

Statistics for Business and Economics

The background of the cover is an abstract composition. It features large, irregular shapes in a warm orange-brown color, some of which have a rough, torn-paper texture. These are set against a solid black background. On the right side, there are vertical bands of a dark, ribbed material, possibly representing a book binding or a textured surface. A prominent, diagonal band of a gold-colored, corrugated material runs across the lower half of the cover.

FIFTH EDITION

JAMES T. McCLAVE
P. GEORGE BENSON

FIFTH EDITION

Statistics for Business and Economics

JAMES T. MCCLAVE

College of Business Administration
University of Florida

P. GEORGE BENSON

Curtis L. Carlson School of Management
University of Minnesota

DELLEN PUBLISHING COMPANY

San Francisco

a division of

MACMILLAN PUBLISHING
COMPANY

New York

COLLIER MACMILLAN CANADA

Toronto

MAXWELL MACMILLAN INTERNATIONAL

New York Oxford Singapore Sydney

On the cover: The detail on the cover is from a three-paneled screen created by San Francisco artist Michael Carr. The three-dimensional, mixed-media screen measures 9 feet in length and 8 feet high. Mr. Carr is an associate of Robert Hutchinson Designs in San Francisco.

Copyright 1991 by Dellen Publishing Company.

Printed in the United States of America

All rights reserved. No part of this book may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the Publisher.

Permissions: Dellen Publishing Company
400 Pacific Avenue
San Francisco, California 94133

Orders: Dellen Publishing Company
c/o Macmillan Publishing Company
Front and Brown Streets
Riverside, New Jersey 08075

Macmillan Publishing Company
866 Third Avenue, New York, New York 10022

Collier Macmillan Canada, Inc.
1200 Eglinton Avenue East
Suite 200
Don Mills, Ontario M3C 3N1

Library of Congress Cataloging in Publication Data

McClave, James T.

Statistics for business and economics / James T. McClave,

P. George Benson.—5th ed.

Includes bibliographical references and index.

ISBN 0-02-379182-9

1. Commercial statistics. 2. Economics—Statistical methods.

3. Statistics. I. Benson, P. George, 1946— II. Title.

HF1017.M36 1991

519.5—dc20

91-2078

CIP

Printing: 2 3 4 5 6 7 8 9 Year: 2 3 4 5

ISBN 0-02-379182-9

Preface

The fifth edition of *Statistics for Business and Economics* finds the authors continuing to try to walk the fine line between classical statistical inference and the “new wave” of business statistics. We note with interest the new texts that have adopted a “contemporary” approach, focused primarily on data analysis and emphasizing pre-inferential methods. Of course, something must be sacrificed in order to adopt this approach, which typically results in the delay of, and sometimes even the elimination of, the traditional inferential techniques. We continue to think it important to present inferential techniques and, in fact, to make them the theme of the text. However, we also recognize that the methods and focus of the applications of statistics in business are changing ever more rapidly. In particular, the worldwide quality movement is convincing profit and nonprofit organizations alike of the importance of applying statistical reasoning in all aspects of their operations. Thus, our objective is to achieve the appropriate blend of the contemporary and classical approaches. With that objective in mind, the following are the new features of the fifth edition:

1. The most important change in the fifth edition is the addition of a new chapter on Methods for Quality Improvement (Chapter 14). In previous editions we treated the statistical aspects of quality in various case studies, examples, and exercises throughout the text. Because the issue of quality transcends statistical methods, we resisted devoting a chapter to the topic until we could develop a treatment of quality that covers more than just statistical control charts. With this edition we introduce a chapter on quality improvement, beginning with the history of the quality movement in the United States, introducing and explaining the concepts of “systems thinking” and “process management,” and finally presenting the ultimate consequence of these concepts—the statistical control of systems. This chapter is longer and more encompassing than the typical treatment of statistical quality control; we believe that this more complete treatment of quality is essential to a comprehensive understanding of the quality movement that is sweeping the business world.
2. Our treatment of quality really begins in Chapter 1. We have added the concept of a dynamic process to the traditional static population, so that the instructor who wishes to focus on process improvement early in the course and/or inferences about both populations and processes can now do so. We also introduce the concept of “variables” in Chapter 1. We do this by redefining the population to consist of “units” rather than “data,” and then defining a variable to be the characteristic of these units. Data are then obtained by measuring the variable of interest. This will focus more attention on measurement and will make an easier transition to the concept of random variables and their probability distributions.
3. In the same vein, we have added more on the concept of measuring different types of variables in Chapter 2, introducing and defining the four types of

