

# Contents

Preface

13

## 1

### Statistics, Data, and Statistical Thinking

19

1.1	The Science of Statistics	22
1.2	Types of Statistical Applications in Business	22
1.3	Fundamental Elements of Statistics	25
1.4	Processes (Optional)	29
1.5	Types of Data	32
1.6	Collecting Data: Sampling and Related Issues	33
1.7	Business Analytics: Critical Thinking with Statistics	40
	<b>STATISTICS IN ACTION:</b> A 20/20 View of Surveys and Studies: Facts or Fake News?	19
	<b>ACTIVITY 1.1:</b> <i>Keep the Change:</i> Collecting Data	49
	<b>ACTIVITY 1.2:</b> Identifying Misleading Statistics	49
	<b>USING TECHNOLOGY:</b> Accessing and Listing Data	50

## 2

### Methods for Describing Sets of Data

57

2.1	Describing Qualitative Data	59
2.2	Graphical Methods for Describing Quantitative Data	69
2.3	Numerical Measures of Central Tendency	81
2.4	Numerical Measures of Variability	92
2.5	Using the Mean and Standard Deviation to Describe Data	98
2.6	Numerical Measures of Relative Standing	106
2.7	Methods for Detecting Outliers: Box Plots and z-Scores	111
2.8	Graphing Bivariate Relationships (Optional)	121
2.9	The Time Series Plot (Optional)	126
2.10	Distorting the Truth with Descriptive Techniques	128
	<b>STATISTICS IN ACTION:</b> Can Money Buy Love?	57
	<b>ACTIVITY 2.1:</b> Real Estate Sales	141
	<b>ACTIVITY 2.2:</b> <i>Keep the Change:</i> Measures of Central Tendency and Variability	142
	<b>USING TECHNOLOGY:</b> Describing Data	142
	<b>MAKING BUSINESS DECISIONS:</b> The Kentucky Milk Case—Part I (Covers Chapters 1 and 2)	148

## 3

### Probability

150

3.1	Events, Sample Spaces, and Probability	152
3.2	Unions and Intersections	166
3.3	Complementary Events	169
3.4	The Additive Rule and Mutually Exclusive Events	171
3.5	Conditional Probability	178

3.6	The Multiplicative Rule and Independent Events	181
3.7	Bayes's Rule	191
	<b>STATISTICS IN ACTION:</b> Lotto Buster!	150
	<b>ACTIVITY 3.1:</b> <i>Exit Polls:</i> Conditional Probability	204
	<b>ACTIVITY 3.2:</b> <i>Keep the Change:</i> Independent Events	204
	<b>USING TECHNOLOGY:</b> Combinations and Permutations	205

## 4

## Random Variables and Probability Distributions 208

4.1	Two Types of Random Variables	209
	<b>PART I: DISCRETE RANDOM VARIABLES</b>	212
4.2	Probability Distributions for Discrete Random Variables	212
4.3	The Binomial Distribution	223
4.4	Other Discrete Distributions: Poisson and Hypergeometric	236
	<b>PART II: CONTINUOUS RANDOM VARIABLES</b>	243
4.5	Probability Distributions for Continuous Random Variables	243
4.6	The Normal Distribution	244
4.7	Descriptive Methods for Assessing Normality	261
4.8	Other Continuous Distributions: Uniform and Exponential	266
	<b>STATISTICS IN ACTION:</b> Probability in a Reverse Cocaine Sting: Was Cocaine Really Sold?	208
	<b>ACTIVITY 4.1:</b> <i>Warehouse Club Memberships:</i> Exploring a Binomial Random Variable	282
	<b>ACTIVITY 4.2:</b> Identifying the Type of Probability Distribution	283
	<b>USING TECHNOLOGY:</b> Discrete Probabilities, Continuous Probabilities, and Normal Probability Plots	284

