Six Sigma and Quality Management

MBA Student Text

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Quality Management

Quality control

Quality control, or **QC** for short, is a process by which entities review the quality of all factors involved in production. This approach places an emphasis on three aspects:

1. Elements such as controls, job management, defined and well managed processes,[1][2] performance and integrity criteria, and identification of records
2. Competence, such as knowledge, skills, experience, and qualifications
3. Soft elements, such as personnel integrity, confidence, organizational culture, motivation, team spirit, and quality relationships.

Controls include product inspection, where every product is examined visually, and often using a stereo microscope for fine detail before the product is sold into the external market. Inspectors will be provided with lists and descriptions of unacceptable product defects such as cracks or surface blemishes for example.

The quality of the outputs is at risk if any of these three aspects is deficient in any way.

Quality control emphasizes testing of products to uncover defects and reporting to management who make the decision to allow or deny product release, whereas quality assurance attempts to improve and stabilize production (and associated processes) to avoid, or at least minimize, issues which led to the defect(s) in the first place. For contract work, particularly work awarded by government agencies, quality control issues are among the top reasons for not renewing a contract.[3]

Maintenance check of electronic equipment on a U.S. Navy aircraft.
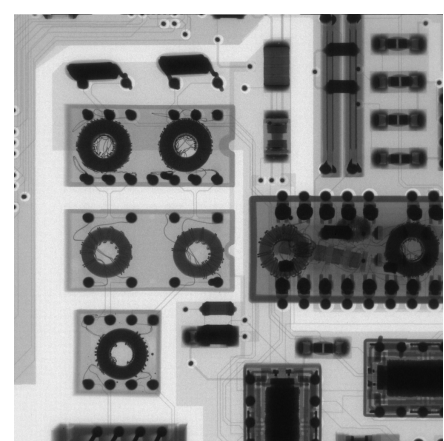
X-ray zoom series of a network adapter card.

Total quality control

"Total quality control", also called total quality management, is an approach that extends beyond ordinary statistical quality control techniques and quality improvement methods. It implies a complete overview and re-evaluation of the specification of a product, rather than just considering a more limited set of changeable features within an existing product. If the original specification does not reflect the correct quality requirements, quality cannot be inspected or manufactured into the product. For instance, the design of a pressure vessel should include not only the material and dimensions, but also operating, environmental, safety, reliability and maintainability requirements, and documentation of findings about these requirements.

Quality control in project management

In project management, quality control requires the project manager and the project team to inspect the accomplished work to ensure its alignment with the project scope.[4] In practice, projects typically have a dedicated quality control team which focuses on this area.

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Total quality management

Total quality management or **TQM** is an integrative philosophy of management for continuously improving the quality of products and processes.[1]

TQM functions on the premise that the quality of products and processes is the responsibility of everyone who is involved with the creation or consumption of the products or services offered by an organization. In other words, TQM capitalizes on the involvement of management, workforce, suppliers, and even customers, in order to meet or exceed customer expectations. Considering the practices of TQM as discussed in six empirical studies, Cua, McKone, and Schroeder (2001) identified the nine common TQM practices as cross-functional product design, process management, supplier quality management, customer involvement, information and feedback, committed leadership, strategic planning, cross-functional training, and employee involvement.[2]

TQM and Six Sigma

The TQM concept was developed by a number of American management consultants, including W. Edwards Deming, Joeseph Juran, and A.V. Feigenbaum.[3] Originally, these consultants won few converts in the United States. However, managers in Japan embraced their ideas enthusiastically and even named their premier annual prize for manufacturing excellence after Deming.

The Six Sigma management strategy originated in 1986 from Motorola's drive towards reducing defects by minimizing variation in processes.[4]

The main difference between TQM and Six Sigma (a newer concept) is the approach.[5] At its core, Total Quality Management (TQM) is a management approach to long-term success through customer satisfaction.

In a TQM effort, all members of an organization participate in improving processes, products, services and the culture in which they work.

The methods for implementing this approach come from people such as Philip B. Crosby, W. Edwards Deming, Armand V. Feigenbaum, Kaoru Ishikawa and Joseph M. Juran.

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Quality management system

A **quality management system** (QMS) can be expressed as the organizational structure, procedures, processes and resources needed to implement quality management. Early systems emphasized predictable outcomes of an industrial product production line, using simple statistics and random sampling. By the 20th century, labour inputs were typically the most costly inputs in most industrialized societies, so focus shifted to team cooperation and dynamics, especially the early signalling of problems via a continuous improvement cycle. In the 21st century, QMS has tended to converge with sustainability and transparency initiatives, as both investor and customer satisfaction and perceived quality is increasingly tied to these factors. Of all QMS regimes the ISO 9000 and ISO 14000 series are probably the most widely implemented worldwide - the ISO 19011 audit regime applies to both, and deals with quality and sustainability and their integration.

Other QMS, e.g. Natural Step, focus on sustainability issues and assume that other quality problems will be reduced as result of the systematic thinking, transparency, documentation and diagnostic discipline that sustainability focus implies. *See sustainability for more on this approach to quality management.*

Elements of a Quality Management System

1. Organizational structure
2. Responsibilities
3. Methods
4. Data Management
5. Processes - including purchasing
6. Resources - including natural resources and human capital
7. Customer Satisfaction
8. Continuous Improvement
9. Product Quality
10. Maintenance
11. Sustainability - including efficient resource use and responsible environmental operations
12. Transparency and independent audit

Concept of quality - historical background

The concept of quality as we think of it now first emerged out of the Industrial Revolution. Previously goods had been made from start to finish by the same person or team of people, with handcrafting and tweaking the product to meet 'quality criteria'. Mass production brought huge teams of people together to work on specific stages of production where one person would not necessarily complete a product from start to finish. In the late 19th century pioneers such as Frederick Winslow Taylor and Henry Ford recognized the limitations of the methods being used in mass production at the time and the subsequent varying quality of output. Birland established Quality Departments to oversee the quality of production and rectifying of errors, and Ford emphasized standardization of design and component standards to ensure a standard product was produced. Management of quality was the responsibility of the Quality department and was implemented by Inspection of product output to 'catch' defects.

Application of statistical control came later as a result of World War production methods, and were advanced by the work done of W. Edwards Deming, a statistician, after whom the Deming Prize for quality is named. Joseph M. Juran focused more on managing for quality. The first edition of Juran's Quality Control Handbook was published in 1951. He also developed the "Juran's trilogy," an approach to cross-functional management that is composed of three managerial processes: quality planning, quality control and quality improvement. These functions all play a vital role when evaluating quality.

Quality, as a profession and the managerial process associated with the quality function, was introduced during the second-half of the 20th century, and has evolved since then. Over this period, few other disciplines have seen as many changes as the quality profession.

The quality profession grew from simple control, to engineering, to systems engineering. Quality control activities were predominant in the 1940s, 1950s, and 1960s. The 1970s were an era of quality engineering and the 1990s saw quality systems as an emerging field. Like medicine, accounting, and engineering, quality has achieved status as a recognized profession

Quality system for medical devices

Quality System requirements for medical have been internationally recognized as a way to assure product safety and efficacy and customer satisfaction since at least 1983, and were instituted as requirements in a final rule published on October 7, 1996 [1]. The U.S. Food and Drug Administration (FDA) had documented design defects in medical devices that contributed to recalls from 1983 to 1989 that would have been prevented if Quality Systems had been in place. The rule is promulgated at 21 CFR 820 [2].

According to current Good Manufacturing Practice (GMP), medical device manufacturers have the responsibility to use good judgment when developing their quality system and apply those sections of the FDA Quality System (QS) Regulation that are applicable to their specific products and operations, in Part 820 [2] of the QS regulation. As with GMP, operating within this flexibility, it is the responsibility of each manufacturer to establish requirements for each type or family of devices that will result in devices that are safe and effective, and to establish methods and procedures to design, produce, and distribute devices that meet the quality system requirements.

The FDA has identified in the QS regulation the essential elements that a quality system shall embody for design, production and distribution, without prescribing specific ways to establish these elements. These elements include:

- personnel training and qualification;
- controlling the product design;
- controlling documentation;
- controlling purchasing;
- product identification and traceability at all stages of production;
- controlling and defining production and process;
- defining and controlling inspection, measuring and test equipment;
- validating processes;
- product acceptance;
- controlling nonconforming product;
- instituting corrective and preventive action when errors occur;
- labeling and packaging controls;

Quality System

- handling, storage, distribution and installation;
- records;
- servicing;
- statistical techniques;

all overseen by Management Responsibility and Quality Audits.

Because the QS regulation covers a broad spectrum of devices and production processes, it allows some leeway in the details of quality system elements. It is left to manufacturers to determine the necessity for, or extent of, some quality elements and to develop and implement procedures tailored to their particular processes and devices. For example, if it is impossible to mix up labels at a manufacturer because there is only one label to each product, then there is no necessity for the manufacturer to comply with all of the GMP requirements under device labeling.

Drug manufactures are regulated under a different section of the Code of Federal Regulations:

Quality management organizations and awards

The International Organization for Standardization's ISO 9001:2008 series describes standards for a QMS addressing the principles and processes surrounding the design, development and delivery of a general product or service. Organizations can participate in a continuing certification process to ISO 9001:2008 to demonstrate their compliance with the standard, which includes a requirement for continual (i.e. planned) improvement of the QMS.

(ISO 9000:2005 provides information the fundamentals and vocabulary used in quality management systems. ISO 9004:2009 provides guidance on quality management approach for the sustained success of an organization. Neither of these standards can be used for certification purposes as they provide guidance, not requirements).

The Baldrige Performance Excellence Program [3] educates organizations in performance excellence management and administers the Malcolm Baldrige National Quality Award. The Baldrige Award recognizes U.S. organizations for performance excellence based on the Baldrige Criteria for Performance Excellence [4]. The Criteria address critical aspects of management that contribute to performance excellence: leadership; strategic planning; customers; measurement, analysis, and knowledge management; the workforce; operations; and results.

The European Foundation for Quality Management's EFQM Excellence Model supports an award scheme similar to the Baldrige Award for European companies.

In Canada, the National Quality Institute [5] presents the 'Canada Awards for Excellence [6]' on an annual basis to organisations that have displayed outstanding performance in the areas of Quality and Workplace Wellness, and have met the Institute's criteria with documented overall achievements and results.

The Alliance for Performance Excellence [7] is a network of state and local organizations that use the Malcolm Baldrige National Quality Award Criteria at the grassroots level to improve the performance of local organizations and economies. browsers can find Alliance members in their state and get the latest news and events from the Baldrige community.

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External links

- Baldrige Performance Excellence Program Website [9]
- ICH Website [10]
- FDA Website [11]
- Code of Federal Regulations (CFR) Website [12]
- Health Canada Website [13]

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[4] http://www.nist.gov/baldrige/publications/criteria.cfm

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[13] http://www.hc-sc.gc.ca/index-eng.php

The Roots of Modern Quality Management

Walter A. Shewhart

Walter A. Shewhart	
Walter A. Shewhart	
Born	March 18, 1891 New Canton, Illinois
Died	March 11, 1967 (aged 75)
Fields	physics, engineering, statistics
Institutions	Western Electric
Alma mater	University of Illinois, University of California, Berkeley

Walter Andrew Shewhart (pronounced like "shoe-heart", March 18, 1891 - March 11, 1967) was an American physicist, engineer and statistician, sometimes known as the *father of statistical quality control* and also related to the Shewhart cycle.

W. Edwards Deming said of him:

> *As a statistician, he was, like so many of the rest of us, self-taught, on a good background of physics and mathematics.*

Early life and education

Born in New Canton, Illinois to Anton and Esta Barney Shewhart, he attended the University of Illinois before being awarded his doctorate in physics from the University of California, Berkeley in 1917.

Work on industrial quality

Bell Telephone's engineers had been working to improve the reliability of their transmission systems. Because amplifiers and other equipment had to be buried underground, there was a business need to reduce the frequency of failures and repairs. When Dr. Shewhart joined the Western Electric Company Inspection Engineering Department at the Hawthorne Works in 1918, industrial quality was limited to inspecting finished products and removing defective items. That all changed on May 16, 1924. Dr. Shewhart's boss, George D. Edwards, recalled: "Dr. Shewhart prepared a little memorandum only about a page in length. About a third of that page was given over to a simple diagram which we would all recognize today as a schematic control chart. That diagram, and the short text which preceded and followed it, set forth all of the essential principles and considerations which are involved in what we know today as process quality control."[1] Shewhart's work pointed out the importance of reducing variation in a manufacturing process and the understanding that continual process-adjustment in reaction to non-conformance actually increased variation and degraded quality.

Shewhart framed the problem in terms of assignable-cause and chance-cause variation and introduced the control chart as a tool for distinguishing between the two. Shewhart stressed that bringing a production process into a state of statistical control, where there is only chance-cause variation, and keeping it in control, is necessary to predict future output and to manage a process economically. Dr. Shewhart created the basis for the control chart and the concept of a state of statistical control by carefully designed experiments. While Dr. Shewhart drew from pure

mathematical statistical theories, he understood data from physical processes never produce a "normal distribution curve" (a Gaussian distribution, also commonly referred to as a "bell curve"). He discovered that observed variation in manufacturing data did not always behave the same way as data in nature (Brownian motion of particles). Dr. Shewhart concluded that while every process displays variation, some processes display controlled variation that is natural to the process, while others display uncontrolled variation that is not present in the process causal system at all times.[2]

Shewhart worked to advance the thinking at Bell Telephone Laboratories from their foundation in 1925 until his retirement in 1956, publishing a series of papers in the *Bell System Technical Journal*.

His work was summarized in his book *Economic Control of Quality of Manufactured Product* (1931).

Shewhart's charts were adopted by the American Society for Testing and Materials (ASTM) in 1933 and advocated to improve production during World War II in American War Standards Z1.1-1941, Z1.2-1941 and Z1.3-1942.

Later work

From the late 1930s onwards, Shewhart's interests expanded out from industrial quality to wider concerns in science and statistical inference. The title of his second book *Statistical Method from the Viewpoint of Quality Control* (1939) asks the audacious question: *What can statistical practice, and science in general, learn from the experience of industrial quality control?*

Shewhart's approach to statistics was radically different from that of many of his contemporaries. He possessed a strong operationalist outlook, largely absorbed from the writings of pragmatist philosopher C. I. Lewis, and this influenced his statistical practice. In particular, he had read Lewis's *Mind and the World Order* many times. Though he lectured in England in 1932 under the sponsorship of Karl Pearson (another committed operationalist) his ideas attracted little enthusiasm within the English statistical tradition. The British Standards nominally based on his work, in fact, diverge on serious philosophical and methodological issues from his practice.

His more conventional work led him to formulate the statistical idea of tolerance intervals and to propose his data presentation rules, which are listed below:

1. Data have no meaning apart from their context.
2. Data contain both signal and noise. To be able to extract information, one must separate the signal from the noise within the data.

Walter Shewhart visited India in 1947-48 under the sponsorship of P. C. Mahalanobis of the Indian Statistical Institute. Shewhart toured the country, held conferences and stimulated interest in statistical quality control among Indian industrialists.[3]

He died at Troy Hills, New Jersey in 1967.

Influence

In 1938 his work came to the attention of physicists W. Edwards Deming and Raymond T. Birge. The two had been deeply intrigued by the issue of measurement error in science and had published a landmark paper in *Reviews of Modern Physics* in 1934. On reading of Shewhart's insights, they wrote to the journal to wholly recast their approach in the terms that Shewhart advocated.

The encounter began a long collaboration between Shewhart and Deming that involved work on productivity during World War II and Deming's championing of Shewhart's ideas in Japan from 1950 onwards. Deming developed some of Shewhart's methodological proposals around scientific inference and named his synthesis the Shewhart cycle.

Achievements and honours

In his obituary for the American Statistical Association, Deming wrote of Shewhart:

> *As a man, he was gentle, genteel, never ruffled, never off his dignity. He knew disappointment and frustration, through failure of many writers in mathematical statistics to understand his point of view.*

He was founding editor of the *Wiley Series in Mathematical Statistics*, a role that he maintained for twenty years, always championing freedom of speech and confident to publish views at variance with his own.

His honours included:

- Founding member, fellow and president of the Institute of Mathematical Statistics;
- Founding member, first honorary member and first Shewhart Medalist of the American Society for Quality;
- Fellow and President of the American Statistical Association;
- Fellow of the International Statistical Institute;
- Honorary fellow of the Royal Statistical Society;
- Holley medal of the American Society of Mechanical Engineers;
- Honorary Doctor of Science, Indian Statistical Institute, Calcutta.

Notes

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External links

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W. Edwards Deming

W. Edwards Deming	
Born	October 14, 1900 Sioux City, Iowa
Died	December 20, 1993 (aged 93) Washington DC
Fields	Statistician
Alma mater	University of Wyoming BSc, University of Colorado MS, Yale PhD
Influences	Walter A. Shewhart

William Edwards Deming (October 14, 1900 − December 20, 1993) was an American statistician, professor, author, lecturer and consultant. He is perhaps best known for his work in Japan. There, from 1950 onward, he taught top management how to improve design (and thus service), product quality, testing, and sales (the last through global markets)[1] through various methods, including the application of statistical methods.

Deming made a significant contribution to Japan's later reputation for innovative high-quality products and its economic power. He is regarded as having had more impact upon Japanese manufacturing and business than any other individual not of Japanese heritage. Despite being considered something of a hero in Japan, he was only just beginning to win widespread recognition in the U.S. at the time of his death.[2] President Reagan awarded the National Medal of Technology to Deming in 1987. He received in 1988 the Distinguished Career in Science award from the National Academy of Sciences.

Overview

Deming's teachings and philosophy are best illustrated by examining the results they produced after they were adopted by Japanese industry, as the following example shows: Ford Motor Company was simultaneously manufacturing a car model with transmissions made in Japan and the United States. Soon after the car model was on the market, Ford customers were requesting the model with Japanese transmission over the US-made transmission, and they were willing to wait for the Japanese model. As both transmissions were made to the same specifications, Ford engineers could not understand the customer preference for the model with Japanese transmission. Finally, Ford engineers decided to take apart the two different transmissions. The American-made car parts were all within specified tolerance levels. On the other hand, the Japanese car parts were virtually identical to each other, and much closer to the nominal values for the parts - e.g., if a part was supposed to be one foot long, plus or minus 1/8 of an inch - then the Japanese parts were all within 1/16 of an inch. This made the Japanese cars run more smoothly and customers experienced fewer problems. Engineers at Ford could not understand how this was done until they met Deming.[3]

Deming received a BSc in electrical engineering from the University of Wyoming at Laramie (1921), an M.S. from the University of Colorado (1925), and a Ph.D. from Yale University (1928). Both graduate degrees were in mathematics and physics. Deming had an internship at Bell Telephone Laboratories while studying at Yale. He later worked at the U.S. Department of Agriculture and the Census Department. While working under Gen. Douglas MacArthur as a census consultant to the Japanese government, he famously taught statistical process control methods to Japanese business leaders, returning to Japan for many years to consult and witness the economic growth he had predicted would come as a result of the application of techniques learned from Walter Shewhart at Bell Laboratories. Later, he became a professor at New York University while engaged as an independent consultant in Washington, D.C.

Deming was the author of *Out of the Crisis* (1982−1986) and *The New Economics for Industry, Government, Education* (1993), which includes his System of Profound Knowledge and the 14 Points for Management (described below). Deming played the flute and drums and composed music throughout his life, including sacred choral compositions and an arrangement of *The Star Spangled Banner*.[4]

In 1993, Deming founded the W. Edwards Deming Institute in Washington, D.C., where the Deming Collection at the U.S. Library of Congress includes an extensive audiotape and videotape archive. The aim of the W. Edwards Deming Institute is to foster understanding of the Deming System of Profound Knowledge to advance commerce, prosperity, and peace.[5]

Family

Born in Sioux City, Iowa, William Edwards Deming was raised in Polk City, Iowa on his grandfather Henry Coffin Edwards's chicken farm, then later on a 40-acre (**unknown operator: u'strong'** ha) farm purchased by his father in Powell, Wyoming. He was the son of William Albert Deming and Pluma Irene Edwards,[6] His parents were well educated and emphasized the importance of education to their children. Pluma had studied in San Francisco and was a musician. William Albert had studied mathematics and law.

He was a direct descendant of John Deming,[7] (1615−1705) an early Puritan settler and original patentee of the Connecticut Colony, and Honor Treat, the daughter of Richard Treat (1584−1669) an early New England settler, Deputy to the Connecticut Legislature and also a Patentee of the Royal Charter of Connecticut, 1662.

Deming married Agnes Bell in 1922, and together they survived the difficult college years. But in 1930, she died. Her death came a little more than a year after they had adopted a daughter, Dorothy. Deming made use of various private homes to help raise the infant, and following his marriage in 1932 to Lola Elizabeth Shupe, with whom he coauthored several papers, he brought her back home to stay. He and Lola had two more children, Diana and Linda. Diana and Linda survive, along with seven grandchildren and three great-grandchildren. Dorothy died in 1984 and Lola in 1986.[8]

Early life and work

In 1917, he enrolled in the University of Wyoming at Laramie, graduating in 1921 with a B.Sc. in electrical engineering. In 1925, he received an M.S. from the University of Colorado, and in 1928, a Ph.D. from Yale University. Both graduate degrees were in mathematics and mathematical physics. Deming worked as a mathematical physicist at the United States Department of Agriculture (1927−39), and was a statistical adviser for the United States Census Bureau (1939−45). He was a professor of statistics at New York University's graduate school of business administration (1946−1993), and he taught at Columbia University's graduate school of business (1988−1993). He also was a consultant for private business.

In 1927, Deming was introduced to Walter A. Shewhart of the Bell Telephone Laboratories by C.H. Kunsman of the United States Department of Agriculture (USDA). Deming found great inspiration in the work of Shewhart, the originator of the concepts of statistical control of processes and the related technical tool of the control chart, as Deming began to move toward the application of statistical methods to industrial production and management. Shewhart's idea of common and special causes of variation led directly to Deming's theory of management. Deming saw that these ideas could be applied not only to manufacturing processes, but also to the processes by which enterprises are led and managed. This key insight made possible his enormous influence on the economics of the industrialized world after 1950.[9]

In 1936, he studied under Sir Ronald Aylmer Fisher and Jerzy Neyman at University College, London, England.

Deming edited a series of lectures delivered by Shewhart at USDA, *Statistical Method from the Viewpoint of Quality Control*, into a book published in 1939. One reason he learned so much from Shewhart, Deming remarked in a videotaped interview, was that, while brilliant, Shewhart had an "uncanny ability to make things difficult." Deming

thus spent a great deal of time both copying Shewhart's ideas and devising ways to present them with his own twist.[10]

Deming developed the sampling techniques that were used for the first time during the 1940 U.S. Census, formulating the Deming-Stephan algorithm for iterative proportional fitting in the process.[11] During World War II, Deming was a member of the five-man Emergency Technical Committee. He worked with H.F. Dodge, A.G. Ashcroft, Leslie E. Simon, R.E. Wareham, and John Gaillard in the compilation of the American War Standards (American Standards Association Z1.1-3 published in 1942)[12] and taught statistical process control (SPC) techniques to workers engaged in wartime production. Statistical methods were widely applied during World War II, but faded into disuse a few years later in the face of huge overseas demand for American mass-produced products.

Work in Japan

In 1947, Deming was involved in early planning for the 1951 Japanese Census. The Allied powers were occupying Japan, and he was asked by the United States Department of the Army to assist with the census. While in Japan, Deming's expertise in quality control techniques, combined with his involvement in Japanese society, led to his receiving an invitation from the Japanese Union of Scientists and Engineers (JUSE).[6]

JUSE members had studied Shewhart's techniques, and as part of Japan's reconstruction efforts, they sought an expert to teach statistical control. From June–August 1950, Deming trained hundreds of engineers, managers, and scholars in statistical process control (SPC) and concepts of quality. He also conducted at least one session for top management.(The list includes top Japanese industrialists the likes of Akio Morita, the cofounder of Sony Corp)[13] Deming's message to Japan's chief executives: improving quality will reduce expenses while increasing productivity and market share.[1] Perhaps the best known of these management lectures was delivered at the Mt. Hakone Conference Center in August 1950.

A number of Japanese manufacturers applied his techniques widely and experienced heretofore unheard-of levels of quality and productivity. The improved quality combined with the lowered cost created new international demand for Japanese products.

Deming declined to receive royalties from the transcripts of his 1950 lectures, so JUSE's board of directors established the Deming Prize (December 1950) to repay him for his friendship and kindness.[13] Within Japan, the Deming Prize continues to exert considerable influence on the disciplines of quality control and quality management.[14]

Honors

In 1960, the Prime Minister of Japan (Nobusuke Kishi), acting on behalf of Emperor Hirohito, awarded Deming Japan's Order of the Sacred Treasure, Second Class.[15] The citation on the medal recognizes Deming's contributions to Japan's industrial rebirth and its worldwide success. The first section of the meritorious service record describes his work in Japan:[13]

- 1947, Rice Statistics Mission member
- 1950, assistant to the Supreme Commander of the Allied Powers
- instructor in sample survey methods in government statistics

The second half of the record lists his service to private enterprise through the introduction of epochal ideas, such as quality control and market survey techniques.

Among his many honors, an exhibit memorializing Deming's contributions and his famous Red Bead Experiment is on display outside the board room of the American Society for Quality.[16]

Later work in the U.S.

David Salsburg wrote:

> "He was known for his kindness to and consideration for those he worked with, for his robust, if very subtle, humor, and for his interest in music. He sang in a choir, played drums and flute, and published several original pieces of sacred music."[17][18]

Later, from his home in Washington, D.C., Deming continued running his own consultancy business in the United States, largely unknown and unrecognized in his country of origin and work. In 1980, he was featured prominently in an NBC documentary titled *If Japan can... Why can't we?* about the increasing industrial competition the United States was facing from Japan. As a result of the broadcast, demand for his services increased dramatically, and Deming continued consulting for industry throughout the world until his death at the age of 93.

Ford Motor Company was one of the first American corporations to seek help from Deming. In 1981, Ford's sales were falling. Between 1979 and 1982, Ford had incurred $3 billion in losses. Ford's newly appointed Division Quality Manager, John A. Manoogian, was charged with recruiting Deming to help jump-start a quality movement at Ford.[19] Deming questioned the company's culture and the way its managers operated. To Ford's surprise, Deming talked not about quality but about management. He told Ford that management actions were responsible for 85% of all problems in developing better cars. In 1986, Ford came out with a profitable line of cars, the Taurus-Sable line. In a letter to *Autoweek Magazine*, Donald Petersen, then Ford Chairman, said, "We are moving toward building a quality culture at Ford and the many changes that have been taking place here have their roots directly in Deming's teachings."[20] By 1986, Ford had become the most profitable American auto company. For the first time since the 1920s, its earnings had exceeded those of arch rival General Motors (GM). Ford had come to lead the American automobile industry in improvements. Ford's following years' earnings confirmed that its success was not a fluke, for its earnings continued to exceed GM and Chrysler's.

In 1990, Marshall Industries (NYSE:MI, 1984–1999) CEO, Robert Rodin, trained with the then 90-year-old Deming and his colleague Nida Backaitus. Marshall Industries' dramatic transformation and growth from $400 million to $1.8 billion in sales was chronicled in Deming's last book "The New Economics", a Harvard Case Study, and "Free Perfect and Now".

In 1982, Deming, as author, had his book published by the MIT Center for Advanced Engineering as *Quality, Productivity, and Competitive Position*, which was renamed *Out of the Crisis* in 1986. Deming offers a theory of management based on his famous 14 Points for Management. Management's failure to plan for the future brings about loss of market, which brings about loss of jobs. Management must be judged not only by the quarterly dividend, but by innovative plans to stay in business, protect investment, ensure future dividends, and provide more jobs through improved products and services. "Long-term commitment to new learning and new philosophy is required of any management that seeks transformation. The timid and the fainthearted, and the people that expect quick results, are doomed to disappointment."

Over the course of his career, Deming received dozens of academic awards, including another, honorary, Ph.D. from Oregon State University. In 1987, he was awarded the National Medal of Technology: "For his forceful promotion of statistical methodology, for his contributions to sampling theory, and for his advocacy to corporations and nations of a general management philosophy that has resulted in improved product quality." In 1988, he received the *Distinguished Career in Science* award from the National Academy of Sciences.[6]

Deming and his staff continued to advise businesses large and small. In 1986, Deming served as a consultant to Vernay Laboratories, a rubber-manufacturing firm in Yellow Springs, Ohio, with less than 500 employees. He held several of week-long seminars for employees and suppliers of the small company where his infamous example "Workers on the Red Beads" spurred several major changes in Vernay's manufacturing processes.

Deming joined the Graduate School of Business at Columbia University in 1988. In 1990, during his last year, he founded the W. Edwards Deming for Quality, Productivity, and Competitiveness at Columbia Business School to

promote operational excellence in business through the development of research, best practices and strategic planning.

In 1993, Deming published his final book, *The New Economics for Industry, Government, Education*, which included the System of Profound Knowledge and the 14 Points for Management. It also contained educational concepts involving group-based teaching without grades, as well as management without individual merit or performance reviews.

In December 1993, W. Edwards Deming died in his sleep at the age of 93 in his Washington home at about 3 a.m. due to "natural causes". His family was by his side when he died.[21]

Deming philosophy synopsis

The philosophy of W. Edwards Deming has been summarized as follows:

> "Dr. W. Edwards Deming taught that by adopting appropriate principles of management, organizations can increase quality and simultaneously reduce costs (by reducing waste, rework, staff attrition and litigation while increasing customer loyalty). The key is to practice continual improvement and think of manufacturing as a system, not as bits and pieces."[22]

In the 1970s, Deming's philosophy was summarized by some of his Japanese proponents with the following 'a'-versus-'b' comparison:

> (a) When people and organizations focus primarily on quality, defined by the following ratio,

$$\text{Quality} = \frac{\text{Results of work efforts}}{\text{Total costs}}$$

quality tends to increase and costs fall over time.

> (b) However, when people and organizations focus primarily on *costs*, costs tend to rise and quality declines over time.

The Deming System of Profound Knowledge

"The prevailing style of management must undergo transformation. A system cannot understand itself. The transformation requires a view from outside. The aim of this chapter is to provide an outside view—a lens—that I call a system of profound knowledge. It provides a map of theory by which to understand the organizations that we work in.

"The first step is transformation of the individual. This transformation is discontinuous. It comes from understanding of the system of profound knowledge. The individual, transformed, will perceive new meaning to his life, to events, to numbers, to interactions between people.

"Once the individual understands the system of profound knowledge, he will apply its principles in every kind of relationship with other people. He will have a basis for judgment of his own decisions and for transformation of the organizations that he belongs to. The individual, once transformed, will:

- Set an example;
- Be a good listener, but will not compromise;
- Continually teach other people; and
- Help people to pull away from their current practices and beliefs and move into the new philosophy without a feeling of guilt about the past."

Deming advocated that all managers need to have what he called a System of Profound Knowledge, consisting of four parts:

1. *Appreciation of a system*: understanding the overall processes involving suppliers, producers, and customers (or recipients) of goods and services (*explained below*);

2. ***Knowledge of variation***: the range and causes of variation in quality, and use of statistical sampling in measurements;

3. ***Theory of knowledge***: the concepts explaining knowledge and the limits of what can be known.

4. ***Knowledge of psychology***: concepts of human nature.

Deming explained, "One need not be eminent in any part nor in all four parts in order to understand it and to apply it. The 14 points for management in industry, education, and government follow naturally as application of this outside knowledge, for transformation from the present style of Western management to one of optimization."

"The various segments of the system of profound knowledge proposed here cannot be separated. They interact with each other. Thus, knowledge of psychology is incomplete without knowledge of variation.

"A manager of people needs to understand that all people are different. This is not ranking people. He needs to understand that the performance of anyone is governed largely by the system that he works in, the responsibility of management. A psychologist that possesses even a crude understanding of variation as will be learned in the experiment with the Red Beads (Ch. 7) could no longer participate in refinement of a plan for ranking people."[23]

The *Appreciation of a system* involves understanding how interactions (i.e., feedback) between the elements of a system can result in internal restrictions that force the system to behave as a single organism that automatically seeks a steady state. It is this steady state that determines the output of the system rather than the individual elements. Thus it is the structure of the organization rather than the employees, alone, which holds the key to improving the quality of output.

The *Knowledge of variation* involves understanding that everything measured consists of both "normal" variation due to the flexibility of the system and of "special causes" that create defects. Quality involves recognizing the difference to eliminate "special causes" while controlling normal variation. Deming taught that making changes in response to "normal" variation would only make the system perform worse. Understanding variation includes the mathematical certainty that variation will normally occur within six standard deviations of the mean.

