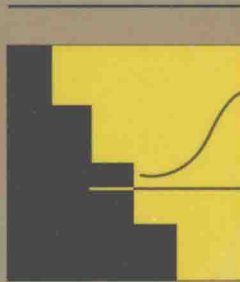




STATISTICAL PROCESS ANALYSIS



L a y t h C . A l w a n

STATISTICAL PROCESS ANALYSIS

Layth C. Alwan

University of Wisconsin—Milwaukee



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To Amir and Vanessa

PREFACE

The purpose in writing *Statistical Process Analysis (SPA)* is to give readers a strategy for effective use of statistics in the area of process management/analysis. There are a number of excellent books that treat this topic from the perspective of traditional coverage of statistical process control (SPC) methods. As such, *SPA* does not intend to provide another *purely* traditional approach to the area of SPC and its primary tool, the control chart. This does not imply traditional SPC methods and concepts will not be treated, they indeed are, and they even serve as unifying themes throughout the book. However, this book markedly differs in that SPC methods are treated within a broader data analysis perspective.

There are a number of efforts being made to change statistics curricula in business and engineering schools. In part, these efforts are motivated by signals from industry that universities have failed to train students with tools that are useful for analyzing real applications. Reports from the annual American Statistical Association conferences on “Making Statistics More Effective in Schools of Business” consistently reflect a need for instructors, curricula, teaching materials, and books to emphasize and integrate the themes of statistical thinking, quality management, and practical data analysis in conjunction with a user friendly software package. Furthermore, there is a need to speak to a general audience, not just those in manufacturing. *SPA* attempts to address all of these needs.

UNIQUE FEATURES

Using a variety of real world data sets, the book emphasizes the visual examination of data plots and the development of an intuitive understanding of statistical modeling. Since the data sets are real, the reader will experience a wide assortment of applications: some that allow for the appropriate use of traditional SPC methods while others challenge the appropriateness of the use of traditional SPC methods.

When SPC methods are not most appropriate, the book helps the reader develop the data skills to better understand the process at hand. This unique contribution of the book should be underscored. It is safe to say that nearly all SPC textbooks rely primarily on data sets that demonstrate the appropriateness of traditional SPC techniques, that is, the data sets are “textbook” examples. *SPA* shows the readers that the real world is much more interesting, with processes behaving in a variety of fashions that can not be properly controlled or analyzed by traditional methods. Most SPC books either give no coverage to real-world challenges, or, on the other hand, treat the issue as a special topic limited to one or two sections of some chapter.

To truly understand most processes encountered in practice, one needs to be armed with a broad range of data analysis skills. Still, the book resists the temptation to use overly sophisticated statistical models. Instead, *SPA* keeps the data analysis down to easily understood tools such as regression methods. All the statistical

tools presented in the book have been successfully understood and implemented by students (undergraduate, MBA, and EMBA) from introductory statistics to elective quality courses taught by the author at the University of Wisconsin-Milwaukee as well as similar courses taught by colleagues at the University of Chicago.

Below is a summary of the unique features of *Statistical Process Analysis (SPA)*:

- ✓ *SPA* is self-contained, flexible, and informative for different audiences: those with limited statistical backgrounds, those with statistical and/or SPC training interested in developing skills beyond the standard treatment, students (undergraduate or graduate, business or engineering), and industry practitioners.
- ✓ *SPA* provides a detailed background discussion of the principal features of the modern management paradigm and the integral role of statistical thinking and problem solving within this paradigm.
- ✓ *SPA* provides thorough coverage of the traditional SPC methods, using real world examples and data, from elementary to advanced topics.
- ✓ *SPA* recognizes that process data analysis is applicable to *any* process not just manufacturing processes. Because of the origins of SPC methods, most books focus primarily on manufacturing processes; *SPA* looks at manufacturing and many other processes.
- ✓ *SPA* helps readers develop skills for general process data analysis. *SPA* keeps the data analysis tools understandable. This helps promote the use of the book material beyond the classroom to industry itself.
- ✓ *SPA* integrates a popular (both in education and industry) statistical software package, Minitab. This is not a trivial point. No currently available book focussed on the area of SPC *fully* integrates an all-purpose statistical package for general data analysis flexibility. Some books make “spotty” connections to a general statistical package, such as Minitab. However, most books either do not incorporate software (hand-generated plots) or incorporate SPC software narrowly designed for the given book.
- ✓ *SPA* uses real data sets throughout the book, both within the main text presentation and the exercises. These data sets are made available on a data disk in the Instructors Manual or at the McGraw-Hill Web site. (www.mhhe.com/bstat)
- ✓ *SPA* contains nearly 400 end-of-chapter questions. Each chapter has a balance of review questions (designed to check students’ understanding of major concepts), solving problems (designed to help students develop their technical comprehension), and computer-based problems (designed to help students practice and hone their data analysis skills).

LEVEL AND AUDIENCE

To use the text, little mathematical expertise beyond basic college algebra is necessary; no knowledge of calculus is required. For those without formal statistics

training, Chapter 2 serves as a self-contained introduction to the basic statistical concepts useful for subsequent developments.

