Quality Management in Systems

by Guangming Zhang

- Deming Criteria
- Statistical Quality Control
- Malcolm Baldrige
- ISO9000
- Total Quality Management

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To my wife Jinyu
And my children Zumei and Haowei

who have always been with me especially at those difficult times. Their love and understanding have supported me in a journey for survival and success

ABOUT THE AUTHOR

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Professor Zhang worked at the Northwest Medical Surgical Instruments Factory in China where he served as a principal engineer to design surgical instruments and dental equipment. He also taught at the Beijing Institute of Printing and received the National Award for Outstanding Teaching from the Press and Publication Administration of the People's Republic of China in 1987. In 1992, he was selected by his peers at the University of Maryland to receive the Outstanding Systems Engineering Faculty Award. Also in 1992, he was a recipient of the Blackall Machine Tool & Gage Award of the American Society of Mechanical Engineers. He was the recipient of the E. Robert Kent Outstanding Teaching Award of the College of Engineering in 1993. In 1995 and 1997, he received Awards of Commendation from the Society of Manufacturing Engineers, Region 3, for his outstanding service as the Faculty Advisor to the SME Student Chapter at College Park.

He has actively participated in the NSF sponsored ECSEL grant since 1990. He currently serves as the principal investigator for this grant at the University of Maryland, and coordinates the ECSEL sponsored projects on integration of design, on active learning and hands-on experiences, and on developing methods for team learning. He is an Associate Editor of the International Journal of Advanced Manufacturing Systems, and a member of the editorial board of the International Journal of Flexible Automation and Integrated Manufacturing. He has written about 90 technical papers, published one book and holds one patent.

Preface

This textbook is about Quality Engineering. This book has been written to support a course in Quality Engineering offered by the University of Maryland at College Park. The course, entitled "Quality Management in Systems," is taught in the first year of the Systems Engineering Program. While this course is for Systems Engineering majors, the content is broad and suitable for students of any engineering discipline.

The importance of selling quality products and providing a quality service to customers is well recognized. In fact, providing customers with a quality product and quality service is an integrated part of the business strategy to maintain competitiveness in the marketplace. In the United States of America, commitments to quality service are becoming basic requirements for companies developing new products and providing services to customers. The federal and/or local governments work with the business community to ensure that such commitments are enacted to protect the benefits of customers. In today's dynamic international environment, success or failure of a company not only depends on its ability to rapidly adapt to environmental changes, but also relies on the company's commitment to delivering a quality product.

The uniqueness of this textbook is its emphasis on the approach to Systems Engineering. As we all recognize, meeting the quality needs of customers requires all departments in an organization to take an active role. It must start at the top management level and the president of the company has to take the leadership role. The philosophy of implementing Quality Engineering is "To improve quality, everyone contributes and to maintain quality, everyone shares responsibility."

There are seven chapters in this book. The first chapter presents a comprehensive picture of Quality Engineering. In the second chapter, three Quality Management Systems developed in the United States are described. Chapter 3 presents the fundamentals of Engineering Statistics. Statistical Process Control is presented in Chapter 4. Data analysis, design of experimentation and model building are presented in Chapters 5, 6 and 7 respectively.

The experience gained from teaching "Quality Management in Systems" has been extremely positive. The author would like to take this opportunity to extend his deep appreciation to the students who have participated in the development of this textbook. The support from the administration of the School of Engineering, Department of Mechanical Engineering and the Institute for Systems Research at the University of Maryland has been invaluable. Special thanks are due to the publisher, the Commerce Press, Beijing, China, whose collaboration has made this textbook a reality.

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CHAPTER 1

INTRODUCTION TO QUALITY MANAGEMENT IN SYSTEMS

Today the subject of quality is so popular that people from every walk of life address it. Even the presidential candidates speak of quality issues during the election years. Based on an interview by the American Society for Quality Control (ASQC), it seemed like both the candidates for the 1996 election, Clinton and Dole understood the concept of quality. Here is the statement made by President Clinton in the 1997 Malcolm Baldrige National Quality Award ceremony in Washington, D.C., "Quality is one of the keys to the continued competitive success of U.S. businesses. The Malcolm Baldrige National Quality Award, which highlights customer satisfaction, workforce empowerment and increased productivity, has come to symbolize America's commitment to excellence." All these statements sounded promising, but was there really any substance behind them? Quality, like politicians during an election year or in office, promises new success and has much potential, but can change be accomplished? Some think so. However, certain elements, such as those in Total Quality Management (TQM), must exist before quality can be established. Sometimes, trying to explain quality to others is like trying to grab air. For those who know little about quality, the lack of a mathematical background makes quality less tangible and more difficult to define. On the other hand, for those who have an idea of the meaning of quality, the absence of formal metrics to define and measure quality, results in many interpretations and different understandings of quality. This situation, though, is changing and must continue to progress because U.S. companies must now compete not only with themselves, but also with the rest of the world. Competitiveness and globalization are becoming the core of business strategy to strive for success.

