

Reliability and Quality Control

ESE 405 / 505

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Chapter 1. Quality Improvement in the Modern Business Environment

Eight Dimensions of Quality

1. Performance
2. Reliability
3. Durability
4. Serviceability
5. Aesthetics
6. Features
7. Perceived Quality
8. Conformance to Standards

- Quality: traditionally, fitness for use
 - Quality of design
 - Quality of conformance
 - Inversely proportional to variability (modern concept)
- Quality Improvement: Reduction of variability in processes and products (or elimination of waste)

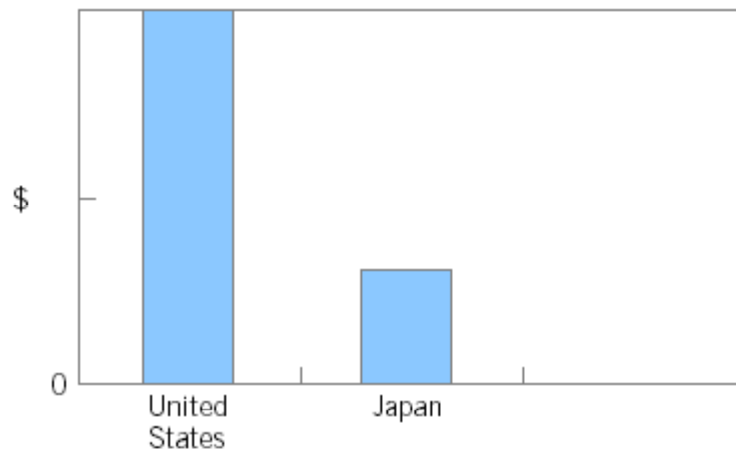


Figure 1-1 Warranty costs for transmissions.

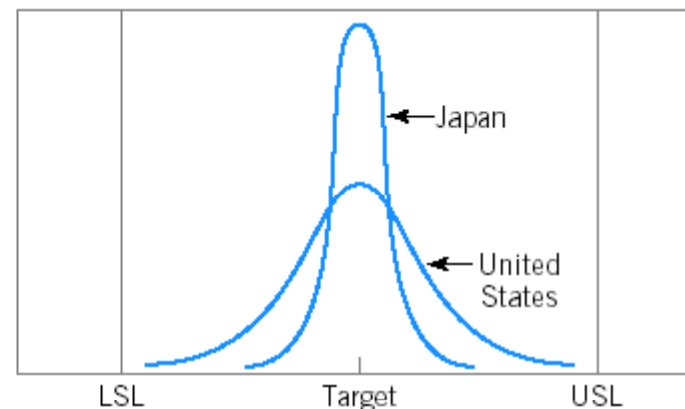


Figure 1-2 Distributions of critical dimensions for transmissions.

Critical-to-Quality Characteristics (CTQ)

- Physical: length, weight, voltage, viscosity
- Sensory: taste, appearance, color
- Time Orientation: reliability, durability, serviceability

- Specifications
 - Lower specification limit
 - Upper specification limit
 - Target or nominal values
- Defect versus nonconformity: Products not meeting the specification limits are not necessarily defective

History of Quality Improvement

Table 1-1 A Timeline of Quality Methods

1700–1900	Quality is largely determined by the efforts of an individual craftsman. Eli Whitney introduces standardized, interchangeable parts to simplify assembly.
1875	Frederick W. Taylor introduces “Scientific Management” principles to divide work into smaller, more easily accomplished units—the first approach to dealing with more complex products and processes. The focus was on productivity. Later contributors were Henry Gilbreth and Frank Gantt.
1900–1930	Henry Ford—the assembly line—further refinement of work methods to improve productivity and quality; Ford developed mistake-proof assembly concepts, self-checking, and inprocess inspection.
1901	First standards laboratories established in Great Britain.
1907–1908	AT&T begins systematic inspection and testing of products and materials.
1908	W.S. Gosset (writing as “Student”) introduces the <i>t</i> -distribution—results from his work on quality control at Guinness Brewery.
1915–1919	WWI—British government begins a supplier certification program.
1919	Technical Inspection Association is formed in England; this later becomes the Institute of Quality Assurance.
1920s	AT&T Bell Laboratories forms a quality department—emphasizing quality, inspection and test, and product reliability. B. P. Dudding at General Electric in England uses statistical methods to control the quality of electric lamps.
1922–1923	R.A. Fisher publishes series of fundamental papers on designed experiments and their application to the agricultural sciences.
1924	W.A. Shewhart introduces the control chart concept in a Bell Laboratories technical memorandum.
1928	Acceptance sampling methodology is developed and refined by H. F. Dodge and H. G. Romig at Bell Labs.
1931	W.A. Shewhart publishes <i>Economic Control of Quality of Manufactured Product</i> —outlining statistical methods for use in production and control chart methods.
1932	W.A. Shewhart gives lectures on statistical methods in production and control charts at the University of London.
1932–1933	British textile and woolen industry and German chemical industry begin use of designed experiments for product/process development.
1933	The Royal Statistical Society forms the Industrial and Agricultural Research Section.

