Basic Business Statistics Concepts and Applications

Mark L. Berenson

Department of Information Management and Business Analytics School of Business, Montclair State University

David M. Levine

Department of Information Systems and Statistics

Zicklin School of Business, Baruch College, City University of New York

Kathryn A. Szabat

Department of Business Systems and Analytics School of Business, La Salle University

David F. Stephan

Two Bridges Instructional Technology



Contents

Preface 24

First Things First 33

USING STATISTICS: "The Price of Admission" 33

FTF.1 Think Differently About Statistics 34

Statistics: A Way of Thinking 34

Statistics: An Important Part of Your Business Education 35

FTF.2 Business Analytics: The Changing Face of Statistics 36

"Big Data" 36

FTF.3 Starting Point for Learning Statistics 37

Statistic 37

Can Statistics (pi., statistic) Lie? 38

FTF.4 Starting Point for Using Software 38

Using Software Properly 40

REFERENCES 41

KEY TERMS 41

EXCEL GUIDE 42

EG.1 Getting Started with Excel 42

EG.2 Entering Data 42

EG.3 Open or Save a Workbook 42

EG.4 Working with a Workbook 43

EG.5 Print a Worksheet 43

EG.6 Reviewing Worksheets 43

EG.7 If You Use the Workbook Instructions 43

JMP GUIDE 44

JG.1 Getting Started with JMP 44

JG.2 Entering Data 45

JG.3 Create New Project or Data Table 45

JG.4 Open or Save Files 45

JG.5 Print Data Tables or Report Windows 45

JG.6 JMP Script Files 45

MINITAB GUIDE 46

MG.1 Getting Started with Minitab 46

MG.2 Entering Data 46

MG.3 Open or Save Files 46

MG.4 Insert or Copy Worksheets 47

MG.5 Print Worksheets 47

1 Defining and Collecting Data 48

USING STATISTICS: Defining Moments 48

1.1 Defining Variables 49

Classifying Variables by Type 49 Measurement Scales 50

1.2 Collecting Data 51

Populations and Samples 52

Data Sources 52

1.3 Types of Sampling Methods 53

Simple Random Sample 54

Systematic Sample 54

Stratified Sample 55

Cluster Sample 55

1.4 Data Cleaning 56

Invalid Variable Values 57

Coding Errors 57

Data Integration Errors 57

Missing Values 58

Algorithmic Cleaning of Extreme Numerical Values 58

1.5 Other Data Preprocessing Tasks 58

Data Formatting 58

Stacking and Unstacking Data 59

Recoding Variables 59

1.6 Types of Survey Errors 60

Coverage Error 60

Nonresponse Error 60

Sampling Error 60

Measurement Error 61

Ethical Issues About Surveys 61

CONSIDER THIS: New Media Surveys/Old Survey

Errors 61

USING STATISTICS: Defining Moments, Revisited 63

SUMMARY 63

REFERENCES 63

KEY TERMS 63

CHECKING YOUR UNDERSTANDING 64

CHAPTER REVIEW PROBLEMS 64

CASES FOR CHAPTER 1 65

Managing Ashland MultiComm Services 65

CardioGood Fitness 65

Clear Mountain State Student Survey 66

Learning with the Digital Cases 66

CHAPTER 1 EXCEL GUIDE 67

EG1.1 Defining Variables 67

EG1.2 Collecting Data 67

EG1.3 Types of Sampling Methods 67

EG1.4 Data Cleaning 68

EG1.5 Other Data Preprocessing 68

CHAPTER 1 JMP GUIDE 69

JG1.1 Defining Variables 69

JG1.2 Collecting Data 69

JG1.3 Types of Sampling Methods 69

JG1.4 Data Cleaning 70

JG1.5 Other Preprocessing Tasks 71

CHAPTER 1 MINITAB GUIDE 71

MG1.1 Defining Variables 71

MG1.2 Collecting Data 71

MG1.3 Types of Sampling Methods 71

MG1.4 Data Cleaning 72

MG1.5 Other Preprocessing Tasks 72

2 Organizing and Visualizing Variables 73

USING STATISTICS: "The Choice /s Yours" 73

2.1 Organizing Categorical Variables 74

The Summary Table 74

The Contingency Table 75

2.2 Organizing Numerical Variables 78

The Frequency Distribution 79

Classes and Excel Bins 81

The Relative Frequency Distribution and the

Percentage Distribution 81

The Cumulative Distribution 83

2.3 Visualizing Categorical Variables 86

The Bar Chart 86

The Pie Chart and the Doughnut Chart 87

The Pareto Chart 88

Visualizing Two Categorical Variables 90

2.4 Visualizing Numerical Variables 93

The Stem-and-Leaf Display 93

The Histogram 93

The Percentage Polygon 95

The Cumulative Percentage Polygon (Ogive) 96

2.5 Visualizing Two Numerical Variables 99

The Scatter Plot 99

The Time-Series Plot 100

2.6 Organizing a Mix of Variables 102

Drill-down 103

2.7 Visualizing a Mix of Variables 104

Colored Scatter Plot 104

Bubble Charts 105

PivotChart (Excel) 105

Treemap (Excel, JMP) 105

Sparklines (Excel) 106

2.8 Filtering and Querying Data 107

Excel Slicers 107

2.9 Pitfalls in Organizing and Visualizing Variables 109

Obscuring Data 109

Creating False Impressions 110

Chartjunk 111

EXHIBIT: Best Practices for Creating Visual Summaries 112

USING STATISTICS: "The Choice Is Yours," Revisited 113

SUMMARY 113

REFERENCES 114

KEY EQUATIONS 114

KEY TERMS 115

CHECKING YOUR UNDERSTANDING 115

CHAPTER REVIEW PROBLEMS 115

CASES FOR CHAPTER 2 120

Managing Ashland MultiComm Services 120

Digital Case 120

CardioGood Fitness 121

The Choice Is Yours Follow-Up 121

Clear Mountain State Student Survey 121

CHAPTER 2 EXCEL GUIDE 122

EG2.1 Organizing Categorical Variables 122

EG2.2 Organizing Numerical Variables 124

EG2 Charts Group Reference 126

EG2.3 Visualizing Categorical Variables 126

