Setting the Stage

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Quality Basics

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Learning Opportunities:

1. To develop a definition for quality
2. To understand the complexities of defining quality
3. To become familiar with differing definitions of quality from such sources as the American Society for Quality Control, Dr. W. Edwards Deming, Philip Crosby, and Armand Feigenbaum
4. To gain insight into the evolution of total quality management concepts
5. To become familiar with the definitions of specifications, tolerance limits, inspection, prevention, quality, quality control, statistical quality control, statistical process control, total quality management, and process improvement
6. To understand the differences between the philosophies of inspection, quality control, statistical quality control, statistical process control, total quality management, and continuous improvement
7. To understand the differences between actions necessary in inspection, quality control, statistical quality control, statistical process control, total quality management, and continuous improvement
8. To understand that a variety of different approaches to organizing for quality exist, including standards like ISO 9000 and methodologies like Six Sigma
The cartoon above is meant to make us chuckle a little about the difficulties consumers can experience in communicating what they want. But when you take a closer look, it isn’t so funny. How can a company expect to stay in business if no connection is made between what the customer wants and what the company provides? This chapter begins the exploration of using process-improvement concepts to fulfill customers’ needs, requirements, and expectations.
DEFINING QUALITY

For many companies, the reality of their situation is competition. They face competition on price, value, features, nearly everything related to the products and services they provide. Let’s face it, customers have so many choices in today’s marketplace, if they’re not impressed, they’ll go elsewhere. An organization’s very survival is based on their ability to do what they said they would do faster, better, and cheaper than anyone else. Your success in your own job will be based upon your ability to find ways to design and implement processes that enable your organization to do what they do faster, better, and cheaper. A tall order for most of us, fortunately, the tools and techniques taught in this text will help. Effective employees in effective organizations everywhere in the world are already using them.

From Wal-mart and cross-docking to Toyota and just-in-time, these companies know winning does not depend on a clever plan or a hot concept. It depends on how regular, mundane, basic work is carried out. If you can consistently do your work faster, cheaper, and better than the other guy, then you get to wipe the floor with him—without any accounting tricks. Relentless operational innovation is the only way to establish a lasting advantage. And new ideas are popping up all over.

Operational innovation isn’t glamorous. It doesn’t make for amusing cocktail party conversation, and it’s unlikely to turn up in the world of glam-business journalism. It’s detailed and nerdy. This is old business, this is new business, this is real business. Get used to it.

Michael Hammer “Forward to Basics,”

The topics in this text comprise a set of statistical tools that are equal to more than the sum of their parts. They provide users with the power to understand process behavior. With this knowledge, users can find ways to improve the way their organization provides its products and services. These tools can be applied to all sorts of processes including manufacturing, services, and government. Together, they provide a means of reducing process variation. The tools themselves are fundamental to good process management. Applying them is fundamental to good management, period.

The study of these tools begins with the definition of quality: The American Society for Quality Control defines **quality** as a subjective term for which each person has his or her own definition. In technical usage, quality can have two meanings: (1) the characteristics of a product or service that bear on its ability to satisfy stated or implied needs and (2) a product or service free of deficiencies.

Definitions have been developed by many prominent professionals in the field. Dr. W. Edwards Deming, well-known consultant and author on the subject of quality, describes quality as nonfaulty systems. To Dr. Deming, nonfaulty systems were error free systems that have the ability to provide the consumer with a product or service as specified. In Out of the Crisis, Dr. Deming stresses that quality efforts should be directed at the present and future needs of the consumer. Deming is careful to point out that future needs of the customer may not be identified by the customer but rather for the customer. The need for some of the products we use in our day-to-day lives (VCRs,
microwaves, electronic mail, deodorants) was developed by the companies designing, manufacturing, and advertising these products. In other words, consumers do not necessarily know what they want until they have used the product or received the service. From there, consumers may refine the attributes they desire in a product or service.

Dr. Joseph M. Juran, in his book *Juran’s Quality Control Handbook*, describes quality as *fitness for use*. In his text, *Quality Is Free*, Philip Crosby discusses quality as *conformance to requirements* and nonquality as *nonconformance*.

Quality can take many forms. The above definitions mention three types: quality of design, quality of conformance, and quality of performance. Quality of design means that the product has been designed to successfully fill a consumer need, real or perceived. Quality of conformance—conformance to requirements—refers to the manufacture of the product or the provision of the service that meets the specific requirements set by the consumer. Quality of performance means that the product or service performs its intended function as identified by the consumer. Clearly communicating the needs, requirements, and expectations of the consumer requires a more complete definition of quality.

Armand Feigenbaum, author of *Total Quality Control*, states that quality is a *customer determination which is based on the customer’s actual experience with the product or service, measured against his or her requirements—stated or unstated, conscious or merely sensed, technically operational or entirely subjective—and always representing a moving target in a competitive market*. Several key words stand out in this definition:

- **Customer determination**: Only a customer can decide if and how well a product or service meets his or her needs, requirements, and expectations.
- **Actual experience**: The customer will judge the quality of a product or service not only at the time of purchase but throughout usage of the product or service.
- **Requirements**: Necessary aspects of a product or service called for or demanded by the customer may be stated or unstated, conscious or merely sensed.
- **Technically operational**: Aspects of a product or service may be clearly identified in words by the consumer.
- **Entirely subjective**: Aspects of a product or service may only be conjured in a consumer’s personal feelings.

Feigenbaum’s definition shows how difficult it is to define quality for a particular product or service. Quality definitions are as different as people. In many cases, no two customers will have exactly the same expectations for the same product or service. Notice that Feigenbaum’s definition also recognizes that a consumer’s needs, requirements, and expectations change over time and with different situations. Under some circumstances customer expectations will not remain the same from purchase to purchase or encounter to encounter. To produce or supply a quality product or service, a company must be able to define and meet the customer’s reasonable needs, requirements, and expectations, even as they change over time. This is true whether the product is tangible (automobiles, stereos, or computers) or intangible (airplane schedules, hospital care, or repair service). Because of Feigenbaum’s broad emphasis on customer requirements, this text will use his description of quality as its guide.
EXAMPLE 1.1  Tying It All Together*

This example, as well as the questions and case study at the end of the chapter, encourage you to think about quality from the viewpoints of customers and providers of products and services.