- 1938 W.E. Deming invites Shewhart to present seminars on control charts at the U.S. Department of Agriculture Graduate School.
- 1940 The U.S. War Department publishes a guide for using control charts to analyze process data.
- 1940–1943 Bell Labs develop the forerunners of the military standard sampling plans for the U.S. Army.
- 1942 In Great Britain, the Ministry of Supply Advising Service on Statistical Methods and Quality Control is formed.
- 1942–1946 Training courses on statistical quality control are given to industry; more than 15 quality societies are formed in North America.
- 1944 *Industrial Quality Control* begins publication.
- 1946 The American Society for Quality Control (ASQC) is formed as the merger of various quality societies. The International standards organization (ISO) is founded. Deming is invited to Japan by the Economic and Scientific Services Section of the U.S. War Department to help occupation forces in rebuilding Japanese industry. The Japanese Union of Scientists and Engineers (JUSE) is formed.
- 1946–1949 Deming is invited to give statistical quality control seminars to Japanese industry.
- 1948 G. Taguchi begins study and application of experimental design.
- 1950 Deming begins education of Japanese industrial managers; statistical quality control methods begin to be widely taught in Japan. K. Ishikawa introduces the cause-and-effect diagram.
- 1950s Classic texts on statistical quality control by Eugene Grant and A. J. Duncan appear.

- 1951 A. V. Feigenbaum publishes the first edition of his book, *Total Quality Control*. JUSE establishes the “Deming Prize” for significant achievement in quality control and quality methodology.
- 1951+ G. E. P. Box and K. B. Wilson publish fundamental work on using designed experiments and response surface methodology for process optimization; focus is on chemical industry. Applications of designed experiments in the chemical industry grow steadily after this.
- 1954 Joseph M. Juran is invited by the Japanese to lecture on quality management and improvement. British statistician E. S. Page introduces the cumulative sum (CUSUM) control chart.
- 1957 J. M. Juran and F. M. Gryna’s *Quality Control Handbook* is first published.
- 1959 *Technometrics* (a journal of statistics for the physical, chemical, and engineering sciences) is established; J. Stuart Hunter is the founding editor. S. Roberts introduces the exponentially weighted moving average (EWMA) control chart. The U.S. manned spaceflight program makes industry aware of the need for reliable products; the field of reliability engineering grows from this starting point.
- 1960 G. E. P. Box and J. S. Hunter write fundamental papers on 2^{k-P} factorial designs. The quality control circle concept is introduced in Japan by K. Ishikawa.
- 1961 National Council for Quality and Productivity is formed in Great Britain as part of the British Productivity Council.
- 1960s Courses in statistical quality control become widespread in Industrial Engineering academic programs. Zero defects (ZD) programs are introduced in certain U.S. industries.
- 1969 *Industrial Quality Control* ceases publication, replaced by *Quality Progress* and the *Journal of Quality Technology* (Lloyd S. Nelson is the founding editor of *JQT*).
- 1970s In Great Britain the NCQP and the Institute of Quality Assurance merge to form the British Quality Association.
- 1975–1978 Books on designed experiments oriented toward engineers and scientists begin to appear. Interest in quality circles begins in North America—this grows into the total quality management (TQM) movement.

- 1980s Experimental design methods are introduced to and adopted by a wider group of organizations, including electronics, aerospace, semiconductor, and the automotive industries.
The works of Taguchi on designed experiments first appear in the United States.
- 1984 The American Statistical Association (ASA) establishes the Ad Hoc Committee on Quality and Productivity; this later becomes a full Section of the ASA.
The journal *Quality and Reliability Engineering International* appears.
- 1986 Box and others visit Japan, noting the extensive use of designed experiments and other statistical methods.
- 1987 ISO publishes the first quality systems standard.
- 1988 The Malcolm Baldrige National Quality Award is established by the U.S. Congress.
The European Foundation for Quality Management is founded; this organization administers the European Quality Award.
- 1989 The journal *Quality Engineering* appears.
Motorola's six-sigma initiative begins.
- 1990s ISO 9000 certification activities increase in U.S. industry; applicants for the Baldrige award grow steadily; many states sponsor quality awards based on the Baldrige criteria.
- 1995 Many undergraduate engineering programs require formal courses in statistical techniques, focusing on basic methods for process characterization and improvement.
- 1997 Motorola's six-sigma approach spreads to other industries.
- 1998 The American Society for Quality Control becomes the American Society for Quality (see www.asq.org), attempting to indicate the broader aspects of the quality improvement field.
- 2000s ISO 9000:2000 standard is issued. Supply-chain management and supplier quality become even more critical factors in business success. Quality improvement activities expand beyond the traditional industrial setting into many other areas including financial services, health care, insurance, and utilities.