1.1 History of Quality Control

The idea of quality control has evolved during each technological era. During Medieval times, quality control consisted of doing the best job and taking pride in your work. When the individual craftsman was replaced by guilds and made to work under a manager, quality was assured through inspection. This idea continued into the industrial age. However, around this time, several people started applying statistics to aid in quality control. The founding fathers of statistical quality control include people such as Walter A. Shewhart, who contributed many ideas including control charts; Harold F. Dodge and Harry G. Romig who together developed the Dodge and Romig Tables for sampling plans; Eugene L. Grant and J.M. Juran, who were both leaders in field of quality management; Ellis R. Ott, a founding member of the American Society for Quality Control (ASQC); and W. Edwards Deming. As the world enters the information age, the new challenges will be to improve software quality, computer hardware reliability, and network availability. There are three main levels of quality implementation. They are listed in the decreasing order of comprehensiveness:

1. Quality assurance
2. Quality control
3. Inspection

The most comprehensive level of quality implementation that can be reached by a company is the quality assurance level. It involves everyone in the organization including managers, engineers, manufacturers, suppliers, marketing personnel, and even customers. To achieve this high level of implementing quality, a company must plan for quality in the design, manufacturing, and maintenance phases of the system life cycle. The goals at this level are to find and reduce sources of variation in the product life cycle and to correct failures through a maintenance plan. The second level is quality control. The main goal here is to prevent defects, but not failure correction. The methods used include sophisticated inspections and controls such as sampling plans. Finally, the third and least effective level of quality implementation is inspection. The goal at this level is to react to system failures, not to prevent them. Companies at this level do not usually consider quality early in the design phase of the system. Therefore, they resort to corrective actions. Defects are fixed as they occur. This results in higher defect rate, lower level of customer satisfaction, and higher maintenance costs in terms of money and time.

1.2 The Need for Statistical Quality Control (SQC)

Historically, quality management was initiated through the introduction of statistical quality controls. Back in the 1930s and 1940s, people on the shop floor were facing the challenge to manage the quality of their manufactured products. They believed the measurements taken from a product or component made in the production line could provide information on the production variability. Therefore, measurements were collected and statistical methods were used to analyze the data. Such practice has been adopted by industry ever since.

Why does statistical quality control (SQC) receive such attention even today? One major reason is the vigorous worldwide economic competition. To remain competitive on a global basis, U.S. industries need to incorporate a holistic design approach. Issues of importance include: customer satisfaction with the quality of products, detection and prevention of defects, life cycle analysis, and research aimed at the development of new and innovative manufacturing methodologies. Furthermore, technology is progressing very rapidly, customers' expectations of system functions and quality are higher, and the overall life cycle of a product is much shorter. Altogether, the following facts exemplify the new conditions.

1. The size of the U.S. economy is approximately three times the size of the Japanese economy and twice as large as the combined economies of France, Germany, and Britain. Needless to say, the American people are still the most significant economic force in the world.
2. During a two-decade long period, the U.S. domestic manufacturers lost a significant percentage of the market shares to foreign countries such as Japan, Germany, Korea, etc. In the late 1980s, U.S. companies had to go through a painful process to re-construct its infrastructure and business strategy by focusing on product development, improving product quality, and laying off hundreds and thousands of workers and managers to re-orient the technological development. The restructuring process has been successful. It has led to a booming U.S. economy with low inflation and a low unemployment rate, starting in the middle 1990s.
3. American consumers have developed a taste for foreign products, the reason being the quality and value of foreign goods. The trade imbalance is one indication that the ability of the U.S. to participate in the world market has eroded. This can be seen in Figure 1-1. To regain the U.S. competitiveness, the U.S. industry has to focus on product quality and American consumers have to rethink their shopping patterns.
4. In the 1980s, the American public was extremely worried about the loss of

economic leadership and the transfer of wealth from the United States to other places in the world. During the recent years, the U.S. Congress and the Government Administration have worked closely with private sectors to enforce new policies that aim at promoting business and technological developments. In the meantime, U.S. business leaders are realizing that they must take decisive action to improve their management styles and manufacturing processes, and to meet the needs and expectations of customers. At present, the U.S. economy stands out in the global economy for its prosperity.

