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Richard Valliant • Jill A. Dever • Frauke Kreuter

Practical Tools for Designing and Weighting Survey Samples

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Richard Valliant
University of Michigan
Ann Arbor, MI, USA

Jill A. Dever
RTI International
Washington, DC, USA

Frauke Kreuter
University of Maryland
College Park, MD, USA

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*To Carla and Joanna
Vince, Mark, and Steph
Gerit and Konrad*

Preface

Survey sampling is fundamentally an applied field. Even though there have been many theoretical advances in sampling in the last 40 or so years, the theory would be pointless in isolation. The reason to develop the theory was to solve real-world problems. Although the mathematics behind the procedures may seem, to many, to be impenetrable, you do not have to be a professional mathematician to successfully use the techniques that have been developed. Our goal in this book is to put an array of tools at the fingertips of practitioners by explaining approaches long used by survey statisticians, illustrating how existing software can be used to solve survey problems and developing some specialized software where needed. We hope this book serves at least three audiences:

- (1) *Students* seeking a more in-depth understanding of applied sampling either through a second semester-long course or by way of a supplementary reference
- (2) *Survey statisticians* searching for practical guidance on how to apply concepts learned in theoretical or applied sampling courses
- (3) *Social scientists* and *other survey practitioners* who desire insight into the statistical thinking and steps taken to design, select, and weight random survey samples

Some basic knowledge of random sampling methods (e.g., single- and multistage random sampling, the difference between with- and without-replacement sampling, base weights calculated as the inverse of the sample inclusion probabilities, concepts behind sampling error, and hypothesis testing) is required. The more familiar these terms and techniques are, the easier it will be for the reader to follow. We first address the student perspective.

A familiar complaint that students have after finishing a class in applied sampling or in sampling theory is: “I still don’t really understand how to design a sample.” Students learn a lot of isolated tools or techniques but do not have the ability to put them all together to design a sample from start to

finish. One of the main goals of this book is to give students (and practitioners) a taste of what is involved in designing single- and multistage samples in the real world. This includes devising a sampling plan from sometimes incomplete information, deciding on a sample size given a specified budget and estimated response rates, creating strata from a choice of variables, allocating the sample to the strata given a set of constraints and requirements for detectable differences, and determining sample sizes to use at different stages in a multistage sample. When appropriate, general rules of thumb will be given to assist in completing the task.

Students will find that a course taught from this book will be a combination of hands-on applications and general review of the theory and methods behind different approaches to sampling and weighting. Detailed examples will enable the completion of exercises at the end of the chapters. Several small, but realistic projects are included in several chapters. We recommend that students complete these by working together in teams to give a taste of how projects are carried out in survey organizations.

For survey statisticians, the book is meant to give some practical experience in applying the theoretical ideas learned in previous courses in balance with the experience already gained by working in the field. Consequently, the emphasis here is on learning how to employ the methods rather than on learning all the details of the theory behind them. Nonetheless, we do not view this as just a high-level cookbook. Enough of the theoretical assumptions are reviewed so that a reader can apply the methods intelligently. Additional references are provided for those wishing more detail or those needing a refresher. Several survey data sets are used to illustrate how to design samples, to make estimates from complex surveys for use in optimizing the sample allocation, and to calculate weights. These data sets are available through a host web site discussed below and in the R package `PracTools` so that the reader may replicate the examples or perform further analyses.

This book will also serve as a useful reference for other professionals engaged in the conduct of sample surveys. The book is organized into four parts. The first three parts—*Designing Single-Stage Sample Surveys*, *Multistage Designs*, and *Survey Weights and Analyses*—begin with a description of a realistic survey project. General tools and some specific examples in the intermediate chapters of the part help to address the interim tasks required to complete the project. With these chapters, it will become apparent that the process toward a solution to a sample design, a weighting methodology, or an analysis plan takes time and input from all members of the project team. Each part of the book concludes with a chapter containing a solution to the project. Note that we say “a solution” instead of “the solution” since survey sampling can be approached in many artful but correct ways.

The book contains a discussion of many standard themes covered in other sources but from a slightly different perspective as noted above. We also cover several interesting topics that either are not included or are dealt with in a limited way in other texts. These areas include:

- Sample size computations for multistage designs
- Power calculations as related to surveys
- Mathematical programming for sample allocation in a multi-criteria optimization setting
- Nuts and bolts of area probability sampling
- Multiphase designs
- Quality control of survey operations
- Statistical software for survey sampling and estimation

Multiphase designs and quality control procedures comprise the final part of the book—*Other Topics*. Unlike the other areas listed above, aspects related to statistical software are used throughout the chapters to demonstrate various techniques.

Experience with a variety of statistical software packages is essential these days to being a good statistician. The systems that we emphasize are:

- R[®] (R Core Team 2012; Crawley 2007)
- SAS^{®1}
- Microsoft Excel^{®2} and its add-on Solver^{®3}
- Stata^{®4}
- SUDAAN^{®5}

There are many other options currently available, but we must limit our scope. Other software is likely to be developed in the near term, so we encourage survey practitioners to keep their eyes open.

R, a free implementation of the S language, receives by far the most attention in this book. We assume some knowledge of R and have included basic information plus references in Appendix C for those less familiar. The book and the associated R package, `PracTools`, contain a number of specialized functions for sample size and other calculations and provide a nice complement to the base package downloaded from the main R web site, www.r-project.org. The package `PracTools` also includes data sets used in the book. In addition to `PracTools`, the data sets and the R functions developed for the book are available individually through the book's web site hosted by the Joint Program in Survey Methodology (JPSM) located at www.jpsm.org, from the Faculty page. Unless otherwise specified, any R function referred to in the text is located in the `PracTools` package.

Despite the length of this book, we have not covered everything that a practitioner should know. An obvious omission is what to do about missing data. There are whole books on that subject that some readers may find

¹ www.sas.com.

² office.microsoft.com.

³ www.solver.com.

⁴ stata.com.

⁵ www.rti.org/sudaan.

useful. Another topic is dual or multiple frame sampling. Dual frames can be especially useful when sampling rare populations if a list of units likely to be in the rare group can be found. The list can supplement a frame that gives more nearly complete coverage of the group but requires extensive screening to reach member of the rare group.

At this writing, we have collectively been in survey research for more years than we care to count (or divulge). This field has provided interesting puzzles to solve, new perspectives on the substantive research within various studies, and an ever growing network of enthusiastic collaborators of all flavors. Regardless from which of the three perspectives you approach this book, we hope that you find the material presented here to be enlightening or even empowering as your career advances. Now let the fun begin . . .

Ann Arbor, MI
Washington, DC
College Park, MD

Richard Valliant
Jill A. Dever
Frauke Kreuter
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Timothy Elig at the Defense Manpower Data Center consented for us to use the data set for the Survey of Forces-Reserves. Daniel Foley at the Substance Abuse and Mental Health Services Administration permitted us to use the Survey of Mental Health Organizations data set. Other data sets used in the book, like those from the National Health Interview Survey, are publicly available.

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