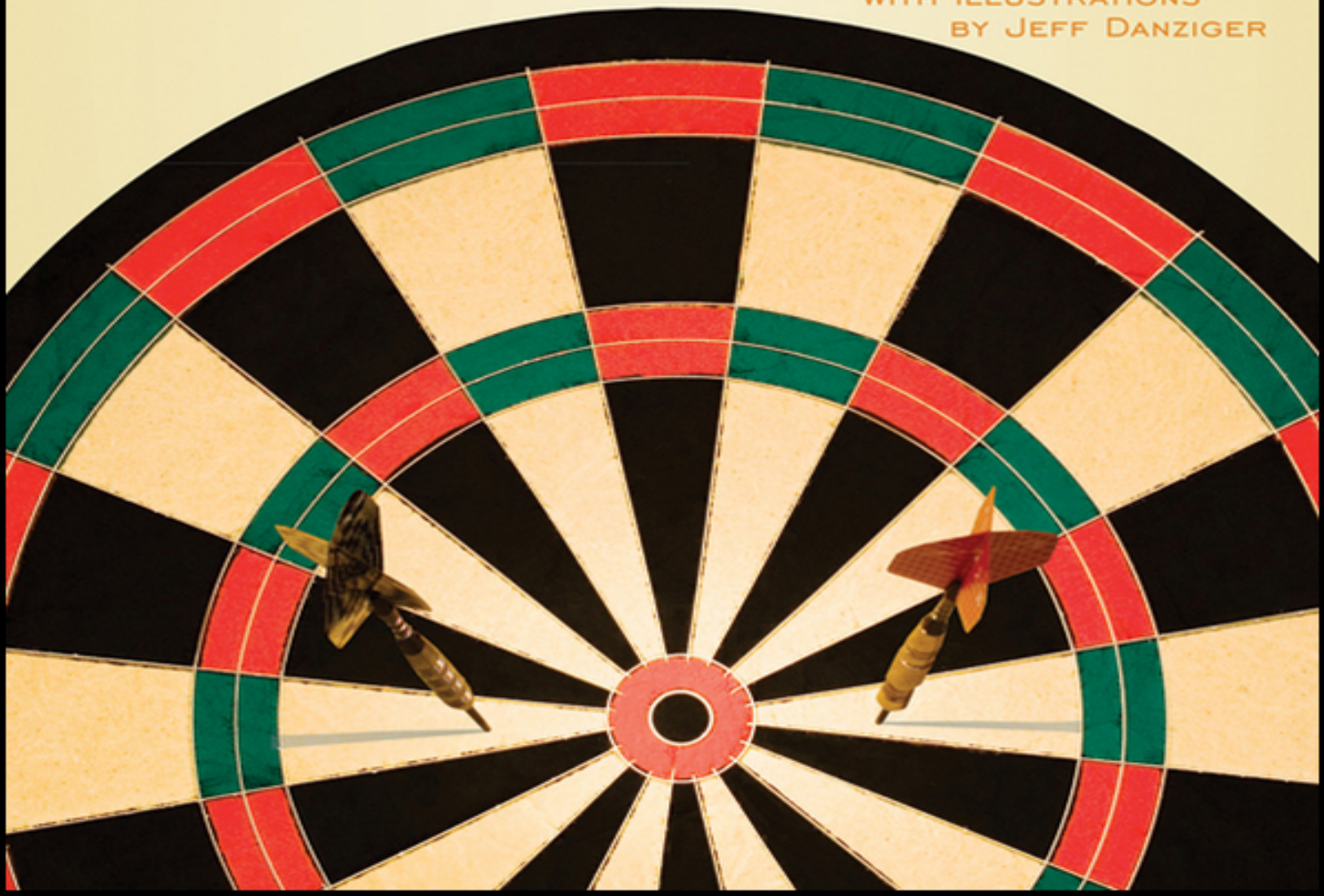
FOREWORD BY HARRY MARKOWITZ,
NOBEL LAUREATE IN ECONOMICS

WHY WE UNDERESTIMATE RISK IN THE FACE OF UNCERTAINTY

THE FLAW OF AVERAGES

SAM L. SAVAGE

WITH ILLUSTRATIONS BY JEFF DANZIGER



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The Flaw of Averages

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For Daryl, Jacob, and Russell, and in memory of Fruipit, our beloved dog

