THE CERTIFIED SIX SIGMA BLACK BELT PRIMER

SIX SIGMA HAS FOREVER CHANGED GE®. EVERYONE... IS A TRUE BELIEVER IN SIX SIGMA, THE WAY THIS COMPANY NOW WORKS.

JOHN F. WELCH
FORMER GE CHAIRMAN

Enterprise-Wide Deployment

Enterprise-wide Deployment is reviewed in the following topic areas:

- **Enterprise-wide view**
- **Enterprise leadership**

Enterprise-wide View is presented in the following topic areas:

- **Value of six sigma**
- **Six sigma foundations**
- **Value and foundations of lean**
- **Integration of lean and six sigma**
- **Business processes and systems**

These topic areas vary somewhat from the wording and sequence of the ASQ BOK but the authors feel the coverage is adequate.

Value of Six Sigma

Six sigma is a highly disciplined process that focuses on developing and delivering near-perfect products and services consistently. It is also a management strategy to use statistical tools and project work to achieve breakthrough profitability and quantum gains in quality. It has been stated that product characteristics with six sigma process capabilities (C_{pk} > 1.5) are of world class performance. The average American company is at four sigma level. (Harry, 1998)[29]. Snee (1999)[70] describes six sigma as, "A business improvement approach that seeks to find and eliminate causes of mistakes or defects in business processes by focusing on outputs that are of critical importance to customers."

Motorola®, under the direction of Chairman Bob Galvin, used statistical tools to identify and eliminate variation. From Bill Smith's yield theory in 1984, Motorola® developed six sigma as a key business initiative in 1987. Many credit the resulting improvements as a key factor in Motorola® winning the Malcolm Baldrige Award in 1988. Dr. Mikel Harry, who had led the corporate effort, subsequently left Motorola® and later founded the Six Sigma Academy to accelerate the efforts of corporations to achieve world class standards. (Harry, 1998)[29]

Value of Six Sigma (Continued)

Sigma is a statistical term that refers to the standard deviation of a process about it's mean. In a normally distributed process, 99.73% of measurements will fall within ± 3.0 sigma and 99.99966% will fall within ± 4.5 sigma. In a stable attribute distributed process, 99.73% of values will fall within the probability of 0.00135 and 0.99865.

Motorola® noted that many operations, such as complex assemblies, tended to shift 1.5 sigma over time. So a process, with a normal distribution and normal variation of the mean, would need to have specification limits of ± 6 sigma in order to produce less than 3.4 defects per million opportunities. This failure rate can be referred to as defects per opportunity (DPO), or defects per million opportunities (DPMO).

Figure 2.1 illustrates the ±1.5 sigma shift and Table 2.2 provides some indications of possible defect levels.

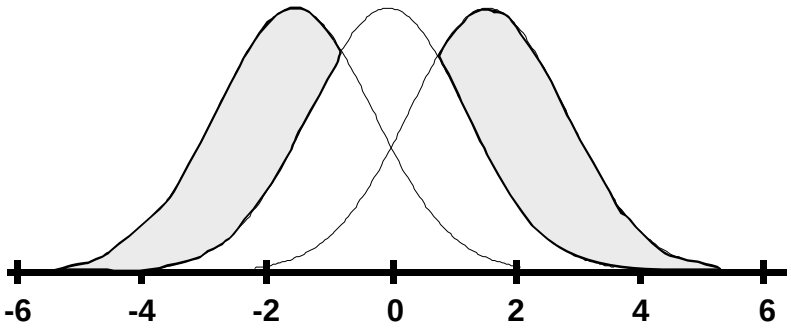

Figure 2.1 The ± 1.5 Sigma Shift

Sigma Level	ppm
6 sigma	3.4 ppm
5 sigma	233 ppm
4 sigma	6,210 ppm
3 sigma	66,810 ppm
2 sigma	308,770 ppm
1 sigma	697,672 ppm

Table 2.2 Defect Levels

Note that Table II in the Appendix provides defect levels at other sigma values. Various authors report slightly different failure rates based upon rounding effects and slight miscalculations.

It should be noted that the term "six sigma" has been applied to many operations including those with non-normal distributions, for which a calculation of sigma would be inappropriate. The principle remains the same, deliver near perfect products and services by improving the process and eliminating defects. The end objective is to delight customers.