EG2.4 Visualizing Numerical Variables 128

EG2.5 Visualizing Two Numerical Variables 131

EG2.6 Organizing a Mix of Variables 132

EG2.7 Visualizing a Mix of Variables 133

EG2.8 Filtering and Querying Data 134

CHAPTER 2 JMP GUIDE 134

JG2 JMP Choices for Creating Summaries 134

JG2.1 Organizing Categorical Variables 135

JG2.2 Organizing Numerical Variables 136

JG2.3 Visualizing Categorical Variables 138

JG2.4 Visualizing Numerical Variables 139

JG2.5 Visualizing Two Numerical Variables 141

JG2.6 Organizing a Mix of Variables 142

JG2.7 Visualizing a Mix of Variables 142

JG2.8 Filtering and Querying Data 143
JMP Guide Gallery 144

CHAPTER 2 MINITAB GUIDE 145

MG2.1 Organizing Categorical Variables 145

MG2.2 Organizing Numerical Variables 145

MG2.3 Visualizing Categorical Variables 145

MG2.4 Visualizing Numerical Variables 147

MG2.5 Visualizing Two Numerical Variables 149

MG2.6 Organizing a Mix of Variables 150

MG2.7 Visualizing a Mix of Variables 150

MG2.8 Filtering and Querying Data 151

3 Numerical Descriptive Measures 152

USING STATISTICS: More Descriptive Choices 152

3.1 Measures of Central Tendency 153

The Mean 153

The Median 155

The Mode 156

The Geometric Mean 157

3.2 Measures of Variation and Shape 158

The Range 158

The Variance and the Standard Deviation 159

The Coefficient of Variation 162

Z Scores 162

Shape: Skewness 164

Shape: Kurtosis 164

3.3 Exploring Numerical Variables 169

Quartiles 169

EXHIBIT: Rules for Calculating the Quartiles from a Set of Ranked Values 169

The Interquartile Range 171
The Five-Number Summary 171

The Boxplot 173

3.4 Numerical Descriptive Measures for a Population 175

The Population Mean 176

The Population Variance and Standard Deviation 176

The Empirical Rule 177

Chebyshev's Theorem 178

3.5 The Covariance and the Coefficient of Correlation 180

The Covariance 180

The Coefficient of Correlation 180

3.6 Descriptive Statistics: Pitfalls and Ethical Issues 184

USING STATISTICS: More Descriptive Choices, Revisited 185

SUMMARY 185

REFERENCES 186

KEY EQUATIONS 186

KEY TERMS 186

CHECKING YOUR UNDERSTANDING 187

CHAPTER REVIEW PROBLEMS 187

CASES FOR CHAPTER 3 190

Managing Ashland MultiComm Services 190

Digital Case 190

CardioGood Fitness 190

More Descriptive Choices Follow-up 191

Clear Mountain State Student Survey 191

CHAPTER 3 EXCEL GUIDE 192

EG3.1 Measures of Central Tendency 192

EG3.2 Measures of Variation and Shape 193

EG3.3 Exploring Numerical Variables 193

EG3.4 Numerical Descriptive Measures for a Population 194

EG3.5 The Covariance and the Coefficient of Correlation 194

CHAPTER 3 JMP GUIDE 195

JG3.1 Measures of Central Tendency 195

JG3.2 Measures of Variation and Shape 195

JG3.3 Exploring Numerical Variables 196

JG3.4 Numerical Descriptive Measures for a Population 196

JG3.5 The Covariance and the Coefficient of Correlation 196

CHAPTER 3 MINITAB GUIDE 197

MG3.1 Measures of Central Tendency 197

MG3.2 Measures of Variation and Shape 198

MG3.3 Exploring Numerical Variables 198

MG3.4 Numerical Descriptive Measures for a Population 199

MG3.5 The Covariance and the Coefficient of Correlation 199

4 Basic Probability 200

USING STATISTICS: Possibilities at M&R Electronics World 200

4.1 Basic Probability Concepts 201

Events and Sample Spaces 201

Types of Probability 202

Summarizing Sample Spaces 203

Simple Probability 204

Joint Probability 205

Marginal Probability 206

General Addition Rule 206

4.2 Conditional Probability 210

Computing Conditional Probabilities 210

Decision Trees 211

Independence 213

Multiplication Rules 214

Marginal Probability Using the General Multiplication Rule 215

4.3 Ethical Issues and Probability 217

4.4 Bayes' Theorem 218

CONSIDER THIS: Divine Providence and Spam 220

4.5 Counting Rules 221

USING STATISTICS: Possibilities at M&R Electronics World, Revisited 224

SUMMARY 225

REFERENCES 225

KEY EQUATIONS 225

KEY TERMS 226

CHECKING YOUR UNDERSTANDING 226

CHAPTER REVIEW PROBLEMS 226

CASES FOR CHAPTER 4 228

Digital Case 228

CardioGood Fitness 228

The Choice Is Yours Follow-Up 228

Clear Mountain State Student Survey 228

CHAPTER 4 EXCEL GUIDE 229

EG4.1 Basic Probability Concepts 229

EG4.4 Bayes' Theorem 229

EG4.5 Counting Rules 229

CHAPTER 4 JMP

JG4.4 Bayes' Theorem 230

CHAPTER 4 MINITAB GUIDE 230

MG4.5 Counting Rules 230

Discrete Probability Distributions 231

USING STATISTICS: Events of Interest at Ricknel Home Centers 231

5.1 The Probability Distribution for a Discrete Variable 232 Expected Value of a Discrete Variable 232

Variance and Standard Deviation of a Discrete Variable 233

5.2 Binomial Distribution 236

EXHIBIT: Properties of the Binomial Distribution 236

Histograms for Discrete Variables 239

Summary Measures for the Binomial Distribution 240

5.3 Poisson Distribution 243

5.4 Covariance of a Probability Distribution and Its Application in Finance 246

5.5 Hypergeometric Distribution (online) 246

5.6 Using the Poisson Distribution to Approximate the Binomial Distribution (online) 246

