1

HOW SIX SIGMA COMPARES TO OTHER QUALITY INITIATIVES

As the competition gets tougher, there is more pressure on organizations to improve quality and customer satisfaction while decreasing costs and increasing work output. This becomes an increasingly difficult challenge when there are fewer resources available. Peter Senge (1990) writes, "Learning disabilities are tragic in children, but they are fatal in organizations. Because of them, few corporations live even half as long as a person—most die before they reach the age of forty." "Learning organizations" defy these odds and overcome learning disabilities to understand threats and recognize new opportunities. Six Sigma can help organizations learn and excel at the challenges they encounter—if it is implemented *wisely*.

A question we frequently hear from executives is "How does Six Sigma fit with other company initiatives?" We believe that Six Sigma should not be considered just another initiative but should integrate other programs and initiatives at a higher level as part of an overall business strategy. Six Sigma should not replace other initiatives, but instead offer a tactical methodology to determine the best approach for a given situation/process.

Our Smarter Six Sigma Solutions (S^4) business strategy offers a road map for changing data into knowledge that leads to new opportunities. The major components to consider during Six Sigma implementation are "metrics" and "strategy," as shown in Figure 1.1. The upper half of the figure involves the measurement of how well business processes meet their goals. The success of Six Sigma is linked to a set of cross-functional metrics that lead to significant improvements in customer satisfaction and bottom-line benefits. Organizations

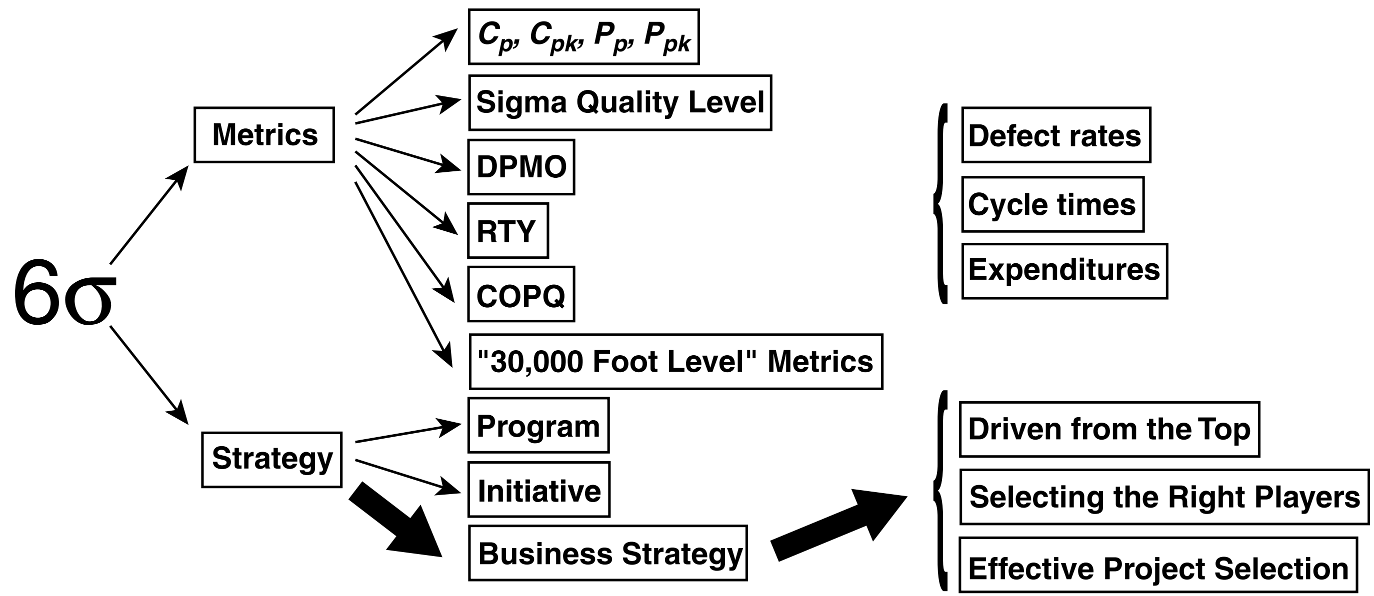

Figure 1.1 Six Sigma implementation considerations

do not necessarily need to use all the measurements listed (often presented within typical Six Sigma programs). It is most important to choose the best set of metrics for a situation, metrics that yield insight into a situation or process.

Our S^4 approach advocates the development of cross-functional teams to provide a holistic approach to problem solving, encompassing all levels of complex processes. We often describe the methodology as a murder mystery, where practitioners are determining "who done it?" or, equivalently, "what is the major cause of defects in a process?" By following a structured methodology, project teams can determine the "biggest hitters" and make substantial areas for improvement that provide real benefits to an organizations bottom line.

Subsequent chapters of this book will provide the details of effective Six Sigma metrics and the importance of implementing Six Sigma as a business strategy. In this chapter, we first discuss current myths surrounding Six Sigma. We then provide a brief history of quality leaders and other quality systems that preceded the creation of Six Sigma. Last, we answer a few of the more frequently asked questions (FAQs) about Six Sigma.

1.1 WHAT IS SIX SIGMA?

Some people view Six Sigma quality as merely a rigorous application of basic and advanced statistical tools throughout an organization. There are a number of Six Sigma consultants and training organizations that have simply repackaged the statistical components of their previous TQM programs and renamed them "Six Sigma." These groups would define Six Sigma quality in terms like those in the upper half of Figure 1.1.

Others view Six Sigma as merely a sophisticated version of Total Quality Management (TQM), as represented by the lower half of Figure 1.1. They see it as an advanced form of TQM in which various continuous improvement systems must be put in place with a small amount of statistical analyses added in for good measure.

The S^4 view of Six Sigma emphasizes an intelligent blending of the wisdom of the organization with proven statistical tools to improve both the efficiency and effectiveness of the organization in meeting customer needs. The ultimate goal is not improvement for improvement's sake, but rather the creation of economic wealth for the customer and provider alike. Our Smarter Solutions approach recommends that Six Sigma be viewed as a strategic business initiative rather than a quality program. This implies, not that Six Sigma replaces existing and ongoing quality initiatives in an organization, but that senior management focuses on those processes identified as critical-to-quality in the eyes of customers. Those critical systems are then the subject of intense scrutiny and improvement efforts, using the most powerful soft and hard skills the organization can bring to bear. The success of each and every Six Sigma initiative is linked to a set of multidimensional metrics that demand world-class performance, which, if achieved, lead to significant improvements in market share, new product development, customer satisfaction, and shareholder wealth.

