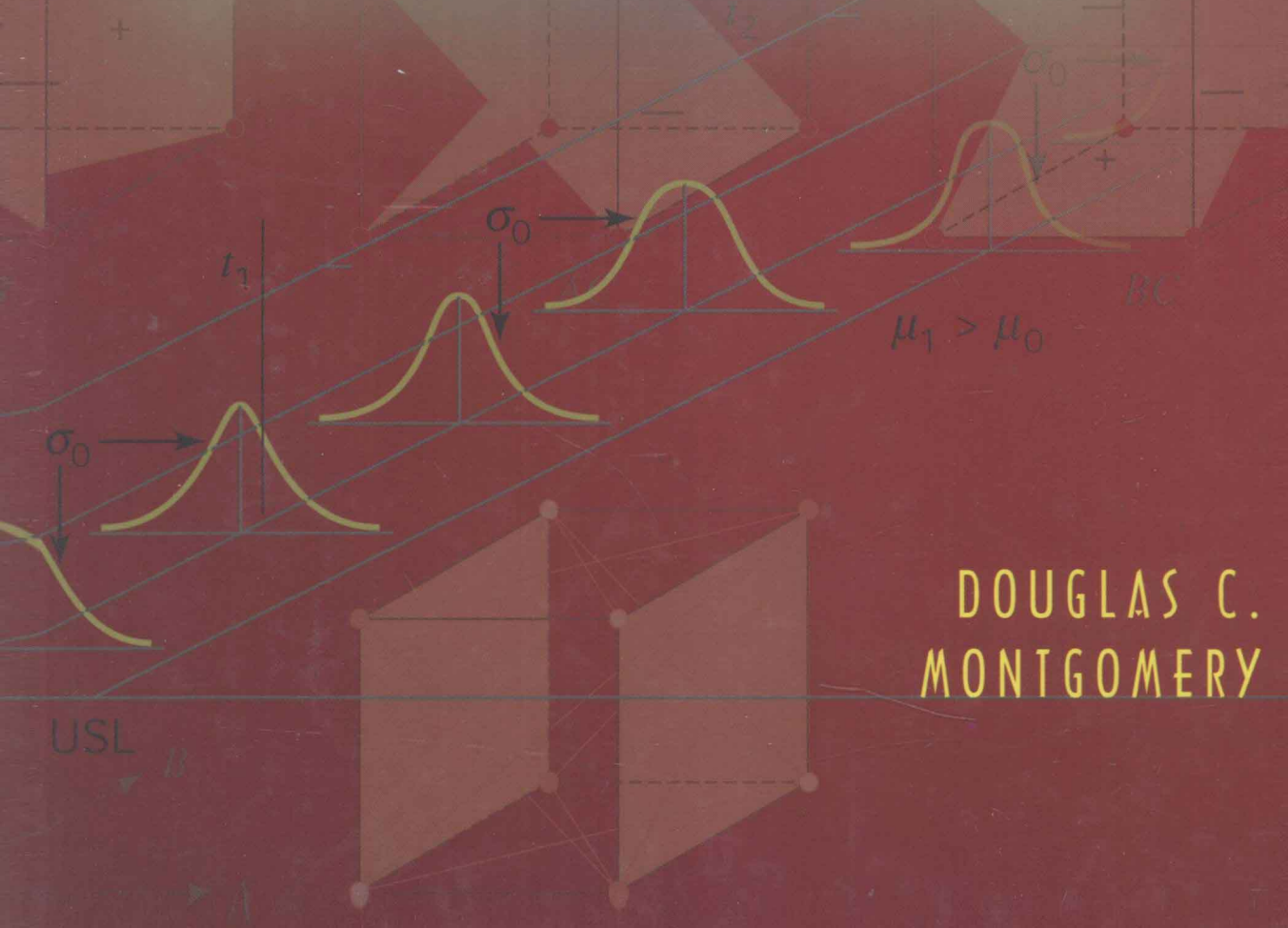
4TH EDITION

INTRODUCTION TO STATISTICAL QUALITY CONTROL



DOUGLAS C. MONTGOMERY

Introduction to Statistical Quality Control

Fourth Edition

Douglas C. Montgomery
Arizona State University

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Introduction to Statistical Quality Control

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About the Author

Douglas C. Montgomery, Professor of Industrial Engineering at Arizona State University, received his B.S., M.S., and Ph.D. degrees from Virginia Polytechnic Institute, all in engineering. From 1969 to 1984 he was a faculty member of the School of Industrial & Systems Engineering at the Georgia Institute of Technology; from 1984 to 1988 he was at the University of Washington, where he held the John M. Fluke Distinguished Chair of Manufacturing Engineering, was Professor of Mechanical Engineering, and Director of the Program in Industrial Engineering.