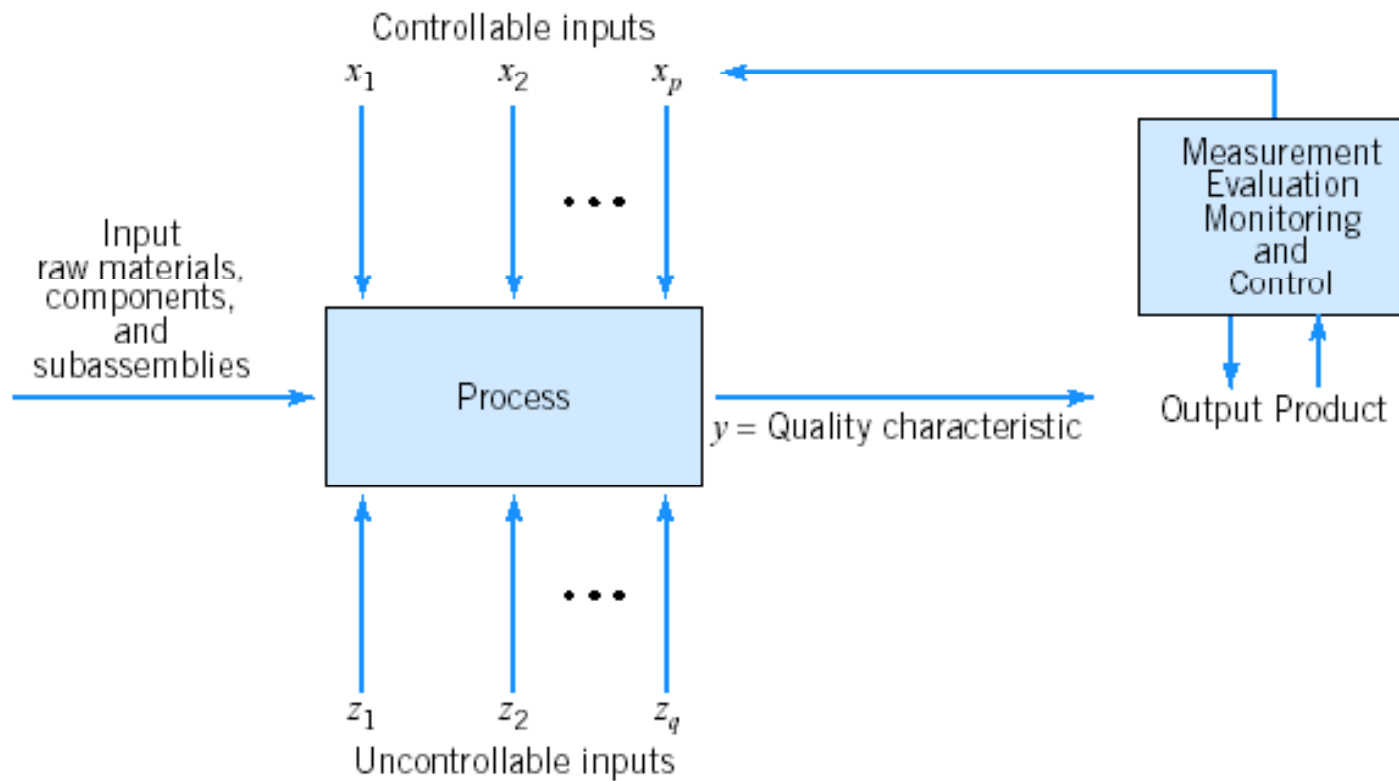


Figure 1-3 Production process inputs and outputs.

Statistical Methods

- Statistical process control (SPC)
 - Control charts, plus other problem-solving tools
 - Useful in monitoring processes, reducing variability through elimination of assignable causes
 - On-line technique
- Designed experiments (DOX)
 - Discovering the key factors that influence process performance
 - Process optimization
 - Off-line technique
- Acceptance Sampling

Walter A. Shewart (1891-1967)

- Trained in engineering and physics
- Long career at Bell Labs
- Developed the first control chart about 1924

