STATISTICAL PROCEDURES FOR ENGINEERING, MANAGEMENT, AND SCIENCE

Leland Blank, PE

PREFACE

The field of statistics is very extensive in both its theory and applications. Basically, the uses of statistics are applications of mathematics and rational decision making by analysts, be they engineers, managers, or scientists. This book presents the fundamentals of probability analysis and statistical tools which assist in decision making, using a language that is understandable to the person learning statistics, not in a style that simply impresses those already expert in statistics.

Uses of the Text

The modularized learning technique used in this text to present the distributions and tools of statistics allows the reader to first become very familiar with the fundamentals of statistical distributions and then learn the logic and procedures of the appropriate statistical tools. Specific questions are posed for each tool to determine when the procedure should and should not be used. Clearly written examples, which are separated from the explanatory text material, are included for every procedure to illustrate it and explain the conclusions. All examples are written in the context of real-world situations; that is, the "ball and urn" approach is not used.

This text may be used to cover statistics in one three-semester-hour course or a two-course sequence for engineers, scientists, or quantitatively oriented business majors. If the text is used in a one-semester course, some optional sections (explained later) should be omitted; and if it is used in a two-semester sequence, some supplementation with material listed in the Epilog is suggested. In the use of this material in the classroom it has been found that virtually all the material can be covered in the one-semester course. The chapters which present the relatively simple fundamentals about distributions may be assigned as reading because the presentation format requires only minimal classroom presentation by the instructor. This frees valuable hours for coverage of the more difficult concepts and applications with which the students will surely need assistance.

An operational knowledge of differential and integral calculus is necessary to master the material, so in general this text is usable for undergraduate students at the sophomore level or above. It may also be used for first-year graduate students taking a "core" course in statistics in a master's program.

Because of the building block approach used in its design, a practitioner unacquainted with statistics can easily use this text to learn, understand, and correctly apply the distributions and procedures of statistical decision making.

Chapter Composition

Each chapter starts with an objective statement and several specific learning criteria, which should be considered goals to the reader. Each criterion explains a skill which the reader should be able to demonstrate, given certain, specified information, once the section has been studied. These criteria are section-keyed: for example, the material for criteria 3 in Chapter 3 is discussed in Section 3.3. There are optional (starred) sections in most chapters. These sections, which present a summary or an expansion of the statistical theory applied in the chapter, may be omitted with no loss of understanding of how to correctly use the procedures. Further, subsequent chapters and sections do not require material from earlier optional sections unless they are themselves optional.

Within each section the most important equation or equations are emphasized with the symbol ●. The reader should pay particular attention to these relations and commit to memory as many of them as possible as they are commonly used in subsequent sections.

At the end of each section there are problems which utilize the concepts developed in the section. This provides the opportunity either to apply the material on a section-by-section basis or to wait until an entire chapter is completed. The final answers to most problems are included in Appendix A. Cross reference to the most appropriate section in the chapter is also given in this appendix.

If the section covers a statistical procedure that can be performed in a step-by-step fashion, the steps are presented and the accompanying example details these steps. Many chapters include solved problems after the last section containing examples which further illustrate the material in one or more sections of the chapter. These examples are often presented in the form of case studies which apply several techniques to one situation and set of data.

Finally, each chapter includes an Additional Material list which directs the reader to similar and advanced material in other texts on applied and mathematical statistics listed in the Bibliography.

Text Overview

The book is composed of 30 chapters collected into four learning levels. A flowchart or prerequisite chapter table at the beginning of Levels Two, Three, and Four gives the reader a good idea of what chapters are needed to understand the material presented in each chapter.

Level One (Chapters 1 to 5) covers basic computations, probability, and data presentation techniques for collected data. All chapters in this level should be covered in order. This is the only level which deals exclusively with collected data. Level Two (Chapters 6 to 18) presents the fundamentals of the most commonly used discrete and continuous probability density functions. Chapter 6 is an introduction to be referenced throughout the Level Two chapters as a source of the formulas used in working with statistical distributions. For each distribution the reader will learn the equation, graphs, parameters and their estimates, properties, use of the table, and some simple applications. Confidence interval determination and functions of more than one variable are also covered in this level.