- data: nominal, ordinal, interval, and ratio. Also, Pareto analysis is introduced and a new section on time series plots has been added to Chapter 2.
4. The introduction to the classical inferential techniques of estimation and tests of hypotheses had made for a very long Chapter 8 in the fourth edition, especially with the (optional) material on Type II errors. In the fifth edition we have separated single-sample inference into two chapters: one on estimation (Chapter 8) and the second on tests of hypotheses (Chapter 9).
 5. Also on the topic of inferential techniques, a new section on the use of the sign test for single-sample inferences has been added to the Nonparametric Statistics chapter (Chapter 18).
 6. New exercises have been added throughout, this time concentrating on new and better mechanical exercises in the Learning the Mechanics sections at the beginning of most exercise sets. Some new applied exercises have been added as well, especially accompanying the new material. We continue to introduce business terminology in the prologues of a portion of our Applying the Concepts exercises.
 7. We have also been made aware by our users that the text was getting too bulky. This is a problem that “grows” with each new edition, when new material is added but old material is rarely removed. We have tried to deal with the problem in the fifth edition in two ways. First, the new design of the text enables more material to be presented on each page. Second, and more painfully, some material has been removed, including optional sections on the hypergeometric and geometric distributions. Also, the two decision analysis chapters, old Chapters 18 and 19, have been combined into a single chapter (new Chapter 20). Alas, we still have added more than we have subtracted, and the text remains somewhat bulky.
 8. We have placed all of the large exercise data sets on a computer disk. The Appendix of the text contains an index that describes these data sets, indicates the exercise number, the page number, and the file names of the data sets. Instructors who adopt the text may obtain the disk by writing to Dellen Publishing Company, 400 Pacific Avenue, San Francisco, California 94133, or by calling 415-433-9900.

We have been told by our users that our treatment of regression analysis is a “signature” of our text. We hope that our new chapter on Quality Improvement will be added to the list of topics that distinguishes our text.

Instructors who would like to emphasize processes and process improvement might cover all of Chapter 1, followed immediately by the first four sections of Chapter 14, Methods for Quality Improvement. Then later, after covering the relevant sections of Chapters 7, 8, and 9, return to Chapter 14 and cover the last four sections on statistical process control. An even fuller treatment of processes would include time series and forecasting in Chapters 15 and 16. Chapters 14, 15, and 16 are devoted entirely to the study of processes and their output.

The flexibility of past editions is maintained in this edition. Sections that are not prerequisite to succeeding sections and chapters are marked “(Optional).” For example, an instructor who wishes to devote significant time to exploratory data analysis might cover all topics in Chapters 2 and 3. In contrast, an instructor who wishes to move rapidly into inferential procedures might omit optional sections, devoting only several lectures to these chapters.

We have maintained the features of this text that we believe make it unique among introductory statistics texts for business courses. These features, which assist the student in achieving an overview of statistics and an understanding of its relevance in the solution of business problems, are as follows:

1. **Case Studies.** (See the list of case studies on page xviii.) Many important concepts are emphasized by the inclusion of case studies, which consist of brief summaries of actual business applications of the concepts and are often drawn directly from the business literature. These case studies allow the student to see business applications of important statistical concepts immediately after the introduction of the concepts. The case studies also help to answer by example the often asked questions, “Why should I study statistics? Of what relevance is statistics to business?” Finally, the case studies constantly remind the student that each concept is related to the dominant theme—statistical inference.
2. **Where We’ve Been . . . Where We’re Going . . .** The first page of each chapter is a “unification” page. Our purpose is to allow the student to see how the chapter fits into the scheme of statistical inference. First, we briefly show how the material presented in previous chapters helps us to achieve our goal (Where We’ve Been). Then, we indicate what the next chapter (or chapters) contributes to the overall objective (Where We’re Going). This feature allows us to point out that we are constructing the foundation block by block, with each chapter an important component in the structure of statistical inference. Furthermore, this feature provides a series of brief résumés of the material covered as well as glimpses of future topics.
3. **Many Examples and Exercises.** We believe that most students learn by doing. The text contains many worked examples to demonstrate how to solve various types of problems. We then provide the student with a large number (more than 1,300) of exercises. The answers for odd-numbered exercises are included at the end of the text. The exercises are of two types:
 - a. **Learning the Mechanics.** These exercises are intended to be straightforward applications of the new concepts. They are introduced in a few words and are unhampered by a barrage of background information designed to make them “practical,” but which often detracts from instructional objectives. Thus, with a minimum of labor, the student can recheck his or her ability to comprehend a concept or a definition.
 - b. **Applying the Concepts.** The mechanical exercises described above are followed by realistic exercises that allow the student to see applications of statistics to the solution of problems encountered in business and economics. Once the mechanics are mastered, these exercises develop the student’s skills at comprehending realistic problems that describe situations to which the techniques may be applied.
4. **On Your Own . . .** The chapters end with an exercise entitled “On Your Own . . .” The intent of this exercise is to give the student some hands-on experience with a business application of the statistical concepts introduced in the chapter. In most cases, the student is required to collect, analyze, and interpret data relating to some business phenomenon.
5. **Using the Computer.** A new feature has been added at the end of most chapters to encourage the use of computers in the analysis of real data. A

demographic data base, consisting of 1,000 observations on 15 variables, has been described in Appendix C and is available on diskette from the publisher. Each "Using the Computer" section provides one or more computer exercises that utilize the data in Appendix C and enhance the new material covered in the chapter.

6. **A Simple, Clear Style.** We have tried to achieve a simple and clear writing style. Subjects that are tangential to our objective have been avoided, even though some may be of academic interest to those well versed in statistics. We have not taken an encyclopedic approach in the presentation of material.
7. **An Extensive Coverage of Multiple Regression Analysis and Model Building.** This topic represents one of the most useful statistical tools for the solution of business problems. Although an entire text could be devoted to regression modeling, we feel that we have presented a coverage that is understandable, usable, and much more comprehensive than the presentations in other introductory business statistics texts. We devote three chapters to discussing the major types of inferences that can be derived from a regression analysis, showing how these results appear in computer printouts and, most important, selecting multiple regression models to be used in an analysis. Thus, the instructor has the choice of a one-chapter coverage of simple regression, a two-chapter treatment of simple and multiple regression, or a complete three-chapter coverage of simple regression, multiple regression, and model building. This extensive coverage of such useful statistical tools will provide added evidence to the student of the relevance of statistics to the solution of business problems.
8. **Footnotes and Appendix A.** Although the text is designed for students with a noncalculus background, footnotes explain the role of calculus in various derivations. Footnotes are also used to inform the student about some of the theory underlying certain results. Appendix A presents some useful counting rules for the instructor who wishes to place greater emphasis on probability. Consequently, we think the footnotes and Appendix A provide an opportunity for flexibility in the mathematical and theoretical level at which the material is presented.
9. **Supplementary Material.** A solutions manual, a study guide, a Minitab supplement, an integrated companion software system, a computer-generated test system, and a 1,000-observation demographic data base are available.
 - a. **Solutions Manual** (by Nancy Shafer Boudreau). The solutions manual presents detailed solutions to most odd-numbered exercises in the text. Many points are clarified and expanded to provide maximum insight into and benefits from each exercise.
 - b. **Study Guide** (by Susan L. Reiland). For each chapter, the study guide includes (1) a brief summary that highlights the concepts and terms introduced in the textbook; (2) section-by-section examples with detailed solutions; and (3) exercises (with answers provided at the end of the study guide) that allow the student to check mastery of the material in each section.
 - c. **Minitab Supplement** (by Ruth K. Meyer and David D. Krueger). The Minitab computer supplement was developed to be used with Minitab Release 7.0, a general-purpose statistical computing system. The supplement, which was written especially for the student with no previous experience with computers, provides step-by-step descriptions of how to use

Minitab effectively as an aid in data analysis. Each chapter begins with a list of new commands introduced in the chapter. Brief examples are then given to explain new commands, followed by examples from the text illustrating the new and previously learned commands. Where appropriate, simulation examples are included. Exercises, many of which are drawn from the text, conclude each chapter.