USING STATISTICS: Events of Interest..., Revisited 247 SUMMARY 247

REFERENCES 247

KEY EQUATIONS 247

KEY TERMS 248

CHECKING YOUR UNDERSTANDING 248

CHAPTER REVIEW PROBLEMS 248

CASES FOR CHAPTER 5 250

Managing Ashland MultiComm Services 250 Digital Case 250

CHAPTER 5 EXCEL GUIDE 251

EG5.1 The Probability Distribution for a Discrete Variable 251

EG5.2 Binomial Distribution 251

EG5.3 Poisson Distribution 251

CHAPTER 5 JMP GUIDE 252

JG5.1 The Probability Distribution for a Discrete Variable 252

JG5.2 Binomial Distribution 252

JG5.3 Poisson Distribution 253

CHAPTER 5 MINITAB GUIDE 253

MG5.1 The Probability Distribution for a Discrete Variable 253

MG5.2 Binomial Distribution 254

MG5.3 Poisson Distribution 254

6 The Normal Distribution and Other Continuous Distributions 255

USING STATISTICS!: Normal Load Times at MyTVLab 255

- **6.1** Continuous Probability Distributions 256
- 6.2 The Normal Distribution 256

EXHIBIT: Normal Distribution Important Theoretical Properties 257

Role of the Mean and the Standard Deviation 258

Calculating Normal Probabilities 259

VISUAL EXPLORATIONS: Exploring the Normal

Distribution 263

Finding X Values 264

CONSIDER THIS: What Is Normal? 267

6.3 Evaluating Normality 269

Comparing Data Characteristics to Theoretical Properties 269

Constructing the Normal Probability Plot 270

- 6.4 The Uniform Distribution 273
- 6.5 The Exponential Distribution (online) 275
- 6.6 The Normal Approximation to the Binomial Distribution (*online*) 275

USING STATISTICS: Normal Load Times..., Revisited 275

SUMMARY 275

REFERENCES 276

KEY EQUATIONS 276

KEY TERMS 276

CHECKING YOUR UNDERSTANDING 277

CHAPTER REVIEW PROBLEMS 277

CASES FOR CHAPTER 6 278

Managing Ashland MultiComm Services 278 CardioGood Fitness 279 More Descriptive Choices Follow-up 279

Clear Mountain State Student Survey 279

Digital Case 279

CHAPTER 6 EXCEL GUIDE 280

EG6.2 The Normal Distribution 280 EG6.3 Evaluating Normality 280

CHAPTER 6 JMP GUIDE 281

JG6.2 The Normal Distribution 281 JG6.3 Evaluating Normality 281

CHAPTER 6 MINITAB GUIDE 282

MG6.2 The Normal Distribution 282

MG6.3 Evaluating Normality 282

7 Sampling Distributions 284

USING STATISTICS: Sampling Oxford Cereals 284

- 7.1 Sampling Distributions 285
- 7.2 Sampling Distribution of the Mean 285

The Unbiased Property of the Sample Mean 285 Standard Error of the Mean 287

Sampling from Normally Distributed Populations 288
Sampling from Non-normally Distributed Populations—
The Central Limit Theorem 291

EXHIBIT: Normality and the Sampling Distribution of the Mean 292

VISUAL EXPLORATIONS: Exploring Sampling Distributions 295

- 7.3 Sampling Distribution of the Proportion 296
- 7.4 Sampling from Finite Populations (online) 299

USING STATISTICS: Sampling Oxford Cereals, Revisited 299

SUMMARY 300

REFERENCES 300

KEY EQUATIONS 300

KEY TERMS 300

CHECKING YOUR UNDERSTANDING 301

CHAPTER REVIEW PROBLEMS 301

CASES FOR CHAPTER 7 302

Managing Ashland MultiComm Services 302 Digital Case 303

CHAPTER 7 EXCEL GUIDE 304

EG7.2 Sampling Distribution of the Mean 304

CHAPTER 7 JMP GUIDE 305

JG7.2 Sampling Distribution of the Mean 305

CHAPTER 7 MINITAB GUIDE 306

MG7.2 Sampling Distribution of the Mean 306

8 Confidence Interval Estimation 307

USING STATISTICS: Getting Estimates at Ricknel Home Centers 307

8.1 Confidence Interval Estimate for the Mean (a Known) 308 Sampling Error 309

Can You Ever Know the Population Standard Deviation? 312

8.2 Confidence Interval Estimate for the Mean (a Unknown) 313

Student's t Distribution 314

The Concept of Degrees of Freedom 314

Properties of the f Distribution 314

The Confidence Interval Statement 316

- 8.3 Confidence Interval Estimate for the Proportion 321
- 8.4 Determining Sample Size 324

Sample Size Determination for the Mean 324 Sample Size Determination for the Proportion 326

- 8.5 Confidence Interval Estimation and Ethical Issues 329
- 8.6 Application of Confidence Interval Estimation in Auditing (*online*) 329
- **8.7** Estimation and Sample Size Estimation for Finite Populations *(online)* 330
- 8.8 Bootstrapping (online) 330

USING STATISTICS: Getting Estimates..., Revisited 330

SUMMARY¹ 330

REFERENCES 331

KEY EQUATIONS 331

KEY TERMS 331

CHECKING YOUR UNDERSTANDING 331

CHAPTER REVIEW PROBLEMS 332

CASES FOR CHAPTER 8 334

Managing Ashland MultiComm Services 334

Digital Case 335

Sure Value Convenience Stores 336

CardioGood Fitness 336

More Descriptive Choices Follow-Up 336

Clear Mountain State Student Survey 336

CHAPTER 8 EXCEL GUIDE 337

EG8.1 Confidence Interval Estimate for the Mean (o Known) 337

EG8.2 Confidence Interval Estimate for the Mean (a Unknown) 337

EG8.3 Confidence Interval Estimate for the Proportion 338

EG8.4 Determining Sample Size 338

CHAPTER 8 JMP GUIDE 339

JG8.1 Confidence Interval Estimate for the Mean (a Known) 339

JG8.3 Confidence Interval Estimate for the Proportion 340

JG8.4 Determining Sample Size 340

CHAPTER 8 MINITAB GUIDE 341

MG8.1 Confidence Interval Estimate for the Mean (a Known) 341 MG8.2 Confidence Interval Estimate for the Mean (a Unknown) 341