Dr. Montgomery has research and teaching interests in engineering statistics including statistical quality control techniques, design of experiments, regression analysis and empirical model building, and the application of operations research methodology to problems in manufacturing systems. He has authored and coauthored many technical papers in these fields and is an author of eleven other books. Dr. Montgomery is a Fellow of the American Society for Quality Control, a Fellow of the American Statistical Association, a Fellow of the Royal Statistical Society, and a Fellow of the Institute of Industrial Engineers. He is a Shewhart Medalist of the American Society for Quality Control, and has also received the Brumbaugh Award, the William G. Hunter Award, and the Shewell Award from the ASQC. He is a recipient of the Ellis R. Ott Award. He is a former editor of the *Journal of Quality Technology*, the current editor of *Quality and Reliability Engineering International*, and serves on the editorial boards of several journals.

Preface

This book is about the use of modern statistical methods for quality control and improvement. It provides comprehensive coverage of the subject from basic principles to state-of-the-art concepts and applications. The objective is to give the reader a sound understanding of the principles and the basis for applying them in a variety of both product and nonproduct situations. Although statistical techniques are emphasized throughout, the book has a strong engineering and management orientation. Extensive knowledge of statistics is not a necessary prerequisite for using this book. Readers whose background includes a basic course in statistical methods will find much of the material easily accessible.

The book is an outgrowth of over 25 years of teaching, research, and consulting in the application of statistical methods in quality engineering and quality improvement. It is designed as a textbook for students enrolled in colleges and universities who are studying engineering, management, statistics, and related fields and are taking a first course in statistical quality control. This course is often taught at the junior or senior level. All of the basic topics for this course are covered in detail. There is also some advanced material in the book, which could be used with advanced undergraduates who have had some previous exposure to the basics, or in a course aimed at graduate students. I have also used the text materials extensively in programs for professional practitioners, including quality and reliability engineers, manufacturing and development engineers, managers, procurement specialists, marketing personnel, technicians and laboratory analysts, and some inspectors and operating personnel. Many professionals have also used the material for self-study and preparation for certification examinations.

Chapter 1 is an introduction to the philosophy and basic concepts of quality improvement. It notes that quality has become a major business strategy and that organizations that successfully improve quality can increase their productivity, enhance their market penetration, and achieve greater profitability and a strong competitive advantage. Some of the managerial and implementation aspects of quality improvement are included.

Following the introductory chapter, the book is divided into five parts. Part I is a description of statistical methods useful in quality improvement. Topics covered include sampling and descriptive statistics, the basic notions of probability and probability distributions, point and interval estimation of parameters, and statistical hypothesis testing. These topics are usually covered in a basic course in statistical methods; however, their

presentation in this text is from the quality-engineering viewpoint. My experience has been that even readers with a strong statistical background will find the approach to this material useful and somewhat different from that of a standard statistics textbook.

Part II contains four chapters covering the basic methods of statistical process control (or SPC) and methods for process capability analysis. Although several SPC problem-solving tools are discussed (including Pareto charts and cause-and-effect diagrams, for example), the primary focus in this section is on the Shewhart control chart for variables and attributes. The Shewhart control chart is certainly not new, but its use in modern-day business and industry is of tremendous value. Process capability analysis and methods for evaluating measurement systems are discussed in detail in Chapter 7.

There are four chapters in Part III that present some more advanced SPC methods. Chapter 8 is devoted to the cumulative sum and exponentially weighted moving average control charts. This is not really very advanced material, but it is a nice transition between the traditional topics of Parts II and III. The other chapters in Part III cover other important univariate control charts such as procedures for short production runs, autocorrelated data, and multiple-stream processes (Chapter 9), multivariate process monitoring and control (Chapter 10), and feedback adjustment techniques (Chapter 11). Some of this material is at a higher level than Part II, but it is accessible by advanced undergraduates or first-year graduate students. Much of this material forms the basis of a second course in statistical quality control and improvement for this audience.