Later in this chapter and in subsequent chapters, we will spend more time explaining what Six Sigma is. But first we will explain what it is not. We will start by dispelling the 10 myths of Six Sigma (Snee, 1999b) listed in Table 1.1.

TABLE 1.1 The 10 Myths of Six Sigma

Six Sigma Myths
• Works only in manufacturing
• Ignores the customer in search of bottom-line benefits
• Creates a parallel organization
• Is an add-on effort
• Requires massive training
• Requires large teams
• Creates bureaucracy
• Is just another quality program
• Requires complicated, difficult statistics
• Is not cost-effective

Works only in manufacturing

Much of the initial success in applying Six Sigma was based on manufacturing applications; however, recent publications have addressed other applications of Six Sigma. Breyfogle (1999), *Implementing Six Sigma*, includes many transactional/service applications. In GE's *1997 Annual Report* (GE, 1997), CEO Jack Welch proudly states that Six Sigma "focuses on moving every process that touches our customers—every product and *service* [emphasis added]—toward near-perfect quality."

Ignores the customer in search of profits

This statement is not myth, but rather misinterpretation. Projects worthy of Six Sigma investment should (1) be of primary concern to the customer, and (2) have the potential for significantly improving the bottom line. Both criteria must be met. The customer is driving this boat. In today's competitive environment, there is no surer way of going out of business than to ignore the customer in a blind search for profits.

Creates a parallel organization

An objective of Six Sigma is to eliminate every ounce of organizational waste that can be found and then reinvest a small percentage of those savings to continue priming the pump for improvements. With the large amount of downsizing that has taken place throughout the world during the past decade, there is no room or inclination to waste money through the duplication of functions. Many functions are understaffed as it is. Six Sigma is about nurturing any function that adds significant value to the customer while adding significant revenue to the bottom line.

Requires massive training

"Valuable innovations are the positive result of this age [we live in], but the cost is likely to be continuing system disturbances owing to members' nonstop tinkering. . . . [P]ermanent white water conditions are regularly taking us all out of our comfort zones and asking things of us that we never imagined would be required. . . . It is well for us to pause and think carefully about the idea of being continually catapulted back into the beginner mode, for that is the real meaning of being a continual learner. . . . We do not need competency skills for this life. We need incompetency skills, the skills of being effective beginners." (Vaill)

Is an add-on effort

This is simply the myth "creates a parallel organization" in disguise. Same question, same response.

Requires large teams

There are many books and articles within business literature declaring that teams have to be small if they are to be effective. If teams are too large, the thinking goes, a combinational explosion occurs in the number of possible communication channels between team members, and hence no one knows what the other person is doing.

Creates bureaucracy

A dictionary definition of bureaucracy is "rigid adherence to administrative routine." The only thing rigid about wisely applied Six Sigma methodology is its relentless insistence that customer needs be addressed.

Is just another quality program

Based upon the poor performance of untold quality programs during the past three to five decades (Micklethwait and Wooldridge, 1997), an effective quality program would be welcome. More to the point (Pyzdek, 1999c), Six Sigma is "an entirely new way to manage an organization."

Requires complicated, difficult statistics

There is no question that a number of advanced statistical tools are extremely valuable in identifying and solving process problems. We believe that practitioners need to possess an analytical background and understand the wise use of these tools, but do not need to understand all the mathematics behind the statistical techniques. The wise application of statistical techniques can be accomplished through the use of statistical analysis software.

Is not cost-effective

If Six Sigma is implemented wisely, organizations can obtain a very high rate of return on their investment within the first year.

1.2 THE QUALITY LEADERS

Numerous individuals have had a significant impact on the Six Sigma quality movement in the United States and abroad. Unfortunately, we don't have time or space to acknowledge them all. The six we have chosen to give a diverse perspective are W. Edwards Deming, William Conway, Joseph Juran, Philip Crosby, Genichi Taguchi, and Shigeo Shingo. This brief review is more than a historical perspective. At the conclusion of this section, we will discuss how Six Sigma relates to the previous generation of quality programs.

W. Edwards Deming

Dr. W. Edwards Deming was born on October 14, 1900. By 1928, he had earned a B.S. in engineering at the University of Wyoming in Laramie, an M.S. in mathematics and physics at the University of Colorado, and a Ph.D. in mathematical physics at Yale. He is best known for revitalizing Japanese industry after the end of World War II. In 1950, he visited Japan at the request of the Secretary of War to conduct a population census. While there he was invited by a member of the Japanese Union of Science and Engineering (JUSE) to lecture on statistical methods for business at a session sponsored by the Keidanren, a prestigious society of Japanese executives. Deming told the Japanese leaders that they could "take over the world" if they followed his teachings. The rest is history. Today the the most prestigious quality award in Japan is called the "Deming Prize." Deming, who has been heralded as the "founder of the Third Wave of the Industrial Revolution," often sounded like a quality crusader when he issued statements such as "It is time to adopt a new religion in America." He gained national recognition in 1980 when he was interviewed for the NBC television "white paper," "If Japan Can, Why Can't We?"

Dr. Deming is equally well known for his "Fourteen Points" (Table 1.2) and "Seven Deadly Diseases" (Table 1.3) (Deming, 1986). He made numerous modifications to the first list throughout his life as he grew in knowledge and wisdom. Additional references that provide commentary on Deming's Fourteen Points are provided in the references section of this book (Breyfogle, 1999; Neave, 1990; Scherkenbach, 1988; Gitlow and Gitlow, 1987).

TABLE 1.2 Deming's Fourteen Points

1. Create constancy of purpose toward improvement of product and service, with the aim to become competitive and stay in business and to provide jobs.
2. Adopt the new philosophy. We are in a new economic age. Western management must awaken to the challenge, must learn their responsibilities, and take on leadership for change.
3. Cease dependence on 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 tag. Instead, minimize total cost. Move toward a single supplier for any one item, on a long-term relationship of loyalty and trust.
5. Improve constantly and forever the system of production and service, to improve quality and productivity, and thus 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. Supervision of management is in need of overhaul, as well as supervision of production workers.
8. Drive out fear, so that everyone may work effectively for the company.
9. Break down barriers between departments. People in research, design, sales, and production must work as a team to foresee problems of production and in use that may be encountered with the product or service.
10. Eliminate slogans, exhortations, and targets for the work force asking for zero defects and new levels of productivity. Such exhortations only create adversary relationships, as the bulk of the causes of low quality and low productivity belong to the system and thus lie beyond the power of the work force.

11a. Eliminate work standards (quotas) on the factory floor. Substitute leadership.

11b. Eliminate management by objective. Eliminate management by numbers, numerical goals. Substitute leadership.