Value of Six Sigma (Continued)

The six sigma steps for many organizations are described as DMAIC:

Define: **Select the appropriate responses (the "Ys") to be improved.**

Measure: **Data must be gathered to measure the response variable.**

Analyze: **Identify the root causes of defects, defectives, or significant measurement deviations whether in or out of specifications. (The "Xs", independent variables).**

Improve: **Reduce variability or eliminate the cause.**

Control: **With the desired improvements in place, monitor the process to sustain the improvements.**

Modified from (Hahn, 1999)[27]

Harry (2000)[30] proposes that the entire six sigma breakthrough strategy should consist of the following eight elements:

R Recognize the true states of your business.
D Define what plans must be in place to realize improvement of each state.
M Measure the business systems that support the plans.
A Analyze the gaps in system performance benchmarks.
I Improve system elements to achieve performance goals.
C Control system-level characteristics that are critical to value.
S Standardize the systems that prove to be best-in-class.
I Integrate best-in-class systems into the strategic planning framework.

Because of the integration of a number of tools, such as lean manufacturing, DOE (design of experiments), and DFSS (design for six sigma), six sigma has been referred to as TQM (total quality management) on steroids.

The business successes that result from a six sigma initiative include:

- **Cost reductions**
- **Market - share growth**
- **Defect reductions**
- **Culture changes**
- **Productivity improvements**
- **Customer relations improvements**
- **Product and service improvements**
- **Cycle - time reductions**

(Pande, 2000)[52]

Value of Six Sigma (Continued)

Motorola® credits the six sigma initiative for savings of $940 million over three years. AlliedSignal® (now Honeywell®) reported an estimated $1.5 billion in savings in 1997. GE® has invested a billion dollars with a return of $1.75 billion in 1998 and an accumulated savings of $2.5 billion for 1999. (Hahn, 1999)[27]

Harry (1998)[29] reports that the average black belt project will save about $175,000. There should be about 5 to 6 projects per year, per black belt. The ratio of one black belt per 100 employees can provide a 6% cost reduction per year. For larger companies, there is usually one master black belt for every 100 black belts.

Snee (1999)[70] provides some reasons why six sigma works:

- **Bottom line results**
- **Senior management is involved**
- **A disciplined approach is used (DMAIC)**
- **Short project completion times (3 to 6 months)**
- **Clearly defined measures of success**
- **Infrastructure of trained individuals (black belts, green belts)**
- **Customers and processes are the focus**
- **A sound statistical approach is used**

Organizations that follow a six sigma improvement process for several years find that some operations achieve greater than six sigma quality. When operations reach six sigma quality, defects become so rare that when they do occur, they receive the full attention necessary to determine and correct the root cause. As a result, key operations frequently end up realizing better than six sigma quality.

Companies that have embraced six sigma include:

- **Motorola**
- **General Electric**
- **Dupont**
- **Polaroid**
- **Kodak**
- **Sony**
- **Toshiba**
- **AlliedSignal**
- **Black & Decker**
- **Dow Chemical**
- **Federal Express**
- **Boeing**
- **Johnson & Johnson**
- **Navistar**

Six Sigma Foundations

Listed below are some well-known gurus and what they have contributed to the business and technical foundations of six sigma. This list is far from inclusive.

Guru	Contribution
Philip B. Crosby	Senior management involvement 4 absolutes of quality management Quality cost measurements
W. Edwards Deming	Plan-do-study-act (wide usage) Top management involvement Concentration on system improvement Constancy of purpose
Armand V. Feigenbaum	Total quality control/management Top management involvement
Kaoru Ishikawa	4M (5M) or cause-and-effect diagram Companywide quality control (CWQC) Next operation as customer
Joseph M. Juran	Top management involvement Quality trilogy (project improvement) Quality cost measurement Pareto analysis
Walter A. Shewhart	Assignable cause vs. chance cause Control charts Plan-do-check-act (as a design approach) Use of statistics for improvement
Genichi Taguchi	Loss function concepts Signal to noise ratio Experimental design methods Concept of design robustness
Bill Smith	First introduced the term “six sigma”
Mikel Harry	The main architect of six sigma
Forrest Breyfogle III	Author of *Implementing Six Sigma*

Table 2.3 Major Contributors to the Six Sigma Knowledge Bank (Wortman, 2001)[79]

Philip B. Crosby (1928 - 2001)

Philip B. Crosby was vice-president of ITT for 14 years. In 1979, he founded Philip Crosby Associates, Inc. in Winter Park, Florida. Mr. Crosby consulted, spoke, and wrote about strategic quality issues throughout his professional life.

