

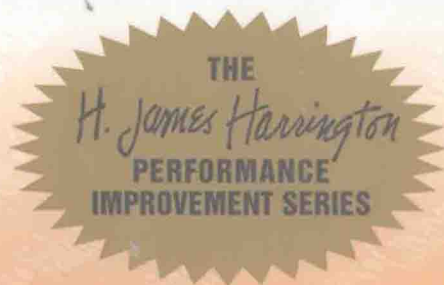
Statistical Analysis Simplified

THE EASY-TO-UNDERSTAND GUIDE TO SPC AND DATA ANALYSIS

H. JAMES
HARRINGTON

INTERNATIONAL QUALITY ADVISOR, ERNST & YOUNG LLP

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Statistical Analysis Simplified

*The Easy-to-Understand
Guide to SPC and
Data Analysis*

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Glen D. Hoffherr

Robert P. Reid, Jr.

McGraw-Hill

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About the Series

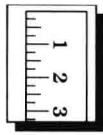
Statistical Analysis Simplified is one title in McGraw-Hill's Harrington's Performance Improvement Series. The series is designed to meet an organization's need to understand the most useful approaches now available to bring about improvements in organizational performance as measured by:

- ▶ Return on investment,
- ▶ Value added per employee, and
- ▶ Customer satisfaction.

Each title in the series is written in an easy-to-read, user-friendly style to reach employees at all levels of an organization. Our goal is to present complex methodologies in a way that is simple but not simplistic. The following are other subjects covered in the books in this series:

- ▶ Statistical Process Control
- ▶ Process Redesign
- ▶ Process Reengineering
- ▶ Establishing a Balanced Scorecard
- ▶ Reliability Analysis
- ▶ Fostering Teamwork
- ▶ Simulation Modeling
- ▶ Rewards and Recognition
- ▶ Managing the Change Process

We believe that the books in this series will provide an effective way to learn about these practices as well as a training tool for use in any type of organization. In each title in the series, the design features a series of icons in the margins that call your attention to different points. Use these icons to guide your reading and study:



Requirement, Rule,
or Principle



Example



Concept or Idea



Quote



Guide



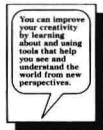
Exercise



Definition



Checks and Alarms

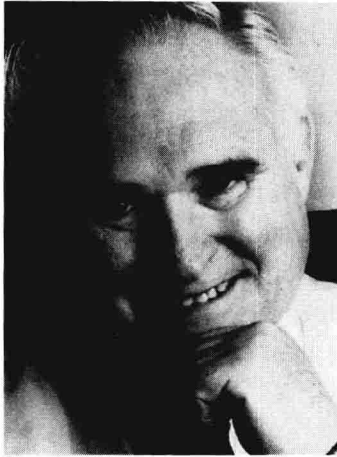


Discussion

It is our hope that you will find this series of Performance Improvement Management books enjoyable and useful.

H. James Harrington
Principal, Ernst & Young LLP
International Quality Advisor

About the Authors



Dr. H. James Harrington is one of the world's quality system gurus with more than 45 years of experience. He has been involved in developing quality management systems in Europe, South America, North America, and Asia. He currently serves as a Principal with Ernst & Young, LLP and is their International Quality Advisor. He is also chairman of Emergence Technology Ltd., a high tech software and hardware manufacturer and developer.

Before joining Ernst & Young LLP, he was president of the consulting firm Harrington, Hurd, and Rieker. He was a Senior Engineer and Project Manager for IBM, and for almost 40 years, he worked in quality function. He was chairman and president of the prestigious International Academy for Quality and the American Society for Quality Control. He has released a series of videos and CD ROM programs that covered ISO 9000 and QS-9000. He has also authored a computer program on benchmarking, plus members' video tapes on performance improvement. He has written ten books on performance improvement and hundreds of technical reports.

