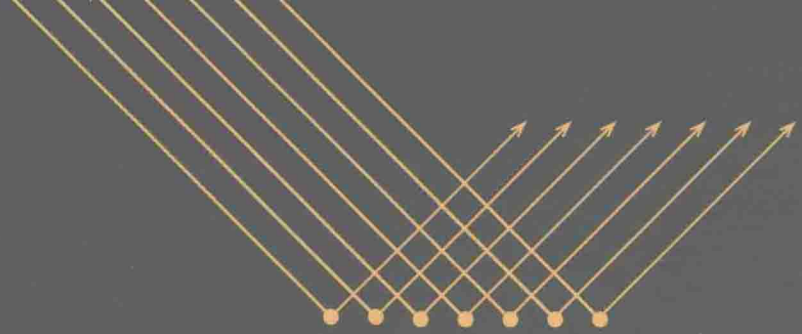

Statistical Process Control and Quality Improvement

Third Edition

Gerald M. Smith

Third Edition

STATISTICAL PROCESS CONTROL AND QUALITY IMPROVEMENT

Gerald M. Smith
Cayuga Community College

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To Julie

PREFACE

The third edition was written to update the text, expand the coverage on selected topics, arrange the topics in a better logical sequence, and increase the number of exercises. Chapter 13 has been eliminated and the case studies that were in it along with others have been placed throughout the text by topic. Chapter 4 has been completely rewritten by moving the introduction to control charting to Chapter 6 and consolidating all the other statistical tools used in SPC in the new version. This creates a better learning sequence of introduction to statistics followed by statistical tables, charts, and graphs; then on to normal curve concepts and an expanded section on the central limit theorem; and finally to control charts.

More work has been done in Chapter 2 with Deming's contributions to quality improvement. Also, the work on Total Quality Management (TQM) and customer-driven quality has been increased. The applications of SPC to the service sector have been expanded: There are more illustrations of how and to what extent it can be applied and more service sector exercises. The expanded coverage of the central limit theorem in Chapter 5 shows the underlying logic in its application to control charts. The importance of classifying the type of variation as special cause or common cause with the use of control charts and its consequences in reducing or eliminating variation has been stressed.

The basic algebra section has been eliminated in Chapter 3, but has been retained in Appendix A for those who wish to review the use of signed numbers and algebra before the introduction to statistics. In Chapter 6 a simpler method for estimating control chart scales is introduced. The introductory control chart work was moved in from the previous Chapter 4 and the short-run $\bar{x}$ and R charts have been moved in from Chapter 7, so all the $\bar{x}$ and R chart variations are in one chapter. More has been done with continuation charts in the explanation and in the exercises. A new discussion on the effect of sample times on control chart patterns is presented in Chapters 6 and 9.

The problem-solving tools have been taken out of Chapter 10 and placed in Chapter 4 for a cohesive treatment of statistical tables, charts, and graphs. More work has been done with team building and mistake proofing in Chapter 10, and a new section on

problem solving in the classroom is included. Appendix A has been streamlined and now contains just the basic algebra review and the optional work with probability. All the other topics have been placed in the appropriate sections of the text.

NEED

Statistical process control (SPC) is not a new topic in industry: It has been used off and on since its development in the 1920s. However, since the 1970s it has become an extremely important tool. A new economic age is developing in which the demand for quality is rapidly increasing, with a resulting global competition of companies striving to provide that quality. The detection system of final inspection, a costly method of quality control, is giving way to a prevention system that uses in-process inspection and SPC to build quality into a process. This change requires extensive training in SPC. Also, for the most effective application of SPC, management must coordinate a team effort in which everyone in the work force can contribute meaningfully to the quality effort.

PURPOSE

This book was written with the following goals:

1. To provide an understanding of basic statistical concepts.
2. To present a management philosophy for successful application of statistical process control.
3. To give the student a solid foundation on control charts: setting scales, charting, interpreting, and analyzing process capability.
4. To teach the student the quality concepts and problem-solving techniques associated with statistical process control.
5. To provide a readable source of SPC topics that the student can refer to as the on-the-job need arises.

FLEXIBILITY

The book is designed for use in two-year and four-year colleges, as well as industry. The order of the chapters features a low-level mathematics approach so that anyone with a basic mathematics background can learn the control chart concepts in Chapters 1 through 9 and the problem-solving concepts in Chapter 10.

The book is mathematics friendly:

- Only the needed mathematics is presented.
- The mathematics knowledge that is required for each topic is reviewed at the introduction of the topic.

The entire book contains enough material for a three-credit-hour course. The mathematics prerequisite for someone studying the entire book should be elementary algebra.

The recommended sequence for college is Chapters 1 through 12, with the basic algebra in Appendix A reviewed at the beginning of Chapter 3. The probability section in the Appendix is optional and can be taught with the introduction to probability in Chapter 5 or with the applications of probability in Chapters 7 or 9. One possible variation in the sequence would be to do Chapter 9 after Chapter 5. Then all of the out-of-control patterns would be available for analyzing the control charts presented in Chapters 6, 7, and 8. The book sequence introduces a few basic out-of-control patterns for use in the presentation of control charts, followed by a more comprehensive analysis after all the control charts have been introduced. Another variation would be to follow the sequence of topics from the previous edition and do Chapters 1 through 4, the introductory control chart work in 6.1–6.4, and then Chapter 5, the rest of Chapter 6, and the following chapters in order. Chapter 9 can also be done at the end of Chapter 5 in this sequence too.