A special feature of the supplement is a chapter describing a survey sampling project. The objectives of the project are to illustrate the evaluation of a questionnaire, provide a review of statistical techniques, and illustrate the use of Minitab for questionnaire evaluation.

- d. **DellenStat** (By Michael Conlon). DellenStat is an integrated statistics package consisting of a workbook and an IBM PC floppy diskette with software and example sets of data. The system contains a file creation and management facility, a statistics facility, and a presentation facility. The software is menu-driven and has an extensive help facility. It is completely compatible with the text.

The DellenStat workbook describes the operation of the software and uses examples from the text. After an introductory chapter for new computer users, the remaining chapters follow the outline of the text. Additional chapters show how to create new sets of data. Technical appendices cover material for advanced users and programmers.

DellenStat runs on any IBM PC or close compatible with at least 256K of memory and at least one floppy disk drive.

- e. **DellenTest**. This unique computer-generated random test system is available to instructors without cost. Utilizing an IBM PC computer and a number of commonly used dot-matrix printers, the system will generate an almost unlimited number of quizzes, chapter tests, final examinations, and drill exercises. At the same time, the system produces an answer key and student worksheet with an answer column that exactly matches the column on the answer key.
- f. **Data Base**. A demographic data set was assembled based on a systematic random sample of 1,000 U.S. zip codes. Demographic data for each zip code area selected were supplied by CACI, an international demographic and market information firm. Fifteen demographic measurements (including population, number of households, median age, median household income, variables related to the cost of housing, educational levels, the work force, and purchasing potential indexes based on the Bureau of the Census Consumer Expenditure Surveys) are presented for each zip code area.

Some of the data are referenced in the "Using the Computer" sections. The objectives are to enable the student to analyze real data in a relatively large sample using the computer, and to gain experience using the statistical techniques and concepts on real data.

Acknowledgments

We owe thanks to the many people who assisted in reviewing and preparing this textbook. Their names are listed below. We particularly acknowledge the editorial assistance of Susan L. Reiland, the administrative support of Jane Oas Benson, and the typing and assistance of Brenda Dobson and Karen Lundquist. Without

these four, we never could have completed this work. We are also indebted to Professor Richard W. Andrews of the University of Michigan and his teaching assistants for using and critiquing a preliminary version of our new chapter on Methods for Quality Improvement (Chapter 14). Their comments and suggestions resulted in numerous improvements to the chapter.

Gordon J. Alexander	Ronald L. Coccari
University of Minnesota	Cleveland State University
Larry M. Austin	Ken Constantine
Texas Tech University	University of New Hampshire
Donald W. Bartlett	Jim Daly
University of Minnesota	California State Polytechnic Institute
Clarence Bayne	Dileep Dhavale
Concordia University	University of Northern Iowa
Carl Bedell	Mark Eakin
Philadelphia College of Textiles and Science	University of Texas at Arlington
David M. Bergman	Carol Eger
University of Minnesota	Stanford University
William H. Beyer	Robert Elrod
University of Akron	Georgia State University
Atul Bhatia	Douglas A. Elvers
University of Minnesota	University of North Carolina at Chapel Hill
Jim Branscome	Susan Flach
University of Texas at Arlington	General Mills, Inc.
Francis J. Brewerton	Alan E. Gelfand
Middle Tennessee State University	University of Connecticut
Daniel Brick	Joseph Glaz
Kean College	University of Connecticut at Storrs
Robert W. Brobst	Paul W. Guy
University of Texas at Arlington	California State University, Chico
Michael S. Broida	Michael E. Hanna
Miami University of Ohio	University of Texas at Arlington
Glenn J. Browne	Don Holbert
University of Minnesota	Oklahoma State University
Edward Carlstein	James Holstein
University of North Carolina at Chapel Hill	University of Missouri
John M. Charnes	Warren M. Holt
University of Miami	Southeastern Massachusetts University
Chih-Hsu Cheng	Steve Hora
University of Minnesota	University of Hawaii, Hilo
Larry Claypool	Iris B. Ibrahim
Oklahoma State University	Clemson University
Edward R. Clayton	Marius Janson
Virginia Polytechnic Institute and State University	University of Missouri