12a. Remove barriers that rob the hourly worker(s) of their right to pride of workmanship. The responsibility of supervisors must be changed from sheer numbers to quality.

12b. Remove barriers that rob people in management and in engineering of their right to pride of workmanship. This means, inter alia, abolishment of the annual or merit rating and of managing by objective.

13. Institute a vigorous program of education and self-improvement.

14. Put everybody in the company to work to accomplish the transformation. The transformation is everybody's job.

TABLE 1.3 Deming's Seven Deadly Diseases

1. Lack of constancy of purpose to plan product and service that will have a market and keep the company in business, and provide jobs.
2. 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 push from bankers and owners for dividends.
3. Evaluation of performance, merit rating, or annual review.
4. Mobility of management: job hopping.
5. Management by use only of visible figures, with little or no consideration of figures that are unknown or unknowable.
6. Excessive medical costs.
7. Excessive costs of liability, swelled by lawyers that work on contingency fees.

Deming's basic quality philosophy is that productivity improves as variability decreases. Since all things vary, he says, statistical methods are needed to control quality. "Statistical control does not imply absence of defective items. It is a state of random variation, in which the limits of variation are predictable," he explains.

There are two types of variation: chance and assignable. Deming states that "the difference between these is one of the most difficult things to comprehend." His "red bead experiment" (Walton, 1986) revealed the confusion generated by not appreciating the difference between the two. It is a waste of time and money to look for the cause of chance variation, yet, he says, this is exactly what many companies do when they attempt to solve quality problems without using statistical methods. He advocates the use of statistics to measure performance in all areas, not just conformance to product specifications. Furthermore, he says, it is not enough to meet specifications; one has to keep working to reduce the variation as well.

Deming is extremely critical of the U.S. approach to business management and is an advocate of worker participation in decision making. He claims that management is responsible for 94% of quality problems, and he believes that it is management's task to help people work smarter, not harder. There is much in common between Dr. Deming's teachings and the Smarter Six Sigma Solutions (S^4) methodology.

William E. Conway

William E. Conway (Conway, 1999) is the founder, chairman, and CEO of Conway Management Company. He attended Harvard College and is a graduate of the United States Naval Academy.

In 1980, after viewing the NBC television broadcast of "If Japan Can, Why Can't We?", he invited Dr. W. Edwards Deming to Nashua Corporation, becoming one of the first American executives to approach Deming for help. The visits went on for three years. Because of his close and early association with Deming, Conway is sometimes described as a "Deming disciple," but he has developed his own philosophy of and approach to quality.

Conway has created a system of management that lets organizations achieve lasting, bottom-line improvements. That system is called "The Right Way to Manage." Much of the content of this two-day course is also presented in one of Mr. Conway's quality books (Conway, 1992). In this book he discusses the impact of variation on quality, and introduces his approach to using the seven simple tools (including control charts) to eliminate waste. The core activity of the Conway System is eliminating waste in all processes. While most executives are familiar with the waste associated with manufacturing operations, it actually exists throughout all functions of an organization. This approach has been adopted by diverse organizations in a wide range of industries: wholesale, retail, service, manufacturing, distribution, health care, and government.

Conway notes that it takes more than just a critical eye to spot the hidden or "institutionalized" waste. Training and education are needed, as well as the right tools and techniques. He reports a solid return on investment (ROI) in his firm's education and training programs; ROIs of 4:1 to 10:1 are not uncommon.

In his most recent book (Conway, 1994), Mr. Conway delves into some of the infrastructure and implementation issues involved in eliminating organizational waste across the board.

Joseph M. Juran

Joseph Moses Juran (Juran, 1999a) was born December 24, 1904, in Braila, Romania. In 1920, Juran enrolled at the University of Minnesota. In 1924, he graduated with a B.S. degree in electrical engineering and took a job with Western Electric in the Inspection Department of the Hawthorne Works in Chicago. In 1926, a team from Bell Laboratories (including Walter Shewhart and Harold Dodge) made a visit to the factory with the intention of applying the laboratory tools and methods they had been developing. Juran was selected as one of 20 trainees, and he was subsequently chosen as one of two engineers to work in the newly created Inspection Statistical Department. In 1928, Juran authored his first work on quality, a pamphlet that became an input to the well-known *AT&T Statistical Quality Control Handbook*, which is still published today.

In 1937, Juran conceptualized the Pareto principle. In December 1941, he took a leave of absence from Western Electric to serve in Washington with the Lend-Lease Administration. It was here that he first experimented with what today might be called "business process reengineering." His team successfully eliminated the paper logjam that kept critical shipments stalled on the docks. In 1945, Juran left Washington and Western Electric to work as an independent consultant. In 1951, his standard reference work on quality control, *Quality Control Handbook* (Juran, 1999b), was first published.

In 1954, the Union of Japanese Scientists and Engineers (JUSE) and the Keidanren invited the celebrated author to Japan to deliver a series of lectures. These talks addressed managing for quality, and were delivered soon after Dr. W. Edwards Deming had delivered his lectures on statistical quality methods.

Dr. Juran has been called the father of quality, a quality guru, and the man who "taught quality to the Japanese." He is recognized as the person who added the "human dimension" to quality, expanding it beyond its historical statistical origins to what we now call total quality management. Says Peter Drucker, "Whatever advances American manufacturing has made in the last thirty to forty years, we owe to Joe Juran and to his … work." A few of Juran's important quality books are listed in the reference section of this book (Juran, 1964, 1988, 1989, 1992).

Philip B. Crosby

Phil Crosby (Crosby, 1999) was born in Wheeling, West Virginia, on June 18, 1926. He started work as a quality professional on an assembly line at Crosley in 1952 after serving in World War II and Korea. He took it upon himself to try to convince management that it was more profitable to prevent problems than to fix them. He worked for Crosley from 1952 to 1955; Martin-Marietta from 1957 to 1965; and ITT from 1965 to 1979. As quality manager for Martin-Marietta he created the Zero Defects concept and program. During his 14 years as corporate vice president for ITT, he worked with many industrial and service companies around the world, implementing his pragmatic philosophy.

In 1979, Crosby founded Philip Crosby Associates, Inc. (PCA), and over the next 10 years grew it into a publicly traded organization with 300 employees around the world. In 1991, he retired from PCA and founded Career IV, Inc., a company that provided lectures and seminars aimed at helping current and prospective executives grow. In 1997 he purchased the assets of PCA and established Philip Crosby Associates II, Inc. Now his "Quality College" operates in more than 20 countries around the world.