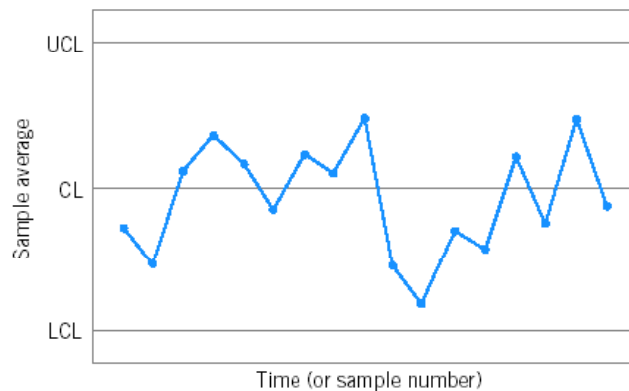
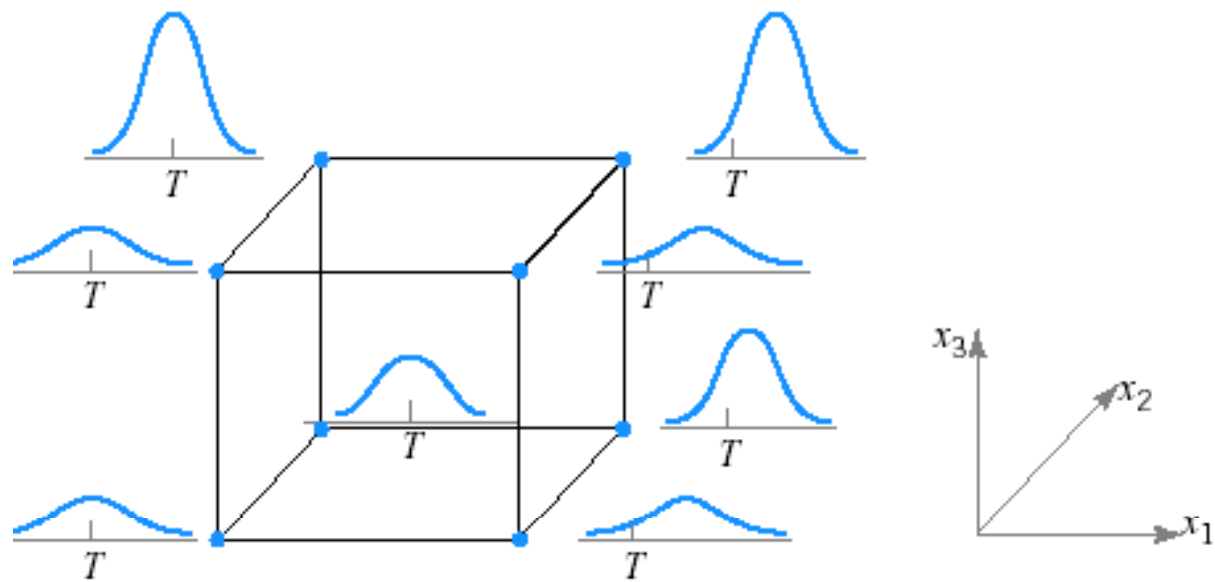


Figure 1-4 A typical control chart.