Scheduled air carriers handle about two million pieces of luggage each day. That's a lot of luggage to keep track of, and unfortunately sometimes the passenger and the bag don't end up going to the same place at the same time. Each day, approximately one-half of 1 percent (10,000) of the two million bags are mishandled. A mishandled bag either doesn't arrive with the passenger or it is damaged while en route. Each day, 100 unlucky travelers learn that their bags have been irretrievably lost or stolen. As late as 2001, on domestic flights airlines were liable for only $1,250 of the cost of lost, damaged, or delayed luggage. International travelers received $9.07 per pound of checked luggage. Passenger reports of lost, damaged, or delayed baggage on domestic flights steadily decreased throughout the 1990s only to rise by 2004 (Figure 1.1). What would be your definition of quality for this example? One hundred percent of the bags arriving with their passengers? Is one-half of 1 percent (99.5 percent good) an acceptable level of quality? What about the enormous amount of luggage being handled each day? Two million bags versus 10,000 bags mishandled? Seven hundred thirty million bags correctly handled annually versus 36,500 bags irretrievably lost or stolen? Do we hold other industries to such a high performance level? Do you turn in perfect term papers?

CHAPTER 1 QUALITY BASICS

Can you identify the customers in this example? Are they the passengers or the airlines (as represented by the baggage handlers, the check-in clerks, and the lost-luggage finders)? What are their needs, requirements and expectations? In order to do a quality job in the eyes of passengers—i.e., in order to get the luggage to the right place at the right time—the airlines must label bags correctly, bar code them to ensure efficient handling, employ trained baggage handlers and clerks, and determine ways to reduce the number of mishandled bags. Passengers also play a role in the overall quality of the system. At a minimum, passengers must label bags clearly and correctly. Passengers must arrive in ample time before the flight and not overfill their suitcases so the suitcases do not unexpectedly open while being handled.

How will a customer recognize quality? Feigenbaum’s definition of quality stresses that quality is a customer determination based on the customer’s actual experience with the product or service and measured against his or her requirements. Different people will see this example differently. An individual about to make a very important presentation without needed clothing that was lost with a suitcase will be very angry. A traveler who receives his or her baggage on the next flight with only a small delay may be annoyed but minimally inconvenienced.

There are many aspects to quality. In this text, we explore techniques that enable us to improve the way we do business.

INGREDIENTS FOR SUCCESS

Corporate Culture

Companies seeking to remain competitive in today’s global markets must integrate quality into all aspects of their organization. Successful companies focus on customers and their needs, requirements, and expectations. The voice of the customer serves as a significant source of information for making improvements to a company’s products and services. A successful enterprise has a vision of how it sees itself in the future. This vision serves as a guide, enabling company leaders to create strategic plans supporting the organization’s objectives. A clear vision helps create an atmosphere within an organization that is cohesive, with its members sharing a common culture and value system focused on the customer. Teamwork and a results-oriented, problem-solving approach are often mainstays in this type of environment.

Processes and Process Improvement

A process takes inputs and performs value-added activities on those inputs to create an output (Figure 1.2). Most of us do not realize how many processes we perform on a day-to-day basis. For instance, you go through a process when you select a movie to see. The input is the information about show times and places, whom you are going with, and what criteria you have for choosing a movie. The value-added activities are driving to the movie theater, buying a ticket, and watching the movie. And the output is the result, the entertainment value of the movie.
Industries have innumerable processes that enable them to provide products or services for customers. Think about the number of processes necessary to provide a shirt by mail order over the Internet. The company must have a catalog website preparation process, a website distribution process, a process for obtaining the goods it plans to sell, an ordering process, a credit-check process, a packaging process, a mailing process, and a billing process, to name a few. Other processes typically found in organizations include financial management; customer service; equipment maintenance and installation; production and inventory control; employee hiring, training, reviewing, firing, and payroll; software development; and product or service design, creation, inspection, packaging, delivery, and improvement.

Many processes develop over time, with little concern for whether or not it is the most effective manner in which to provide a product or service. To remain competitive in the world marketplace, companies must seek out wasteful processes and improve them. The processes providing the products and services will need to be quality-engineered, with the aim of preventing defects and increasing productivity by reducing process cycle times and eliminating waste. Many of the quality techniques discussed in this text support process improvement.

Variation

In any process that produces a product or provides a service, rarely are two products or service experiences exactly alike. Even identical twins have their differences. Because variation is present in any natural process, no two products or occurrences are exactly alike. In manufacturing, variation is often identified as the difference between the specified target dimension and the actual part dimension. In service industries, variation may be the difference between the type of service received and the type of service expected. Companies interested in providing a quality product or service use statistical process-control techniques to carefully study the variation present in their processes. Determining the reasons why differences exist between similar products or services and then removing the causes of these differences from the processes that produce them enable a company to more consistently provide a high-quality product or service. Think of it this way: If you are carpooling with an individual who is sometimes late, sometimes early, and sometimes
time, it is difficult to plan when you should be ready to leave. If, however, the person is always five minutes late, you may not like it, but you can plan around it. The first person exhibits a lot of variation; you never know when to expect him or her. The second person, although late, has very little variation in his or her process; hence you know that if you need to leave at exactly 5 P.M., you had better tell that person to be ready at 4:55. The best situation would be to be on time every time. It is this best situation at which companies are aiming when they seek to eliminate or reduce the variation present in a process. Methods of improving processes by removing variation are the focus of this text.

