Quality and Reliability/52

TQM Engineering Handbook

D.H. Stamatis

TQM Engineering Handbook

QUALITY AND RELIABILITY

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Ειζ τουζ αγαπητουζ
Γιαννη, Χαριαννα,
Γιωργω, Τασσο και Φωτη

To my dear
John, Harianna,
George, Tasso and Foti

About the Series

The genesis of modern methods of quality and reliability will be found in a sample memo dated May 16, 1924, in which Walter A. Shewhart proposed the control chart for the analysis of inspection data. This led to a broadening of the concept of inspection from emphasis on detection and correction of defective material to control of quality through analysis and prevention of quality problems. Subsequent concern for product performance in the hands of the user stimulated development of the systems and techniques of reliability. Emphasis on the consumer as the ultimate judge of quality serves as the catalyst to bring about the integration of the methodology of quality with that of reliability. Thus, the innovations that came out of the control chart spawned a philosophy of control of quality and reliability that has come to include not only the methodology of the statistical sciences and engineering, but also the use of appropriate management methods together with various motivational procedures in a concerted effort dedicated to quality improvement.

This series is intended to provide a vehicle to foster interaction of the elements of the modern approach to quality, including statistical applications, quality and reliability engineering, management, and motivational aspects. It is a forum in which the subject matter of these various areas can be brought together to allow for effective integration of appropriate techniques. This will promote the true benefit of each, which can be achieved only through their interaction. In this sense, the whole of quality and reliability is greater than the sum of its parts, as each element augments the others.

The contributors to this series have been encouraged to discuss fundamental concepts as well as methodology, technology, and procedures at the leading edge of the discipline. Thus, new concepts are placed in proper perspective in these evolving disciplines. The series is intended for those in manufacturing, engineering, and marketing and management, as well as the consuming public, all of whom have an interest and stake in the products and services that are the lifeblood of the economic system.

The modern approach to quality and reliability concerns excellence: excellence when the product is designed, excellence when the product is made, excellence as the product is used, and excellence throughout its lifetime. But excellence does not result without effort, and products and services of superior quality and reliability require an appropriate combination of statistical, engineering, management, and motivational effort. This effort can be directed for maximum benefit only in light of timely knowledge of approaches and methods that have been developed and are available in these areas of expertise. Within the volumes of this series, the reader will find the means to create, control, correct, and improve quality and reliability in ways that are cost effective, that enhance productivity, and that create a motivational atmosphere that is harmonious and constructive. It is dedicated to that end and to the readers whose study of quality and reliability will lead to greater understanding of their products, their processes, their workplaces, and themselves.

Edward G. Schilling

Preface

In a famous cartoon Pogo said long ago: "We have found the enemy, and it is us." How profound that statement is and how relevant to quality. In the past 50 years or so, quality has been the Gideon's trumpet for a variety of ailments. Programs, in the name of quality, have come and gone, but the problems persist. Is quality a bad thing, or are we going about it the wrong way? Is it corporate greed that is causing our problems? Is it that technology has increased in complexity? Is it that the desire for "return on investment" is causing a frenzy for better prices? Is it the competition? Is it that we don't use the appropriate tools in pursuing our goals? Obviously, we can keep on asking questions. However, what is the answer?

In this book we address some of these issues and we provide an answer. The answer, in simple terms, is Quality—not just in name, but internalized throughout the organization, for the benefit of the customers (including ultimate consumers and stockholders), suppliers, society at large, and even the employees. The quality philosophy and program we cover here is what some people have called Total Quality Management, Total Improvement Management, Total Quality Improvement, and even a Breakthrough Philosophy to Improvement. The name is not as important as what is presented.

One may ask at this early juncture, why another book on quality, or even on Total Quality Management? A fair question, which needs to be addressed. To begin with, there is no doubt that corporations not only in the United States but all over the world proclaim that quality is a way of doing business, and furthermore they aim to please the customer. We suggest that that claim is only partially true. To be sure, improvements have been made because of quality awareness and implementation practices emphasizing quality. However, that is not good enough. We still produce and market for price! Why? Because we have been conditioned, all of us, to buy on price. This is a serious charge. But what happens if we dig a little deeper to identify the enemy and find it is us? There are, for instance, more than 20 million American families who own stock. It is safe to assume they are not all investing in environmentally aware companies. Rather, they are putting their money in companies with the expectation that they will get even more money out.

Many millions of individuals are counting on a comfortable retirement thanks to the strong financial performance of the companies in which their pensions are invested. When corporations fail to offer a good return, a responsible pension fund manager gets rid of the stock and buys something else. A company whose profits fall below expectations quickly comes under pressure from managers of pension funds across the country. Such managers have a responsibility to provide the best return possible to their clients, many of whom are teachers, state police, janitors, and so on. Institutional investors are much more demanding than they were 30 years ago, and much more willing to do things to bring about change, because they are under pressure themselves. Pressure is everywhere. Corporate managers, individual investors, and institutional investors all are looking for a return on their investment, to the point where quality often takes a second seat to profits. Let us look at what has been happening in the name of quality. In the semiconductor industry, the engineers push their hard drives on the basis of price and quality. But if you look at the actual product the megabytes may not be correctly identified. In some cases, they are off by 5%.[1] Why? In the software industry, it is not unusual to ship a new version of a program even though the beta site testing is not complete or "bugs" in the program are still present.[2] This is done in the name of beating the competition to the market. What happened to quality. Why? In the food industry, if you look at labels, you may notice that what the picture shows and the ingredient list presents are not the same.[3] Why? In the automotive industry, if you examine the end product, a car, you may find that when consumers have a problem, they have a rough time fixing it—that is, if they are lucky enough to find the appropriate representative. On the other hand, even when the company knows about a problem, it may still try to dismiss it as "misleading" and not important.[4] Why? In health care, politics, education,[5] and many industries the same tune is being played, that is; stretching the truth, outright lying, misrepresentation, and so on. Why? If quality is as important as everyone claims it to be, especially in the automotive industry, why are none of the American automotive companies in the top ten for perceived quality cars in the United States,[6] even though they all have practiced quality control for a very long time? Nevertheless, in all industries quality is proclaimed as the only way to true improvement.

The pressure is high for everyone to perform, but performance alone will not do it. An organization must produce effectively and efficiently in order for it to survive. One way of surviving is through quality. This quality, however, has to be totally in the minds of employees, corporate management, and the public at large. We must as a society try to do our best and as organizations try to be good corporate citizens. If that means that we have to tell the truth, educate our employees and our stockholders, and focus on long-term survival rather than short-term gains, so be it. If we practice quality, then the integrity of everything we do is the primary issue. We must recognize that cutting corners is not the way to practice quality. Quality is practiced by having a vision, goals, and appropriate action plans. In this book we present the philosophy of Total Quality Management, an implementation strategy, basic and advanced tools, and the leading issues every organization should embrace in order to be successful in the years to come.

Why this book? Many books have been written about quality including Total Quality Management. This book is quite different in many ways. Not only does it present the basic concepts of quality and the traditional basic tools, but it goes much further to address issues that in the 1990s and the next century will be of paramount importance in any organization for survival. Some of the topics that will be addressed and the reader will find unique are the chapters on a design of experiments, issues of reliability, advanced topics of quality—QED, FMEA, benchmarking, meetings, teams, quality awards, training, international standards, and much more.

How can this book be used? The book can be used as both a reference and text on quality. To facilitate these objectives each of the chapters is designed independently of the others and is self-contained. Also, additional references are provided either at the end of each chapter or in the selected bibliography.

Who can use this book? This book is directed to several groups. First, quality practitioners will find the book refreshing because it provides many tools with which quality can be defined, monitored, and evaluated. It goes beyond the content of other quality books, as it expands the discussion of traditional concepts and tools and, furthermore, provides the reader with the crucial issues of quality for the years to come. Second, anyone interested in quality of the future will find the book an excellent reference for both traditional concepts and tools, and advanced tools and approaches to quality. The academic group will find the book contains a variety of topics to be used in a classroom format, since the topics are geared for both graduate and undergraduate work. In all cases the book serves as a springboard for further research in any of the topics covered or as a textbook in quality-related classes.

D. H. Stamatis

NOTES

These notes are not an exhaustive study on the issue of "price" versus "quality." Rather they are a cross section of some specific examples that show the power of price.

1. A discussion on how the software industry is able to manipulate the disk space in a computer is covered in the November 1995 issue of *Multimedia World*, p. 133, in the article "Q & A: Working with Multimedia" by Bronwyn Fryer.
2. All of us who have used any type of computer software have come across "bugs" in the software system itself, in spite of the fact that all software packages go through a "beta" testing process.
3. During a *20/20* television program on March 1, 1996, a program on "food and apple juice" was aired that showed how large companies were manipulating data to sell watered-down maple syrup as real "maple syrup."
4. During the television program of *Prime Time* on February 28, 1996, a program on "auto" lemons was aired that showed how the dealers of some of the largest automotive companies were passing "lemon" cars from state to state, and in the process they were making thousands of dollars.

   Fix, J. (May 3, 1996). "Memo implies Ford recall left out some fire-prone cars." *Detroit Free Press*—Business, p. E1. This article reports that an internal document suggests the automaker did not recall vehicles that may be prone to ignition switch fires other than the 8.7 million in last weeks recall. The best that a Ford representative had to say was that "we are not hiding anything. Fires happen for many different reasons."
5. (September 13, 1993). "End the phony 'asbestos panic.'" *USA Today*, p. 11A. The article notes that millions of dollars were wasted, where in fact there was no danger of asbestos.

   (April 15, 1996). "Truth-in-savings law may be gutted." *Detroit Free Press*—Business Monday, p. 4F. The article discusses the greed the banking community is displaying by its efforts to repeal the Truth-in-Savings Act. Although the customer is better off knowing the actual annual percentage yield (APY), the banks do not want to disclose that figure. If the act is repealed, the result will be an unfair comparison between financial institutions, since the APY is calculated by using different methods. The customer is the loser.

Khanuja, G. H. (February 14, 1996). "Is service on par with the price?" *Mid-Day.* (New Delhi, India), p. 17. The article points out that while price tags are getting higher, service is deteriorating to the point of becoming nonexistent.