A factorial experiment with three factors

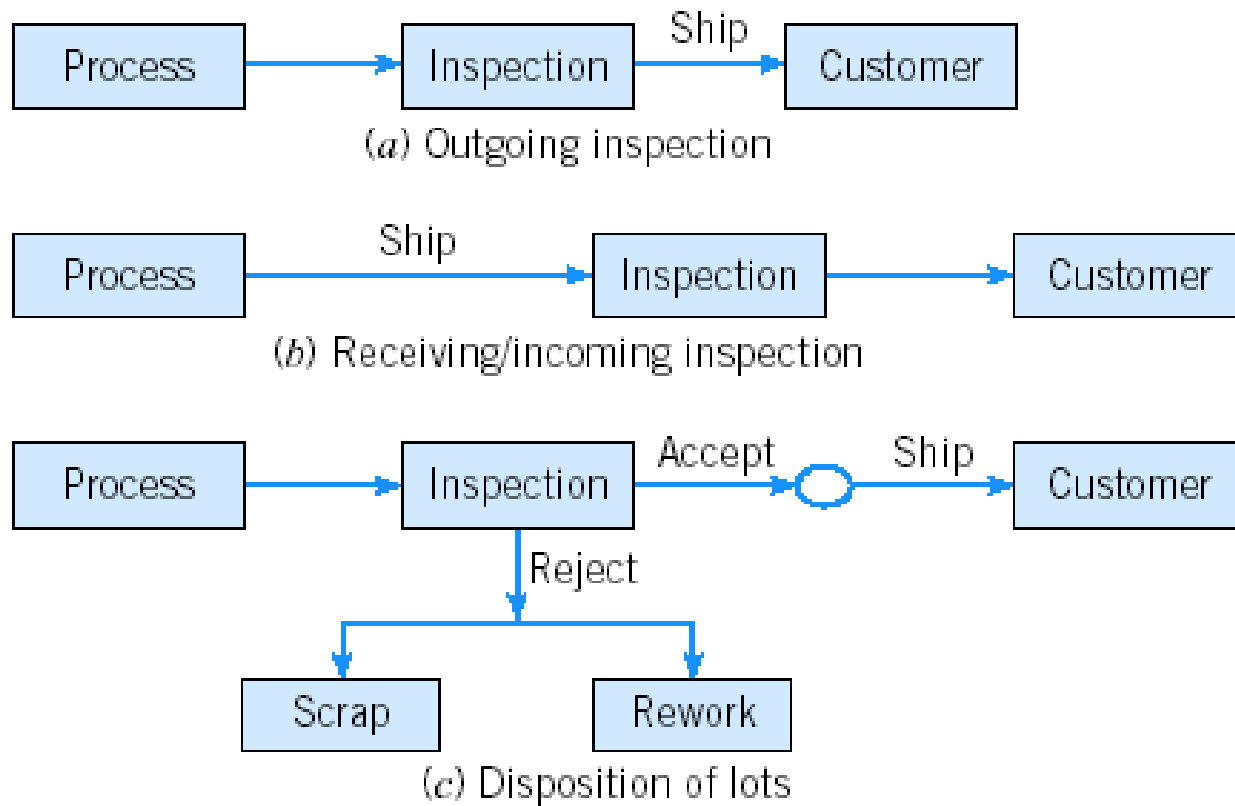


Figure 1-6 Variations of acceptance sampling.

Effective management of quality requires the execution of three activities:

1. Quality Planning
2. Quality Assurance
3. Quality Control and Improvement

Quality Philosophies and Management Strategies

W. Edwards Deming

- Taught engineering, physics in the 1920s, finished PhD in 1928
- Met Walter Shewhart at Western Electric
- Long career in government statistics, USDA, Bureau of the Census
- During WWII, he worked with US defense contractors, deploying statistical methods
- Sent to Japan after WWII to work on the census



Deming

- Deming was asked by JUSE to lecture on statistical quality control to management
- Japanese adopted many aspects of Deming's management philosophy
- Deming stressed “continual never-ending improvement”
- Deming lectured widely in North America during the 1980s; he died 24 December 1993

Deming's 14 Points

1. Create constancy of purpose toward improvement
2. Adopt a new philosophy, recognize that we are in a time of change, a new economic age
3. Cease reliance on mass inspection to improve quality
4. End the practice of awarding business on the basis of price alone
5. Improve constantly and forever the system of production and service
6. Institute training
7. Improve leadership, recognize that the aim of supervision is help people and equipment to do a better job
8. Drive out fear
9. Break down barriers between departments

14 Points continued

10. Eliminate slogans and targets for the workforce such as zero defects
11. Eliminate work standards
12. Remove barriers that rob workers of the right to pride in the quality of their work
13. Institute a vigorous program of education and self-improvement
14. Put everyone to work to accomplish the transformation

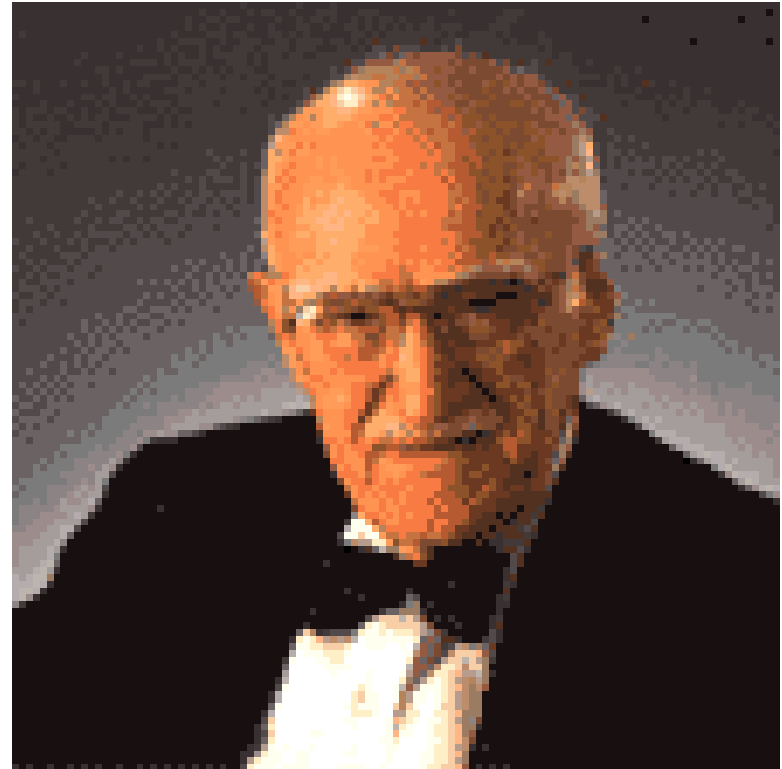
Note that the 14 points are about change