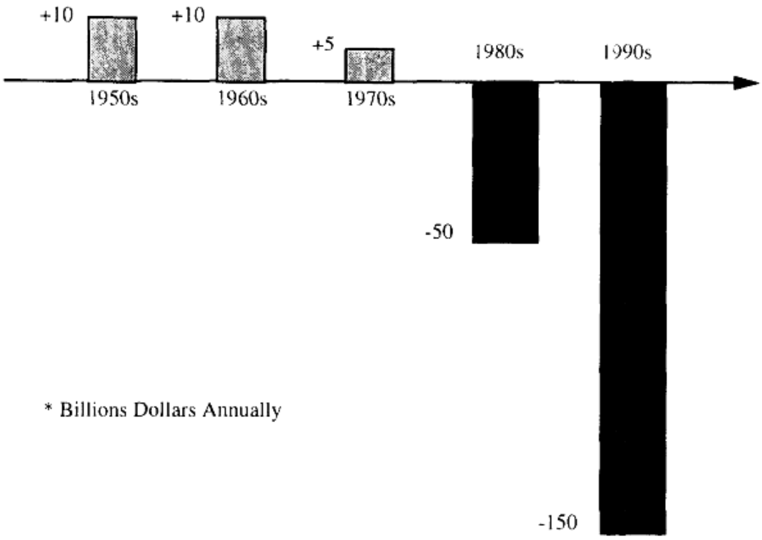

Figure 1-1 United States Trade Balance

1.2.1 Definition of Quality

Generally speaking, quality is a basic business strategy that provides goods and services that completely satisfy both internal and external customers by meeting their explicit and implicit expectations. Furthermore, this strategy utilizes the talents of all employees to the benefit of the organization in particular and society in general, and provides a positive return to the shareholders.

1.2.2 Fundamental Principles of Quality

There are three fundamental principles in quality engineering.

1. Customer Focus: Quality is based on the concept that every organization has a customer and that the requirements, needs, and expectations of that customer must be continually met if the organization is going to succeed. This concept requires a thorough collection and analysis of customer requirements. Once these requirements are understood and accepted, they must be met.
2. Process Improvement: Continuous improvement of key manufacturing and business processes is fundamental in quality engineering. All the processes should be made reliable by reducing and controlling variability. When the process output is undesirable, redesign of the process is necessary to produce an output that is better able to meet the customer's requirements.
3. Total involvement: Employees at all levels, leaders of management, and suppliers should actively participate in the continuous improvement of product quality. Higher management should organize and establish the quality management system through education, training, communications, rewards, and recognition. The quality management system should cover the assurance of the continued operation of the entire process, from purchasing of materials to final delivery of finished goods, while maintaining a quality management standard.

1.3 Quality Through Systems Engineering

Based on some of the current facts stated above, one challenging problem facing companies today is to create quality management systems that function as desired by customers. These systems must manage and integrate reliability and maintainability into their system design. To achieve the goals of satisfying customers and creating high quality products, a methodology must be used when designing such a system. One such method that has been gaining greater attention is the systems engineering process. The systems engineering process seeks a solution to meet the design specifications and the need of customers based on the concept of a system's life cycle. In terms of quality, systems engineering focuses on customer satisfaction, statistical quality control, variation control tools, and quality management systems. Figure 1-2 exemplifies the quality management system and its principles. Before the steps involved in the systems engineering process are described, the concept of a system will be defined in the following section.