MG8.3 Confidence Interval Estimate for the Proportion 342 MG8.4 Determining Sample Size 342

Fundamentals of Hypothesis Testing: One-Sample Tests 343

USING STATISTICS: Significant Testing at Oxford Cereals 343

9.1 Fundamentals of Hypothesis Testing 344

EXHIBIT: Fundamental Hypothesis Testing Concepts 345

The Critical Value of the Test Statistic 345

Regions of Rejection and Nonrejection 346

Risks in Decision Making Using Hypothesis Testing 346

Z Test for the Mean (a Known) 348

Hypothesis Testing Using the Critical Value Approach 349

EXHIBIT: The Critical Value Approach to Hypothesis Testing 350

Hypothesis Testing Using the p-Value Approach 352

EXHIBIT: The p-Value Approach to Hypothesis Testing 353

A Connection Between Confidence Interval Estimation and Hypothesis Testing 354

Can You Ever Know the Population Standard Deviation? 355

9.2 *t* Test of Hypothesis for the Mean (a Unknown) 356

The Critical Value Approach 357

p-Value Approach 358

Checking the Normality Assumption 359

9.3 One-Tail Tests 362

The Critical Value Approach 362

The p-Value Approach 363

EXHIBIT: The Null and Alternative Hypotheses in One-Tail Tests 365

9.4 Z Test of Hypothesis for the Proportion 366

The Critical Value Approach 367

The p-Value Approach 368

9.5 Potential Hypothesis-Testing Pitfalls and Ethical Issues 370 EXHIBIT: Questions for the Planning Stage of Hypothesis

Testing 370

Statistical Significance Versus Practical Significance 370 Statistical *Insignificance* Versus Importance 371

Reporting of Findings 371

Ethical Issues 371

9.6 Power of the Test (online) 371

USING STATISTICS: Significant Testing ... Revisited 372

SUMMARY 372

REFERENCES 372

KEY EQUATIONS 373

KEY TERMS 373

CHECKING YOUR UNDERSTANDING 373

CHAPTER REVIEW PROBLEMS 373

CASES FOR CHAPTER 9 375

Managing Ashland MultiComm Services 375

Digital Case 375

Sure Value Convenience Stores 376

CHPATER 9 EXCEL GUIDE 377

EG9.1 Fundamentals of Hypothesis Testing 377

EG9.2 f Test of Hypothesis for the Mean (<r Unknown) 377

EG9.3 One-Tail Tests 378

EG9.4 ZTest of Hypothesis for the Proportion 378

CHAPTER 9 JMP GUIDE 379

JG9.1 Fundamentals of Hypothesis Testing 379

JG9.2 f Test of Hypothesis for the Mean (<x Unknown) 379

JG9.3 One-Tail Tests 380

JG9.4 ZTest of Hypothesis for the Proportion 380

CHAPTER 9 MINITAB GUIDE 380

MG9.1 Fundamentals of Hypothesis Testing 380

MG9.2 t Test of Hypothesis for the Mean (<r Unknown) 381

MG9.3 One-Tail Tests 381

MG9.4 ZTest of Hypothesis for the Proportion 381

10 Two-Sample Tests 383

USING STATISTICS: Differing Means for Selling Streaming Media Players at Arlingtons? 383

10.1 Comparing the Means of Two Independent Populations 384

Pooled-Variance f Test for the Difference Between

Two Means Assuming Equal Variances 384

Evaluating the Normality Assumption 387

Confidence Interval Estimate for the Difference Between

Two Means 389

Separate-Variance *t* Test for the Difference Between

Two Means, Assuming Unequal Variances 390

CONSIDER THIS: Do People Really Do This? 391

10.2 Comparing the Means of Two Related Populations 393

Paired t Test 394

Confidence Interval Estimate for the Mean Difference 399

10.3 Comparing the Proportions of Two Independent Populations 401

> ZTest for the Difference Between Two Proportions 401 Confidence Interval Estimate for the Difference Between