## 5

## Sampling Distributions 291

5.1	The Concept of a Sampling Distribution	293
5.2	Properties of Sampling Distributions: Unbiasedness and Minimum Variance	299
5.3	The Sampling Distribution of the Sample Mean and the Central Limit Theorem	303
5.4	The Sampling Distribution of the Sample Proportion	312
	<b>STATISTICS IN ACTION:</b> The Insomnia Pill: Is It Effective?	291
	<b>ACTIVITY 5.1:</b> Simulating a Sampling Distribution—Cell Phone Usage	322
	<b>USING TECHNOLOGY:</b> Simulating a Sampling Distribution	323
	<b>MAKING BUSINESS DECISIONS:</b> The Furniture Fire Case (Covers Chapters 3–5)	326

## 6

## Inferences Based on a Single Sample: Estimation with Confidence Intervals 328

6.1	Identifying and Estimating the Target Parameter	330
6.2	Confidence Interval for a Population Mean: Normal ( $z$ ) Statistic	331
6.3	Confidence Interval for a Population Mean: Student's $t$ -Statistic	339
6.4	Large-Sample Confidence Interval for a Population Proportion	349
6.5	Determining the Sample Size	356

6.6	Finite Population Correction for Simple Random Sampling (Optional)	363
6.7	Confidence Interval for a Population Variance (Optional)	366
	<b>STATISTICS IN ACTION:</b> Medicare Fraud Investigations	328
	<b>ACTIVITY 6.1:</b> Conducting a Pilot Study	378
	<b>USING TECHNOLOGY:</b> Confidence Intervals and Sample Size Determination	379

## 7

## Inferences Based on a Single Sample: Tests of Hypotheses 387

7.1	The Elements of a Test of Hypothesis	388
7.2	Formulating Hypotheses and Setting Up the Rejection Region	393
7.3	Observed Significance Levels: $p$ -Values	399
7.4	Test of Hypothesis About a Population Mean: Normal ( $z$ ) Statistic	403
7.5	Test of Hypothesis About a Population Mean: Student's $t$ -Statistic	412
7.6	Large-Sample Test of Hypothesis About a Population Proportion	419
7.7	Test of Hypothesis About a Population Variance	427
7.8	Calculating Type II Error Probabilities: More About $\beta$ (Optional)	432
	<b>STATISTICS IN ACTION:</b> Diary of a Kleenex <sup>®</sup> User—How Many Tissues in a Box?	387
	<b>ACTIVITY 7.1:</b> <i>Challenging a Company's Claim:</i> Tests of Hypotheses	446
	<b>ACTIVITY 7.2:</b> <i>Keep the Change:</i> Tests of Hypotheses	446
	<b>USING TECHNOLOGY:</b> Tests of Hypotheses	447

## 8

## Inferences Based on Two Samples: Confidence Intervals and Tests of Hypotheses 454

8.1	Identifying the Target Parameter	455
8.2	Comparing Two Population Means: Independent Sampling	456
8.3	Comparing Two Population Means: Paired Difference Experiments	472
8.4	Comparing Two Population Proportions: Independent Sampling	483
8.5	Determining the Required Sample Size	491
8.6	Comparing Two Population Variances: Independent Sampling	496
	<b>STATISTICS IN ACTION:</b> <i>ZixIt Corp. v. Visa USA Inc.—A Libel Case</i>	454
	<b>ACTIVITY 8.1:</b> <i>Box Office Receipts:</i> Comparing Population Means	514
	<b>ACTIVITY 8.2:</b> <i>Keep the Change:</i> Inferences Based on Two Samples	514
	<b>USING TECHNOLOGY:</b> Two-Sample Inferences	515
	<b>MAKING BUSINESS DECISIONS:</b> The Kentucky Milk Case—Part II (Covers Chapters 6–8)	525

## 9

## Design of Experiments and Analysis of Variance 526

9.1	Elements of a Designed Experiment	528
9.2	The Completely Randomized Design: Single Factor	534
9.3	Multiple Comparisons of Means	551
9.4	The Randomized Block Design	558
9.5	Factorial Experiments: Two Factors	572

<b>STATISTICS IN ACTION:</b> Tax Compliance Behavior—Factors That Affect Your Level of Risk Taking When Filing Your Federal Tax Return	526
<b>ACTIVITY 9.1:</b> Designed vs. Observational Experiments	598
<b>USING TECHNOLOGY:</b> Analysis of Variance	599