Product and service designers translate customer needs, requirements, and expectations into tangible requirements called specifications. Specifications state product or service characteristics in terms of a desired target value or dimension. In service industries, specifications may take the form of descriptions of the types of services that are expected to be performed (Table 1.1). In manufacturing, specifications may be given as nominal target dimensions (Table 1.2), or they may take the form of tolerance limits (Table 1.3). Tolerance limits show the permissible changes in the dimension of a quality characteristic. Parts manufactured between the tolerance, or specification, limits are considered acceptable. Designers should seek input from the customer, from engineering and manufacturing professionals, and from any others who can assist in determining the appropriate specifications and tolerances for a given item.

To manufacture products within specifications, the processes producing the parts need to be stable and predictable. A process is considered to be under control when the variability (variation) from one part to another or from one service to another is stable.
and predictable. Just as in the carpooling example, predictability enables those studying the process to make decisions concerning the product or service. When a process is predictable, very little variation is present. Statistical process-control practitioners use a variety of techniques to locate the sources of variation in a process. Once these sources are located, process improvements should be made to eliminate or reduce the amount of variation present.

**EXAMPLE 1.2 Reducing Variation**

Maps help us find the best route to get where we're going. At Transitplan Inc., map-making is serious business. Transitplan prints and distributes multicolor regional highway maps for locales all across the United States. Printing multicolored maps is tricky business. Rolls of white paper pass through printing presses containing plates etched with map designs. For multicolored maps, eight printing plates, each inked with a different color, are etched with only the items that will appear in that particular color. In many cases, the items are interrelated, as in the case of a yellow line inside two green lines to delineate an expressway. If the map printing plates are not aligned properly with each other and with the map paper, the colors may be offset, resulting in a blurry, unreadable map.

Transitplan's process engineers have worked diligently to reduce or eliminate variation from the map-printing process. Sources of variation include the printing plates, the inks, the paper, and the presses containing the plates. The engineers have improved the devices that hold the plates in place, eliminating plate movement during press cycles. They have developed an inventory-control system to monitor ink freshness in order to ensure a clean print. They have tested different papers to determine which ones hold the best impressions. These improvements have been instrumental in removing variation from the map-printing process.

With a stable printing process that exhibits little variation, process managers at Transitplan can predict future production rates and costs. They can respond knowledgeably to customer inquiries concerning map costs and delivery dates. If the map production process were unstable, exhibiting unpredictable variation and producing both good and bad maps, then the process managers could only guess at what the future would bring (Figure 1.3).
Productivity

Some people believe that quality and productivity are the same or very similar. Actually, there is a difference between the two. To be productive, one must work efficiently and operate in a manner that best utilizes the available resources. Productivity’s principal focus is on doing something more efficiently. Quality, on the other hand, focuses on being effective. Being effective means achieving the intended results or goals while meeting the customer’s requirements. So quality concentrates not only on doing things right (being productive), but on doing the right things right (being effective). In manufacturing terms, if a company can produce 10,000 table lamps in 13 hours instead of in 23 hours, this is a dramatic increase in productivity. However, if customers are not purchasing these table lamps because they are ugly, then the company is not effective, and the increased productivity is meaningless. To remain competitive, companies must focus on effectively meeting the reasonable needs and expectations of their customers. Productivity and quality improvements come from managing work activities as processes. As process performance is measured and sources of variation are removed, the effectiveness of the process increases.

THE EVOLUTION OF QUALITY

Quality principles have evolved over time (Figure 1.4). Up until the advent of mass production, artisans completed individual products and inspected the quality of their own work or that of an apprentice before providing the product to the customer. If the customer experienced any dissatisfaction with the product, he or she dealt directly with the artisan.
Firearms were originally created individually. The stock, barrel, firing mechanism, and other parts were fabricated for a specific musket. If part of the musket broke, a new part was painstakingly prepared for that particular firearm or the piece was discarded. In 1798, Eli Whitney began designing and manufacturing muskets with interchangeable parts. Firing mechanisms, barrels, or other parts could be used on any musket of the same design. By making parts interchangeable, Eli Whitney created the need for quality control.

In a mass production setting, the steps necessary to create a finished product are divided among many workstations which each perform a single repetitive operation. In order to be interchangeable, the parts must be nearly identical. This allows the assembler to randomly select a part from a group of parts and assemble it with a second randomly selected part. For this to occur without problems, the machines must be capable of producing parts with minimal variation, within the specifications set by the designer. If the parts are not made to specification, during assembly a randomly selected part may or may not fit together easily with its mating part. This situation defeats the idea of interchangeable parts.

**Inspection**

As the variety of items being mass-produced grew, so did the need for monitoring the quality of the parts produced by those processes. The customer no longer dealt directly with the individuals responsible for creating the product, and industries needed to ensure that the customer received a quality product. **Inspection refers to those activities designed to detect or find nonconformances existing in already completed products and services.** Inspection, the detection of defects, is a regulatory process.

Inspection involves the measuring, examining, testing, or gauging of one or more characteristics of a product or service. Inspection results are compared with established standards to determine whether or not the product or service conforms. In a detection environment, inspection, sorting, counting, and grading of products comprise the major aspects of a quality professional’s position. This results in the general feeling that the responsibility for quality lies in the inspection department. Philosophically, this approach encourages the belief that good quality can be inspected into a product and bad quality can be inspected out of the product.

Inspection occurring only after the part or assembly has been completed can be costly. If a large number of defective products has been produced and the problem has gone unnoticed, then scrap or rework costs will be high. For instance, if a preliminary
operation is making parts incorrectly, and inspection does not occur until the product has been through a number of other operations, a large number of defective items will have been fabricated before the defect is discovered by the inspectors. This type of mistake is very costly to the producer because it involves not only the defective aspect of the part but also the cost of performing work on that part by later workstations (Figure 1.5).

The same is true in a service environment. If the service has been incorrectly provided, the customer receiving the service must spend additional time in the system having the problem corrected. Even if the problems have been fixed, there is always the threat that the customer receiving the incorrect service may choose not to return.