Two Proportions 406

10.4 F Test for the Ratio of Two Variances 408

10.5 Effect Size (online) 412

USING STATISTICS: Differing Means for Selling Revisited 413

SUMMARY 413

REFERENCES 414

KEFEKENCES 414

KEY EQUATIONS 414

KEY TERMS 415

CHECKING YOUR UNDERSTANDING 415

CHAPTER REVIEW PROBLEMS 415

CASES FOR CHAPTER 10 417

Managing Ashland MultiComm Services 417

Digital Case 418

Sure Value Convenience Stores 418

CardioGood Fitness 418

More Descriptive Choices Follow-Up 418

Clear Mountain State Student Survey 419

CHAPTER 10 EXCEL GUIDE 420

EG10.1 Comparing the Means of Two Independent Populations 420

EG10.2 Comparing the Means of Two Related Populations 422

EG10.3 Comparing the Proportions of Two Independent Populations 423

EG10.4 F Test for the Ratio of Two Variances 424

CHAPTER 10 JMP GUIDE 425

JG10.1 Comparing the Means of Two Independent Populations 425

JG10.2 Comparing the Means of Two Related Populations 426

JG10.3 Comparing the Proportions of Two Independent Populations 426

JG10.4 F Test for the Ratio of Two Variances 426

CHAPTER 10 MINITAB GUIDE 427

MG10.1 Comparing the Means of Two Independent Populations 427

MG10.2 Comparing the Means of Two Related Populations 428

MG10.3 Comparing the Proportions of Two Independent Populations 428

MG10.4 F Test for the Ratio of Two Variances 429

11 Analysis of Variance 430

USING STATISTICS: The Means to Find Differences at Arlingtons 430

11.1 The Completely Randomized Design: One-Way ANOVA 431

Analyzing Variation in One-Way ANOVA 432

F Test for Differences Among More Than Two Means 434

One-Way ANOVA F Test Assumptions 439

Levene Test for Homogeneity of Variance 439

Multiple Comparisons: The Tukey-Kramer Procedure 441

The Analysis of Means (ANOM) 443

11.2 The Factorial Design: Two-Way ANOVA 446

Factor and Interaction Effects 447

Testing for Factor and Interaction Effects 448

Multiple Comparisons: The Tukey Procedure 452

Visualizing Interaction Effects: The Cell Means Plot 453

Interpreting Interaction Effects 454

11.3 The Randomized Block Design (online) 458

11.4 Fixed Effects, Random Effects, and Mixed Effects Models (*online*) 458

USING STATISTICS: The Means to Find Differences at Arlingtons Revisited 458

SUMMARY 458

REFERENCES 459

KEY EQUATIONS 459

KEY TERMS 460

CHECKING YOUR UNDERSTANDING 460

CHAPTER REVIEW PROBLEMS 460

CASES FOR CHAPTER 11 462

Managing Ashland MultiComm Services 462

Digital Case 463

Sure Value Convenience Stores 463

CardioGood Fitness 463

More Descriptive Choices Follow-Up 463

Clear Mountain State Student Survey 463

CHAPTER 11 EXCEL GUIDE 464

EG11.1 The Completely Randomized Design: One-Way ANOVA 464 EG11.2 The Factorial Design: Two-Way ANOVA 466

CHAPTER 11 JMP GUIDE 467

JG11.1 The Completely Randomized Design: One-Way ANOVA 467 JG11.2 The Factorial Design: Two-Way ANOVA 468

CHAPTER 11 MINITAB GUIDE 469

MG11.1 The Completely Randomized Design: One-Way ANOVA 469 MG11.2 The Factorial Design: Two-Way ANOVA 470

12 Chi-Square and Nonparametric Tests 472

USING STATISTICS: Avoiding Guesswork About Resort Guests 472

- **12.1** Chi-Square Test for the Difference Between Two Proportions 473
- **12.2** Chi-Square Test for Differences Among More Than Two Proportions 480

The Marascuilo Procedure 483
The Analysis of Proportions (ANOP) 485

- 12.3 Chi-Square Test of Independence 486
- **12.4** Wilcoxon Rank Sum Test for Two Independent Populations 492
- 12.5 Kruskal-Wallis Rank Test for the One-Way ANOVA 498 Assumptions of the Kruskal-Wallis Rank Test 501
- **12.6** McNemar Test for the Difference Between Two Proportions (Related Samples) (*online*) 502
- **12.7** Chi-Square Test for the Variance or Standard Deviation (*online*) 502
- **12.8** Wilcoxon Signed Ranks Test for Two Related Populations (*online*) 503
- **12.9** Friedman Rank Test for the Randomized Block Design (*online*) 503

USING STATISTICS: Avoiding Guesswork..., Revisited 503

SUMMARY 503

REFERENCES 504

KEY EQUATIONS 504

KEY TERMS 505

CHECKING YOUR UNDERSTANDING 505

CHAPTER REVIEW PROBLEMS 505

CASES FOR CHAPTER 12 507

Managing Ashland MultiComm Services 507

Digital Case 508

Sure Value Convenience Stores 508

CardioGood Fitness 508

More Descriptive Choices Follow-Up 509

Clear Mountain State Student Survey 509

CHAPTER 12 EXCEL GUIDE 510

EG12.1 Chi-Square Test for the Difference Between Two Proportions 510

EG12.2 Chi-Square Test for Differences Among More Than Two Proportions 510

- EG12.3 Chi-Square Test of Independence 511
- EG12.4 Wilcoxon Rank Sum Test: A Nonparametric Method for Two Independent Populations 511
- EG12.5 Kruskal-Wallis Rank Test: A Nonparametric Method for the One-Way ANOVA 512

CHAPTER 12 JMP GUIDE 513

- JG12.1 Chi-Square Test for the Difference Between Two Proportions 513
- JG12.2 Chi-Square Test tor Difference Among More Than Two Proportions 513
- JG12.3 Chi-Square Test Of Independence 513
- JG12.4 Wilcoxon Rank Sum Test for Two Independent Populations 513
- JG12.5 Kruskal-Wallis Rank Test for the One-Way ANOVA 514

CHAPTER 12 MINITAB GUIDE 514

- MG12.1 Chi-Square Test for the Difference Between Two Proportions 514
- MG12.2 Chi-Square Test for Differences Among More Than
 Two Proportions 515
- MG12.3 Chi-Square Test of Independence 515
- MG12.4 Wilcoxon Rank Sum Test: A Nonparametric Method for Two Independent Populations 515
- MG12.5 Kruskal-Wallis Rank Test: A Nonparametric Method for the One-Way ANOVA 515

13 Simple Linear Regression 516

USING STATISTICS: Knowing Customers at Sunflowers Apparel 516

Preliminary Analysis 517

- 13.1 Simple Linear Regression Models 518
- **13.2** Determining the Simple Linear Regression Equation 519

The Least-Squares Method 519

Predictions in Regression Analysis: Interpolation Versus Extrapolation 522

Computing the Y Intercept, b_0 and the Slope, b^{\wedge} 523 VISUAL EXPLORATIONS: Exploring Simple Linear Regression Coefficients 525

13.3 Measures of Variation 527

Computing the Sum of Squares 527 The Coefficient of Determination 528 Standard Error of the Estimate 530

- 13.4 Assumptions of Regression 532
- 13.5 Residual Analysis 532

Evaluating the Assumptions 532

13.6 Measuring Autocorrelation: The Durbin-Watson Statistic 536

Residual Plots to Detect Autocorrelation 536 The Durbin-Watson Statistic 537

13.7 Inferences About the Slope and Correlation Coefficient 540

t Test for the Slope 540

F Test for the Slope 541

Confidence Interval Estimate for the Slope 543

t Test for the Correlation Coefficient 543

13.8 Estimation of Mean Values and Prediction of Individual Values 546

The Confidence Interval Estimate for the Mean Response 547 The Prediction Interval for an Individual Response 548