**10****Categorical Data Analysis 603**

<b>10.1</b> Categorical Data and the Multinomial Experiment	604
<b>10.2</b> Testing Category Probabilities: One-Way Table	606
<b>10.3</b> Testing Category Probabilities: Two-Way (Contingency) Table	613
<b>10.4</b> A Word of Caution About Chi-Square Tests	629
<b>STATISTICS IN ACTION:</b> The Illegal Transplant Tissue Trade—Who Is Responsible for Paying Damages?	603
<b>ACTIVITY 10.1:</b> Binomial vs. Multinomial Experiments	635
<b>ACTIVITY 10.2:</b> Contingency Tables	636
<b>USING TECHNOLOGY:</b> Chi-Square Analyses	636
<b>MAKING BUSINESS DECISIONS:</b> Discrimination in the Workplace (Covers Chapters 9–10)	641

**11****Simple Linear Regression 644**

<b>11.1</b> Probabilistic Models	646
<b>11.2</b> Fitting the Model: The Least Squares Approach	650
<b>11.3</b> Model Assumptions	662
<b>11.4</b> Assessing the Utility of the Model: Making Inferences About the Slope $\beta_1$	667
<b>11.5</b> The Coefficients of Correlation and Determination	675
<b>11.6</b> Using the Model for Estimation and Prediction	684
<b>11.7</b> A Complete Example	693
<b>STATISTICS IN ACTION:</b> Legal Advertising—Does It Pay?	644
<b>ACTIVITY 11.1:</b> Applying Simple Linear Regression to Your Favorite Data	707
<b>USING TECHNOLOGY:</b> Simple Linear Regression	707

**12****Multiple Regression and Model Building 711**

<b>12.1</b> Multiple Regression Models	712
<b>PART I: FIRST-ORDER MODELS WITH QUANTITATIVE INDEPENDENT VARIABLES</b>	714
<b>12.2</b> Estimating and Making Inferences About the $\beta$ Parameters	714
<b>12.3</b> Evaluating Overall Model Utility	720
<b>12.4</b> Using the Model for Estimation and Prediction	731
<b>PART II: MODEL BUILDING IN MULTIPLE REGRESSION</b>	737
<b>12.5</b> Interaction Models	737
<b>12.6</b> Quadratic and Other Higher-Order Models	744
<b>12.7</b> Qualitative (Dummy) Variable Models	754
<b>12.8</b> Models with Both Quantitative and Qualitative Variables	762

12.9	Comparing Nested Models	771
12.10	Stepwise Regression	778
<b>PART III: MULTIPLE REGRESSION DIAGNOSTICS</b>		787
12.11	Residual Analysis: Checking the Regression Assumptions	787
12.12	Some Pitfalls: Estimability, Multicollinearity, and Extrapolation	800
<b>STATISTICS IN ACTION:</b> Bid Rigging in the Highway Construction Industry		711
<b>ACTIVITY 12.1:</b> <i>Insurance Premiums:</i> Collecting Data for Several Variables		821
<b>ACTIVITY 12.2:</b> Collecting Data and Fitting a Multiple Regression Model		822
<b>USING TECHNOLOGY:</b> Multiple Regression		822
<b>MAKING BUSINESS DECISIONS:</b> The Condo Sales Case (Covers Chapters 11–12)		828

## 13

## Methods for Quality Improvement: Statistical Process Control (Available Online) 13-1

13.1	Quality, Processes, and Systems	13-3
13.2	Statistical Control	13-6
13.3	The Logic of Control Charts	13-13
13.4	A Control Chart for Monitoring the Mean of a Process: The $\bar{x}$ -Chart	13-17
13.5	A Control Chart for Monitoring the Variation of a Process: The $R$ -Chart	13-33
13.6	A Control Chart for Monitoring the Proportion of Defectives Generated by a Process: The $p$ -Chart	13-43
13.7	Diagnosing the Causes of Variation	13-52
13.8	Capability Analysis	13-55
<b>STATISTICS IN ACTION:</b> Testing Jet Fuel Additive for Safety		13-1
<b>ACTIVITY 13.1:</b> <i>Quality Control:</i> Consistency		13-66
<b>USING TECHNOLOGY:</b> Control Charts		13-67
<b>MAKING BUSINESS DECISIONS:</b> The Gasket Manufacturing Case (Covers Chapter 13)		13-70