Philip Crosby's lectures provide a thoughtful and stimulating discussion of managements' role in causing their organizations, their employees, their suppliers, and themselves to be successful. He has published 13 books, all of which have been best-sellers. His first business book, *Quality Is Free* (Crosby, 1979), has been credited with beginning the quality revolution in the United States and Europe. A few of his other titles are included in the references section of this book (Crosby, 1984, 1992).

Philip Crosby's books are easy to read and explain his program for quality improvement and defect prevention. He emphasizes the importance of management's role in making quality happen. His approach is team based but is not highly statistical, as are some of the competing approaches to TQM. He does teach the use of the simple tools and statistical quality control, but in a very generic, non-mathematical sense. He is an interesting and knowledgeable speaker who both entertains and educates his audiences. He has certainly had an impact on the quality revolution over the years.

Dr. Genichi Taguchi

Dr. Genichi Taguchi's (Taguchi, 1999) system of quality engineering is one of the great engineering achievements of the twentieth century. He is widely acknowledged as a leader in the U.S. industrial quality movement. His philosophy began taking shape in the early 1950s when he was recruited to help correct postwar Japan's crippled telephone system. After noting the deficiencies inherent in the trial-and-error approach to identifying problems, he developed his own integrated methodology for designed experiments.

Systematic and widespread application of Dr. Taguchi's philosophy, and of his comprehensive set of experimental design decision-making tools, has contributed significantly to Japan's prowess in rapidly producing world-class, low-cost products.

The experimental procedures developed and taught by Genichi Taguchi (Taguchi and Konishi, 1987; Ross, 1988) have met with both skepticism and acclaim. Some nonstatisticians find his techniques highly practical and useful. Most statisticians, however, have identified and published evidence that use of some of his techniques can lead to erroneous conclusions.

We avoid these and other controversies, and instead make use of Taguchi Methods where they are of benefit and where they avoid known pitfalls and weaknesses. The two major areas where Dr. Taguchi's contributions to quality are recognized are (1) variance-reduction strategies and (2) robust design techniques.

Shigeo Shingo

Shigeo Shingo was born in Saga City, Japan, in 1909. In 1930, he graduated with a degree in mechanical engineering from Yamanashi Technical College and went to work for the Taipei Railway Factory in Taiwan. Subsequently he became a professional management consultant in 1945 with the Japan Management Association. It was in his role as head of the Education Department in 1951, that he first heard of, and applied, statistical quality control. By 1954 he had studied 300 companies. In 1955, he took charge of industrial engineering and factory improvement training at the Toyota Motor Company for both its employees and parts suppliers (100 companies). During the period 1956–1958, at Mitsubishi Heavy Industries in Nagasaki, Shigeo was responsible for reducing the time for hull assembly of 65,000-ton supertankers from four months to two months. In 1959, he left the Japan Management Association and established the Institute of Management Improvement, with himself as president. In 1962, he started industrial engineering and plant-improvement training at Matsushita Electrical Industrial Company, where he trained some 7,000 people.

Shingo's supreme contribution in the area of quality was his development in the 1960s of poka-yoke (pronounced "POH-kah YOH-kay"). The term comes from the Japanese words "poka" (inadvertent mistake) and "yoke" (prevent). The essential idea of poka-yoke is to design processes so mistakes are impossible to make or at least easily detected and corrected.

Poka-yoke devices fall into two major categories: prevention and detection. A prevention device affects the process in such a way that it is impossible to make a mistake. A detection device signals the user when a mistake has been made, so that the user can quickly correct the problem. Shingo's first poka-yoke device was a detection implement he created after visiting Yamada Electric in 1961. He was told of a problem in the factory that occasionally led to workers' assembling a small, two-push-button switch without inserting a spring under each push-button. The problem of the missing spring was both costly and embarrassing, but despite everyone's best effort the problem continued. Shingo's solution was simple. The new procedure completely eliminated the problem:

- Old method: a worker began by taking two springs out of a large parts box and then assembled a switch.
- New approach: a small dish was placed in front of the parts box and the worker's first task was to take two springs out of the box and place them on the dish. Then the worker assembled the switch. If any spring remained on the dish, then the worker knew that he or she had forgotten to insert it.

Although Shigeo Shingo is perhaps less well known in the West, his impact on Japanese industry has been immense. Norman Bodek, president of Productivity, Inc., stated: "If I could give a Nobel Prize for exceptional contributions to world economy, prosperity, and productivity, I wouldn't have much difficulty selecting a winner—Shigeo Shingo." Shingo died in November of 1990 at 81 years of age.

1.3 TQM AND SIX SIGMA

The six quality professionals we discussed have a lot in common with respect to the intellectual content of their quality approaches. They have chosen to emphasize different aspects of the body of knowledge known as quality. Deming and Taguchi emphasize the statistical aspects of quality; Deming, Crosby, and Juran focus on management's role in the improvement process; Conway relentlessly drives home the need to eliminate waste wherever it can be found; Shingo preaches error-proofing. There is no doubt that these individuals had a marked impact on how we thought about quality during the second half of the twentieth century. But does their expertise transfer to bottom-line benefits for organizations? In a survey of chief executive officers who subscribe to *Electronic Business,* only 16% reported improved market share and only 13% reported improved operating income or profits as a result of their quality efforts (Boyett et al., 1992). Mikel J. Harry (2000b) reports that even as increasing numbers of companies jumped on the quality "express" during this time, fewer were reporting any meaningful impact on profitability.

A study published by the American Society for Quality (Bergquist and Ramsing, 1999) compares the performance of winners and applicants of both the Malcolm Baldrige National Quality Award (MBNQA) and state-level award programs with nonapplicants in the same two categories. The authors are unable to "conclusively determine whether quality award winning companies perform better than others [i.e., nonapplicants]."

One of the problems that plagued many of the early TQM initiatives was the preeminence placed on quality at the expense of all other aspects of the business. Some organizations went bankrupt, or experienced severe financial consequences, in the rush to make quality "first among equals." Harry (2000a) notes that "what's good for the customer is not always good for the provider." The disconnect between management systems designed to measure customer satisfaction and those designed to measure provider profitability often led to unwise investments in quality.

We believe that Six Sigma is more than a simple repackaging of the best from other TQM programs. Tom Pyzdek (1999c) agrees: "Six Sigma is such a drastic extension of the old idea of statistical control as to be an entirely different subject. . . . In short, Six Sigma is . . . an entirely new way to manage an organization. . . . Six Sigma is not primarily a technical program; it's a management program."