13.9 Potential Pitfalls in Regression 550

EXHIBIT: Seven Steps for Avoiding the Potential Pitfalls 550

USING STATISTICS: Knowing Customers..., Revisited 552

SUMMARY 553

REFERENCES 554

KEY EQUATIONS 554

KEY TERMS 555

CHECKING YOUR UNDERSTANDING 555

CHAPTER REVIEW PROBLEMS 556

CASES FOR CHAPTER 13 559

Managing Ashland MultiComm Services 559

Digital Case 559

Rye Packaging 560

CHAPTER 13 EXCEL GUIDE 561

EG13.2 Determining the Simple Linear Regression Equation 561

EG13.3 Measures of Variation 562

EG13.4 Assumptions of Regression 562

EG13.5 Residual Analysis 562

EG13.6 Measuring Autocorrelation: the Durbin-Watson Statistic 563

EG13.7 Inferences about the Slope and Correlation Coefficient 563

EG13.8 Estimation of Mean Values and Prediction of Individual Values 563

CHAPTER 13 JMP GUIDE 564

JG13.2 Determining the Simple Linear Regression Equation 564

JG13.3 Measures of Variation 564

JG13.4 Assumptions of Regression 564

JG13.5 Residual Analysis 564

JG13.6 Measuring Autocorrelation: the Durbin-Watson Statistic 564

JG13.7 Inferences about the Slope and Correlation Coefficient 564

JG13.8 Estimation of Mean Values and Prediction of Individual Values 565

CHAPTER 13 MINITAB GUIDE 566

MG13.2 Determining the Simple Linear Regression Equation 566

MG13.3 Measures of Variation 567

MG13.4 Assumptions of Regression 567

MG13.5 Residual Analysis 567

MG13.6 Measuring Autocorrelation: the Durbin-Watson Statistic 567

MG13.7 Inferences about the Slope and Correlation Coefficient 567

MG13.8 Estimation of Mean Values and Prediction of Individual Values 567

14 Introduction to Multiple Regression 568

USING STATISTICS: The Multiple Effects of OmniPower Bars 568

14.1 Developing a Multiple Regression Model 569
Interpreting the Regression Coefficients 570
Predicting the Dependent Variable Y 572

14.2 r^2 , Adjusted r^2 , and the Overall FTest 574

Coefficient of Multiple Determination 574

Adjusted r2 575

Test for the Significance of the Overall Multiple Regression Model 575

14.3 Multiple Regression Residual Analysis 578

14.4 Inferences About the Population Regression Coefficients 579

Tests of Hypothesis 580

Confidence Interval Estimation 581

14.5 Testing Portions of the Multiple Regression Model 583 Coefficients of Partial Determination 587

14.6 Using Dummy Variables and Interaction Terms 589 Interactions 592

14.7 Logistic Regression 601

14.8 Influence Analysis (online) 607

USING STATISTICS: The Multiple Effects..., Revisited 607

SUMMARY 607

REFERENCES 609

KEY EQUATIONS 609

KEY TERMS 610

CHECKING YOUR UNDERSTANDING 610

CHAPTER REVIEW PROBLEMS 610

CASES FOR CHAPTER 14 613

Managing Ashland MultiComm Services 613 Digital Case 613

CHAPTER 14 EXCEL GUIDE 614

EG14.1 Developing a Multiple Regression Model 614

EG14.2 r2, Adjustedr2, and the Overall FTest 615

EG14.3 Multiple Regression Residual Analysis 615

EG14.4 Inferences about the Population Regression Coefficients 616

EG14.5 Testing Portions of the Multiple Regression Model 616

EG14.6 Using Dummy Variables and Interaction Terms 616

EG14.7 Logistic Regression 617

CHAPTER 14 JMP GUIDE 617

JG14.1 Developing a Multiple Regression Model 617

JG14.2 r^2 , Adjusted r^2 , and the Overall FTest Measures of Variation 618

JG14.3 Multiple Regression Residual Analysis 618

JG14.4 Inferences about the Population 618

JG14.5 Testing Portions of the Multiple Regression Model 619

JG14.6 Using Dummy Variables and Interaction Terms 619

JG14.7 Logistic Regression 619

CHAPTER 14 MINITAB GUIDE 620

MG14.1 Developing a Multiple Regression Model 620

MG14.2 r^2 , Adjusted r^2 , and the Overall FTest 621

MG14.3 Multiple Regression Residual Analysis 621

MG14.4 Inferences about the Population Regression Coefficients 621

MG14.5 Testing Portions of the Multiple Regression Model 621

MG14.6 Using Dummy Variables and Interaction Terms

in Regression Models 621

MG14.7 Logistic Regression 622

MG14.8 Influence Analysis 623

15 Multiple Regression Model Building 624

USING STATISTICS: Valuing Parsimony at WSTA-TV 624

15.1 Quadratic Regression Model 625

Finding the Regression Coefficients and Predicting Y 626 Testing for the Significance of the Quadratic Model 628

Testing the Quadratic Effect 629
The Coefficient of Multiple Determination 631

15.2 Using Transformations in Regression Models 633The Square-Root Transformation 633The Log Transformation 635

15.3 Collinearity 637

15.4 Model Building 639

EXHIBIT: Sucessful Model Building 639

The Stepwise Regression Approach to Model Building 641 The Best Subsets Approach to Model Building 642 Model Validation 645

15.5 Pitfalls in Multiple Regression and Ethical Issues 647 Pitfalls in Multiple Regression 647 Ethical Issues 648

USING STATISTICS: Valuing Parsimony..., Revisited 648 SUMMARY 649

REFERENCES 650 KEY EQUATIONS 650 KEY TERMS 650

CHECKING YOUR UNDERSTANDING 650

CHAPTER REVIEW PROBLEMS 650

CASES FOR CHAPTER 15 652

The Mountain States Potato Company 652
Sure Value Convenience Stores 653
Digital Case 653
The Craybill Instrumentation Company Case