Pepper, J. (April 14, 1996). "GM quietly takes care of business the old fashioned way, one step at a time." *The Detroit News*—Business Section, p. 1-D. In the article, Mr. Pepper quotes a University of Michigan study in which price was the overwhelming criteria over quality in the selection of a family car.

Gottlier, M. (March 1992). "Hospital's ethical quandaries in crunch to pass inspection." *New York Times*, pp. A1, B4. The author reports how a particular hospital falsified records to ensure certification. Never mind the safety of the patients. What was important was that the hospital continue to do its business.

(April 25, 1996). "Power acknowledges Japanese excellence." *Business Free Press*, p. 1G. The article points out that in the category of reported problems per 100 cars by nameplate, none of them were American.

Brennan, M. (May 8, 1996). "Japanese automakers top poll." *Detroit Free Press*—Business, pp. E1–2E. The article notes that American automakers still lag behind the Japanese. The Japanese are also winning the battle of light trucks, as they won top honors in three of the five categories.

Gardner, G. (April 25, 1996). "Luxury models riding high in quality survey." *Business Free Press*, pp. 1G-2G. The author points out that even in the luxury category American automobiles are behind. They are catching up, but they are not in the top group.

Acknowledgments

William Blake defined gratitude in one of his poems as "heaven itself." In this spirit, it is a pleasure to record the many archival and intellectual debts that I have accumulated while writing this book. Many people and organizations have contributed. To identify them all by name is an impossible task, but I would like to name some to whom I am deeply indebted. They are:

The SAS Institute for granting me permission to use information from Littel, Ramon C., Freund, Rundolf J., Spector, Philip C., *SAS System for Linear Models*, Third Edition, Cary, NC, 1991, pp. 57–84. Copyright SAS Institute, Inc. The material is found in the regression discussion.

Quirk's Marketing Research Review for granting me permission to summarize some information regarding the various regression approaches. The material may be found in the chapter on regression.

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Contents

Introduction

Much has been written about quality and more specifically, Total Quality Management (TQM). The benefits, the advantages, and disadvantages have been discussed to the point where lately we have seen articles that TQM is dead and not appropriate for the rest of the 1990s and the twenty-first century. How wrong can they be! TQM is alive and kicking and will be with us for a very long time. We may change the name, but its essence will be with us. To believe that the TQM will no longer exist means that organizations will not care about continual improvement and all of its limitations, customer satisfaction, measurement, and efficiency. Concurrently, without TQM the customer will not care about quality, value, and satisfaction of their purchase.

Obviously these statements are wrong. Why? First, because as time passes, organizations become much more cognizant about productivity, efficiency, and costs, and second, customers become ever more conscious about value. How can TQM help? To see what is TQM and how it can affect both the customer and the organization as well as the supplier, let us focus on the improvement process of TQM.

TQM is a philosophy rather than a program; this means that it is always evolving. It is a formalized, yet "common sense" approach to the elimination of wasted time, energy, and materials. By using time, energy, and materials in their simplest form, we are making something simpler or easier to do, and in so doing, have created an easier task, conserved time, energy, or material, and accomplished a better result in less time and with a minimum of waste. TQM can be used not only in factories and offices, but also in our homes and in any phase of human activity. Remember it is a philosophy—a way of thinking—rather than something concrete and definite. There is nothing difficult about the application of the fundamental principles of the techniques used to implement the TQM philosophy. It simply involves thinking in an orderly manner about the work under consideration, and then selecting the best available method that we know of at the present time.

Fundamentally, when we speak of wasted effort and wasted activity, we refer to the unnecessary, nonproductive, tiring actions that are present in anything we do. We are concerned with the elements of work which tire us but contribute nothing what-so-ever to the product.

TQM is also a way of thinking as well as a relatively simple analytic approach (although it can be very complicated to implement) with which it is possible to eliminate most of the useless movements and to adapt more productive and useful actions. TQM will make it possible to produce more work with less expenditure of effort. Sutermeister (1969) said it best when he discussed the issue of productivity. He said that the only way tually to increase the average income and purchasing power of the worker is to find the means to increase his productivity. This is a rather straightforward observation although few people seem willing to understand it. Whenever we increase a worker's productivity, nothing has ever prevented the worker from benefiting in proportion to the increase. Neither depression nor boom, politicians nor profiteers have prevented the average income per worker from remaining proportional to productivity.

I. ADVANTAGES TO THE ORGANIZATION AND TO THE EMPLOYEE

Educating and training in the use of the principles and tools of TQM has numerous advantages to help anyone in their daily work. Through the application of the tools provided and the resultant simplification of a few of the primary jobs in the work environment, the following advantages should begin to develop.

Training of new workers should be quicker and easier on the simplified jobs, thus making available to you additional time for your other duties as well as additional education. (There is a distinction between education and training in that education answers the "why" and the training answers the "how." Both are necessary. Education presents the "whole" picture, whereas training presents the details needed for the task.) A truly simplified job will require less attention on your part to see that production and quality standards are met and maintained.

As more and more jobs are simplified and waste is eliminated, production has a tendency to increase. The additional production will undoubtedly be accomplished with less physical effort and fatigue to the operator. Increased production will make it easier to meet promised delivery dates to the customers.

A simplified job is a safer job and reduces hazards to the operator. Simplified machines, equipment, and maintenance procedures save much trouble and loss of production time in the work environment; this just another way of helping meet production goals.

The benefits from consistent application of the principles and tools of TQM will make more of your time and energy available for more complete and efficient work, and for further experimentation and development of ideas which are essential to progress. These ideas are equally applicable to both manufacturing and service industries.

II. OBJECTIVE OF TQM

Before starting any job, we must have an objective. The objective of TQM is to make a better product/service at a lower cost in shorter time with less effort, every time. This philosophy is designed to make individuals think creatively toward the better use of time, energy, and materials. It employs a common sense system for measuring and analyzing a given process in order to find the berrer way of doing work. TQM should help do a better job by:

1. Bringing people together for discussion and exchange of ideas
2. Developing an alert, open-minded, questioning attitude on the part of all employees
3. Uncovering and eliminating wasteful and time consuming-methods, thereby leaving more time for the development of effective procedures
4. Eliminating fear in all levels of the organization

III. ATTAINING THE OBJECTIVES

In order to attain the objectives an organization must:

1. Produce the best product and give the best service of which the organization is capable
2. Operate at the lowest cost by the most direct method and with proper consideration for the interest of all groups necessary to obtain the desired result
3. Deliver the product/service at the right time

These points should be the objectives of everyone in the organization, regardless of title or position, if the organization is expected to make continual progress. Above all, it should be realized that attaining these objectives involves a human problem, perhaps even more than a material one. TQM, as applied in industry or any phase of human activity, deals with human beings. In most organizations, we are fascinated by what we see in the way of machines, methods, and materials. These things are perhaps more intriguing to the average person than the men and women whose efforts are expended toward putting life into lifeless machinery. However, we must not forget that the machines, methods, and materials themselves never invented anything; they never presented a new idea to the world, and are only as good as the people who use them.

IV. HUMAN ENGINEERING

To attain our objectives, the problem of human engineering is of the utmost importance. It has been said that Thomas Edison once said, "Problems in human engineering will in the future receive the same thought that the last century gave to engineering in more material forms." Can we apply the engineering approach that is used in more material forms in trying to solve our problems of getting the human energy and force to work correctly? To answer this question intelligently, we must have an understanding of what is meant by the engineering approach. It is:

1. Collection of all the facts possible
2. Analyzing the facts at hand as a basis for judgement
3. Making decisions based upon that judgment of the facts
4. Acting on those decisions and checking for improvement confirmation through a systematic follow-up

To say it in more simple terms, it is: find out what is wrong with something, correct it, and then confirm the results. However, whereas this approach is a workable model and has served industry for a long time, it is not enough. In the 1990s and beyond we must look at something and even though nothing is wrong with it, we should try to improve it. It is that improvement and vision that the TQM encourages throughout the organization.

The engineer is concerned with more material things such as the generation, transportation, and application of power. The effectiveness of the application of power is such that we are almost certain that throwing a switch will immediately turn on the power. If the right switch is turned on and no mistakes are made, it is not necessary to go back and check. Management actions, however, are quite different from engineering actions. Do we find the same effectiveness in translating a decision made by management into action at the bench or machine as we find in transmitting steam or electric power from the coal pile or waterfall to the machine? By checking back on your own experience, you will find that the answer is quite obvious—no!

The probable reason is that no two of us are exactly alike: we do things differently, we do not see things the same way, and we react differently. Knowing that this is so, we realize that beyond a certain point it is necessary to consider each human being as an individual. First of all then, we must consider each human being and the things that affect them. Then we can discuss the applied power which is commonly called "work."

Remember that the engineer's method of approach is finding out what is wrong with a thing and then correcting it. Applying this approach to our human problems, we find that there are three common concerns with people that must be recognized and changed appropriately, if we are going to do a good job in human engineering. The three concerns are:

1. It is human nature to resist changes.
2. It is human nature to resist the new.
3. It is human nature to resent criticism.

A. We Resist Change

It is a universal trait in human nature to resist change. Why is it so? Probably the reason is that changes require thinking and considerable effort to get out of the old groove. The easiest way is the familiar way. Complacency—the feeling that all is right with the world, especially with us—is a comfortable feeling. When we feel that this comfortable state of affairs may be upset, we go into action; or when it has been upset, we act to restore it. There is grave doubt that we ever do anything at any time except to prevent our complacency from being disrupted or to recover it if it had been disrupted. This has nothing to do with reasoning. It is an emotional reaction. A Greek story will help explain this:

> A myth of the ancient world states that the Wind and the Sun one day wager who would be the first to cause a pedestrian to remove his hat. The Wind, of course, was very certain of his win and he chose to go first. So, with the first blow, the pedestrian raised his hand and pushed the hat deeper onto his head. The Wind blew stronger and the pedestrian repeated the action. The Wind tried again, to no avail; the pedestrian just as stubborn kept placing his hat deeper onto his head. Finally, the Wind blew with all his might, thinking that the pedestrian not only will loose his hat, but will bounce him all around as well. The pedestrian, however, put both his arms on top of his hat and took cover in the trunk of a nearby

tree. When the Wind saw his reaction, he told the Sun to take over.