The System of Profound Knowledge is the basis for application of Deming's famous 14 Points for Management, described below.

Key principles

Deming offered fourteen key principles to managers for transforming business effectiveness. The points were first presented in his book *Out of the Crisis.* (p. 23-24)[24] Although Deming does not use the term in his book, it is credited with launching the Total Quality Management movement.[25]

1. Create constancy of purpose toward improvement of product and service, with the aim to become competitive, 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 massive inspection by building quality into the product in the first place.

4. End the practice of awarding business on the basis of a price tag. Instead, minimize total cost. Move towards 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 (see Point 12 and Ch. 8 of "Out of the Crisis"). The aim of supervision should be to help people and machines and gadgets 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. (See Ch. 3 of "Out of the Crisis")

9. Break down barriers between departments. People in research, design, sales, and production must work as a team, in order to foresee problems of production and usage 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 adversarial 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.

11. a. Eliminate work standards (quotas) on the factory floor. Substitute with leadership.
    b. Eliminate management by objective. Eliminate management by numbers and numerical goals. Instead substitute with leadership.

12. a. Remove barriers that rob the hourly worker of his right to pride of workmanship. The responsibility of supervisors must be changed from sheer numbers to quality.
    b. 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 management by objective (See Ch. 3 of "Out of the Crisis").

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.

"Massive training is required to instill the courage to break with tradition. Every activity and every job is a part of the process."[26]

Seven Deadly Diseases

The "Seven Deadly Diseases" include:

1. Lack of constancy of purpose
2. Emphasis on short-term profits
3. Evaluation by performance, merit rating, or annual review of performance
4. Mobility of management
5. Running a company on visible figures alone
6. Excessive medical costs
7. Excessive costs of warranty, fueled by lawyers who work for contingency fees

"A Lesser Category of Obstacles" includes

1. Neglecting long-range planning
2. Relying on technology to solve problems
3. Seeking examples to follow rather than developing solutions
4. Excuses, such as "our problems are different"
5. Obsolescence in school that management skill can be taught in classes[27]
6. Reliance on quality control departments rather than management, supervisors, managers of purchasing, and production workers
7. Placing blame on workforces who are only responsible for 15% of mistakes where the system designed by management is responsible for 85% of the unintended consequences
8. Relying on quality inspection rather than improving product quality

Deming's advocacy of the Plan-Do-Check-Act cycle, his 14 Points, and Seven Deadly Diseases have had tremendous influence outside of manufacturing and have been applied in other arenas, such as in the relatively new field of sales process engineering.[28]

Quotations and concepts

In his later years, Deming taught many concepts, which he emphasized by key sayings or quotations that he repeated. A number of these quotes have been recorded.[29] Some of the concepts might seem to be oxymorons or contradictory to each other; however, the student is given each concept to ponder its meaning in the whole system, over time.

- *"There is no substitute for knowledge."* This statement emphasizes the need to know more, about everything in the system. It is considered as a contrast to the old statement, "There is no substitute for hard work" by Thomas Alva Edison (1847–1931). Instead, a small amount of knowledge could save many hours of hard work.

- *""In God we trust; all others must bring data."* (Trevor Hastie, Robert Tibshirani, and Jerome Friedman, co-authors of The Elements of Statistical Learning in their Preface to the Second Edition have a footnote which reads: "On the Web, this quote has been widely attributed to both Deming and Robert W. Hayden; however Professor Hayden told us that he can claim no credit for this quote, and ironically we could find no 'data' confirming Deming actually said this.") - The quote in The Elements of Statistical Learning actually reads "In God we trust, all others bring data."[30]]

- *"The most important things cannot be measured."* The issues that are most important, long term, cannot be measured in advance. However, they might be among the factors that an organization is measuring, just not understood as most important at the time.

- *"The most important things are unknown or unknowable."* The factors that have the greatest impact, long term, can be quite surprising. Analogous to an earthquake that disrupts service, other "earth-shattering" events that most affect an organization will be unknown or unknowable, in advance. Other examples of important things would be: a drastic change in technology, or new investment capital.

- *"Experience by itself teaches nothing."*[29] This statement emphasizes the need to interpret and apply information against a theory or framework of concepts that is the basis for knowledge about a system. It is considered as a contrast to the old statement, "Experience is the best teacher" (Deming disagreed with that). To Deming, knowledge is best taught by a master who explains the overall system through which experience is judged; experience, without understanding the underlying system, is just raw data that can be misinterpreted against a flawed theory of reality. Deming's view of experience is related to Shewhart's concept, "Data has no meaning apart from its context".

- *"By what method?... Only the method counts."*[29] When information is obtained, or data is measured, the method, or process used to gather information, greatly affects the results. For example, the "Hawthorne effect" showed that people just asking frequently for opinions seemed to affect the resulting outcome, since some people felt better just being asked for their opinion. Deming warned that basing judgments on customer complaints alone ignored the general population of other opinions, which should be judged together, such as in a statistical sample of the whole, not just isolated complaints: survey the entire group about their likes and dislikes (see Sampling (statistics)). The extreme complaints might not represent the attitudes of the whole group. Similarly, measuring or counting data depends on the instrument or method used. Changing the method changes the results. Aim and method are essential. An aim without a method is useless. A method without an aim is dangerous. It leads to action without direction and without constancy of purpose. Deming used an illustration of washing a table to teach a lesson about the relationship between purpose and method. If you tell someone to wash a table, but not the reason for washing it, they cannot do the job properly (will the table be used for chopping food or potting plants?). That does not mean just giving the explanation without an operational definition. The information about why the table needs to be washed, and what is to be done with it, makes it possible to do the job intelligently.

- *"You can expect what you inspect."* Deming emphasized the importance of measuring and testing to predict typical results. If a phase consists of inputs + process + outputs, all 3 are inspected to some extent. Problems with inputs are a major source of trouble, but the process using those inputs can also have problems. By inspecting the

inputs and the process more, the outputs can be better predicted, and inspected less. Rather than use mass inspection of every output product, the output can be statistically sampled in a cause-effect relationship through the process.

- *"Special Causes and Common Causes"*: Deming considered anomalies in quality to be variations outside the control limits of a process. Such variations could be attributed to one-time events called "special causes" or to repeated events called "common causes" that hinder quality.

- *Acceptable Defects*: Rather than waste efforts on zero-defect goals, Deming stressed the importance of establishing a level of variation, or anomalies, acceptable to the recipient (or customer) in the next phase of a process. Often, some defects are quite acceptable, and efforts to remove all defects would be an excessive waste of time and money.

- *The Deming Cycle* (or *Shewhart Cycle*): As a repetitive process to determine the next action, the Deming Cycle describes a simple method to test information before making a major decision. The 4 steps in the Deming Cycle are: Plan-Do-Check-Act (PDCA), also known as Plan-Do-Study-Act or PDSA. Deming called the cycle the *Shewhart Cycle*, after Walter A. Shewhart. The cycle can be used in various ways, such as running an experiment: PLAN (design) the experiment; DO the experiment by performing the steps; CHECK the results by testing information; and ACT on the decisions based on those results.

- *Semi-Automated, not Fully Automated*: Deming lamented the problem of automation gone awry ("robots painting robots"): instead, he advocated human-assisted semi-automation, which allows people to change the semi-automated or computer-assisted processes, based on new knowledge. Compare to Japanese term 'autonomation' (which can be loosely translated as "automation with a human touch").

- *"The problem is at the top; management is the problem."* [23] Dr. Deming emphasized that the top-level management had to change to produce significant differences, in a long-term, continuous manner. As a consultant, Deming would offer advice to top-level managers, if asked repeatedly, in a continuous manner.

- *"What is a system? A system is a network of interdependent components that work together to try to accomplish the aim of the system. A system must have an aim. Without an aim, there is no system. The aim of the system must be clear to everyone in the system. The aim must include plans for the future. The aim is a value judgment. (We are of course talking here about a man-made system.)"* [23]

- *"A system must be managed. It will not manage itself. Left to themselves in the Western world, components become selfish, competitive. We can not afford the destructive effect of competition."* [23]

- *"To successfully respond to the myriad of changes that shake the world, transformation into a new style of management is required. The route to take is what I call profound knowledge—knowledge for leadership of transformation."* [23]

- *"The worker is not the problem. The problem is at the top! Management!"* [31] Management's job. It is management's job to direct the efforts of all components toward the aim of the system. The first step is clarification: everyone in the organization must understand the aim of the system, and how to direct his efforts toward it. Everyone must understand the damage and loss to the whole organization from a team that seeks to become a selfish, independent, profit centre." [23]

- *"They realized that the gains that you get by statistical methods are gains that you get without new machinery, without new people. Anybody can produce quality if he lowers his production rate. That is not what I am talking about. Statistical thinking and statistical methods are to Japanese production workers, foremen, and all the way through the company, a second language. In statistical control, you have a reproducible product hour after hour, day after day. And see how comforting that is to management, they now know what they can produce, they know what their costs are going to be."* [32]

- *"I think that people here expect miracles. American management thinks that they can just copy from Japan—but they don't know what to copy!"* [32]

- *"What is the variation trying to tell us about a process, about the people in the process?"* [23] Dr. Shewhart created the basis for the control chart and the concept of a state of statistical control by carefully designed experiments. While Shewhart drew from pure mathematical statistical theories, he understood that data from physical processes never produce a "normal distribution curve" (a Gaussian distribution, also commonly referred to as a "bell curve"). He discovered that observed variation in manufacturing data did not always behave the same way as data in nature (Brownian motion of particles). Shewhart concluded that while every process displays variation, some processes display controlled variation that is natural to the process, while others display uncontrolled variation that is not present in the process causal system at all times.[33] Deming renamed these distinctions "common cause" for chance causes and "special cause" for assignable causes. He did this so the focus would be placed on those responsible for doing something about the variation, rather than the source of the variation. It is top management's responsibility to address "common cause" variation, and therefore it is management's responsibility to make improvements to the whole system. Because "special cause" variation is assignable, workers, supervisors or middle managers that have direct knowledge of the assignable cause best address this type of specific intervention.[9]

- (Deming on Quality Circles) *"That's all window dressing. That's not fundamental. That's not getting at change and the transformation that must take place. Sure we have to solve problems. Certainly stamp out the fire. Stamp out the fire and get nowhere. Stamp out the fires puts us back to where we were in the first place. Taking action on the basis of results without theory of knowledge, without theory of variation, without knowledge about a system. Anything goes wrong, do something about it, overreacting; acting without knowledge, the effect is to make things worse. With the best of intentions and best efforts, managing by results is, in effect, exactly the same, as Myron Tribus put it, while driving your automobile, keeping your eye on the rear view mirror, what would happen? And that's what management by results is, keeping your eye on results."* [2]

- *"Knowledge is theory. We should be thankful if action of management is based on theory. Knowledge has temporal spread. Information is not knowledge. The world is drowning in information but is slow in acquisition of knowledge. There is no substitute for knowledge."* [23] This statement emphasizes the need for theory of knowledge.

- *"Uncertainty makes research predictable, but you still need proof to satisfy everyone else."* [23] Deming was referencing the sometimes paradoxical aspects of research.

- *"The most important figures that one needs for management are unknown or unknowable (Lloyd S. Nelson, director of statistical methods for the Nashua corporation), but successful management must nevertheless take account of them."* [24] Deming realized that many important things that must be managed couldn't be measured. Both points are important. One, not everything of importance to management can be measured. And two, you must still manage those important things. Spend $20,000 training 10 people in a special skill. What's the benefit? "You'll never know," answered Deming. "You'll never be able to measure it. Why did you do it? Because you believed it would pay off. Theory." Deming is often incorrectly quoted as saying, "You can't manage what you can't measure." In fact, he stated that one of the seven deadly diseases of management is running a company on visible figures alone.

- *"joy in work"* the phrase, originally "pride in work" was amended to "joy" by Deming in 1988, after David Kerridge, professor of statistics at Aberdeen, pointed out that "joy" in labour was found twice in the Book of Ecclesiastes.[34] [35]

Notes

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[16] "**Red beads on display at ASQ headquarters**". *Deming Interaction* **9** (1): 2. Spring 2005.

[17] Salsburg (2002) page 254

[18] Deming and his statistical methods are profiled by Salsburg(2002, Chapter 24)

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[35] *Quality or else: the revolution in world business* Lloyd Dobyns, Clare Crawford-Mason - 1991 "Of the four experts, Deming, who can be the harshest as a teacher, seems the most humanistic, insisting that it is every person's right to have "joy in work." He used to say "pride" until David Kerridge, a professor at the University of Aberdeen, pointed out that the Book of Ecclesiastes says "joy" in two different verses. Deming, whose one known hobby is writing liturgical masses, switched to joy. He estimates that no more than two in a hundred managers and ten in a hundred workers now have joy in their work.

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- statistical-process-control.org (http://www.statistical-process-control.org/w-edwards-deming/) W. Edwards Deming Founder of Statistical Process Control for Quality Management.
- The Deming Forum home page (http://www.deming.org.uk) The Deming Forum
- ManagementWisdom.com (http://www.managementwisdom.com/)
- "Quality As Defined By Deming": Lecture by Newt Gingrich (http://terrenceberres.com/ginren06.html)
- Obituary from Philadelphia Inquirer, Dec. 1993 (http://www.highbeam.com/doc/1G1:14738127/Quality+Control+Pioneer+W~R~+Edwards+Deming+Dead+at+.html?refid=ency_botnm)
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- (http://www.demingcollaboration.com) The Deming Collaboration
- Mike Upstone on Free Energy as a New Economic Standard, and other Alternative Solutions (http://pesn.com/2012/03/05/9602050_Mike_Upstone_on_Alternative_Economic_Solutions_and_Free_Energy/) - cites Deming as a major source of inspiration.

Kaoru Ishikawa

Kaoru Ishikawa	
Born	July 13, 1915 Tokyo, Japan
Died	April 16, 1989 (aged 73)
Citizenship	Japan
Fields	quality, chemical engineering
Institutions	University of Tokyo, Musashi Institute of Technology
Alma mater	University of Tokyo
Known for	Ishikawa diagram, quality circle
Notable awards	Walter A. Shewhart Medal, Order of the Sacred Treasures

Kaoru Ishikawa (石川馨 *Ishikawa Kaoru*, July 13, 1915 - April 16, 1989) was a Japanese university professor and influential quality management innovator best known in North America for the Ishikawa or cause and effect diagram (also known as fishbone diagram) that is used in the analysis of industrial process.

Biography

Born in Tokyo, the oldest of the eight sons of Ichiro Ishikawa. In 1939 he graduated University of Tokyo with an engineering degree in applied chemistry. His first job was as a naval technical officer (1939-1941) then moved on to work at the Nissan Liquid Fuel Company until 1947. Ishikawa would now start his career as an associate professor at the University of Tokyo. He then undertook the presidency of the Musashi Institute of Technology in 1978.

In 1949, Ishikawa joined the Japanese Union of Scientists and Engineers (JUSE) quality control research group. After World War II Japan looked to transform its industrial sector, which in North America was then still perceived as a producer of cheap wind-up toys and poor quality cameras. It was his skill at mobilizing large groups of people towards a specific common goal that was largely responsible for Japan's quality-improvement initiatives. He translated, integrated and expanded the management concepts of W. Edwards Deming and Joseph M. Juran into the Japanese system.

After becoming a full professor in the Faculty of Engineering at The University of Tokyo (1960) Ishikawa introduced the concept of quality circles (1962) in conjunction with JUSE. This concept began as an experiment to see what effect the "leading hand" (Gemba-cho) could have on quality. It was a natural extension of these forms of training to all levels of an organization (the top and middle managers having already been trained). Although many companies were invited to participate, only one company at the time, Nippon Telephone & Telegraph, accepted. Quality circles would soon become very popular and form an important link in a company's Total Quality Management system. Ishikawa would write two books on quality circles (*QC Circle Koryo* and *How to Operate QC Circle Activities*).

Among his efforts to promote quality were the Annual Quality Control Conference for Top Management (1963) and several books on quality control (the *Guide to Quality Control* was translated into English). He was the chairman of the editorial board of the monthly *Statistical Quality Control*. Ishikawa was involved in international standardization activities.

1982 saw the development of the Ishikawa diagram which is used to determine root causes.

At Ishikawa's 1989 death, Juran delivered this eulogy:

> "There is so much to be learned by studying how Dr. Ishikawa managed to accomplish so much during a single lifetime. In my observation, he did so by applying his natural gifts in an exemplary way. He was dedicated to serving society rather than serving himself. His manner was modest, and this elicited the cooperation of others. He followed his own teachings by securing facts and subjecting them to rigorous analysis. " He was completely sincere, and as a result was trusted completely.

[1]

Contributions to quality

- User Friendly Quality Control
- Fishbone Cause and Effect Diagram - Ishikawa diagram
- Implementation of Quality Circles
- Emphasised the Internal customer
- Shared Vision

Awards and recognition

- 1972 American Society for Quality's Eugene L. Grant Award
- 1977 Blue Ribbon Medal by the Japanese Government for achievements in industrial standardization
- 1982 Walter A. Shewhart Medal
- 1988 Awarded the Order of the Sacred Treasures, Second Class, by the Japanese government.

Books

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Joseph M. Juran

Joseph M. Juran	
Born	December 24, 1904 Brăila, Romania
Died	February 28, 2008 (aged 103) Rye, New York, U.S.
Occupation	Management consultant, quality guru
Spouse	Sadie Shapiro (1926–2008, his death)
Children	4

Joseph Moses Juran (December 24, 1904 – February 28, 2008) was a 20th-century management consultant who is principally remembered as an evangelist for quality and quality management, having written several influential books on those subjects.[1] He was the brother of Academy Award winner Nathan H. Juran.

Early life

Juran was born to a Jewish family in 1904 in Brăila, Romania, and later lived in Gura Humorului.[2] In 1912, he immigrated to America with his family, settling in Minneapolis, Minnesota. Juran excelled in school, especially in mathematics. He was a chess champion at an early age,[3] and dominated chess at Western Electric. Juran graduated from Minneapolis South High School in 1920.

In 1924, with a bachelor's degree in electrical engineering from the University of Minnesota, Juran joined Western Electric's Hawthorne Works. His first job was troubleshooting in the Complaint Department.[4] In 1925, Bell Labs proposed that Hawthorne Works personnel be trained in its newly developed statistical sampling and control chart techniques. Juran was chosen to join the Inspection Statistical Department, a small group of engineers charged with applying and disseminating Bell Labs' statistical quality control innovations. This highly visible position fueled Juran's rapid ascent in the organization and the course of his later career.[5]

In 1926, he married Sadie Shapiro, and they had four children: Charles, Donald, Robert, and Sylvia. They had been married for over 81 years when he died in 2008.

Juran was promoted to department chief in 1928, and the following year became a division chief. He published his first quality-related article in *Mechanical Engineering* in 1935. In 1937, he moved to Western Electric/AT&T's headquarters in New York City.

As a hedge against the uncertainties of the Great Depression, he enrolled in Loyola University Chicago School of Law in 1931. He graduated in 1935 and was admitted to the Illinois bar in 1936, though he never practiced law.[6]

During the Second World War, through an arrangement with his employer, Juran served in the Lend-Lease Administration and Foreign Economic Administration. Just before war's end, he resigned from Western Electric, and his government post, intending to become a freelance consultant.[7] He joined the faculty of New York University as an adjunct professor in the Department of Industrial Engineering, where he taught courses in quality control and ran round table seminars for executives. He also worked through a small management consulting firm on projects for Gilette, Hamilton Watch Company and Borg-Warner. After the firm's owner's sudden death, Juran began his own independent practice, from which he made a comfortable living until his retirement in the late 1990s. His early clients included the now defunct Bigelow-Sanford Carpet Company, the Koppers Company, the International Latex Company, Bausch & Lomb and General Foods.

Japan

The end of World War II compelled Japan to change its focus from becoming a military power to becoming an economic one. Despite Japan's ability to compete on price, its consumer goods manufacturers suffered from a long-established reputation of poor quality. The first edition of Juran's *Quality Control Handbook* in 1951 attracted the attention of the Japanese Union of Scientists and Engineers (JUSE), which invited him to Japan in 1952. When he finally arrived in Japan in 1954, Juran met with ten manufacturing companies, notably Showa Denko, Nippon Kōgaku, Noritake, and Takeda Pharmaceutical Company.[8] He also lectured at Hakone, Waseda University, Ōsaka, and Kōyasan. During his life, he made ten visits to Japan, the last in 1990.

Working independently of W. Edwards Deming (who focused on the use of statistical process control), Juran—who focused on managing for quality—went to Japan and started courses (1954) in quality management. The training started with top and middle management. The idea that top and middle management needed training had found resistance in the United States. For Japan, it would take some 20 years for the training to pay off. In the 1970s, Japanese products began to be seen as the leaders in quality. This sparked a crisis in the United States due to quality issues in the 1980s.

Contributions

Pareto principle

In 1941, Juran stumbled across the work of Vilfredo Pareto and began to apply the Pareto principle to quality issues (for example, 80% of a problem is caused by 20% of the causes). This is also known as "the vital few and the trivial many". In later years, Juran preferred "the vital few and the useful many" to signal the remaining 80% of the causes should not be totally ignored.

Management theory

When he began his career in the 1920s, the principal focus in quality management was on the quality of the end, or finished, product. The tools used were from the Bell system of acceptance sampling, inspection plans, and control charts. The ideas of Frederick Winslow Taylor dominated.

Juran is widely credited for adding the human dimension to quality management. He pushed for the education and training of managers. For Juran, human relations problems were the ones to isolate. Resistance to change—or, in his terms, cultural resistance—was the root cause of quality issues. Juran credits Margaret Mead's book *Cultural Patterns and Technical Change* for illuminating the core problem in reforming business quality.[9] He wrote *Managerial Breakthrough*, which was published in 1964, outlining the issue.

Juran's vision of quality management extended well outside the walls of the factory to encompass nonmanufacturing processes, especially those that might be thought of as service related. For example, in an interview published in 1997[10] he observed:

> The key issues facing managers in sales are no different than those faced by managers in other disciplines. Sales managers say they face problems such as "It takes us too long...we need to reduce the error rate." They want to know, "How do customers perceive us?" These issues are no different than those facing managers trying to improve in other fields. The systematic approaches to improvement are identical. ... There should be no reason our familiar principles of quality and process engineering would not work in the sales process.

The Juran trilogy

Juran was one of the first to think about the cost of poor quality.[11] This was illustrated by his "Juran trilogy", an approach to cross-functional management, which is composed of three managerial processes: quality planning, quality control and quality improvement. Without change, there will be a constant waste, during change there will be increased costs, but after the improvement, margins will be higher and the increased costs get recouped.

Transferring quality knowledge between East and West

During his 1966 visit to Japan, Juran learned about the Japanese concept of quality circles, which he enthusiastically evangelized in the West.[12] Juran also acted as a matchmaker between U.S. and Japanese companies looking for introductions to each other.[13]

Later life and death

Juran was active well into his 90s, and only gave up international travel at age 86. His accomplishments during the second half of his life include:

- Consulting for U.S. companies such as Armour and Company, Dennison Manufacturing Company, Merck, Sharp & Dohme, Otis Elevator Company, Xerox, and the United States Navy Fleet Ballistic Missile System.[14]
- Consulting for Western European and Japanese companies, such as Rolls-Royce Motors, Philips, Volkswagen, Royal Dutch Shell and Toyota Motor Company[15]
- *Pro bono* consulting for Soviet-bloc countries (Hungary, Romania, Czechoslovakia, Russia, Poland, and Yugoslavia)[16]
- Founding the Juran Institute[17] and the Juran Foundation.[18]

In 2004, he turned 100 years old, and was awarded an honorary doctor from Luleå University of Technology in Sweden.[19]

He and Sadie celebrated their 80th wedding anniversary in June 2006 both of them were 101 years old at the time. They were 102 years old at the time of their 81st wedding anniversary, He was even active on his 103rd birthday and he was caring for Sadie when he died.

Juran died of a stroke at age 103 in Rye, New York. He was survived by his wife Sadie who died on 2 December 2008 (aged 103 years, 259 days), his four children, nine grandchildren and ten great-grandchildren.[20][21]

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- *Lectures in Quality Control*, 1956
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External links

- The Juran Institute's official web site (http://www.juran.com)
- List of people with the longest marriages

PDCA

PDCA (**plan–do–check–act** or **plan–do–check–adjust**) is an iterative four-step management method used in business for the control and continuous improvement of processes and products. It is also known as the **Deming circle/cycle/wheel**, **Shewhart cycle**, **control circle/cycle**, or **plan–do–study–act** (**PDSA**).

Meaning

The steps in each successive PDCA cycle are[2][3] :

PLAN

> Establish the objectives and processes necessary to deliver results in accordance with the expected output (the target or goals). By establishing output expectations, the completeness and accuracy of the specification is also a part of the targeted improvement. When possible start on a small scale to test possible effects.

The PDCA cycle[1]

DO

> Implement the plan, execute the process, make the product. Collect data for charting and analysis in the following "CHECK" and "ACT" steps.

CHECK

> Study the actual results (measured and collected in "DO" above) and compare against the expected results (targets or goals from the "PLAN") to ascertain any differences. Look for deviation in implementation from the plan and also look for the appropriateness/completeness of the plan to enable the execution i.e.,"Do". Charting data can make this much easier to see trends over several PDCA cycles and in order to convert the collected data into information. Information is what you need for the next step "ACT".

ACT

> Request corrective actions on significant differences between actual and planned results. Analyze the differences to determine their root causes. Determine where to apply changes that will include improvement of the process or product. When a pass through these four steps does not result in the need to improve, the scope to which PDCA is applied may be refined to plan and improve with more detail in the next iteration of the cycle, or attention needs to be placed in a different stage of the process.
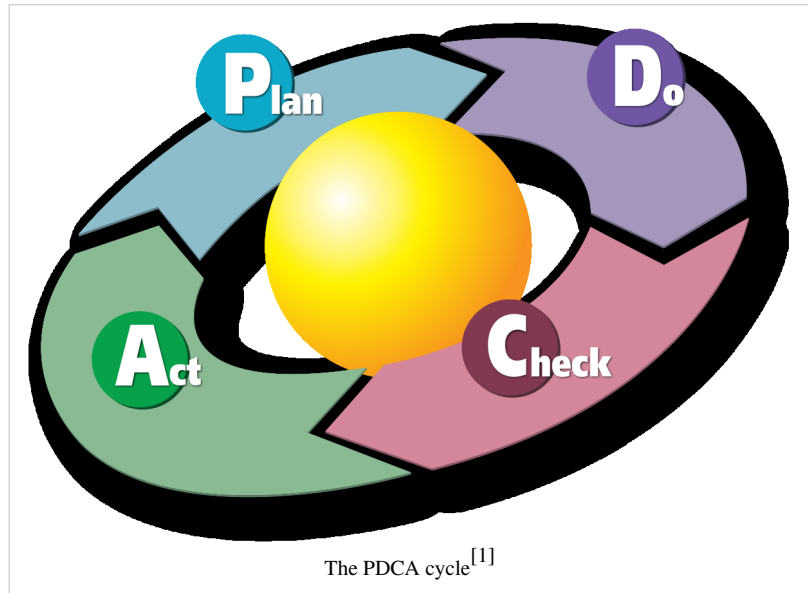
About

PDCA was made popular by Dr. W. Edwards Deming, who is considered by many to be the father of modern quality control; however he always referred to it as the "Shewhart cycle". Later in Deming's career, he modified PDCA to "Plan, Do, Study, Act" (PDSA) because he felt that "check" emphasized inspection over analysis.[4]

The concept of PDCA is based on the scientific method, as developed from the work of Francis Bacon (Novum Organum, 1620). The scientific method can be written as "hypothesis"–"experiment"–"evaluation" or plan, do and check. Shewhart described manufacture under "control"—under statistical control—as a three step process of specification, production, and inspection.[5] He also specifically related this to the scientific method of hypothesis, experiment, and evaluation. Shewhart says that the statistician "must help to change the demand [for goods] by showing [...] how to close up the tolerance range and to improve the quality of goods."[6] Clearly, Shewhart intended the analyst to take action based on the conclusions of the evaluation. According to Deming, during his lectures in Japan in the early 1950s, the Japanese participants shortened the steps to the now traditional *plan, do, check, act*.[7] Deming preferred *plan, do, study, act* because "study" has connotations in English closer to Shewhart's intent than "check".[2]

A fundamental principle of the scientific method and PDCA is iteration—once a hypothesis is confirmed (or negated), executing the cycle again will extend the knowledge further. Repeating the PDCA cycle can bring us closer to the goal, usually a perfect operation and output.[2]

In Six Sigma programs, the PDCA cycle is called "define, measure, analyze, improve, control" (DMAIC). The iterative nature of the cycle must be explicitly added to the DMAIC procedure.

PDCA should be repeatedly implemented in spirals of increasing knowledge of the system that converge on the ultimate goal, each cycle closer than the previous. One can envision an open coil spring, with each loop being one cycle of the scientific method - PDSA, and each complete cycle indicating an increase in our knowledge of the system under study. This approach is based on the belief that our knowledge and skills are limited, but improving. Especially at the start of a project, key information may not be known; the PDCA—scientific method—provides feedback to justify our guesses (hypotheses) and increase our knowledge. Rather than enter "analysis paralysis" to get it perfect the first time, it is better to be approximately right than exactly wrong. With the improved knowledge, we may choose to refine or alter the goal (ideal state). Certainly, the PDCA approach can bring us closer to whatever goal we choose.[8]

Rate of change, that is, rate of improvement, is a key competitive factor in today's world. PDCA allows for major "jumps" in performance ("breakthroughs" often desired in a Western approach), as well as Kaizen (frequent small improvements). In the United States a PDCA approach is usually associated with a sizable project involving numerous people's time, and thus managers want to see large "breakthrough" improvements to justify the effort expended. However, the scientific method and PDCA apply to all sorts of projects and improvement activities.[9]

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[5]   Shewhart (1939), p. 45

[6]   Shewhart (1939), p. 48

[7]   Deming, p. 88

[8]   Rother, Mike (2009), *Toyota Kata*, McGraw-Hill, p. 160

[9]   Rother, Mike (2009), *Toyota Kata*, McGraw-Hill, p. 76

[10]   http://www.josseybass.com/WileyCDA/WileyTitle/productCd-0470192410.html

External links

- PDCA Guidance (http://www.iso-9001-checklist.co.uk/iso-9001-training.htm)

Kaizen

Kaizen (改善), Japanese for "improvement", or "change for the better" refers to philosophy or practices that focus upon continuous improvement of processes in manufacturing, engineering, game development, and business management. It has been applied in healthcare,[1] psychotherapy,[2] life-coaching, government, banking, and other industries. When used in the business sense and applied to the workplace, kaizen refers to activities that continually improve all functions, and involves all employees from the CEO to the assembly line workers. It also applies to processes, such as purchasing and logistics, that cross organizational boundaries into the supply chain.[3] By improving standardized activities and processes, kaizen aims to eliminate waste (see lean manufacturing). Kaizen was first implemented in several Japanese businesses after the Second World War, influenced in part by American business and quality management teachers who visited the country. It has since spread throughout the world[4] and is now being implemented in many other venues besides just business and productivity.

Introduction

Kaizen is a daily process, the purpose of which goes beyond simple productivity improvement. It is also a process that, when done correctly, humanizes the workplace, eliminates overly hard work ("muri"), and teaches people how to perform experiments on their work using the scientific method and how to learn to spot and eliminate waste in business processes. In all, the process suggests a humanized approach to workers and to increasing productivity: "The idea is to nurture the company's human resources as much as it is to praise and encourage participation in kaizen activities."[5] Successful implementation requires "the participation of workers in the improvement."[6] People at all levels of an organization participate in kaizen, from the CEO down to janitorial staff, as well as external stakeholders when applicable. The format for kaizen can be individual, suggestion system, small group, or large group. At Toyota, it is usually a local improvement within a workstation or local area and involves a small group in improving their own work environment and productivity. This group is often guided through the kaizen process by a line supervisor; sometimes this is the line supervisor's key role. Kaizen on a broad, cross-departmental scale in companies, generates total quality management, and frees human efforts through improving productivity using machines and computing power.

While kaizen (at Toyota) usually delivers small improvements, the culture of continual aligned small improvements and standardization yields large results in the form of compound productivity improvement. This philosophy differs

from the "command and control" improvement programs of the mid-twentieth century. Kaizen methodology includes making changes and monitoring results, then adjusting. Large-scale pre-planning and extensive project scheduling are replaced by smaller experiments, which can be rapidly adapted as new improvements are suggested.

