Business Statistics in Practice

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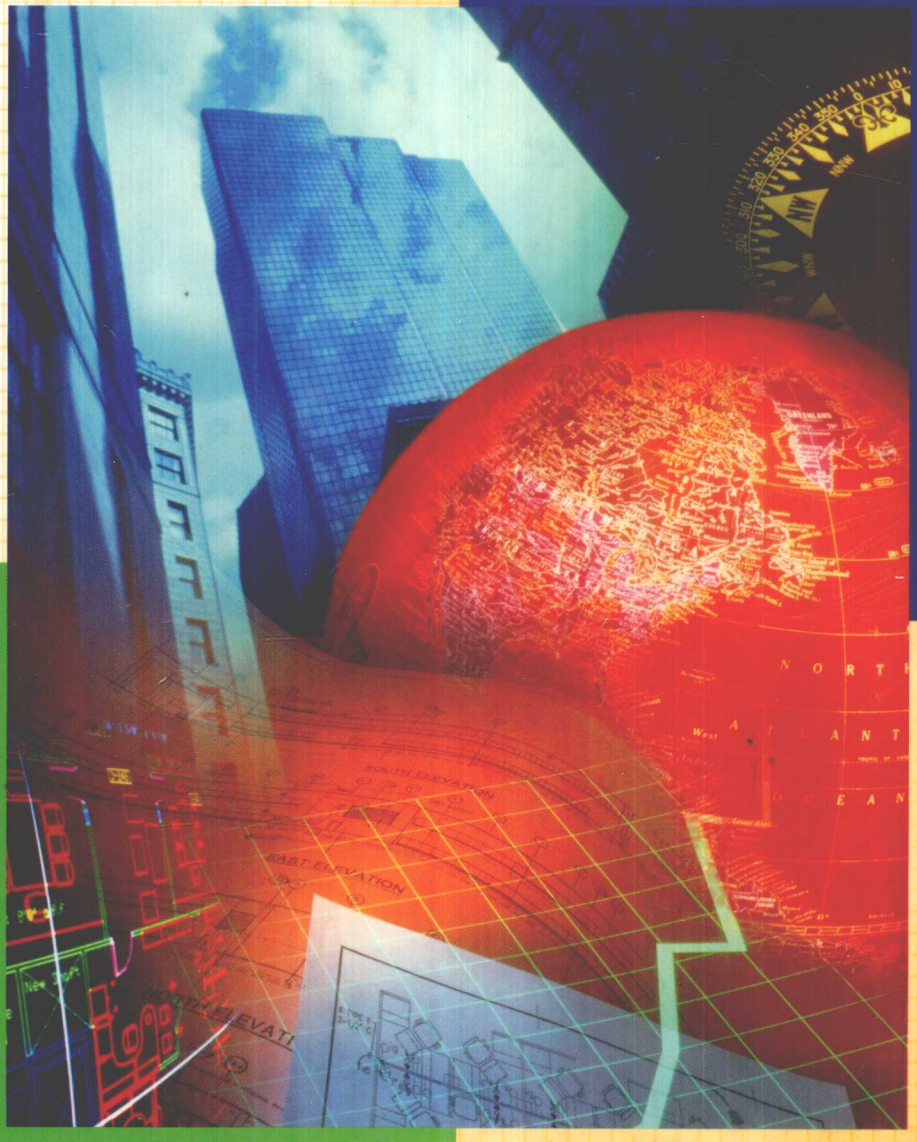
Third Edition



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Business Statistics in Practice

THIRD EDITION

with MegaStat and other contributions by J. Burdeane Orris

Butler University

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McGraw-Hill Higher Education
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BUSINESS STATISTICS IN PRACTICE

This book is printed on acid-free paper.

domestic 4 5 6 7 8 9 0 QWV/QWV 0 9 8 7 6 5 4
international 2 3 4 5 6 7 8 9 0 QWV/QWV 0 9 8 7 6 5 4

ISBN 0-07-247026-7 (student edition)
ISBN 0-07-247084-4 (instructor's edition)