The Craybill Instrumentation Company Case 653 More Descriptive Choices Follow-Up 654

CHAPTER 15 EXCEL GUIDE 655

EG15.1 The Quadratic Regression Model 655 EG15.2 Using Transformations in Regression Models 655 EG15.3 Collinearity 656

EG15.4 Model Building 656

CHAPTER 15 JMP GUIDE 657

JG15.1 The Quadratic Regression Model 657 JG15.2 Using Transformations in Regression Models 657 JG15.3 Collinearity 657

JG15.4 Model Building 657

CHAPTER 15 MINITAB GUIDE 658

MG15.1 The Quadratic Regression Model 658
MG15.2 Using Transformations in Regression Models 659
MG15.3 Collinearity 659
MG15.4Model Building 659

16 Time-Series Forecasting 661

USING STATISTICS: Is the ByYourDoor Service Trending? 661

16.1 Time Series Component Factors 662

16.2 Smoothing an Annual Time Series 664

Moving Averages 665

Exponential Smoothing 667

16.3 Least-Squares Trend Fitting and Forecasting 669

The Linear Trend Model 669
The Quadratic Trend Model 671
The Exponential Trend Model 672
Model Selection Using First, Second, and Percentage Differences 674

EXHIBIT: Model Selection Using First, Second, and Percentage Differences 674

16.4 Autoregressive Modeling for Trend Fitting and Forecasting 679

Selecting an Appropriate Autoregressive Model 680 Determining the Appropriateness of a

Selected Model 681

EXHIBIT: Autoregressive Modeling Steps 683

16.5 Choosing an Appropriate Forecasting Model 687

Residual Analysis 687

The Magnitude of the Residuals Through Squared or Absolute Differences 688
The Principle of Parsimony 688

A Comparison of Four Forecasting Methods 689

16.6 Time-Series Forecasting of Seasonal Data 691

Least-Squares Forecasting with Monthly or Quarterly Data 691

16.7 Index Numbers (online) 697

CONSIDER THIS: Let the Model User Beware 697
USING STATISTICS: Is the ByYourDoor..., Revisited 697

SUMMARY 697
REFERENCES 698
KEY EQUATIONS 698
KEY TERMS 699

CHECKING YOUR UNDERSTANDING 700 CHAPTER REVIEW PROBLEMS 700

CASES FOR CHAPTER 16 701

Managing Ashland MultiComm Services 701 Digital Case 701

CHAPTER 16 EXCEL GUIDE 702

EG16.2 Smoothing an Annual Time Series 702 EG16.3 Least-Squares Trend Fitting and Forecasting 703

EG16.4 Autoregressive Modeling for Trend Fitting and Forecasting 703

EG16.5 Choosing an Appropriate Forecasting Model 704 EG16.6 Time-Series Forecasting of Seasonal Data 704

CHAPTER 16 JMP GUIDE 705

JG16.3 Least-Squares Trend Fitting and Forecasting 706 JG16.4 Autoregressive Modeling for Trend Fitting and Forecasting 706 JG16.5 Choosing an Appropriate Forecasting Model 707

JG16.6 Time-Series Forecasting of Seasonal Data 707

JG16.2 Smoothing an Annual Time Series 705

CHAPTER 16 MINITAB GUIDE 707

MG16.2 Smoothing an Annual Time Series 707 MG16.3 Least-Squares Trend Fitting and Forecasting 708

MG16.4 Autoregressive Modeling for Trend Fitting and Forecasting 709

MG16.5 Choosing an Appropriate Forecasting Model 709 MG16.6 Time-Series Forecasting of Seasonal Data 709

17 Business Analytics 710

USING STATISTICS: Back to Arlingtons for the Future 710

17.1 Business Analytics Categories 711
 Inferential Statistics and Predictive Analytics 712
 Supervised and Unsupervised Methods 712

CONSIDER THIS: What's My Major if I Want to be a Data Miner? 713

17.2 Descriptive Analytics 714

Dashboards 714

Data Dimensionality and Descriptive Analytics 715

17.3 Predictive Analytics for Prediction 716

17.4 Predictive Analytics for Classification 719

17.5 Predictive Analytics for Clustering 720

17.6 Predictive Analytics for Association 723

Multidimensional scaling (MDS) 724

17.7 Text Analytics 725

17.8 Prescriptive Analytics 726

USING STATISTICS: Back to Arlingtons..., Revisited 727

REFERENCES 727 KEY EQUATIONS 728

KEY TERMS 728

CHECKING YOUR UNDERSTANDING 728

CHAPTER REVIEW PROBLEMS 728

CASES FOR CHAPTER 17 730

The Mountain States Potato Company 730 The Craybill Instrumentation Company 730

CHAPTER 17 SOFTWARE GUIDE 731

Introduction 731

SG17.2 Descriptive Analytics 731

SG17.3 Predictive Analytics for Prediction 733

SG17.4 Predictive Analytics for Classification 733

SG17.5 Predictive Analytics for Clustering 734

SG17.6 Predictive Analytics for Association 734

18 Getting Ready to Analyze Data in the Future 736

USING STATISTICS: Mounting Future Analyses 736

18.1 Analyzing Numerical Variables 737

EXHIBIT: Questions to Ask When Analyzing Numerical Variables 737

Describe the Characteristics of a Numerical Variable? 737

Reach Conclusions About the Population Mean or the

Standard Deviation? 737

Determine Whether the Mean and/or Standard Deviation

Differs Depending on the Group? 738

Determine Which Factors Affect the Value of a Variable? 738

Predict the Value of a Variable Based on the Values of

Other Variables? 739

Classify or Associate Items 739

Determine Whether the Values of a Variable Are Stable

Over Time? 739

18.2 Analyzing Categorical Variables 739

EXHIBIT: Questions to Ask When Analyzing Categorical Variables 739

Describe the Proportion of Items of Interest in Each Category? 739

Reach Conclusions About the Proportion of Items of Interest? 740

Determine Whether the Proportion of Items of Interest Differs Depending on the Group? 740