In modern usage, it is designed to address a particular issue over the course of a week and is referred to as a "kaizen blitz" or "kaizen event". These are limited in scope, and issues that arise from them are typically used in later blitzes.

History

After WWII, to help restore Japan, American occupation forces brought in American experts to help with the rebuilding of Japanese industry while The Civil Communications Section (CCS) developed a Management Training Program that taught statistical control methods as part of the overall material. This course was developed and taught by Homer Sarasohn and Charles Protzman in 1949-50. Sarasohn recommended W. Edwards Deming for further training in Statistical Methods.

The Economic and Scientific Section (ESS) group was also tasked with improving Japanese management skills and Edgar McVoy was instrumental in bringing Lowell Mellen to Japan to properly install the Training Within Industry (TWI) programs in 1951.

Prior to the arrival of Mellen in 1951, the ESS group had a training film to introduce the three TWI "J" programs (Job Instruction, Job Methods and Job Relations)---the film was titled "Improvement in 4 Steps" (Kaizen eno Yon Dankai). Thus the original introduction of "Kaizen" to Japan. For the pioneering, introduction, and implementation of Kaizen in Japan, the Emperor of Japan awarded the 2nd Order Medal of the Sacred Treasure to Dr. Deming in 1960. Consequently, the Union of Japanese Science and Engineering (JUSE) instituted the annual Deming Prizes for achievement in quality and dependability of products.

On October 18, 1989, JUSE awarded the Deming Prize to Florida Power & Light Co. (FPL), based in the US, for its exceptional accomplishments in process and quality control management. FPL was the first company outside Japan to win the Deming Prize.

[7]

Implementation

The Toyota Production System is known for kaizen, where all line personnel are expected to stop their moving production line in case of any abnormality and, along with their supervisor, suggest an improvement to resolve the abnormality which may initiate a kaizen.

The cycle of kaizen activity can be defined as:

- Standardize an operation and activities.
- Measure the standardized operation (find cycle time and amount of in-process inventory)
- Gauge measurements against requirements
- Innovate to meet requirements and increase productivity
- Standardize the new, improved operations
- Continue cycle *ad infinitum*

The PDCA cycles[8]
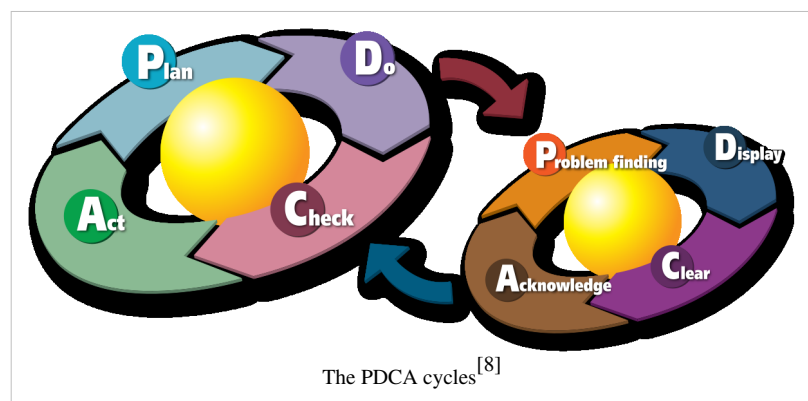
This is also known as the Shewhart cycle, Deming cycle, or PDCA. Other techniques used in conjunction with PDCA include 5 Whys, which is a form of root cause analysis in which the user asks "why" to a problem and its

answer five successive times. There are normally a series of root causes stemming from one problem,[9] and they can be visualized using fishbone diagrams or tables.

Masaaki Imai made the term famous in his book *Kaizen: The Key to Japan's Competitive Success*.

Apart from business applications of the method, both Anthony Robbins and Robert Maurer have popularized the kaizen principles into personal development principles. In the book *One Small Step Can Change Your life: The Kaizen Way*, and CD set *The Kaizen Way to Success*, Maurer looks at how individuals can take a kaizen approach in both their personal and professional lives.[10][11]

In the *Toyota Way Fieldbook*, Liker and Meier discuss the kaizen blitz and kaizen burst (or kaizen event) approaches to continuous improvement. A kaizen blitz, or rapid improvement, is a focused activity on a particular process or activity. The basic concept is to identify and quickly remove waste. Another approach is that of the kaizen burst, a specific kaizen activity on a particular process in the value stream.[12]

WebKaizen Events, written by Kate Cornell, condenses the philosophies of kaizen events into a one-day, problem solving method that leads to prioritized solutions. This method combines Kaizen Event tools with PMP concepts. It introduces the Focused Affinity Matrix and the Cascading Impact Analysis. The Impact/Constraint Diagram and the Dual Constraint Diagram are tools used in this method.[13]

Key elements of kaizen are quality, effort, involvement of all employees, willingness to change, and communication.

The five main elements of kaizen

- Teamwork
- Personal discipline
- Improved morale
- Quality circles
- Suggestions for improvement

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External links

- Kaizen and Process Improvement (http://www.shmula.com/2035/no-standard-then-no-kaizen) Written by Shmula
- Guide to Kaizen question and answer (http://www.creativesafetysupply.com/kaizenguide.html) Written by Mike Wilson
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- Practice your personal Kaizen (http://lifehacker.com/207029/practice-your-personal-kaizen) Written by Jason Thomas
- Kaizen Implementation Model (http://blog.bulsuk.com/2009/01/how-to-really-implement-kaizen.html)

Just in time (business)

Just in time (**JIT**) is a production strategy that strives to improve a business return on investment by reducing in-process inventory and associated carrying costs. Just-in-time production method is also called the Toyota Production System. To meet JIT objectives, the process relies on signals or Kanban (看板 *Kanban*) between different points in the process, which tell production when to make the next part. Kanban are usually 'tickets' but can be simple visual signals, such as the presence or absence of a part on a shelf. Implemented correctly, JIT focuses on continuous improvement and can improve a manufacturing organization's return on investment, quality, and efficiency. To achieve continuous improvement key areas of focus could be flow, employee involvement and quality.

Quick notice that stock depletion requires personnel to order new stock is critical to the inventory reduction at the center of JIT, which saves warehouse space and costs, but JIT relies on other elements in the inventory chain: for instance, its effective application cannot be independent of other key components of a lean manufacturing system or it can "end up with the opposite of the desired result."[1] In recent years manufacturers have continued to try to hone forecasting methods such as applying a trailing 13-week average as a better predictor for JIT planning;[2] however, some research demonstrates that basing JIT on the presumption of stability is inherently flawed.[3]

Philosophy

The philosophy of JIT is simple: inventory is waste. JIT inventory systems expose hidden cost of keeping inventory, and are therefore not a simple solution for a company to adopt. The company must follow an array of new methods to manage the consequences of the change. The ideas in this way of working come from many different disciplines including statistics, industrial engineering, production management, and behavioral science. The JIT inventory philosophy defines how inventory is viewed and how it relates to management.

Inventory is seen as incurring costs, or waste, instead of adding and storing value, contrary to traditional accounting. This does not mean to say JIT is implemented without an awareness that removing inventory exposes pre-existing manufacturing issues. This way of working encourages businesses to eliminate inventory that does not compensate for manufacturing process issues, and to constantly improve those processes to require less inventory. Secondly, allowing any stock habituates management to stock keeping. Management may be tempted to keep stock to hide production problems. These problems include backups at work centers, machine reliability, process variability, lack of flexibility of employees and equipment, and inadequate capacity.

In short, the Just-in-Time inventory system focus is having "the right material, at the right time, at the right place, and in the exact amount"-Ryan Grabosky, without the safety net of inventory. The JIT system has broad implications for implementers.

Transaction cost approach

JIT reduces inventory in a firm. However, a firm may simply be outsourcing their input inventory to suppliers, even if those suppliers don't use Just-in-Time (Naj 1993). Newman (1994) investigated this effect and found that suppliers in Japan charged JIT customers, on average, a 5% price premium.

Environmental concerns

During the birth of JIT, multiple daily deliveries were often made by bicycle. Increased scale has required a move to vans and lorries (trucks). Cusumano (1994) highlighted the potential and actual problems this causes with regard to gridlock and burning of fossil fuels. This violates three JIT waste guidelines:

1. Time—wasted in traffic jams
2. Inventory—specifically pipeline (in transport) inventory

3. Scrap—fuel burned while not physically moving

Price volatility

JIT implicitly assumes a level of input price stability that obviates the need to buy parts in advance of price rises. Where input prices are expected to rise, storing inventory may be desirable.

Quality volatility

JIT implicitly assumes that input parts quality remains constant over time. If not, firms may hoard high-quality inputs. As with price volatility, a solution is to work with selected suppliers to help them improve their processes to reduce variation and costs. Longer term price agreements can then be negotiated and agreed-on quality standards made the responsibility of the supplier. Fixing up of standards for volatility of quality according to the quality circle

Demand stability

Karmarker (1989) highlights the importance of relatively stable demand, which helps ensure efficient capital utilization rates. Karmarker argues that without significantly stable demand, JIT becomes untenable in high capital cost production.

Supply stability

In the U.S., the 1992 railway strikes caused General Motors to idle a 75,000-worker plant because they had no supply.

JIT implementation design

Based on a diagram modeled after the one used by Hewlett-Packard's Boise plant to accomplish its JIT program.

    1) **F** Design **F**low Process

```
─ F  Redesign/relayout for flow
      ─ L  Reduce lot sizes
      ─ O  Link operations
      ─ W  Balance workstation capacity
      ─ M  Preventive maintenance
      ─ S  Reduce setup Times
```

    2) **Q** Total **Q**uality Control

```
─ C  worker compliance
      ─ I  Automatic inspection
      ─ M  quality measures
      ─ M  fail-safe methods
      ─ W  Worker participation
```

    3) **S** Stabilize **S**chedule

```
─ S  Level schedule
      ─ W  Establish freeze windows
      ─ UC  Underutilize Capacity
```

    4) **K** **K**anban Pull System

```
─ D Demand pull
        ─ B Backflush
        ─ L Reduce lot sizes
```

5) **V** Work with **V**endors

```
─ L Reduce lead time
        ─ D Frequent deliveries
        ─ U Project usage requirements
        ─ Q Quality expectations
```

6) **I** Further Reduce **I**nventory in Other Areas

```
─ S Stores
        ─ T Transit
        ─ C Implement carrousel to reduce motion waste
        ─ C Implement conveyor belts to reduce motion waste
```

7) **P** Improve **P**roduct Design

```
─ P Standard production configuration
        ─ P Standardize and reduce the number of parts
        ─ P Process design with product design
        ─ Q Quality expectations
```

Effects

A surprising effect was that factory response time fell to about a day. This improved customer satisfaction by providing vehicles within a day or two of the minimum economic shipping delay.

Also, the factory began building many vehicles to order, eliminating the risk they would not be sold. This improved the company's return on equity.

Since assemblers no longer had a choice of which part to use, every part had to fit perfectly. This caused a quality assurance crisis, which led to a dramatic improvement in product quality. Eventually, Toyota redesigned every part of its vehicles to widen tolerances, while simultaneously implementing careful statistical controls for quality control. Toyota had to test and train parts suppliers to assure quality and delivery. In some cases, the company eliminated multiple suppliers.

When a process or parts quality problem surfaced on the production line, the entire production line had to be slowed or even stopped. No inventory meant a line could not operate from in-process inventory while a production problem was fixed. Many people in Toyota predicted that the initiative would be abandoned for this reason. In the first week, line stops occurred almost hourly. But by the end of the first month, the rate had fallen to a few line stops per day. After six months, line stops had so little economic effect that Toyota installed an overhead pull-line, similar to a bus bell-pull, that let any worker on the line order a line stop for a process or quality problem. Even with this, line stops fell to a few per week.

The result was a factory that has been studied worldwide. It has been widely emulated, but not always with the expected results, as many firms fail to adopt the full system.[4]

The just-in-time philosophy was also applied to other segments of the supply chain in several types of industries. In the commercial sector, it meant eliminating one or all of the warehouses in the link between a factory and a retail establishment. Examples in sales, marketing, and customer service involve applying information systems and mobile hardware to deliver customer information as needed, and reducing waste by video conferencing to cut travel time.[5]

Benefits

Main benefits of JIT include:

- *Reduced setup time.* Cutting setup time allows the company to reduce or eliminate inventory for "changeover" time. The tool used here is SMED (single-minute exchange of dies).
- *The flow of goods from warehouse to shelves improves.* Small or individual piece lot sizes reduce lot delay inventories, which simplifies inventory flow and its management.
- *Employees with multiple skills are used more efficiently.* Having employees trained to work on different parts of the process allows companies to move workers where they are needed.
- *Production scheduling and work hour consistency synchronized with demand.* If there is no demand for a product at the time, it is not made. This saves the company money, either by not having to pay workers overtime or by having them focus on other work or participate in training.
- *Increased emphasis on supplier relationships.* A company without inventory does not want a supply system problem that creates a part shortage. This makes supplier relationships extremely important.
- *Supplies come in at regular intervals throughout the production day.* Supply is synchronized with production demand and the optimal amount of inventory is on hand at any time. When parts move directly from the truck to the point of assembly, the need for storage facilities is reduced.
- *Minimizes storage space needed.*
- *Smaller chance of inventory breaking/expiring.*

Problems

Within a JIT system

Just-in-time operation leaves suppliers and downstream consumers open to supply shocks and large supply or demand changes. For internal reasons, Ohno saw this as a feature rather than a bug. He used an analogy of lowering the water level in a river to expose the rocks to explain how removing inventory showed where production flow was interrupted. Once barriers were exposed, they could be removed. Since one of the main barriers was rework, lowering inventory forced each shop to improve its own quality or cause a holdup downstream. A key tool to manage this weakness is production levelling to remove these variations. Just-in-time is a means to improving performance of the system, not an end.

Very low stock levels means shipments of the same part can come in several times per day. This means Toyota is especially susceptible to flow interruption. For that reason, Toyota uses two suppliers for most assemblies. As noted in Liker (2003), there was an exception to this rule that put the entire company at risk because of the 1997 Aisin fire. However, since Toyota also makes a point of maintaining high quality relations with its entire supplier network, several other suppliers immediately took up production of the Aisin-built parts by using existing capability and documentation. Thus, a strong, long-term relationship with a few suppliers is better than short-term, price-based relationships with many competing suppliers. Toyota uses this long-term relationship to send Toyota staff to help suppliers improve their processes. These interventions have been going on for twenty years and have created a more reliable supply chain, improved margins for Toyota and suppliers, and lowered prices for customers. Toyota encourages their suppliers to use JIT with their own suppliers.

Within a raw material stream

As noted by Liker (2003) and Womack and Jones (2003), it ultimately would be desirable to introduce synchronised flow and link JIT through the entire supply stream. However, none followed this in detail all the way back through the processes to the raw materials. With present technology, for example, an ear of corn cannot be grown and delivered to order. The same is true of most raw materials, which must be discovered and/or grown through natural processes that require time and must account for natural variability in weather and discovery. The part of this currently viewed as impossible is the *synchronised* part of flow and the *linked* part of JIT. It is for the reasons stated

raw materials companies decouple their supply chain from their clients' demand by carrying large 'finished goods' stocks. Both flow and JIT can be implemented in isolated process islands within the raw materials stream. The challenge becomes to achieve that isolation by some means other than carrying huge stocks, as most do today.

Because of this, almost all value chains are split into a part made-to-forecast and a part that could, by using JIT, become make-to-order. Historically, the make-to-order part has often been within the retailer portion of the value chain. Toyota took Piggly Wiggly's supermarket replenishment system and drove it at least half way through their automobile factories. Their challenge today is to drive it all the way back to their goods-inwards dock. Of course, the mining of iron and making of steel is still not connected to an order for a particular car. Recognising JIT could be driven back up the supply chain has reaped Toyota huge benefits and a dominant position in the auto industry.

Note that the advent of the mini mill steelmaking facility is starting to challenge how far back JIT can be implemented, as the electric arc furnaces at the heart of many mini-mills can be started and stopped quickly, and steel grades changed rapidly.

Oil

It has been frequently charged that the oil industry has been influenced by JIT.[6][7][8]

The argument is presented as follows:

> The number of refineries in the United States has fallen from 279 in 1975 to 205 in 1990 and further to 149 in 2004. As a result, the industry is susceptible to supply shocks, which cause spikes in prices and subsequently reduction in domestic manufacturing output. The effects of hurricanes Katrina and Rita are given as an example: in 2005, Katrina caused the shutdown of 9 refineries in Louisiana and 6 more in Mississippi, and a large number of oil production and transfer facilities, resulting in the loss of 20% of the US domestic refinery output. Rita subsequently shut down refineries in Texas, further reducing output. The GDP figures for the third and fourth quarters showed a slowdown from 3.5% to 1.2% growth. Similar arguments were made in earlier crises.

Beside the obvious point that prices went up because of the reduction in supply and not for anything to do with the practice of JIT, JIT students and even oil and gas industry analysts question whether JIT as it has been developed by Ohno, Goldratt, and others is used by the petroleum industry. Companies routinely shut down facilities for reasons other than the application of JIT. One of those reasons may be economic rationalization: when the benefits of operating no longer outweigh the costs, including opportunity costs, the plant may be economically inefficient. JIT has never subscribed to such considerations directly; following Waddel and Bodek (2005), this ROI-based thinking conforms more to Brown-style accounting and Sloan management. Further, and more significantly, JIT calls for a reduction in inventory capacity, not production capacity. From 1975 to 1990 to 2005, the annual average stocks of gasoline have fallen by only 8.5% from 228,331 to 222,903 bbls to 208,986 (Energy Information Administration data). Stocks fluctuate seasonally by as much as 20,000 bbls. During the 2005 hurricane season, stocks never fell below 194000000 bbl (**unknown operator: u'strong'** m^3), while the low for the period 1990 to 2006 was 187017000 bbl (**unknown operator: u'strong'** m^3) in 1997. This shows that while industry storage capacity has decreased in the last 30 years, it hasn't been drastically reduced as JIT practitioners would prefer. Specialty (SRS)

Finally, as shown in a pair of articles in the "Oil & Gas Journal", JIT does not seem to have been a goal of the industry. In Waguespack and Cantor (1996), the authors point out that JIT would require a significant change in the supplier/refiner relationship, but the changes in inventories in the oil industry exhibit none of those tendencies. Specifically, the relationships remain cost-driven among many competing suppliers rather than quality-based among a select few long-term relationships. They find that a large part of the shift came about because of the availability of short-haul crudes from Latin America. In the follow-up editorial, the Oil & Gas Journal claimed that "casually adopting popular business terminology that doesn't apply" had provided a "rhetorical bogey" to industry critics. Confessing that they had been as guilty as other media sources, they confirmed that "It also happens not to be accurate."

Business models following similar approach

Vendor-managed inventory

Vendor-managed inventory (VMI) employs the same principles as those of JIT inventory, however, the responsibilities of managing inventory is placed with the vendor in a vendor/customer relationship. Whether it's a manufacturer managing inventory for a distributor, or a distributor managing inventory for their customers, the management role goes to the vendor.

An advantage of this business model is that the vendor may have industry experience and expertise that lets them better anticipate demand and inventory needs. The inventory planning and controlling is facilitated by applications that allow vendors access to their customer's inventory data.

Another advantage to the customer is that inventory cost usually remains on the vendor's books until used by the customer, even if parts or materials are on the customer's site.

Customer-managed inventory

With customer-managed inventory (CMI), the customer, as opposed to the vendor in a VMI model, has responsibility for all inventory decisions. This is similar to JIT inventory concepts. With a clear picture of their inventory and that of their supplier's, the customer can anticipate fluctuations in demand and make inventory replenishment decisions accordingly.

Early use of a JIT system

A type of JIT was used successfully in the UK by Perkins to supply F3 engines to Ford from 1957 until 1964.

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ISO 9000

The **ISO 9000** family of standards are related to quality management systems and designed to help organizations ensure that they meet the needs of customers and other stakeholders.[1] The standards are published by ISO, the International Organization for Standardization, and available through National standards bodies while meeting statutory and regulatory requirements. ISO 9000 deals with the fundamentals of quality management systems,[2] including the eight management principles[3][2] on which the family of standards is based. ISO 9001 deals with the requirements that organizations wishing to meet the standard have to fulfill.[4]

Third party certification bodies provide independent confirmation that organizations meet the requirements of ISO 9001. Over a million organizations worldwide[5] are independently certified, making ISO 9001 one of the most widely used management tools in the world today. Despite widespread use, however, the ISO certification process has been criticized[6][7] as being wasteful and not being useful for all organizations.[8][9][10]

Reasons for use

The ISO 9000 family of standards is the only international standard that addresses systemic change. The global adoption of ISO 9001 may be attributable to a number of factors. A number of major purchasers require their suppliers to hold ISO 9001 certification. In addition to several stakeholders' benefits [11], a number of studies have identified significant financial benefits for organizations certified to ISO 9001, with a 2011 survey from the British Assessment Bureau showing 44% of their certified clients had won new business.[12] Corbett *et al.* showed that certified organizations achieved superior return on assets[13] compared to otherwise similar organizations without certification.[14] Heras *et al.* found similarly superior performance[15] and demonstrated that this was statistically significant and not a function of organization size.[16] Naveha and Marcus claimed that implementing ISO 9001 led to superior operational performance in the US motor carrier industry.[17] Sharma identified similar improvements in operating performance and linked this to superior financial performance.[18] Chow-Chua *et al.* showed better overall financial performance was achieved for companies in Denmark.[19] Rajan and Tamimi (2003) showed that ISO 9001 certification resulted in superior stock market performance and suggested that shareholders were richly rewarded for the investment in an ISO 9001 system.[20]
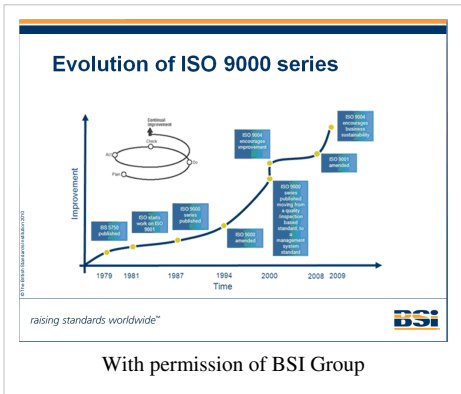
While the connection between superior financial performance and ISO 9001 may be seen from the examples cited, there remains no proof of direct causation, though longitudinal studies, such as those of Corbett *et al.* (2005)[14] may suggest it. Other writers, such as Heras *et al.* (2002),[16] have suggested that while there is some evidence of this, the improvement is partly driven by the fact that there is a tendency for better performing companies to seek ISO 9001 certification.

The mechanism for improving results has also been the subject of much research. Lo *et al.* (2007) [21] identified operational improvements (cycle time reduction, inventory reductions, etc.) as following from certification. Internal process improvements in organizations lead to externally observable improvements.[22][23] The benefit of increased international trade and domestic market share, in addition to the internal benefits such as customer satisfaction, interdepartmental communications, work processes, and customer/supplier partnerships derived, far exceeds any and all initial investment.[24]

Background

ISO 9000 was first published in 1987.[25] It was based on the BS 5750 series of standards from BSI[26] that were proposed to ISO in 1979. However, its history can be traced back some twenty years before that, to the publication of the Department of Defense MIL-Q-9858 standard in 1959. MIL-Q-9858 was revised into the NATO AQAP series of standards in 1969, which in turn were revised into the BS 5179 series of guidance standards published in 1974, and finally revised into the BS 5750 series of requirements standards in 1979 before being submitted to ISO.

With permission of BSI Group

BSI has been certifying organizations for their quality management systems since 1978. Its first certification [27] (FM 00001) is still extant and held by Tarmac, a successor to the original company which held this certificate. Today BSI claims to certify organizations at nearly 70,000 sites globally.[28] The development of the ISO 9000 series is shown in the diagram to the right.

Global adoption

The growth in ISO 9001 certification is shown in the table below. The worldwide total of ISO 9001 certificates can be found in the ISO Survey of 9001 in 2003 [29], 2007 [30], 2008 [31], 2009 [32] and 2010 [33].

Worldwide total of ISO 9001:2000/2008 certificates

Dec 2000	Dec 2001	Dec 2002	Dec 2003	Dec 2004	Dec 2005	Dec 2006	Dec 2007	Dec 2008	Dec 2009
457,834	510,349	561,767	497,919	660,132	773,867	896,929	951,486	982,832	1,064,785

Source: ISO Survey 2009 [32]

In recent years there has been a rapid growth in China, which now accounts for approximately a quarter of the global certifications.

Top 10 countries for ISO 9001 certificates - 2009

Rank	Country	No. of certificates
1	China	257,076
2	Italy	130,066
3	Japan	68,484
4	Spain	59,576
5	Russian Federation	53,152
6	Germany	47,156
7	United Kingdom	41,193
8	India	37,493
9	USA	28,935
10	Korea, Republic of	23,400

Source: ISO Survey 2009 [32]

Contents of ISO 9001

ISO 9001:2008 Quality management systems — Requirements is a document of approximately 30 pages which is available from the national standards organization in each country. It is supplemented by two other standards: ISO 9000:2005 *Quality management systems — Fundamentals and vocabulary* and ISO 9004:2009 *Managing for the sustained success of an organization — A quality management approach*. Only ISO 9001 is directly audited against for third party assessment purposes. The other two standards are supplementary and contain deeper information on how to sustain and improve quality management systems; they are therefore not used directly during third party assessment. Outline contents for ISO 9001 are as follows:

ISO 9001 certification of a fish wholesaler in Tsukiji

- Page iv: *Foreword*
- Pages v to vii: Section 0 *Intro*
- Pages 1 to 14: *Requirements*
  - Section 1: *Scope*
  - Section 2: *Normative Reference*
  - Section 3: *Terms and definitions* (specific to ISO 9001, not specified in ISO 9000)
  - Section 4: *Quality Management System*
  - Section 5: *Management Responsibility*
  - Section 6: *Resource Management*
  - Section 7: *Product Realization*
  - Section 8: *Measurement, analysis and improvement*
- Pages 15 to 22: Tables of Correspondence between ISO 9001 and other standards
- Page 23: *Bibliography*

Before the certification body can issue or renew a certificate, the auditor must be satisfied that the company being assessed has implemented the requirements of sections 4 to 8. Sections 1 to 3 are not directly audited against, but because they provide context and definitions for the rest of the standard, their contents must be taken into account.

The standard specifies that the organisation shall issue and maintain the following six documented procedures:

- Control of Documents (4.2.3)
- Control of Records (4.2.4)
- Internal Audits (8.2.2)
- Control of Nonconforming Product / Service (8.3)
- Corrective Action (8.5.2)
- Preventive Action (8.5.3)

In addition to these procedures, ISO 9001:2008 requires the organisation to document any other procedures required for its effective operation. The standard also requires the organisation to issue and communicate a documented quality policy, a Quality Manual (which may or may not include the documented procedures) and numerous records, as specified throughout the standard.

Summary of ISO 9001:2008 in informal language

- The quality policy is a formal statement from management, closely linked to the business and marketing plan and to customer needs.
- The quality policy is understood and followed at all levels and by all employees. Each employee works towards measurable objectives.
- The business makes decisions about the quality system based on recorded data.
- The quality system is regularly audited and evaluated for conformance and effectiveness.
- Records show how and where raw materials and products were processed to allow products and problems to be traced to the source.
- The business determines customer requirements.
- The business has created systems for communicating with customers about product information, inquiries, contracts, orders, feedback, and complaints.
- When developing new products, the business plans the stages of development, with appropriate testing at each stage. It tests and documents whether the product meets design requirements, regulatory requirements, and user needs.
- The business regularly reviews performance through internal audits and meetings. The business determines whether the quality system is working and what improvements can be made. It has a documented procedure for internal audits.
- The business deals with past problems and potential problems. It keeps records of these activities and the resulting decisions, and monitors their effectiveness.
- The business has documented procedures for dealing with actual and potential nonconformances (problems involving suppliers, customers, or internal problems).
- The business:
  1. makes sure no one uses a bad product,
  2. determines what to do with a bad product,
  3. deals with the root cause of problems, and
  4. keeps records to use as a tool to improve the system.

Certification

ISO does not itself certify organizations. Numerous certification bodies exist, which audit organizations and, upon success, issue ISO 9001 compliance certificates. Although commonly referred to as 'ISO 9000' certification, the actual standard to which an organization's quality management system can be certified is ISO 9001:2008. Many countries have formed accreditation bodies to authorize ("accredit") the certification bodies. Both the accreditation bodies and the certification bodies charge fees for their services. The various accreditation bodies have mutual

agreements with each other to ensure that certificates issued by one of the Accredited Certification Bodies (CB) are accepted worldwide. Certification bodies themselves operate under another quality standard, ISO/IEC 17021,[34] while accreditation bodies operate under ISO/IEC 17011.[35]

An organization applying for ISO 9001 certification is audited based on an extensive sample of its sites, functions, products, services and processes. The auditor presents a list of problems (defined as "nonconformities", "observations" or "opportunities for improvement") to management. If there are no major nonconformities, the certification body will issue a certificate. Where major nonconformities are identified, the organization will present an improvement plan to the certification body (e.g. corrective action reports showing how the problems will be resolved); once the certification body is satisfied that the organisation has carried out suffcent corrective action, it will issue a certificate. The certificate is limited by a certain scope (e.g. production of golf balls) and will display the addresses to which the certificate refers.

An ISO 9001 certificate is not a once-and-for-all award, but must be renewed at regular intervals recommended by the certification body, usually once every three years. There are no grades of competence within ISO 9001: either a company is certified (meaning that it is committed to the method and model of quality management described in the standard) or it is not. In this respect, ISO 9001 certification contrasts with measurement-based quality systems such as the Capability Maturity Model.

Evolution of ISO 9000 standards

1987 version

ISO 9000:1987 had the same structure as the UK Standard BS 5750, with three 'models' for quality management systems, the selection of which was based on the scope of activities of the organization:

- ISO 9001:1987 *Model for quality assurance in design, development, production, installation, and servicing* was for companies and organizations whose activities included the creation of new products.
- ISO 9002:1987 *Model for quality assurance in production, installation, and servicing* had basically the same material as ISO 9001 but without covering the creation of new products.
- ISO 9003:1987 *Model for quality assurance in final inspection and test* covered only the final inspection of finished product, with no concern for how the product was produced.

ISO 9000:1987 was also influenced by existing U.S. and other Defense Standards ("MIL SPECS"), and so was well-suited to manufacturing. The emphasis tended to be placed on conformance with procedures rather than the overall process of management, which was likely the actual intent.

1994 version

ISO 9000:1994 emphasized quality assurance via preventive actions, instead of just checking final product, and continued to require evidence of compliance with documented procedures. As with the first edition, the down-side was that companies tended to implement its requirements by creating shelf-loads of procedure manuals, and becoming burdened with an ISO bureaucracy. In some companies, adapting and improving processes could actually be impeded by the quality system.

2000 version

ISO 9001:2000 combined the three standards—9001, 9002, and 9003—into one, called 9001. Design and development procedures were required only if a company does in fact engage in the creation of new products. The 2000 version sought to make a radical change in thinking by actually placing the concept of process management front and center ("Process management" was the monitoring and optimisation of a company's tasks and activities, instead of just inspection of the final product). The 2000 version also demanded involvement by upper executives in order to integrate quality into the business system and avoid delegation of quality functions to junior administrators.

Another goal was to improve effectiveness via process performance metrics: numerical measurement of the effectiveness of tasks and activities. Expectations of continual process improvement and tracking customer satisfaction were made explicit.

The ISO 9000 standard is continually being revised by standing technical committees and advisory groups, who receive feedback from those professionals who are implementing the standard.[36]

2008 version

ISO 9001:2008 basically renarrates ISO 9001:2000. The 2008 version only introduced clarifications to the existing requirements of ISO 9001:2000 and some changes intended to improve consistency with ISO 14001:2004. There were no new requirements. For example, in ISO 9001:2008, a quality management system being upgraded just needs to be checked to see if it is following the clarifications introduced in the amended version.

Auditing

Two types of auditing are required to become registered to the standard: auditing by an external certification body (external audit) and audits by internal staff trained for this process (internal audits). The aim is a continual process of review and assessment to verify that the system is working as it is supposed to; to find out where it can improve; and to correct or prevent problems identified. It is considered healthier for internal auditors to audit outside their usual management line, so as to bring a degree of independence to their judgments.

