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HISTORY / LESSONS LEARNED

Chapter

1

Quality Thrust

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Ron Randall is an independent consultant, and an associate of the Six Sigma Academy, specializing in applying the principles of Six Sigma quality. Since the 1980s, Ron has applied Statistical Process Control and Design of Experiments principles to engineering and manufacturing at Texas Instruments Defense Systems and Electronics Group. While at Texas Instruments, he served as chairman of the Statistical Process Control Council, a Six Sigma Champion, Six Sigma Master Black Belt, and a Senior Member of the Technical Staff. His graduate work has been in engineering and statistics with study at SMU, the University of Tennessee at Knoxville, and NYU's Stern School of Business under Dr. W. Edwards Deming. Ron is a Registered Professional Engineer in Texas, a Senior Member of the American Society for Quality, and a Certified Quality Engineer. Ron served two terms on the Board of Examiners for the Malcolm Baldrige National Quality Award.

1.1 Meaning of Quality

What do we mean by the word *quality*? The word quality has multiple meanings. Some very important meanings are:

- Quality consists of those product features that meet the needs of customers and thereby provide product satisfaction.
- Quality consists of freedom from deficiencies, or in other words, absence of defects. (Reference 5)

Most corporations manage the business by understanding the financials. They spend significant resources on financial planning, financial control, and financial improvement. Successful companies also spend significant effort on quality planning, quality control, and quality improvement.

1.2 The Evolution of Quality

The evolution of product quality and quality-of-service has received a great deal of attention by corporations, educational institutions, and health care providers especially in the last 15 years. (Reference 8) Some corporations have been very successful financially because the quality of the products and services is superior to anything offered by a competitor. The relationship of quality and financial success in the automotive industry in the 1980s is a familiar example.

The winners of the Deming Prize in Japan, the Malcolm Baldrige National Quality Award in the United States, and similar awards around the world all have something in common. They have proven the strong relationship of quality and customer satisfaction to business excellence and financial success.

1.3 Some Quality Gurus and Their Contributions

1.3.1 W. Edwards Deming

The most famous name in Japanese quality control is American.

Dr. W. Edwards Deming (1900–1993) was the quality control expert whose work in the 1950s led Japanese industry into new principles of management and revolutionized their quality and productivity.

In 1950, the Union of Japanese Scientists and Engineers (J.U.S.E.) invited Dr. Deming to lecture several times in Japan. These lectures turned out to be overwhelmingly successful. To commemorate Dr. Deming's visit and to further Japan's development of quality control, J.U.S.E. shortly thereafter established the Deming prizes to be presented each year to the Japanese companies with the most outstanding achievements in quality control. (Reference 6)

In 1985 Deming wrote:

> "For a long period after World War II, till around 1962, the world bought whatever American Industry produced. The only problem American management faced was lack of capacity to produce enough for the market. No ability was required for management under those circumstances. There was no way to lose.
>
> It is different now. Competition from Japan wrought challenges that Western industry was not prepared to meet. The change has been gradual and was, in fact, ignored and denied over a number of years. All the while, Western management generated explanations for decline of business that now can be described as creative. The plain fact is that management was caught off guard, unable to manage anything but an expanding market.
>
> People in management cannot learn on the job what the job of management is. Help must come from the outside.
>
> The statistician's job is to find sources of improvement and sources of trouble. This is done with the aid of the theory of probability, the characteristic that distinguishes statistical work from that of other professions. Sources of improvement, as well as sources of obstacles and inhibitors that afflict Western industry, lie in top management. Fighting fires and solving problems downstream is important, but relatively insignificant compared with the contributions that management must make. Examination of sources of improvement has brought the 14 points for management and an awareness of the necessity to eradicate the deadly diseases and obstacles that infest Western industry." (Reference 6)

In his book *Out of the Crisis* (Reference 2) published in 1982 and again in 1986, Deming illustrates his 14 points:

1. Create constancy of purpose for improvement of product and service.
2. Adopt the new philosophy.

3. Cease dependence on inspection to achieve quality.
4. End the practice of awarding business on the basis of price tag alone. Instead, minimize total cost by working with a single supplier.
5. Improve constantly and forever every process for planning, production, and service.
6. Institute training on the job.
7. Adopt and institute leadership.
8. Drive out fear.
9. Break down barriers between staff areas.
10. Eliminate slogans, exhortations, and targets for the work force.
11. Eliminate numerical quotas for the work force and numerical goals for management.
12. Remove barriers that rob people of pride of workmanship. Eliminate the annual rating or merit system.
13. Institute a vigorous program of education and self-improvement for everyone.
14. Put everybody in the company to work to accomplish the transformation.