SPA is intended to appeal to a wide variety of audiences. In a university setting, the book has natural opportunities in courses for management, engineering, or statistics students. For instance, *SPA* can serve as a textbook for junior-, senior-, or graduate-level courses in quality control or management often found in engineering schools (such as, industrial engineering) and business schools.

Beyond quality-related courses, there is an opportunity for the use of this book in a university setting. The book can be used as the principal text in application-oriented statistics courses focussed on diverse topics such as basic statistical methods, time-series analysis, statistical quality control, regression, forecasting, and, of course, data analysis. Or, as an alternative, the book can be used as a supplementary resource that enables students to achieve practical data analysis skills while the instructor focuses on more theoretical concepts. Indeed, most of the data sets and the corresponding data analysis found in this book serve as the core of an Executive MBA-required business statistics course I teach at the University of Wisconsin-Milwaukee. It should be noted that the only prerequisite for the course is a two-week refresher course on basic mathematics and algebra. Given the course's emphasis on practical data analysis, I am happy to report that the course has been a tremendous success with students often reporting being "hooked" on data analysis.

Beyond the university setting, *SPA* can serve as a resource for individual practitioners and for company training programs focussed on statistical quality control and continual process improvement. As noted in Chapter 1, many companies (such as, General Electric) are providing in-depth statistical training (often known as "black belt" training) for all their employees. My review of black belt training materials suggests that even though they provide excellent coverage of important statistical techniques, they still fall short on providing trainees with the important basic data analysis skills integrated throughout this book. As such, *SPA* can serve as valuable complement to many of the training materials currently in use.

USE OF MINITAB

This book is unique in its integration with the statistical computer package Minitab; in particular, this book is tied to Release 12. This integration emphasizes the computer as a practical tool for insightful data analysis. Access to a statistical package is essential and presumed for all but the most sophisticated readers. One can not learn data analysis by simply reading text; one should attempt to develop a degree of skill in actual computation.

Although there are many excellent statistical packages currently available, I chose to use Minitab because of its wide acceptance by educational institutions and its extensive accessibility around the world in business and government. It is currently used by more than 2,000 colleges and universities and in the business world, by companies of all sizes, from start-ups to major corporations, including Allied Signal, Ford Motor Company, 3M, General Electric, General Motors, and Lockheed Martin. In fact, the majority of Fortune 500 companies use Minitab as part of their routine operations.

My choice is also based on the fact that Minitab can be learned quickly and easily, providing students with a powerful data analysis system that can also be used in other courses and in their professional careers. Minitab's intuitive user interface along with its context-sensitive online Help and simple tutorials make it easy for first-time users to perform statistical analysis without spending an inordinate amount of time learning the software.

Notwithstanding the ease of learning Minitab on one's own, I have incorporated two aids in this book. First, for any Minitab output that is first encountered, I have superimposed next to the output the pull-down menu choices required to produce the output. For instance, the first example of a scatter plot is in Figure 1.10. Referring to this figure, you will find "Graph >> Plot" superimposed next to the scatter plot. Since many outputs can easily be obtained by directly typing in a Session command, I have also shown for certain first-encountered output both the pull-down menu choices and the corresponding Session command, leaving to the user to decide which approach to use. For example, refer to Figure 2.14 to find that summary statistics are shown to be obtained by either the Session command "MTB> describe 'reading'" or by the pull-down menu choices of "Stat >> Basic Statistics >> Descriptive Statistics". As a second aid, in an end-of-book appendix, I have also provided an overview of Minitab along with a basic summary of some important utility functions (e.g., inputting data and saving data).

As a note to instructors, there are two versions of Minitab: the full (or professional) version and the student version. The professional version offers the complete range of statistical and quality-related capabilities. Many universities have a site license for Minitab which brings to the students the full power of Minitab. The student version of Minitab is a trimmed version of the full Minitab. I mention this version because Irwin/McGraw-Hill (the publisher of this book) can "bundle" a personal copy of the student version of Minitab with each copy of this book. Bundling is economically attractive because students get the textbook and the software at a price much lower than buying each separately.

With respect to the student version capabilities, it has all the basic statistical capabilities necessary to carry out the data analysis techniques of this book such as, descriptive statistics, graphing, time-series functions, and regression modeling. The student version retains a large subset of the full version's SPC capabilities. The only notable exception is the CUSUM control chart which is only available on the full version. This is not an insurmountable obstacle, one could perform the CUSUM computations by hand or spreadsheet (see Chapter 8) and then use Minitab's graphing options to create a CUSUM chart.

Even though Minitab is used extensively throughout the book, it should be emphasized that the reader is not bound to the software and is not disadvantaged using another software package. Because the computer output from most statistical packages is quite similar, the reader can safely use this book with programs other than Minitab. To allow for this flexibility, all data sets used in this book are provided both in Minitab and ASCII formats. An ASCII formatted data set is a text file, which can be universally read into any statistical or spreadsheet software. ASCII data files found in the supplied data disk are identified by the ".dat" filename extension while the Minitab data files are identified by the ".mtw"

filename extension. To avoid confusion, a given data set will have the same prefix file name. For example, a data set found in a file named “response.dat” would be an ASCII file and the Minitab formatted file would be named “response.mtw.”