Part IV contains two chapters that show how statistically designed experiments can be used for process design, development, and improvement. Chapter 12 presents the fundamental concepts of designed experiments and introduces the reader to factorial and fractional factorial designs, with particular emphasis on the two-level system of designs. These designs are used extensively in industry for factor screening and process characterization. Although the treatment of the subject is not extensive and is no substitute for a formal course in experimental design, it will enable the reader to appreciate more sophisticated examples of experimental design. Chapter 13 introduces response surface methods and designs, illustrates evolutionary operation (EVOP) for process monitoring, and shows how statistically designed experiments can be used for process robustness studies. Chapters 12 and 13 emphasize the important interrelationship between statistical process control and experimental design for process improvement.

There are two chapters on acceptance sampling in Part V. The focus is on lot-by-lot acceptance sampling, although there is some discussion of continuous sampling and MIL STD 1235C in Chapter 15. Other sampling topics presented include various aspects of the design of acceptance-sampling plans, a discussion of MIL STD 105E, MIL STD 414 (and their civilian counterparts, ANSI/ASQC ZI.4 and ANSI/ASQC ZI.9), and other techniques such as chain sampling and skip-lot sampling.

Throughout the book guidelines are given for selecting the proper type of statistical technique to use in a wide variety of product and nonproduct situations. There are also extensive references to journal articles and other technical literature that should assist the reader in applying the methods described.

CHANGES IN THE FOURTH EDITION

Based on my own teaching experiences and extensive feedback from other users of the text, I have made several important changes in this edition of the book. I have grouped all the basic SPC and process capability techniques into a single section of the book (Part II) to facilitate topical flow in a first course. I have also expanded the material on process and measurement systems capability analysis. Much of the process monitoring and control material in Part III is either new or an expanded version of topics that were only briefly introduced in earlier editions. There are numerous examples that illustrate computer usage for construction and application of control charts and other techniques. Part IV on process improvement with designed experiments has been reorganized to move more quickly to the factorial design concept. I have also continued to illustrate how the computer is used in the analysis of data from designed experiments. I realize that it is possible to present this material without introducing the student to the analysis of variance (indeed, some books have done that) and give a manual analysis procedure for the two-level designs. I chose to use the analysis of variance because when the students plan and conduct experiments in the real world they will use a computer package that uses this method. It's a disservice to the students to teach them otherwise.

SUPPORTING TEXT MATERIALS

Computer Software

The computer plays an important role in a modern quality control course. This edition of the book uses Minitab as the primary illustrative software package. Instructors may order this book with Minitab included. Another option is a set of statistical programs supporting most of the control charting and experimental design methods in the book that are add-ins to the popular Microsoft Excel spreadsheet program. I strongly recommend that one of these alternatives be specified and that the course have a meaningful computing component.

Supplemental Text Material

I have written a set of supplemental material to augment the book. The supplemental material contains topics that I could not easily fit in the text without seriously disrupting the flow. Some of this material is proofs or derivations, new topics of a (sometimes) more advanced nature, supporting details concerning remarks or concepts presented in the text, and answers to frequently asked questions. There are many references to the supplemental material throughout the text. The supplemental material is an interesting set of accompanying readings for anyone curious about the field. It is available on the Instructor's CD-ROM and on the Web at www.wiley.com/college/montgomery.

Student Solutions Manual

The text contains answers to most of the odd-numbered exercises. There is also a Student Solutions Manual available on CD-ROM that presents comprehensive annotated solutions to these same odd-numbered problems. This is an excellent study aid that many text users will find extremely helpful.

Instructor's CD-ROM

The instructor's CD-ROM contains the following:

1. Solutions to the text problems
2. The supplemental text material described above
3. A set of Power Point slides for the basic SPC course
4. Data sets from the book in electronic form

Web Site

The Web Site, **www.wiley.com/college/montgomery**, contains the supplemental text material and the data sets in electronic form. It will also be used to post items of interest to text users.

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The editorial and production staff at Wiley, particularly Ms. Charity Robey (with whom I worked for many years) and Mr. Wayne Anderson have had much patience with me over the years, and have contributed greatly to the success of this book. Dr. Cheryl Jennings made many valuable contributions by her careful checking of the manuscript and proof materials, and in preparing the solutions. I also thank Dr. Gary Hogg, Chair of the Department of Industrial Engineering at Arizona State University, for his support and for providing a terrific environment in which to teach and conduct research.

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Douglas C. Montgomery
Tempe, Arizona

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