Publisher: *Brent Gordon*
Executive editor: *Scott Isenberg*
Senior development editor: *Wanda J. Zeman*
Senior marketing manager: *Zina Craft*
Producer, media technology: *Anthony Sherman*
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Photo research coordinator: *Jeremy Cheshareck*
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Lead supplement producer: *Cathy L. Tepper*
Senior digital content specialist: *Brian Nacik*
Cover and interior design: *Jennifer McQueen*
Typeface: *10/12 Times Roman*
Compositor: *Interactive Composition Corporation*
Printer: *Quebecor World Versailles Inc.*

Library of Congress Control Number: 2002112963

INTERNATIONAL EDITION ISBN 0-07-115142-7

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Bruce L. Bowerman
To my wife, children, sister, and other family members:
Drena
Michael and Jinda
Asa and Nicole
Susan
Fiona and Radeesa
Daphne, Chloe, and Edgar

Richard T. O'Connell
To my wife and children:
Jean
Christopher and Bradley

About the Authors

Bruce L. Bowerman Bruce L. Bowerman is professor of decision sciences at Miami University in Oxford, Ohio. He received his Ph.D. degree in statistics from Iowa State University in 1974, and he has over 34 years of experience teaching basic statistics, regression analysis, time series forecasting, survey sampling, and design of experiments to both undergraduate and graduate students. In 1987 Professor Bowerman received an Outstanding Teaching award from the Miami University senior class, and in 1992 he received an Effective Educator award from the Richard T. Farmer School of Business Administration. Together with Richard T. O'Connell, Professor Bowerman has written eight textbooks. These include *Forecasting and Time Series: An Applied Approach* and *Linear Statistical Models: An Applied Approach.* The first edition of *Forecasting and Time Series* earned an Outstanding Academic Book award from *Choice* magazine. Professor Bowerman has also published a number of articles in applied stochastic processes, time series forecasting, and statistical education. In his spare time, Professor Bowerman enjoys watching movies and sports, playing tennis, and designing houses.

Richard T. O'Connell Richard T. O'Connell is associate professor of decision sciences at Miami University in Oxford, Ohio. He has more than 29 years of experience teaching basic statistics, statistical quality control and process improvement, regression analysis, time series forecasting, and design of experiments to both undergraduate and graduate business students. He also has extensive consulting experience and has taught workshops dealing with statistical process control and process improvement for a variety of companies in the Midwest. In 2000 Professor O'Connell received an Effective Educator award from the Richard T. Farmer School of Business Administration. Together with Bruce L. Bowerman, he has written eight textbooks. These include *Forecasting and Time Series: An Applied Approach* and *Linear Statistical Models: An Applied Approach.* Professor O'Connell has published a number of articles in the area of innovative statistical education. He is one of the first college instructors in the United States to integrate statistical process control and process improvement methodology into his basic business statistics course. He (with Professor Bowerman) has written several articles advocating this approach. He has also given presentations on this subject at meetings such as the Joint Statistical Meetings of the American Statistical Association and the Workshop on Total Quality Management: Developing Curricula and Research Agendas (sponsored by the Production and Operations Management Society). Professor O'Connell received an M.S. degree in decision sciences from Northwestern University in 1973, and he is currently a member of both the Decision Sciences Institute and the American Statistical Association. In his spare time, Professor O'Connell enjoys fishing, collecting 1950s and 1960s rock music, and following the Green Bay Packers and Purdue University sports.

Preface

In *Business Statistics in Practice,* Third Edition, we provide a modern, practical, and unique framework for teaching the first course in business statistics. This framework features case study and example driven discussions of all basic business statistics topics. In addition, we have endeavored to make this book the most clearly written, motivating, and easy to use business statistics text available. We have taken great pains to explain concepts simply from first principles. Therefore, the only prerequisite for this book is high school algebra.

Business Statistics in Practice has five attributes that make it an effective learning tool:

- A consistent theme of business improvement through statistical analysis.
- A unique use of case studies that integrates different statistical areas.
- A real emphasis on the study of variation that stresses that the analysis of individual population observations is as important as the analysis of population means.
- A flexible topic flow that facilitates different topic choices and encourages different teaching approaches. In particular, since many courses give different emphases to probability, hypothesis testing, regression and statistical modeling, nonparametric statistics, and quality control, this book provides great flexibility with respect to how, when, and whether to cover these topics.
- A modern use of the statistical capabilities of the software packages MINITAB, Excel, and MegaStat (an Excel add-in package included on the text's student CD-ROM) that stresses statistical interpretation and that reflects the use of these packages in the real world.

