1 The Simple Linear Regression Model 125

Regression Model and Regression Equation 125 Estimated Regression Equation 126

#### 4.2 Least Squares Method 127

Least Squares Estimates of the Regression Parameters 129 Using Excel's Chart Tools to Compute the Estimated Regression Equation 132

## **4.3** Assessing the Fit of the Simple Linear Regression Model 133 The Sums of Squares 134

The Coefficient of Determination 136

Using Excel's Chart Tools to Compute the Coefficient of Determination 137

#### 4.4 The Multiple Regression Model 138

Regression Model and Regression Equation 138 Estimated Multiple Regression Equation 138 Least Squares Method and Multiple Regression 139 Butler Trucking Company and Multiple Regression 140 Using Excel's Regression Tool to Develop the Estimated Multiple Regression Equation 140

#### 4.5 Inference and Regression 143

Conditions Necessary for Valid Inference in the Least Squares Regression Model 144

Testing for an Overall Regression Relationship 148

Testing Individual Regression Parameters 150 Addressing Nonsignificant Independent Variables 153 Multicollinearity 154 Inference and Very Large Samples 156 **Categorical Independent Variables 161** 4.6 Butler Trucking Company and Rush Hour 161 Interpreting the Parameters 162 More Complex Categorical Variables 164 **Modeling Nonlinear Relationships** 165 4.7 Quadratic Regression Models 167 Piecewise Linear Regression Models 170 Interaction Between Independent Variables 173 4.8 Model Fitting 177 Variable Selection Procedures 177 Overfitting 179 Summary 180 **Glossary** 180 Problems 182 Case Problem: Alumni Giving 197 **Appendix: Using XLMiner for Regression 198** Chapter 5 Time Series Analysis and Forecasting 202 Analytics in Action: Forecasting Demand for a Broad Line

## of Office Products 203

## 5.1 Time Series Patterns 205

Horizontal Pattern 205 Trend Pattern 207 Seasonal Pattern 209 Trend and Seasonal Pattern 209 Cyclical Pattern 211 Identifying Time Series Patterns 212

#### 5.2 Forecast Accuracy 212

#### 5.3 Moving Averages and Exponential Smoothing 217

Moving Averages 217 Forecast Accuracy 221 Exponential Smoothing 221 Forecast Accuracy 224

## 5.4 Using Regression Analysis for Forecasting 226

Linear Trend Projection 226 Seasonality 228 Seasonality Without Trend 228 Seasonality with Trend 230 Using Regression Analysis as a Causal Forecasting Method 231 Combining Causal Variables with Trend and Seasonality Effects 235 Considerations in Using Regression in Forecasting 235 5.5 Determining the Best Forecasting Model to Use 236 Summary 237 Glossary 237 Problems 238 Case Problem: Forecasting Food and Beverage Sales 246 Appendix: Using XLMiner for Forecasting 247

## Chapter 6 Data Mining 251

Analytics in Action: Online Retailers Using Predictive Analytics to Cater to Customers 252 6.1 Data Sampling 253 6.2 Data Preparation 254 Treatment of Missing Data 254 Identification of Outliers and Erroneous Data 254 Variable Representation 254 6.3 Unsupervised Learning 255 Cluster Analysis 256 Association Rules 265 6.4 Supervised Learning 269 Partitioning Data 269 Classification Accuracy 273 Prediction Accuracy 277 k-Nearest Neighbors 277 Classification and Regression Trees 283 Logistic Regression 299 Summary 308 **Glossary 309** Problems 311 Case Problem: Grey Code Corporation 319

## Chapter 7 Spreadsheet Models 320

Analytics in Action: Procter and Gamble Sets Inventory Targets Using Spreadsheet Models 321

7.1 Building Good Spreadsheet Models 322

Influence Diagrams 322Building a Mathematical Model 322Spreadsheet Design and Implementing the Model in a Spreadsheet 324 7.2 What-If Analysis 327 Data Tables 327 Goal Seek 331 Some Useful Excel Functions for Modeling 332 7.3 SUM and SUMPRODUCT 332 IF and COUNTIF 333 VLOOKUP 337 7.4 Auditing Spreadsheet Models 339 Trace Precedents and Dependents 339 Show Formulas 340 Evaluate Formulas 340 Error Checking 341 Watch Window 342 Summary 343 **Glossary 343** Problems 344 **Case Problem: Retirement Plan 350** 

## Chapter 8 Linear Optimization Models 352

Analytics in Action: Timber Harvesting Model at MeadWestvaco Corporation 353		
8.1	A Simple Maximization Problem 354	
	Problem Formulation 355	
	Mathematical Model for the Par, Inc. Problem 357	
8.2	Solving the Par, Inc. Problem 358	
	The Geometry of the Par, Inc. Problem 358	
	Solving Linear Programs with Excel Solver 360	
8.3	A Simple Minimization Problem 364	
	Problem Formulation 364	
	Solution for the M&D Chemicals Problem 365	
8.4	Special Cases of Linear Program Outcomes 367	
	Alternative Optimal Solutions 367	
	Infeasibility 368	
	Unbounded 370	
8.5	Sensitivity Analysis 372	
	Interpreting Excel Solver Sensitivity Report 372	
8.6	General Linear Programming Notation and More Examples 374	
	Investment Portfolio Selection 375	
	Transportation Planning 378	
	Advertising Campaign Planning 381	
8.7	Generating an Alternative Optimal Solution for a Linear Program 386	
Sum	mary 388	
01	<b>2</b> 22	