The Sun slowly and continuously warmed the ambient temperature, as well as the earth. Before too long, the pedestrian felt warmer and before he knew it, he took his hat off to wipe his sweat from his head. The Sun won.

So it is with us. Nothing gets accomplished by force, anger, and shouting, except that the other person gets more defensive, argumentative, withdrawn, and so on. Just like the pedestrian we button up and run for cover when there is a force that we do not like or that is too sudden. On the other hand, just like the pedestrian when the change is slowly and consistent we get used to it and we learn to leave with it. The moral of the story of course is that when you make a change slowly, very few will object to or resist it.

B. We Resist the New

Like a parachute, the mind functions only when it is open. Check your own reaction to this first challenge. When somebody presents you with a new idea, what do you do about it? I believe it is true that one of the first things you say is: "It can't be done." Perhaps you immediately start searching for reasons why the idea will not work. What was your first reaction, for example, to Quality Circles, Participative Management, Management By Objective, Streamlining, and so on? Compare your first reaction to man flying across the ocean in the beginning of aviation with the present day service which we now enjoy. What would you have said years ago if anyone had outlined our present air transport service? What is your reaction to pictures without film? And so on. Your reaction to these ideas is probably no different from the reaction of the people who laughed at Columbus, Fulton, and Whitney for their impossible and unimaginable ideas. History is full of examples of this resistance to the new.

Some years ago, it took thirty seven days to paint a Cadillac car and twenty one days for a Buick. As automobile production increased, it was obvious that something had to be done to bring about an expansion. There was not room in the General Motors plants to store all the cars made in thirty seven days, so a conference of plant executives was called.

Again, C. F. Kettering suggested that the paint-drying time might be cut down, possibly to one hour. This statement broke up the meeting and as the men left, they pitied Kettering for making himself so ridiculous and said: "The man is out of his mind." Not long after this meeting, Mr. Kettering was walking down Fifth Avenue in New York City. In a window, he saw a lacquered pin tray and purchased it. Inquiry revealed that the tray was made in Newark, NJ. He went and requested some of the lacquer to "paint an automobile door" and he was told by the company, "You can't paint an automobile with that; it dries too damn fast." From that day on, Kettering spent all his time experimenting with various paints and lacquers.

At a later date, one of the executives who was very positive in his statement that it was impossible to paint a car in an hour, drove to New York to attend a meeting with Mr. Kettering. On the way to lunch, Mr. Kettering commented on how shabby the car looked, but the executive stated that he could not spare the car long enough to get it painted. On the way in, Kettering made a telephone call.

After lunch, they returned to where the car had been parked, but it could not be found. Finally, Kettering asked his associate if the new looking blue car parked there could possibly be the right one. It was. An hour to paint a car—not so crazy after all!

But the paint story is not unique. Throughout human history there have been many examples of "It can't be done." For example, consider the following.

1. The first cast iron plow invented in the United States in 1797 was rejected by New Jersey farmers under the theory that the cast iron poisoned the land and stimulated the growth of weeds.
2. Commodore Vanderbilt dismissed Westinghouse and his new air brakes for trains, stating that he had no time to waste on fools.
3. The people who loaned Robert Fulton money for his steamboat stipulated that their names be withheld for fear of ridicule were it known that they had supported anything so "foolhardy."
4. In 1881, when the New York Y.M.C.A. announced typing lessons for women, vigorous protests were made on the grounds that the female constitution would break down under the strain.
5. Men insisted that iron ships would not float, that they would damage more easily than wooden ships, that it would be difficult to preserve the iron bottoms from rust, and that the iron would deflect the compass.
6. Joshua Coppersmith was arrested in Boston, MA, for attempting to sell stock in the telephone. "All well-informed people know that it is impossible to transmit the human voice over a wire."
7. The first reaction to bathtubs was that the new device was a menace to health and morals. The city of Canton, OH, at one time had an ordinance which prohibited the ownership of a bathtub.

If we are to get along with people, consideration must be given to the human failing of resistance to the new. The moment we forget this, we are wasting our time and the results will be disappointing.

C. We Resent Criticism

Do you believe that people like to be told when they are wrong? I believe that we will all admit as we look back over our own experience that those who helped us the most were those who had been able to show us where we were wrong. But how many are ever willing to take advice? We do not refer to "destructive criticism," but deal exclusively with "constructive criticism." But if criticism is so good for us, why do we constantly resent it? Is not the answer that we would much rather be told that we are right? When we ask for advice, most of us merely want to have our own good opinions of ourselves verified. If we do not get this, we will very likely dismiss the advice. The best way to avoid the "malady of self-delusion" is to be known as a person who welcomes criticism—a person who wants the facts as people see them no matter how much they may deflate their ego or upset their present method or future plans.

There is no truer test of a man's qualities for permanent success than the way in which he takes criticism. The little man cannot stand it. It breaks his ego and he makes excuses. Then when he finds that excuses will not take the place of results, he sulks and pouts. It never occurs to him that he might profit from the experience.

V. ARE YOU TOO OLD TO LEARN? ARE YOU TOO OLD TO CHANGE?

How old are you? The answer to this question depends upon what you call old. Age is only a state of mind and a point of view. We know old people who are "young" and young people who are "old." In business if you are at the point where you think you know all about something, you are definitely old. And if you believe you are doing anything as well as it can be done, you are very old. You are old enough to die. In fact, you are dead and waiting for your competitors to hold your funeral. But if you are glad to admit that you know very little about anything, you are young; *and if you are sure that everything can be done much better than it is now being done or ever will be done*, then you are young and growing, and prosperous years are ahead of you.

Another story may help in understanding the issue of age: In ancient Athens, the advanced in age Plato, was making the rounds for his lecture in the town square. It was a hot day and he was getting very tired from walking and carrying his books and his personal items on his shoulder. As he was passing by a water spring, he decided to take a breather and drink some water. He unloaded his things from his shoulder and as he was preparing his "mug" to get some water, he noticed a child drinking water from the spring by putting the two hands together forming a cup. At that point Plato threw away his mug saying his now famous words "As I get older, I learn new things." Plato was indeed a young man because he recognized the opportunity to improve. His improvement was to carry one less item around which meant less weight, and of course the application of a new tool formed with his own hand. You see Plato was willing to learn from a child. He was indeed a young man.

VI. PROGRESS IN INDUSTRY

Progress always involves risks—you cannot steal second base and keep your foot on first. Even though we claim that we know many things, actually if you think it, you will find that we do not know much about many basic things. For instance, what does sunlight do to make people well, what is magnetism or electric current, and so on. We know very little about some chemical reactions, why we transmit voices over a wire, and various other phenomena common to industry today. (It must be emphasized that just because we do not know or understand something, that does not mean that we cannot use it. In fact, the examples just given are used in industry and personal life all the time.)

As far back as 1886, a Federal Commissioner of Labor allegedly has stated "while new processes of manufacturing and new discoveries will undoubtedly continue, these will no longer be on the scale that will permit us to make such remarkable advances as have been witnessed during the last fifty years from 1836 to 1886." If this commissioner was alive today, he would see in full operation many, many industries that have started since he made this statement; and these industries supply jobs for well over one-third of all the people who work in the United States.

If you really want progress and the changes that result from that progress, you may find yourself in the minority, for only a few are willing to pay the price of progress. As has been already discussed, most people resist the new and resent criticism. If this is true, how do we explain the marvelous progress that we have made, especially in the last fifty years? There are three reasons for this:

1. Occasionally, there is an individual intensely interested in trying to make something better through inventions.
2. Competition
3. Quality

History is full of stories of the early inventors, such as Marconi, Edison, Westinghouse, and many others who were more or less individualists. These men planned and completed their own jobs although some of the first inventions were quite obvious. We needed machines to improve the quality and reduce the cost of clothing; we needed better communication methods; we needed improved office machinery to take care of increased business. These inventions, although obviously needed, were not readily accepted when first developed. The cry went up that we would save so much labor that people would be out of work. This did not happen; these new inventions actually created entirely new industries that resulted in more jobs than had ever been thought possible. In comparison to the time of these early inventors who were more or less individuals and who planned and completed their own jobs, new inventions today are usually the product of the cooperative effort of both engineers and practical manufacturing people. Problems in industry today are too vast for one person to have all the answers, and specialization is the order of the day.

This brings us to our problem of finding and developing better ways of processing, conditioning, testing, handling, and fabricating materials in organizations throughout the United States and the world at large. The reason why we are now engaged in TQM is because many of the problems which we encounter today are too involved for one person, or even a small group of people, to solve and to make the necessary improvements required to keep pace with the demands made on us today.

Under present conditions, it is necessary to change production schedules more often and more rapidly than was necessary even a short time ago. This time must be shortened if we are to get material where it is needed and when it is needed. The best way of doing this is by eliminating waste, unnecessary steps, and finding simpler methods of handling.

Now let us consider the issue of competition. Competition in business has been called "the great universal supervisor," for it is the force that puts us to work or out of work. There are rare cases where companies or individuals who have no competition make continual improvements in products, quality, or service or voluntarily reduce their prices. Most companies and individuals take the line of least resistance and require competition to force them to change or improve.

The only place where you can sit down and rest is immediately in front of the undertaker's establishment, for the moment you are satisfied, the concrete has began to set in your head.

What if there were no competition? As we know, industry today is a very strenuous undertaking. Things move fast and it is a struggle to stay in the game. Many times when pressure is high, people think wishfully how fine it would be if there were no competition and how easy their jobs would be.

This is not sound thinking, however. The elimination of competition would not make jobs easy, it would simply allow people to take it easy. The stiffer the competition, the more necessary are the services of men who can help the organization better its position. One way to better our position is to attain the objective of TQM. In order to obtain this objective, we cannot follow old habits, good or bad, but we must develop new methods and new ideas. We must not be discouraged because people think new things will not work. We must challenge our paradigms and encourage innovations.