Philip Crosby started his career as a junior technician testing fire control systems for B-47s. He eventually moved on to ITT and became one of the first corporate VPs of quality in the country. He attributed his management training to Harold Geneen and to the monthly general management meetings. It was Philip Crosby's deep understanding of the concerns of management that made him akin to top management. The other quality deep thinkers could be viewed as academicians, but Crosby was considered a businessman. This explained the numbers of top management that flocked to his quality college.

Crosby believed that quality was a significant part of the company and senior managers must take charge of it. He believed the quality professional must become more knowledgeable and communicative about the business. Crosby stated that corporate management must make the cost of quality a part of the financial system of their company.

Philip Crosby was a fellow and past president of ASQ. One of his most popular statements on quality was, "Quality is conformance to requirements."

Some of Mr. Crosby's more popular books include:

***Quality Is Free: The Art of Making Quality Certain* (1980)**
***The Art of Getting Your Own Sweet Way* (1981)**
***Quality Without Tears: The Art of Hassle-free Management* (Crosby, 1984)[11]**
***The Eternally Successful Organization: The Art of Corporate Wellness* (1988)**
***Leading, the Art of Becoming an Executive* (1990)**
***Completeness: Quality for the 21st Century* (1992)**
***Running Things: The Art of Making Things Happen* (1992)**
***Quality and Me: Lessons from an Evolving Life* (1999)**

Philip B. Crosby (Continued)

Philip Crosby preached four absolutes of quality management:

1. **Quality means conformance to requirements**

   The requirements are what the customer says they are. There is a need to emphasize a "do it right the first time" attitude.

2. **Quality comes from prevention**

   Opportunities are available to correct problems in the system.

3. **The quality performance standard is zero defects**

   One must insist on zero defects. Otherwise, it is acceptable to send out nonconforming parts and goods. If there is a nonconformance, then action must be taken to eliminate it and prevent it from occurring again.

4. **Quality measurement is the price of nonconformance**

   A measurement of quality is needed to get management's attention, prioritize problems, correct problems, and to measure progress.

The four absolutes of quality management are basic requirements for understanding the purpose of a quality system. Philip Crosby also developed a 14 step approach to quality improvement:

1. **Management Commitment**
2. **Quality Improvement Team**
3. **Measurement**
4. **Cost of Quality**
5. **Quality Awareness**
6. **Corrective Action**
7. **Zero Defects Planning**
8. **Employee Education**
9. **Zero Defects Day**
10. **Goal Setting**
11. **Error Cause Removal**
12. **Recognition**
13. **Quality Councils**
14. **Do It All Over Again**

Dr. W. Edwards Deming (1900 - 1993)

Dr. Deming obtained a B.S. from the University of Wyoming, and a M.S. from the University of Colorado and a Ph.D. in Physics from Yale. Dr. Deming was also considered the founder of the third wave of the industrial revolution.

Dr. Deming was an honorary member of ASQ. He was awarded the ASQ Shewhart Medal in 1955. During his life Dr. Deming published over 200 papers, articles, and books. Notable books include:

***Quality, Productivity, and Competitive Position* (1982)**
***Out of the Crisis* (Deming, 1986)[15]**

W. Edwards Deming was the one individual who stood for quality and for what it means. He is a national folk hero in Japan and was perhaps the leading speaker for the quality revolution in the world. He did summer work at the Hawthorne plant while working on his Ph.D. At the Hawthorne plant he became acquainted with W. Shewhart and studied Shewhart's statistical methods.

The World War II effort enabled Deming to teach classes in statistical methods to thousands of American engineers, foremen, and workers. The statistical methods were later credited to be a major factor in the war effort. But, as he would state it, after the war, all traces of statistical methods were gone in a puff of smoke.

There were several visits to Japan between 1946 and 1948 for the purpose of census taking. He developed a fondness for the Japanese people during that time. JUSE invited Deming back in 1950 for executive courses in statistical methods. He refused royalties on his seminar materials and insisted that the proceeds be used to help the Japanese people. JUSE named their ultimate quality prize after him.

Deming would return to Japan on many other occasions to teach and consult. He was well known in Japan, but not so in America. Only when NBC published its white paper, "If Japan can, why can't we?" did America discover him. An overnight success at age 80, W.E. Deming died at the age of 93. During his last 13 years, Deming gave American industry a dose of strong medicine in quality. His message to America is listed in his famous 14 points and 7 deadly diseases.