- Ross H. Johnson
Madison College
- Timothy J. Killeen
University of Connecticut
- David D. Krueger
St. Cloud State University
- Richard W. Kulp
Wright-Patterson AFB, Air Force
Institute of Technology
- Martin Labbe
State University of New York College
at New Paltz
- James Lackritz
California State University at
San Diego
- Philip Levine
William Patterson College
- Eddie M. Lewis
University of Southern Mississippi
- Fred Leysieffer
Florida State University
- Pi-Erh Lin
Florida State University
- Robert Ling
Clemson University
- G. E. Martin
Clarkson University
- * Brenda Masters
Oklahoma State University
- Ruth K. Meyer
St. Cloud State University
- Paul I. Nelson
Kansas State University
- Paula M. Oas
General Office Products
- William M. Partian
Fordham College
- Vijay Pisharody
University of Minnesota
- P. V. Rao
University of Florida
- Don Robinson
Illinois State University
- Jan Saraph
St. Cloud State University
- Craig W. Slinkman
University of Texas at Arlington
- Robert K. Smidt
California Polytechnic State
University
- Donald N. Steinnes
University of Minnesota at Duluth
- Virgin F. Stone
Texas A and I University
- Katheryn Szabet
La Salle University
- Alireza Tahai
Mississippi State University
- Chipei Tseng
Northern Illinois University
- Pankaj Vaish
Arthur Andersen & Company
- Robert W. Van Cleave
University of Minnesota
- Charles F. Warnock
Colorado State University
- William J. Weida
United States Air Force Academy
- T. J. Wharton
University of New Hampshire
- Kathleen M. Whitcomb
University of South Carolina
- Edna White
Florida Atlantic University
- Steve Wickstrom
University of Minnesota
- James Willis
Louisiana State University
- Douglas A. Wolfe
Ohio State University
- Dilek Yeldan
Bilkent University, Turkey
- Fike Zahroon
Moorhead State University

Contents

CHAPTER 1	What Is Statistics?	1
	1.1 Statistics: What Is It?	2
	1.2 The Elements of Statistics	5
	1.3 Statistics: Witchcraft or Science?	9
	1.4 Processes (Optional)	10
	1.5 The Role of Statistics in Managerial Decision-Making	14
CHAPTER 2	Graphical Descriptions of Data	21
	2.1 Types of Data	22
	2.2 Graphical Methods for Describing Qualitative Data: The Bar Chart (Optional)	27
	2.3 Graphical Methods for Describing Qualitative Data: The Pie Chart (Optional)	34
	2.4 Graphical Methods for Describing Quantitative Data: Stem and Leaf Displays	40
	2.5 Graphical Methods for Describing Quantitative Data: Histograms	47
	2.6 Graphical Methods for Describing Quantitative Data: Cumulative Relative Frequency Distributions (Optional)	59
	2.7 Graphical Methods for Describing Quantitative Data Produced Over Time: The Time Series Plot (Optional)	64
	2.8 Distorting the Truth with Pictures (Optional)	66
CHAPTER 3	Numerical Descriptive Measures	81
	3.1 The Mode: A Measure of Central Tendency	82
	3.2 The Arithmetic Mean: A Measure of Central Tendency	83
	3.3 The Median: Another Measure of Central Tendency	88
	3.4 The Range: A Measure of Variability	95
	3.5 Variance and Standard Deviation	98
	3.6 Calculation Formulas for Variance and Standard Deviation	101
	3.7 Interpreting the Standard Deviation	106

- 3.8 Calculating a Mean and Standard Deviation from Grouped Data (Optional) 115
- 3.9 Measures of Relative Standing 117
- 3.10 Box Plots: Graphical Descriptions Based on Quartiles (Optional) 124

CHAPTER 4 **Probability** 141

- 4.1 Events, Sample Spaces, and Probability 142
- 4.2 Compound Events 155
- 4.3 Complementary Events 158
- 4.4 Conditional Probability 164
- 4.5 Probabilities of Unions and Intersections 168
- 4.6 Random Sampling 178