Foreword

Enterprise analysis under uncertainty has long been an academic ideal. In 1954 Sam Savage's father Leonard "Jimmie" Savage published *The Foundations of Statistics*, which addressed this subject through an elegant and highly mathematical framework for rational decision making. It had a profound effect on the fields of statistics and economics in the following decades. Sam, whose training is in computer science, has definitely not followed in his father's footsteps. Although deeply influenced as a child by Jimmie and his academic colleagues, he also spent time as an automobile mechanic, which taught him the value of tactile learning. Sam's approach to analyzing uncertainty developed relatively late in life, through running simulations on computers. In his book and tightly coupled Web site, Sam covers the knowledge required for grasping the fundamentals of uncertainty and risk, not with mathematical formulas, but with everyday items such as game board spinners and dice. He defines the *mindle* (*pronounced* mīn-dəl) as a handle for the mind, and provides five clear mindles for the concepts of risk attitude, uncertain numbers, diversification, plans based on uncertain inputs, and interrelated uncertainties.

He then goes on to show that when we use single numbers to estimate uncertain future outcomes that we are not just usually wrong, but are consistently wrong. He provides numerous examples of what he calls the Flaw of Averages, in which plans based on average assumptions are wrong on average. This is summarized in the Seven Deadly Sins of Averaging, in which it is apparent just how widespread these problems are in today's society.

In the same informal style he goes on to describe the foundations of modern finance, the first field to formally

conquer such problems. He then argues that the concepts of modern finance can be generalized to problems in healthcare, climate change, supply chains, the war on terror, and several other hot-button issues.

The last section of the book is devoted to what he sees as a potential cure for the Flaw of Averages. He recommends that the analysis take the form of a Monte Carlo simulation with which senior executives can interact, so that the user can draw on stochastic libraries that are available throughout the firm, that sublibraries can be combined and substituted, and that the results of any simulation include its pedigree, that is, the audit trail of the assumptions that went into it. While helping large firms better model their portfolios of risky projects, Savage developed a new data type, the *Distribution String*, which represents a major breakthrough in the communication of risk and uncertainty. It significantly widens the practical applicability of sound theory in these fields. This book describes these advances, which help transform the ideals of enterprise analysis under uncertainty into a practical reality.

Harry Markowitz

Nobel Laureate in Economics

Preface

The Flaw of Averages describes a set of common avoidable mistakes in assessing risk in the face of uncertainty. It helps explain why conventional methods of gauging the future are so *wrong* so *often*, and is an accessory to the recent economic catastrophe. Once grasped, these ideas can lead us to more effective forecasting and decision making. Traditionally, these topics have been the domain of probability and statistics. Although I will assume no prior knowledge of these subjects, for those who *have* had formal training in statistics, it should take only a few chapters to repair the damage.

My perspective no doubt derives largely from my father, Leonard Jimmie Savage. Although well *below* average on academic scales during his early education, he emerged as a prominent mathematical statistician who collaborated closely with Milton Friedman, among others. One of their students was the founder of modern portfolio theory, Harry Markowitz, who claims that my father "indoctrinated him at point blank range with rational expectation theory." Thus I am a child of the University of Chicago School of Economics.

Early on it was clear I possessed at least one of my father's traits. I, too, was a below-average student, displaying neither athletic nor academic aptitude. The defining moment of my high school education came in an after-class conference with my English teacher in my junior year at the University of Chicago Laboratory School. She explained that I was failing the course, but with a monumental effort might achieve a D by the second semester. Then she helpfully explained the underlying problem: The Lab School was for students who would go on to college, which, quite clearly, I would not. Instead she suggested a technical school where I could get practical training as a mechanic or a plumber.

She therefore presented me with my first serious career decision: to work my butt off for a lousy D in English or play my guitar for immediate gratification. I made the obvious choice, and music has brought me joy and solace ever since. Better yet, I was able to have my cake and eat it too, because I ended up with a D anyway. In retrospect I cannot question this individual teacher's judgment, because all told I received three D's in four years of high school English, each under a different instructor.