Glossary 389

Problems 390 Case Problem: Investment Strategy 398 Appendix: Solving Linear Optimization Models Using Analytic Solver Platform 399

## Chapter 9 Integer Linear Optimization Models 405

Analytics in Action: Optimizing the Transport of Oil Rig Crews 406

- 9.1 Types of Integer Linear Optimization Models 406
- **9.2 Eastborne Realty, An Example of Integer Optimization 407** The Geometry of Linear All-Integer Optimization 408
- **9.3** Solving Integer Optimization Problems with Excel Solver 410 A Cautionary Note About Sensitivity Analysis 414

### 9.4 Applications Involving Binary Variables 415

Capital Budgeting 415

Fixed Cost 416 Bank Location 420

Product Design and Market Share Optimization 424

- **9.5** Modeling Flexibility Provided by Binary Variables 426 Multiple-Choice and Mutually Exclusive Constraints 427 *k* out of *n* Alternatives Constraint 427 Conditional and Corequisite Constraints 427
- 9.6 Generating Alternatives in Binary Optimization 428 Summary 430

**Glossary 430** 

Problems 431

Case Problem: Applecore Children's Clothing 441

Appendix: Solving Integer Linear Optimization Problems Using Analytic Solver Platform 442

## Chapter 10 Nonlinear Optimization Models 448

Analytics in Action: Intercontinental Hotels Optimizes Retail Pricing 449

10.1 A Production Application: Par, Inc. Revisited 449

An Unconstrained Problem 450 A Constrained Problem 450 Solving Nonlinear Optimization Models Using Excel Solver 453 Sensitivity Analysis and Shadow Prices in Nonlinear Models 454

- **10.2 Local and Global Optima 455** Overcoming Local Optima with Excel Solver 457
- 10.3 A Location Problem 459
- 10.4 Markowitz Portfolio Model 461
- 10.5 Forecasting Adoption of a New Product 465

Summary 469 Glossary 470 Problems 470 Case Problem: Portfolio Optimization with Transaction Costs 477 Appendix: Solving Nonlinear Optimization Problems with Analytic Solver Platform 480

## Chapter 11 Monte Carlo Simulation 485

Analy	tics in Action: Reducing Patient Infections in the ICU 486
11.1	What-If Analysis 487
	The Sanotronics Problem 487
	Base-Case Scenario 487
	Worst-Case Scenario 488
	Best-Case Scenario 488
11.2	Simulation Modeling with Native Excel Functions 488
	Use of Probability Distributions to Represent
	Random Variables 489
	Generating Values for Random Variables with Excel 491
	Executing Simulation Trials with Excel 495
	Measuring and Analyzing Simulation Output 495
11.3	Simulation Modeling with Analytic Solver Platform 498
	The Land Shark Problem 499
	Spreadsheet Model for Land Shark 499
	Generating Values for Land Shark's Random Variables 500
	Tracking Output Measures for Land Shark 503
	Executing Simulation Trials and Analyzing Output for Land Shark 504
	The Zappos Problem 506
	Spreadsheet Model for Zappos 507
	Modeling Random Variables for Zappos 510
	Tracking Output Measures for Zappos 515
	Executing Simulation Trials and Analyzing Output for Zappos 517
11.4	Simulation Optimization 518
11.5	Simulation Considerations 524
	Verification and Validation 524
	Advantages and Disadvantages of Using Simulation 524
Summ	ary 525
Glossa	ry 526
Proble	ms 527
Case P	roblem: Four Corners 536
Appen	dix 11.1: Incorporating Dependence Between
	Random Variables 537
Appen	dix 11.2: Probability Distributions for Random Variables 545

## Chapter 12 Decision Analysis 550

Analytics in Action: Phytopharm's New Product Research and Development 551		
12.1	Problem Formulation 552	
	Payoff Tables 553	
	Decision Trees 553	
12.2	Decision Analysis Without Probabilities 554	
	Optimistic Approach 554	
	Conservative Approach 555	
	Minimax Regret Approach 555	
12.3	Decision Analysis with Probabilities 557	
	Expected Value Approach 557	
	Risk Analysis 559	
	Sensitivity Analysis 560	
12.4	Decision Analysis with Sample Information 561	
	Expected Value of Sample Information 566	
	Expected Value of Perfect Information 567	
12.5	Computing Branch Probabilities with Bayes' Theorem 568	
12.6	Utility Theory 571	
	Utility and Decision Analysis 573	
	Utility Functions 577	
	Exponential Utility Function 580	
Sumn	uary 581	
Glossary 582		
Probl	ems 584	
Case ]	Problem: Property Purchase Strategy 595	
Apper	ndix: Using Analytic Solver Platform to Create Decision Trees 596	
1 ppc		
Арр	endix A Basics of Excel 609	
Арр	endix B Data Management and Microsoft Access 621	
Арр	endix C Answers to Even-Numbered Exercises (online)	

References 659 Index 661