CHAPTER 5 **Discrete Random Variables** 193

- 5.1 Two Types of Random Variables 194
- 5.2 Probability Distributions for Discrete Random Variables 196
- 5.3 Expected Values of Discrete Random Variables 201
- 5.4 The Binomial Random Variable 210
- 5.5 The Poisson Random Variable (Optional) 224

CHAPTER 6 **Continuous Random Variables** 237

- 6.1 Continuous Probability Distributions 238
- 6.2 The Uniform Distribution 239
- 6.3 The Normal Distribution 243
- 6.4 The Exponential Distribution (Optional) 257
- 6.5 Approximating a Binomial Distribution with a Normal Distribution 264

CHAPTER 7 **Sampling Distributions** 277

- 7.1 Introduction to Sampling Distributions 279
- 7.2 Properties of Sampling Distributions: Unbiasedness and Minimum Variance 284
- 7.3 The Sampling Distribution of the Sample Mean 287
- 7.4 The Relationship Between Sample Size and a Sampling Distribution 295

CHAPTER 8 **Inferences Based on a Single Sample: Estimation** 309

- 8.1 Large-Sample Estimation of a Population Mean 310
- 8.2 Determining the Sample Size Necessary to Estimate a Population Mean 318
- 8.3 Small-Sample Estimation of a Population Mean 322
- 8.4 Large-Sample Estimation of a Binomial Probability 329
- 8.5 Determining the Sample Size Necessary to Estimate a Binomial Probability 334

CHAPTER 9	Inferences Based on a Single Sample: Tests of Hypotheses	345
	9.1 The Elements of a Test of Hypothesis	346
	9.2 Large-Sample Test of Hypothesis About a Population Mean	352
	9.3 Observed Significance Levels: p -Values	361
	9.4 Small-Sample Test of Hypothesis About a Population Mean	365
	9.5 Large-Sample Test of Hypothesis About a Binomial Probability	371
	9.6 Calculating Type II Error Probabilities: More about β (Optional)	378
CHAPTER 10	Inferences Based on Two Samples: Estimation and Tests of Hypotheses	393
	10.1 Large-Sample Inferences About the Difference Between Two Population Means: Independent Sampling	394
	10.2 Small-Sample Inferences About the Difference Between Two Population Means: Independent Sampling	402
	10.3 Comparing Two Population Variances: Independent Random Samples	412
	10.4 Inferences About the Difference Between Two Population Means: Paired Difference Experiments	421
	10.5 Inferences About the Difference Between Population Proportions: Independent Binomial Experiments	433
	10.6 Determining the Sample Size	441
CHAPTER 11	Simple Linear Regression	455
	11.1 Probabilistic Models	456
	11.2 Fitting the Model: The Method of Least Squares	460
	11.3 Model Assumptions	469
	11.4 An Estimator of σ^2	470
	11.5 Assessing the Usefulness of the Model: Making Inferences About the Slope β_1	474
	11.6 Correlation: Another Measure of the Usefulness of the Model	481
	11.7 The Coefficient of Determination	484
	11.8 Using the Model for Estimation and Prediction	492
	11.9 Simple Linear Regression: An Example	500
	11.10 Using the Computer for Simple Linear Regression	504
CHAPTER 12	Multiple Regression	521
	12.1 A Multiple Regression Analysis: The Model and the Procedure	522
	12.2 Fitting the Model: The Method of Least Squares	523
	12.3 Model Assumptions	526
	12.4 Estimating and Testing Hypotheses About the β Parameters	529
	12.5 Checking the Usefulness of a Model: R^2 and the Analysis of Variance F Test	540
	12.6 Using the Model for Estimation and Prediction	553

- 12.7 Multiple Regression: An Example 557
- 12.8 Statistical Computer Programs 560
- 12.9 Residual Analysis: Checking the Regression Assumptions 563
- 12.10 Some Pitfalls: Estimability, Multicollinearity, and Extrapolation 583