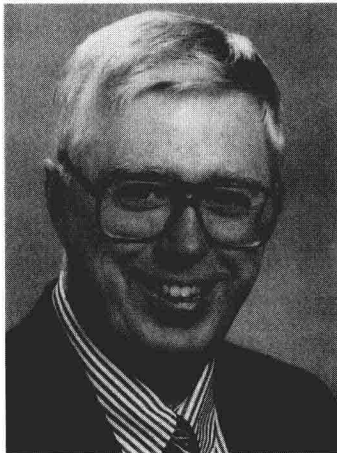
The Harrington/Ishikawa Medal was named after him in recognition of his support to developing nations in implementing quality systems. China named him their Honorary Quality Advisor, and he was elected into the Singapore Productivity Hall of Fame. He has been elected honorary member of seven quality professional societies, and has received numerous awards and medals for his work in the quality field, including the 1996 Lancaster Award from ASQC in recognition of his work to further the Quality Movement internationally.



Glen D. Hoffherr is a senior consultant for James Martin Government Consulting. He has spent over 20 years in management in the high technology industry. For the last eight years he has been a consultant and author focusing on strategic planning, organizational design, change management, and creative decision making.

He has authored, co-authored, or been a contributing author to more than 15 books and numerous magazine articles. He is an animated, interesting, and entertaining speaker who has lectured at national and international conferences on five continents, and at numerous colleges and universities around the world.

He has worked with organizations in many fields including local, state, and national government, foreign governments, telecommunications, high technology, service, manufacturing, health care, and software.



Robert P. Reid, Jr., is a dynamic and innovative presenter, with over 30 years experience as an educator, author, speaker and organizational developer. Reid has written extensively in the areas of organizational change management, creative thinking, and systems design. He has worked with more than one hundred major organizations on six continents, and has conducted courses and seminars at seventeen universities. His ability to communicate complex systems issues in a clear non-threatening fashion is recognized world-wide.

Dedication

This book is dedicated to the two men who taught me the power of numbers. The first was my father, Robert P. Reid, Sr., who from an early age provided me with an endless set of mathematical games, puzzles, and conundrums that stimulated my ability to think quantitatively. The second was W. Edwards Deming, who taught me that most things in life cannot be measured. He was fond of saying, “The important things in life are unknown and unknowable. How can you measure the impact of an unhappy customer; for that matter how can you measure the impact of a happy customer?”

Bob Reid

Foreword

Why Numbers Are Important

Measurement stands as one of the great inventions of all time. Every day we make thousands of decisions—what to eat for breakfast, which route to take to work, and so forth. This book is about making better decisions using numbers. Many of our everyday decisions contain the question “How much?” or “How many?” The answers to these and many other questions involve measurement and numbers. “What time do I have to get up tomorrow?” The answer is a number, 6:30 A.M.

That answer is a measure of time. When ancient people first began measuring time, they based their measurements on observations of night and day, changing seasons, and cycles of the moon. These observations became the basis for units of measure that we now call days, months, and years. As life became more complicated, the Babylonians used the sundial to segment the day into 12 parts, each called an hour.

Measures of weight likewise go back to ancient times—over 5,000 years. Egyptian tombs dating to 4000 B.C. contain stone weights. Ancient Egyptians used weights on balance pans to weigh gold. And when you buy groceries, you base many of your purchasing decisions on this common measuring concept. If you ask yourself, “How much hamburger do I need to make meatloaf for my family?” the answer will be in pounds or kilograms. Think of your supermarket and the many everyday products that are bought and sold on the basis of weight. You can buy fresh meat, vegetables, butter, sugar, flour, and coffee by the pound or the kilogram. Many manufacturing processes are also controlled on the basis of weight. Chemical manufacturers measure the ingredients in their processes to ensure the quality of their products.

The history of measurement is a fascinating story of methods that evolved as civilization progressed. In ancient Egypt, the Nile flowed quietly for most of the year. Farmers tended their crops and worked their farms. When the spring floods roared down the Nile, all signs of their fields were washed away. After the flooding river deposited thousands of tons of rich silt on top of the fields, each farmer asked, “Where is my field?” Posts and stone markers could not withstand the flood waters. The solution the Egyptians developed was a means of measuring accurately from a distant point of reference beyond the flood waters. They invented surveying.