Deming's Deadly Diseases

1. Lack of constancy of purpose
2. Emphasis on short-term profits
3. Performance evaluation, merit rating, annual reviews
4. Mobility of management
5. Running a company on visible figures alone
6. Excessive medical costs for employee health care
7. Excessive costs of warranties

Joseph M. Juran

- Born in Romania (1904), immigrated to the US
- Worked at Western Electric, influenced by Walter Shewhart
- Emphasizes a more strategic and planning oriented approach to quality than does Deming
- Juran Institute is still an active organization promoting the Juran philosophy and quality improvement practices



The Juran Trilogy

1. Planning
 2. Control
 3. Improvement
- These three processes are interrelated
 - Control versus breakthrough
 - Project-by-project improvement

- Kaoru Ishikawa
 - Son of the founder of JUSE, promoted widespread use of basic tools
- Armand Feigenbaum
 - Author of Total Quality Control, promoted overall organizational involvement in quality
 - Three-step approach emphasized quality leadership, quality technology, and organizational commitment

Total Quality Management (TQM)

- Started in the early 1980s, Deming/Juran philosophy as the focal point
- Emphasis on widespread training, quality awareness
- Training often turned over to HR function
- Not enough emphasis on quality control and improvement tools, poor follow-through, no project-by-project implementation strategy
- TQM was largely unsuccessful

Quality Systems and Standards

International Standard Organization (ISO) in 1987

ISO 9000:2000 Quality Management System – Fundamentals and Vocabulary

ISO 9001:2000 Quality Management System – Requirements

ISO 9004:2000 Quality Management System – Guidelines for Performance
Improvement

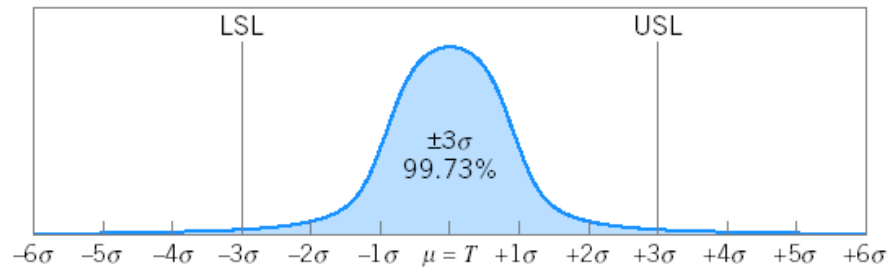
A company can be certified by selecting a registrar and receiving a certification audit. Once certified, the company also receives periodic surveillance audits.

Six Sigma

- Use of statistics & other analytical tools has grown steadily for over 80 years
 - Statistical quality control (origins in 1920, explosive growth during WW II, 1950s)
 - Operations research (1940s)
 - FDA, EPA in the 1970's
 - TQM (Total Quality Management) movement in the 1980's
 - Reengineering of business processes (late 1980's)
 - Six-Sigma (origins at Motorola in 1987, expanded impact during 1990s to present)

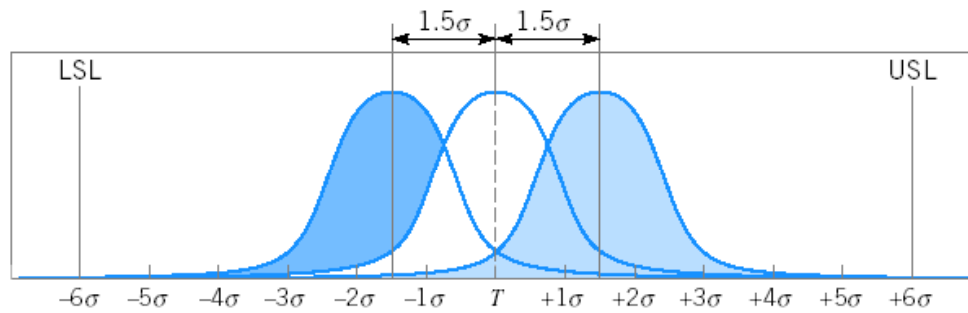
Focus of Six Sigma is on Process Improvement with an Emphasis on Achieving Significant Business Impact

- A process is an organized sequence of activities that produces an output that adds value to the organization
- All work is performed in (interconnected) processes
 - Easy to see in some situations (manufacturing)
 - Harder in others
- Any process can be improved
- An organized approach to improvement is necessary
- The process focus is essential to Six Sigma



Spec. Limit	Percent Inside Specs	ppm Defective
± 1 Sigma	68.27	317300
± 2 Sigma	95.45	45500
± 3 Sigma	99.73	2700
± 4 Sigma	99.9937	63
± 5 Sigma	99.999943	0.57
± 6 Sigma	99.999998	0.002

(a) Normal distribution centered at the target (T)



Spec. Limit	Percent inside specs	ppm Defective
± 1 Sigma	30.23	697700
± 2 Sigma	69.13	608700
± 3 Sigma	93.32	66810
± 4 Sigma	99.3790	6210
± 5 Sigma	99.97670	233
± 6 Sigma	99.999660	3.4

(b) Normal distribution with the mean shifted by $\pm 1.5\sigma$ from the target

Figure 1-11 The Motorola six-sigma concept.