Much of industry's Total Quality Management (TQM) practices stem from Deming's work. The turnaround of many U.S. companies is directly attributable to Deming. This author had the privilege of completing Deming's four-day course in 1987 and two subsequent courses at New York University in 1990 and 1991. He was a great man who completed great works.

1.3.2 Joseph Juran

Juran showed us how to organize for quality improvement.

Another pioneer and leader in the quality transformation is Dr. Joseph M. Juran (1904–), founder and chairman emeritus of the Juran Institute, Inc. in Wilton, Connecticut. Juran has authored several books on quality planning, and quality by design, and is the editor-in-chief of Juran's *Quality Control Handbook*, the fourth edition copyrighted in 1988. (Reference 5)

Juran was an especially important figure in the quality changes taking place in American industry in the 1980s. Through the Juran Institute, Juran taught industry that work is accomplished by processes. Processes can be improved, products can be improved, and important financial gains can be accomplished by making these improvements. Juran showed us how to organize for quality improvement, that the language of management is money, and promoted the concept of project teams to improve quality. Juran introduced the Pareto principle to American industry. The Italian economist, Wilfredo Pareto, demonstrated that a small fraction of the people held most of the wealth. As applied to the cost of poor quality, the Pareto principle states that a few contributors to the cost are responsible for most of the cost. From this came the 80-20 rule, which states 20% of all the contributors to cost, account for 80% of the total cost.

Juran taught us how to manage for quality, organize for quality, and design for quality. In his 1992 book, *Juran on Quality by Design* (Reference 4), he tells us that poor quality is usually planned that way and quality planning in the past has been done by amateurs.

Juran discussed the need for unity of language with respect to quality and defined key words and phrases that are widely accepted today: (Reference 4)

> "A product is the output of a process. Economists define products as goods and services.
>
> A product feature is a property possessed by a product that is intended to meet certain customer needs and thereby provide customer satisfaction.

> Customer satisfaction is a result achieved when product features respond to customer needs. It is generally synonymous with product satisfaction. Product satisfaction is a stimulus to product salability. *The major impact is on share of market, and thereby on sales income.*
>
> A product deficiency is a product failure that results in *product dissatisfaction. The major impact is on the costs* incurred to redo prior work, to respond to customer complaints, and so on.
>
> Product deficiencies are, in all cases, sources of customer *dissatisfaction*.
>
> Product satisfaction and product dissatisfaction are not opposites. Satisfaction has its origins in product features and is why clients buy the product. Dissatisfaction has its origin in non-conformances and is why customers complain. There are products that give no dissatisfaction; they do what the supplier said they would do. Yet, the customer is dissatisfied with the product if there is some competing product providing greater satisfaction.
>
> A customer is anyone who is impacted by the product or process. Customers may be internal or external."

This author has had the honor and privilege to work with Dr. Juran on company and national quality efforts in the 1980s and 1990s. Dr. Juran showed us how to manage for quality. He is a great teacher, leader, and mentor.

1.3.3 Philip B. Crosby

Doing things right the first time adds nothing to the cost of your product of service. Doing things wrong is what costs money.

In his book, *Quality is Free—The Art of Making Quality Certain* (Reference 1) Crosby introduced valuable quality-building tools that caught the attention of Western Management in the early 1980s. Crosby developed many of these ideas and methods during his industrial career at International Telephone and Telegraph Corporation. Crosby went on to teach these methods to managers at the Crosby Quality College in Florida.

- Quality Management Maturity Grid—An entire objective system for measuring your present quality system. Easy to use, it pinpoints areas in your operation for potential improvement.
- Quality Improvement Program—A proven 14-step procedure to turn your business around.
- Make Certain Program—The first defect prevention program ever for white-collar and nonmanufacturing employees.
- Management Style Evaluation—A self-examination process for managers that shows how personal qualities may be influencing product quality.

Crosby demonstrated that the typical American corporation spends 15% to 20% of its sales dollars on inspection, tests, warranties, and other quality-related costs. Crosby's work went on to define the elements of the cost of poor quality that are in use today at many corporations. Prevention costs, appraisal costs, and failure costs are well defined, and a system for periodic accounting is demonstrated.