Quality Control

Quality control (QC) refers to the use of specifications and inspection of completed parts, subassemblies, and products to design, produce, review, sustain, and improve the quality of a product or service. Quality control goes beyond inspection by

1. Establishing standards for the product or service, based on the customer needs, requirements, and expectations.
2. Ensuring conformance to these standards. Poor quality is evaluated to determine the reasons why the parts or services provided are incorrect.
3. Taking action if there is a lack of conformance to the standards. These actions may include sorting the product to find the defectives. In service industries, actions may involve contacting the customer and correcting the situation.
4. Implementing plans to prevent future nonconformance. These plans may include design or manufacturing changes; in a service industry they may include procedural changes.

These four activities work together to improve the production of a product or provision of a service.

Statistical Quality Control

Building on the four tenets of quality control, statistics were added to map the results of parts inspection. In the 1920s, statistical charts used to monitor and control product variables were developed by Walter A. Shewhart of Bell Telephone Laboratories. At the same time H. F. Dodge and H. G. Romig, also of Bell Telephone Laboratories, used statistics to develop acceptance sampling as a substitute for 100 percent inspection. The use of statistical methods for production monitoring and parts inspection became
known as statistical quality control (SQC), wherein statistical data are collected, analyzed, and interpreted to solve problems. The primary concern of individuals involved in quality is the monitoring and control of variation in the product being produced or service being provided.

**Statistical Process Control**

Over time, companies came to realize that there was a need to be proactive when dealing with problems. Thus the emphasis shifted from utilizing statistical quality control methods for the inspection or detection of poor quality to their use in the prevention of poor quality. Prevention of defects by applying statistical methods to control the process is known as statistical process control (SPC).

Statistical process control emphasizes the prevention of defects. **Prevention refers to those activities designed to prevent defects, defectives, and nonconformance in products and services.** The most significant difference between prevention and inspection is that with prevention, the process—rather than solely the product—is monitored, controlled, and adjusted to ensure correct performance. By using key indicators of product performance and statistical methods, those monitoring the process are able to identify changes that affect the quality of the product and adjust the process accordingly. To do this, information gained about the process is fed back to those involved in the process. This information is then used to prevent defects from occurring. The emphasis shifts away from inspecting quality into a completed product or service toward making process improvements to design and manufacture quality into the product or service. The responsibility for quality moves from the inspectors to the design and manufacturing departments.

Statistical process control also seeks to limit the variation present in the item being produced or the service being provided. While it once was considered acceptable to produce parts that fell somewhere between the specification limits, statistical process control seeks to produce parts as close to the nominal dimension as possible and to provide services of consistent quality from customer to customer. To relate loss to only those costs incurred when a product or service fails to meet specifications is unrealistic. The losses may be due to reduced levels of performance, marginal customer service, a slightly shorter product life, lower product reliability, or a greater number of repairs. In short, losses occur when the customer has a less-than-optimal experience with the product or service. The larger the deviation from the desired value, the greater the loss. These losses occur regardless of whether or not the specifications have been met. Reducing process variation is important because any reduction in variation will lead to a corresponding reduction in loss.

Statistical process control can be used to help a company meet the following goals:

- To create products and services that will consistently meet customer expectations and product specifications
- To reduce the variability between products or services so that the results match the desired design quality
- To achieve process stability that allows predictions to be made about future products or services
To allow for experimentation to improve the process and to know the results of changes to the process quickly and reliably
- To minimize production costs by eliminating the costs associated with scrapping or reworking out-of-specification products
- To place the emphasis on problem solving and statistics
- To support decisions with statistical information concerning the process
- To give those closest to the process immediate feedback concerning current production
- To assist with the problem-solving process
- To increase profits
- To increase productivity

The positive results provided by statistical process control can be seen in Figure 1.6. Many of the techniques associated with SPC are covered in this text.

**Total Quality Management**

As the use of statistical process control grew in the 1980s, industry saw the need to monitor and improve the entire system of providing a quality product or service. Sensing that meeting customer needs, requirements, and expectations involved more than providing a product or service, industry began to integrate quality into all areas of operations, from the receptionist to the sales and billing departments to the manufacturing, shipping, and service departments. This integrated process improvement approach, involving all departments in a company in providing a quality product or service, became known as “total quality management” (Figure 1.7).
Total quality management (TQM) is a management approach that places emphasis on continuous process and system improvement as a means of achieving customer satisfaction to ensure long-term company success. Total quality management focuses on process improvement and utilizes the strengths and expertise of all the employees of a company as well as the statistical problem-solving and charting methods of statistical process control. TQM relies on the participation of all members of an organization to continuously improve the processes, products, and services their company provides as well as the culture they work in.

Most important, quality management encourages a long-term, never-ending commitment to the improvement of the process, not a temporary program to be begun at one point in time and ended at another. The total quality process is a culture that top-level management develops within a company to replace the old management methods. Chapter 2 expands on the idea that the commitment to quality must come from upper management to guide corporate activities year after year toward specified goals. Given this long-term commitment to integrating quality into all aspects of the organization, companies pursuing quality management have an unwavering focus on meeting the customer's needs, requirements, and expectations. Since the customer's needs, requirements, and expectations are always changing, total quality management must be adaptable in order to pursue a moving target.

CONTINUOUS IMPROVEMENT

The continuous improvement (CI) philosophy focuses on improving processes to enable companies to give customers what they want the first time, every time. This customer-focused, process-improvement oriented approach to doing business results in increased satisfaction and delight for both customers and employees. Continuous improvement efforts are characterized by their emphasis on determining the best
method of operation for a process or system. The key words to note are continuous and process. Continuous improvement represents an ongoing, continuous commitment to improvement. Because the quest for continuous improvement has no end, only new directions in which to head, continuous improvement is a process, not a program.

One of the strengths of the CI process is that a company practicing these methods develops flexibility. A company focusing on continuous improvement places greater emphasis on customer service, teamwork, attention to details, and process improvement. Table 1.4 shows some other differences between a traditional company and one that practices continuous improvement.