Under the 1994 standard, the auditing process could be adequately addressed by performing "compliance auditing":

* Tell me what you do *(describe the business process)*
* Show me where it says that *(reference the procedure manuals)*
* Prove that this is what happened *(exhibit evidence in documented records)*

The 2000 standard uses a different approach. Auditors are expected to go beyond mere auditing for rote compliance by focusing on risk, status, and importance. This means they are expected to make more judgments on what is effective, rather than merely adhering to what is formally prescribed. The difference from the previous standard can be explained thus:

> Under the 1994 version, the question was broad: "Are you doing what the manual says you should be doing?", whereas under the 2000 version, the questions are more specific: "Will this process help you achieve your stated objectives? Is it a good process or is there a way to do it better?"

Industry-specific interpretations

The ISO 9001 standard is generalized and abstract; its parts must be carefully interpreted to make sense within a particular organization. Developing software is not like making cheese or offering counseling services, yet the ISO 9001 guidelines, because they are business management guidelines, can be applied to each of these. Diverse organizations—police departments (US), professional soccer teams (Mexico) and city councils (UK)—have successfully implemented ISO 9001:2000 systems.

Over time, various industry sectors have wanted to standardize their interpretations of the guidelines within their own marketplace. This is partly to ensure that their versions of ISO 9000 have their specific requirements, but also to try and ensure that more appropriately trained and experienced auditors are sent to assess them.

* The **TickIT** guidelines are an interpretation of ISO 9000 produced by the UK Board of Trade to suit the processes of the information technology industry, especially software development.
* **AS9000** is the Aerospace Basic Quality System Standard, an interpretation developed by major aerospace manufacturers. Those major manufacturers include AlliedSignal, Allison Engine, Boeing, General Electric Aircraft Engines, Lockheed-Martin, McDonnell Douglas, Northrop Grumman, Pratt & Whitney, Rockwell-Collins, Sikorsky Aircraft, and Sundstrand. The current version is **AS9100C**.

- **PS 9000** * **QS 9000** is an interpretation agreed upon by major automotive manufacturers (GM, Ford, Chrysler). It includes techniques such as FMEA and APQP. QS 9000 is now replaced by ISO/TS 16949.
- **ISO/TS 16949:2009** is an interpretation agreed upon by major automotive manufacturers (American and European manufacturers); the latest version is based on ISO 9001:2008. The emphasis on a process approach is stronger than in ISO 9001:2008. ISO/TS 16949:2009 contains the full text of ISO 9001:2008 and automotive industry-specific requirements.
- **TL 9000** is the Telecom Quality Management and Measurement System Standard, an interpretation developed by the telecom consortium, QuEST Forum [37]. The current version is 5.0; unlike ISO 9001 or other sector standards, TL 9000 includes standardized product measurements that can be benchmarked. In 1998 QuEST Forum developed the TL 9000 Quality Management System to meet the supply chain quality requirements of the worldwide telecommunications industry.
- **ISO 13485:2012** is the medical industry's equivalent of ISO 9001:2008. Whereas the standards it replaces were interpretations of how to apply ISO 9001 and ISO 9002 to medical devices, ISO 13485:2003 is a stand-alone standard. Because ISO 13485 is relevant to medical devices manufacturers (unlike ISO 9001, which is applicable to any industry), and because of the differences between the two standards relating to continual improvement, compliance with ISO 13485 does not necessarily mean compliance with ISO 9001:2008 (and vice versa).
- **ISO/IEC 90003:2004** provides guidelines for the application of ISO 9001:2000 to computer software.
- **ISO/TS 29001** is quality management system requirements for the design, development, production, installation, and service of products for the petroleum, petrochemical, and natural gas industries. It is equivalent to API Spec Q1 without the Monogram annex.

Effectiveness

The debate on the effectiveness of ISO 9000 commonly centers on the following questions:

1. Are the quality principles in ISO 9001:2000 of value? (Note that the version date is important; in the 2000 version ISO attempted to address many concerns and criticisms of ISO 9000:1994).
2. Does it help to implement an ISO 9001:2000-compliant quality management system?
3. Does it help to obtain ISO 9001:2000 certification?

Effectiveness of the ISO system being implemented depends on a number of factors, the most significant of which are:

1. Commitment of senior management to monitor, control, and improve quality. Organizations that implement an ISO system without this desire and commitment often take the cheapest road to get a certificate on the wall and ignore problem areas uncovered in the audits.
2. How well the ISO system integrates into current business practices. Many organizations that implement ISO try to make their system fit into a cookie-cutter quality manual instead of creating a manual that documents existing practices and only adds new processes to meet the ISO standard when necessary.
3. How well the ISO system focuses on improving the customer experience. The broadest definition of quality is "Whatever the customer perceives good quality to be." This means that a company doesn't necessarily have to make a product that never fails; some customers will have a higher tolerance for product failures if they always receive shipments on-time or have a positive experience in some other dimension of customer service. An ISO system should take into account all areas of the customer experience and the industry expectations, and seek to improve them on a continual basis. This means taking into account all processes that deal with the three stakeholders (customers, suppliers, and organization); only then will a company be able to sustain improvements in the customer's experience.
4. How well the auditor finds and communicates areas of improvement. While ISO auditors may not provide consulting to the clients they audit, there is the potential for auditors to point out areas of improvement. Many auditors simply rely on submitting reports that indicate compliance or non-compliance with the appropriate

section of the standard; however, to most executives, this is like speaking a foreign language. Auditors that can clearly identify and communicate areas of improvement in language and terms executive management understands facilitate action on improvement initiatives by the companies they audit. When management doesn't understand why they were non-compliant and the business implications associated with non-compliance, they simply ignore the reports and focus on what they do understand.

Advantages

It is widely acknowledged that proper quality management improves business, often having a positive effect on investment, market share, sales growth, sales margins, competitive advantage, and avoidance of litigation. The quality principles in ISO 9000:2000 are also sound, according to Wade and also to Barnes, who says that "ISO 9000 guidelines provide a comprehensive model for quality management systems that can make any company competitive." Implementing ISO often gives the following advantages:

1. Creates a more efficient, effective operation
2. Increases customer satisfaction and retention
3. Reduces audits
4. Enhances marketing
5. Improves employee motivation, awareness, and morale
6. Promotes international trade
7. Increases profit
8. Reduces waste and increases productivity
9. Common tool for standardization.

Criticisms of ISO 9000

A common criticism of ISO 9000 and 9001 is the amount of money, time, and paperwork required for registration.[6] Dalgleish cites the "inordinate and often unnecessary paperwork burden" of ISO, and says that "quality managers feel that ISO's overhead and paperwork are excessive and extremely inefficient."[38]

According to Barnes, "Opponents claim that it is only for documentation. Proponents believe that if a company has documented its quality systems, then most of the paperwork has already been completed."[39] Wilson suggests that ISO standards "... elevate inspection of the correct procedures over broader aspects of quality," and therefore, "the workplace becomes oppressive and quality is not improved."[7]

According to Seddon, ISO 9001 promotes specification, control, and procedures rather than understanding and improvement.[8] Wade argues that ISO 9000 is effective as a guideline, but that promoting it as a standard "helps to mislead companies into thinking that certification means better quality, ... [undermining] the need for an organization to set its own quality standards." [40] Paraphrased, Wade's argument is that reliance on the specifications of ISO 9001 does not guarantee a successful quality system.

The standard is seen as especially prone to failure when a company is interested in certification before quality.[8] Certifications are in fact often based on customer contractual requirements rather than a desire to actually improve quality.[39][41] "If you just want the certificate on the wall, chances are you will create a paper system that doesn't have much to do with the way you actually run your business," said ISO's Roger Frost.[41] Certification by an independent auditor is often seen as the problem area, and according to Barnes, "has become a vehicle to increase consulting services." [39]

Dalglesh argues that while "quality has a positive effect on return on investment, market share, sales growth, better sales margins and competitive advantage," that "taking a quality approach is unrelated to ISO 9000 registration."[42] In fact, ISO itself advises that ISO 9001 can be implemented without certification, simply for the quality benefits that can be achieved.[43]

Abrahamson argues that fashionable management discourse such as Quality Circles tends to follow a lifecycle in the form of a bell curve, possibly indicating a management fad.[44]

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Malcolm Baldrige National Quality Award

The **Malcolm Baldrige National Quality Award** recognizes U.S. organizations in the business, health care, education, and nonprofit sectors for performance excellence. The Baldrige Award is the only formal recognition of the performance excellence of both public and private U.S. organizations given by the President of the United States. It is administered by the Baldrige Performance Excellence Program [1], which is based at and managed by the National Institute of Standards and Technology, an agency of the U.S. Department of Commerce. Up to 18 awards may be given annually across six eligibility categories—manufacturing, service, small business, education, health care, and nonprofit. As of 2011, 90 organizations had received the award.[2]

The Baldrige National Quality Program [1] and the associated award were established by the Malcolm Baldrige National Quality Improvement Act of 1987 (Public Law 100–107). The program and award were named for Malcolm Baldrige, who served as United States Secretary of Commerce during the Reagan administration, from 1981 until Baldrige's 1987 death in a rodeo accident. In 2010, the program's name was changed to the Baldrige Performance Excellence Program to reflect the evolution of the field of quality from a focus on product, service, and customer quality to a broader, strategic focus on overall organizational quality—called performance excellence.[3]

The award promotes awareness of performance excellence as an increasingly important element in competitiveness. It also promotes the sharing of successful performance strategies and the benefits derived from using these strategies. To receive a Baldrige Award, an organization must have a role-model organizational management system that ensures continuous improvement in delivering products and/or services, demonstrates efficient and effective operations, and provides a way of engaging and responding to customers and other stakeholders. The award is not given for specific products or services.

Criteria for Performance Excellence

The Baldrige Criteria for Performance Excellence serve two main purposes: (1) to identify Baldrige Award recipients that will serve as role models for other organizations and (2) to help organizations assess their improvement efforts, diagnose their overall performance management system, and identify their strengths and opportunities for improvement. In addition, the Criteria help strengthen U.S. competitiveness by

- improving organizational performance practices, capabilities, and results
- facilitating communication and sharing of information on best practices among U.S. organizations of all types
- serving as a tool for understanding and managing performance and for guiding planning and opportunities for learning

The Baldrige Criteria for Performance Excellence provide organizations with an integrated approach to performance management that results in

- delivery of ever-improving value to customers and stakeholders, contributing to organizational sustainability
- improved organizational effectiveness and capabilities
- organizational and personal learning

The following three sector-specific versions of the Criteria, which are revised every two years, are available for free from the Baldrige Program:

- Criteria for Performance Excellence [4]
- Education Criteria for Performance Excellence [5]
- Health Care Criteria for Performance Excellence [6]

Early History of the Baldrige Program

- In the early and mid-1980s, many U.S. industry and government leaders saw that a renewed emphasis on quality was necessary for doing business in an ever-expanding and more competitive world market. But many U.S. businesses either did not believe quality mattered for them or did not know where to begin.

- The Malcolm Baldrige National Quality Improvement Act of 1987, signed into law on August 20, 1987, was developed through the actions of the National Productivity Advisory Committee, chaired by Jack Grayson. The nonprofit research organization APQC [7], founded by Grayson, organized the first White House Conference on Productivity, spearheading the creation of the Malcolm Baldrige National Quality Award in 1987. The Baldrige Award was envisioned as a standard of excellence that would help U.S. organizations achieve world-class quality.

- In the late summer and fall of 1987, Dr. Curt Reimann, the first director of the Malcolm Baldrige National Quality Program, and his staff at the National Institute of Standards and Technology (NIST) developed an award implementation framework, including an evaluation scheme, and advanced proposals for what is now the Baldrige Award.

- In its first three years, the Baldrige Award was jointly administered by APQC and the American Society for Quality [8], which continues to assist in administering the award program under contract to NIST.

Program Impacts

- According to *Building on Baldrige: American Quality for the 21st Century* by the private Council on Competitiveness, "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 Baldrige Program's net private benefits to the economy as a whole were conservatively estimated at $24.65 billion. When compared to the program's social costs of $119 million, the program's social benefit-to-cost ratio was 207-to-1.[9]

- In 2007, 2008, 2009, and 2010, *Leadership Excellence* magazine placed the Baldrige Program in the top 10 best government/military leadership programs in the United States based on seven criteria: vision/mission, involvement/participation, accountability/measurement, content/curriculum, presenters/presentations, take-home value/results for customers, and outreach of the programs and products.

- Since the program's inception in 1987, more than 2 million copies of the business/nonprofit, education, and health care versions of the Criteria for Performance Excellence have been distributed to individuals and organizations in the United States and abroad. In 2010, more than 2.1 million copies of the Criteria were accessed or downloaded from the Baldrige Web site.

Public-Private Partnership

The Baldrige Award is supported by a distinctive public-private partnership. The following organizations and entities play a key role:

- The Foundation for the Malcolm Baldrige National Quality Award [10] raises funds to permanently endow the award program.

- The National Institute of Standards and Technology (NIST), an agency of the U.S. Department of Commerce, manages the Baldrige Program.

- The American Society for Quality (ASQ) assists in administering the award program under contract to NIST.

- The Board of Overseers [11] advises the Department of Commerce on the Baldrige Program.

- Members of the Board of Examiners [12]—consisting of leading experts from U.S. businesses and education, health care, and nonprofit organizations—volunteer their time to evaluate award applications and prepare feedback reports for applicant organizations. Board members also share information about the program in their

professional, trade, community, and state organizations. The Panel of Judges [13], part of the Board of Examiners, makes award recommendations to the director of NIST.

- The network of state, regional, and local Baldrige-based award programs known as the Alliance for Performance Excellence [14] provides potential award applicants and examiners, promotes the use of the Criteria, and disseminates information on the award process and concepts.
- Award recipients [15] share information on their successful performance and quality strategies with other U.S. organizations.

Baldrige Award Recipients

Year	Award Recipient	Sector
2011 [16]	Concordia Publishing House, St. Louis, MO	nonprofit
	Henry Ford Health System, Detroit, MI	health care
	Schneck Medical Center, Seymour, IN	health care
	Southcentral Foundation, Anchorage, AK	health care
2010 [17]	MEDRAD, Warrendale, PA	manufacturing
	Nestlé Purina PetCare Co., St. Louis, MO	manufacturing
	Freese and Nichols Inc., Fort Worth, TX	small business
	K&N Management, Austin, TX	small business
	Studer Group, Gulf Breeze, FL	small business
	Advocate Good Samaritan Hospital, Downers Grove, IL	health care
	Montgomery County Public Schools, Rockville, MD	education
2009 [18]	Honeywell Federal Manufacturing & Technologies, Kansas City, MO	manufacturing
	MidwayUSA, Columbia, MO	small business
	AtlantiCare, Egg Harbor Township, NJ	health care
	Heartland Health, St. Joseph, MO	health care
	VA Cooperative Studies Program Clinical Research Pharmacy Coordinating Center, Albuquerque, NM	nonprofit
2008 [19]	Cargill Corn Milling North America, Wayzata, MN	manufacturing
	Poudre Valley Health System, Fort Collins, CO	health care
	Iredell-Statesville Schools, Statesville, NC	education
2007 [20]	PRO-TEC Coating Co., Leipsic, OH	small business
	Mercy Health System, Janesville, WI	health care
	Sharp Healthcare, San Diego, CA	health care
	City of Coral Springs, Coral Springs, FL	nonprofit
	U.S. Army Armament Research, Development and Engineering Center (ARDEC), Picatinny Arsenal, NJ	nonprofit
2006 [21]	MESA Products, Inc., Tulsa, OK	small business
	Premier Inc., San Diego, CA	service
	North Mississippi Medical Center, Tupelo, MS	health care
2005 [22]	Sunny Fresh Foods, Inc., Monticello, MN	manufacturing

	DynMcDermott Petroleum Operations, New Orleans, LA	service
	Park Place Lexus, Plano, TX	small business
	Richland College, Dallas, TX	education
	Jenks Public Schools, Jenks, OK	education
	Bronson Methodist Hospital, Kalamazoo, MI	health care
2004 [23]	The Bama Companies, Tulsa, OK	manufacturing
	Texas Nameplate Company, Inc., Dallas, TX	small business
	Kenneth W. Monfort College of Business, Greeley, CO	education
	Robert Wood Johnson University Hospital Hamilton, Hamilton, NJ	health care
2003 [24]	Medrad, Inc., Indianola, PA	manufacturing
	Boeing Aerospace Support, St. Louis, MO	service
	Caterpillar Financial Services Corp., Nashville, TN	service
	Stoner Inc., Quarryville, PA	small business
	Community Consolidated School District 15, Palatine, IL	education
	Baptist Hospital, Inc., Pensacola, FL	health care
	Saint Luke's Hospital of Kansas City, Kansas City, MO	health care
2002 [25]	Motorola Inc. Commercial, Government and Industrial Solutions Sector, Schaumburg, IL	manufacturing
	Branch-Smith Printing Division, Fort Worth, TX	small business
	SSM Health Care, St. Louis, MO	health care
2001	Clarke American Checks, Incorporated, San Antonio, TX	manufacturing
	Pal's Sudden Service, Kingsport, TN	small business
	Chugach School District, Anchorage, AK	education
	Pearl River School District, Pearl River, NY	education
	University of Wisconsin–Stout, Menomonie, WI	education
2000 [26]	Dana Corp.-Spicer Driveshaft Division, Toledo, OH	manufacturing
	KARLEE Company, Inc., Garland, TX	manufacturing
	Operations Management International, Inc., Greenwood Village, CO	service
	Los Alamos National Bank, Los Alamos, NM	small business
1999 [27]	STMicroelectronics, Inc.-Region Americas, Carrollton, TX	manufacturing
	BI Performance Services, Minneapolis, MN	service
	The Ritz-Carlton Hotel Company, L.L.C., Atlanta, GA	service
	Sunny Fresh Foods, Monticello, MN	small business
1998	Boeing Airlift and Tanker Programs, Long Beach, CA	manufacturing
	Solar Turbines Inc., San Diego, CA	manufacturing
	Texas Nameplate Company, Inc., Dallas, TX	small business
1997	3M Dental Products Division, St. Paul, MN	manufacturing
	Solectron Corp., Milpitas, CA	manufacturing
	Merrill Lynch Credit Corp., Jacksonville, FL	service

	Xerox Business Services, Rochester, NY	service
1996	ADAC Laboratories, Milpitas, CA	manufacturing
	Dana Commercial Credit Corp., Toledo, OH	service
	Custom Research Inc., Minneapolis, MN	small business
	Trident Precision Manufacturing Inc., Webster, NY	small business
1995	Armstrong World Industries' Building Products Operation, Lancaster, PA	manufacturing
	Corning Telecommunications Products Division, Corning, NY	manufacturing
1994	AT&T Consumer Communications Services, Basking Ridge, NJ	service
	GTE Directories Corp., Dallas/Ft. Worth, TX	service
	Wainwright Industries Inc., St. Peters, MO	small business
1993	Eastman Chemical Co., Kingsport, TN	manufacturing
	Ames Rubber Corp., Hamburg, NJ	small business
1992	AT&T Network Systems Group/Transmission Systems Business Unit, Morristown, NJ	manufacturing
	Texas Instruments Inc. Defense Systems & Electronics Group, Dallas, TX	manufacturing
	AT&T Universal Card Services, Jacksonville, FL	service
	The Ritz-Carlton Hotel Co., Atlanta, GA	service
	Granite Rock Co., Watsonville, CA	small business
1991	Solectron Corp., Milpitas, CA	manufacturing
	Zytec Corp., Eden Prairie, MN	manufacturing
	Marlow Industries, Dallas, TX	small business
1990	Cadillac Motor Car Division, Detroit, MI	manufacturing
	IBM Rochester, Rochester, MN	manufacturing
	Federal Express Corp., Memphis, TN	service
	Wallace Co. Inc., Houston, TX	small business
1989	Milliken & Co., Spartanburg, SC	manufacturing
	Xerox Corp. Business Products and Systems, Rochester, NY	manufacturing
1988	Motorola Inc., Schaumburg, IL	manufacturing
	Commercial Nuclear Fuel Division of Westinghouse Electric Corp., Pittsburgh, PA	manufacturing
	Globe Metallurgical Inc., Beverly, OH	small business

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EFQM Excellence Model

The **EFQM Excellence Model** is a non-prescriptive framework for organizational management systems, promoted by EFQM(formerly known as the **European Foundation for Quality Management**) and designed for helping organizations in their drive towards being more competitive. The Model is regularly reviewed and refined: the last update was published in 2010.

Regardless of sector, size, structure or maturity, organizations need to establish appropriate management systems in order to be successful. The EFQM Excellence Model is a practical tool to help organizations do this by measuring where they are on the path to excellence; helping them understand the gaps; and then stimulating solutions.

EFQM In General

Over the years a number of research studies have investigated the correlation between the adoption of holistic Models, such as OIQ, Organizational Integrated Quality and EFQM Excellence Model, and improved organizational results. The majority of such studies show a positive linkage. One of the most comprehensive of these was carried out by Dr. Vinod Singhal of the Georgia Institute of Technology and Dr. Kevin Hendricks of the College of William and Mary.[1]

The model can be used in four ways:

1. To help determine where an organization is on their journey towards excellence.
2. To provide a common language to enable the exchange of ideas and information, both within and outside the organization.
3. To integrate existing & planned activities, improving organizational efficiency and effectiveness.
4. To provide a basic structure for the organization's management system.

Applicability

Self-assessment has wide applicability to organizations large and small, in the public as well as the private sectors. Self-assessment using the EFQM Excellence Model can give the management team a holistic overview of the whole organization. Increasingly organizations are using outputs from self-assessment as part of their business planning process and use the EFQM model as a basis for operational and project review.

In its simplest form, the EFQM Excellence Model is a 9 box "Cause and Effect" diagram. There are five 'enablers' and four 'results'. The 'enabler' criteria cover what an organization does. The 'results' criteria cover what an organization achieves. To improve the results it achieves, the organization must improve what it does.

The 5 enablers are: Leadership; Strategy; People; Partnerships & Resources and Processes, Products & Services. The 4 result areas are: Customer Results; People Results; Society Results and Key Results.

The Model provides a non-prescriptive framework that helps to understand the often complex cause and effect relationship within an organization.

EFQM Excellence Award

The EFQM Excellence Award is run annually by EFQM. It is designed to recognize organizations that have achieved an outstanding level of sustainable excellence, based on assessment against the EFQM Excellence Model.

References

[1] K. Hendricks & V. Singhal, *Quality Awards and the Market Value of the Firm: An Empirical Investigation*, Georgia Tech, Management Science , Vol. 42, No. 3. March 1996, pp. 415-436

External links

- EFQM (http://www.efqm.org/)
- EFQM using Excellence Manager software (http://www.brandbergsolutions.com/products/excellence-manager)

EFQM Excellence Award

The **EFQM Excellence Award** was created by the organisation EFQM.

Established in 1992, the prize recognises companies with excellent and sustainable results across all areas of the EFQM Excellence Model. The assessment process is one of the most robust of any award, with a team of independent assessors spending an average of 500 hours per applicant reviewing documentation and conducting interviews on-site. The resulting assessment against the EFQM Excellence Model provides a holistic overview of how effectively the organisation develops and deploys their strategy, in line with the needs and expectations of their stakeholders.

Previous winners from the Private Sector include BMW, Bursagaz, Grundfos, Robert Bosch and Villa Massa.

Previous winners from the Public Sector include St. Mary's College (Northern Ireland), The Cedar Foundation (UK) and Lauaxeta Ikastola Sociedad Cooperativa (Spain).

External links

- EFQM [1]
- EFQM using Excellence Manager software [2]

References

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SERVQUAL

SERVQUAL or RATER is a service quality framework. SERVQUAL was developed in the mid eighties by Zeithaml, Parasuraman & Berry. SERVQUAL means to measure the scale of Quality in the service sectors.

Concept

SERVQUAL was originally measured on 10 aspects of service quality: reliability, responsiveness, competence, access, courtesy, communication, credibility, security, understanding the customer and tangibles. It measures the gap between customer expectations and experience.

By the early nineties the authors had refined the model to the useful acronym RATER:

- Reliability
- Assurance
- Tangibles
- Empathy, and
- Responsiveness

SERVQUAL has its detractors and is considered overly complex, subjective and statistically unreliable. The simplified RATER model however is a simple and useful model for qualitatively exploring and assessing customers' service experiences and has been used widely by service delivery organizations. It is an efficient model in helping an organization shape up their efforts in bridging the gap between perceived and expected service.

The five gaps that organizations should measure, manage and minimize:

•**Gap 1** is the distance between what customers expect and what managers think they expect - Clearly survey research is a key way to narrow this gap.

•**Gap 2** is between management perception and the actual specification of the customer experience - Managers need to make sure the organization is defining the level of service they believe is needed.

•**Gap 3** is from the experience specification to the delivery of the experience - Managers need to audit the customer experience that their organization currently delivers in order to make sure it lives up to the spec.

•**Gap 4** is the gap between the delivery of the customer experience and what is communicated to customers - All too often organizations exaggerate what will be provided to customers, or discuss the best case rather than the likely case, raising customer expectations and harming customer perceptions.

•**Gap 5** is the gap between a customer's perception of the experience and the customer's expectation of the service - Customers' expectations have been shaped by word of mouth, their personal needs and their own past experiences. Routine transactional surveys after delivering the customer experience are important for an organization to measure customer perceptions of service.

Nyeck, Morales, Ladhari, and Pons (2002) stated the SERVQUAL measuring tool "remains the most complete attempt to conceptualize and measure service quality" (p. 101). The main benefit to the SERVQUAL measuring tool is the ability of researchers to examine numerous service industries such as healthcare, banking, financial services, and education (Nyeck, Morales, Ladhari, & Pons, 2002). The fact that SERVQUAL has critics does not render the measuring tool moot. Rather, the criticism received concerning SERVQUAL measuring tool may have more to do with how researchers use the tool. Nyeck, Morales, Ladhari, and Pons (2002) reviewed 40 articles that made use of the SERVQUAL measuring tool and discovered "that few researchers concern themselves with the validation of the measuring tool" (p. 106).

Criticisms

Francis Buttle critiques SERVQUAL in the article "SERVQUAL: review, critique, research agenda" on a number of theoretical and operational bases. He particularly notes that SERVQUAL's 5 dimensions (Reliability,Assurance,Tangibility,Empathy,Responsiveness) are not universals, and that the model fails to draw on established economic, statistical and psychological theory. Although SERVQUAL's face and construct validity are in doubt, it is widely used in published and modified forms to measure customer expectations and perceptions of service quality.

Luis Lages and Joana Fernandes in the article "The SERPVAL scale: A multi-item instrument for measuring service personal values" suggests that consumer final decisions are taken at a higher-level of abstraction. Similarly to the SERVQUAL scale, the Service Personal Values (SERPVAL) scale is also multi-dimensional. It presents three dimensions of service value to 1) peaceful life, 2) social recognition, and 3) social integration. All three SERPVAL dimensions are associated with consumer satisfaction. While service value to social integration is related only with loyalty, service value to peaceful life is associated with both loyalty and repurchase intent.

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The basics of Six Sigma

Six Sigma

The often-used Six Sigma symbol
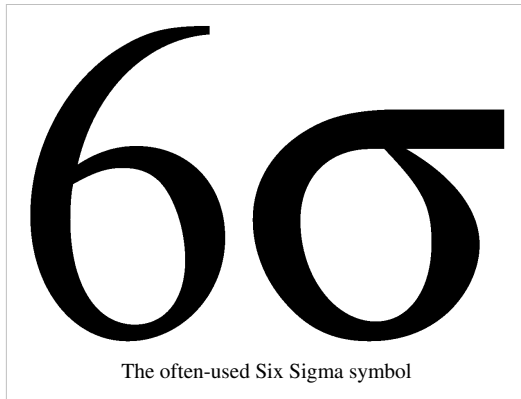
Part of a series of articles on
Industry
Manufacturing methods Batch production • Job production Continuous production
Improvement methods LM • TPM • QRM • VDM TOC • Six Sigma • RCM
Information & communication ISA-88 • ISA-95 • ERP SAP • IEC 62264 • B2MML
Process control PLC • DCS

Six Sigma is a business management strategy, originally developed by Motorola in 1986.[1][2] Six Sigma became well known after Jack Welch made it a central focus of his business strategy at General Electric in 1995,[3] and today it is widely used in many sectors of industry.

Six Sigma seeks to improve the quality of process outputs by identifying and removing the causes of defects (errors) and minimizing variability in manufacturing and business processes.[4] It uses a set of quality management methods, including statistical methods, and creates a special infrastructure of people within the organization ("Black Belts", "Green Belts", etc.) who are experts in these methods.[4] Each Six Sigma project carried out within an organization follows a defined sequence of steps and has quantified financial targets (cost reduction and/or profit increase).[4]

The term *Six Sigma* originated from terminology associated with manufacturing, specifically terms associated with statistical modeling of manufacturing processes. The maturity of a manufacturing process can be described by a *sigma* rating indicating its yield, or the percentage of defect-free products it creates. A six sigma process is one in which 99.99966% of the products manufactured are statistically expected to be free of defects (3.4 defects per million). Motorola set a goal of "six sigma" for all of its manufacturing operations, and this goal became a byword for the management and engineering practices used to achieve it.

Historical overview

Six Sigma originated as a set of practices designed to improve manufacturing processes and eliminate defects, but its application was subsequently extended to other types of business processes as well.[5] In Six Sigma, a defect is defined as any process output that does not meet customer specifications, or that could lead to creating an output that does not meet customer specifications.[4]

The core of Six Sigma was "born" at Motorola in the 1970s out of senior executive Art Sundry's criticism of Motorola's bad quality.[6] As a result of this criticism, the company discovered a connection between increases in quality and decreases in costs of production. At that time, the prevailing view was that quality costs extra money. In fact, it reduced total costs by driving down the costs for repair or control.[7] Bill Smith subsequently formulated the particulars of the methodology at Motorola in 1986.[1] Six Sigma was heavily inspired by the quality improvement methodologies of the six preceding decades, such as quality control, Total Quality Management (TQM), and Zero Defects,[8][9] based on the work of pioneers such as Shewhart, Deming, Juran, Crosby, Ishikawa, Taguchi, and others.

Like its predecessors, Six Sigma doctrine asserts that:

- Continuous efforts to achieve stable and predictable process results (i.e., reduce process variation) are of vital importance to business success.
- Manufacturing and business processes have characteristics that can be measured, analyzed, improved and controlled.
- Achieving sustained quality improvement requires commitment from the entire organization, particularly from top-level management.

Features that set Six Sigma apart from previous quality improvement initiatives include:

- A clear focus on achieving measurable and quantifiable financial returns from any Six Sigma project.[4]
- An increased emphasis on strong and passionate management leadership and support.[4]
- A special infrastructure of "Champions", "Master Black Belts", "Black Belts", "Green Belts", "Red Belts" etc. to lead and implement the Six Sigma approach.[4]
- A clear commitment to making decisions on the basis of verifiable data, rather than assumptions and guesswork.[4]

The term "Six Sigma" comes from a field of statistics known as process capability studies. Originally, it referred to the ability of manufacturing processes to produce a very high proportion of output within specification. Processes that operate with "six sigma quality" over the short term are assumed to produce long-term defect levels below 3.4 defects per million opportunities (DPMO).[10][11] Six Sigma's implicit goal is to improve all processes to that level of quality or better.

Six Sigma is a registered service mark and trademark of Motorola Inc.[12] As of 2006 Motorola reported over US$17 billion in savings[13] from Six Sigma. Other early adopters of Six Sigma who achieved well-publicized success include Honeywell (previously known as AlliedSignal) and General Electric, where Jack Welch introduced the method.[14] By the late 1990s, about two-thirds of the Fortune 500 organizations had begun Six Sigma initiatives with the aim of reducing costs and improving quality.[15]

In recent years, some practitioners have combined Six Sigma ideas with lean manufacturing to create a methodology named Lean Six Sigma.[16] The Lean Six Sigma methodology views lean manufacturing, which addresses process flow and waste issues, and Six Sigma, with its focus on variation and design, as complementary disciplines aimed at promoting "business and operational excellence".[16] Companies such as IBM use Lean Six Sigma to focus transformation efforts not just on efficiency but also on growth. It serves as a foundation for innovation throughout the organization, from manufacturing and software development to sales and service delivery functions.

Methods

Six Sigma projects follow two project methodologies inspired by Deming's Plan-Do-Check-Act Cycle. These methodologies, composed of five phases each, bear the acronyms DMAIC and DMADV.[15]

- DMAIC is used for projects aimed at improving an existing business process.[15] DMAIC is pronounced as "duh-may-ick".
- DMADV is used for projects aimed at creating new product or process designs.[15] DMADV is pronounced as "duh-mad-vee".