The final concern is that of quality. Quality is something that we all know, we all have experienced, yet it is an elusive concept that depends on the customer's expectation. In today's business environment, however, Quality is the name of the game, and the way that the organization will pursue it, communicate it, and internalize it will be the difference between a successful and a not so successful organization.

In the following chapters we will explain the issues of quality, the implementation strategy and some of the new ideas and approaches to improve the efficiency of an organization for the years to come.

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1

The Quality Revolution

As Juran has pointed out in his most recent book on the history of quality (Juran 1995d), quality is nothing new. In fact, there has been quality in both the ancient world and the modern world. What makes it different in the modern world, however, is our perspective of quality. Whereas in the past the emphasis was on appraising quality through inspection techniques, sorting, and so on, the modern world is focusing on prevention methods, namely, to design quality into the product. That change of attitude in the world of quality obviously was not overnight. It took time and it was slowly developed over a period of years. There are many people who have contributed to this development. This chapter covers this paradigm change and the individuals who were instrumental not only in the theory, tools, and methodologies of pursuing quality, but also gave us the inspiration and rationale for aiming our goals to nothing but excellence. In our view these individuals are the true pioneers who indeed revolutionized the concept and the practice of quality.

I. QUALITY OVERVIEW

What is quality? Many definitions are given to the word quality. From the ancient world to the modern world we all talk about quality as an abstract. However, the basis for that abstract has been in the notion that if we produce something that does not meet customer requirements, we need to find the deficiency before giving it to the customer. Hence, our efforts have been in defining sampling plans, operating curves, average quality levels, and so on.

To be sure, that mentality was acceptable and worth pursuing for a long time. It made sense. However, in the 1990s and beyond, the old methods are not acceptable. The modern approach to quality is to base its notion on the old adage "an ounce of prevention is worth a pound of cure." Quality then, must be viewed as designing processes that prevent errors as opposed to simply finding them. It is a customer perception issue as well as a value added to the product and/or service for the customer.

II. THE PARADIGM CHANGE

Quality for most American companies—at least up to the mid-1980s—was an issue of "wishful thinking." This wishful thinking allowed many problems to be swept downstream. In fact, a large number ended up in the hands of the customer. Since the mid-1980s to about 1990 we saw some aggressive companies address their problems based on a Total Quality Control system. This system of quality was based on the notion of finding and correcting the root causes of the problem. The information is fed upstream so that the same problem is not introduced back in the process.

Both approaches worked in an acceptable manner for a long time and with good result for many organizations. However, to be successful in international competition today and in the future, it is absolutely necessary to achieve a level of quality that is based on prevention. This philosophy of prevention is based on the notion that potential problems and their root causes are identified before they occur. Optimization positions the design of quality as far as possible from all potential problems. The information is fed downstream to ensure that the problem is not introduced. In other words, *quality must be designed into the product, not inspected out of the product.*

We must change our paradigms of quality or, as Deming (1986) pointed out, we will pay some series consequences in the world of competition. If we do not change our thinking about quality, we are going to end up like the caterpillars in the following story.

> Processionary caterpillars feed upon needles. They move through the trees in a long procession, one leading and the other following, each

> with his eyes closed and his head snugly fitted against the rear extremity of his predecessor. Jean Henri Fabre, the French naturalist, after experimenting with a group of these caterpillars, finally enticed them to the rim of a large flower pot where he succeeded in getting the first one connected with the last one, thus forming a complete circle which started moving around in a procession which had neither a beginning nor an ending. The naturalist expected that they would soon get tired of their useless march and start off in a new direction, but not so.
>
> Through sheer force of habit, the living, creeping circle kept moving around the rim of the pot, around and around, keeping the same relentless pace for seven days and seven nights, and would have continued longer had it not been for sheer exhaustion and ultimate starvation.

Incidentally, an ample supply of food was close at hand and plainly visible, but outside the range of the circle, so they continued along the beaten path. They were following instinct, habit, custom, tradition, precedent, past experience, "standard practice," or whatever you may choose to call it, but they were following it blindly. They mistook activity for accomplishment. They meant well, but they got no place. There must be a better way.

The inspection approach and technology to achieve quality was the "new and better way" of the 1850s. It is now widely recognized that inspection in any environment has many problems. Everyone who is involved in achieving quality in any organization now recognizes that some form of online control is needed to react to problem tendencies before the problem actually occur.

To achieve improved quality and reliability, lower cost, and shorter development time, performance must be elevated to a new level. The old approaches and thinking have to be changed in order to accommodate the new wave of quality which is:

- prevention of problems
- reduction of unreliability
- elimination of waste

III. THE GURUS OF QUALITY

A. W. Edwards Deming

One of the most inspirational and influential gurus of quality in the twentieth century, is W. Edwards Deming. Much has been written about both him and his philosophy, so this section simply summarizes his philosophy and his 14 points for transformation of management. The reader is encouraged to see other sources about Deming (such as Deming, 1986; Scherkenbach, 1991; Dobyns and Crawford-Mason, 1994; and Latzko, Saunders, and Saunders, 1995.

Deming and Quality

- Real profits are generated by loyal customers, not just satisfied customers.
- The company that develops loyal customers has much higher earnings than the company that just pushes the product out the door.
- Merit reviews, by whatever name (e.g., management by objectives), are the single most destructive force in American management today.
- The belief that the worker is responsible for the poor quality and low productivity of American firms is wrong.
- Workers cannot change the system, only management can.

Summary of Deming's Philosophy

- Quality and cost are not opposites or trade-offs, with one being improved at the expense of the other. Instead both can be constantly improved.
- Quality is best understood from the point of view of the customer, but one important component of quality is improving uniformity.
- Variation is a naturally occurring phenomenon.
- Cooperation is a fundamental ingredient that leads to improvement. In conventional thinking competition is always preferred over cooperation.

The Typical Deming Company

The following characteristics, beliefs, and philosophy are necessary for the typical Deming company.

- Quality leads to lower costs.
- Inspection is too late. If workers can produce defect-free goods, eliminate inspectors.
- Quality is made in the board room.
- Most defects are caused by the system.
- Process never optimized; it can always be improved.
- Elimination of all work standards and quotas is necessary.
- Fear leads to disaster.
- People should be made to feel secure in their jobs.
- Most variations are caused by the system. Review systems that judge, punish, and reward above or below average performance destroy teamwork and the company.

- Buy from suppliers committed to quality.
- Work with suppliers.
- Invest time and knowledge to help suppliers improve quality and costs. Develop long-term relationships with suppliers.
- Profits are generated by loyal customers.
- Running a company by profit alone is like driving a car by looking in the rearview mirror. It tells you where you have been, not where you are going.
- Workers are really paying for the errors of management.
- Quality must come first. As quality increases, costs are decreased.
- If quality is sacrificed in trying to increase profitability, the actions will backfire.
- We bought European and Japanese products because we got stung by the quality of domestic goods. Our problem has been quality.
- The financial statements are not reality. They are a financial description of the past, a one-dimensional picture of a multidimensional world.
- Our competitive problems are not due to the workers in the system. They are due to poor management. More accurately, they are due to our managing under a set of ideas that is outmoded and incorrect.
- Quality has to be considered from the point of view of the user. One definition of quality is anything that enhances the product from the viewpoint of the customer.
- One important ingredient of quality is uniformity.
- The benefit of loyal customers and happy employees is unknown and unknowable. The improvement in costs because of better quality is also rarely measurable in full.
- As long as your attitude toward quality is that we just need to meet the competition or obtain a curtain level of quality, we are going to be in trouble.
- By allowing and even urging workers to experience the intrinsic rewards that come from doing something well and by using their innate and acquired abilities, productivity improves, quality improves, and customer satisfaction improves.
- Knowledge is the key ingredient of quality.
- Profound knowledge is knowledge universal to all businesses, large or small, in service or manufacturing, profit-making or not-for-profit. Clarity in the definition of quality and knowledge of the principle that increasing quality leads to increase productivity and higher profits are two elements. Other aspects include knowledge of variation, some psychology, and knowledge of the need for cooperation.
- Quality is everyone's responsibility.

- The people who are most in need of profound knowledge are the managers, particularly top managers.
- Quality defined from the user's point of view is anything that enhances satisfaction.
- No business can operate for long unless a certain amount of stability has been achieved. Deming estimates that in most business situations 94% (originally 85%) of the problems are problems of the system while only 6% (originally 15%) are special in nature.
- Giving workers higher pay will not improve quality but will cause resentment among those who do not receive incentive pay.
- Quotas double the cost of production.
- It is not unusual to find workers stopping an hour before the whistle blows. Great peer pressure is expected to keep production down so that all can meet the quota. No one makes suggestions that may improve production. The workers in such an environment are unhappy, but from management's point of view the quota is being met and that is all that counts.
- Neither the workers nor the foremen are capable of making the changes necessary to improve the quality of the incoming materials are changes in policy that only management can authorize.
- Management is responsible for making sure the employees are properly trained for their new job.
- When top management blames every accident on the lax behavior of the workers, they are admitting their ignorance and abdicating their responsibility.
- Whenever management uses fear, they will get incorrect numbers and misleading information.
- The causes of common problems cannot be attacked directly. It is a mistake to believe that one is improving quality when an inspector recognized and rejects a defective product or when a major quality flow is found. That is just recognizing a defect being produced by the system; it is not improving quality, it is not improving the system.
- A company that operates using fear, positioning top management against workers and middle management against the top, cannot produce the continual improvement in quality necessary to compete in the market place.
- One part of profound knowledge is obvious to children but not to some college presidents. In any group, half, will be below average.
- Cooperation is one of the key ingredients of improvement. Quality cannot be obtained and improvement is impossible without cooperation. Competition that most benefits the consumer occurs in a framework of cooperation.

- Quality Control Circles are nothing more than formalized meetings of workers, foremen, and engineers from various departments. By pooling their knowledge of a process, they are better able to tackle problems of quality.
- Perhaps 10% of the hourly workers and 2% of middle management really enjoy their work. By this measure, at least, American management has failed.
- It is the leader's job to lead the charge toward better quality.
- There is one job that belongs to the leader alone, and that is making sure all the parts and all the people work together.
- A leader's job is to see that everyone in his/her group works together and that his/her group works with the rest of the organization harmoniously to achieve the aims of the organization.
- Management is people.
- It is the leader's job to foster joy in work, harmony, and teamwork.
- Leaders have to be the primary agents for improvement.