The foundation of continuous improvement is a management philosophy that supports meeting customer requirements the first time, every time. Management must be actively involved with and committed to improving quality within the corporation. Merely stating that quality is important is not sufficient. Philosophies are easy to preach but difficult to implement. The strongest continuous improvement processes are the ones that begin with and have the genuine involvement of top-level management. This commitment is exemplified through the alignment of performance expectations and reward systems.

A variety of different approaches exist for integrating continuous improvement efforts into everyday business activities. The flowchart in Figure 1.8 illustrates a typical CI process. Note that many activities are ongoing and that several overlap. Most CI efforts begin with a vision. Visions, which are developed and supported by senior management, are statements describing how a company views itself now and in the future. A company's vision is the basis for all subsequent strategies, objectives, and decisions.

Top management often develops a mission statement to support the organization's vision. The mission sets the stage for improvement by making a strong statement about the corporation's goals. The mission statement should be short enough for its essence to be remembered by everyone, but it should also be complete. The mission statement should be timeless and adaptable to organizational changes. Examples of mission statements are shown in Figure 1.9.
One Company’s Journey to Continuous Improvement

When PLC Inc. began operations three decades ago, their job shop specialized in machining large forgings into finished products. At that time, they utilized three separate inspections as their primary method of ensuring the quality of their products. The first inspection occurred following the initial machining operations, (grinding, milling, and boring) and before the part was sent to a subcontractor for heat-treating. After the part returned from heat treatment, key dimensions were checked at the second inspection. A final inspection was conducted before the finished part left the plant. With these three inspections, discrepancies between actual part dimensions
and the specifications were found only after the part had completed several machining operations. Though this method resulted in significant scrap and rework costs, PLC continued to use it with only one minor modification. They determined that occasional forgings were not up to standard so they added an incoming materials inspection to ensure the quality of the blank forgings.

Even with these four inspections, scrap and rework costs were still very high. If the forging passed incoming inspection and began to progress through the machining operations, for a typical part, four to six operations would have been completed before any errors were caught during the in-process inspection that occurred before the part was shipped out to be heat-treated. The work done after the operation where the error occurred was wasted because each subsequent machining operation was performed on a faulty part. Beyond a few minor measurements taken once they completed their work on the part, operators were not responsible for checking actual part dimensions against specifications. This type of inspection scheme was very costly to PLC because it involved not only the defective aspect of these large parts, but also the labor cost of performing work on a defective part by later workstations.

In an attempt to correct this situation, PLC established a Quality Control Department. The members of this department developed a documented quality control program. The program was designed to ensure conformance to established standards for each product. They also initiated a corrective action plan that required a root cause analysis and corrective action for each nonconformance to standards. Following this plan enabled them to implement corrective action plans that prevented future similar errors.

By the mid-1980s, the companies they did business with began requiring statistical process control information. Statistical process control was a new concept for PLC. Fortunately they realized that the prevention of defects could make a significant impact on their profit performance. With this in mind, they set up control charts to monitor key characteristics over the long term and within a particular run.

Key characteristics like safety critical dimensions, working diameters, ID/OD for mating parts, radius, and any tight tolerances set by the designer were charted. Besides having each operator inspect his own work for each part production run, the first piece was inspected for all critical dimensions by the chief inspector on a coordinate measuring machine. Once the first part was approved, the operator had permission to run the rest of the parts in the lot. The “first part” designation applied to any part following a change to the process, such as a new operator, a new setup, a setup after broken tool, etc. By tracking the critical part dimensions, those monitoring the processes were able to identify changes that affected the quality of the product and adjust the process accordingly.

They sought additional ways to reduce the variation present in the process that prevented them from producing parts as close to the nominal dimension as possible. Thus, emphasis shifted away from inspecting quality into the parts and toward making process improvements by designing and machining quality into the product.

Realizing that in a job shop, the small lot sizes made significant use of statistical process control techniques difficult, PLC took a good hard look at the way they did business. In order to stay in this highly competitive business, PLC needed to
determine what market need they were going to meet and how they were going to fill that need in an error-free, customer-service oriented manner. With this in mind, they began studying the ideas and concepts surrounding total quality management and continuous improvement. This lead them to consider all of their business operations from a process point of view instead of a part-by-part focus. Over the next few years, they applied continuous improvement concepts to how they managed their business.

Their continuous improvement efforts lead to an increase in their competitive position. In the 1990s, PLC began specializing in machining large complex parts for the aviation industry. Soon the shop was full of axles, pistons, steering collars, braces, and other parts for landing gear. The forgings brought in were made from many different kinds of materials including steel, a variety of alloys, and aluminum. Since the parts could cost anywhere from $6,500 to $65,000 each, not including material and heat treatment or coatings costs, PLC had to develop effective methods to run such a wide variety of material and part types on their machines. They realized they needed to shift their focus away from part inspection to controlling the processes that they used to make the parts.

When they asked themselves what really needed to improve in order to please their customers, they realized that reducing the number of tags on parts for out-of-specification conditions was critical. In order to do this effectively over the long term, PLC focused on processes, specifically designing processes, equipment, fixtures, and tooling to meet the needs of the product. This approach resulted in fewer setups, and reduced the number of times a part needed to be handled, which reduced the number of times a part could be damaged. Fewer setups also reduced the number of opportunities for mistakes in setups, incorrect or inaccurate setups. Better fixtures and tooling enabled the machining process to hold part dimensions throughout the part. Changes like these resulted in improved quality and throughput.

Their efforts paid off. As PLC improved their part uniformity, rework and defect rates fell and machine uptime increased as did labor productivity. These factors enabled them to increase output because less time was spent fixing problems and the focus shifted to where it belonged: making parts right the first time. Increased output enabled PLC to meet ship dates predictably. They were even able to reduce their prices while maintaining their profitability. As word got out to their customers about pricing, quality, and delivery, PLC was able to attract more and more business. Two plant expansions occurred as their competitive position improved with increasing customer satisfaction. Management at PLC felt that their increased understanding of the processes utilized in making parts enabled them to make better decisions and enhanced their focus on their customers.