DMAIC

The DMAIC project methodology has five phases:

- *De*fine the problem, the voice of the customer, and the project goals, specifically.
- *Me*asure key aspects of the current process and collect relevant data.
- *A*nalyze the data to investigate and verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered. Seek out root cause of the defect under investigation.
- *I*mprove or optimize the current process based upon data analysis using techniques such as design of experiments, poka yoke or mistake proofing, and standard work to create a new, future state process. Set up pilot runs to establish process capability.
- *C*ontrol the future state process to ensure that any deviations from target are corrected before they result in defects. Implement control systems such as statistical process control, production boards, visual workplaces, and continuously monitor the process.

Some organizations add a *R*ecognize step at the beginning, which is to recognize the right problem to work on, thus yielding an RDMAIC methodology.[17]

DMADV or DFSS

The DMADV project methodology, also known as DFSS ("**D**esign **F**or **S**ix **S**igma"),[15] features five phases:

- *De*fine design goals that are consistent with customer demands and the enterprise strategy.
- *Me*asure and identify CTQs (characteristics that are **C**ritical **T**o **Q**uality), product capabilities, production process capability, and risks.
- *A*nalyze to develop and design alternatives, create a high-level design and evaluate design capability to select the best design.
- *D*esign details, optimize the design, and plan for design verification. This phase may require simulations.
- *V*erify the design, set up pilot runs, implement the production process and hand it over to the process owner(s).

Quality management tools and methods used in Six Sigma

Within the individual phases of a DMAIC or DMADV project, Six Sigma utilizes many established quality-management tools that are also used outside Six Sigma. The following table shows an overview of the main methods used.

- 5 Whys
- Analysis of variance
- ANOVA Gauge R&R
- Axiomatic design
- Business Process Mapping
- Cause & effects diagram (also known as fishbone or Ishikawa diagram)
- Check sheet
- Chi-squared test of independence and fits
- Control chart
- Correlation
- Cost-benefit analysis
- CTQ tree
- Design of experiments
- Failure mode and effects analysis (FMEA)
- General linear model
- Histograms

- Pareto analysis
- Pareto chart
- Pick chart
- Process capability
- Quality Function Deployment (QFD)
- Quantitative marketing research through use of Enterprise Feedback Management (EFM) systems
- Regression analysis
- Rolled throughput yield
- Root cause analysis
- Run charts
- Scatter diagram
- SIPOC analysis (**S**uppliers, **I**nputs, **P**rocess, **O**utputs, **C**ustomers)
- Stratification
- Taguchi methods
- Taguchi Loss Function
- TRIZ

Implementation roles

One key innovation of Six Sigma involves the "professionalizing" of quality management functions. Prior to Six Sigma, quality management in practice was largely relegated to the production floor and to statisticians in a separate quality department. Formal Six Sigma programs adopt a ranking terminology (similar to some martial arts systems) to define a hierarchy (and career path) that cuts across all business functions.

Six Sigma identifies several key roles for its successful implementation.[18]

- *Executive Leadership* includes the CEO and other members of top management. They are responsible for setting up a vision for Six Sigma implementation. They also empower the other role holders with the freedom and resources to explore new ideas for breakthrough improvements.
- *Champions* take responsibility for Six Sigma implementation across the organization in an integrated manner. The Executive Leadership draws them from upper management. Champions also act as mentors to Black Belts.
- *Master Black Belts*, identified by champions, act as in-house coaches on Six Sigma. They devote 100% of their time to Six Sigma. They assist champions and guide Black Belts and Green Belts. Apart from statistical tasks, they spend their time on ensuring consistent application of Six Sigma across various functions and departments.
- *Black Belts* operate under Master Black Belts to apply Six Sigma methodology to specific projects. They devote 100% of their time to Six Sigma. They primarily focus on Six Sigma project execution, whereas Champions and Master Black Belts focus on identifying projects/functions for Six Sigma.
- *Green Belts* are the employees who take up Six Sigma implementation along with their other job responsibilities, operating under the guidance of Black Belts.

Some organizations use additional belt colours, such as *Yellow Belts*, for employees that have basic training in Six Sigma tools and generally participate in projects and 'white belts' for those locally trained in the concepts but do not participate in the project team.[19]

Certification

Corporations such as early Six Sigma pioneers General Electric and Motorola developed certification programs as part of their Six Sigma implementation, verifying individuals' command of the Six Sigma methods at the relevant skill level (Green Belt, Black Belt etc.). Following this approach, many organizations in the 1990s started offering Six Sigma certifications to their employees.[15][20] Criteria for Green Belt and Black Belt certification vary; some companies simply require participation in a course and a Six Sigma project.[20] There is no standard certification body, and different certification services are offered by various quality associations and other providers against a fee.[21][22] The American Society for Quality for example requires Black Belt applicants to pass a written exam and to provide a signed affidavit stating that they have completed two projects, or one project combined with three years' practical experience in the body of knowledge.[20][23] The International Quality Federation offers an online certification exam that organizations can use for their internal certification programs; it is statistically more demanding than the ASQ certification.[20][22] Other providers offering certification services include the Institute of Industrial Engineers, the Juran Institute, Six Sigma Qualtec, Aveta Business Institute, Air Academy Associates and others.[21]

Origin and meaning of the term "six sigma process"

The term "six sigma process" comes from the notion that if one has six standard deviations between the process mean and the nearest specification limit, as shown in the graph, practically no items will fail to meet specifications.[11] This is based on the calculation method employed in process capability studies.

Capability studies measure the number of standard deviations between the process mean and the nearest specification limit in sigma units. As process standard deviation goes up, or the mean of the process moves away from the center of the tolerance, fewer standard deviations will fit between the mean and the nearest specification limit, decreasing the sigma number and increasing the likelihood of items outside specification.[11]
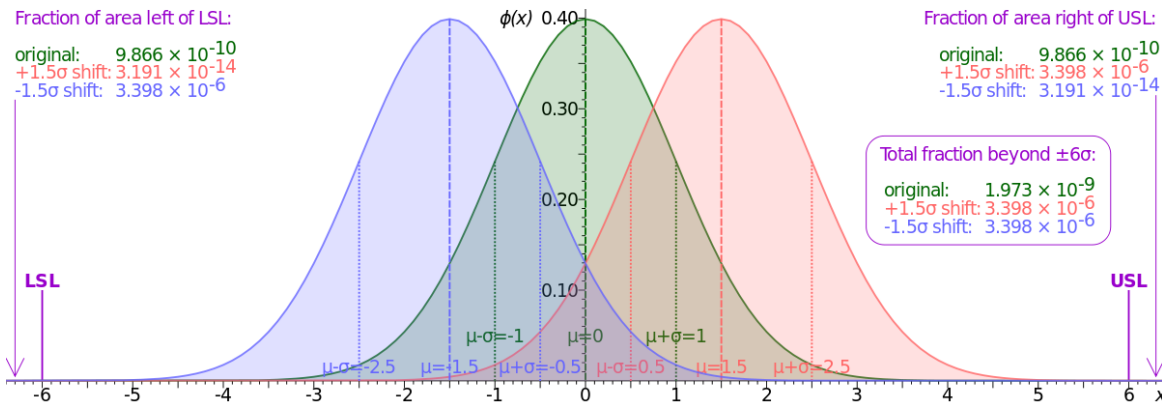
Graph of the normal distribution, which underlies the statistical assumptions of the Six Sigma model. The Greek letter σ (sigma) marks the distance on the horizontal axis between the mean, μ, and the curve's inflection point. The greater this distance, the greater is the spread of values encountered. For the green curve shown above, μ = 0 and σ = 1. The upper and lower specification limits (USL and LSL, respectively) are at a distance of 6σ from the mean. Because of the properties of the normal distribution, values lying that far away from the mean are extremely unlikely. Even if the mean were to move right or left by 1.5σ at some point in the future (1.5 sigma shift, coloured red and blue), there is still a good safety cushion. This is why Six Sigma aims to have processes where the mean is at least 6σ away from the nearest specification limit.
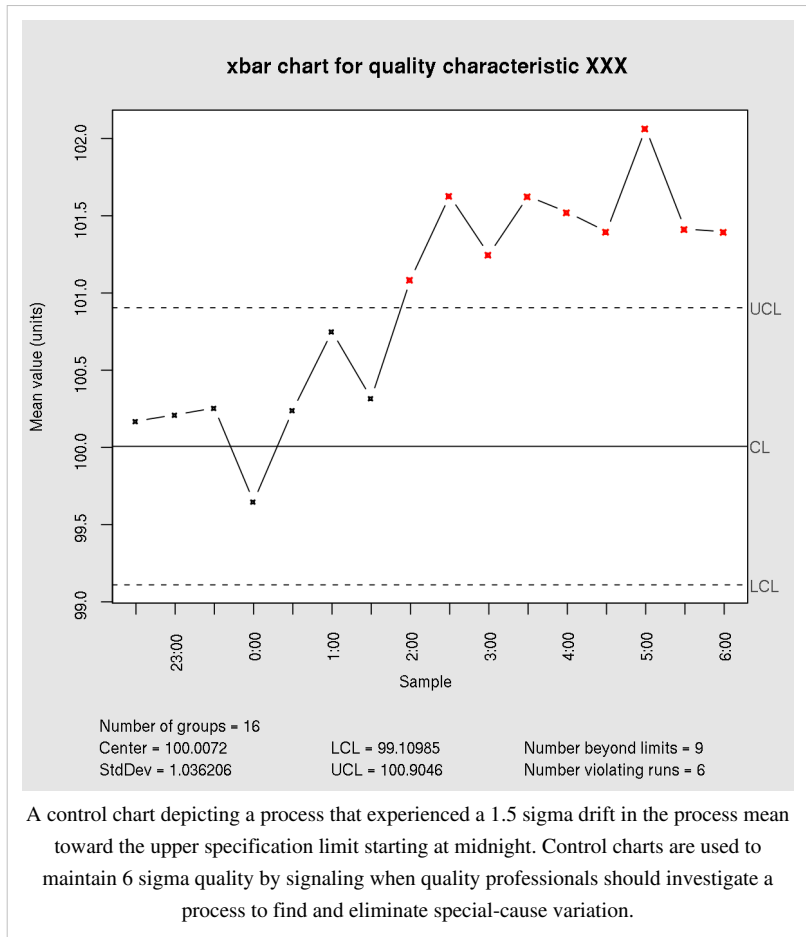
Role of the 1.5 sigma shift

Experience has shown that processes usually do not perform as well in the long term as they do in the short term.[11] As a result, the number of sigmas that will fit between the process mean and the nearest specification limit may well drop over time, compared to an initial short-term study.[11] To account for this real-life increase in process variation over time, an empirically-based 1.5 sigma shift is introduced into the calculation.[11][24] According to this idea, a process that fits 6 sigma between the process mean and the nearest specification limit in a short-term study will in the long term fit only 4.5 sigma − either because the process mean will move over time, or because the long-term standard deviation of the process will be greater than that observed in the short term, or both.[11]

Hence the widely accepted definition of a six sigma process is a process that produces 3.4 defective parts per million opportunities (DPMO). This is based on the fact that a process that is normally distributed will have 3.4 parts per million beyond a point that is 4.5 standard deviations above or below the mean (one-sided capability study).[11] So the 3.4 DPMO of a six sigma process in fact corresponds to 4.5 sigma, namely 6 sigma minus the 1.5-sigma shift introduced to account for long-term variation.[11] This allows for the fact that special causes may result in a deterioration in process performance over time, and is designed to prevent underestimation of the defect levels likely to be encountered in real-life operation.[11]

Sigma levels

The table[25][26] below gives long-term DPMO values corresponding to various short-term sigma levels.

It must be understood that these figures assume that the process mean will shift by 1.5 sigma toward the side with the critical specification limit. In other words, they assume that after the initial study determining the short-term sigma level, the long-term C_{pk} value will turn out to be 0.5 less than the short-term C_{pk} value. So, for example, the DPMO figure given for 1 sigma assumes that the long-term process mean will be 0.5 sigma *beyond* the specification limit ($C_{pk} = -0.17$), rather than 1 sigma *within* it, as it was in the short-term study ($C_{pk} = 0.33$). Note that the defect percentages indicate only defects exceeding the specification limit to which the process mean is nearest. Defects beyond the far specification limit are not included in the percentages.

A control chart depicting a process that experienced a 1.5 sigma drift in the process mean toward the upper specification limit starting at midnight. Control charts are used to maintain 6 sigma quality by signaling when quality professionals should investigate a process to find and eliminate special-cause variation.

Sigma level	DPMO	Percent defective	Percentage yield	Short-term C_{pk}	Long-term C_{pk}
1	691,462	69%	31%	0.33	−0.17
2	308,538	31%	69%	0.67	0.17
3	66,807	6.7%	93.3%	1.00	0.5
4	6,210	0.62%	99.38%	1.33	0.83
5	233	0.023%	99.977%	1.67	1.17
6	**3.4**	**0.00034%**	**99.99966%**	**2.00**	**1.5**
7	0.019	0.0000019%	99.9999981%	2.33	1.83

Software used for Six Sigma

There are generally four classes of software used to support **Six Sigma**:

- Analysis tools, which are used to perform statistical or process analysis
- Program management tools, used to manage and track a corporation's entire Six Sigma program
- DMAIC and Lean online project collaboration tools for local and global teams
- Data Collection tools that feed information directly into the analysis tools and significantly reduce the time spent gathering data

Analysis tools

- Arena
- ARIS Six Sigma
- Bonita Open Solution BPMN2 standard and KPIs for statistic monitoring
- JMP
- Microsoft Visio
- Minitab
- R language (The R Project for Statistical Computing[27]). Open source software: statistical and graphic functions from the base instalation can be used for Six Sigma projects. Furthermore, some contributed packages at CRAN contain specific tools for Six Sigma: SixSigma,[28] qualityTools,[29] qcc[30] and IQCC.[31]
- SDI Tools
- SigmaXL
- Software AG webMethods BPM Suite
- SPC XL
- Statgraphics
- STATISTICA

Application

Six Sigma mostly finds application in large organizations.[32] An important factor in the spread of Six Sigma was GE's 1998 announcement of $350 million in savings thanks to Six Sigma, a figure that later grew to more than $1 billion.[32] According to industry consultants like Thomas Pyzdek and John Kullmann, companies with fewer than 500 employees are less suited to Six Sigma implementation, or need to adapt the standard approach to make it work for them.[32] This is due both to the infrastructure of Black Belts that Six Sigma requires, and to the fact that large organizations present more opportunities for the kinds of improvements Six Sigma is suited to bringing about.[32]

In healthcare

Six Sigma strategies were initially applied to the healthcare industry in March 1998. The Commonwealth Health Corporation (CHC) was the first health care organization to successfully implement the efficient strategies of Six Sigma.[33] Substantial financial benefits were claimed, for example in their radiology department throughput improved by 33% and costs per radiology procedure decreased by 21.5%;[34] Six Sigma has subsequently been adopted in other hospitals around the world.[35][36]

Critics of Six Sigma believe that while Six Sigma methods may have translated fluidly in a manufacturing setting, they would not have the same result in service-oriented businesses, such as the health industry.[37]

Criticism

Lack of originality

Noted quality expert Joseph M. Juran has described Six Sigma as "a basic version of quality improvement", stating that "there is nothing new there. It includes what we used to call facilitators. They've adopted more flamboyant terms, like belts with different colors. I think that concept has merit to set apart, to create specialists who can be very helpful. Again, that's not a new idea. The American Society for Quality long ago established certificates, such as for reliability engineers."[38]

Role of consultants

The use of "Black Belts" as itinerant change agents has (controversially) fostered an industry of training and certification. Critics argue there is overselling of Six Sigma by too great a number of consulting firms, many of which claim expertise in Six Sigma when they have only a rudimentary understanding of the tools and techniques involved.[4]

Potential negative effects

A *Fortune* article stated that "of 58 large companies that have announced Six Sigma programs, 91 percent have trailed the S&P 500 since". The statement was attributed to "an analysis by Charles Holland of consulting firm Qualpro (which espouses a competing quality-improvement process)."[39] The summary of the article is that Six Sigma is effective at what it is intended to do, but that it is "narrowly designed to fix an existing process" and does not help in "coming up with new products or disruptive technologies." Advocates of Six Sigma have argued that many of these claims are in error or ill-informed.[40][41]

A more direct criticism is the "rigid" nature of Six Sigma with its over-reliance on methods and tools. In most cases, more attention is paid to reducing variation and less attention is paid to developing robustness (which can altogether eliminate the need for reducing variation).[42]

Articles featuring critics have appeared in the November-December 2006 issue of USA Army Logistician regarding Six-Sigma: "The dangers of a single paradigmatic orientation (in this case, that of technical rationality) can blind us to values associated with double-loop learning and the learning organization, organization adaptability, workforce creativity and development, humanizing the workplace, cultural awareness, and strategy making."[43]

A *BusinessWeek* article says that James McNerney's introduction of Six Sigma at 3M had the effect of stifling creativity and reports its removal from the research function. It cites two Wharton School professors who say that Six Sigma leads to incremental innovation at the expense of blue skies research.[44] This phenomenon is further explored in the book *Going Lean*, which describes a related approach known as lean dynamics and provides data to show that Ford's "6 Sigma" program did little to change its fortunes.[45]

Lack of evidence of its success

In articles and especially on Internet sites and in text books, claims are made about the huge successes and millions of dollars that Six Sigma has saved. Six Sigma seems to be a "silver bullet" method. However, there does not seem to be trustworthy evidence for this:

> [P]robably more to the Six Sigma literature than concepts, relates to the evidence for Six Sigma's success. So far, documented case studies using the Six Sigma methods are presented as the strongest evidence for its success. However, looking at these documented cases, and apart from a few that are detailed from the experience of leading organizations like GE and Motorola, most cases are not documented in a systemic or academic manner. In fact, the majority are case studies illustrated on websites, and are, at best, sketchy. They provide no mention of any specific Six Sigma methods that were used to resolve the problems. It has been argued that by relying on the Six Sigma criteria, management is lulled into the idea that something is being done about quality, whereas any resulting improvement is accidental (Latzko 1995). Thus, when looking at the evidence put forward for Six Sigma success, mostly by consultants and people with vested interests, the question that begs to be asked is: are we making a true improvement with Six Sigma methods or just getting skilled at telling stories? Everyone seems to believe that we are making true improvements, but there is some way to go to document these empirically and clarify the causal relations.[42]

Based on arbitrary standards

While 3.4 defects per million opportunities might work well for certain products/processes, it might not operate optimally or cost effectively for others. A pacemaker process might need higher standards, for example, whereas a direct mail advertising campaign might need lower standards. The basis and justification for choosing six (as opposed to five or seven, for example) as the number of standard deviations, together with the 1.5 sigma shift is not clearly explained. In addition, the Six Sigma model assumes that the process data always conform to the normal distribution. The calculation of defect rates for situations where the normal distribution model does not apply is not properly addressed in the current Six Sigma literature. This particularly counts for reliability-related defects and other problems that are not time invariant. The IEC, ARP, EN-ISO, DIN and other (inter)national standardization organizations have not created standards for the Six Sigma process. This might be the reason that it became a dominant domain of consultants (see critics above).[4]

Criticism of the 1.5 sigma shift

The statistician Donald J. Wheeler has dismissed the 1.5 sigma shift as "goofy" because of its arbitrary nature.[46] Its universal applicability is seen as doubtful.[4]

The 1.5 sigma shift has also become contentious because it results in stated "sigma levels" that reflect short-term rather than long-term performance: a process that has long-term defect levels corresponding to 4.5 sigma performance is, by Six Sigma convention, described as a "six sigma process."[11][47] The accepted Six Sigma scoring system thus cannot be equated to actual normal distribution probabilities for the stated number of standard deviations, and this has been a key bone of contention over how Six Sigma measures are defined.[47] The fact that it is rarely explained that a "6 sigma" process will have long-term defect rates corresponding to 4.5 sigma performance rather than actual 6 sigma performance has led several commentators to express the opinion that Six Sigma is a confidence trick.[11]

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Seven Basic Tools of Quality

The **Seven Basic Tools of Quality** is a designation given to a fixed set of graphical techniques identified as being most helpful in troubleshooting issues related to quality.[1] They are called *basic* because they are suitable for people with little formal training in statistics and because they can be used to solve the vast majority of quality-related issues.[2]:198

The tools are:[3]

- The cause-and-effect (a.k.a., "fishbone" or Ishikawa diagram)
- The check sheet
- The control chart
- The histogram
- The Pareto chart
- The scatter diagram
- Stratification (alternately flow chart or run chart)

The designation arose in postwar Japan, inspired by the seven famous weapons of Benkei.[4] At that time, companies that had set about training their workforces in statistical quality control found that the complexity of the subject intimidated the vast majority of their workers and scaled back training to focus primarily on simpler methods which suffice for most quality-related issues anyway.[2]:18

The Seven Basic Tools stand in contrast with more advanced statistical methods such as survey sampling, acceptance sampling, statistical hypothesis testing, design of experiments, multivariate analysis, and various methods developed in the field of operations research.[2]:199

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Tools

Ishikawa diagram

Ishikawa diagram
Factors contributing to defect XXX Measurements · Materials · Personnel Calibration · Alloys · Shifts Microscopes · Lubricants · Training Inspectors · Suppliers · Operators → Defect XXX Angle Humidity · Engager · Blade wear Temperature · Brake · Speed Environment · Methods · Machines
One of the Seven Basic Tools of Quality

First described by	Kaoru Ishikawa
Purpose	To break down (in successive layers of detail) root causes that potentially contribute to a particular effect

Ishikawa diagrams (also called **fishbone diagrams**, or **herringbone diagrams** , **cause-and-effect diagrams**, or **Fishikawa**) are causal diagrams that show the causes of a specific event -- created by Kaoru Ishikawa (1968).[1] [2] Common uses of the Ishikawa diagram are product design and quality defect prevention, to identify potential factors causing an overall effect. Each cause or reason for imperfection is a source of variation. Causes are usually grouped into major categories to identify these sources of variation. The categories typically include:

- People: Anyone involved with the process
- Methods: How the process is performed and the specific requirements for doing it, such as policies, procedures, rules, regulations and laws
- Machines: Any equipment, computers, tools etc. required to accomplish the job
- Materials: Raw materials, parts, pens, paper, etc. used to produce the final product
- Measurements: Data generated from the process that are used to evaluate its quality
- Environment: The conditions, such as location, time, temperature, and culture in which the process operates

Overview

Ishikawa diagram, in fishbone shape, showing factors of Equipment, Process, People, Materials, Environment and Management, all affecting the overall problem. Smaller arrows connect the sub-causes to major causes.
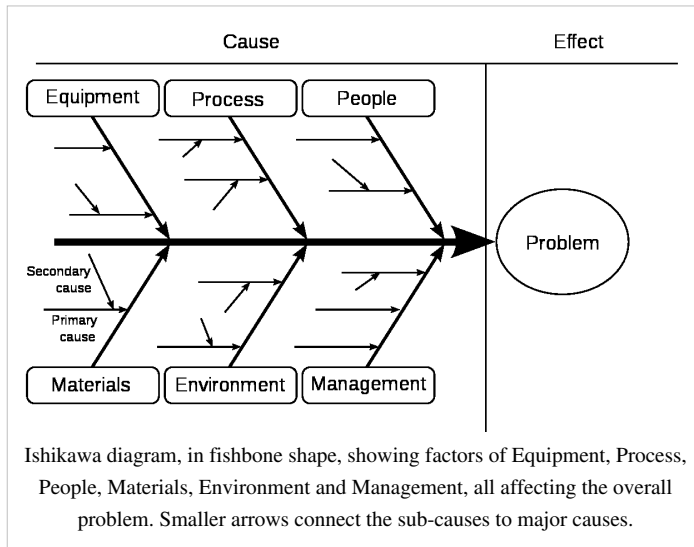
Ishikawa diagrams were proposed by Kaoru Ishikawa[3] in the 1960s, who pioneered quality management processes in the Kawasaki shipyards, and in the process became one of the founding fathers of modern management.

It was first used in the 1940s, and is considered one of the seven basic tools of quality control.[4] It is known as a fishbone diagram because of its shape, similar to the side view of a fish skeleton.

Mazda Motors famously used an Ishikawa diagram in the development of the Miata sports car, where the required result was "Jinba Ittai" (Horse and Rider as One — jap. 人馬一体).

The main causes included such aspects as "touch" and "braking" with the lesser causes including highly granular factors such as "50/50 weight distribution" and "able to rest elbow on top of driver's door". Every factor identified in the diagram was included in the final design.

Causes

Causes in the diagram are often categorized, such as to the 6 M's, described below. Cause-and-effect diagrams can reveal key relationships among various variables, and the possible causes provide additional insight into process behavior.

Causes can be derived from brainstorming sessions. These groups can then be labeled as categories of the fishbone. They will typically be one of the traditional categories mentioned above but may be something unique to the application in a specific case. Causes can be traced back to root causes with the 5 Whys technique.

Typical categories are:

The 6 Ms (used in manufacturing)

- Machine (technology)
- Method (process)
- Material (Includes Raw Material, Consumables and Information.)
- Man Power (physical work)/Mind Power (brain work): Kaizens, Suggestions
- Measurement (Inspection)
- Milieu/Mother Nature (Environment)

The original 6Ms used by the Toyota Production System have been expanded by some to included the following and are referred to as the 8Ms. However, this is not globally recognized. It has been suggested to return to the roots of the tools and to keep the teaching simple while recognizing the original intent, most programs do not address the 8Ms.

- Management/Money Power
- Maintenance

The 7 Ps (used in manufacturing industry)

- Product=Service
- Price
- Place
- Promotion
- People/personnel
- Process
- Physical Evidence

The 5 Ss (used in service industry)

- Surroundings
- Suppliers
- Systems
- Skills
- Safety

Questions to be asked while building a Fishbone Diagram

Man/Operator − Was the document properly interpreted? − Was the information properly circulated to all the functions? − Did the recipient understand the information? − Was the proper training to perform the task administered to the person? − Was too much judgment required to perform the task? − Were guidelines for judgment available? − Did the environment influence the actions of the individual? − Are there distractions in the workplace? − Is fatigue a mitigating factor? - Is his work efficiency acceptable? - Is he responsible/accountable? - Is he qualified? - Is he experienced? - Is he medically fit and healthy? − How much experience does the individual have in performing this task? - can he carry out the operation without error?

Machines − Was the correct tool/tooling used? - Does it meet production requirements? - Does it meet process capabilities? − Are files saved with the correct extension to the correct location? − Is the equipment affected by the environment? − Is the equipment being properly maintained (i.e., daily/weekly/monthly preventative maintenance schedule) − Does the software or hardware need to be updated? − Does the equipment or software have the features to support our needs/usage? - Was the machine properly maintained? − Was the machine properly programmed? − Is the tooling/fixturing adequate for the job? − Does the machine have an adequate guard? − Was the equipment used within its capabilities and limitations? − Are all controls including emergency stop button clearly labeled and/or color coded or size differentiated? − Is the equipment the right application for the given job?

Measurement − Does the gauge have a valid calibration date? − Was the proper gauge used to measure the part, process, chemical, compound, etc.? − Was a gauge capability study ever performed? - Do measurements vary significantly from operator to operator? - Do operators have a tough time using the prescribed gauge? - Is the gauge fixturing adequate? − Does the gauge have proper measurement resolution? − Did the environment influence the measurements taken?

Material (Includes Raw Material, Consumables and Information) − Is all needed information available and accurate? − Can information be verified or cross-checked? − Has any information changed recently / do we have a way of keeping the information up to date? − What happens if we don't have all of the information we need? − Is a Material Safety Data Sheet (MSDS) readily available? − Was the material properly tested? − Was the material substituted? − Is the supplier's process defined and controlled? - Was the raw material defective? - was the raw material the wrong type for the job? − Were quality requirements adequate for the part's function? − Was the material contaminated? − Was the material handled properly (stored, dispensed, used & disposed)?

Method − Was the canister, barrel, etc. labeled properly? − Were the workers trained properly in the procedure? − Was the testing performed statistically significant? − Was data tested for true root cause? − How many "if necessary" and "approximately" phrases are found in this process? − Was this a process generated by an Integrated Product Development (IPD) Team? − Did the IPD Team employ Design for Environmental (DFE) principles? − Has a capability study ever been performed for this process? − Is the process under Statistical Process Control (SPC)? − Are the work instructions clearly written? − Are mistake-proofing devices/techniques employed? − Are the work instructions complete? - Is the work standard upgraded and to current revision? − Is the tooling adequately designed and controlled? − Is handling/packaging adequately specified? − Was the process changed? − Was the design changed? - Are the lighting and ventilation adequate? − Was a process Failure Modes Effects Analysis (FMEA) ever performed? − Was adequate sampling done? − Are features of the process critical to safety clearly spelled out to the Operator?

Environment − Is the process affected by temperature changes over the course of a day? − Is the process affected by humidity, vibration, noise, lighting, etc.? − Does the process run in a controlled environment? − Are associates distracted by noise, uncomfortable temperatures, fluorescent lighting, etc.?

Management - Is management involvement seen? − Inattention to task − Task hazards not guarded properly − Other (horseplay, inattention....) − Stress demands − Lack of Process − Training or education lacking − Poor employee involvement − Poor recognition of hazard − Previously identified hazards were not eliminated

Criticism

In a discussion of the nature of a cause it is customary to distinguish between necessary and sufficient conditions for the occurrence of an event. A necessary condition for the occurrence of a specified event is a circumstance in whose absence the event cannot occur. A sufficient condition is a circumstance in whose presence the event must occur.[5] Ishikawa diagrams have been criticized for failing to make the distinction between necessary conditions and sufficient conditions. It seems that Ishikawa was not even aware of this distinction.[6]

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• Dale, Barrie G. et al. (2007); *Managing Quality 5th ed*; ISBN 978-1-4051-4279-3 OCLC 288977828

External links

• Article from HCI Australia on Cause and Effect Diagrams (http://www.hci.com.au/hcisite5/library/materials/Cause and effect diagrams.htm)

• Example Ishikawa diagram template (http://tools.adaptivebms.com/download/Ishikawa Fish Bone Tool AdaptiveBMS.xls)

Check sheet

Check sheet
Motor Assembly Check Sheet Name of Data Recorder: Lester B. Rapp Location: Rochester, New York Data Collection Dates: 1/17 – 1/23

Defect Types/ Event Occurrence	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	TOTAL
Supplied parts rusted		|||||||||	|||||	||||	||			20
Misaligned weld			|||			||		5
Improper test procedure								0
Wrong part issued				||				3
Film on parts								0
Voids in casting				|||||	||			6
Incorrect dimensions					||			2
Adhesive failure								0
Masking insufficient								1
Spray failure			|||||					5
TOTAL		10	13	10	5	4		

One of the Seven Basic Tools of Quality	
Purpose	To provide a structured way to collect quality-related data as a rough means for assessing a process or as an input to other analyses

The **check sheet** is a form (document) used to collect data in real time at the location where the data is generated. The data it captures can be quantitative or qualitative. When the information is quantitative, the check sheet is sometimes called a **tally sheet**.[1]

The check sheet is one of the seven basic tools of quality control.[2]

Format

The defining characteristic of a check sheet is that data is recorded by making marks ("checks") on it. A typical check sheet is divided into regions, and marks made in different regions have different significance. Data is read by observing the location and number of marks on the sheet.

Check sheets typically employ a heading that answers the Five Ws:

- Who filled out the check sheet
- What was collected (what each check represents, an identifying batch or lot number)
- Where the collection took place (facility, room, apparatus)
- When the collection took place (hour, shift, day of the week)
- Why the data was collected

Function

Kaoru Ishikawa identified five uses for check sheets in quality control:[3]

- To check the shape of the probability distribution of a process
- To quantify defects by type
- To quantify defects by location
- To quantify defects by cause (machine, worker)
- To keep track of the completion of steps in a multistep procedure (in other words, as a checklist)

Check sheet to assess the shape of a process's probability distribution

When assessing the probability distribution of a process one can record all process data and then wait to construct a frequency distribution at a later time. However, a check sheet can be used to construct the frequency distribution as the process is being observed.[4]

This type of check sheet consists of the following:

- A grid that captures
  - The histogram bins in one dimension
  - The count or frequency of process observations in the corresponding bin in the other dimension
- Lines that delineate the upper and lower specification limits

Frequency distribution constructed from a check sheet
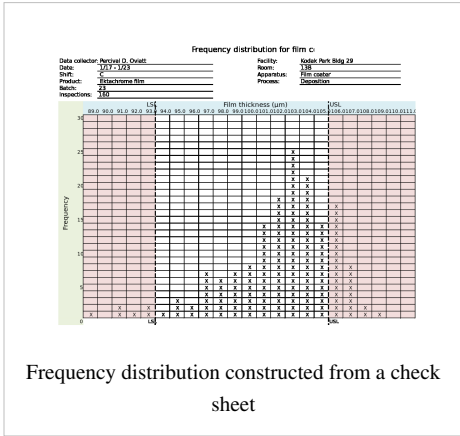
Note that the extremes in process observations must be accurately predicted in advance of constructing the check sheet.