The recommended sequence for industry is Chapters 1 through 10. Chapters 11 and 12 are more job specific and may be taught to particular groups. The probability in Appendix A can be taught at any time if a more thorough understanding of the probability concepts in chart interpretation or sampling is desired. The basic algebra in Appendix A can be taught at the beginning of Chapter 3.

EXAMPLES AND ILLUSTRATIONS

The examples have been carefully chosen to provide a thorough understanding of the concepts involved. A detailed, step-by-step format has been used throughout the book to provide a pattern that can be used effectively, both for the immediate problems and for future reference. The examples feature worksheets and control charts to be filled in by the student and completed worksheets and charts for checking results. Control chart masters have been included at the end of the solutions manual.

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1

INTRODUCTION TO QUALITY CONCEPTS AND STATISTICAL PROCESS CONTROL

OBJECTIVES

- Know the definitions of quality.
- Know the statistical signals that are used to improve a manufacturing process.
- Differentiate between the detection model and the prevention model for quality control.
- Identify the goals for using statistical process control (SPC).
- Learn the techniques that utilize SPC.
- Identify several positive effects of SPC.
- Learn the problem-solving model that utilizes SPC for process improvement.
- Describe the important aspects of quality.
- Know the seven tools for SPC.
- Describe how designed experiments are used.

1.1 WHAT IS QUALITY?

Quality can mean different things to different people and can be interpreted in a variety of ways by an individual. Quality may be thought to have two main divisions: the quality of a manufactured product and the quality of services received. From a manufacturing standpoint quality is simply conformance to specifications. The ultimate customer could describe quality as fitness for use. When trying to edge out the competition, quality can be interpreted as producing the very best product or providing the very best service. In some industries a set of classifications have been established by *design quality.* For example, several levels of design quality exist in the automotive industry, from top-of-the-line luxury models down to economy cars. At each level, however, the buyer would

expect good *conformance quality.* In fact, auto manufacturers encourage in-class comparisons to show that they have the best conformance quality in their class. Buyers who are not pleased with the overall quality of a specific model car are encouraged to "step up" a class or two (for more money, of course!). In the service sector, the hotel industry provides a good example of differences in design quality. All hotels and motels provide a place to sleep, but many features of design quality, such as services available, comfortable to luxurious surroundings, exercise rooms, pools, and hot tubs, separate the bargain hotel from a five-star hotel. Companies that produce products at the higher levels of design quality and companies that produce products for a market that has primarily a single level of design quality would be more inclined to use the combination of the two categories which stresses excellence in the quality definition.

Quality can also be linked to customer satisfaction. Some companies have used that definition for years, but there is now a broad move toward defining quality as total customer satisfaction. To use that definition, a company must know its customer, and in the multilevel markets, it must know the customers at each level for which it produces. The customer is becoming the driving force for quality.

Many companies that initially aimed at improving the quality of their products found that to satisfy the final customer, it was necessary to satisfy a whole sequence of internal customers. Each person involved in the manufacturing process received a partially completed product, performed the assigned operation(s), and passed it on to the next person. At each step in the process the internal customer had to receive a quality product and pass on a quality product. Away from the manufacturing area, those responsible for the order entry, shipping, and billing were also involved in achieving total customer satisfaction. Again, the final customer cannot receive a quality product unless the associated internal customers receive a quality product as well. This awareness led to the concept of total quality, that there are no exceptions to producing quality work. Everyone in a manufacturing environment or in the service sector has customers, internal or external, and must maintain total customer satisfaction.

One more recent development in the definition of quality is that of exceeding the customer's expectations. When the service is so good that the customer feels "special," when a product has an outstanding feature, or when the combination of product, service, and delivery leaves the customer truly amazed, the customer's expectations have been exceeded. Exceeding customer expectations has been extremely effective in building a loyal customer base. It is estimated to be five to seven times more costly to attain a new customer than it is to retain a current one, so it makes a lot of sense to go that extra step.

Quality is

1. Fitness for use
2. Conformance to specifications
3. Producing the very best products
4. Excellence in products and services
5. Total customer satisfaction
6. Exceeding customer expectations

Total quality in an organization means simply that quality work is expected in every job. There are no exemptions. When something is done, it should be done right the first time. When a product is made, it should be defect-free. When a service is provided, the customer should be pleased with the result. Total quality has evolved as a necessary process for delivering a quality product or service. (Figure 1.1).

FIGURE 1.1
Quality definitions.

1.2 THE NEED FOR SPC

Dedication to constant improvement in quality and productivity is needed to prosper in today's economic climate. Yesterday's standards are not good enough. A company's product has competition from companies throughout the world because modern communication and transportation have created a world marketplace. The quality of a product has to be *world class,* as good as the best in the world, in order to compete. Consumers are looking for the best combination of price and quality before they buy. The "Made in America" label is no longer enough to sell a product. If U.S. companies want to succeed in a world market, their products must be competitive.

Today each company employee must be committed to the use of effective methods to achieve optimum efficiency, productivity, and quality to produce competitive goods. Statistical process control (SPC), in its broad sense, is a collection of production methods and management concepts and practices that can be used throughout the organization. SPC involves the use of statistical signals to identify sources of variation, to improve performance, and to maintain control of production at higher quality levels. It can be applied to any area where work is done. The statistical concepts that are applied in SPC are very basic and can be learned by everyone in the organization. Production workers must know how SPC applies to their specific jobs and how it can be used to improve their output. Supervisors must be aware of the ways SPC can be used in their sections, be prepared to help their production workers utilize SPC, and be receptive to suggestions for improvements from the workers who are effectively using SPC. Man-