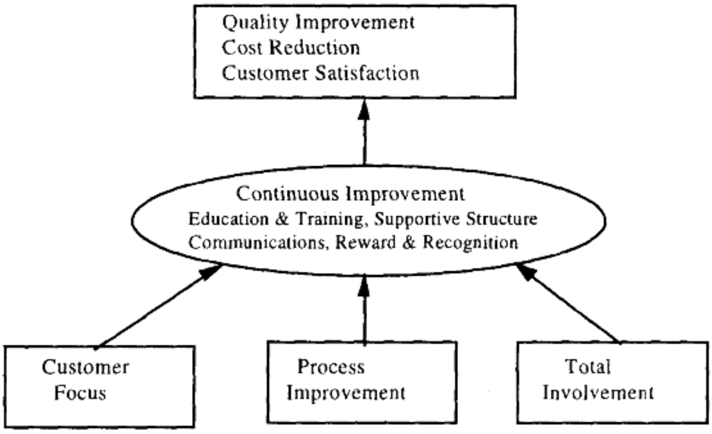

Figure 1-2 Quality Principles and a Quality Management System

1.3.1 Definition of a System

A basic, simple system consists of an input, a process, and an output. It is made up of components that together perform a desired function in a certain environment for a predicted lifetime. Such a system is shown in Figure 1-3. Examples of such a system include calculators, computers, houses, automobiles, and networks. Taking the example of a calculator, the input would be entering instructions by keying the numbers and mathematical functions, the process would be the calculations performed electronically, and the output would be the answer on the display. A system can be defined as open or closed. An open system is the one that alters its process and output based on new information entering through the input from the environment. On the other hand, a closed system does not take in new information to alter its processing. A closed system produces a targeted output independent of its environment.

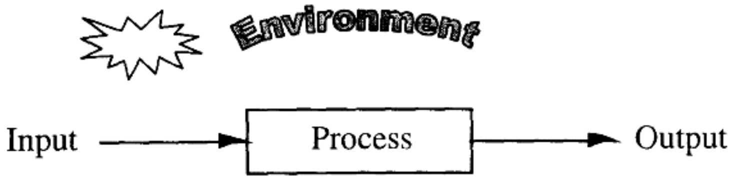

Figure 1-3 Simple System

A more complex system, as shown in Figure 1-4, can be made up of several simple systems, and may contain some type of feedback. Taking the example of an automobile, the input would be the fuel required and the driver and his/her abilities to operate the automobile. The process involves both man and machine, where the machine is designed to perform as required by the human that results in the output, which is transportation. The environment such as road and weather conditions influences the output of the design system. The feedback would be the information provided by the controls, such as the steering handling ability, and traffic conditions, the latter of which is also a part of the environment. As systems become more complex and require higher quality standards, the need for the systems engineering approach to product development will increase.

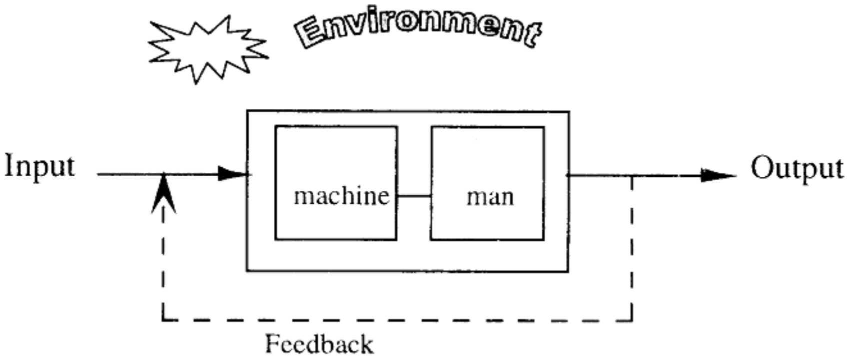

Figure 1-4 Complex System

1.3.2 Systems Engineering Process

Systems engineering is a methodology used to solve problems in an orderly manner. This approach emphasizes the need to understand the problem and plan the procedure of problem-solving before designing solutions. The methodology provides a road map for workers, managers, and administrators at all levels. It gives managers a clear vision on what and how to control a project throughout its complete life cycle, including design, manufacturing, and maintenance. The systems engineering methodology provides engineers with a well-defined set of guidelines to follow in the design process. It verifies that the manufactured product conforms to customer requirements through testing and evaluations. It also considers the level of customer support required when the product finally leaves the factory and enters customer hands.

Systems engineering is an iterative process that should be tailored for each design environment. This involves applying the correct level of engineering effort to bring a system into being. Too much or too little tailoring will result in unnecessary added cost up-front or later in the system's development life cycle. Emphasis is placed on early planning and modifications through feedback.