New to the third edition are

- An expanded and more flexible discussion of descriptive statistics that includes descriptive measures for grouped data, weighted means, and the geometric mean.
- An optional section that covers use of the cumulative standard normal table.
- A simplified approach to hypothesis testing that better motivates and concisely integrates the use of rejection points and p-values.
- An innovative organization of regression analysis that makes it very easy to cover whatever portions of regression analysis are desired.
- Additional advanced topics, such as properties of random variables and the covariance, in the book appendices.

Especially noteworthy in this edition is the inclusion of a new version of the Excel add-in package MegaStat. J. B. Orris of Butler University, the developer of MegaStat, has worked closely with us to increase the capabilities of MegaStat and to further integrate it into the pedagogy of the text. We believe that MegaStat is now the most comprehensive, accurate, and easy to use Excel add-in package currently in existence. MegaStat outputs and input instructions are now fully integrated into the text, replacing the SAS outputs used in the previous edition. (SAS outputs are still used in some advanced topic appendices located on the accompanying student CD-ROM.)

We now discuss in more detail the attributes that make *Business Statistics in Practice* an effective learning tool.

Business improvement through statistical analysis The ultimate goal of statistical analysis in business is business improvement. This theme is the foundation for the case studies

and examples in this text, many of which are based on actual, real world situations. For example, consider the following synopses of three case studies.

- **The Cheese Spread Case:** The marketer of a soft cheese spread wishes to replace the spout on its plastic dispenser with a less expensive spout. The company uses confidence intervals to conclude that demand for the spread will remain sufficiently high when the change is made to make replacing the spout profitable.
- **The Trash Bag Case:** A leading producer of trash bags uses hypothesis testing to convince the standards and practices division of a major television network that advertising claims about its newest trash bag are valid.
- **The Fuel Consumption Case:** A natural gas company uses regression analysis to predict its city's natural gas needs accurately enough to avoid paying fines to a pipeline transmission system.

In each of these cases, statistical analysis leads to an informed action (replace the spout, advertise the claim, use the regression prediction procedure) that results in business improvement. Furthermore, we continue this theme throughout the presentation of all statistical techniques in this book. For instance, we use descriptive and inferential statistics to compare the risk and return characteristics of different investment choices in order to improve the way we manage an investment portfolio; we use statistical process control to improve manufacturing and service processes; and we use design of experiments to study the effects of several different advertising campaigns in order to improve how a product is marketed.

A unique continuity of presentation and use of case studies *Business Statistics in Practice* features a unique continuity of presentation that integrates different statistical areas. This integration is achieved by an early emphasis (in Chapters 1 and 2) on the difference between the population and the sample and by a continuing use of practical, realistic case studies that span not only individual chapters but also groups of chapters. Specifically, Chapter 1 shows how to select random (or approximately random) samples from populations and processes by introducing four case studies as examples and by presenting additional case studies as exercises. Then in Chapter 2 we show how to use descriptive statistics to estimate the important aspects of these populations and processes. We continue to employ these case studies through the probability and sampling distribution chapters until we use confidence intervals and hypothesis testing to make statistical inferences. Furthermore, we introduce new case studies in each and every chapter. For example, we introduce several case studies in our presentation of simple linear regression and then extend these case studies when we discuss multiple regression and model building to show how regression is used in the description, prediction, and control of business variables.

A real emphasis on the importance of variation *Business Statistics in Practice* emphasizes that since businesses must satisfy individual customers, the analysis of individual population observations—which is achieved by analyzing population variation—is as important as analyzing the population mean. Our discussion of variation begins in Chapter 1, where we intuitively examine the variation of sample data and use simple runs plots to evaluate statistical control. This discussion continues in Chapter 2, where we use the empirical rule to estimate tolerance intervals containing different percentages of population observations. For example, we use the empirical rule in the

- **Accounts Receivable Case** to describe the variation of individual bill payment times around the estimated mean bill payment time for a new electronic billing system.
- **Marketing Research Case** to describe the variation of individual customer ratings of a new cookie package design around the estimated mean rating of the new design.
- **Car Mileage Case** to describe the variation of individual gas mileages around the estimated mean mileage obtained by a new midsize car.

In addition, in the **coffee temperature case** we introduce the idea of process capability—determining whether almost all process observations fall within customer requirements—and in other case studies we consider the problems involved with describing the variation of highly skewed populations.