When the process distribution is ready to be assessed, the assessor fills out the check sheet's heading and actively observes the process. Each time the process generates an output, he or she measures (or otherwise assesses) the output, determines the bin in which the measurement falls, and adds to that bin's check marks.

When the observation period has concluded, the assessor should examine it as follows:[5]

- Do the check marks form a bell curve? Are values skewed? Is there more than one peak? Are there outliers?
- Do the check marks fall completely within the specification limits with room to spare? Or are there a significant number of check marks that fall outside the specification limits?

If there is evidence of non-normality or if the process is producing significant output near or beyond the specification limits, a process improvement effort to remove special-cause variation should be undertaken.

Check sheet for defect type

When a process has been identified as a candidate for improvement, it's important to know what types of defects occur in its outputs and their relative frequencies. This information serves as a guide for investigating and removing the sources of defects, starting with the most frequently occurring.[6]

This type of check sheet consists of the following:

- A single column listing each defect category
- One or more columns in which the observations for different machines, materials, methods, operators are to be recorded

A check sheet that tracks quantities of defects by type

Note that the defect categories and how process outputs are to be placed into these categories must be agreed to and spelled out in advance of constructing the check sheet. Additionally, rules for recording the presence of defects of different types when observed for the same process output must be set down.

When the process distribution is ready to be assessed, the assessor fills out the check sheet's heading and actively observes the process. Each time the process generates an output, he or she assesses the output for defects using the agreed-upon methods, determines the category in which the defect falls, and adds to that category's check marks. If no defects are found for a process output, no check mark is made.

When the observation period has concluded, the assessor should generate a Pareto chart from the resulting data. This chart then determines the order in which the process is to be investigated and sources of variation that lead to defects

removed.

Check sheet for defect location

When process outputs are objects for which defects may be observed in varying locations (for example bubbles in laminated products or voids in castings), a defect concentration diagram is invaluable.[7] Note that while most check sheet types aggregate observations from many process outputs, typically one defect location check sheet is used per process output.

This type of check sheet consists of the following:

• A to-scale diagram of the object from each of its sides, optionally partitioned into equally-sized sections

When the process distribution is ready to be assessed, the assessor fills out the check sheet's heading and actively observes the process. Each time the process generates an output, he or she assesses the output for defects and marks the section of each view where each is found. If no defects are found for a process output, no check mark is made.

When the observation period has concluded, the assessor should reexamine each check sheet and form a composite of the defect locations. Using his or her knowledge of the process in conjunction with the locations should reveal the source or sources of variation that produce the defects.

Check sheet for defect cause

When a process has been identified as a candidate for improvement, effort may be required to try to identify the source of the defects by cause.[8]

This type of check sheet consists of the following:

• One or more columns listing each suspected cause (for example machine, material, method, environment, operator)
• One or more columns listing the period during which process outputs are to be observed (for example hour, shift, day)
• One or more symbols to represent the different types of defects to be recorded--these symbols take the place of the check marks of the other types of charts.

Note that the defect categories and how process outputs are to be placed into these categories must be agreed to and spelled out in advance of constructing the check sheet. Additionally, rules for recording the presence of defects of different types when observed for the same process output must be set down.

When the process distribution is ready to be assessed, the assessor fills out the check sheet's heading. For each combination of suspected causes, the assessor actively observes the process. Each time the process generates an output, he or she assesses the output for defects using the agreed-upon methods, determines the category in which the defect falls, and adds the symbol corresponding to that defect category to the cell in the grid corresponding to the combination of suspected causes. If no defects are found for a process output, no symbol is entered.

When the observation period has concluded, the combinations of suspect causes with the most symbols should be investigated for the sources of variation that produce the defects of the type noted.

Optionally, the cause-and-effect diagram may be used to provide a similar diagnostic. The assessor simply places a check mark next to the "twig" on the branch of the diagram corresponding to the suspected cause when he or she observes a defect.

Checklist

While the check sheets discussed above are all for capturing and categorizing observations, the checklist is intended as a mistake-proofing aid when carrying out multi-step procedures, particularly during the checking and finishing of process outputs.

This type of check sheet consists of the following:

- An (optionally numbered) outline of the subtasks to be performed
- Boxes or spaces in which check marks may be entered to indicate when the subtask has been completed

Notations should be made in the order that the subtasks are actually completed.[9]

Other types of check sheet

Check sheets are not limited to those described above. Users should employ their imaginations to design check sheets tailored to the circumstances.[10]

Example checklist

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Histogram

Histogram		
Histogram of arrivals		
One of the Seven Basic Tools of Quality		
First described by	Karl Pearson	
Purpose	To roughly assess the probability distribution of a given variable by depicting the frequencies of observations occurring in certain ranges of values	

In statistics, a **histogram** is a graphical representation showing a visual impression of the distribution of data. It is an estimate of the probability distribution of a continuous variable and was first introduced by Karl Pearson.[1] A histogram consists of tabular frequencies, shown as adjacent rectangles, erected over discrete intervals (bins), with an area equal to the frequency of the observations in the interval. The height of a rectangle is also equal to the frequency density of the interval, i.e., the frequency divided by the width of the interval. The total area of the histogram is equal to the number of data. A histogram may also be normalized displaying relative frequencies. It then shows the proportion of cases that fall into each of several categories, with the total area equaling 1. The categories are usually specified as consecutive, non-overlapping intervals of a variable. The categories (intervals) must be adjacent, and often are chosen to be of the same size.[2] The rectangles of a histogram are drawn so that they touch each other to indicate that the original variable is continuous.[3]

Histograms are used to plot density of data, and often for density estimation: estimating the probability density function of the underlying variable. The total area of a histogram used for probability density is always normalized to 1. If the length of the intervals on the *x*-axis are all 1, then a histogram is identical to a relative frequency plot.

An alternative to the histogram is kernel density estimation, which uses a kernel to smooth samples. This will construct a smooth probability density function, which will in general more accurately reflect the underlying variable.

The histogram is one of the seven basic tools of quality control.[4]

Etymology

An example histogram of the heights of 31 Black Cherry trees.
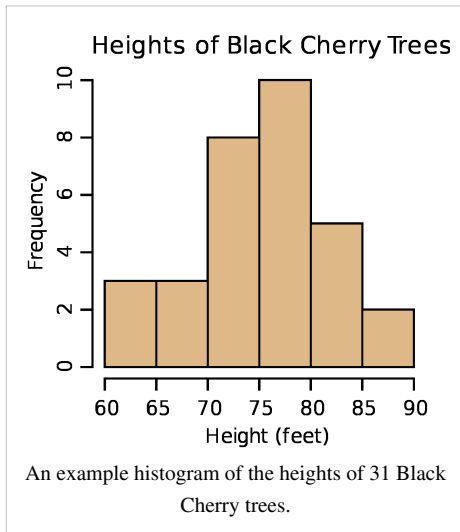
The etymology of the word *histogram* is uncertain. Sometimes it is said to be derived from the Greek *histos* 'anything set upright' (as the masts of a ship, the bar of a loom, or the vertical bars of a histogram); and *gramma* 'drawing, record, writing'. It is also said that Karl Pearson, who introduced the term in 1895, derived the name from "historical diagram".[5]

Examples

The U.S. Census Bureau found that there were **124 million people** who work outside of their homes.[6] Using their data on the time occupied by travel to work, Table 2 below shows the absolute number of people who responded with travel times "at least 15 but less than 20 minutes" is higher than the numbers for the categories above and below it. This is likely due to people rounding their reported journey time. The problem of reporting values as somewhat arbitrarily rounded numbers is a common phenomenon when collecting data from people.

Histogram of travel time, US 2000 census. Area under the curve equals the total number of cases. This diagram uses Q/width from the table.
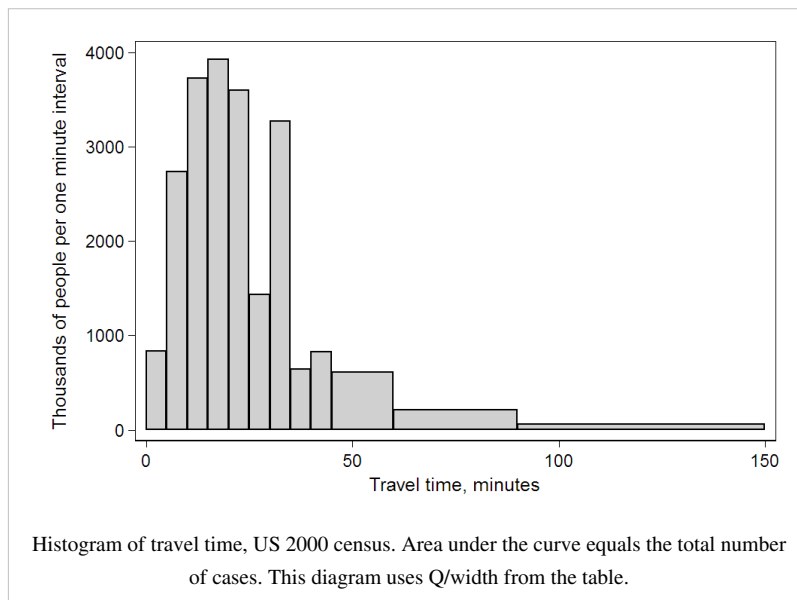
Data by absolute numbers

Interval	Width	Quantity	Quantity/width
0	5	4180	836
5	5	13687	2737
10	5	18618	3723
15	5	19634	3926
20	5	17981	3596
25	5	7190	1438
30	5	16369	3273
35	5	3212	642

40	5	4122	824
45	15	9200	613
60	30	6461	215
90	60	3435	57

This histogram shows the number of cases per unit interval so that the height of each bar is equal to the proportion of total people in the survey who fall into that category. The area under the curve represents the total number of cases (124 million). This type of histogram shows absolute numbers, with Q in thousands.

Histogram of travel time, US 2000 census. Area under the curve equals 1. This diagram uses Q/total/width from the table.
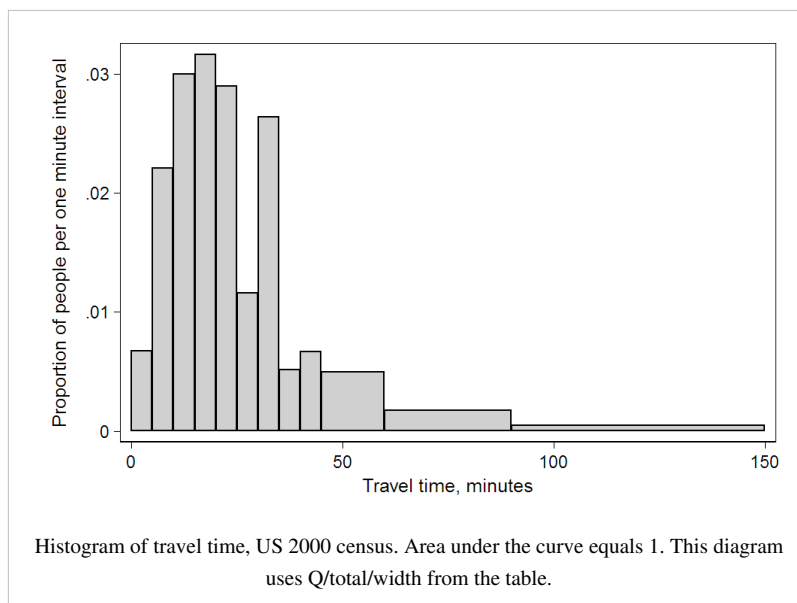
Data by proportion

Interval	Width	Quantity (Q)	Q/total/width
0	5	4180	0.0067
5	5	13687	0.0221
10	5	18618	0.0300
15	5	19634	0.0316
20	5	17981	0.0290
25	5	7190	0.0116
30	5	16369	0.0264
35	5	3212	0.0052
40	5	4122	0.0066
45	15	9200	0.0049
60	30	6461	0.0017
90	60	3435	0.0005

This histogram differs from the first only in the vertical scale. The height of each bar is the decimal percentage of the total that each category represents, and the total area of all the bars is equal to 1, the decimal equivalent of 100%. The curve displayed is a simple density estimate. This version shows proportions, and is also known as a unit area histogram.

In other words, a histogram represents a frequency distribution by means of rectangles whose widths represent class intervals and whose areas are proportional to the corresponding frequencies. The intervals are placed together in order to show that the data represented by the histogram, while exclusive, is also continuous. (E.g., in a histogram it is possible to have two connecting intervals of 10.5−20.5 and 20.5−33.5, but not two connecting intervals of 10.5−20.5 and 22.5−32.5. Empty intervals are represented as empty and not skipped.)[7]

Activities and demonstrations

The SOCR resource pages contain a number of hands-on interactive activities demonstrating the concept of a histogram, histogram construction [8] and manipulation [9] using Java applets and charts [10].

Mathematical definition

In a more general mathematical sense, a histogram is a function m_i that counts the number of observations that fall into each of the disjoint categories (known as *bins*), whereas the graph of a histogram is merely one way to represent a histogram. Thus, if we let n be the total number of observations and k be the total number of bins, the histogram m_i meets the following conditions:

$$n = \sum_{i=1}^{k} m_i.$$

An ordinary and a cumulative histogram of the same data. The data shown is a random sample of 10,000 points from a normal distribution with a mean of 0 and a standard deviation of 1.
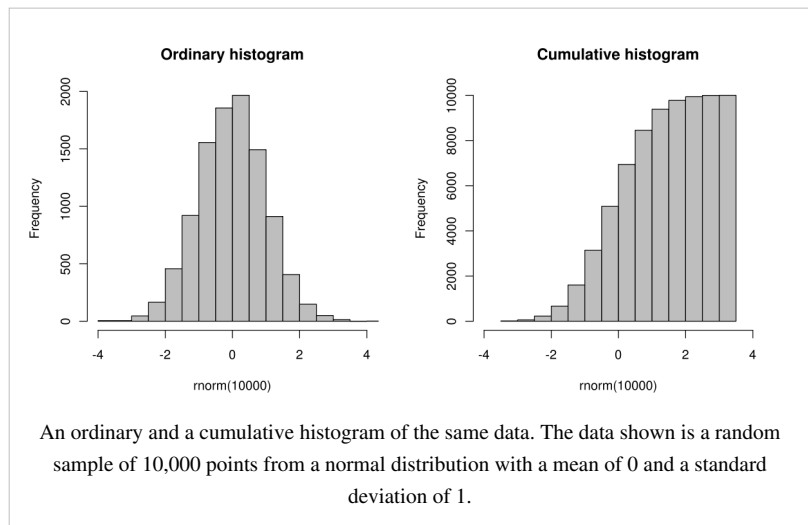
Cumulative histogram

A cumulative histogram is a mapping that counts the cumulative number of observations in all of the bins up to the specified bin. That is, the cumulative histogram M_i of a histogram m_j is defined as:

$$M_i = \sum_{j=1}^{i} m_j.$$

Number of bins and width

There is no "best" number of bins, and different bin sizes can reveal different features of the data. Some theoreticians have attempted to determine an optimal number of bins, but these methods generally make strong assumptions about the shape of the distribution. Depending on the actual data distribution and the goals of the analysis, different bin widths may be appropriate, so experimentation is usually needed to determine an appropriate width. There are, however, various useful guidelines and rules of thumb.[11]

The number of bins k can be assigned directly or can be calculated from a suggested bin width h as:

$$k = \left\lceil \frac{\max x - \min x}{h} \right\rceil.$$

The braces indicate the ceiling function.

Sturges' formula

Sturges' formula[12] is derived from a binomial distribution and implicitly assumes an approximately normal distribution.

$$k = \lceil \log_2 n + 1 \rceil,$$

It implicitly bases the bin sizes on the range of the data and can perform poorly if $n < 30$. It may also perform poorly if the data are not normally distributed.

Doane's formula

Doane's formula[13] is a modification of Sturges' formula which attempts to improve its performance with non-normal data.

$$k = 1 + log_e(n) + log_e(1 + \hat{a}(\frac{n}{6})^{1/2})$$

where a is the estimated kurtosis of the distribution.

Scott's normal reference rule[14]

$$h = \frac{3.5\hat{\sigma}}{n^{1/3}},$$

where $\hat{\sigma}$ is the sample standard deviation. Scott's normal reference rule is optimal for random samples of normally distributed data, in the sense that it minimizes the integrated mean squared error of the density estimate.[15]

Square-root choice

$$k = \sqrt{n},$$

which takes the square root of the number of data points in the sample (used by Excel histograms and many others).

Freedman–Diaconis' choice

The Freedman–Diaconis rule is [16][15]:

$$h = 2\frac{\text{IQR}(x)}{n^{1/3}},$$

which is based on the interquartile range, denoted by IQR. It replaces 3.5σ of Scott's rule with 2 IQR, which is less sensitive than the standard deviation to outliers in data.

Choice based on minimization of an estimated L^2 risk function[17]

$$\arg\min_h \frac{2\bar{m} - v}{h^2}$$

where $\bar{m}$ and v are mean and biased variance of a histogram with bin-width h, $\bar{m} = \frac{1}{k}\sum_{i=1}^{k} m_i$ and $v = \frac{1}{k}\sum_{i=1}^{k}(m_i - \bar{m})^2$.

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Further reading

- Lancaster, H.O. *An Introduction to Medical Statistics.* John Wiley and Sons. 1974. ISBN 0-471-51250-8

External links

- Journey To Work and Place Of Work (http://www.census.gov/population/www/socdemo/journey.html) *(location of census document cited in example)*
- Smooth histogram for signals and images from a few samples (http://www.mathworks.com/matlabcentral/fileexchange/30480-histconnect)
- Histograms: Construction, Analysis and Understanding with external links and an application to particle Physics. (http://quarknet.fnal.gov/toolkits/ati/histograms.html)
- A Method for Selecting the Bin Size of a Histogram (http://2000.jukuin.keio.ac.jp/shimazaki/res/histogram.html)
- Interactive histogram generator (http://www.shodor.org/interactivate/activities/histogram/)
- Matlab function to plot nice histograms (http://www.mathworks.com/matlabcentral/fileexchange/27388-plot-and-compare-nice-histograms-by-default)

Control chart

Control chart
 xbar chart for quality characteristic XXX
One of the Seven Basic Tools of Quality

First described by	Walter A. Shewhart
Purpose	To determine whether a process should undergo a formal examination for quality-related problems
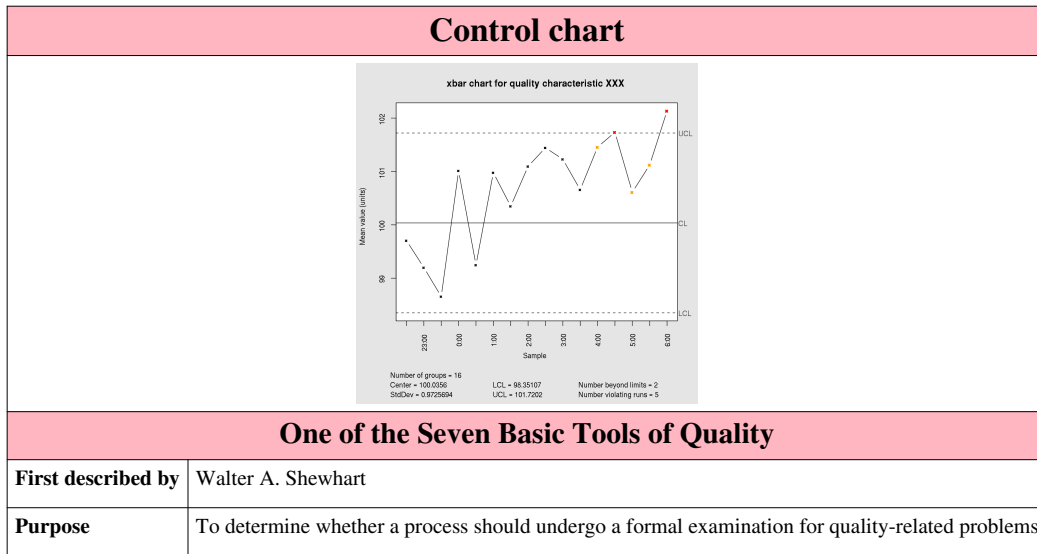
Control charts, also known as **Shewhart charts** or **process-behaviour charts**, in statistical process control are tools used to determine whether a manufacturing or business process is in a state of statistical control.

Overview

If analysis of the control chart indicates that the process is currently under control (i.e. is stable, with variation only coming from sources common to the process) then no corrections or changes to process control parameters are needed or desirable. In addition, data from the process can be used to predict the future performance of the process. If the chart indicates that the process being monitored is not in control, analysis of the chart can help determine the sources of variation, which can then be eliminated to bring the process back into control. A control chart is a specific kind of run chart that allows significant change to be differentiated from the natural variability of the process.

The control chart can be seen as part of an objective and disciplined approach that enables correct decisions regarding control of the process, including whether to change process control parameters. Process parameters should never be adjusted for a process that is in control, as this will result in degraded process performance.[1] A process that is stable but operating outside of desired limits (e.g. scrap rates may be in statistical control but above desired limits) needs to be improved through a deliberate effort to understand the causes of current performance and fundamentally improve the process.[2]

The control chart is one of the seven basic tools of quality control.[3]

History

The control chart was invented by Walter A. Shewhart while working for Bell Labs in the 1920s. The company's engineers had been seeking to improve the reliability of their telephony transmission systems. Because amplifiers and other equipment had to be buried underground, there was a business need to reduce the frequency of failures and repairs. By 1920 the engineers had already realized the importance of reducing variation in a manufacturing process. Moreover, they had realized that continual process-adjustment in reaction to non-conformance actually increased variation and degraded quality. Shewhart framed the problem in terms of Common- and special-causes of variation and, on May 16, 1924, wrote an internal memo introducing the control chart as a tool for distinguishing between the two. Dr. Shewhart's boss, George Edwards, recalled: "Dr. Shewhart prepared a little memorandum only about a page in length. About a third of that page was given over to a simple diagram which we would all recognize today as a

schematic control chart. That diagram, and the short text which preceded and followed it, set forth all of the essential principles and considerations which are involved in what we know today as process quality control."[4] Shewhart stressed that bringing a production process into a state of statistical control, where there is only common-cause variation, and keeping it in control, is necessary to predict future output and to manage a process economically.

Dr. Shewhart created the basis for the control chart and the concept of a state of statistical control by carefully designed experiments. While Dr. Shewhart drew from pure mathematical statistical theories, he understood data from physical processes typically produce a "normal distribution curve" (a Gaussian distribution, also commonly referred to as a "bell curve"). He discovered that observed variation in manufacturing data did not always behave the same way as data in nature (Brownian motion of particles). Dr. Shewhart concluded that while every process displays variation, some processes display controlled variation that is natural to the process, while others display uncontrolled variation that is not present in the process causal system at all times.[5]

In 1924 or 1925, Shewhart's innovation came to the attention of W. Edwards Deming, then working at the Hawthorne facility. Deming later worked at the United States Department of Agriculture and then became the mathematical advisor to the United States Census Bureau. Over the next half a century, Deming became the foremost champion and proponent of Shewhart's work. After the defeat of Japan at the close of World War II, Deming served as statistical consultant to the Supreme Commander of the Allied Powers. His ensuing involvement in Japanese life, and long career as an industrial consultant there, spread Shewhart's thinking, and the use of the control chart, widely in Japanese manufacturing industry throughout the 1950s and 1960s.

Chart details

A control chart consists of:

- Points representing a statistic (e.g., a mean, range, proportion) of measurements of a quality characteristic in samples taken from the process at different times [the data]
- The mean of this statistic using all the samples is calculated (e.g., the mean of the means, mean of the ranges, mean of the proportions)
- A center line is drawn at the value of the mean of the statistic
- The standard error (e.g., standard deviation/sqrt(n) for the mean) of the statistic is also calculated using all the samples
- Upper and lower control limits (sometimes called "natural process limits") that indicate the threshold at which the process output is considered statistically 'unlikely' are drawn typically at 3 standard errors from the center line

The chart may have other optional features, including:

- Upper and lower warning limits, drawn as separate lines, typically two standard errors above and below the center line
- Division into zones, with the addition of rules governing frequencies of observations in each zone
- Annotation with events of interest, as determined by the Quality Engineer in charge of the process's quality
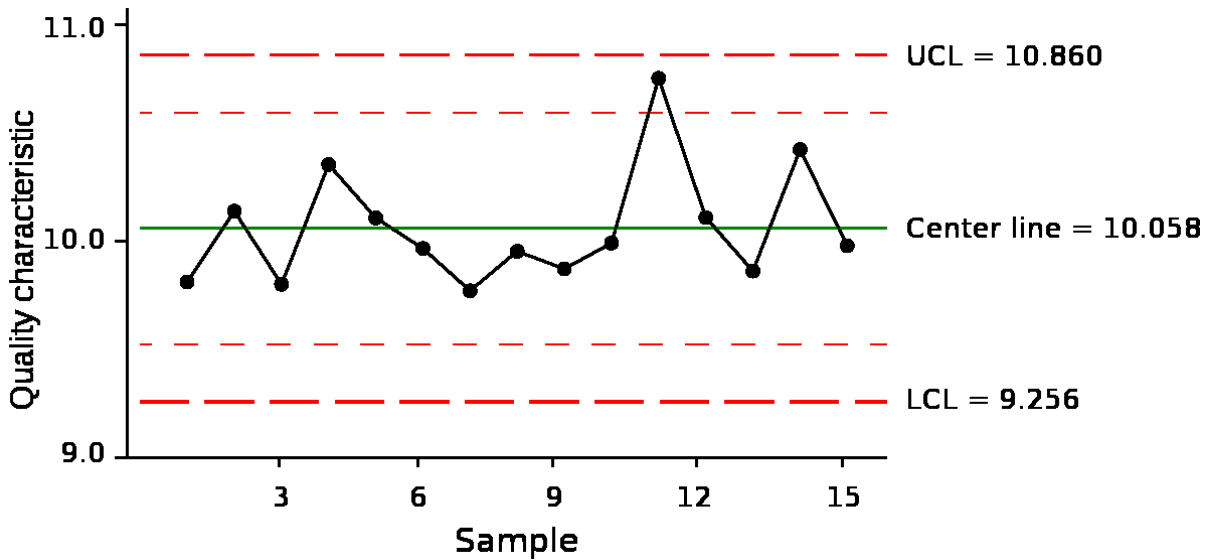
Chart usage

If the process is in control (and the process statistic is normal), 99.7300% of all the points will fall between the control limits. Any observations outside the limits, or systematic patterns within, suggest the introduction of a new (and likely unanticipated) source of variation, known as a special-cause variation. Since increased variation means increased quality costs, a control chart "signaling" the presence of a special-cause requires immediate investigation.

This makes the control limits very important decision aids. The control limits tell you about process behavior and have no intrinsic relationship to any specification targets or engineering tolerance. In practice, the process mean (and hence the center line) may not coincide with the specified value (or target) of the quality characteristic because the process' design simply cannot deliver the process characteristic at the desired level.

Control charts limit specification limits or targets because of the tendency of those involved with the process (e.g., machine operators) to focus on performing to specification when in fact the least-cost course of action is to keep process variation as low as possible. Attempting to make a process whose natural center is not the same as the target perform to target specification increases process variability and increases costs significantly and is the cause of much inefficiency in operations. Process capability studies do examine the relationship between the natural process limits (the control limits) and specifications, however.

The purpose of control charts is to allow simple detection of events that are indicative of actual process change. This simple decision can be difficult where the process characteristic is continuously varying; the control chart provides statistically objective criteria of change. When change is detected and considered good its cause should be identified and possibly become the new way of working, where the change is bad then its cause should be identified and eliminated.

The purpose in adding warning limits or subdividing the control chart into zones is to provide early notification if something is amiss. Instead of immediately launching a process improvement effort to determine whether special causes are present, the Quality Engineer may temporarily increase the rate at which samples are taken from the process output until it's clear that the process is truly in control. Note that with three-sigma limits, common-cause variations result in signals less than once out of every twenty-two points for skewed processes and about once out of every three hundred seventy (1/370.4) points for normally distributed processes.[6] The two-sigma warning levels will be reached about once for every twenty-two (1/21.98) plotted points in normally distributed data. (For example, the means of sufficiently large samples drawn from practically any underlying distribution whose variance exists are normally distributed, according to the Central Limit Theorem.)

Choice of limits

Shewhart set *3-sigma* (3-standard error) limits on the following basis.

- The coarse result of Chebyshev's inequality that, for any probability distribution, the probability of an outcome greater than k standard deviations from the mean is at most $1/k^2$.
- The finer result of the Vysochanskii-Petunin inequality, that for any unimodal probability distribution, the probability of an outcome greater than k standard deviations from the mean is at most $4/(9k^2)$.
- The most common probability distributions, Normal distribution, reveals that 99,7% of observations occurred within three standard deviations of the mean.

Shewhart summarized the conclusions by saying:

> *... the fact that the criterion which we happen to use has a fine ancestry in highbrow statistical theorems does not justify its use. Such justification must come from empirical evidence that it works. As the practical engineer might say, the proof of the pudding is in the eating.*

Though he initially experimented with limits based on probability distributions, Shewhart ultimately wrote:

> *Some of the earliest attempts to characterize a state of statistical control were inspired by the belief that there existed a special form of frequency function f and it was early argued that the normal law characterized such a state. When the normal law was found to be inadequate, then generalized functional forms were tried. Today, however, all hopes of finding a unique functional form f are blasted.*

The control chart is intended as a heuristic. Deming insisted that it is not a hypothesis test and is not motivated by the Neyman-Pearson lemma. He contended that the disjoint nature of population and sampling frame in most industrial situations compromised the use of conventional statistical techniques. Deming's intention was to seek insights into the cause system of a process *...under a wide range of unknowable circumstances, future and past....* He claimed that, under such conditions, *3-sigma* limits provided ... *a rational and economic guide to minimum economic loss...* from the two errors:

1. *Ascribe a variation or a mistake to a special cause (assignable cause) when in fact the cause belongs to the system (common cause).* (Also known as a Type I error)
2. *Ascribe a variation or a mistake to the system (common causes) when in fact the cause was a special cause (assignable cause).* (Also known as a Type II error)

Calculation of standard deviation

As for the calculation of control limits, the standard deviation (error) required is that of the common-cause variation in the process. Hence, the usual estimator, in terms of sample variance, is not used as this estimates the total squared-error loss from both common- and special-causes of variation.

An alternative method is to use the relationship between the range of a sample and its standard deviation derived by Leonard H. C. Tippett, an estimator which tends to be less influenced by the extreme observations which typify special-causes.

Rules for detecting signals

The most common sets are:

- The Western Electric rules
- The Wheeler rules (equivalent to the Western Electric zone tests[7])
- The Nelson rules

There has been particular controversy as to how long a run of observations, all on the same side of the centre line, should count as a signal, with 6, 7, 8 and 9 all being advocated by various writers.

The most important principle for choosing a set of rules is that the choice be made before the data is inspected. Choosing rules once the data have been seen tends to increase the Type I error rate owing to testing effects suggested by the data.

Alternative bases

In 1935, the British Standards Institution, under the influence of Egon Pearson and against Shewhart's spirit, adopted control charts, replacing *3-sigma* limits with limits based on percentiles of the normal distribution. This move continues to be represented by John Oakland and others but has been widely deprecated by writers in the Shewhart-Deming tradition.

Performance of control charts

When a point falls outside of the limits established for a given control chart, those responsible for the underlying process are expected to determine whether a special cause has occurred. If one has, it is appropriate to determine if the results with the special cause are better than or worse than results from common causes alone. If worse, then that cause should be eliminated if possible. If better, it may be appropriate to intentionally retain the special cause within the system producing the results.

It is known that even when a process is *in control* (that is, no special causes are present in the system), there is approximately a 0.27% probability of a point exceeding *3-sigma* control limits. So, even an in control process plotted on a properly constructed control chart will eventually signal the possible presence of a special cause, even though one may not have actually occurred. For a Shewhart control chart using *3-sigma* limits, this *false alarm* occurs on average once every 1/0.0027 or 370.4 observations. Therefore, the *in-control average run length* (or in-control ARL) of a Shewhart chart is 370.4.