Deming's Cycle of Continuous Improvement

1. Plan to change whatever you are trying to improve.
2. Carry out the change on a small scale.
3. Study the results.
4. Decide on an action, based on what you have learned from the change.
5. Repeat the cycle over and over.

This cycle can be seen in Figure 1.1.

Deming's 14 points for Transformation of Management

1. Create constancy of purpose toward improvement of product and service with the aim to become competitive, to stay in business, and to provide jobs.
2. Adopt a new philosophy.
3. Cease reliance on mass inspection to achieve quality. Eliminate the need for inspection on a mass basis by building quality into the product in the first place.
4. End the practice of awarding business on the basis of price alone.
5. Constantly improve the system of production and service; this will improve quality and productivity and constantly decrease costs.
6. Institute training on the job.
7. Institute leadership; the aim of supervision should be to help people and machines and gadgets to do a better job.
8. Drive out fear so that everyone may work effectively for the company.

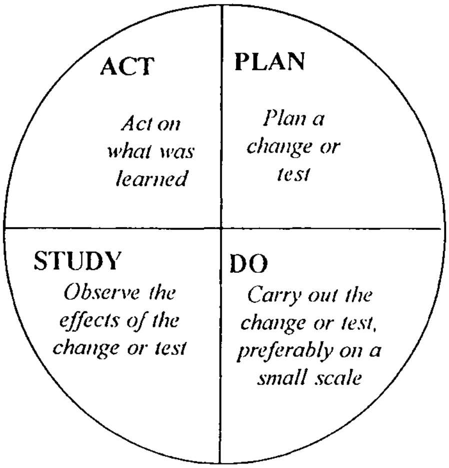

Figure 1.1 The Plan-Do-Study-Act cycle.

9. Break down barriers between departments.
10. Eliminate slogans.
11. Substitute leadership for work standards and management by objectives.
12. Remove barriers that rob the hourly workers and management of their right to pride of workmanship. The responsibility of supervisors must be changed from mere numbers to quality. End annual reviews or merit rating and management by objectives.
13. Institute a rigorous program of education and self-improvement.
14. Put everybody in the company to work to accomplish the transformation—it is everybody's job.

Barriers to Pride of Workmanship

1. Lack of direction
2. Goals without the tools to achieve them; time, resources
3. Arbitrary decisions by supervisors
4. Lack of clear goals and objectives
5. Lack of clarity as to how contribution is valued
6. Lack of expectations setting up criteria
7. Insufficient information available
8. Different organizational goals withing the company
9. Too much group management

10. Deadline anxiety
11. Lack of product definition: purpose and product arbitrarily changed by consumer and/or customer within company
12. Organization not valued by line organization
13. Hierarchy tries to run a technology that it does not understand
14. Lack of communication
    - conflicting and unclear objectives
    - lack of advance information
    - inadequate information flow
    - inadequate feedback
    - lack of authority to do what needs to be done
15. Lack of resources, time, and proper tools and equipment
16. Short-term objectives conflict with long-term ones
17. Nonuniform application of policy
18. Poor training
19. Specifications constrain creativity and procurement and manufacturing
20. Fear
21. Company and union adversarial relationship
22. Red tape/bureaucracy.
23. Unrealistic goals and objectives

The Seven Deadly Sins

In his wisdom, Deming, in addition to crystallizing his philosophy in the 14 points, also identified seven deadly diseases that, if unattended, cause harm in the organization and prevent it from becoming a "world-class" organization. The seven deadly sins are:

1. A lack of constancy of purpose to plan products and services that will have a market and keep the company in business and provide jobs.
2. An emphasis on short-term profits: short-term thinking (just the opposite from constancy of purpose to stay in business), fed by fear of unfriendly takeover, and by the push from bankers and owners for dividends.
3. The evaluation of performance by merit rating or annual review. It nourishes short-term performance, annihilates long-term planning, builds fear, demolishes teamwork, nourishes rivalry and politics. It leaves people, bitter, crushed, bruised, battered, desolate, despondent, dejected, feeling inferior, some even depressed, unfit for work for weeks after receipt of rating, unable to comprehend why they are inferior. It is unfair, as it ascribes to the people in a group differences that may be caused totally by the system (management)

that they work in, and not by anything that they themselves could control.

4. A constant change in management due to job hopping or continuous replacement or exchange of people in leadership positions. This leaves everyone wondering about stability, having to deal with new styles of leadership and changes in direction.
5. Management by the use of only visible figures, with little or no consideration of the figures that are unknown or knowable. This is peculiar to industry in the United Sstates. (He that would run his company on visible figures alone will in time have neither company nor figures.) What are the figures for failing to satisfy the customer, improving quality and productivity, poor leadership, inept design of a product, and the failure to improve processes?
6. The presence of excessive medical costs, unsafe products, unsafe processes, unsafe work place, and job stress.
7. Excessive costs of liability, swelled by lawyers that work only on contingency fees.

B. J. M. Juran

Juran, like Deming, is credited with part of the quality success story of Japan, where he went in 1954 to lecture on how to manage for quality. He is the author of numerous books on quality, leadership, and management as well as delivering speeches and seminars all over the world.

Juran was the first to deal with the broad management aspects of quality, which distinguishes him from those who espouse specific techniques, statistical or otherwise. As far back as 1940s, he pointed out that the technical aspects of quality control had been well covered, but that organizations did not know how to manage for quality. He identified some of the problems as organization, communication, and coordination of functions—in other words, the human element.

According to Juran, there are two kinds of quality: "fitness for use" and "conformance to specifications." Furthermore, there are three steps to progress: structured annual improvements combined with devotion and a sense of urgency, massive training programs, and upper management leadership. In his view less than 20% of quality problems are due to workers, with the remainder being caused by management. Because of this, Juran believes that all managers should have training in quality in order to oversee and participate in quality improvement projects.

Juran is also a strong believer of avoiding campaigns to motivate the workforce to solve the company's quality problems by doing perfect work. He claims that these exhortations are only shallow slogans that fail to set specific goals, establish specific plans to meet these goals, or provide the needed resources. However, he also points out that upper managers like these programs because they do not detract from their time.

Other important issues that Juran brought to the quality field are:

- The notion that quality circles improve communications between management and labor.
- The use of statistical process control, but he warns that it can lead to a tool-oriented approach.
- The notion that quality is not free (because of the law of diminishing returns). There is an optimum point of quality, beyond which conformance is more costly than the value of the quality obtained.
- The recognition of purchasing's role in quality and control of the suppliers, because they are part of the quality chain. He is a strong supporter of supplier qualification and surveys to insure that the supplier can consistently manufacture to specifications.
- The notion that single sourcing is counterproductive for an organization, since a single source can more easily neglect to sharpen its competitive edge in quality, cost, and service.

Juran's philosophy can be summarized by his 10 steps to quality improvement.

1. Build awareness of the need and opportunity for improvement
2. Set goals for improvement
3. Organize to reach the goals (establish a quality council, identify problems, select projects, appoint teams, designate facilitators)
4. Provide training
5. Carry out projects to solve problems
6. Report progress
7. Give recognition
8. Communicate results
9. Keep score
10. Maintain momentum by making annual improvement part of the regular systems and processes of the company

For more detailed information on Juran's philosophy, see Juran and Gryna (1988, 1993) and Juran (1989, 1992, 1995a,b).

C. Armand V. Feigenbaum

Armand V. Feigenbaum has been credited with the approach to quality and productivity that has profoundly influenced the competition for world markets. That approach is the Total Quality Control concept. Feigenbaum's philosophy is articulated in a series of principles which define the quality of products and services as a primary business strategy and a fundamental determinant for business health, growth, and economic viability. The main principles of the theory are:

1. Total quality control for Feigenbaum may be defined as: An effective system for integrating the quality-development, quality maintenance, and quality improvement efforts of the various groups in an organization so as to enable marketing, engineering, production, and service at the most economical levels which allow for full customer satisfaction.
2. In the phrase "quality control," the word "quality" does not have the popular meaning of "best" in any absolute sense. It means "best for certain customer requirements." These requirements are the actual use and selling price of the product.
3. In the phrase "quality control," the word "control" represents a management tool with four steps: a) setting quality standards, b) appraising conformance to these standards, c) acting when the standards are exceeded, and d) planning for improvements in the standards.
4. Quality has to be integrated in the entire organization for any measurable impact and improvement.
5. The factors affecting quality are: a) technological and b) human. Of these, the human factor is of greater importance by far.
6. Effective control over the factors affecting quality demands controls at all important stages. These stages fall in the four natural classifications: a) new design control, b) incoming material control, c) product control, and d) special process control.
7. The details for a quality control program must be tailored to fit the needs of individual organizations.
8. Quality costs are a means for measuring and optimizing total quality control activities. Quality costs are divided into four types: a) prevention costs, b) appraisal costs, c) internal failure costs, and d) external failure costs.
9. From the human relations point of view, quality control organization is both a channel of communication for product quality information among all concerned employees/groups, and a means of participation in the overall quality control program by these employees and groups.
10. Necessary to the success of the quality program in an organization is the spirit of quality mindedness, extending from top management to the employees at the work floor.
11. Statistics may be used in an overall quality control program, but statistics are only one part of the total quality control pattern; they are not the pattern itself. The five most basic statistical tools are:

a) frequency distributions, b) control charts, c) sampling tables, d) special methods, and e) product reliability.

12. The total quality program provides the discipline methodology and techniques to assure consistently high product quality throughout the organization. Furthermore, it coordinates the efforts of the people, the machines, and the information which are basic to total quality control to provide high customer quality satisfaction which brings competitive advantage to the company.

See Feigenbaum (1991) for his detailed theory.

D. Philip B. Crosby

Philip B. Crosby is best known for introducing the concept of zero defects in the 1960s. According to Crosby the definition of quality is conformance to requirements and it can only be measured by the cost of nonconformance. His approach to quality means that the only standard of performance is zero defects. To be successful at this, the focus is on prevention which he defines as perfection. There is no place in his philosophy for statically acceptable levels of quality.