In this author's experience with many large corporations, there is a direct correlation between the number of defects produced and the cost of poor quality. Crosby was the leader who showed how to qualitatively correlate defects with money, which Juran showed us, is the language of management.

1.3.4 Genichi Taguchi

Monetary losses occur with any deviation from the nominal.

Dr. Genichi Taguchi is the Japanese engineer that understood and quantified the effects of variation on the final product quality. (Reference 11) He understood and quantified the fact that any deviation from the nominal will cause a quantifiable cost, or loss. Most of Western management thinking today still believes that loss occurs only when a specification has been violated, which usually results in scrap or rework. The truth is that any design works best when all elements are at their target value.

Taguchi quantified the cost of variation and set forth this important mathematical relationship. Taguchi quantified what Juran, Crosby and others continue to teach. The language of management is money, and deviations from standard are losses. These losses are in performance, customer satisfaction, and supplier and manufacturing efficiency. These losses are real and can be quantified in terms of money.

Taguchi's Loss Function (Fig. 1-1) is defined as follows:

Monetary loss is a function of each product feature (x), and its difference from the best (target) value.

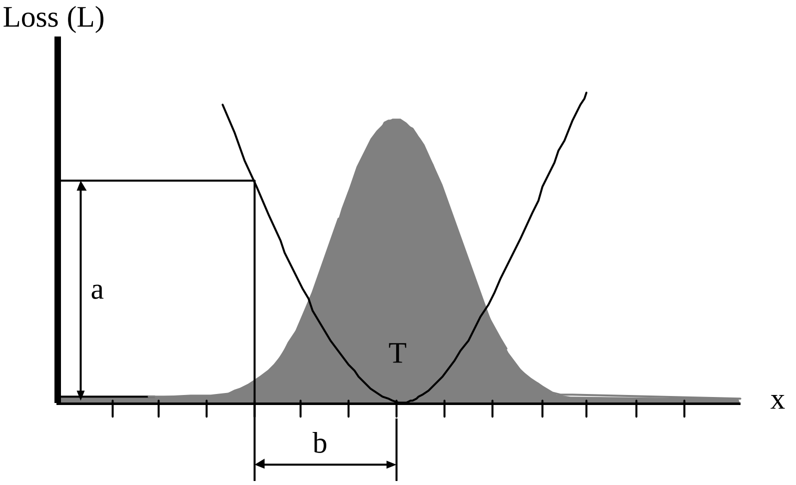

Figure 1-1 Taguchi's loss function and a normal distribution

x is a measure of a product characteristic
T is the target value of x
a = amount of loss when x is not on target T
b = amount that x is away from the target T

In this illustration, $T = \bar{x}$, where $\bar{x}$ is the mean of the sample of x'**s**

In the simple case for one value of x, the loss is:

$L = k(x - T)^2$, where $k = a/b^2$

This simple quadratic equation is a good model for estimating the cost of not being on target.

The more general case can be expressed using knowledge of how the product characteristic (x) varies. The following model assumes a normal distribution, which is symmetrical about the average $\bar{x}$.

$L(x) = k[(\bar{x} - T)^2 + s^2]$, where s = the standard deviation of the sample of x'**s**

The principles of Taguchi's Loss Function are fundamental to modern manufacturability and systems engineering analyses. Each function and each feature of a product can be analyzed individually. The summation of the estimated losses can lead an integrated design and manufacturing team to make tradeoffs quantitatively and early in the design process. (Reference 12)

1.4 The Six Sigma Approach to Quality

An aggressive campaign to boost profitability, increase market share, and improve customer satisfaction that has been launched by a select group of leaders in American Industry. (Reference 3)

1.4.1 The History of Six Sigma (Reference 10)

> "In 1981, Bob Galvin, then chairman of Motorola, challenged his company to achieve a tenfold improvement in performance over a five-year period. While Motorola executives were looking for ways to cut waste, an engineer by the name of Bill Smith was studying the correlation between a product's field life and how often that product had been repaired during the manufacturing process. In 1985, Smith presented a paper concluding that if a product were found defective and corrected during the production process, other defects were bound to be missed and found later by the customer during the early use by the consumer. Additionally, Motorola was finding that best-in-class manufacturers were making products that required no repair or rework during the manufacturing process. (These were Six Sigma products.)
>
> In 1988, Motorola won the Malcolm Baldrige National Quality Award, which set the standard for other companies to emulate.
>
> (This author had the opportunity to examine some of Motorola's processes and products that were very near Six Sigma. These were nearly 2,000 times better than any products or processes that we at Texas Instruments (TI) Defense Systems and Electronics Group (DSEG) had ever seen. This benchmark caused DSEG to re-examine its product design and product production processes. Six Sigma was a very important element in Motorola's award winning application. TI's DSEG continued to make formal applications to the MBNQA office and won the award in 1992. Six Sigma was a very important part of the winning application.)
>
> As other companies studied its success, Motorola realized its strategy to attain Six Sigma could be further extended." (Reference 3)