Their continuous improvement changes included customer-focused changes, internal process changes, and human resources changes.

**Customer-Focused Changes**

**Equipment**  
PLC acquired new machines of a better designs for machining long, relatively thin parts. For instance, they replaced a milling machine that used a cantilevered work-holding system with a horizontal milling machine. Having the part hang as a cantilever allowed vibration and tool movement to play a role in the machining of the part, affecting the ability to hold tolerance. This new machine
significantly lowered rework due to the reduction in the variation inherent in the older process.

**Machining** PLC made significant investments in their other machining operations. Their equipment now includes numerically controlled turning and three-axis contour machining centers, boring, honing, milling, grinding, and drilling machines. Most machines are able to perform multiple machining functions in one setup. The equipment is functionally grouped for efficient work flow and close tolerance control.

**Job Tracking** PLC implemented a new system of job tracking. First, a manufacturing plan is created and reviewed with the customer. The manufacturing plan provides key information including part dimensions and the sequence of operations that the part will complete. Once approved, this information is converted to dimensional part drawings for each applicable workstation. Also included is a “traveler,” a bill of material that moves through the operations with each part, that must be signed and dated by each operator as he or she completes the work. Inspections for the part are also noted on the traveler.

**Internal Process Changes**

**Supplier Involvement** When quoting a job, sales engineers at PLC involve their tooling suppliers. The supplier is able to help select the best cutting tools for the type of job. Improved cutting tool technology enables the machining operations to run at higher speeds while holding part dimensions more accurately.

**Gage Control System** A new gage verification system has resulted in fewer gage-related errors. Each gage is now calibrated regularly and is part of a preventive maintenance program. These changes have significantly reduced the possibility of measurement error.

**Inventory Control Systems** A new tooling inventory control system was recently installed. Using this system has resulted in fewer tooling selection errors which in the past had caused production delays. Inventory control is easier now that taking inventory is a visual task that has reduced the potential of not having the correct tool when it is needed. Cost savings are expected with this system because inventory can be monitored more easily, thus reducing the potential for lost or misplaced tools.

**Smaller Lot Sizes** Recently, PLC has been moving toward single piece production runs rather than multiple part runs. This is possible with the new machining and cutting tool technology that allows the machine to run much faster. Now a single piece can be machined in less than one-third the time required previously. Not only is this a time savings, but if something goes wrong, only one part will be damaged. The single piece lot size also enables them to be very reactive to small customer orders.

**Human Resources Changes**

**Cross-functional Involvement** PLC was quick to realize that an early understanding of what it would take to machine a part resulted in higher quality parts produced more efficiently. At PLC, sales engineers work with machine tool designers, as well as operators and tooling suppliers, when quoting jobs to establish the best machining practices for holding and cutting each particular part based on its material type.
CHAPTER 1 QUALITY BASICS

Communication  Prior to their continuous improvement efforts, machine operators at PLC were not considered a valuable source of information. Now, management at PLC is working to increase operator involvement and enhance communication so that an operator will tell management when opportunities for improvement arise. Operators work together with engineers to conduct root cause analysis investigations and implement corrective actions. Operators are also involved in audits of proper use of procedures.

Many of the improvements listed above came about because PLC had an understanding of the material presented in chapters in this text. As a result of their continuous improvement efforts, PLC have increased their efficiency and effectiveness. During the last three years, their growth rate has been 10–15% annually without adding any additional employees. For PLC, continuous improvement begins with the design of processes, tooling, machining centers, and fixtures that support producing quality parts. Well-designed processes and procedures combine to make quality parts and successful customers.

ORGANIZING FOR QUALITY

To make the journey from a company focused on inspection of completed products or services to a company that is proactive in meeting and exceeding the needs of their customers, many organizations follow particular methodologies or standards. ISO 9000 and QS 9000 are quality standards developed for the purpose of providing guidelines for improving a company's quality management system. Six Sigma is a methodology that also provides direction for a company seeking to improve its performance. Summarized below, a more complete discussion of these standards and methodologies may be found in Chapter 14.

Quality Standards

The most widely known of the quality standards are ISO 9000 and QS 9000. ISO 9000 was created to deal with the growing trend toward economic globalization. In order to facilitate doing business in a variety of countries, a series of quality standards was developed by the International Organization for Standardization. Applicable to nearly all organizations, the standards provide a baseline against which an organization’s quality system can be judged. Eight key principles are integrated into the ISO 9000 standards: customer-focused organization, leadership, involvement of people, process approach, systems approach to management, continuous improvement, factual approach to decision-making, and mutually beneficial supplier relationships. Because of the similarities between these key principles and the continuous improvement philosophy, many organizations use ISO 9000 as the foundation of their continuous improvement efforts.

Prior to QS 9000, suppliers to the U.S. automotive companies were subjected to different, yet similar, quality system and documentation requirements from each automotive manufacturer. Recognizing the overlapping requirements, QS 9000 was
developed by the major U.S. motor vehicle manufacturers and their suppliers to provide baseline quality system requirements. QS 9000 eliminates the redundant requirements while maintaining customer-specific, division-specific, and commodity-specific requirements. QS 9000 has two major components: ISO 9000 and customer specific requirements.