Meanwhile, if a special cause does occur, it may not be of sufficient magnitude for the chart to produce an immediate *alarm condition*. If a special cause occurs, one can describe that cause by measuring the change in the mean and/or variance of the process in question. When those changes are quantified, it is possible to determine the out-of-control ARL for the chart.

It turns out that Shewhart charts are quite good at detecting large changes in the process mean or variance, as their out-of-control ARLs are fairly short in these cases. However, for smaller changes (such as a *1-* or *2-sigma* change in the mean), the Shewhart chart does not detect these changes efficiently. Other types of control charts have been developed, such as the EWMA chart, the CUSUM chart and the real-time contrasts chart, which detect smaller changes more efficiently by making use of information from observations collected prior to the most recent data point.

Most control charts work best for numeric data with Gaussian assumptions. The real-time contrasts chart was proposed able to handle process data with complex characteristics, e.g. high-dimensional, mix numerical and categorical, missing-valued, non-Gaussian, non-linear relationship.

Criticisms

Several authors have criticised the control chart on the grounds that it violates the likelihood principle. However, the principle is itself controversial and supporters of control charts further argue that, in general, it is impossible to specify a likelihood function for a process not in statistical control, especially where knowledge about the cause system of the process is weak.

Some authors have criticised the use of average run lengths (ARLs) for comparing control chart performance, because that average usually follows a geometric distribution, which has high variability and difficulties.

Some authors have criticized that most control charts focus on numeric data. Nowadays, process data can be much more complex, e.g. non-Gaussian, mix numerical and categorical, missing-valued.[8]

Types of charts

Chart	Process observation	Process observations relationships	Process observations type	Size of shift to detect
$\bar{x}$ and R chart	Quality characteristic measurement within one subgroup	Independent	Variables	Large (≥ 1.5σ)
$\bar{x}$ and s chart	Quality characteristic measurement within one subgroup	Independent	Variables	Large (≥ 1.5σ)
Shewhart individuals control chart (ImR chart or XmR chart)	Quality characteristic measurement for one observation	Independent	Variables[†]	Large (≥ 1.5σ)
Three-way chart	Quality characteristic measurement within one subgroup	Independent	Variables	Large (≥ 1.5σ)
p-chart	Fraction nonconforming within one subgroup	Independent	Attributes[†]	Large (≥ 1.5σ)
np-chart	Number nonconforming within one subgroup	Independent	Attributes[†]	Large (≥ 1.5σ)
c-chart	Number of nonconformances within one subgroup	Independent	Attributes[†]	Large (≥ 1.5σ)
u-chart	Nonconformances per unit within one subgroup	Independent	Attributes[†]	Large (≥ 1.5σ)
EWMA chart	Exponentially weighted moving average of quality characteristic measurement within one subgroup	Independent	Attributes or variables	Small (< 1.5σ)
CUSUM chart	Cumulative sum of quality characteristic measurement within one subgroup	Independent	Attributes or variables	Small (< 1.5σ)
Time series model	Quality characteristic measurement within one subgroup	Autocorrelated	Attributes or variables	N/A
Regression control chart	Quality characteristic measurement within one subgroup	Dependent of process control variables	Variables	Large (≥ 1.5σ)
Real-time contrasts chart	Sliding window of quality characteristic measurement within one subgroup	Independent	Attributes or variables	Small (< 1.5σ)

[†]Some practitioners also recommend the use of Individuals charts for attribute data, particularly when the assumptions of either binomially distributed data (p- and np-charts) or Poisson-distributed data (u- and c-charts) are violated.[9] Two primary justifications are given for this practice. First, normality is not necessary for statistical control, so the Individuals chart may be used with non-normal data.[10] Second, attribute charts derive the measure of dispersion directly from the mean proportion (by assuming a probability distribution), while Individuals charts derive the measure of dispersion from the data, independent of the mean, making Individuals charts more robust than

attributes charts to violations of the assumptions about the distribution of the underlying population.[11] It is sometimes noted that the substitution of the Individuals chart works best for large counts, when the binomial and Poisson distributions approximate a normal distribution. i.e. when the number of trials n > 1000 for p- and np-charts or λ > 500 for u- and c-charts.

Critics of this approach argue that control charts should not be used when their underlying assumptions are violated, such as when process data is neither normally distributed nor binomially (or Poisson) distributed. Such processes are not in control and should be improved before the application of control charts. Additionally, application of the charts in the presence of such deviations increases the type I and type II error rates of the control charts, and may make the chart of little practical use.

Notes

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External links

Note: Before adding your company's link, please read WP:Spam#External_link_spamming and WP:External_links#Links_normally_to_be_avoided.

- NIST/SEMATECH e-Handbook of Statistical Methods (http://www.itl.nist.gov/div898/handbook/index.htm)
- Monitoring and Control with Control Charts (http://www.itl.nist.gov/div898/handbook/pmc/pmc.htm)

Pareto chart

Pareto chart	
Pareto chart of titanium investment casting defects	
One of the Seven Basic Tools of Quality	
First described by	Joseph M. Juran
Purpose	To assess the most frequently occurring defects by category†
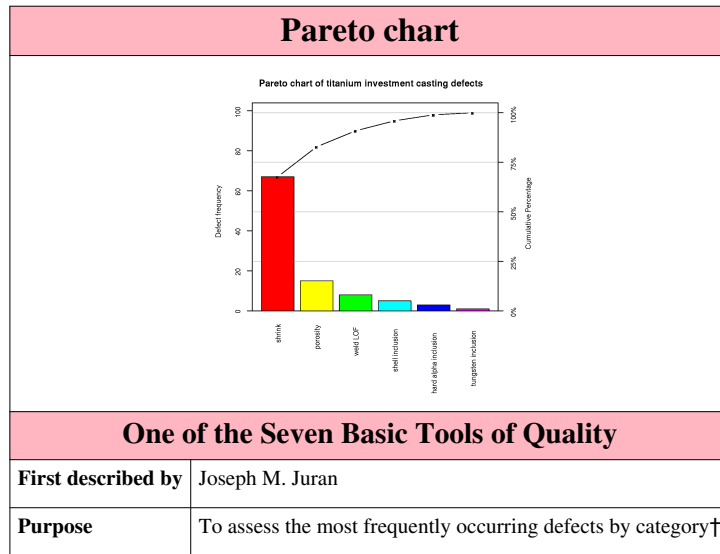
A **Pareto chart**, named after Vilfredo Pareto, is a type of chart that contains both bars and a line graph, where individual values are represented in descending order by bars, and the cumulative total is represented by the line.

Simple example of a Pareto chart using hypothetical data showing the relative frequency of reasons for arriving late at work
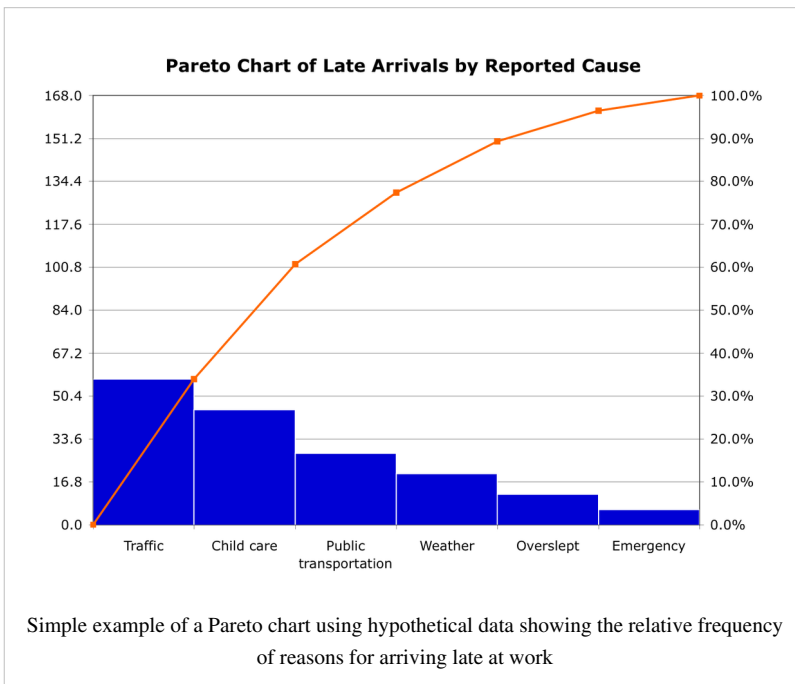
The left vertical axis is the frequency of occurrence, but it can alternatively represent cost or another important unit of measure. The right vertical axis is the cumulative percentage of the total number of occurrences, total cost, or total of the particular unit of measure. Because the reasons are in decreasing order, the cumulative function is a concave function. To take the example above, in order to lower the amount of late arriving by 78%, it is sufficient to solve the first three issues.

The purpose of the Pareto chart is to highlight the most important among a (typically large) set of factors. In quality control, it often represents the most common sources of defects, the highest occurring type of defect, or the most frequent reasons for customer complaints, and so on. Wilkinson (2006) devised an algorithm for producing statistically based acceptance limits (similar to confidence intervals) for each bar in the Pareto chart.

These charts can be generated by simple spreadsheet programs, such as OpenOffice.org Calc and Microsoft Excel and specialized statistical software tools as well as online quality charts generators.

The Pareto chart is one of the seven basic tools of quality control.[1]

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Scatter plot

Scatter plot
Scatterplot for quality characteristic XXX
One of the Seven Basic Tools of Quality

First described by	Francis Galton
Purpose	To identify the type of relationship (if any) between two variables
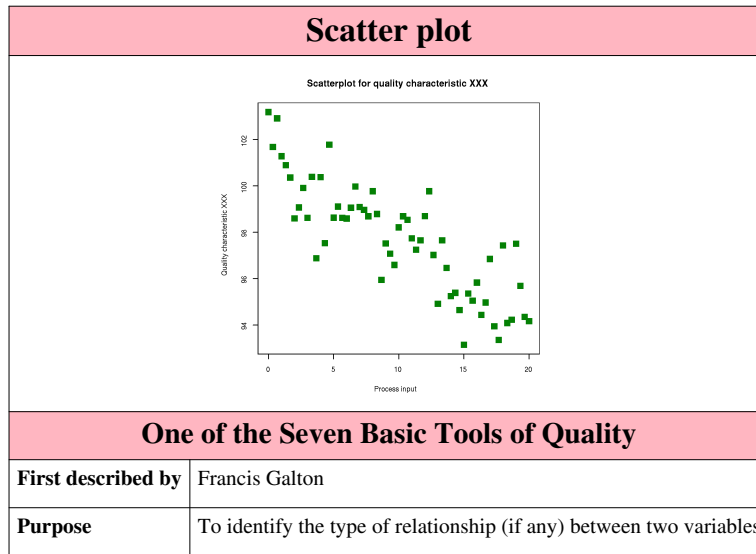
A **scatter plot** or **scattergraph** is a type of mathematical diagram using Cartesian coordinates to display values for two variables for a set of data.

The data is displayed as a collection of points, each having the value of one variable determining the position on the horizontal axis and the value of the other variable determining the position on the vertical axis.[2] This kind of plot is also called a *scatter chart*, *scattergram*, *scatter diagram* or *scatter graph*.

Overview

A scatter plot is used when a variable exists that is under the control of the experimenter. If a parameter exists that is systematically incremented and/or decremented by the other, it is called the *control parameter* or independent variable and is customarily plotted along the horizontal axis. The measured or dependent variable is customarily plotted along the vertical axis. If no dependent variable exists, either type of variable can be plotted on either axis and a scatter plot will illustrate only the degree of correlation (not causation) between two variables.

Waiting time between eruptions and the duration of the eruption for the Old Faithful Geyser in Yellowstone National Park, Wyoming, USA. This chart suggests there are generally two "types" of eruptions: short-wait-short-duration, and long-wait-long-duration.

A scatter plot can suggest various kinds of correlations between variables with a certain confidence interval. For example, weight and height, weight would be on x axis and height would be on the y axis. Correlations may be positive (rising), negative (falling), or null (uncorrelated).
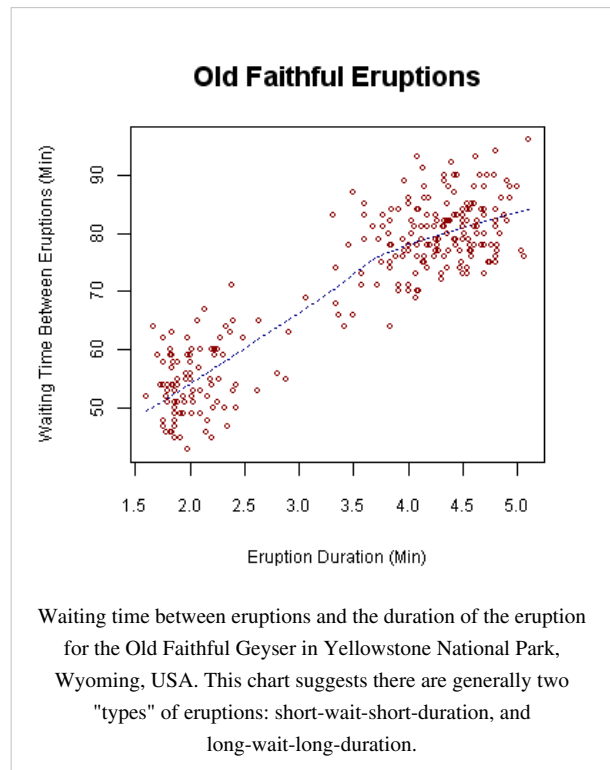
If the pattern of dots slopes from lower left to upper right, it suggests a positive correlation between the variables being studied. If the pattern of dots slopes from upper left to lower right, it suggests a negative correlation. A line of best fit (alternatively called 'trendline') can be drawn in order to study the correlation between the variables. An equation for the correlation between the variables can be determined by established best-fit procedures. For a linear correlation, the best-fit procedure is known as linear regression and is guaranteed to generate a correct solution in a finite time. No universal best-fit procedure is guaranteed to generate a correct solution for arbitrary relationships. A scatter plot is also very useful when we wish to see how two comparable data sets agree with each other. In this case, an identity line, *i.e.*, a *y=x* line, or an 1:1 line, is often drawn as a reference. The more the two data sets agree, the more the scatters tend to concentrate in the vicinity of the identity line; if the two data sets are numerically identical, the scatters fall on the identity line exactly.
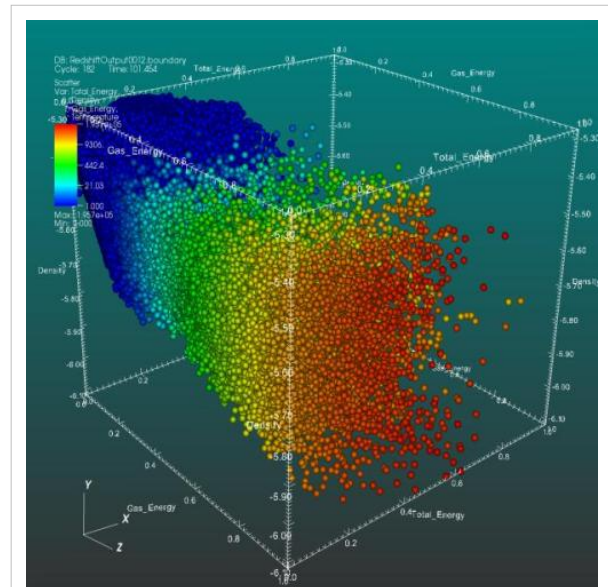
A 3D scatter plot allows for the visualization of multivariate data of up to four dimensions. The Scatter plot takes multiple scalar variables and uses them for different axes in phase space. The different variables are combined to form coordinates in the phase space and they are displayed using glyphs and colored using another scalar variable.[1]

One of the most powerful aspects of a scatter plot, however, is its ability to show nonlinear relationships between variables. Furthermore, if the data is represented by a mixture model of simple relationships, these relationships will be visually evident as superimposed patterns.

The scatter diagram is one of the seven basic tools of quality control.[3]

Example

For example, to display values for "lung capacity" (first variable) and how long that person could hold his breath, a researcher would choose a group of people to study, then measure each one's lung capacity (first variable) and how long that person could hold his breath (second variable). The researcher would then plot the data in a scatter plot, assigning "lung capacity" to the horizontal axis, and "time holding breath" to the vertical axis.

A person with a lung capacity of 400 ml who held his breath for 21.7 seconds would be represented by a single dot on the scatter plot at the point (400, 21.7) in the Cartesian coordinates. The scatter plot of all the people in the study would enable the researcher to obtain a visual comparison of the two variables in the data set, and will help to determine what kind of relationship there might be between the two variables.

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External links

- What is a scatterplot? (http://www.psychwiki.com/wiki/What_is_a_scatterplot?)
- Correlation scatter-plot matrix - for ordered-categorical data (http://www.r-statistics.com/2010/04/correlation-scatter-plot-matrix-for-ordered-categorical-data/) - Explanation and R code
- Tool for visualizing scatter plots (http://www.icanplot.org)
- Density scatterplot for large datasets (http://www.r-bloggers.com/ggplot2-for-big-data/) (hundreds of millions of points)

Stratified sampling

In statistics, **stratified sampling** is a method of sampling from a population.

In statistical surveys, when subpopulations within an overall population vary, it is advantageous to sample each subpopulation (stratum) independently. **Stratification** is the process of dividing members of the population into homogeneous subgroups before sampling. The strata should be mutually exclusive: every element in the population must be assigned to only one stratum. The strata should also be collectively exhaustive: no population element can be excluded. Then simple random sampling or systematic sampling is applied within each stratum. This often improves the representativeness of the sample by reducing sampling error. It can produce a weighted mean that has less variability than the arithmetic mean of a simple random sample of the population.

In computational statistics, stratified sampling is a method of variance reduction when Monte Carlo methods are used to estimate population statistics from a known population.

Stratified sampling strategies

1. Proportionate allocation uses a sampling fraction in each of the strata that is proportional to that of the total population. For instance, if the population consists of 60% in the male stratum and 40% in the female stratum, then the relative size of the two samples (three males, two females) should reflect this proportion.
2. Optimum allocation (or Disproportionate allocation) - Each stratum is proportionate to the standard deviation of the distribution of the variable. Larger samples are taken in the strata with the greatest variability to generate the least possible sampling variance.

A real-world example of using stratified sampling would be for a political survey. If the respondents needed to reflect the diversity of the population, the researcher would specifically seek to include participants of various minority groups such as race or religion, based on their proportionality to the total population as mentioned above. A stratified survey could thus claim to be more representative of the population than a survey of simple random sampling or systematic sampling.

Similarly, if population density varies greatly within a region, stratified sampling will ensure that estimates can be made with equal accuracy in different parts of the region, and that comparisons of sub-regions can be made with equal statistical power. For example, in Ontario a survey taken throughout the province might use a larger sampling fraction in the less populated north, since the disparity in population between north and south is so great that a sampling fraction based on the provincial sample as a whole might result in the collection of only a handful of data

from the north.

Randomized stratification can also be used to improve population representativeness in a study.

Disadvantages

Stratified sampling is not useful when the population cannot be exhaustively partitioned into disjoint subgroups. It would be a misapplication of the technique to make subgroups' sample sizes proportional to the amount of data available from the subgroups, rather than scaling sample sizes to subgroup sizes (or to their variances, if known to vary significantly e.g. by means of an F Test). Data representing each subgroup are taken to be of equal importance if suspected variation among them warrants stratified sampling. If, on the other hand, the very variances vary so much, among subgroups, that the data need to be stratified by variance, there is no way to make the subgroup sample sizes proportional (at the same time) to the subgroups' sizes within the total population. (What is the most efficient way to partition sampling resources among groups that vary in both their means and their variances?)

Practical example

In general the size of the sample in each stratum is taken in proportion to the size of the stratum. This is called proportional allocation. Suppose that in a company there are the following staff:

- male, full time: 90
- male, part time: 18
- female, full time: 9
- female, part time: 63
- Total: 180

and we are asked to take a sample of 40 staff, stratified according to the above categories.

The first step is to find the total number of staff (180) and calculate the percentage in each group.

- % male, full time = 90 / 180 = 50%
- % male, part time = 18 / 180 = 10%
- % female, full time = 9 / 180 = 5%
- % female, part time = 63 / 180 = 35%

This tells us that of our sample of 40,

- 50% should be male, full time.
- 10% should be male, part time.
- 5% should be female, full time.
- 35% should be female, part time.

- 50% of 40 is 20.
- 10% of 40 is 4.
- 5% of 40 is 2.
- 35% of 40 is 14.

Another easy way without having to calculate the percentage is to multiply each group size by the sample size and divide by the total population size (size of entire staff):

- male, full time = 90 x (40 / 180) = 20
- male, part time = 18 x (40 / 180) = 4
- female, full time = 9 x (40 / 180) = 2
- female, part time = 63 x (40 / 180) = 14

[1]

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Flowchart

A **flowchart** is a type of diagram that represents an algorithm or process, showing the steps as boxes of various kinds, and their order by connecting these with arrows. This diagrammatic representation can give a step-by-step solution to a given problem. Process operations are represented in these boxes, and arrows connecting them represent flow of control. Data flows are not typically represented in a flowchart, in contrast with data flow diagrams; rather, they are implied by the sequencing of operations. Flowcharts are used in analyzing, designing, documenting or managing a process or program in various fields.[1]

Overview

Flowcharts are used in designing and documenting complex processes or programs. Like other types of diagram, they help visualize what is going on and thereby help the viewer to understand a process, and perhaps also find flaws, bottlenecks, and other less-obvious features within it. There are many different types of flowcharts, and each type has its own repertoire of boxes and notational conventions. The two most common types of boxes in a flowchart are:

A simple flowchart representing a process for dealing with a non-functioning lamp.

- a processing step, usually called *activity*, and denoted as a rectangular box
- a decision, usually denoted as a diamond.

A flowchart is described as "cross-functional" when the page is divided into different swimlanes describing the control of different organizational units. A symbol appearing in a particular "lane" is within the control of that organizational unit. This technique allows the author to locate the responsibility for performing an action or making a decision correctly, showing the responsibility of each organizational unit for different parts of a single process.

Flowcharts depict certain aspects of processes and they are usually complemented by other types of diagram. For instance, Kaoru Ishikawa defined the flowchart as one of the seven basic tools of quality control, next to the histogram, Pareto chart, check sheet, control chart, cause-and-effect diagram, and the scatter diagram. Similarly, in UML, a standard concept-modeling notation used in software development, the activity diagram, which is a type of flowchart, is just one of many different diagram types.

Nassi-Shneiderman diagrams are an alternative notation for process flow.

Common alternate names include: flowchart, process flow chart, functional flow chart, process map, process chart, functional process chart, business process model, process model, process flow diagram, work flow diagram, business flow diagram.
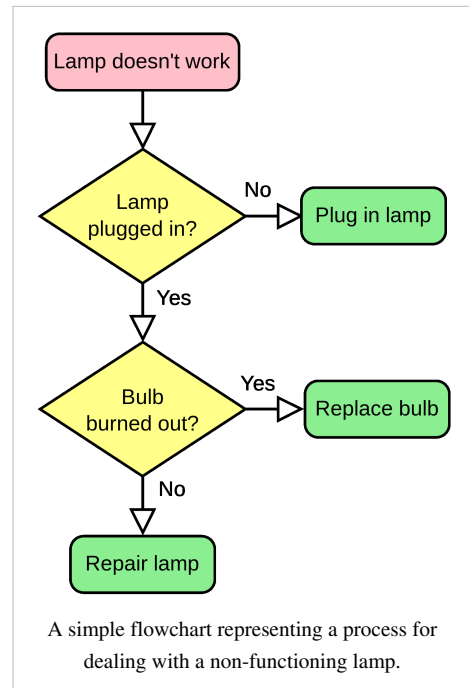
History

The first structured method for documenting process flow, the "flow process chart", was introduced by Frank Gilbreth to members of the American Society of Mechanical Engineers (ASME) in 1921 in the presentation "Process Charts—First Steps in Finding the One Best Way". Gilbreth's tools quickly found their way into industrial engineering curricula. In the early 1930s, an industrial engineer, Allan H. Mogensen began training business people in the use of some of the tools of industrial engineering at his Work Simplification Conferences in Lake Placid, New York.

A 1944 graduate of Mogensen's class, Art Spinanger, took the tools back to Procter and Gamble where he developed their Deliberate Methods Change Program. Another 1944 graduate, Ben S. Graham, Director of Formcraft Engineering at Standard Register Industrial, adapted the flow process chart to information processing with his development of the multi-flow process chart to display multiple documents and their relationships.[2] In 1947, ASME adopted a symbol set derived from Gilbreth's original work as the ASME Standard for Process Charts.

Douglas Hartree explains that Herman Goldstine and John von Neumann developed the flow chart (originally, diagram) to plan computer programs.[3] His contemporary account is endorsed by IBM engineers[4] and by Goldstine's personal recollections.[5] The original programming flow charts of Goldstine and von Neumann can be seen in their unpublished report, "Planning and coding of problems for an electronic computing instrument, Part II, Volume 1" (1947), which is reproduced in von Neumann's collected works.[6]

Flowcharts used to be a popular means for describing computer algorithms and are still used for this purpose.[7] Modern techniques such as UML activity diagrams can be considered to be extensions of the flowchart. In the 1970s the popularity of flowcharts as an own method decreased when interactive computer terminals and third-generation programming languages became the common tools of the trade, since algorithms can be expressed much more concisely as source code in such a language, and also because designing algorithms using flowcharts was more likely to result in spaghetti code because of the need for gotos to describe arbitrary jumps in control flow. Often pseudo-code is used, which uses the common idioms of such languages without strictly adhering to the details of a particular one.

Flowchart building blocks

Examples

A flowchart for computing the factorial of N — written N! and equal to $1 \times 2 \times 3 \times ... \times N$.

Symbols

A typical flowchart from older basic computer science textbooks may have the following kinds of symbols:

Start and end symbols

Represented as circles, ovals or rounded rectangles, usually containing the word "Start" or "End", or another phrase signaling the start or end of a process, such as "submit inquiry" or "receive product".

Arrows

Showing "flow of control". An arrow coming from one symbol and ending at another symbol represents that control passes to the symbol the arrow points to. The line for the arrow can be solid or dashed. The meaning of the arrow with dashed line may differ from one flowchart to another and can be defined in the legend.

Generic processing steps

Represented as rectangles. Examples: "Add 1 to X"; "replace identified part"; "save changes" or similar.

Subroutines

Represented as rectangles with double-struck vertical edges; these are used to show complex processing steps which may be detailed in a separate flowchart. Example: PROCESS-FILES. One subroutine may have multiple distinct entry points or exit flows (see coroutine); if so, these are shown as labeled 'wells' in the rectangle, and control arrows connect to these 'wells'.

Input/Output

Represented as a parallelogram. Examples: Get X from the user; display X.

Prepare conditional

Represented as a hexagon. Shows operations which have no effect other than preparing a value for a subsequent conditional or decision step (see below).

Conditional or decision

A simple flowchart for computing factorial N (N!)

Template for drawing flowcharts (late 1970s) showing the different symbols.

Represented as a diamond (rhombus) showing where a decision is necessary, commonly a Yes/No question or True/False test. The conditional symbol is peculiar in that it has two arrows coming out of it, usually from the bottom point and right point, one corresponding to Yes or True, and one corresponding to No or False. (The
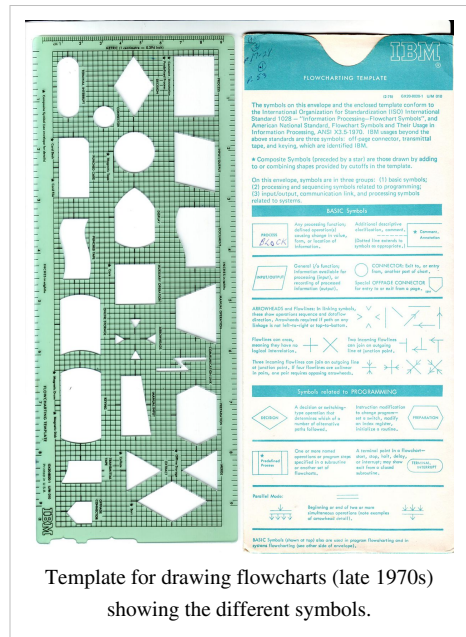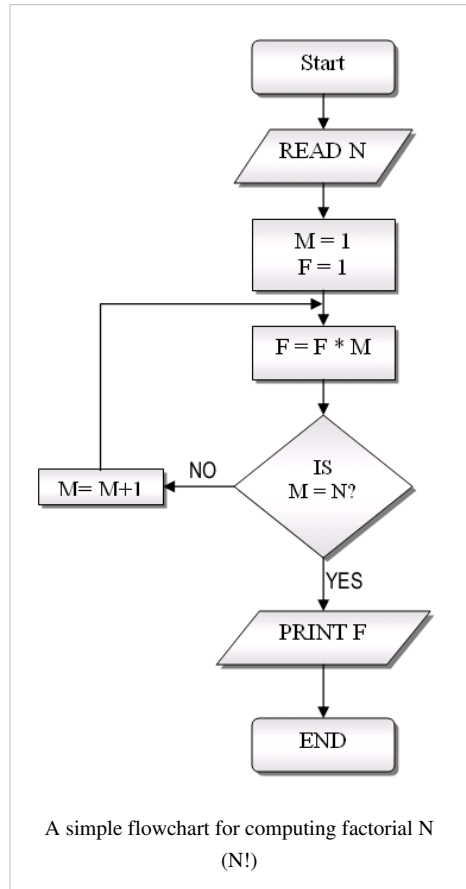
arrows should always be labeled.) More than two arrows can be used, but this is normally a clear indicator that a complex decision is being taken, in which case it may need to be broken-down further or replaced with the "pre-defined process" symbol.

Junction symbol

Generally represented with a black blob, showing where multiple control flows converge in a single exit flow. A junction symbol will have more than one arrow coming into it, but only one going out.

In simple cases, one may simply have an arrow point to another arrow instead. These are useful to represent an iterative process (what in Computer Science is called a loop). A loop may, for example, consist of a connector where control first enters, processing steps, a conditional with one arrow exiting the loop, and one going back to the connector.

For additional clarity, wherever two lines accidentally cross in the drawing, one of them may be drawn with a small semicircle over the other, showing that no junction is intended.

Labeled connectors

Represented by an identifying label inside a circle. Labeled connectors are used in complex or multi-sheet diagrams to substitute for arrows. For each label, the "outflow" connector must always be unique, but there may be any number of "inflow" connectors. In this case, a junction in control flow is implied.

Concurrency symbol

Represented by a double transverse line with any number of entry and exit arrows. These symbols are used whenever two or more control flows must operate simultaneously. The exit flows are activated concurrently when all of the entry flows have reached the concurrency symbol. A concurrency symbol with a single entry flow is a *fork*; one with a single exit flow is a *join*.

It is important to remember to keep these connections logical in order. All processes should flow from top to bottom and left to right.

Data-flow extensions

A number of symbols have been standardized for data flow diagrams to represent data flow, rather than control flow. These symbols may also be used in control flow charts (e.g. to substitute for the parallelogram symbol).

- A *Document* represented as a rectangle with a wavy base;
- A *Manual input* represented by quadrilateral, with the top irregularly sloping up from left to right. An example would be to signify data-entry from a form;
- A *Manual operation* represented by a trapezoid with the longest parallel side at the top, to represent an operation or adjustment to process that can only be made manually.
- A *Data File* represented by a cylinder.

Types of flowchart

Sterneckert (2003) suggested that flowcharts can be modeled from the perspective of different user groups (such as managers, system analysts and clerks) and that there are four general types:[8]

- *Document flowcharts*, showing controls over a document-flow through a system
- *Data flowcharts*, showing controls over a data-flow in a system
- *System flowcharts* showing controls at a physical or resource level
- *Program flowchart*, showing the controls in a program within a system

Notice that every type of flowchart focuses on some kind of control, rather than on the particular flow itself.[8]

However there are several of these classifications. For example Andrew Veronis (1978) named three basic types of flowcharts: the *system flowchart*, the *general flowchart*, and the *detailed flowchart*.[9] That same year Marilyn Bohl (1978) stated "in practice, two kinds of flowcharts are used in solution planning: *system flowcharts* and *program flowcharts*...".[10] More recently Mark A. Fryman (2001) stated that there are more differences: "Decision flowcharts, logic flowcharts, systems flowcharts, product flowcharts, and process flowcharts are just a few of the different types of flowcharts that are used in business and government".[11]

In addition, many diagram techniques exist that are similar to flowcharts but carry a different name, such as UML activity diagrams.