Ronald Snee (1999a) points out that although some people believe it is nothing new, Six Sigma is unique in its approach and deployment. He defines Six Sigma as a strategic business improvement approach that seeks to increase *both* customer satisfaction and an organization's financial health. Snee goes on to claim that eight characteristics account for Six Sigma's increasing bottom-line success and popularity with executives:

- Bottom-line results expected and delivered
- Senior management leadership
- A disciplined approach (Measure, Analyze, Improve, and Control)
- Rapid (3–6 month) project completion
- Clearly defined measures of success
- Infrastructure roles for Six Sigma practitioners and leadership
- Focus on customers and processes
- A sound statistical approach to improvement

Other quality initiatives have laid claim to one or two of these characteristics, but only Six Sigma attributes its success to the simultaneous application of all eight.

Mikel Harry (2000b) goes even farther and claims that Six Sigma represents a new, holistic, multidimensional systems approach to quality that replaces the "form, fit and function specifications" of the past. In his New World view of quality, both the customer and provider receive benefits of *utility, availability*, and *worth*.

- Utility
  - Form (is in a pleasing/effective physical form)
  - Fit (made to the correct size/dimensions)
  - Function (performs all required tasks well)
- Availability
  - Volume (production capacity, inventory levels, and/or distribution channels are adequate to meet varying demand)
  - Timing (a short product development cycle time; lot size = 1; and/or JIT availability)
- Worth
  - Intellectual (innovative; sought by early adopters)
  - Emotional (satisfies one's pride, passions, or psyche)
  - Economic (customer perceived value [quality-to-price ratio] is high)

We believe Six Sigma encompasses all of these things and more. As Figure 1.1 depicts, the S^4 approach encourages the following:

- Creating an infrastructure with executive management that supports cultural change
- Using "30,000 foot level" metrics and the cost of poor quality when selecting projects (to be discussed in detail in later chapters)
- Selecting the "right" people and realigning resources as needed
- Selecting the right provider with an effective training approach
- Selecting the right projects that meet customer needs and provide bottom-line benefits
- Developing project metrics that yield insight into the process and discourage the "firefighting" approach to solving problems
- Applying the right tools at the right time
- Setting SMART goals (Simple, Measurable, Agreed to, Realistic, Time-based)
- Making holistic process improvements through wisdom of the organization

1.4 SIX SIGMA AND INTEGRATION OF THE STATISTICAL TOOLS

The Smarter Six Sigma Solutions (S^4) approach involves identifying projects that target the customer's concerns and have the potential for significant payback. This is accomplished using a team-based approach (demanding soft skills) coupled with a wide range of statistical tools (demanding hard skills). Zinkgraf and Snee (1999) have drawn up a list of the eight tools they believe are essential to getting the job done (Table 1.4). These tools represent a subset of a much larger array of statistical and management tools at one's disposal. Breyfogle (1999), in *Implementing Six Sigma*, illustrates a 21-step integration of the tools, which is shown in Table 1.5 and further elaborated upon in later chapters.

TABLE 1.4 The "Right" Tools

Sigma Breakthrough Technologies Inc. (SBTI) "Right" Tools
Process Maps
Cause-and-Effects Matrix
Measurement Systems Analysis (Gage R&R)
Process Capability Studies
Failure Modes and Effects Analysis (FMEA)
Multi-Vari Studies
Design of Experiments (DOE)
Control Plans

TABLE 1.5 The 21-Step Integration of the Tools [From Breyfogle (1999), with permission]

Step	Action	Participants	Source of Information
1	Identify critical customer requirements from a high-level project measurement point of view. Identify KPOVs that will be used for project metrics. Implement a balanced scorecard considering **COPQ** and **RTY** metrics.	S^4 black belt and champion	Current data
2	Identify team of key "stakeholders."	S^4 black belt and champion	Current data
3	Describe business impact. Address financial measurement issues of project.	S^4 black belt and finance	Current data
4	Plan overall project.	Team	Current data
5	Start compiling project metrics in time series format. Utilize a sampling frequency that reflects "long-term" variability. Create **run charts** and **control charts** of KPOVs.	Team	Current and collected data
6	Determine "long-term" **process capability/ performance** of KPOVs. Quantify nonconformance proportion. Determine baseline performance. **Pareto chart** types of defects.	Team	Current and collected data
7	Create a process **flowchart/ process map.**	Team	Organization wisdom
8	Create a **cause and effect diagram** to identify variables that can affect the process output.	Team	Organization wisdom

9	Create a **cause and effect matrix** assessing strength of relationships that are thought to exist between KPIVs and KPOVs.	Team	Organization wisdom
10	Conduct a **measurement systems analysis.** Consider a **variance components** analysis.	Team	Collected data
11	Rank importance of KPIVs using a **Pareto chart.**	Team	Organization wisdom
12	Prepare a focused **FMEA.** Assess **current control plans**.	Team	Organization wisdom
13	Collect data for assessing the KPIV/KPOV relationships that are thought to exist.	Team	Collected data
14	Create **multi-vari charts** and **box plots.**	Team	Passive data analysis
15	Conduct **correlation** studies.	Team	Passive data analysis
16	Assess statistical significance of relationships using **hypothesis tests.**	Team	Passive data analysis
17	Conduct **regression** and **analysis of variance (ANOVA)** studies.	Team	Passive data analysis
18	Conduct designed experiments **(DOE)** and **response surface methods (RSM)** analyses.	Team	Active experimentation
19	Determine optimum operating windows of KPIVs from **DOEs, response surface methods (RSM)** and other tools.	Team	Passive data analysis and active experimentation

20	Update **control plan.** Implement **control charts** to timely identify special cause excursions of KPIVs.	Team	Passive data analysis and active experimentation
21	Verify process improvements, stability, and **capability/ performance** using demonstration runs.	Team	Active experimentation

In addition to the array of tools, there are numerous implementation strategies for introducing these tools into S^4 projects depending on whether the application involves manufacturing, development, or service/transactional processes. The order in which these tools are introduced is also very important. Part 1 of this book gives a concise, generic road map to the essential tools that may be utilized for any project. Part 4, "Applying Six Sigma," includes other possible sequences for approaching an S^4 project and integrating tools appropriately for manufacturing, service/transactional, and development applications.

There are no fixed rules that specify the correct order of tool usage. Each project can evolve in its own unique way, demanding its own order of tool usage. The role of the Six Sigma practitioner is to determine tool selection and their use. As organizations acquire experience using Six Sigma tools and techniques, team members can become as capable as formally trained Black Belts in utilizing the tools of Six Sigma.