**Six Sigma Methodology**

The Six Sigma concept was developed at Motorola Corporation as a strategy to deal with product and system failures. The increasing complexity of systems and products used by consumers created higher than desired system failure rates. To increase system reliability and reduce failure rates, organizations following the Six Sigma methodology utilize a rigorous process-improvement methodology—define-measure-analyze-improve-control (DMAIC). This procedure encourages managing by fact with data and measurement tools, techniques, and systems. Many of the tools and techniques used by Six Sigma practitioners are covered in this text (Figure 1.10). Six Sigma projects are chosen based on their ability to provide clearly defined and auditable financial results. Six Sigma encourages people at all levels in the company to listen to each other, to understand and utilize metrics, to know when and what kind of data to collect, and to build an atmosphere of trust. Six Sigma seeks to improve quality through reduced variation for every product, process, or transaction in a company, with the ultimate goal being to virtually eliminate all defectives. The Six Sigma methodology is covered in greater detail in Chapter 14.
BEYOND CONTINUOUS IMPROVEMENT

Over time, as consumers became more quality conscious, companies expanded their quality-management practices beyond the traditional manufacturing arena. Continuous improvement continues to evolve and embrace such concepts as optimization of processes, elimination of waste, and creation of a customer focus. Companies seeking to optimize business processes take a systems approach, emphasizing improving the systems and processes that enable a company to provide products or services for their customers. Examples of systems include ordering processes, billing processes, manufacturing processes, and shipping processes, among others. Improving processes means finding and eliminating sources of waste, such as idle time, rework time, excess variation, and underutilized resources. In today's world of global competition, companies must develop a customer-oriented approach to quality, studying how their product or service is used from the moment a customer first comes in contact with the product or service until the moment that the product is disposed of or the service is complete. Global competition has also encouraged companies to seek out and emulate best practices. The term “best practices” refers to choosing a method of work that has been found to be the most effective and efficient, i.e., with no waste in the process. As long as there is competition, companies will continue to seek ways in which to improve their competitive position. The quality concepts presented in this text provide a firm foundation for any company seeking to continually improve the way it does business. Case Study 1.1 lets you determine where companies are in their quality revolution.

WHO USES QUALITY TOOLS AND TECHNIQUES?

Nearly every organization that provides products and services to the public monitors its quality in some manner or another. A recent visit to the American Society for Quality's Career Center website (http://careers.asq.org/search) provided the job listings for over 120 jobs. These jobs were found at organizations worldwide and included pharmaceuticals, musical instruments, railways, hospitals, clinics, software, orthopedics, furniture, durable household goods, food production, glassware, technology, automotive, aerospace, shipping (train, plane, trucking, and boat), distribution, wireless technologies, toys, heavy machinery, education, entertainment, package delivery, and the list goes on. Job titles and descriptions included analysts, auditors, managers, inspectors, engineers, software developers, supervisors, and technicians. Figure 1.11 provides some sample job descriptions in the field of quality. Quality affects all organizations making training in quality tools and techniques valuable.

SUMMARY

A man purchased and installed a new answering machine in his home. After work each day, he checked his messages only to discover no messages on his answering machine. The next weekend, he returned the answering machine to the store, claiming it was defective because it didn't record messages. The helpful sales clerk asked him if
he read the instructions. Yes, he had. Had he followed the instructions when installing
the unit? Yes, he had. Had he attached cord A to plug B? Yes, he had. Well, since our
products are of very high quality, the clerk said with a smile, the only explanation is
that no one has called you.

Can we ever be that sure about the products and services that our company offers?
Sure enough to say that the fault lies with the user, not the product or service? Probably
not, but the quality tools and techniques taught in this text can help prevent the creation or provision of defective products and services.

In order to meet the challenges of a global economy, manufacturers and providers of services must balance the economic and profit aspects of their businesses with the goal of achieving total customer satisfaction. Quality must be designed into, built into, and maintained for each product or service provided by the company. Variation must be removed from the processes involved in providing products and services. Knowledge of consumer needs, requirements, and expectations will allow the company to succeed in the marketplace. Statistical process control, with its inherent emphasis on the creation of a quality product, is paramount in helping companies meet the challenges of global markets.

Dr. Joseph Juran once said that quality improvement “... requires the application of statistical methods which, up to the present time, have been for the most part, left undisturbed in the journals in which they appeared.” The tools and techniques discussed in this text have formed the underpinnings of each of the major quality improvement initiatives including Total Quality Management and Six Sigma. These tools have affected the way people think, work, and act in relation to everyday work issues. Effective organizations recognize these powerful tools for what they are, the cornerstone to organizational success.

■ Lessons Learned

1. Quality is defined by a consumer’s individual and reasonable needs, requirements, and expectations.
2. Processes perform value-added activities on inputs to create outputs.
3. Variation is present in any natural process. No two products or occurrences are exactly alike.
4. Specifications are used to help define a customer’s needs, requirements, and expectations.
5. Productivity is doing something efficiently; quality focuses on effectiveness, doing the right things right.
6. The monitoring and control of quality has evolved over time. Inspection, quality control, statistical quality control, statistical process control, and total quality management are all aspects of the evolution of quality.

■ Chapter Problems

1. What is your definition of quality? How does your definition compare with Feigenbaum’s?
2. Describe the differences among the definitions for quality given by the American Society for Quality, Dr. W. Edwards Deming, and Armand Feigenbaum.
3. Using Feigenbaum's definition, focus on the key aspects and discuss how a customer may define quality for having a muffler put on his or her car. Be sure to discuss the key terms identified in the definition of quality.

4. In your own words, describe the difference between productivity and quality.

5. Every day a dry cleaner receives a wide variety of clothes to clean. Some items may be silk, others may be wool, others rayon. Some fabrics may be delicate, other fabrics may be sturdier. Some clothing may contain stains. As a customer bringing your clothes in to be cleaned, what needs, requirements, and expectations can you identify? What must the dry cleaner do to do a quality job? How much would you be willing to pay for the service?

6. Describe the evolution of total quality management.

7. Define the following: specifications, tolerances, inspection, prevention.

8. Describe the philosophical differences between inspection, prevention, quality, quality control, statistical quality control, statistical process control, total quality management, and continuous improvement.

9. Describe the differences between the actions necessary in inspection, quality control, statistical quality control, statistical process control, and total quality management.

10. Choose and describe a quality (or nonquality) situation that you or someone close to you has experienced. What role did quality—and the customer's needs, requirements, and expectations—play in this situation? Describe how the creator of the product or the provider of the service could have dealt with the incident. What was your role in the situation? Could you have provided better quality inputs?