CHAPTER 13 Introduction to Model Building 605

- 13.1 The Two Types of Independent Variables: Quantitative and Qualitative 606
- 13.2 Models with a Single Quantitative Independent Variable 609
- 13.3 Models with Two Quantitative Independent Variables 618
- 13.4 Model Building: Testing Portions of a Model 625
- 13.5 Models with One Qualitative Independent Variable 637
- 13.6 Comparing the Slopes of Two or More Lines 647
- 13.7 Comparing Two or More Response Curves 660
- 13.8 Model Building: Stepwise Regression 671
- 13.9 Model Building: Residual Analysis and Transformations 677

CHAPTER 14 Methods for Quality Improvement 703

- 14.1 History of the Quality Movement in the United States 704
- 14.2 Quality: What Is It? 707
- 14.3 Systems Thinking 708
- 14.4 Process Management 713
- 14.5 Statistical Control 718
- 14.6 The Logic of Control Charts 727
- 14.7 A Control Chart for Monitoring the Mean of a Process: The \bar{x} -Chart 732
- 14.8 A Control Chart for Monitoring the Variation of a Process: The R-Chart 747
- 14.9 A Control Chart for Monitoring the Proportion of Defectives Generated by a Process: The p -Chart 755

CHAPTER 15 Time Series: Index Numbers and Descriptive Analyses 771

- 15.1 Index Numbers: An Introduction 772
- 15.2 Simple Index Numbers 773
- 15.3 Composite Index Numbers 778
- 15.4 Smoothing with Moving Averages 788
- 15.5 Exponential Smoothing 795

CHAPTER 16 Time Series: Models and Forecasting 807

- 16.1 Time Series Components 808
- 16.2 Forecasting: Exponential Smoothing 810
- 16.3 Forecasting Trends: The Holt–Winters Forecasting Model 813

- 16.4 Forecasting Trends: Simple Linear Regression 822
- 16.5 Seasonal Regression Models 826
- 16.6 Autocorrelation and the Durbin–Watson Test 834
- 16.7 Forecasting with Autoregressive Models 841

CHAPTER 17 **Design of Experiments and Analysis of Variance** 859

- 17.1 Elements of a Designed Experiment 860
- 17.2 The Completely Randomized Design 866
- 17.3 The Randomized Block Design 886
- 17.4 Factorial Experiments 904
- 17.5 Using Regression Analysis for ANOVA (Optional) 920

CHAPTER 18 **Nonparametric Statistics** 947

- 18.1 Single-Population Inferences: The Sign Test 949
- 18.2 Comparing Two Populations: Wilcoxon Rank Sum Test for Independent Samples 954
- 18.3 Comparing Two Populations: Wilcoxon Signed Rank Test for the Paired Difference Experiment 962
- 18.4 Kruskal–Wallis H Test for a Completely Randomized Design 972
- 18.5 The Friedman F_r Test for a Randomized Block Design 978
- 18.6 Spearman's Rank Correlation Coefficient 985

CHAPTER 19 **The Chi-Square Test and the Analysis of Contingency Tables** 1007

- 19.1 One-Dimensional Count Data: Multinomial Distribution 1008
- 19.2 Contingency Tables 1016
- 19.3 Caution 1029

CHAPTER 20 **Decision Analysis** 1041

- 20.1 Three Types of Decision Problems 1043
- 20.2 Decision-Making Under Uncertainty: Basic Concepts 1045
- 20.3 Two Ways of Expressing Outcomes: Payoffs and Opportunity Losses 1049
- 20.4 Characterizing the Uncertainty in Decision Problems 1054
- 20.5 Solving the Decision Problem Using the Expected Payoff Criterion 1056
- 20.6 The Expected Utility Criterion 1064
- 20.7 Classifying Decision-Makers by Their Utility Functions 1069
- 20.8 Revising State of Nature Probabilities: Bayes' Rule 1075
- 20.9 Solving Decision Problems Using Posterior Probabilities 1081
- 20.10 The Expected Value of Perfect Information 1085
- 20.11 The Expected Value of Sample Information: Preposterior Analysis (Optional) 1091