The systems engineering process is made up of design, manufacturing, and maintenance functions. Within each of these major functions there are several phases to ensure the creation of a comprehensive life cycle design and that the functions of the designed system meet their specifications. Typical phases of a systems engineering process include:

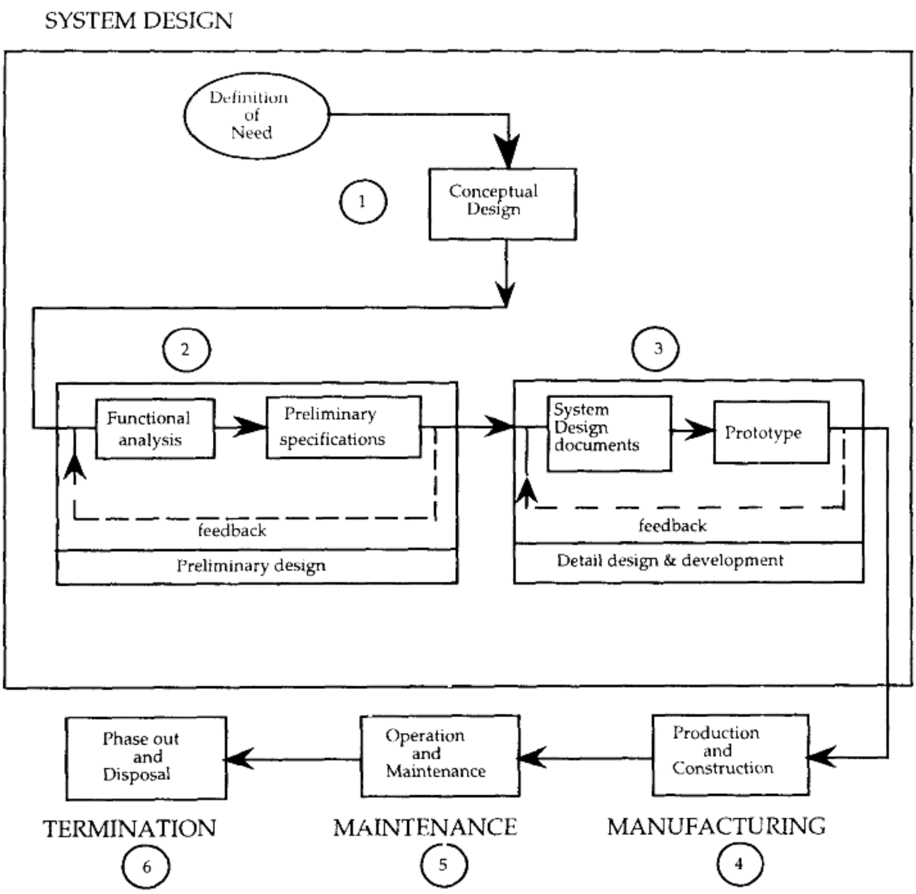

Figure1-5 Systems Life Cycle Process

1. Definition of need and conceptual design phase
2. Preliminary research and design phase
3. Detail design and development phase
4. Production and construction phase
5. Operation, maintenance, and support phase
6. Phase out and disposal

These steps are illustrated in Figure 1-5. An example is given to demonstrate the definition of each of these elements involved in the system life cycle process.

1.3.2.1 Definition of Need and Conceptual Design

A need statement should only define the problem, not possible solutions.

Example: Suppose a customer comes to company X and states that "they need a helicopter to transport a 200 ton piece of equipment to the top of a mountain". By following the systems engineering methodology, company X first analyzes this customer's needs before designing the helicopter. Based on this initial analysis, the company discovers that the customer has assumed that a helicopter is the best means of transporting the heavy equipment.

This example illustrates the goal of this initial phase. When a problem is presented, it should never contain a design solution. Instead, it should establish a need statement. The main goal of this phase is to define the operational requirements and maintenance concept of the future system. The first step is to establish a concise need statement that represents the requirements of customers and users. Satisfying the needs of customers and users by using proper identification processes is one of the benefits of systems engineering. If the requests of a customer are granted directly without evaluation, the end result is usually a dissatisfied customer. A customer or user need is an objective for a system solution due to a deficiency or problem found through basic research. Before a need statement is created, it must be established that a need really exists. This is accomplished by questioning and analyzing the input from customers to completely understand their needs. This statement should include a statement of the problem, magnitude of resources available, relative priority of the system, and date of installation and operation. The establishment of a precise need statement is extremely important. This is because the focus and direction of the system life cycle and associated engineering activities that follow, will be based on the need statement. A need statement that is inaccurate, vague, or too restrictive, will result in a product that does not fulfill the requirements of customers.

Analysis of similar systems, where partial or total concepts applied to related