The first 17 steps listed in Table 1.5 primarily involve collecting and analyzing process output data, compiling information on what can be done differently to make improvements using the wisdom of the organization, and analyzing data passively in an attempt to detect a cause-and-effect relationship between input and output variables. We are suggesting that the first step in an S^4 approach is not to immediately conduct a designed experiment on the production floor, but rather to identify the requirements deemed critical by the customer. Notice that more advanced statistical tools are found near the middle and end of the 21-step process. Examples of these include regression analysis, hypothesis testing, analysis of variance, variance components analysis, multi-vari charts, measurement systems analysis (Gage R&R), design of experiments (DOE), response surface methods (RSM), statistical process control (SPC), and process capability/performance analyses.

It is important to extract and analyze the existing information on a process before proceeding to change it. We suggest the early use of high-level control charts, which we call "30,000-foot level" control charts. These charts can be useful in establishing a baseline of the current process from which monetary and other project parameters can be quantified. Later in this book, we describe how this chart can be used to get organizations out of the "firefighting mode." The simple tools of Pareto charts, flowcharts, process maps, and so forth also come in handy at the beginning of a project as ways of displaying and analyzing data. It is important to realize that the assigned Six Sigma practitioners are involved in every step of the process. They are an integral part of the project team but are identified individually in the first three steps, since prior to step 4 the team itself does not yet exist. There is important work to be done before team members are identified and trained.

1.5 LEAN MANUFACTURING AND SIX SIGMA

Most of the information in this section was reproduced (with minor additions, deletions, and modifications) from an article by Denecke (1998), and is reproduced with the permission of Honeywell International Inc. (formerly AlliedSignal). We decided to share the article with readers of this book. We have paraphrased it extensively, with permission, and included our own response to the article.

It should be noted that in our opinion the differences between how Six Sigma and lean manufacturing would address a project are even less than what is suggested by this article. We believe that Six Sigma should have metrics, such as cycle time, that lead to the application of the discipline of lean manufacturing when it is most appropriate. In addition, the techniques of Six Sigma should be used within processes to reduce defects, which can be a very important prerequisite for a lean manufacturing project to be successful.

Background

Currently there are two premier approaches to improving manufacturing operations. One is lean manufacturing; the other is Six Sigma. They are promoted as different approaches and different thought processes. Yet, upon close inspection, both approaches attack the same enemy and behave like two links within a chain—that is, they are dependent on each other for success. They both battle variation, but from two different points of view. Lean and Six Sigma integration takes two powerful problem-solving techniques and bundles them into a powerful package. The two approaches should be viewed as complements to each other rather than as equivalents of or replacements for each other (Pyzdek, 2000).

In theory, lean manufacturing (hereinafter referred to as "lean") is a winning strategy. In practice, manufacturers that have widely adopted lean practices record performance metrics superior to those achieved by plants that have not adopted lean practices. Those practices cited as lean in a recent industrial survey (Jusko,

1999) include (1) quick changeover techniques to reduce setup time; (2) adoption of manufacturing cells in which equipment and workstations are arranged sequentially to facilitate small-lot, continuous-flow production; (3) just-in-time (JIT) continuous-flow production techniques to reduce lot sizes, setup time, and cycle time; and (4) JIT supplier delivery in which parts and materials are delivered to the shop floor on a frequent, as-needed basis.

Lean evaluates the entire operation of a factory and restructures the manufacturing method to reduce wasteful activities like waiting, transportation, material hand-offs, inventory, and overproduction. It co-locates the processes in sequential order and, in so doing, reduces variation associated with manufacturing routings, material handling, storage, lack of communication, batch production, and so forth. Six Sigma tools, on the other hand, commonly focus on specific part numbers and processes to reduce variation. The combination of the two approaches represents a formidable opponent to variation in that it includes both relayout of the factory and a focus on specific part numbers and processes. The next section discusses the similarities and differences between the two approaches.

Lean Manufacturing and Noise

Lean tackles the most common form of process noise by aligning the organization in such a way that it can begin working as a coherent whole instead of as separate units. Lean manufacturing seeks to co-locate, in sequential order, all the processes required to produce a product. Instead of focusing on the part number, lean methodology focuses on product flow and on the operator. How can the product be produced in the least amount of time, and how can there be standardization of operator methods along with transfer to the operator of what he or she needs? Flow-focused cells in an organization reduce the communication barriers that exist at the numerous interfaces between operations and greatly reduce the time to achieve a completed part.

Figure 1.2 illustrates Denecke's view that a lean approach attacks variation differently than a Six Sigma system does (Denecke, 1998). For example, lean manufacturing focuses on variation associated with different lean practices employed to speed production and improve quality. Examples of individual practices that can contribute to noise include maintenance, cleanliness, process sequence/co-location issues, and so on. Lean drives two key components of quality: process speed and the feedback of information. If all required machinery is placed together and parts are flowed one piece at a time, any quality problem should be identified by downstream processes immediately. Furthermore, the co-location of multidisciplinary operators allows for speedy communication and problem solving without outside intervention. With cross-training, operators understand how upstream processes affect downstream quality.

Lean manufacturing changes the set of problems the organization must address and increases the price of failure. The organization is forced to respond to the lean definition of waste in the process—travel distance, wait time, non-value-added cycle time, setup time, inventory levels, overproduction, and so on. Setup time is an especially important measure in the lean manufacturing line. Once the first machine starts setting up for a different part configuration, the rest of the line becomes starved for parts—in other words, setup time becomes cumulative. The time involved in setting up the entire cell is the sum of all the individual setup times. A two-hour setup per machine may result in 20 hours of downtime for the entire cell. A host of problems and opportunities that the organization could afford to hide in the past now become critical owing to this cumulative effect. A Six Sigma organization needs to understand the special demands of lean manufacturing if it plans to move toward a quality system that embraces both approaches.

Six Sigma and Noise

The data-driven nature of Six Sigma problem solving lends itself well to lean standardization and the physical rearrangement of the factory. Lean provides a solid foundation for Six Sigma problem solving where the system is measured by deviation from and improvements to the standard.

One of the most difficult aspects of Six Sigma work is implementing and sustaining gains. Even experts in the application of Six Sigma techniques struggle to effectively safeguard the production process from noise. Typically, the employee responsible for implementing Six Sigma is such a strong agent of change that when he or she leaves the area in question to work on a new problem, a vacuum of sorts is created. The process variation may build up over time and allow quality problems to resurface. As Figure 1.2 illustrates, the types of noise that resurface typically involve part variation and overall process variation—for example, poor yield, scrap and rework, raw material variability from multiple vendors, and so forth. Lean provides an excellent safeguard for Six Sigma practitioners against many common sources of noise.

Synergy

Lean and Six Sigma, working together, represent a formidable weapon in the fight against process variation. Six Sigma methodology uses problem-solving techniques to determine how systems and processes operate and how to reduce variation in processes. In a system that combines the two philosophies, lean creates the standard and Six Sigma investigates and resolves any variation from the standard.