Galvin requested that Mikel J. Harry, then employed at Motorola's Government Electronics Group in Phoenix, Arizona, start the Six Sigma Research Institute (SSRI), circa 1990, at Motorola's Schaumburg, Illinois campus. With the financial support and participation of IBM, TI's DSEG, Digital Equipment Corporation (DEC), Asea Brown Boveri Ltd. (ABB), and Kodak, the SSRI began developing deployment strategies, and advanced applications of statistical methods for use by engineers and scientists.

Six Sigma Academy President, Richard Schroeder, and Harry joined forces at ABB to deploy Six Sigma and refined the breakthrough strategy by focusing on the relationship between net profits and product quality, productivity, and costs. The strategy resulted in a 68% reduction in defect levels and a 30% reduction in product costs, leading to $898 million in savings/cost reductions each year for two years. (Reference 13)

Schroeder and Harry established the Six Sigma Academy in 1994. Its client list includes companies such as Allied Signal, General Electric, Sony, Texas Instruments DSEG (now part of Raytheon), Bombardier, Crane Co., Lockheed Martin, and Polaroid. These companies correlate quality to the bottom line.

1.4.2 Six Sigma Success Stories

There are thousands of black belts working at companies worldwide. A blackbelt is an expert that can apply and deploy the Six Sigma Methods. (Reference 13)

> Jennifer Pokrzywinski, an analyst with Morgan Stanley, Dean Witter, Discover & Co., writes "Six Sigma companies typically achieve faster working capital turns; lower capital spending as capacity is freed up; more productive R&D spending; faster new product development; and greater customer satisfaction." Pokrzywinski estimates that by the year 2000, GE's gross annual benefit from Six Sigma could be $6.6 billion, or 5.5% of sales. (Reference 7)

General Electric alone has trained about 6,000 people in the Six Sigma methods. The other companies mentioned above have trained thousands more. Each black belt typically completes three or four projects per year that save about $150,000 each. The savings are huge, and customers and shareholders are happier.

1.4.3 Six Sigma Basics

"The philosophy of Six Sigma recognizes that there is a direct correlation between the number of product defects, wasted operating costs, and the level of customer satisfaction. The Six Sigma statistic measures the capability of the process to perform defect-free work….

With Six Sigma, the common measurement index is defects per unit and can include anything from a component, piece of material, or line of code, to an administrative form, time frame, or distance. The sigma value indicates how often defects are likely to occur. The higher the sigma value, the less likely a process will produce defects.

Consequently, as sigma increases, product reliability improves, the need for testing and inspection diminishes, work in progress declines, costs go down, cycle time goes down, and customer satisfaction goes up.

Fig. 1-2 displays the short-term understanding of Six Sigma for a single critical-to-quality (CTQ) characteristic; in other words, when the process is centered. Fig. 1-3 illustrates the long-term perspective after the influence of process factors, which tend to affect process centering. From these figures, one can readily see that the short-term definition will produce 0.002 parts per million (ppm) defective. However, the long-term perspective reveals a defect rate of 3.4 ppm.