11. The following is a list of specifications for operating a hotel. Add four or five of your own customer specifications to this list.

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Perception of Service/Quality:</td>
<td>2 or Fewer Complaints per Month</td>
</tr>
<tr>
<td>Downtime of Reservation/Check-in Computer</td>
<td>Not to Exceed 15 Minutes per Month</td>
</tr>
<tr>
<td>Room Reservations Incorrect/Overbooked</td>
<td>1 or Fewer Occurrences per Month</td>
</tr>
<tr>
<td>Credit Card Billing/Transaction Errors</td>
<td>1 or Fewer per Month</td>
</tr>
</tbody>
</table>

12. Several department stores have coined famous mottos such as “the customer is always right” (John Wanamaker, Philadelphia department store magnate, 1865). Mr. Wanamaker went on to say: “It is our intention always to give
value for value in every sale we make and those who are not pleased with what they buy do us a positive favor to return the goods and get their money back.” How does Mr. Wanamaker’s philosophy relate to Feigenbaum’s definition of quality?

13. Whenever you visit an organization (for instance, on a job interview or as your company’s representative), you will need to recognize how that company views quality assurance. Describe how you would recognize the differences between a company practicing inspection functions versus one practicing statistical process control. Support your description with examples.

14. Whenever you visit an organization (for instance, on a job interview or as your company’s representative), you will need to recognize how that company views quality assurance. Describe how you would recognize that the company is following a total quality management approach.
CASE STUDY 1.1
Quality Evolution: Where Are They Now?

Read the following scenarios and determine where these organizations are in the evolution of quality. What clues did you read that support your conclusions?

CLP INDUSTRIES

CLP Industries, an aircraft electrical systems and component supplier, designs and manufactures many components critical to the safe operation of commercial aircraft. Process improvement efforts emphasize the reduction of variation. Quality is an organization-wide approach to doing business. Quality is designed and manufactured into their products. Systems are in place that emphasize design control, process control, purchasing, inspection and testing, and control of non-conformances. Throughout the plant, processes have been mapped and investigated to remove non-value-added activities. Performance measures are used to monitor and control process performance. Workers in the plant are skilled in statistical process control tools and techniques. They participate in problem-solving teams on an as needed basis. CLP employees from all departments, including engineering, accounting, purchasing, sales, and manufacturing, participate in on- and off-site training opportunities in areas such as statistical process control basics, design of experiments, lean manufacturing, performance metrics, communicating with the customer, and others.

Representatives from the company participate actively in the International Aerospace Quality Group (IAQG). This organization works to establish commonality of quality standards and requirements, encourage continuous improvement processes at suppliers, determine effective methods to share results, and formulate responses to regulatory requirements. Plans are in place to upgrade their existing ISO 9000 Quality System to the AS9100 Quality Standard. Proposed for the aerospace industry worldwide, this quality standard seeks to standardize aerospace quality expectations on a global level. AS9100 adds 83 additional and specific requirements to the 20 elements of ISO 9001, including requirements for safety, reliability, and maintainability.

FIBERGLASS FORMULATIONS

Fiberglass Formulations manufactures fiberglass-based fittings for the automotive and boating industry. At Fiberglass Formulations firefighting is taken quite seriously. Recently, when one of their fiberglass curing ovens caught on fire, they reacted quickly to put out the fire. Encouraged by representatives from the Occupational Safety and Health Association (OSHA), they were determined to prevent future fires. Unfortunately, their approach to finding the root cause of the fire was less than organized. The
responsibility for determining the cause of the fire was never assigned to a specific individual. None of the plant employees had been trained in root cause analysis or statistical methods.

Valiant efforts by the production supervisor yielded little insight into the cause. He was unable to obtain management support for a visit to the nearby equipment manufacturer to study the design of the machine in a search for possible causes. Members of the research lab took their own approach to determining the cause of the fiberglass fire. They analyzed the chemical makeup of the material in the oven at the time of the fire. They also sent some of the material away to a prominent testing lab to have its flammability studied. The process engineer also attacked the problem, calling in experts from the local university. With no responsible individual, no attempts were made to share information, limiting the usefulness of the efforts of the three individuals most closely involved.

In the meantime, production and part quality suffered, as did worker morale. Small fires were reported almost weekly, though workers became skilled at putting them out before they could cause any damage. Small, random fires soon became the status quo of doing business. Additional inspections were added at several workstations to make sure that parts damaged by the small fires did not reach the customers. Having satisfied OSHA with a report on the first fire, management soon lost interest in the fire, many of them unaware that the fires were continuing. Production losses, inspection costs, and quality problems related to the fires continue to mount.

TASTY MORSELS CHOCOLATES

Tasty Morsels Chocolates manufactures chocolate candy. Their main production line is fully automated, requiring little human intervention. Tasty Morsels uses charts to track production amounts, scrap rates, production times, order quantities, and delays in shipment. Every six weeks, these charts are collected and discussed by management. No statistical analysis takes place. Despite their efforts, they have production cost overruns. Cost overruns can be caused by excessive scrap rates, rework amounts, inspection costs, and overtime.

Two areas stand out as having problems. The first occurs following the cooling chamber. Chocolate is mixed until it reaches the right consistency, then it is poured into mold trays. As the chocolates leave the cooling chamber, two workers reorganize the chocolate mold trays on the conveyor belt. This non-value added, inspection-type activity essentially wastes the time of two workers. It also could result in damaged chocolates if the trays were to flip over or off of the conveyor.

Tasty Morsels Chocolates prides itself on their quality product. To maintain their high standards, before packaging, 4 workers inspect nearly every piece of chocolate as it emerges from the wrapping machine. A full 25% of the chocolate production is thrown out in a large garbage can. Though this type of inspection prevents poorly wrapped chocolates from reaching the consumer, this is a very high internal failure cost of quality. So far, though these two problems are apparent to nearly everyone in the plant, no efforts have been made to improve the process.