Statistical inferences for population means, variances, proportions, and goodness of fit are discussed in Level Three (Chapters 19 to 26). Again the first chapter is introductory to the rest and may be used as reference material for all hypothesis-testing procedures. The use of operating characteristic curves is explained in this chapter and applied in the appropriate testing procedure. Chapter 24 presents the technique of graphical goodness-of-fit and parameter estimation for several common distributions. The final chapter of this level introduces the use of Bayesian statistics to estimate population parameters.

The final level, Four (Chapters 27 to 30), introduces the reader to several techniques used by analysts: regression and correlation analysis, quality control, and analysis of variance. These techniques, which use many of the distributions and procedures of the prior levels, are each an entire field of statistics in themselves. Thus only the major applications are presented here.

I greatly appreciate the efforts of the typists who prepared the manuscript and the students who have helped make this a more usable text. The suggestions of Dr. John Hunsucker have assisted in making the problems clear and understandable. In addition, I thank the administration of the Department of Industrial Engineering at Texas A&M University, especially Drs. Newton Ellis and Joseph Foster, for their support in this project.

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*Sections marked with a star may be omitted without loss of continuity.

Level Three Statistical Inference

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Department of Industrial Engineering
Texas A&M University

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CHAPTER
ONE

BASIC CONCEPTS

This chapter introduces some of the basic terminology and concepts of probability and statistics. The meaning of the different phases of probability and statistics are discussed. A case study covering the subjects of several sections is included as the Solved Problem.

CRITERIA

To complete this introductory chapter, you must be able to do the following:

1. Define and give examples of *deterministic data* and *probabilistic data*.
2. Define the terms *event* and *equally likely event*, and state why an event is or is not equally likely, given a description of the event.
3. Define the term *probability*, and state and compute probability by three methods, given the event and the number of times it occurs
4. Define the two phases of probability analysis and state how they are related
5. State the meaning of the terms *population* and *sample*. Define *population parameter* and *sample statistic*, and state how they are related
6. Define the terms *discrete variable* and *continuous variable*, and give an example of each.
7. State the definition of *statistics*, and name and define the two phases of statistics.

STUDY GUIDE

1.1 Deterministic and Probabilistic Data

Only two types of data are used to classify all numerical results:

Deterministic data. There is no variation from one fixed value. A scalar value such as $10 or a 5-kilogram (kg) weight is deterministic data.

Probabilistic data. This is also called stochastic data. There is a possibility that any one of several values can be observed. One fixed value is not sufficient to describe probabilistic data. For example, the number of vehicles needed to fill a river ferry fluctuates with vehicle size, weight, closeness to one another, etc. The number will therefore range from some lower to some upper value, such as 15 to 22 vehicles. The number of vehicles is probabilistic data. Of course, on any particular river crossing a count of vehicles will yield only one of the data values.

We will concentrate on probabilistic data in this book. We will describe it, compute with it, make inferences about it, and make decisions using it. Actually, when deterministic data is used, it is often because the probabilistic aspects are not known or understood.

Try to describe each of the following as probabilistic data: number of people in an elevator, yield strength of an aluminum casting, number of car wrecks per hour on a freeway.

Problems P1.1–P1.3

1.2 Equally Likely Events

Many computations in probability and statistics are based on the occurrence of equally likely events. First, an *event* is one possible outcome of an experiment. Several events can be combined to form another event. For example, if an engineer were looking for defective electronic components, the outcome of one defective component would be an event. Similarly, the occurrence of two defectives is an event. Computations can be performed for either of these events.

Equally likely events are events which have the same chance of occurring under stated conditions. The tossing of a fair coin is an example. Both heads and tails have a 50 percent chance of occurring. In tossing a fair die, the equally likely events of 1, 2, 3, 4, 5, and 6 on the top side have a 1/6 possibility of appearing. The events are not equally likely if the coin or die is unbalanced (loaded). In general, if there are n possible events and each is equally likely, each event has a 1 in n chance of occurring.