Our emphasis on variation continues throughout the book. For example, in Chapter 7 we clearly distinguish between a confidence interval for a population mean and a tolerance interval for a given percentage of individual population measurements. In Chapter 8 we discuss the effect of variation on the interpretation of a hypothesis test about the population mean. In Chapters 11 through 13 we show how prediction intervals can be used to evaluate the predictive capabilities of different regression and time series forecasting models. In addition, we demonstrate how prediction intervals are used to assess whether any individual population observations are "unusual" enough to suggest the need for process improvement. Finally, in Chapter 14 we present a complete discussion of statistical process control and improvement (including the six sigma philosophy adopted by Motorola, Inc., and a number of other prominent U.S. companies). Furthermore, in all of these chapters we use practical case studies to illustrate the ideas being presented.

A flexible topic flow Although the table of contents of this book reveals a rather standard topic organization, the book utilizes a flexible topic flow that facilitates different topic choices and encourages different teaching approaches. In particular, since different courses place different amounts of emphasis on probability, hypothesis testing, regression and statistical modeling, nonparametric statistics, and quality control, this book provides great flexibility with respect to how, when, and whether to cover these topics. Furthermore, in optional sections, appendices, and self-learning exercises, the book gives the student the opportunity to study more advanced topics in a concise and practical way. Thus, as we now discuss, courses with a wide variety of topic coverages and emphases can be taught using this book.

Probability The most minimal approach to probability would cover Section 3.1 (the concept of probability), Section 4.1 (random variables), Section 5.1 (continuous probability distributions), and Section 5.3 (the normal distribution, including an intuitive example of the addition rule for mutually exclusive events). These sections are the only prerequisites for Chapters 6 through 14 (sampling distributions, confidence intervals, hypothesis testing, experimental design, regression, time series forecasting, and quality control).

Instructors who wish to also cover discrete probability distributions (Chapter 4) have the option of doing this either with a fairly minimal probability background or with a complete probability background. The fairly minimal probability background consists of Section 3.1 (the concept of probability) and Section 3.2 (using sample spaces to find probabilities). Note that this background is sufficient because, since Example 4.2 of Chapter 4 intuitively illustrates the multiplication rule for independent events and the addition rule for mutually exclusive events in the context of finding a discrete probability distribution, it is not necessary to cover the complete discussion of probability rules given in Sections 3.3 and 3.4. Of course, this complete discussion is necessary background for covering chi-square tests of independence (Chapter 16) and Bayes' Theorem and decision theory (Chapter 17). Also, the complete discussion features the **AccuRatings Case,** which is a very motivating data driven application of the probability rules.

Hypothesis testing For the third edition we have streamlined the discussion of hypothesis testing in a way that (we believe) significantly clarifies the overall presentation and makes it more accessible to students at all levels. In particular, we have more fully and concisely integrated the discussion of using rejection points and p-values, and we have motivated the link between these techniques by considering how major television networks sometimes use different α values when evaluating advertising claims. We are aware of several courses that introduce hypothesis testing in the context of using p-values to test the significance of regression coefficients. This can be done in our book by totally skipping Chapter 8 and by noting that every section throughout the rest of the book includes self-contained summary boxes (and examples) that fully cover any needed confidence intervals and hypothesis tests. Also, Chapter 6 (sampling distributions) intuitively illustrates the use of p-values in the context of evaluating a claim about a population mean and in the context of evaluating a claim about a population proportion. Therefore, Chapter 6 can be used as an extremely short, intuitive introduction to p-values.

Regression and statistical modeling The third edition features an innovative organization of regression analysis that simplifies the flow of the overall discussion and makes it very easy to