Crosby's contention is that people go to great elaborate things to develop statistical levels of compliance. He claims that we have learned to believe that error is inevitable, and therefore we plan for it. He goes on to say that we must change our way of thinking to the point where we accept that there is absolutely no reason for having errors or defects in any product.

Crosby talks about a quality "vaccine" that organizations can use to prevent nonconformances. The three ingredients of this vaccine are determination, education, and implementation. He points out that quality improvement is a process not a program. His philosophy towards quality may be summarized with his 14 steps to quality improvement. They are:

1. Make it clear that management is committed to quality.
2. Form quality improvement teams with representatives from each department.
3. Determine where current and potential quality problems lie.
4. Evaluate the quality awareness and personal concern of all employees.
5. Raise the quality awareness and personal concern of all employees.
6. Take actions to correct problems identified through previous steps.
7. Establish a committee for the zero defects programs.
8. Train supervisors to actively carry out their part of the quality improvement program.

9. Hold a "zero defects day" to let all employees realize that there has been a change.
10. Encourage individuals to establish improvement goals for themselves and their groups.
11. Encourage employees to communicate to management the obstacles they face in attaining their improvement goals.
12. Recognize and appreciate those who participate.
13. Establish quality councils to communicate on a regular basis.
14. Do it all over again to emphasize that the quality improvement program never ends.

See Crosby (1979) and Philip Crosby Associates (1985) for more detailed information.

E. G. Taguchi

Taguchi's contribution to the field of quality is in the area of parameter design. It is Taguchi's contention that in order to improve quality and reduce cost, one must plan prevention methods to avoid these costs. In addition, Taguchi suggests that all quality problems have an associated cost attached to them and somebody always pays. (The entity that ends up paying may or may not be the producing agent of the problem.) This notion has been quantified through the concept of the "loss function," which measures the cost, as the quality varies about the target (Figure 1.2). As in the case of all the gurus of quality much has been written about Taguchi (see Barker and Clausing, 1984; Taguchi, 1986, 1987; Taguchi and Konishi, 1987; Ross, 1988; Roy, 1990; Peace, 1993). Therefore, we will not elaborate the details of his philosophy; however, because his philosophy is a very potent one and is being utilized in many industries with much success we offer the following summary. (Readers interested in Taguchi's approach to quality are encouraged to see Chapter 9 for more details and/or references.)

1. Problem prevention in the design phase is better than inspection of the design.
   - Comparing designs one by one and selecting the best one is a very inefficient way of optimizing design quality.
   - Do not wait to detect failures of the design. rather identify faulty designs before they fail and/or need improvement.
2. Use a quality loss function to put a dollar value on quality.
   - The loss function allows for early prediction of cost of quality and guides improvements before problems are detected.
   - The loss function helps in improving customer satisfaction, and not simply meeting the customer's specification.

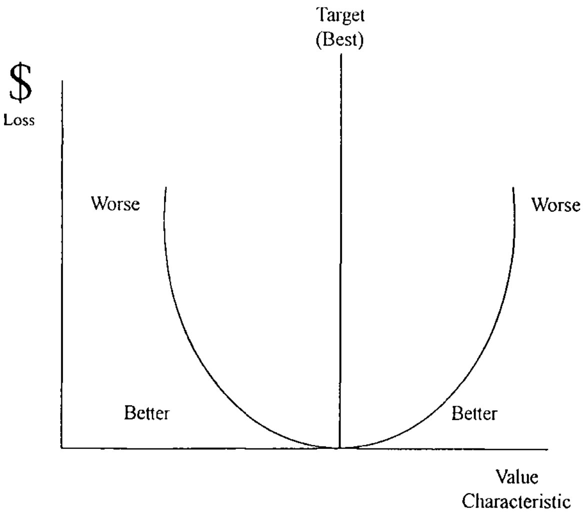

Figure 1.2 The loss function.

3. Use orthogonal arrays, signal-to-noise (S/N) ratios, and quality loss function to rapidly:
   - reduce low-cost production variances
   - enlarge customer-acceptable variances (production, environmental, time)
   - achieve the best balance between resources and quality
   - achieve mature designs with zero defects at launch
   - provide quantitative comparison with competitive benchmark
   - achieve high quality and low reject rates.
4. Common methods for product design and manufacturing:
   - break down traditional barriers
   - provide a common language and approach
   - help integrate suppliers

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2

Traditional Quality Concepts

To understand and implement TQM with positive results, one must understand some of the key concepts that exist within the scope of quality. Without these concepts, TQM is only wishful thinking. This chapter discusses some of the old concepts in quality. None of them, of course, are given an exhaustive discussion. The intent of this chapter is to review these concepts because the foundations of quality are indeed built upon them. The references at the end of the chapter will help the reader to find the details necessary for a more comprehensive discussion and understanding.

I. DATA

In any plan, any single observation about a specified characteristic of interest is called a datum point. It is the basic unit of the quality person's raw material. Any collection of observations about one or more characteristics, of interest, for one or more elementary units, is called a data set. A data set is said to be univariate, bivariate, or multivariate depending on whether it contains information on one, two, or more than two variables (Becker and Harnett, 1987).

The set of all possible observations about a specific characteristic of interest is called a population or universe. It is important to note that when we speak of population or universe, by definition, we speak of all possible observations about a variable. When we speak of any subset (portion) of the population or universe we call it a sample. Conventionally, we represent this dichotomy of population and sample with Greek letters and English letters respectively. For example: A population standard deviation is represented by σ and the sample standard deviation is s.

Caution should be exercised here, however, because a population and/or sample depends entirely on how the question is raised. A sample may be a population and a population may be a sample. For example, Company XYZ had a recall of 1000 parts. The industry that his company belongs to had a recall of 1,000,000 parts. If Company XYZ wants to analyze the 1000 parts only, then the 1000 parts become the population of this study. If on the other hand, Company XYZ wants to analyze and compare the 1000 parts with the 1,000,000 parts then the 1000 parts are in fact a sample of all the recalled parts.

In addition to the sample and population concerns, any given characteristic of interest can differ in kind or in degree among various elementary units. A variable that is normally expressed numerically because it differs in kind rather than degree, is called a qualitative variable. Qualitative variables can be dichotomous or multinominal. Dichotomous qualitative variables are also called attribute or categorical variables because they are of two categories (e.g., go/no go, male/female, good/bad, on/off, good/reject.) Multinominal qualitative variables can be placed in more than two categories (e.g., job titles, types of business, colors; Daniel and Terrell, 1989; Becker and Harnett, 1987; Freund and Williams, 1972).

On the other hand, a variable that is normally expressed numerically, because it differs in degree rather than kind, is called a quantitative variable. Quantitative variables can in turn be discrete or continuous. Observations about discrete quantitative variables can assume values only at specific points on a scale of values, with gaps between them (e.g., cars in stock, rooms in houses).

Observations about continuous quantitative variables can, in contrast, assume values at all points on a scale of values, with no breaks or gaps between them (e.g., weight, time, temperature.) No matter how close two values are to each other, it is always possible for a more precise device to find another value between them. The accuracy of the measurement depends on the ability of the measurement instrument.

The distinction between qualitative and quantitative variables is visually obvious. The observations about one type of variable are recorded in words; those about the other type in numbers. Yet the distinction can be blurred: quantitative variables can be converted into seemingly qualitative ones and the opposite is also true. For instance, when we speak of high or low temperature/pressure we have in fact taken a quantitative (measurable) variable and transform it to an attribute (subjective) variable. When this coding takes place information is lost in the process. Conversely, it is not uncommon to code attribute variables with numerical values such as, for example: "good" as 1 and "bad" as 0.

A. Types of Data

The assignment of numbers and/or values to characteristics that are being observed—measurement—can yield four types of data of increasing sophistication. It can produce nominal, ordinal, interval, or ratio data, and different statistical concepts and techniques are appropriately applied to each type. For the actual selection of statistical techniques see Appendix A.

The weakest level of measurement produces nominal data which are numbers that merely name or label differences in kind and thus can serve the purpose of classifying observations about qualitative variables into mutually exclusive groups. No mathematical operations are possible except counting.

The next level of measurement produces ordinal data which are numbers that by their size order or rank observations on the basis of importance, while intervals between those numbers are meaningless. Again, no arithmetic operations are possible.

In the third level of sophistication are the interval data that permits at least addition and subtraction. Interval data are numbers that by their size, rank observations in order of importance and between which intervals or distances are comparable, while their ratios are meaningless. This kind of data possesses no meaningful origin and thus by a given definition establishes the zero point as well as equally arbitrary intervals between numbers.

The most useful types of data are the ratio data which are numbers that rank observations by their in the order of importance, and between which intervals as well as ratios that are meaningful. All types of arithmetic operations are possible because these types of numbers have a natural or a "true" zero point that denotes the complete absence of the characteristic they measure and makes the ratio of any two such numbers independent of the unit measurement.

B. Data Collection

Data can be gathered in different forms. First, however, the purpose of the data must be determined. Only then can a decision be made as to what kind of data would best serve the purpose. There can be many purposes for collecting data in the world of quality. Some common purposes are:

1. Understand the actual situation. Data is collected to check the extent of the current process.

2. Analysis. Data are collected to perform statistical analysis for a historical perspective of the process and/or future behavior of the same process.
3. Process control. After investigating product quality, this data can be used to determine whether or not the process is normal. In this case, control charts are used in this evaluation and action is taken on the basis of these data.
4. Regulation. This data is used as the basis for regulating the process based on a previously set goal.
5. Acceptance or rejection. This form of data is used to approve or reject parts and/or products after inspection. There are two methods total inspection and sampling. On the basis of the information obtained, a decision of what to do with the parts or products can be made.

It is imperative that the purpose of data collecting is not to put everything into neat figures but to provide a basis for action. The data may be in any form, but is generally divided into the measurement data and the countable (attribute) data. Once the purpose of the data has been defined, data can be generated by conducting a survey or by performing an experiment. A survey or observational study, is the collection of data from basic units without exercising any particular control over factors that may make these units different from one another and therefore affect the characteristic of interest being observed. An experiment on the other hand, involves the collection of data from basic units while exercising control over some or all factors that may make these units different from one another and therefore affect the characteristic of interest being observed.