My father was in no position to complain, because when *he* graduated from high school in Detroit, he too "was classified by his teachers as 'not college material,' and consequently was refused admission to the University of Michigan."[1] My grandfather, in desperation, called on personal connections to get him admitted on probation to Wayne State University. Allen Wallis, with whom my father later cofounded the University of Chicago Statistics Department, reported what happened next: "In his year [at Wayne] he established a good enough record to be admitted on probation to the University of Michigan. However, he caused a fire in a chemistry laboratory and was expelled." [2]

Once again I followed in my father's footsteps, later flunking out of the University of Michigan myself, although based on academics rather than involuntary arson.

As adolescent misfits, then, neither of us was able to conform to the norms expected by our teachers. Thus nonaverageness itself became a family value, perhaps in some way inspiring this book. After being de-Michiganized, however, our careers diverged. My father fought his way back into Michigan, got his PhD in mathematics, and achieved great academic acclaim. I worked as a mechanic and briefly raced a sports car before ultimately getting a degree in computer science, which is, in deference to my English teacher, just plumbing with bits of information instead of water.

Although *The Flaw of Averages* will discuss concepts from both statistics and economics, I have little formal training in either of these subjects—just the basics picked up at an early age at the dinner table. Therefore, I have written not from the perspective of a statistician or an economist, but from the perspective of a former mechanic and current plumber of information who grew up surrounded by statisticians and economists.

I came up with some of the core ideas and title for this book in 1999, and I started writing. I knew the concept had potential, but somehow the book was not uplifting: The Flaw of Averages asserts that everything is below projection, behind schedule, and beyond budget. Where was the happy ending?

In search of one, I continued to teach, consult, and write articles about various aspects of this problem. Feeling the need to stake out the real estate (in case I ever did finish the book), I wrote an article in October 2000 on the Flaw of Averages for the *San Jose Mercury News*.[3] When it was published, it was, to my surprise, adorned with a drawing by the renowned cartoonist Jeff Danziger depicting a statistician drowning in a river that is on average three feet deep. This is reproduced in Chapter 1 of this book.

Over the years, I have had the good fortune to interact with some exceptional people in academia and industry who were grappling with the Flaw of Averages themselves. As a result of this interaction, an approach that we call Probability Management has recently emerged, offering a potential cure for many variants of this problem. And so at last with a happy ending in hand, I renewed my writing efforts in earnest in 2006. All told, on *average*, I have written 21 words per day since 1999.

When my stepbrother, John Pearce, first heard of this writing project, he assumed that I was working through some sort of psychodrama involving my late father. Wrong.

This work has been fueled by a psychodrama involving my high school English teachers.

Sam L. Savage

Palo Alto, California

April 2009

Notes

1. A. F. M. Smith, *The Writings of Leonard Jimmie Savage—A Memorial Collection* (Washington, DC: American Statistical Association and The Institute of Mathematical Statistics, 1981), p. 29.

2. Ibid., p. 14.

3. Sam L. Savage, “The Flaw of Averages,” Soapbox column, *San Jose Mercury News*, October 8, 2000.

Acknowledgments

I must start by chronologically acknowledging those who were directly involved in the evolution of Probability Management. I am indebted to Ben Ball of MIT, first for infecting me with his interest in portfolios of petroleum exploration projects in the late 1980s, and second for the collaboration that laid the foundations for much that lay ahead. In 1992 Mark Broadie of Columbia University gave me a key (a simple spreadsheet model) that unlocked a world of stochastic modeling. In 2003 I had the pleasure of working with Andy Parker of Bessemer Trust on a retirement planning model that pioneered some important ideas in interactive simulation. In 2004, I began an exciting three-way collaboration with Stefan Scholtes of Cambridge University and Daniel Zweidler, then at Shell. This truly put Probability Management on the map with a large interactive simulation application at Shell and a coauthored article in *ORMS Today*. During this time, Dan Fylstra of Frontline Systems made a breakthrough in interactive simulation, turning my dream of interactive simulation in spreadsheets into reality.