CHAPTER 21 Survey Sampling 1115

- 21.1 Terminology 1118
- 21.2 Sample Survey Designs 1119
- 21.3 Estimation in Survey Sampling: Bounds on the Error of Estimation 1123
- 21.4 Estimation for Simple Random Sampling 1125
- 21.5 Simple Random Sampling: Nonresponse 1131
- 21.6 Stratified Random Sampling 1131
- 21.7 Cluster Sampling 1138
- 21.8 Determining the Sample Size 1146

APPENDIX A Basic Counting Rules 1155

APPENDIX B Tables 1159

- Table I Random Numbers 1161
- Table II Binomial Probabilities 1164
- Table III Poisson Probabilities 1168
- Table IV Normal Curve Areas 1173
- Table V Exponentials 1174
- Table VI Critical Values of t 1175
- Table VII Percentage Points of the F Distribution, $\alpha = .10$ 1176
- Table VIII Percentage Points of the F Distribution, $\alpha = .05$ 1178
- Table IX Percentage Points of the F Distribution, $\alpha = .025$ 1180
- Table X Percentage Points of the F Distribution, $\alpha = .01$ 1182
- Table XI Critical Values of T_L and T_U for the Wilcoxon Rank Sum Test: Independent Samples 1184
- Table XII Critical Values of T_0 in the Wilcoxon Paired Difference Signed Rank Test 1185
- Table XIII Critical Values of χ^2 1186
- Table XIV Critical Values for the Durbin–Watson d Statistic, $\alpha = .05$ 1188
- Table XV Critical Values for the Durbin–Watson d Statistic, $\alpha = .01$ 1189
- Table XVI Critical Values of Spearman's Rank Correlation Coefficient 1190
- Table XVII Control Chart Constants 1190

APPENDIX C Demographic Data Set 1191

APPENDIX D Calculation Formulas for Analysis of Variance 1195

- Answers to Selected Exercises 1199
- Index of Exercise Data Sets 1217
- Index 1219

Case Studies

- 1.1 The Consumer Price Index 2
- 1.2 Taste-Preference Scores for Beer 3
- 1.3 Monitoring the Unemployment Rate 4
- 1.4 Auditing Parts and Equipment for Airline Maintenance 4
- 1.5 The Decennial Census of the United States 5
- 1.6 Quality Improvement: U.S. Firms Respond to the Challenge from Japan 13
- 2.1 Pareto Analysis 29
- 2.2 *Statistical Abstract of the United States* 35
- 2.3 Appraising the Market Value of an Asset 53
- 2.4 Deming Warns Against Knee-Jerk Use of Histograms 65
- 3.1 Hotels: A Rational Method for Overbooking 86
- 3.2 Measuring Investors' Reactions to a Corporate Selloff Announcement:
The General Electric/Utah International Case 86
- 3.3 The Delphi Technique for Obtaining a Consensus of Opinion 91
- 3.4 More on the Delphi Technique 97
- 3.5 Becoming More Sensitive to Customer Needs 111
- 3.6 Deciding When to Respond to Consumer Complaints 120
- 4.1 Bloom County Probabilities 145
- 4.2 Purchase Patterns and the Conditional Probability of Purchasing 167
- 4.3 The 1970 Draft Lottery 180
- 5.1 Assessing the Effects of the Deadly Dutch Elm Disease 198
- 5.2 Portfolio Selection 204
- 5.3 The Space Shuttle *Challenger*: Catastrophe in Space 216
- 5.4 Evaluating Customer Response to a New Sales Program 220
- 6.1 Evaluating an Investment's Risk 252
- 6.2 Queueing Theory 259
- 6.3 Assessing the Reliability of Computer Software 261
- 7.1 Evaluating the Condition of Rental Cars 293
- 7.2 Reducing Investment Risk Through Diversification 293
- 8.1 Dancing to the Customer's Tune: The Need to Assess Customer Preferences 314
- 9.1 Statistics Is Murder! 351
- 9.2 Statistical Quality Control, Part 1 357
- 9.3 Statistical Quality Control, Part 2 375
- 10.1 Comparing Salaries for Equivalent Work 428
- 10.2 Hotel Room Interviewing—Anxiety and Suspicion 437
- 11.1 Estimating the Cost of a Construction Project 487
- 12.1 Predicting Corporate Executive Compensation 523