II. SAMPLING

Data collection is the first step in working on problems; this provides information to assure that everything is within allowable tolerances and under control. Data can also be analyzed when things go out of control to find out what went wrong. Ideally, 100% of the given output would be checked for problems. However, this is not usually feasible because of time and cost considerations. Instead, what experimenters do is to design a plan that will be a portion of the 100% data, yet representative of the original without any bias in the selection process. This portion of the original data is called a sample. Representative data can be acquired by closely sampling the given output. This allows the use of smaller numbers, to be used for generalizations to the entire population (output). There are three types of samples used in all forms of statistical analysis; they are:

1. *Convenience sample.* When expediency is of primary concern, a-not-so-representative sample may be selected.

2. *Judgement sample.* A personal judgement is used for the selection of the sample based on "some" previous experience. Although used in the field of quality, caution should be exercised because of inherent biases by the selector of the sample.
3. *Random sample or probability sample.* Nonrepresentativeness is not one of the characteristics of this sample; rather, this sample is a subset of a population, chosen by a random process that gives each unit of that population a known positive (but not necessarily equal) chance to be selected. If properly executed the random selection process allows no discretion to the experimenter as to which particular units in the population enter the sample. This form of sampling maximizes the chance of making valid inferences about the totality from which it is drawn. There are four types of random sampling and they are:

   Simple random sample. This is a subset of a population chosen in such a fashion that every possible subset of like size has an equal chance of being selected. Here be cautioned in that the implication of each individual unit of the population has an equal chance of being selected, but the converse is not true (i.e., giving each individual unit an equal chance of being selected does not assure that every possible subset of like size has an equal chance of selection).

   Systematic random sample. This is a subset of a population chosen by randomly selecting one of the first elements and then inducing every *ith* element thereafter. In this procedure the i is determined by dividing the population size, N, by desired sample size, n.

   Stratified random sample. This is a subset of a population chosen by taking separate (simple or systematic) random samples from every stratum in the population, often in such a way that the sizes of the separate samples vary with the importance of the different strata.

   Clustered random sample. This is a subset of a population, chosen by taking separate censuses in a randomly-chosen subset of geographically distinct clusters.

A. Errors in Sampling Data

The process of gathering information is one of collecting and filtering data. The ultimate solution is a combination of good information at all levels, structures that size the decision-making process, and personal reconnaissance on the part of the decision maker at each level.

Statistics, even when most accurate, can never be the complete substitute for an in-depth knowledge of the situation of collecting, filtering, and analyzing data. Deming (1986) pointed out that there is a difference between visible and invisible numbers. He comments that some managers look only at the visible numbers, "but the visible numbers tell them so little. They know nothing of the invisible numbers. Who can put a price on a satisfied customer, and who can figure out the cost of a dissatisfied customer?"

Every sample from a large population is subject to a random error or chance error or sampling error. This error is the difference between the value of a variable obtained by taking a single random sample and the value obtained from the entire population. The second error is the systematic error or bias or nonsampling and is the difference between the value of a variable obtained by taking the population and the true value. Another way of explaining these errors is by thinking of sampling error as the reliability of data and nonsampling as the validity of the data.

Reliability is a concept like repeatability. If you keep repeating in all executionary details, then there is a probability that your sample will have an operating range. Furthermore, it will have a degree of stability that is based on that operating range. Note that this has nothing to do whatsoever with how accurate your sample was. This is a trap that most practitioners fall into and they are justified with what is called "confidence statement" or "statistical significance." To speak of 90%, 95%, or even 99% confidence is an issue of very limited value in management knowing that findings of a particular sample would probably be very similar to those of a second and/or third sample, if they were identically conducted. Such knowledge begs the issue of whether the sample methodology was any good in the first place. Statements of statistical significance beg the issue of data validity and hence its usefulness.

One can hardly list all possible types of nonsampling error, all the ways that a sample can yield misleading data, and all sources of invalid information about a target process. Only selected few are listed here:

1. In the planning stage
   a. Selection bias is a systematic tendency to favor the inclusion in a sample of selected basic units with particular characteristics, while excluding other units with other characteristics.
   b. Response bias is a tendency for selection of a sample to be wrong in some systematic way.
2. In the collection stage
   a. Selection bias is apt to enter the sample when experimenters are instructed to select within broad guidelines or the particular characteristics that they will sample.
   b. Response bias can arise for a number of reasons during data collection. Both the experimenter and the process may be at fault.
   c. Nonresponse bias may arise when no data (legitimate) is available from the sample.

3. In the processing stage. The emergence of bias during data collection can conceivably be minimized by the careful design of the sample. Nevertheless, bias can enter even at the data processing stage. People who code, edit, keypunch, tabulate, print, and otherwise manipulate data have many opportunities for making non-canceling errors. One of the areas that is a major concern in the quality area is the issue of data "outliers" or "wild values." We have a tendency to eliminate unbelievable data (high, low or just different from the majority), and/or to substitute zero for a "no value" and vice versa.

B. Controlling the Sample Data

To optimize the results of your sampling data the following may be considered.

1. Weighting sample data. This technique involves the multiplication of sample observations by one or more factors to increase or decrease the emphasis that will be given to the observation. The troublesome aspect of weighting is related to the selection or calculation of the weighting factors. The specifications of the weighting scheme must be defined in terms of our overall objective: What is the purpose of weighting? In most cases, the obvious answer is that we would like our sample data to be representative of the population. The immediate follow-up to the first question is another: In what ways are the data to be representative of the population? The answer to this question should lead us to select an appropriate technique.
2. Beware of the homing pigeon syndrome. This is where you become completely dependent for data on the incoming paper flow; you lose the interactive process and find out only what the sender wants you to know.
3. Reports/data required from the bottom up must be balanced by data interchange from the top down. Asking the same old questions gets the same old answers. If the system does not allow for an interchange in the data flow process, you will soon find yourself asking the wrong questions, at which point the answers do not matter.
4. Have appropriate sample for the specific project. It is imperative that we determine the correct sample plan before we begin experimenting.

III. VARIATION

Variation is so important and fundamental to all quality issues that everyone in the organization must understand it. Variation, in its simplest definition, may be defined as "change." In a more formal definition, variation is the difference between the target measurement and the actual measurement.

No two products or characteristics are exactly alike because any production process contains many sources of variability. The differences among products may be large or they may be almost unmeasurably small, but they are always present. The diameter of a cylinder, for instance, would be susceptible to potential variation from the machine (e.g., clearances, bearing wear), tool (e.g., strength, rate of wear), material (e.g., hardness, grade), operator (e.g., part feed, accuracy of centering), maintenance (e.g., lubrication, replacement of worn parts), and environment (e.g., temperature, constancy of power supply).

Some sources of variation in the process cause very short-run piece-to-piece differences such as backlash and clearances within the machine and fixuring, or the accuracy of the operator's work. Other sources of variation tend to cause changes in the product only over a long period of time, either gradually as with tool or machine wear, step-wise as with changes from one raw material lot to the next, or irregularly, as with environmental changes such as power surges. Therefore, the time period and conditions over which measurements are made will affect the amount of the total variation that will be measured.

From a specification standpoint, the only concern is with the total variation, regardless of source. Parts within specification tolerances are acceptable; parts beyond specification tolerances are not acceptable. However, to manage a manufacturing process the total variation must be traced back to its sources. The first step is to make the distinction between common (i.e., natural, inherent) and special (i.e., assignable) causes of variation.

Common causes refer to the many sources of variation within a process that is in statistical control. They behave like a constant system of chance causes. While individual measured values are all different, as a group they can be described as a distribution. This distribution can be characterized by its:

- location (typical value)
- spread (amount by which the smaller values differ from the larger ones)

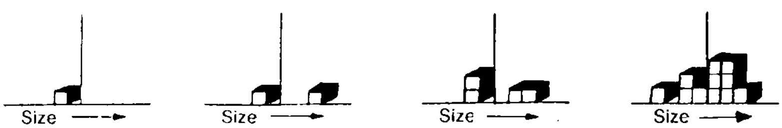

Figure 2.1 Piece-to-piece variation.

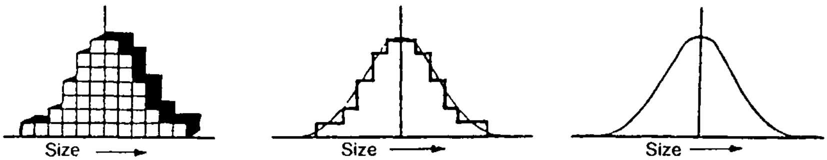

Figure 2.2 Pieces that form a distribution.

- shape (the pattern of variation—whether it is symmetrical, peaked, and so on.)

The illustrations in Figures 2.1, 2.2, and 2.3 reflect the nature of distributions as affected by these factors. Specifically, Figure 2.1 shows pieces vary from each other; Figure 2.2 shows pieces that form a pattern that, if stable, is called a distribution; Figure 2.3 shows that distributions can differ in location, spread, and shape. If only common causes of variation are present, the output of a process forms a distribution that is stable over time; and that is predictable. This is shown in Figure 2.4.

Special causes refer to any factors causing variation which cannot be adequately explained by any single distribution of the process output, as would be the case if the process were in statistical control. Unless all the special causes of variation are identified and corrected, they will continue to affect the process output in unpredictable ways. This is because if special causes are present, the process output will not be stable over time and therefore will be unpredictable. This is shown in Figure 2.5. In general then, we can view the area of process control as one in which special (assignable) causes of variation have been eliminated. This is shown in Figure 2.6. Table 2.1 displays some of the characteristics of variation. For a more detailed discussion see Wheeler (1993), Grant and Leavenworth (1988), and Chrysler, Ford, and General Motors (1995).

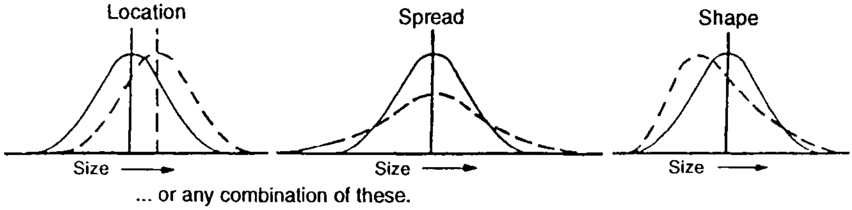

Figure 2.3 Distributions with different location, spread and shape.