If you stop in a fabric store to buy cloth for a new garment, you ask yourself, “How long a piece of fabric do I need?” Length is another measuring concept that dates back over 5,000 years. Measuring length requires comparing one thing to another. Measurement sticks were used to determine length in ancient times. Because sticks could get lost and were of different sizes, it became more convenient to use parts of the human body as standards for length measurement. When building the pyramids, the Egyptians used a measure of length called a *cubit*, which was the distance from a man’s forearm to his fingertip. Body standards were so practical that other parts of the body became standards of measurement. The Romans used the width of the thumb and called it an *uncia*, forerunner of the English word *inch*. A man’s foot was approximately 12 thumbs long; thus 12 inches became a foot. This system worked well until the Middle Ages and the spread of commerce. Because a tradesman could go broke if he had large hands and feet, a universal standard was needed. But whose foot would become the standard? The answer was “the king’s.” To this day, we do not say, “Pass me the king’s foot” when we want to measure something. We say, “Pass me the ruler.”

The numbers used to express measurement also evolved over time. Although base ten numbers seem very logical and familiar to us, it took centuries for the base ten system to evolve. The ancient Egyptians, Babylonians, Greeks, and Romans used symbols different from those in our current system. Imagine a very early counting system in which a shepherd made a mark on a stick or piece of bark for each sheep he owned: A large herd would require a lot of bark and a great many marks. A shorthand developed to represent a group of sheep with a special mark. These special marks, like spoken and written language, evolved differently in different societies (see examples).

Numerals for 1, 10, 100 from Five Civilizations		
Egyptian 3000 B.C.		
	∩	9
1	10	100
Babylonian 1500 B.C.		
√	<	√>
1	10	100
Chinese 500 B.C.		
—	+	百
1	10	100
Greek 400 B.C.		
α	ι	ρ
1	10	100
Roman 200 B.C.		
I	X	C
1	10	100
Arabic A.D. 800		
1	10	100

Not only did symbols differ, but methods for calculations and arithmetic took many forms. About A.D. 600, the Hindus made one of the greatest mathematical breakthroughs of all time with the concept of zero. They invented the symbol 0 , meaning empty space. Modern numerals use zeros as place holders—for instance, 307 is short for three of hundreds, none of tens, and seven of ones. The concept is so simple but so very powerful.

The Power of Numbers

The power of numbers lies in simplicity, but simplicity can be misleading. Oliver Wendell Holmes said, “I would not give a penny for simplicity on this side of complexity, but I would give my purse for simplicity on the other side

of complexity.” Numbers are powerful tools for making better decisions, but numbers alone cannot make decisions. People make decisions.

People run processes. People manage organizations. People create the future. Ultimately, there are no answers, only more questions. We designed this book to help you think about ways to use numbers to make better decisions. You must make the decisions. Numbers help you answer the three basic questions concerning every decision:

1. Am I getting the results I want?
2. Is there too much variation in the results I get?
3. Are the results I get stable over time?

Let’s try out these questions on chocolate chip cookies. The first question is

1. Am I getting the results I want? Are the cookies
 - the right size?
 - done correctly?
 - the proper thickness?

To determine the answers, you must have a standard or reference. Here is our standard: We like our cookies 2 inches in diameter, dark brown on the edges, soft, and with lots of chocolate chips. If the cookies meet these requirements, then by our standards they are good.

The second question is

2. Is there too much variation between cookies? Are the cookies
 - the same size?
 - made with the same number of chocolate chips?

To answer these questions, you must compare each cookie to the others.

The third question is

3. Are they stable over time? Will each batch of cookies
 - produce the same results?
 - be baked the same way every day?Have I found a way to make good cookies consistently?

You may not care about baking cookies, but the least threatening way to talk about measurement is to use simple examples. Baking a pie, driving a car across a bridge, and correcting your golf swing are examples of actions

that can help you visualize how numbers and measurement can help you understand the issues you face.

As you read this book, try to translate the logic and power of measurement to your own applications. Measurement can be fun if you overcome your fear of math. The good news is that because you live in the computer age, you probably will never have to use the boring long division you learned in school. Measurements and numbers pour out of computers. We are tapping more of their potential every day. This is not a book about computers. It is not even a book about mathematical calculations. It is a book about how you can use measurement, numbers, and data to help you do what you have to do and make better decisions. If you don't know what you want to do, then this book cannot help you.

Each of the book's 10 chapters can stand by itself. However, we have structured the book so that each chapter builds on what you have learned in the preceding one. Following are the concepts covered in each chapter.