For most software (e.g., Excel), you can simply open the ASCII file and the software will automatically recognize the number of columns (one or more) associated with the data set and then read them into the software appropriately. If, however, there is a need to know how many columns are associated with the data set prior to the input process, there is a simple process within Windows that will enable you to determine the content of the data file. In particular, you should first double click “My Computer” and then go to the directory in which the ASCII file resides and then double click the file itself. At this point, Windows will automatically open a utility known as WordPad (rudimentary word processing package) and show you the contents of the file. Now that you know the contents of the file, you can proceed to your software to instruct it to input the data appropriately.

A WORD ON STATISTICS

H. G. Wells wrote, “Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write.” For industry that day has arrived. The foundation of “statistical thinking” is increasingly being recognized as *critical* to effective management (at all levels).

However, statistics is not generally perceived as a popular subject. There are many reasons for this perception which I shall not dwell on. I do offer one insight drawn from my many years of teaching. When statistics is approached from a data analysis perspective, students develop an eagerness for the subject and are surprised to find themselves viewing data analysis as useful, interesting, and even exciting. Once you become aware of what data analysis can do, you will see that opportunities for practical application are omnipresent, in business, engineering, and elsewhere. I, personally, have found data analysis skills to be professionally and personally rewarding. In fact, I regard data analysis as a hobby of sorts which I plan to continue well beyond my professional career. I hope that you will come to agree with me as you read this book.

ACKNOWLEDGMENTS

This book was written over a period of several years, and I owe thanks to many people. First, I must recognize the generous assistance from Irwin/McGraw-Hill. Foremost, I am grateful to my editor, Richard T. Hercher, Jr. He was not only enthusiastic about the ideas and approach of this book but he also provided professional guidance and long-term support that brought this project to fruition. I am thankful to Colleen Tuscher for her efforts in resolving some startup problems encountered in the earlier stages of the project. My thanks go to Nicolle Schieffer for her patience, organization, and cheerful attitude that resulted in pleasant culmination of the project. Karen Nelson deserves special recognition for her professional management of the production of the book.

The final stages of the book occurred while I was on sabbatical lecturing at Al Akhawayn University in Morocco as a Fulbright Scholar. Because the univer-

sity is located in a remote town, receipt and delivery of book materials were not trivial tasks. I would like to thank Youssef Senhaji and Lhoussaine Oumaidi of the University Business Office for their tremendous efforts to get materials to and from an express courier service office located in a distant city.

I would like to thank Minitab Inc. for continually providing me, through its author assistance program, with the most recent release of its Minitab Statistical Software (Minitab for Windows). I am also grateful to the many individuals in Minitab's technical support staff who generously gave their time to resolve certain technical issues encountered during the development of this book.

I am greatly indebted to present and former MBA and Executive MBA students at the University of Wisconsin-Milwaukee for their constructive comments on the many data applications found in the book and for their contribution of real data applications from their places of work.

My sincere appreciation is extended to my colleague Timothy C. Haas for being available on numerous occasions to discuss various statistical issues with me. His comments lead to a number of improvements in the presentation of material found in this book. I am also grateful to William A. Berezowitz of General Electric Medical Systems for his many helpful insights and his data contributions.

I am thankful to all the reviewers involved in the review process. I am particularly appreciative of the following reviewers: Charles W. Champ, Georgia Southern University; Sudhakar D. Deshmukh, Kellogg School of Management-Northwestern University; Ben Huneycutt, Clemson University; Binshan Lin, Louisiana State University-Shreveport; Don Richter, Stern School of Business-New York University; Steve E. Rigdon, Southern Illinois University; and Athanasios Vasilopoulos, St. John's University. These reviewers made a multitude of excellent suggestions. I took every suggestion very seriously and I hope they can recognize their contributions within the text.

Given the theme of this book, I would be remiss if I did not acknowledge the profound influence that Professor Harry V. Roberts of the Graduate School of Business at the University of Chicago had on my development as a statistician. From him, I learned the potential and excitement of statistics. It was because of him that practical data analysis permeates my thinking and brings clarity on everything from personal to professional activities. I will forever be grateful for his mentoring.

Finally, I owe very special thanks to my family. I am deeply appreciative of my parents. It was my mother who instilled in me the passion for incessant inquiry for knowledge; her memory is always in my heart. With respect to my father, I owe much of my success and well being to his guidance and loving support from my childhood through my adult years. I am also thankful for his professional contributions to the development of this book. As a professor of statistics himself, he provided valuable comments and criticisms based on reading preliminary versions of the manuscript. Last but not least, I would like to thank my wife, Athena Maria, for her patience, understanding, and love in helping make this book a reality.

Layth C. Alwan

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