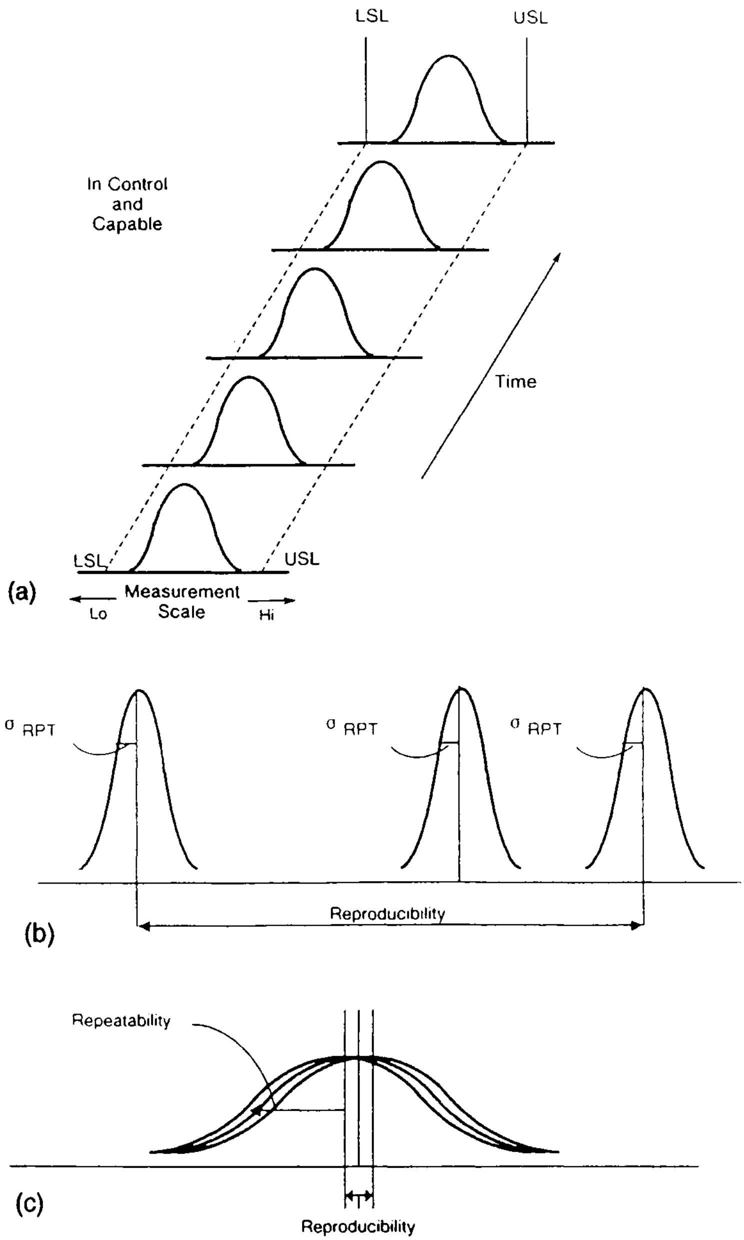

Figure 2.4 (a) A distribution with common variation. (b) Repeatability distributions. (c) Distributions with averages that are almost equal.

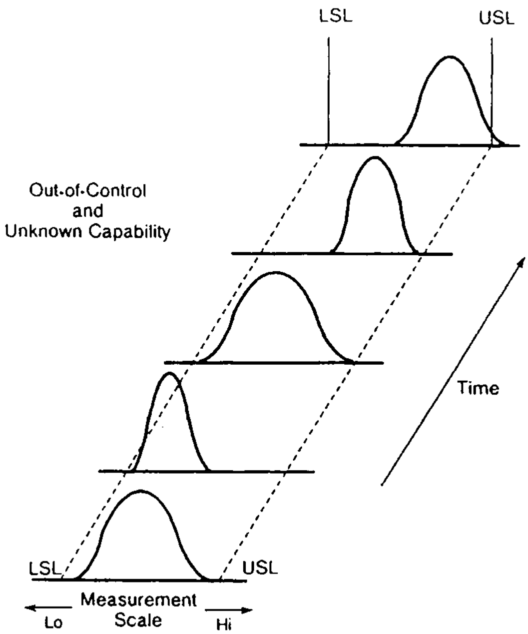

Figure 2.5 An unpredictable and unstable process.

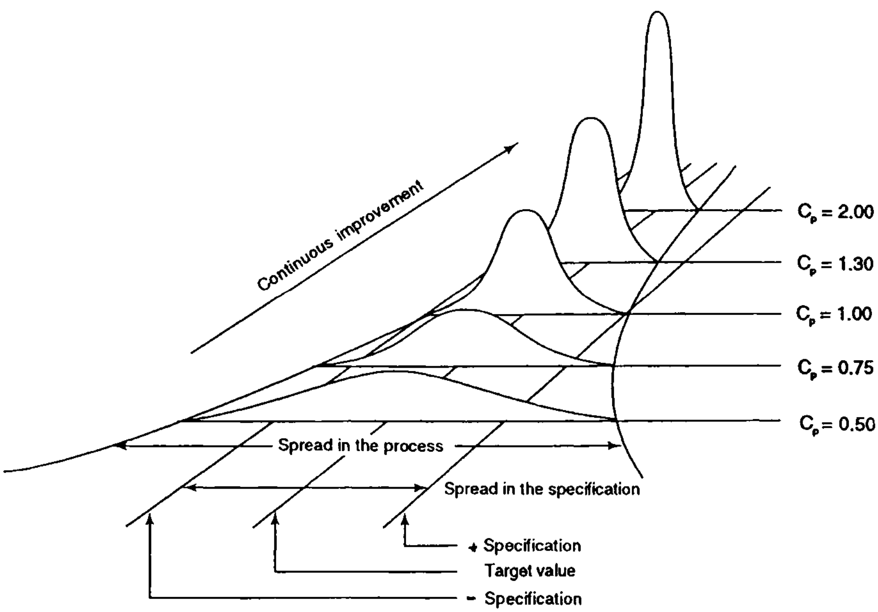

Figure 2.6 A process in which assignable causes have been eliminated.

Table 2.1 Characteristics of Variation

	Common cause	Special cause
Scope of influence	All data in similar manner	Some (or all) data in dissimilar manner
Typical identity	Many small sources	One or a few major sources
Nature	Stable: relatively predictable; inherent in the process	Irregular: unpredictable, appears and disappears
Improvement action	Remove common cause(s)	Eliminate special cause
Improvement action responsibility	System fault: management	Local fault: operator, supervisor

IV. MEASUREMENT

People measure product characteristics or process parameters so they can assess the performance of the system of interest. The measured values provide feedback of the process so that people may adjust settings, replace tools, redesign fixtures, or to allow the operation to continue on its current course. The measurements are indeed the data that allow people to make decisions critical to improvement efforts.

As critical these measurements are, no measurement process is a set of perfect activities. Sometimes different numbers or readings result when the same part or sample is measured a second time. Different readings may be made by different people and gauges, or by the same person using the same gauge. The difference in successive measurements of the same item is called measurement error. This source of variation must be analyzed because the validity of the data directly affects the validity of process improvement decisions.

The measurement system is a major component of the process. In fact, studying variation within the parameters of the measurement system is of paramount importance because:

- Measurement error contributes to process variation and has a negative influence upon the process capability level.
- Measurement error is present whenever measurements are made.

The effects of measurement error influence the assessment of all other items of the process.

In addition to being a part of the process or system, measurement activities also form a process. A typical measurement process is shown in Figure 2.7. There are five components which combine together as the oper-

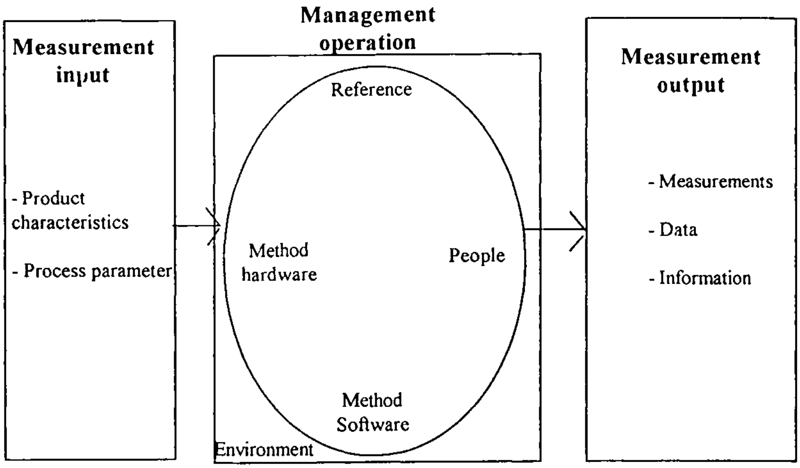

Figure 2.7 Measurement process.

ation or activity of the measurement system to result in the output. The output is the data, readings, or measurements from the process.

It must be emphasized that it is totally inappropriate to view measurement error as merely a function of measurement hardware or instruments. Other components of the measurement process are equally important to measurement error or validity. For example, people contribute to measurement error by having different levels of tactile, auditory, or visual perception. These characteristics account for calibration and/or interpretation differences. Another example in measurement error is the contribution of a "method" change. This kind of error is one of the largest sources of variation in the measurement process. The significance of this is compounded when different people or instruments are used to evaluate the same item or process. Obviously, a standard procedure is needed for every measurement activity. Only this procedure should be used by all people who operate test equipment. Measurement errors that are sometime attributed to differences in people are actually due to differences in methodology. People are usually able to produce similar readings when they use the same methods for operating the measurement equipment. Other examples where measurement error may be introduced include: changes in environment, test equipment, standards, and so on.

In dealing with measurement error, one must be familiar with:

1. *True value.* The true value is a theoretical number that is absolutely "correct" description of the measured characteristic. This is the value