- CHAPTER 1.** How to use measurement as an objective language for promoting honest and open communication
- CHAPTER 2.** How looking at groups of numbers gives you insights into the way things are
- CHAPTER 3.** How you can find one number that represents a large group of numbers
- CHAPTER 4.** How looking at sets of numbers over time reveals trends and movement
- CHAPTER 5.** How to use data as a guideline for deciding when to take action for change and when to leave things alone
- CHAPTER 6.** How to use numbers to compare what you are doing with what your customers and end users want
- CHAPTER 7.** How to experiment to find and identify better methods
- CHAPTER 8.** How to divide things into subsets so you can study your process
- CHAPTER 9.** How to find out why things are as they are by identifying cause-and-effect relationships
- CHAPTER 10.** How to put all these good ideas to work in your organization

Following the 10 chapters are two appendices. **Appendix A** provides additional information about control charts, and **Appendix B** gives answers to questions and quizzes found throughout the book. We have included a bibliography of resources that will give you additional information about the use of numbers and a glossary of terms used throughout the book.

The CD-ROM inside the back cover provides a visual introduction to the power of measurement. The chapters in this book are like tools in a toolbox. They won't do you much good if they stay in the box. For a hammer to work, you must pick it up and use it. Rarely do you use every tool in your toolbox for a given job. On some jobs, certain tools may get used more than once. When you first begin using tools, you may not be very handy with some of the them. Don't become discouraged. Keep using the tools, and you will become more adept at making them work for you. We urge you to try one or two of these tools the next time you need to make a decision. As you become proficient with one tool, begin using another to make your job easier. If a tool complicates your decision-making process, don't use it. We know that once you start using these tools well, you will use them often.

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Measurement

An Objective Language for Communication

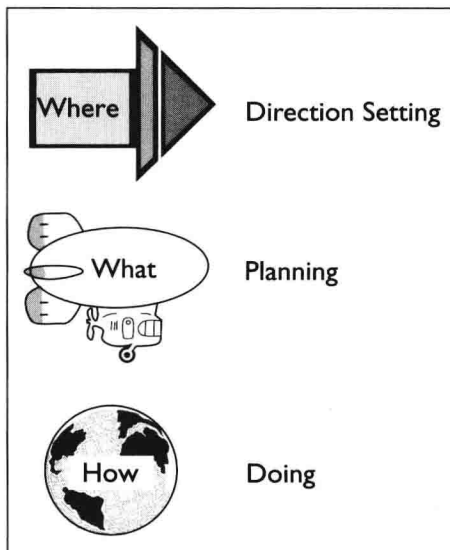
Introduction

This chapter will give you practical insight into the nature of measurement. Measurements have different uses in the management of an organization's work. The first section of the chapter explains that measurement can be used to set directions, establish plans, or track work. All three are important; all must be done. The second section tells you to get MAD—measure, analyze, and do. These elements are the big three of every individual and organizational decision. The third section introduces the measurement chain. Measurement in itself does not accomplish much. Measurement must be connected to key success factors. Numbers, like people, assume different sizes and shapes. Matching the type of measurement with the type of decision to be made is important. The favorite question of every four-year-old—"Why?"—applies to measurement as well. Answering the question of why numbers are important to you is your first step on the road to making decisions based on sound numerical information. The

chapter ends with simple step-by-step guidelines for collecting numbers by using a check sheet.

Three Points of View

The greatest obstacle to the use of numbers is the mistaken idea that they are difficult to understand. Now, we'll admit that using numbers to make better decisions can involve some high-powered mathematics, but you don't have to be a mathematician to use numbers.



You can view everything you do from three important points of view. The first is setting the *direction* you want to move in. The second is *planning* how you are going to move in that direction. The third is actually *doing* the work to get to where you want to go—implementing your plans. For an organization to succeed, everyone, every day must consider and take account of these three points of view.

In many organizations, the executives alone set direction. Managers do the planning work as part of their

back-office responsibilities. The rest of the employees implement the tasks on the front line. All projects involve setting direction, planning how to move in that direction, and implementing the plans.

We have all planned, cooked, or enjoyed meals. Someone must set the direction and determine the menu for tonight's dinner. Someone must plan for buying the ingredients and choosing the recipes. Finally, someone must prepare the ingredients, cook the food, and serve the meal. It may be that the same person performs all of these tasks, or they may be done by a team of people.