Dr. W. Edwards Deming (Continued)

The Fourteen Obligations of Top Management:

1. Create constancy of purpose for improvement of products and service
2. Adopt a new philosophy; we are in a new economic age
3. Cease dependence upon inspection as a way to achieve quality
4. End the practice of awarding business based on price tag
5. Constantly improve the process of planning, production, and service - this system includes people
6. Institute training on the job
7. Institute improved supervision (leadership)
8. Drive out fear
9. Break down barriers between departments
10. Eliminate slogans/targets asking for increased productivity without providing methods
11. Eliminate numerical quotas
12. Remove barriers that stand between workers and their pride of workmanship; the same for all salaried people
13. Institute programs for education and retraining
14. Put all emphasis in the company to work to accomplish the transformation

Seven Deadly Diseases That Management Must Cure:

1. Lack of constancy of purpose to plan a marketable product and service to keep the company in business and provide jobs

2. Emphasis on short-term profits

3. Personal evaluation appraisal, by whatever name, for people in management, the effects of which are devastating

4. Mobility of management; job hopping

5. Use of visible figures for management, with little or no consideration of figures that are unknown or unknowable

6. Excessive medical costs

7. Excessive costs of warranty, fueled by lawyers that work on contingency fees

Among other educational techniques, Deming promoted the parable of the red beads, the PDSA cycle, and the concept of 94% management (system) causes versus 6% special causes. (Deming, 1986)[15]

Dr. W. Edwards Deming (Continued)

Deming's philosophy focused on individuals as fellow members of a system, and treated people as partners, customers, neighbors, and friends. While the Deming philosophy benefits the individuals in a firm, the company itself should be able to reap the benefits from this new philosophy. Among the economic benefits to be gained are:

- **Reduction of the economic burden**
- **Expansion of markets**
- **Survival of organizations that serve customers**

Deming's Chain Reaction

Deming shared the following chain reaction with Japan in the summer of 1950:

Improve quality ➜ Decrease costs (less rework, fewer delays) ➜ Productivity improves ➜ Capture the market with better quality and price ➜ Stay in business ➜ Provide jobs.

Deming's chain reaction is summarized by Delavigne and Robertson (1994)[16] as the following series of events:

1. **The quality and productivity rise**
2. **Costs decrease**
3. **The time required for development and production is reduced**
4. **Management begins to know their cost, "they have a system"**
5. **Increased division of labor and specialization occurs**
6. **The near-term future is more predictable**
7. **The standard of living rises**
8. **The system has a future and can provide "jobs and more jobs"**

As the above sequence is occurring, the marketplace is responding to the firm:

- **The customer obtains reduced prices**
- **There is increased cooperation**
- **New products and services are provided to the customers**
- **There are higher levels of customer satisfaction**
- **There is a reduction of competition for share of the market**

Thus, a "chain reaction" of good things can occur through the Deming philosophy.

Dr. Armand V. Feigenbaum (1920 -)

Dr. Feigenbaum is currently President of General Systems Company, Pittsfield, MA. He was associated with General Electric for 26 years in engineering. Dr. Feigenbaum holds a B.S. from Union College and an M.S. and Ph.D. from MIT.

Some of Dr. Feigenbaum's many distinctions include:

Honorary Member, ASQ, 1986
E. Jack Lancaster Award, ASQ, 1981
Edwards Medal, ASQ, 1965
Fellow, American Association for the Advancement of Science
Life Member, IEEE and ASME
2-time President of ASQ 1961/63
Founding Chairman, International Academy for Quality

A few of Dr. Feigenbaum's many books:

***Quality Control: Principles, Practice* (1951)**
***Total Quality Control- Engineering and Management* (1961)**
***Total Quality Control*, 3rd ed (1983)**
***Total Quality Control, 40th Anniversary Edition* (Feigenbaum, 1991)[20]**

Mr. Feigenbaum is generally given credit for establishing the concept of "total quality control" in the late 1940s while he was at General Electric. His TQC statement was first published in 1961, but, at that time, the concept was so new no one listened.

A.V. Feigenbaum eventually formed his own consulting company in 1968 to provide services in quality management and strategic planning to worldwide clients. Feigenbaum states that the American industry must strive to become as strong as it can be in its own marketplace. This has become valuable as global competitiveness has spread into the U.S. Being strong at home via proper design, production, selling and servicing will provide the potential for supremacy in the marketplace.