With the lean emphasis on standardization, Six Sigma practitioners can be 10 times more effective at tackling process noise. If a number of traditional

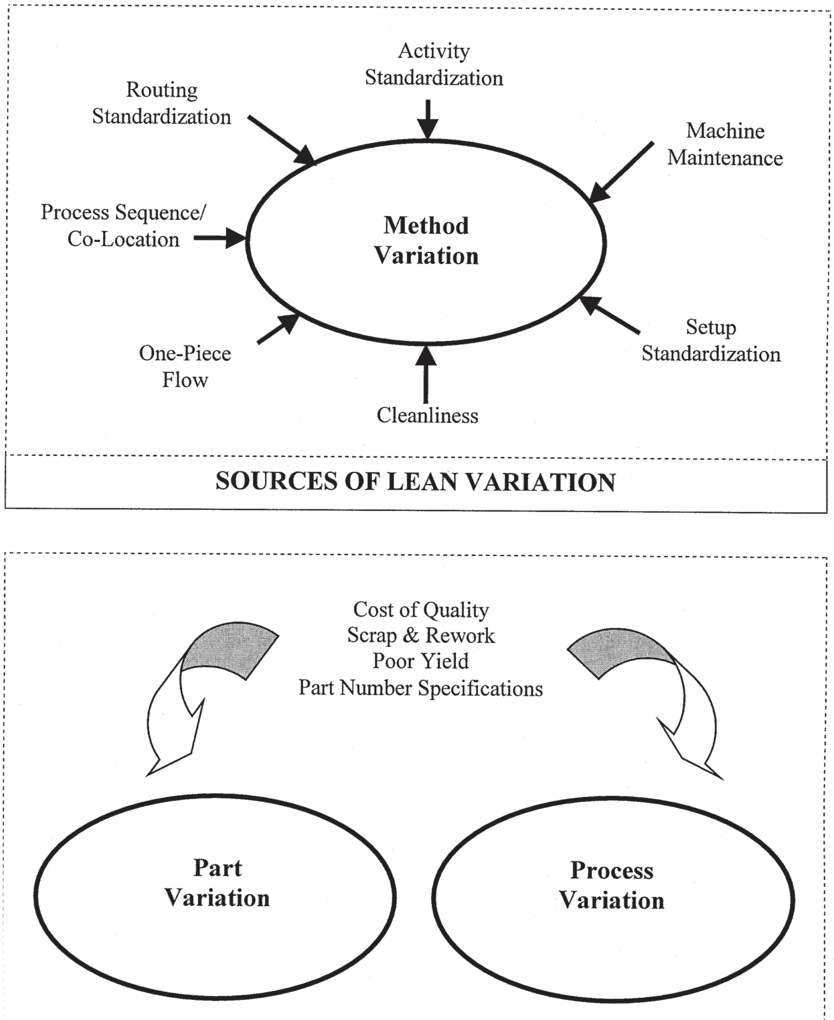

Figure 1.2 Variation as viewed by lean manufacturing and Six Sigma [Adapted from Denecke (1998).]

noise factors have been eliminated by the lean activity, the rest are now easily identifiable through simple observation of the cell. The new system enables rapid problem solving since the Six Sigma practitioner does not have to chase parts through the factory. The hidden factory, now exposed, shows a number of new opportunities for variation—for example, cycle time variation, queuing of parts, downtime of the cell, unpredictable walk patterns, special skill requirements, nonstandard operations, quality problems, and so on. The Six Sigma practitioner can now focus quickly on the problem, assemble the natural work team, collect data in one contained area, compare the results to the standard, and begin the improvement project. The Six Sigma practitioner becomes proactive, continuously seeking to improve upon the standard by expanding on the current process knowledge. It is the responsibility of the organization to go lean so that those implementing Six Sigma are used not as "firefighters" but as proactive and productive problem solvers.

Summary

Again, in our opinion the differences between how Six Sigma and lean manufacturing define and address a project are even less pronounced than what is suggested by the article upon which the preceding discussion is based. We believe that Six Sigma within any organization should have metrics, such as cycle time, that lead to the application of lean manufacturing when it is appropriate. In addition, the techniques of Six Sigma should be applied within an organization's processes to reduce defects, which can be a very important prerequisite to the success of a lean manufacturing project.

1.6 FREQUENTLY ASKED QUESTIONS ABOUT SIX SIGMA

What Is Six Sigma?

Six Sigma provides companies with a series of interventions and statistical tools that can lead to breakthrough profitability and quantum gains in quality, whether the products of a company are durable goods or services. Sigma, σ, is a letter in the Greek alphabet used to denote the standard deviation of a process. Standard deviation measures the variation or amount of spread about the process average. We would like to obtain outputs from processes such that the overall variability of the process is well within specification limits. Sigma quality level, discussed later in this book, is sometimes used to describe the output of a process. A higher sigma quality level value is better. A Six Sigma quality level is said to equate to a 3.4 parts per million outside specification limits. Minitab (2000) claims that today most organizations operate between two and three sigma. Blakeslee (1999) claims that U.S. manufacturing firms frequently attain four sigma quality levels, whereas service firms often operate at quality levels of one or two sigma.

What Is the Practical Difference Between Three and Four Sigma Quality Levels?

To a first approximation, a three sigma quality level is equivalent to 1.5 misspelled words per page in a book such as this one. A six sigma quality level is equivalent to one misspelled word in all of the books in a small library. The differences are huge. The difference stems from the nonlinear relationship between these defect rates and sigma quality levels.

Table 1.6 (Texas Instruments, 1992) provides another basis for comparison among sigma quality levels.

TABLE 1.6 What Is the Magnitude of Difference Between Sigma Levels?

Sigma Level	Area	Spelling	Time	Distance
1	Floor space of the the Astrodome	170 misspelled words per page in a book	31¾ years per century	From here to moon
2	Floor space of a large supermarket	25 misspelled words per page in a book	4½ years per century	1½ times around the world
3	Floor space of a small hardware store	1.5 misspelled words per page in a book	3½ months per century	Coast-to-coast trip
4	Floor space of a typical living room	1 misspelled word per 30 pages (typical book chapter)	2½ days per century	45 minutes of freeway driving
5	Size of the bottom of your telephone	1 misspelled word in a set of encyclopedias	30 minutes per century	1 trip to the local gas station
6	Size of a typical diamond	1 misspelled word in all the books in a small library	6 seconds per century	Four steps in any direction
7	Point of a sewing needle	1 misspelled word in all the books in several large libraries	One eye-blink per century	Inch

Courtesy of Texas Instruments.