cover whatever regression topics are desired. As in the second edition, we have included an optional section on residual analysis at the end of the simple linear regression chapter (Chapter 11). New to the third edition is the combination of the former two chapters on multiple regression and model building into a single chapter (Chapter 12) featuring four innovative parts. Part 1: Basic Multiple Regression discusses the basic descriptive and inferential techniques of multiple regression analysis and would be a sufficient introduction to this topic for many introductory business statistics courses. After completing Part 1, the reader can study Part 2: Using Squared and Interaction Terms, Part 3: Dummy Variables and Advanced Statistical Inferences, and any section of Part 4: Model Building and Model Diagnostics. These parts can be covered in any order and without loss of continuity (note that Part 4 consists of three self-contained sections: model building and the effects of multicollinearity; residual analysis in multiple regression; and diagnostics for detecting outlying and influential observations). Furthermore, an optional discussion and summary example at the end of Part 4, as well as optional exercises in various sections and some of the supplementary exercises, tie key portions of the four parts together. This approach allows instructors to easily cover what they consider most important in courses with limited time devoted to regression analysis. Similarly, since many business statistics courses do not have substantial time to devote to experimental design (Chapter 10) and time series forecasting (Chapter 13), we have put great effort into making our presentation of these topics both complete and easy to get through.

Nonparametric statistics We have placed all of the nonparametric techniques covered in the book in Chapter 15. Furthermore, at the end of the discussion of each parametric technique in Chapters 8 through 11 we refer readers to the section in Chapter 15 that discusses the nonparametric technique that would be used if the assumptions for the parametric technique fail to hold. Therefore, the instructor has the option of integrating the discussion of nonparametric statistics into the main flow of Chapters 8 through 11.

Quality control Process improvement through control charts is discussed in Chapter 14. Thus, this topic is placed outside of the main flow of what might be regarded as classical statistics. However, since Chapter 14 has as its only prerequisite Chapter 6 on sampling distributions, the instructor has the option to cover Chapter 14 at any point after Chapter 6.

Optional Advanced Topics In optional sections, appendices, and self-learning exercises, the book gives the student the opportunity to study more advanced topics in a concise and practical way. Examination of the table of contents reveals that many of the more advanced topics—for example, counting rules (Appendix B), the hypergeometric distribution (Appendix C), the Poisson and exponential distributions (Sections 4.4 and 5.5), calculating the probability of a Type II error (Section 8.6), and statistical inferences for a population variance (Section 8.8)—are included in many other business statistics books. However, some of the more advanced topics, while not unique to this book, are less frequently covered in other basic statistics texts. These topics (the most advanced of which are discussed in CD-ROM Appendices F (Part 2) through L) are as follows:

- Properties of the Mean and Variance of a Random Variable, and the Covariance Between Two Random Variables (Appendix D).
- Derivations of the Mean and the Variance of the Sample Mean and of the Mean and the Variance of the Sample Proportion (Appendix E).
- Confidence Intervals for Parameters of Finite Populations (Section 7.5), including sample size determination (Exercise 7.57).
- An Introduction to Survey Sampling (Section 7.6); estimation formulas, optimal allocation, and sample size determination in stratified random sampling (Appendix F (Part 1)); and estimation formulas in one- and two-stage cluster sampling and ratio estimation (Appendix F (Part 2)).
- A Comparison of Confidence Intervals and Tolerance Intervals (Section 7.7).
- Using Matrix Algebra to Perform Regression Calculations (Appendix G).
- The regression approach to one-way analysis of variance (Exercise 12.45), and the regression approach to two-way analysis of variance (Appendix H).

- Advanced Model Diagnostics (Exercises 12.73 and 12.74) and Model Building with Squared and Interaction Terms (Exercise 12.70).
- Logistic Regression and Discriminant Analysis (Exercises 12.71 and 12.72).
- Factor Analysis, Cluster Analysis, and Multidimensional Scaling (Appendix I).
- Double Exponential Smoothing and Winters' Method (an intuitive discussion in Section 13.5 and a detailed discussion in Appendix K).
- The Box–Jenkins methodology, a fairly complete discussion featuring nonseasonal and seasonal modeling, using autocorrelated error term models in regression analysis, intervention analysis, and transfer function models (Appendix J).
- Individuals charts and c charts (Appendix L).

Furthermore, we have put great effort into making the discussion of all of the more advanced topics clear, concise, and easy to get through. This gives the instructor considerable flexibility in designing different business statistics courses. For example, a professor teaching a second course in business statistics can opt to either cover a variety of intermediate topics or present a more in-depth treatment of regression analysis and forecasting.