Predict the Proportion of Items of Interest Based on the Values of Other Variables? 740

Classify or Associate Items 740

Determine Whether the Proportion of Items of Interest Is

Stable Over Time? 740

USING STATISTICS: The Future to Be Visited 741

CHAPTER REVIEW PROBLEMS 741

19 Statistical Applications in Quality Management (online) 19-1

USING STATISTICS: Finding Quality at the Beachcomber 19-1

19.1 The Theory of Control Charts 19-2

19.2 Control Chart for the Proportion: The p Chart 19-4

19.3 The Red Bead Experiment: Understanding Process Variability 19-10

19.4 Control Chart for an Area of Opportunity:

The c Chart 19-12

19.5 Control Charts for the Range and the Mean 19-15

The R Chart 19-16

The X Chart 19-18

19.6 Process Capability 19-15

Customer Satisfaction and Specification Limits 19-21

Capability Indices 19-23

CPL, CPU, and C_{pk} 19-24

19.7 Total Quality Management 19-26

19.8 Six Sigma 19-28

The DMAIC Model 19-29

Roles in a Six Sigma Organization 19-30

Lean Six Sigma 19-30

USING STATISTICS: Finding Quality at the Beachcomber, Revisited 19-31

SUMMARY 19-31

REFERENCES 19-32

KEY EQUATIONS 19-32

KEY TERMS 19-33

CHAPTER REVIEW PROBLEMS 19-34

CASES FOR CHAPTER 19 19-36

The Harnswell Sewing Machine Company Case 19-36 Managing Ashland Multicomm Services 19-38

CHAPTER 19 EXCEL GUIDE 19-39

EG19.2 Control Chart for the Proportion: Thep Chart 19-39 EG19.4 Control Chart for an Area of Opportunity: The c Chart 19-40

EG19.5 Control Charts for the Range and the Mean 19-41

EG19.6 Process Capability 19-42

CHAPTER 19 JMP GUIDE 19-43

JG19.2 Control Chart for the Proportion: The p Chart 19-43

JG19.4 Control Chart for an Area of Opportunity: The c Chart 19-44

JG19.5 Control Charts for the Range and the Mean 19-45

JG19.6 Process Capability 19-46

CHAPTER 19 MINITAB GUIDE 19-47

MG19.2 Control Chart for the Proportion: The p Chart 19-48

MG19.4 Control Chart for an Area of Opportunity:

The c Chart 19-49

MG19.5 Control Charts for the Range and the Mean 19-50

MG19.6 Process Capability 19-51

20 Decision Making (online) 20-1

USING STATISTICS: Reliable Decision Making 20-1

20.1 Payoff Tables and Decision Trees 20-2

20.2 Criteria for Decision Making 20-2

Maximax Payoff 20-6

Maximin Payoff 20-7

Expected Monetary Value 20-7

Expected Opportunity Loss 20-9

Return-to-Risk Ratio 20-11

20.3 Decision Making with Sample Information 20-16

20.4 Utility 20-21

CONSIDER THIS: Risky Business 20-22

USING STATISTICS: Reliable Decision-Making,

Revisited 20-22

SUMMARY 20-23

REFERENCES 20-23

KEY EQUATIONS 20-23

KEY TERMS 20-23

CHAPTER REVIEW PROBLEMS 20-23

CASES FOR CHAPTER 20 20-26

Digital Case 20-26

CHAPTER 20 **EXCEL GUIDE** 20-27

EG20.1 Payoff Tables and Decision Trees 20-27

EG20.2 Criteria for Decision Making 20-27

Appendices 743

- A. Basic Math Concepts and Symbols 744
 - A.1 Operators 744
 - A.2 Rules for Arithmetic Operations 744
 - A.3 Rules for Algebra: Exponents and Square Roots 744
 - A.4 Rules for Logarithms 745
 - A.5 Summation Notation 746
 - A.6 Greek Alphabet 749
- B. Important Software Skills and Concepts 750
 - B.1 Identifying the Software Version 750
 - B.2 Formulas 750
 - B.3 Excel Cell References 752
 - B.4 Excel Worksheet Formatting 753
 - B.5E Excel Chart Formatting 754
 - B.5J JMP Chart Formatting 755
 - B.5M Minitab Chart Formatting 756

- B.6 Creating Histograms for Discrete Probability
 Distributions (Excel) 756
- B.7 Deleting the "Extra" Histogram Bar (Excel) 757
- C. Online Resources 758
 - C.1 About the Online Resources for This Book 758
 - C.2 Data Files 758
 - C.3 Files Integrated With Microsoft Excel 765
 - C.4 Supplemental Files 765
- D. Configuring Software 766
 - D.1 Microsoft Excel Configuration 766
 - D.2 JMP Configuration 768
 - D.3 Minitab Configuration 768
- E. Table 769
 - E.1 Table of Random Numbers 769
 - E.2 The Cumulative Standardized Normal Distribution 771
 - E.3 Critical Values of t 773
 - E.4 Critical Values of x2 775
 - E.5 Critical Values of F 776
 - E.6 Lower and Upper Critical Values, Tj, of the Wilcoxon Rank Sum Test 780
 - E.7 Critical Values of the Studentized Range, Q 781
 - E.8 Critical Values, d_L and d_u , of the Durbin-Watson Statistic, D (Critical Values Are One-Sided) 783
 - E.9 Control Chart Factors 784
 - E.10 The Standardized Normal Distribution 785
- F. Useful Knowledge 786
 - F.1 Keyboard Shortcuts 786
 - F.2 Understanding the Nonstatistical Functions 786
- G. Software FAQs 788
 - G.1 Microsoft Excel FAQs 788
 - G.2 PHStat FAQs 788
 - G.3 JMP FAQs 789
 - G.4 Minitab FAQs 789
- H. All About PHStat 790
 - H.1 What is PHStat? 790
 - H.2 Obtaining and Setting Up PHStat 791
 - H.3 Using PHStat 791
 - H.4 PHStat Procedures, by Category 792

Self-Test Solutions and Answers to Selected Even-Numbered Problems 793

Index 825

Credits 837