Why “Quality Improvement” is Important: A Simple Example

- A visit to a fast-food store: Hamburger (bun, meat, special sauce, cheese, pickle, onion, lettuce, tomato), fries, and drink.
- This product has 10 components - is 99% good okay?

$$P\{\text{Single meal good}\} = (0.99)^{10} = 0.9044$$

$$\text{Family of four, once a month: } P\{\text{All meals good}\} = (0.9044)^4 = 0.6690$$

$$P\{\text{All visits during the year good}\} = (0.6690)^{12} = 0.0080$$

$$P\{\text{single meal good}\} = (0.999)^{10} = 0.9900, P\{\text{Monthly visit good}\} = (0.99)^4 = 0.9607$$

$$P\{\text{All visits in the year good}\} = (0.9607)^{12} = 0.6186$$

Six Sigma Focus

- Initially in manufacturing
- Commercial applications
 - Banking
 - Finance
 - Public sector
 - Services
- DFSS – Design for Six Sigma
 - Only so much improvement can be wrung out of an existing system
 - New process design
 - New product design (engineering)

Some Commercial Applications

- Reducing average and variation of days outstanding on accounts receivable
- Managing costs of consultants (public accountants, lawyers)
- Skip tracing
- Credit scoring
- Closing the books (faster, less variation)
- Audit accuracy, account reconciliation
- Forecasting
- Inventory management
- Tax filing
- Payroll accuracy