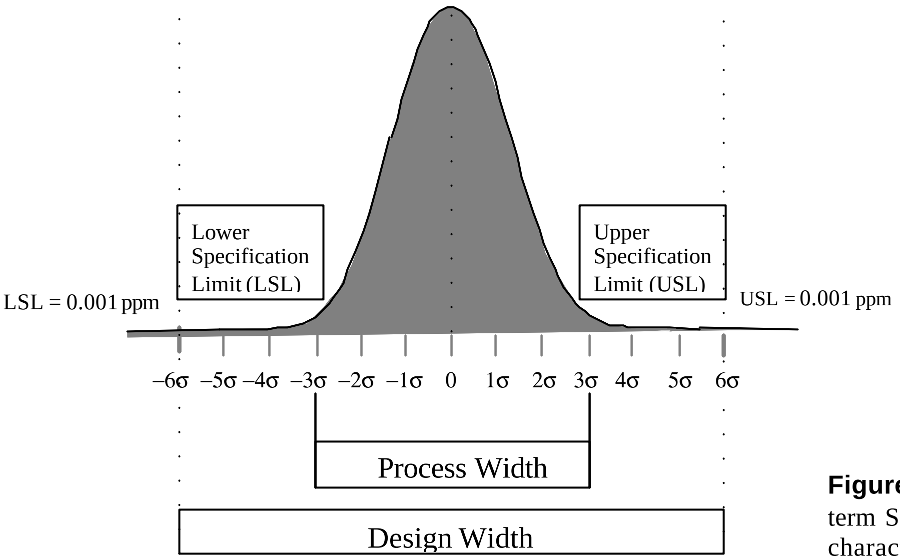

Figure 1-2 Graphical definition of short-term Six Sigma performance for a single characteristic

(This degradation in the short-term performance of the process is largely due to the adverse effect of long-term influences such as tool wear, material changes, and machine setup, just to mention a few. It is these types of factors that tend to upset process centering over many cycles of manufacturing. In fact, research has shown that a typical process is likely to deviate from its natural centered condition by approximately ±1.5 standard deviations at any given moment in time. With this principle in hand, one can make a rational estimate of the long-term process capability with knowledge of only the short-term performance. For example, if the capability of a CTQ characteristic is ±6.0 sigma in the short term, the long-term capability may be approximated as 6.0 sigma – 1.5 sigma = 4.5 sigma, or 3.4 ppm in terms of a defect rate.)" (Reference 3)

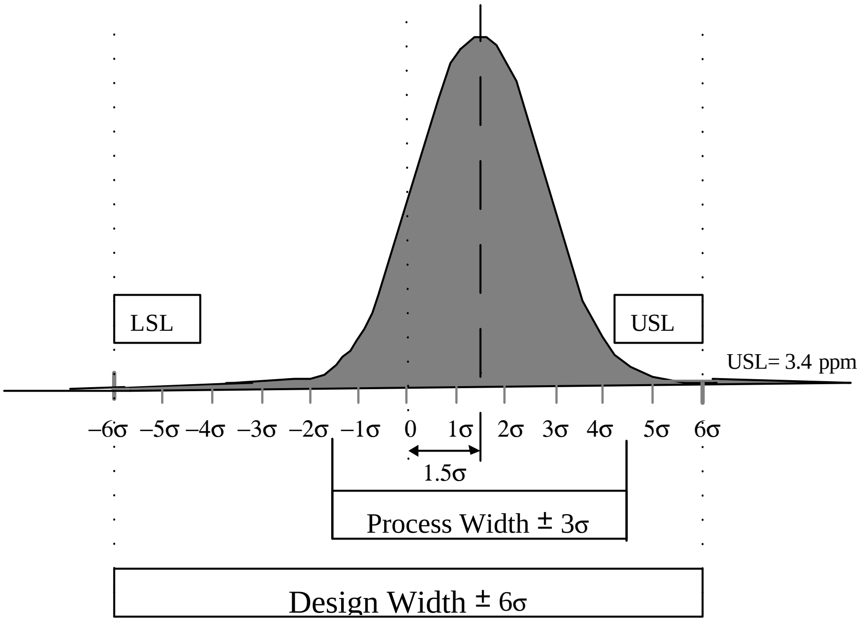

Figure 1-3 Graphical definition of long-term Six Sigma performance for a single characteristic (distribution shifted 1.5σ)

For designers of products, it is vitally important to know the capability of the process that will be used to manufacture a particular product feature. With this knowledge for each CTQ characteristic, an estimate of the number of defects that are likely to happen during manufacturing can be made. Extending this idea to the product level, a sigma value for the product design can be estimated. Products that are truly world-class have values around 6.0 sigma before manufacturing begins. Products that are extremely complex, like a large passenger jetliner, require sigma values greater than 6.0. Project managers and designers should know the sigma value of their design before production begins. The sigma value is a measure of the inherent manufacturability of the product.

Table 1-1 presents various levels of capability (manufacturability) and the implications to quality and costs.