MINITAB, Excel, and MegaStat *Business Statistics in Practice, Third Edition,* features a modern use of the statistical capabilities of the software packages MINITAB, Excel, and the Excel add-in MegaStat. Throughout the book we provide an abundant number of outputs from all three packages in both examples and exercises that allow students to concentrate on statistical interpretations. This use of outputs is particularly prominent in statistical areas where hand calculations are impossible or impractical and where having students run their own programs (while theoretically optimal) would, because of time constraints, not allow them to see a wide variety of applications. These areas include descriptive statistics, ANOVA, regression, and time series forecasting. In addition, appendices at the end of each chapter show in detail how to use MINITAB, Excel, and MegaStat to implement the statistical techniques discussed in the chapter. For the third edition, the developer of MegaStat, Professor J. B. Orris of Butler University, has worked closely with us to significantly increase the capabilities of MegaStat. We believe that MegaStat is now the most comprehensive, accurate, and easy to use Excel add-in package in existence. In addition to remedying most of the computational problems associated with Excel Data Analysis Tools, MegaStat is also specifically designed to enhance the use of *Business Statistics in Practice.* For example,

- In addition to giving the usual descriptive statistics, frequency distributions, and histograms, MegaStat now provides stem-and-leaf displays, box plots, dot plots, runs plots, and output for the Empirical Rule (as well as tolerance intervals estimated to contain any specified percentage of individual observations). MegaStat also gives the option to calculate tolerance intervals and confidence intervals using the same dialog box. Therefore, students can better understand the crucial difference between these two types of intervals (as illustrated on pages 290 and 291).
- The MegaStat dialog box for every one and two sample hypothesis testing procedure for means and proportions now allows the user to calculate a confidence interval for the population parameter being tested. Therefore, the student is encouraged to evaluate both statistical significance and practical importance. Such evaluation is a consistent theme of *Business Statistics in Practice* (in particular, see Chapters 8 and 9).
- MegaStat's one-way ANOVA, randomized block, and two-factor ANOVA procedures now provide graphical output helping students to better analyze experimental data. In addition, each procedure now provides easy to understand pairwise comparisons of population means using both Tukey procedures and individual t-tests. Such graphical analysis and pairwise comparisons are emphasized in Chapter 10.
- In addition to providing confidence intervals and prediction intervals in simple and multiple regression, MegaStat now gives a full range of residual plots, normal plots, and outlying and influential observation diagnostics, as well as the variance inflation factors for the independent variables in a regression model. In addition, MegaStat provides an all possible regressions output that summarizes all well known model selection criteria, as well as the p-values for the independent variables. MegaStat also gives a stepwise selection procedure that provides more

information than given by classical stepwise regression or backward elimination. MegaStat's regression capabilities are designed to enhance the regression coverage in Chapters 11 and 12. Furthermore, all of MegaStat's regression capabilities can be accessed in one very easy to use dialog box, allowing the student to carry out a wide range of regression procedures in a correct, informative, and simple way.

In addition, MegaStat is fully capable of performing analysis related to discrete and continuous probability distributions, time series forecasting, nonparametric statistics, chi-square tests, and statistical quality control charts—virtually all topics covered by *Business Statistics in Practice*. MegaStat is provided on the student CD-ROM.

Further Features The book's CD-ROM, in addition to containing the previously discussed advanced topic appendices and MegaStat, also features Excel templates, data files, tutorials, web links to Internet exercises, self quizzes, PowerPoint presentations, and Visual Statistics 2.0 by Doane, Mathieson, and Tracy. Visual Statistics is a Windows software program that helps students learn statistics through interactive experimentation and visualization. Visual statistics icons in the text identify concepts that are further explained by Visual Statistics. New to this edition is the Homework Management feature. This is an online electronic tutor customized to the text and available as an option to students. Homework Management icons identify exercises where drill and practice are provided on the text website.

In addition, the book has the following supplements: an instructor's solutions manual developed by Susan Cramer, Miami University, and test bank developed by Ceyhun Ozgur, Valparaiso University (included on the instructor's edition CD-ROM and available in print format); a student study guide developed by Sandra Strassar, Valparaiso University (available in print format); and PowerPoint transparency masters.