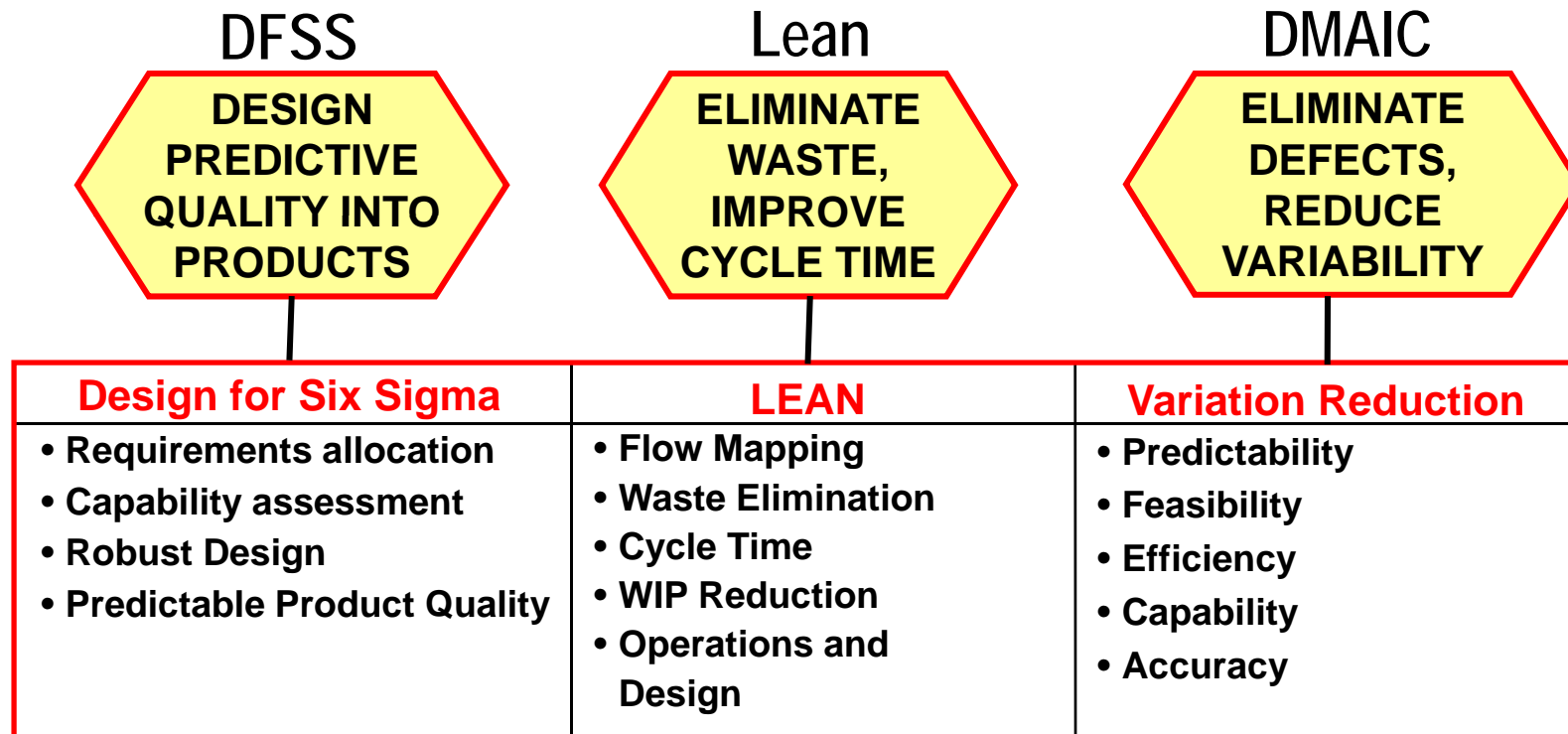
Six Sigma

- A disciplined and analytical approach to process and product improvement
- Specialized roles for people; Champions, Master Black belts, Black Belts, Green Belts
- Top-down driven (Champions from each business)
- BBs and MBBs have responsibility (project definition, leadership, training/mentoring, team facilitation)
- Involves a five-step process (DMAIC) :
 - Define
 - Measure
 - Analyze
 - Improve
 - Control

What Makes it Work?

- Successful implementations characterized by:
 - Committed leadership
 - Use of top talent
 - Supporting infrastructure
 - Formal project selection process
 - Formal project review process
 - Dedicated resources
 - Financial system integration
- Project-by-project improvement strategy (borrowed from Juran)

Process Improvement Triad



DFSS Matches Customer Needs with Capability

- Mean and variability affects product performance and cost
 - Designers can predict costs and yields in the design phase
- Consider mean and variability in the design phase
 - Establish top level mean, variability and failure rate targets for a design
 - Rationally allocate mean, variability, and failure rate targets to subsystem and component levels
 - Match requirements against process capability and identify gaps
 - Close gaps to optimize a producible design
 - Identify variability drivers and optimize designs or make designs robust to variability
- Process capability impact design decisions

Lean Focuses on Waste Elimination

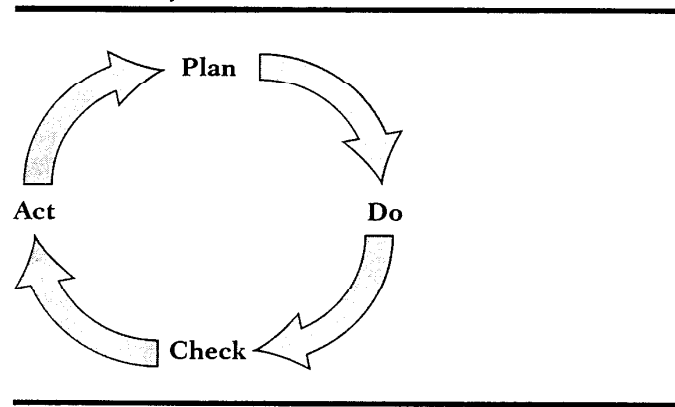
- Definition: A set of methods and tools used to eliminate waste in a process
- Lean helps identify anything not absolutely required to deliver a quality product on time.
- Benefits of using Lean
 - Lean methods help reduce inventory, lead time, and cost
 - Lean methods increase productivity, quality, on time delivery, capacity, and sales

DMAIC Solves Problems by Using Six Sigma Tools

- DMAIC is a problem solving methodology
- Use this method to solve problems:
 - Define problems in processes
 - Measure performance
 - Analyze causes of problems
 - Improve processes—remove variations and nonvalue-added activities
 - Control processes so problems do not recur

Six Sigma

- DMAIC is closely related to the Shewhart cycle



Quality Costs

Table 1-4 Quality Costs

Prevention Costs

- Quality planning and engineering
- New products review
- Product/process design
- Process control
- Burn-in
- Training
- Quality data acquisition and analysis

Appraisal Costs

- Inspection and test of incoming material
- Product inspection and test
- Materials and services consumed
- Maintaining accuracy of test equipment

Internal Failure Costs

- Scrap
- Rework
- Retest
- Failure analysis
- Downtime
- Yield losses
- Downgrading (off-specing)

External Failure Costs

- Complaint adjustment
- Returned product/material
- Warranty charges
- Liability costs
- Indirect costs

Legal Aspects of Quality

- Product liability exposure
- Concept of **strict liability**
 1. Responsibility of both manufacturer and seller/distributor
 2. Advertising must be supported by valid data

Implementing Quality Improvement

- A strategic management process, focused along the eight dimensions of quality

Table 1-6 The Eight Dimensions of Quality from Section 1-1.1

1. Performance	5. Aesthetics
2. Reliability	6. Features
3. Durability	7. Perceived quality
4. Serviceability	8. Conformance to standards

- Suppliers and supply chain management must be involved
- Must focus on all three components: Quality Planning, Quality Assurance, and Quality Control and Improvement