What Kind of Return on Investment (ROI) Can I Expect from Six Sigma Training?

Average project savings can vary between $50,000 and $200,000. Six Sigma Practitioners, with 100% of their time allocated to projects, can execute five or six projects during a 12-month period, potentially adding an average of over $1 million to annual profits.

Why Should I Give Six Sigma Serious Consideration?

The customers that form the base of today's world market are sending a clear and undeniable message: produce high-quality products at lower costs with greater responsiveness. To compete in a world market, a company needs to move toward a Six Sigma level of performance. Many of the most profitable and admired companies in the world have set goals within a Six Sigma context, and many moving toward Six Sigma levels of performance have saved billions of dollars. The changes that occur within corporations striving for Six Sigma quality translate to bottom-line benefits.

What Models Are Used to Implement Six Sigma?

There are two basic models for implementing Six Sigma. One model is based on teaching the tools of Six Sigma. In this model little attention, if any, is given to building an organizational infrastructure that supports Six Sigma. Instead, emphasis is typically given to the mechanics of tool execution, as opposed to when and how a tool should be implemented and integrated with other tools.

The other model is project based: the tools are taught and then applied to projects that are defined before sessions begin. In this model, Six Sigma infrastructure issues need to be addressed; however, this effort is sometimes not given the emphasis it deserves. Organizations can achieve more significant bottom-line benefit with this approach, which we will focus on throughout this book.

What Are the Roles Required in a Six Sigma Implementation?

The term "Six Sigma" originated at Motorola, where the Six Sigma methodology was developed and refined. Eventually the approach was adopted and expanded upon by other organizations. Terms were coined at Motorola and elsewhere to describe various roles in the Six Sigma process. To avoid any controversy or conflict over the use of some of these historical terms, a number of organizations have chosen to refer to their Six Sigma activities using different names. For example, AlliedSignal refers to Six Sigma as "operational excellence."

Typically, special names are given to people within an organization who have Six Sigma roles. A few of the names for these roles given by GE, Motorola, and other companies are Process Owner or Sponsor, Champion, Master Black Belt, Black Belt, and Green Belt (Cheek, 1992; General Electric, 1996; General Electric, 1997; Lowe, 1998; Slater, 1999; Pyzdek, 1999; Harry, 2000). These roles are described in more detail later in this book. Note in Table 1.7 the distinction between a "supporter" and a "champion" of Six Sigma (Schiemann and Lingle, 1999). Both roles are important, but they differ in several crucial respects.

TABLE 1.7 The Difference Between a Champion and a Supporter

Champion	Supporter
• Recruits new supporters of Six Sigma	• Maintains support of the Six Sigma process
• Anticipates and addresses Six Sigma problems before they occur	• Reacts to and helps solve Six Sigma problems that occur
• Speaks inspirationally about Six Sigma	• Speaks supportively of Six Sigma
• Actively seeks opportunities to show support of Six Sigma	• Avoids public actions which appear nonsupportive of Six Sigma
• Initiates important Six Sigma activities	• Participates in planned Six Sigma activities

What Is Six Sigma Training Like?

For those who are to implement Six Sigma techniques, we suggest training that involves a total of four months of coursework and on-the-job preparation. Each of the monthly sessions begins with a week of intensive coursework. Class size ranges from 10 to 25, with 20 the target. Coursework involves use of a laptop computer throughout the week, with a computer software package such as Minitab (2000) statistical software and the Microsoft Office Suite installed.

Participants are assigned a project before they begin training, and are required to make brief progress reports on their projects during the second, third, and fourth week of training. They are also required to submit a written report, when the training is complete, outlining what has been accomplished on the project during the four-month period. Participants are also expected to confirm the declared cost savings resulting from the project, in consultation with a company financial officer.

How Much Quality Experience and Statistical Knowledge Is Required of a Six Sigma Instructor?

When selecting people to become instructors, many organizations focus primarily on the degrees and certifications that an individual has achieved. Rather than focusing on a list of credentials, it is perhaps more important to focus on obtaining instructors who will perform well in a classroom environment with high-quality instructional material. Instructors also need to have practical experience that will allow them to bridge the gap between classroom examples and the application of techniques to specific situations—such as those that students present during training and coaching sessions.

What Traits Should I Look for in Full-Time Practitioners of Six Sigma?

When selecting candidates to become full-time practitioners of Six Sigma, look for these characteristics:

- Fire in the belly; an unquenchable drive to improve products and processes
- "Soft skills" and the respect of others within the organization; an ability to create, facilitate, train, and lead teams to success
- Ability to manage projects and reach closure; a persistent drive toward meaningful bottom-line results and timely completion of projects
- Basic analytical skills; an ability to learn, apply, and wisely link Six Sigma tools, some of which may utilize computer application programs

It should be noted that this list does not call for a knowledge of statistical techniques. Our belief is that trainees with the characteristics listed above will easily pick up statistical techniques if provided with good instructional material and training.

Do We Need Full-Time Personnel for Six Sigma?

Implementing a Six Sigma process requires a considerable investment in infrastructure. The number of projects that can be undertaken is a function of the level of infrastructure support allocated to Six Sigma. As with many other programs and processes, there is a minimum critical mass necessary for success. Six Sigma needs to be a "top-down" process, primarily because executives have the mandate to determine what gets done in an organization. Six Sigma projects should be tied strategically to the business plan and should focus on satisfying customers and delivering world-class performance based on multidimensional metrics. An organization that does not devote personnel full-time to implementing Six Sigma risks having its Six Sigma initiative become diluted.

What Kind of "Soft" Skills Are Required to Be a Successful Six Sigma Practitioner?

Soft skills are as important as, if not more important than, hard skills—and many are more difficult to acquire. For reasons that are not easy to understand, many people who are skilled in technical and statistical methods (left-brain dominance) lack the abilities and finesse in human relations and team building (right-brain dominance). Some important soft skills are the following:

- The ability to be an effective facilitator
- The ability to effectively charter Six Sigma teams
- The ability to provide training covering a wide variety of quality tools
- The ability to explain technical details in layman's terms
- The ability to talk candidly with and effectively influence senior management
- The ability to talk candidly with and effectively influence line worker personnel
- A balanced concern for people issues as well as programmatic issues
- Unquestioned integrity
- The ability to mediate strong disagreements among varied constituencies
- The ability to disassociate from bias on how things were done in the past
- The ability to deal with complex situations and complicated personalities diplomatically
- The ability to make effective presentations to executives, managers, and workers

What Infrastructure Issues Will I Face if I Adopt a Six Sigma Approach?

Refer to Chapter 8 in this book for a complete answer to this important question.