Table 1-1 Practical impact of process capability

Sigma	Parts per Million	Cost of Poor Quality	
6 Sigma	3.4 defects per million	< 10% of sales	World class
5 Sigma	233 defects per million	10-15% of sales	
4 Sigma	6210 defects per million	15-20% of sales	Industry average
3 Sigma	66,807 defects per million	20-30% of sales	
2 Sigma	308,537 defects per million	30-40% of sales	Noncompetitive
1 Sigma	690,000 defects per million		

1.5 The Malcolm Baldrige National Quality Award (MBNQA)

Describe how new products are designed.

The criteria for the MBNQA asks companies to describe how new products are designed, and to describe how production processes are designed, implemented, and improved. Regarding design processes, the criteria further asks *"how design and production processes are coordinated to ensure trouble-free introduction and delivery of products."*

The winners of the MBNQA and other world-class companies have very specific processes for product design and product production. Most have an integrated product and process design process that requires early estimates of manufacturability. Following the Six Sigma methodology will enable design teams to estimate the quantitative measure of manufacturability.

What is the Malcolm Baldrige National Quality Award?

Congress established the award program in 1987 to recognize U.S. companies for their achievements in quality and business performance and to raise awareness about the importance of quality and performance excellence as a competitive edge. The award is not given for specific products or services. Two awards may be given annually in each of three categories: manufacturing, service, and small business.

While the Baldrige Award and the Baldrige winners are the very visible centerpiece of the U.S. quality movement, a broader national quality program has evolved around the award and its criteria. A report, *Building on Baldrige: American Quality for the 21st Century*, by the private Council on Competitiveness, states, "More than any other program, the Baldrige Quality Award is responsible for making quality a national priority and disseminating best practices across the United States."

The U.S. Commerce Department's National Institute of Standards and Technology (NIST) manages the award in close cooperation with the private sector.

Why was the award established?

In the early and mid-1980s, many industry and government leaders saw that a renewed emphasis on quality was no longer an option for American companies but a necessity for doing business in an ever expanding, and more demanding, competitive world market. But many American businesses either did not believe quality mattered for them or did not know where to begin. The Baldrige Award was envisioned as a standard of excellence that would help U.S. companies achieve world-class quality.

How is the Baldrige Award achieving its goals?

The criteria for the Baldrige Award have played a major role in achieving the goals established by Congress. They now are accepted widely, not only in the United States but also around the world, as the standard for performance excellence. The criteria are designed to help companies enhance their competitiveness by focusing on two goals: delivering ever improving value to customers and improving overall company performance.

The award program has proven to be a remarkably successful government and industry team effort. The annual government investment of about $3 million is leveraged by more than $100 million of private-sector contributions. This includes more than $10 million raised by private industry to help launch the program, plus the time and efforts of hundreds of largely private-sector volunteers.

The cooperative nature of this joint government/private-sector team is perhaps best captured by the award's Board of Examiners. Each year, more than 300 experts from industry, as well as universities, governments at all levels, and non-profit organizations, volunteer many hours reviewing applications for the award, conducting site visits, and providing each applicant with an extensive feedback report citing strengths and opportunities to improve. In addition, board members have given thousands of presentations on quality management, performance improvement, and the Baldrige Award.

The award-winning companies also have taken seriously their charge to be quality advocates. Their efforts to educate and inform other companies and organizations on the benefits of using the Baldrige Award framework and criteria have far exceeded expectations. To date, the winners have given approximately 30,000 presentations reaching thousands of organizations.

How does the Baldrige Award differ from ISO 9000?

The purpose, content, and focus of the Baldrige Award and ISO 9000 are very different. Congress created the Baldrige Award in 1987 to enhance U.S. competitiveness. The award program promotes quality awareness, recognizes quality achievements of U.S. companies, and provides a vehicle for sharing successful strategies. The Baldrige Award criteria focus on results and continuous improvement. They provide a framework for designing, implementing, and assessing a process for managing all business operations.

ISO 9000 is a series of five international standards published in 1987 by the International Organization for Standardization (ISO), Geneva, Switzerland. Companies can use the standards to help determine what is needed to maintain an efficient quality conformance system. For example, the standards describe the need for an effective quality system, for ensuring that measuring and testing equipment is calibrated regularly, and for maintaining an adequate record-keeping system. ISO 9000 registration determines whether a company complies with its own quality system.

Overall, ISO 9000 registration covers less than 10 percent of the Baldrige Award criteria. (Reference 9)

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