The following group also played critical roles in the development of this book. My father, Leonard Jimmie Savage, and his colleagues Milton Friedman and Allen Wallis served as towering intellectual role models from my earliest memories. Next, I must thank Linus Schrage of the University of Chicago for his collaboration on What's *Best!*, without which I would not have been reborn as a management scientist. By supporting my seminar series on management science in spreadsheets, Jack Gould, then dean of the University of Chicago Graduate School of Business, helped launch the odyssey during which I discovered the Flaw of Averages. Stanford's Department of

Management Science and Engineering, with which I have been affiliated since 1990, has been the ideal environment in which to experiment with and teach the ideas underlying the book. I owe special thanks to Peter Bernstein, whose own book, *Capital Ideas*, assisted me in my own work and who personally helped get this book off the ground. In 1999, Mina Samuels, who was then an editor for John Wiley & Sons, was inspirational in helping me conceive the book and, when I tracked her down in 2007, was even more supportive as a midwife. In the meantime, Bill Falloon, who inherited my nine-year project at John Wiley, deserves the Most Patient Editor of the Century Award: Thanks. Bill Perry of Stanford University has served as both an inspiration and a foundation of support. Marc Van Allen, of the law firm Jenner and Block, realized that the Flaw of Averages underlies the nation's accounting standards and collaborated in researching and publicizing the issue. Several chapters were inspired by discussions with Howard Wainer, and by a prepublication draft of his book, *Picturing the Uncertain World: How to Understand, Communicate and Control Uncertainty Through Graphical Display*, which I highly recommend. Finally, I owe special thanks to David Empey and Ronald Roth for their programming support over the years and in particular for the implementation of the application at Shell and subsequent development of the DIST (Distribution String) data type.

When it takes you nine years to write a book, there is plenty of time to pick up useful ideas from others. So many people provided assistance, contributions, or comments over the years that they won't fit into a paragraph. Therefore I have used the following table. The laws of probability ensure that I have missed a few people who belong here, for which I apologize in advance.

Dick Abraham

Bob Ameo

Ted Anderson
Matthias Bichsel
Adam Borison
Jerry Brashear
Stewart Buckingham
Mike Campbell
David Cawlfield
Kevin Chang
Terri Dial
Mike Dubis
Ken Dueker
David Eddy
Brad Efron
Martin Farncombe
Roland Frenk
Chris Geczy
Bob Glick
Peter Glynn
Joe Grundfest
Deborah Gordon
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Warren Hausman
Wynship Hillier
Gloria Hom
Ron Howard
John Howell
Doug Hubbard
Darren Johnson
Martin Keane
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Paul Kucik

Andrew Levitch
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David Luenberger
Jeff Magill
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Michael May
Rick Medress
Robert Merton
Mike Naylor
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John Pearce
Mark Permann
Bill Perry
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In the end, I could not possibly have written this without the guiding light of my wife Daryl, who helped extensively with the editing and who continues to make life so much fun.

S. L. S.

INTRODUCTION

Connecting the Seat of the Intellect to the Seat of the Pants

The only certainty is that nothing is certain.

—Pliny the Elder, Roman scholar, 23–79 CE

As the financial meltdown of 2008 has demonstrated, Pliny is still pretty much on target two millennia later. Despite all its promise, the Information Age is fraught with a dizzying array of technological, economic, and political uncertainties. But on the flip side, the Information Age also offers electronic extensions of our intuition that can provide a new experiential feel for risk and uncertainty. This book shows how.

Let's start off with a simple everyday example in which most people's intellects fail. Imagine that you and your spouse have an invitation to a ritzy reception with a bunch of VIPs. You must leave home by 6 p.m. or risk being late. Although you work in different parts of town, each of your average commute times is 30 minutes. So if you both depart work at 5:30, then you should have at least a 50/50 chance of leaving home together for the reception by 6 o'clock.

This thinking sounds right. But your instinct warns that you will probably be late. Which is correct: your brain or your gut?

Your gut is correct, but not being particularly good with words, it may have difficulty winning the argument