Dr. Armand V. Feigenbaum (Continued)

The TQC philosophy maintains that all areas of the company must be involved in the quality effort. The quality effort has generally only affected the shop floor people, but must extend to all sections of the company. Products must not only be made quicker and faster, but also sold faster. Feigenbaum noted that the quality professional has an opportunity to become more than a functional specialist. The opportunity is there to become a true businessman by providing valuable information and direction.

The success of TQC includes these principles:

- **TQC is a company wide process, all functions are involved**
- **Quality is what the customer says it is**
- **Quality and production costs are in partnership**
- **Higher quality will equate to lower costs**
- **Both individual and team zeal are required**
- **Management must provide a continuous and relentless emphasis on quality**
- **Quality and innovation can work together in product development**
- **All of management must be involved in quality, not just the specialists**
- **Requires the use of new and existing technologies**
- **Quality is the most cost-effective route to productivity**
- **Quality must be implemented with both customers and suppliers**

Certain quality phrases of A.V. Feigenbaum:

"Quality does not travel under an exclusive foreign passport."

"Quality and costs are partners, not adversaries."

Failure driven companies... "If it breaks, we'll service it." versus the quality excellence approach... "No defects, no problems, we are essentially moving toward perfect work processes."

"Quality is everybody's job, but because it is everybody's job, it can become nobody's job without the proper leadership and organization."

Dr. Kaoru Ishikawa (1915 - 1989)

Dr. Ishikawa held a B.S. in Chemistry and Doctorate in Engineering from the University of Tokyo. In 1993, ASQ established the Ishikawa Award to recognize outstanding contributions to the improvement of the human aspects of quality.

Some of Dr. Ishikawa's many awards include:

Deming Prize (1952)
Nihon Keizai Press Prize
Industrial Standardization Prize
Grant Award (ASQ)
Shewhart Medal (ASQ), first Japanese to receive this award
Honorary Member, ASQ (1986)

A few notable books include:

Authored the first Japanese book to define the word "TQC" in 1981
***Guide to Quality Control* (1982)[34]**
***What is Total Quality Control? The Japanese Way* (Ishikawa, 1985)[35]**

Kaoru Ishikawa was involved with the quality movement in its earliest beginnings and remained so until his death in 1989. His father, Ichiro Ishikawa, President of the Federation of Economic Organizations and of JUSE, invited Deming to speak before top Japanese executives in 1950. A review of Ishikawa's training tapes, produced in 1981, contain many of the statements of quality that are in vogue today. Subjects such as total quality control, next operation as customer, training of workers, empowerment, customer satisfaction, elimination of sectionalism (it's not our job), and humanistic management of workers, are examples. It is amazing to hear such statements of quality on record from almost three decades ago.

Ishikawa stated that total quality control had been practiced in Japan since 1958. The time for such a philosophy to take hold in a company can range from 2-5 years. That time will depend on the commitment of top management. To reduce confusion between Japanese-style total quality control and western-style total quality control, he called the Japanese method the companywide quality control (CWQC).

Dr. Kaoru Ishikawa (Continued)

CWQC involves the participation of workers from the top to the bottom of an organization and from the start to the finish of the product life cycle. CWQC requires a management philosophy that has respect for humanity. There must be acknowledgment that the worker can contribute to the success of the company through suggestions, creativity, and worthwhile ideas.

One of the first concepts that western management took back to their own shores was the quality circle. The quality circle concept represents the bottom up approach. In Japan in 1988, there were one million quality circles, involving ten million people. Quality circles were originally study groups that workers formed in their department to study the quality concepts that were published in "Quality Control for Foreman" (Ishikawa was the editor). Quality circles involve members from within a department. The circle solves problems on a continuous basis. Circle membership changes dependent upon the task or project under consideration.

Ishikawa also wrote that he originated the concept "next operation as customer" in 1950 when he was working with a steel mill. Operators concerned about their own defects were considered spies whenever they traveled to the next department to view their original work. Departments were defensive when outsiders made tours, thus, a concept of "next operation as customer" was developed to remove those fears. The separation of departments was referred to as sectionalism.

A man with many thoughtful concepts, Kaoru Ishikawa was known for his lifelong efforts as the father of Japanese quality control efforts. The fishbone diagram is also called the Ishikawa diagram in his honor.