## 14

## Time Series: Descriptive Analyses, Models, and Forecasting (Available Online) 14-1

14.1	Descriptive Analysis: Index Numbers	14-2
14.2	Descriptive Analysis: Exponential Smoothing	14-12
14.3	Time Series Components	14-16
14.4	Forecasting: Exponential Smoothing	14-17
14.5	Forecasting Trends: Holt's Method	14-20
14.6	Measuring Forecast Accuracy: MAD and RMSE	14-25
14.7	Forecasting Trends: Simple Linear Regression	14-29
14.8	Seasonal Regression Models	14-32
14.9	Autocorrelation and the Durbin-Watson Test	14-39
<b>STATISTICS IN ACTION:</b> Forecasting the Monthly Sales of a New Cold Medicine		14-1
<b>ACTIVITY 14.1:</b> Time Series		14-49
<b>USING TECHNOLOGY:</b> Forecasting		14-50

## 15

## Nonparametric Statistics (Available Online)

15-1

15.1	Introduction: Distribution-Free Tests	15-2
15.2	Single Population Inferences	15-3
15.3	Comparing Two Populations: Independent Samples	15-8
15.4	Comparing Two Populations: Paired Difference Experiment	15-19
15.5	Comparing Three or More Populations: Completely Randomized Design	15-27
15.6	Comparing Three or More Populations: Randomized Block Design	15-34
15.7	Rank Correlation	15-40

**STATISTICS IN ACTION:** Pollutants at a Housing Development—A Case of Mishandling Small Samples 15-1

**ACTIVITY 15.1:** *Keep the Change:* Nonparametric Statistics 15-54

**USING TECHNOLOGY:** Nonparametric Tests 15-55

**MAKING BUSINESS DECISIONS:** Detecting “Sales Chasing” (Covers Chapters 10 and 15) 15-62

**Appendix A:** Summation Notation 830

**Appendix B:** Basic Counting Rules 832

**Appendix C:** Calculation Formulas for Analysis of Variance 835

**C.1** Formulas for the Calculations in the Completely Randomized Design 835

**C.2** Formulas for the Calculations in the Randomized Block Design 836

**C.3** Formulas for the Calculations for a Two-Factor Factorial Experiment 837

**C.4** Tukey’s Multiple Comparisons Procedure (Equal Sample Sizes) 838

**C.5** Bonferroni Multiple Comparisons Procedure (Pairwise Comparisons) 839

**C.6** Scheffé’s Multiple Comparisons Procedure (Pairwise Comparisons) 839

**Appendix D:** Tables 840

Table I Binomial Probabilities 841

Table II Normal Curve Areas 844

Table III Critical Values of  $t$  845

Table IV Critical Values of  $\chi^2$  846

Table V Percentage Points of the  $F$ -Distribution,  $\alpha = .10$  848

Table VI Percentage Points of the  $F$ -Distribution,  $\alpha = .05$  850

Table VII Percentage Points of the  $F$ -Distribution,  $\alpha = .025$  852

Table VIII Percentage Points of the  $F$ -Distribution,  $\alpha = .01$  854

Table IX Control Chart Constants 856

Table X Critical Values for the Durbin-Watson  $d$ -Statistic,  $\alpha = .05$  857

Table XI Critical Values for the Durbin-Watson  $d$ -Statistic,  $\alpha = .01$  858

Table XII Critical Values of  $T_L$  and  $T_U$  for the Wilcoxon Rank Sum Test: Independent Samples 859

Table XIII Critical Values of  $T_0$  in the Wilcoxon Paired Difference Signed Rank Test 860

Table XIV Critical Values of Spearman’s Rank Correlation Coefficient 861

Table XV Critical Values of the Studentized Range,  $\alpha = .05$  862

**Answers to Selected Exercises 863**

**Index 875**

**Credits 885**