Acknowledgments We wish to thank the many people who have helped to make this book a reality. First, we wish to thank Professor J. B. Orris of Butler University. Professor Orris's hard work and dedication have made MegaStat a truly excellent statistical software package. In addition, his feedback and many intellectual contributions have greatly improved this book. Second, we wish to thank Professor Michael L. Hand of Willamette University, who is a coauthor of the second edition of this book. Although Professor Hand did not work on the third edition, we thank him for his contributions to the second edition and regard him as a valued friend and colleague. We next wish to thank Professor Anne Koehler of Miami University. Professor Koehler wrote the original versions of the MINITAB and Excel appendices included in the text. The final appendices are largely based on her original versions. We cannot thank Professor Koehler enough for her selfless work, which is a hallmark of her career. We also wish to thank the people at McGraw-Hill/Irwin for their dedication to this book. These people include Executive Editor Scott Isenberg, who has made many excellent suggestions for developing the second and third editions of this book and who is, in general, a very positive and helpful resource to the authors; Executive Editor Dick Hercher, who persuaded us initially to publish this book with McGraw-Hill/Irwin and who continues to offer sound advice and support with each revision of the book; Senior Developmental Editor Wanda Zeman, who has shown great dedication through three editions of this book (Wanda's many excellent ideas and tireless attention to detail have been instrumental in the continual improvement of the book); and Senior Project Manager Christina Thornton-Villagomez, who has capably and diligently guided this book through its production, and who consistently proves to be a tremendous help to the authors.

Many people have contributed to the third edition, and we are grateful to all of them. They include

Jafar Alavi, East Tennessee State University
Raji Baradwaj, University of Wisconsin—Eau Claire
Emily Blank, Howard University
Robert Brookshire, James Madison University
Subha Chakraborti, University of Alabama
Phil Cross, Georgetown University
Barry P. Cuffee, Wingate University
Joe Essuman, University of Wisconsin—Waukesha

James Ibe, Morris College
Farid Islam, Utah Valley State College
Yunus Kathawala, Eastern Illinois University
Yih-Wu Liu, Youngstown State University
Richard McGowan, Boston College
Judith McKnew, Clemson University
Patricia Mullins, University of Wisconsin—Madison
Dean L. Ries, University of Missouri—Columbia
Deborah Rumsey, Ohio State University
Richard M. Smith, Bryant College
Toni M. Somers, Wayne State University
Larry Stephens, University of Nebraska—Omaha
Steve Thorpe, University of Northern Iowa
James Todd, University of West Alabama
Bruce C. Walker, University of Los Angeles—Monroe
Keith Womer, University of Mississippi
Roger Woodard, Ohio State University
Mari Yetimyan, San Jose State University
Zhen Zhu, University of Central Oklahoma

We gratefully acknowledge the help of the following reviewers who contributed to the earlier editions: Sung K. Ahn, Washington State University; Pesi J. Amaria, Salem State College; Randy J. Anderson, California State University—Fresno; Ron Barnes, University of Houston—Downtown; Philip Boudreaux, University of Southwestern Louisiana; Zhenmin Chen, Florida International University; Ronald L. Coccari, Cleveland State University; James J. Cochran, University of Cincinnati; Bradford R. Crain, Portland State University; William Duckworth II, Iowa State University; Mark Eakin, University of Texas—Arlington; James Flynn, Cleveland State University; S. B. Fotopoulos, Washington State University; Trellis G. Green, University of Southern Mississippi; Frank Kelly, University of New Mexico; Byung S. Lee, Howard University; Burt Madden, University of Arkansas—Little Rock; Edward P. Markowski, Old Dominion University; Glenn Milligan, Ohio State University; Sharon R. Neidert, University of Tennessee; Ceyhun Ozgur, Valparaiso University; Thomas Page, Michigan State University; Richard A. Paulson, St. Cloud State University; Dane Peterson, Missouri State University; Dennis Petruska, Youngstown State University; Don R. Robinson, Illinois State University; Paige S. Rutner, Georgia Southern University; Andrew Schaffner, California Polytechnic State University; Robert Smidt, California Polytechnic State University; Richard A. Scott, University of Arizona; Bill L. Seaver, University of Tennessee; Rafael Solis, California State University—Fresno; Toni M. Somers, Wayne State University; Richard Spinetto, University of Colorado; Robert Stine, University of Pennsylvania—Wharton; Alireza Tahai, Mississippi State University; and Jack A. Vaughn, University of Texas—El Paso.

We also wish to thank the error checker, Don R. Robinson, Illinois State University, who was very helpful. Most importantly, we wish to thank our families for their acceptance, unconditional love, and support.

Bruce L. Bowerman
Richard T. O'Connell

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