Driving to reach a specific goal can be modeled using a flowchart.
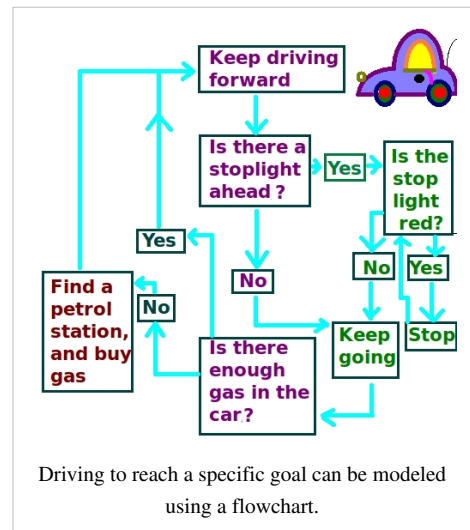
Software

Any drawing program can be used to create flowchart diagrams, but these will have no underlying data model to share data with databases or other programs such as project management systems or spreadsheets. Some tools offer special support for flowchart drawing. Many software packages exist that can create flowcharts automatically, either directly from source code, or from a flowchart description language. On-line Web-based versions of such programs are available.

Notes

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- Advanced Flowchart (http://www.tipskey.com/article/advanced_flowchart/) - Why and how to create advanced flowchart

Run chart

A **run chart**, also known as a **run-sequence plot** is a graph that displays observed data in a time sequence. Often, the data displayed represent some aspect of the output or performance of a manufacturing or other business process.

Overview

Run sequence plots[1] are an easy way to graphically summarize a univariate data set. A common assumption of univariate data sets is that they behave like:[2]

- random drawings;
- from a fixed distribution;
- with a common location; and
- with a common scale.

A simple run chart showing data collected over time. The median of the observed data (73) is also shown on the chart.

With run sequence plots, shifts in location and scale are typically quite evident. Also, outliers can easily be detected.
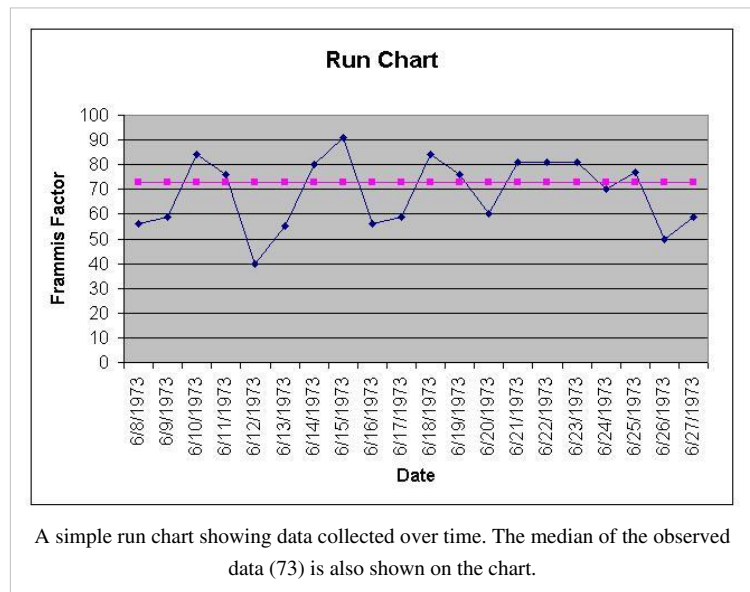
Examples could include measurements of the fill level of bottles filled at a bottling plant or the water temperature of a dishwashing machine each time it is run. Time is generally represented on the horizontal (x) axis and the property under observation on the vertical (y) axis. Often, some measure of central tendency (mean or median) of the data is indicated by a horizontal reference line.

Run charts are analyzed to find anomalies in data that suggest shifts in a process over time or special factors that may be influencing the variability of a process. Typical factors considered include unusually long "runs" of data points above or below

Run chart of eight random walks in one dimension starting at 0. The plot shows the current position on the line (vertical axis) versus the time steps (horizontal axis).

the average line, the total number of such runs in the data set, and unusually long series of consecutive increases or decreases.[1]

Run charts are similar in some regards to the control charts used in statistical process control, but do not show the control limits of the process. They are therefore simpler to produce, but do not allow for the full range of analytic techniques supported by control charts.

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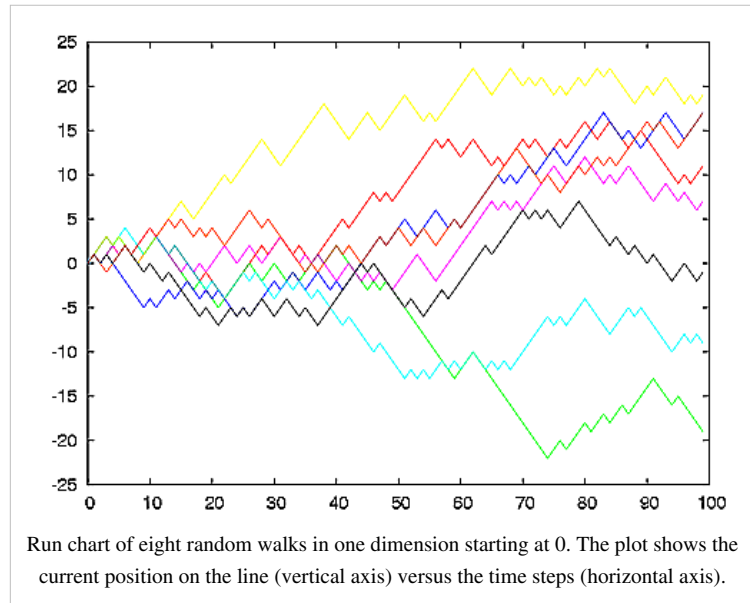
Statistical process control

Statistical process control (SPC) is a method of quality control which uses statistical methods. SPC is applied in order to monitor and control a process. Monitoring and controlling the process ensures that it operates at its full potential. At its full potential, the process can make as much conforming product as possible with a minimum (if not an elimination) of waste (rework or trash). SPC can be applied to any process where the "conforming product" (product meeting specifications) output can be measured. Some key tools are used in SPC. These include control charts; a focus on continuous improvement; and the design of experiments. An example of a process where SPC is applied is manufacturing lines.

Overview

Objective analysis of variation

SPC is a valuable process because it allows examination of specific parts of a process. In particular, it looks at the parts that may conceal sources of variation in the quality of the product. The examination involves objective analysis rather than subjective opinion. SPC also allows the strength of each source of variation to be determined numerically. If sources of variation are detected and measured, they may be amenable to correction. In turn, correction of variations may reduce waste in production and may improve the quality of the product that reaches the customer.

Emphasis on early detection

An advantage of SPC over other methods of quality control, such as "inspection" is that it emphasises early detection and prevention of problems, rather than the correction of problems after they have occurred.

Increasing rate of production

In addition to reducing waste, SPC can lead to a reduction in the time required to produce the product. SPC makes it less likely the finished product will need to be reworked. SPC may also identify bottlenecks, waiting times, and other sources of delays within the process.

Limitations

The application of SPC to a process aims to result in the elimination of process waste. This, in turn, removes the need for the process step of post-manufacture inspection. However, the success of SPC relies not only on the skill with which it is applied but also on how suitable or amenable the process is to SPC. In some cases, it may be difficult to judge when the application of SPC is appropriate.

History

SPC was pioneered by Walter A. Shewhart in the early 1920s. W. Edwards Deming later applied SPC methods in the United States during World War II, to improve quality in the manufacture of munitions and other strategically important products. Deming was also instrumental in introducing SPC methods to Japanese industry after the war had ended.[1][2]Shewhart developed the "control chart" and the concept of a state of statistical control determined by carefully designed experiments.

"Common" and "special" sources of variation

While Shewhart drew from pure mathematical statistical theories, he understood that data from physical processes seldom produced a "normal distribution curve"; that is, a Gaussian distribution or "bell curve". He discovered that data from measurements of variation in manufacturing did not always behave the same way as did data from measurements of natural phenomena (for example, Brownian motion of particles). Shewhart concluded that while every process displays variation, some processes display variation that is controlled and natural to the process ("common" sources of variation). Other processes display variation that is not controlled and that is not present in the causal system of the process at all times ("special" sources of variation).[3]

Application to non-manufacturing processes

In 1988, the Software Engineering Institute suggested that SPC could be applied to non-manufacturing processes, such as software engineering processes, in the Capability Maturity Model (CMM). The Level 4 and Level 5 practices of the Capability Maturity Model Integration (CMMI) uses this concept. The notion that SPC is a useful tool when applied to non-repetitive, knowledge-intensive processes such as engineering has encountered skepticism and remains controversial.[4][5]

Variation in manufacturing

In mass-manufacturing, traditionally, the quality of a finished article is ensured by post-manufacturing inspection of the product. Each article (or a sample of articles from a production lot) may be accepted or rejected according to how well it meets its design specifications. In contrast, SPC uses statistical tools to observe the performance of the production process in order to predict significant variations which may result in the production of a sub-standard article. A sources of variation at any one point of a production process will fall into one of two classes.

    1) "Common" - sometimes referred to as "normal" or "chance" sources of variation and

    2) "Assignable" - sometimes referred to as "special" sources of variation.

Most processes have many sources of variation and most of them are minor and may be ignored. If the dominant sources of variation are identified then resources for change can be focused on them. If the dominant assignable sources of variation can be detected, potentially they can be identified and removed. Once removed, the process is said to be "stable". When a process is stable, its variation should remain within a known set of limits. That is, at least, until another assignable source of variation is introduced. For example, a breakfast cereal packaging line may be designed to fill each cereal box with 500 grams of cereal. Some boxes will have slightly more than 500 grams, and some will have slightly less. When package weight is measured, the data will demonstrate a distribution of net weights. If the production process, its inputs, or its environment (for example, the machines on the line) change, the distribution of the data will change. For example, as the cams and pulleys of the machinery wear, the cereal filling machine may put more than the specified amount of cereal into each box. Although this might benefit the customer, from the manufacturer's point of view, this is wasteful and increases the cost of production. If the manufacturer finds the change and its source in a timely manner, the change can be corrected (for example, the cams and pulleys replaced).

Application of SPC

The application of SPC involves three main sets of activities. The first is understanding of the process. This is achieved by business process mapping. The second is measuring the sources of variation assisted by the use of control charts and the third is eliminating assignable (special) sources of variation.

Control charts

The data from measurements of variations at points on the process map is monitored using control charts. Control charts can differentiate "assignable" ("special") sources of variation from "common" sources. "Common" sources, because they are an expected part of the process, are of much less concern to the manufacturer than "assignable" sources. Using control charts is a continuous activity, ongoing over time.

Stable process

When the process does not trigger any of the control chart "detection rules" for the control chart, it is said to be "stable". A process capability analysis may be performed on a stable process to predict the ability of the process to produce "conforming product" in the future.

Excessive variation

When the process triggers any of the control chart "detection rules",(or alternatively, the process capability is low), other activities may be performed to identify the source of the excessive variation. The tools used in these extra activities include: Ishikawa diagrams, designed experiments and Pareto charts. Designed experiments are critical to this phase of the application of SPC. They are the only means of objectively quantifying the relative importance (strength) of sources of variation. Once the sources of variation have been quantified, those sources that are both statistically and practically significant can be eliminated. (A source that is statistically significant may not be considered cost effect to eliminate. A source that is not statistically significant would not be considered significant in practical terms). Methods of eliminating a source of variation might include: development of standards; staff training; error-proofing and changes to the process itself.

Mathematics of control charts

Digital control charts use logic based rules that determine "derived values" which signal the need for correction. For example,

derived value = last value + average absolute difference between the last N numbers.

Most SPC charts work best using numeric data with Gaussian assumptions. Recently a new type of control chart, the real-time contrasts chart[6] was developed in order to handle process data with complex characteristics. Such data might include high-dimensional data; mixed numerical and categorical data; data with missing values; and data with non-Gaussian distributions or with non-linear relationships.

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Note: Before adding your company's link, please read WP:Spam#External_link_spamming and WP:External_links#Links_normally_to_be_avoided.

- worked example (http://www.4ulr.com/products/statisticalanalysis/redbeadexperiment.html) of the Deming's Red Bead Experiment

- Statistical Process Control (http://www.managers-net.com/statistical_process_control.html)

- Manufacturing Systems - Statistical Process Control (http://reliability.sandia.gov/Manuf_Statistics/Statistical_Process_Control/statistical_process_control.html)

- MIT Course - Control of Manufacturing Processes (http://ocw.mit.edu/courses/mechanical-engineering/2-830j-control-of-manufacturing-processes-sma-6303-spring-2008/)

- NIST Engineering Statistics Handbook (http://www.itl.nist.gov/div898/handbook/index2.htm)

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Systems for Implimentation

DMAIC

The DMAIC Improvement Process

DMAIC refers to a data-driven improvement cycle used for improving, optimizing and stabilizing business processes and designs. The DMAIC improvement cycle is the core process used to drive Six Sigma projects. DMAIC is not exclusive to Six Sigma and can be used as the framework for other improvement applications.

DMAIC is an abbreviation of the five improvement steps: Define, Measure, Analyze, Improve and Control. All of the DMAIC process steps are required and always proceed in this order:

Define

Write down what you currently know. Seek to clarify facts, set objectives and form the project team. Define the following:

- A problem statement
- The customer(s)
- Critical to Quality (CTQs) — what are the critical process outputs?
- The target process and other related business processes
- Project targets
- Project boundaries
- A project charter is often created and agreed during the Define step.

Measure

This is the data collection step. The team decides on what should be measured and how to measure it. This forms a data collection plan. It is usual for teams to invest a lot of effort into assessing the suitability of the proposed measurement systems. Good data is at the heart of the DMAIC process:

- Define the process critical Xs (inputs) and Ys (outputs).
- Define the measurement plan.
- Test the measurement system.
- Collect the data.
- A Measurement System Analysis (gauge study) is performed at this stage.

Analyze

The data collected in the Measure step is analysed to determine root causes of defects. Within Six Sigma, often complex analysis tools are used. However, it is acceptable to use basic tools if these are appropriate.

- Identify gaps between current performance and goal performance
- Identify how the process inputs (Xs) affect the process outputs (Ys)
- List and prioritize potential opportunities to improve
- Identify sources of variation
- Data is analysed to understand the location or distribution of the data collected. Histograms and box plots are often used to do this.

Improve

Identify creative solutions to fix and prevent process problems. Use brainstorming techniques like Six Thinking Hats and Random Word. Some projects can utilise complex analysis tools like DOE (Design of Experiments), but try to

focus on obvious solutions if these are apparent.

- Create innovative solutions
- Focus on the simplest and easiest solutions
- Test solutions using FMEA
- Create a detailed implementation plan
- Deploy improvements
- Ishikawa diagrams can be used throughout all DMAIC stages. Within the Improve step, we can use these to help brainstorm potential solutions.

Control

Monitor the improvements to ensure continued success. Create a control plan. Update documents, business process and training records as required.

Control charts can be useful during the control stage.

Replicate

This is additional to the standard DMAIC steps but it should be considered. Think about replicating the changes in other processes. Share your new knowledge within and outside of your organization.

External links

- DMAIC Tool Reference [1]

References

[1] http://tools.adaptivebms.com/

Design for Six Sigma

Design for Six Sigma (**DFSS**) is a separate and emerging business-process management methodology related to traditional Six Sigma. While the tools and order used in Six Sigma require a process to be in place and functioning, DFSS has the objective of determining the needs of customers and the business, and driving those needs into the product solution so created. DFSS is relevant to the complex system/product synthesis phase, especially in the context of unprecedented system development. It is process *generation* in contrast with process *improvement*.

DMADV, **D**efine – **M**easure – **A**nalyze – **D**esign – **V**erify, is sometimes synonymously referred to as DFSS. The traditional DMAIC (**D**efine – **M**easure – **A**nalyze – **I**mprove – **C**ontrol) Six Sigma process, as it is usually practiced, which is focused on evolutionary and continuous improvement manufacturing or service process development, usually occurs after initial system or product design and development have been largely completed. DMAIC Six Sigma as practiced is usually consumed with solving existing manufacturing or service process problems and removal of the defects and variation associated with defects. On the other hand, DFSS (or DMADV) strives to generate a new process where none existed, or where an existing process is deemed to be inadequate and in need of replacement. DFSS aims to create a process with the end in mind of optimally building the efficiencies of Six Sigma methodology into the process *before* implementation; traditional Six Sigma seeks for continuous improvement *after* a process already exists.

DFSS as an approach to design

DFSS seeks to avoid manufacturing/service process problems by using advanced Voice of the Customer techniques and proper systems engineering techniques to avoid process problems at the outset (i.e., fire prevention). When combined, these methods obtain the proper needs of the customer, and derive engineering system parameter requirements that increase product and service effectiveness in the eyes of the customer. This yields products and services that provide greater customer satisfaction and increased market share.These techniques also include tools and processes to predict, model and simulate the product delivery system (the processes/tools, personnel and organization, training, facilities, and logistics to produce the product/service) as well as the analysis of the developing system life cycle itself to ensure customer satisfaction with the proposed system design solution. In this way, DFSS is closely related to systems engineering, operations research (solving the Knapsack problem), systems architecture and concurrent engineering. DFSS is largely a design activity requiring specialized tools including: quality function deployment (QFD), axiomatic design, TRIZ, Design for X, design of experiments (DOE), Taguchi methods, tolerance design, Robustification and Response Surface Methodology for a single or multiple response optimization. While these tools are sometimes used in the classic DMAIC Six Sigma process, they are uniquely used by DFSS to analyze new and unprecedented systems/products. A graphical flowchart of common DFSS tools can be seen at DFSS Roadmap [1]. An additional roadmap for the metrics that may be utilized to deploy DFSS on a company-wide level may be seen at DFSS Metrics [2].

Arguments over the separation of DFSS from DMAIC / Six Sigma or Lean Six Sigma

Proponents of DMAIC and Lean techniques might claim that DFSS falls under the general rubric of Six Sigma or Lean Six Sigma. It is often seen that the tools used for DFSS techniques vary widely from those used for DMAIC Six Sigma. In particular, DMAIC practitioners often use new or existing mechanical drawings and manufacturing process instructions as the originating information to perform their analysis, while DFSS practitioners often use system simulations and parametric system design/analysis tools to predict both cost and performance of candidate system architectures. While it can be claimed that two processes are similar, in practice the working medium differs enough so that DFSS requires different tool sets in order to perform its system design tasks. DMAIC Six Sigma may still be used during depth-first plunges into the system architecture analysis and for "back end" Six Sigma processes; DFSS provides system design processes used in front-end complex system designs.

Similarities with other methods

Arguments about what makes DFSS different from Six Sigma demonstrate the similarities between DFSS and other established engineering practices such as Probabilistic design and design for quality. In general Six Sigma with its DMAIC roadmap focuses on improvement of an existing process or processes. DFSS focuses on the creation of new value with inputs from customers, suppliers and business needs. While traditional Six Sigma may also use those inputs, the focus is again on improvement and not design of some new product or system. It also shows the engineering background of DFSS. However, like other methods developed in engineering, there is no theoretical reason why DFSS can't be used in areas outside of engineering.

DFSS, applied to Software Engineering

Historically, although the first successful Design for Six Sigma projects in 1989 and 1991 predate establishment of the DMAIC process improvement process, Design for Six Sigma (DFSS) is accepted in part because Six Sigma organisations found that they could not optimise products past three or four Sigma without fundamentally redesigning the product, and because improving a process or product after launch is considered less efficient and effective than designing in quality. 'Six Sigma' levels of performance have to be 'built-in'.

DFSS for Software is essentially a non superficial modification of *"classical DFSS"* since the character and nature of software is different from other fields of engineering. The methodology describes the detailed process for successfully applying DFSS methods and tools throughout the Software Product Design, covering the overall Software Development life cycle: Requirements, Architecture, Design, Implementation, Integration, Optimization, Verification and Validation (RADIOV). The methodology explains how to build predictive statistical models for software reliability and robustness and shows how simulation and analysis techniques can be combined with structural design and architecture methods to effectively produce software and information systems at Six Sigma levels.

DFSS in Software acts as a glue to blend the classical modelling techniques of software engineering such as OOD or ERD with statistical, predictive models and simulation techniques. The methodology provides Software Engineers with practical tools for measuring and predicting the quality attributes of the software product and also enables them to include software in system reliability models.

Critics

Many critics have been written on the internet (search for "Six Sigma Comments, DFSS comments" / "Six Sigma sucks") about the exact process that DFSS (and Six Sigma) tries to describe. The general way of working might currently not be so clear.

There are no official standards from international bodies that describe the way of working for DFSS. This can however change in the future.

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Voice of the customer

Voice of the customer (VOC) is a term used in business and Information Technology (through ITIL, for example) to describe the in-depth process of capturing a customer's expectations, preferences and aversions.[1] Specifically, the Voice of the Customer is a market research technique that produces a detailed set of customer wants and needs, organized into a hierarchical structure, and then prioritized in terms of relative importance and satisfaction with current alternatives. Voice of the Customer studies typically consist of both qualitative and quantitative research steps. They are generally conducted at the start of any new product, process, or service design initiative in order to better understand the customer's wants and needs, and as the key input for new product definition, Quality Function Deployment (QFD), and the setting of detailed design specifications.

Much has been written about this process,[2] and there are many possible ways to gather the information – focus groups, individual interviews, contextual inquiry, ethnographic techniques, etc. But all involve a series of structured in-depth interviews, which focus on the customers' experiences with current products or alternatives within the category under consideration. Needs statements are then extracted, organized into a more usable hierarchy, and then prioritized by the customers.

It is critical that the product development core team own and are highly involved in this process. They must be the ones who take the lead in defining the topic, designing the sample (i.e. the types of customers to include), generating the questions for the discussion guide, either conducting or observing and analyzing the interviews, and extracting and processing the needs statements.

Voice of the Customer Initiatives

1. A detailed understanding of the customer's requirements
2. A common language for the team going forward
3. Key input for the setting of appropriate design specifications for the new product or service
4. A highly useful springboard for product innovation.

Qualities of Desirable Voice of Customer Metrics

Credibility: How widely accepted is the measure? Does it have a good track record of results? Is it based on a scientifically and academically rigorous methodology? Will management trust it? Is there proof that it is tied to financial results?

Reliability: Is it a consistent standard that can be applied across the customer lifecycle and multiple channels?

Precision: Is it specific enough to provide insight? Does it use multiple related questions to deliver greater accuracy and insight?

Accuracy: Is the measurement right? Is it representative of the entire customer base, or just an outspoken minority? Do the questions capture self-reported importance or can they derive importance based on what customers say? Does it have an acceptable margin of error and realistic sample sizes?

Actionability: Does it provide any insight into what can be done to encourage customers to be loyal and to purchase? Does it prioritize improvements according to biggest impacts?

Ability to Predict: Can it project the future behaviors of the customer based on their satisfaction?

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Poka-yoke

Poka-yoke (ポ カ ヨ ケ) Japanese pronunciation: [poka joke] is a Japanese term that means "fail-safing" or "mistake-proofing". A poka-yoke is any mechanism in a lean manufacturing process that helps an equipment operator avoid (*yokeru*) mistakes (*poka*). Its purpose is to eliminate product defects by preventing, correcting, or drawing attention to human errors as they occur.[1] The concept was formalised, and the term adopted, by Shigeo Shingo as part of the Toyota Production System.[2][3] It was originally described as *baka-yoke*, but as this means "fool-proofing" (or "idiot-proofing") the name was changed to the milder *poka-yoke*.

More broadly, the term can refer to any behavior-shaping constraint designed into a process to prevent incorrect operation by the user. Similarly, a constraint that is part of the product (or service) design is considered DFM or DFX.

Implementation in manufacturing

Poka-yoke can be implemented at any step of a manufacturing process where something can go wrong or an error can be made.[4] For example, a jig that holds pieces for processing might be modified to only allow pieces to be held in the correct orientation,[5] or a digital counter might track the number of spot welds on each piece to ensure that the worker executes the correct number of welds.[6]

Shigeo Shingo recognized three types of poka-yoke for detecting and preventing errors in a mass production system:[2][4]

1. The *contact* method identifies product defects by testing the product's shape, size, color, or other physical attributes.
2. The *fixed-value* (or *constant number*) method alerts the operator if a certain number of movements are not made.
3. The *motion-step* (or *sequence*) method determines whether the prescribed steps of the process have been followed.

Either the operator is alerted when a mistake is about to be made, or the poka-yoke device actually prevents the mistake from being made. In Shingo's lexicon, the former implementation would be called a *warning* poka-yoke, while the latter would be referred to as a *control* poka-yoke.[7]

Shingo argued that errors are inevitable in any manufacturing process, but that if appropriate poka-yokes are implemented, then mistakes can be caught quickly and prevented from resulting in defects. By eliminating defects at the source, the cost of mistakes within a company is reduced.[8]

Poka yoke system is generally known as PKS.

Implementation in service industries

Poka-yoke can also be implemented in service industries. Call centers have long had a challenge with compliance. Poor training, fatigue, forgetfulness, and the limits on human consistency all can lead to agents skipping key steps in the process. Disclosures are a good example. When a consumer makes a purchase of some kind, the call center agent is often required to provide the customer with key information. What the customer purchases dictates the disclosures that are required. It can be hard to train the agents in all the required combination of disclosures or the agents can sometimes forget to read the disclosures. Using agent-assisted automation, the agents can provide the customers with all the required disclosures using pre-recorded audio files.[9] By integrating the agent-assisted automation with the customer relationship management software, you can ensure that the agent cannot process/complete the order until the required disclosures are played.

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External links

- Poka-Yoke Example (http://www.shmula.com/1993/everyday-poka-yoke-preventing-theft) Written by Shmula

- Mistake-Proofing Example Wiki (http://pokayoke.wikispaces.com)

Muda (Japanese term)

Muda (無 駄)[1] is a traditional Japanese term for an activity that is wasteful and doesn't add value or is unproductive, etymologically none (無)+ trivia or un-useful (駄) in practice or others. It is also a key concept in the Toyota Production System (TPS) and is one of the three types of waste (muda, mura, muri[2]) that it identifies. Waste reduction is an effective way to increase profitability. Toyota merely picked up these three words beginning with the prefix *mu-*,[3] which in Japan are widely recognized as a reference to a product improvement program or campaign. A process adds value by producing goods or providing a service that a customer will pay for. A process consumes resources and waste occurs when more resources are consumed than are necessary to produce the goods or provide the service that the customer actually wants. The attitudes and tools of the TPS heighten awareness and give whole new perspectives on identifying waste and therefore the unexploited opportunities associated with reducing waste.

Muda has been given much greater attention as waste than the other two which means that whilst many Lean practitioners have learned to see muda they fail to see in the same prominence the wastes of mura (unevenness) and muri (overburden). Thus whilst they are focused on getting their process under control they do not give enough time to process improvement by redesign.

The seven wastes

One of the key steps in Lean and TPS is the identification of which steps add value and which do not. By classifying all the process activities into these two categories it is then possible to start actions for improving the former and eliminating the latter. Some of these definitions may seem rather 'idealist' but this tough definition is seen as important to the effectiveness of this key step. Once value-adding work has been separated from waste then waste can be subdivided into 'needs to be done but non-value adding' waste and pure waste. The clear identification of 'non-value adding work', as distinct from waste or work, is critical to identifying the assumptions and beliefs behind the current work process and to challenging them in due course.

The expression "Learning to see" comes from an ever developing ability to see waste where it was not perceived before. Many have sought to develop this ability by 'trips to Japan' to visit Toyota to see the difference between their operation and one that has been under continuous improvement for thirty years under the TPS. Shigeo Shingo, a co-developer of TPS, observed that it's only the last turn of a bolt that tightens it - the rest is just movement.[4] This level of refined 'seeing' of waste has enabled him to cut car body die changeover time to less than 3% of its duration in the 1950s as of 2010. Note that this period has allowed all the supporting services to adapt to this new capability and for the changeover time to undergo multiple improvements. These multiple improvements were in new technologies, refining value required by 'downstream' processes and by internal process redesigns.

The following "seven wastes" identify resources which are commonly wasted. They were identified by Toyota's Chief Engineer, Taiichi Ohno as part of the Toyota Production System:[5]

Transportation

Each time a product is moved it stands the risk of being damaged, lost, delayed, etc. as well as being a cost for no added value. Transportation does not make any transformation to the product that the consumer is willing to pay for.

Inventory

Inventory, be it in the form of raw materials, work-in-progress (WIP), or finished goods, represents a capital outlay that has not yet produced an income either by the producer or for the consumer. Any of these three items not being actively processed to add value is waste.

Motion

In contrast to transportation, which refers to damage to products and transaction costs associated with moving them, motion refers to the damage that the production process inflicts on the entity that creates the product, either over time (wear and tear for equipment and repetitive stress injuries for workers) or during discrete events (accidents that damage equipment and/or injure workers).

Waiting

or (WIP) Work in Process

Whenever goods are not in transport or being processed, they are waiting. In traditional processes, a large part of an individual product's life is spent waiting to be worked on.

Over-processing

Over-processing occurs any time more work is done on a piece than what is required by the customer. This also includes using tools that are more precise, complex, or expensive than absolutely required.

Over-production

Overproduction occurs when more product is produced than is required at that time by your customers. One common practice that leads to this muda is the production of large batches, as often consumer needs change over the long times large batches require. Overproduction is considered the worst muda because it hides and/or generates all the others. Overproduction leads to excess inventory, which then requires the expenditure of resources on storage space and preservation, activities that do not benefit the customer.

Defects

Whenever defects occur, extra costs are incurred reworking the part, rescheduling production, etc.

An easy way to remember the 7 wastes is TIMWOOD.

- T: Transportation
- I: Inventory
- M: Motion
- W: Wait
- O: Over-processing
- O: Over-production
- D: Defect

Other candidate wastes

Other sources have proposed additional wastes. These may work for the proposers or they may overlap or be inconsistent with the originals which came from a coherent source.

Latent skill

Organizations employ their staff for specific skills that they may have. These employees have other skills too, it is wasteful to not take advantage of these skills as well. "It is only by capitalizing on employees' creativity that organizations can eliminate the other seven wastes and continuously improve their performance."[6]

Implementation

Shigeo Shingo divides process related activity into Process and Operation.[7] He distinguishes "Process", the course of material that is transformed into product, from "Operation" which are the actions performed on the material by workers and machines. This distinction is not generally recognized because most people would view the "Operations" performed on the raw materials of a product by workers and machines as the "Process" by which those raw materials are transformed into the final product. He makes this distinction because value is added to the product by the process but not by most of the operations. He states that whereas many see Process and Operations in parallel he sees them at right angles (orthogonal) (see Value Stream Mapping). This starkly throws most of operations into the waste category.

Many of the TPS/Lean techniques work in a similar way. By planning to reduce manpower, or reduce change-over times, or reduce campaign lengths, or reduce lot sizes the question of waste comes immediately into focus upon those elements that prevent the plan being implemented. Often it is in the operations area rather than the process area that muda can be eliminated and remove the blockage to the plan. Tools of many types and methodologies can then be employed on these wastes to reduce or eliminate them.

The plan is therefore to build a fast, flexible process where the immediate impact is to reduce waste and therefore costs. By ratcheting the process towards this aim with focused muda reduction to achieve each step, the improvements are 'locked in' and become required for the process to function. Without this intent to build a fast, flexible process there is a significant danger that any improvements achieved will not be sustained because they are *just* desirable and can slip back towards old behaviours without the process stopping.

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[7]   A study of the Toyota Production System, Shigeo Shingo, Productivity Press, 1989, p xxxi

External links

- "The 7 Manufacturing Wastes" (http://www.emsstrategies.com/dm090203article2.html)

Nemawashi

Nemawashi (根回し) in Japanese means an informal process of quietly laying the foundation for some proposed change or project, by talking to the people concerned, gathering support and feedback, and so forth. It is considered an important element in any major change, before any formal steps are taken, and successful *nemawashi* enables changes to be carried out with the consent of all sides.

Nemawashi literally translates as "going around the roots", from 根 (*ne*, root) and 回す (*mawasu*, to go around [something]). Its original meaning was literal: digging around the roots of a tree, to prepare it for a transplant.

Nemawashi is often cited as an example of a Japanese word which is difficult to translate effectively, because it is tied so closely to Japanese culture itself, although it is often translated as 'laying the groundwork.'

External links

- Toyota Production System (TPS) Toyota Production System
- Pubmed: Nemawashi essential for conducting research in Japan. [1]
- Kirai, a geek in Japan: Nemawashi [2]

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Blue Ocean Strategy

Blue Ocean Strategy	
First edition cover	
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Blue Ocean Strategy is a business strategy book first published in 2005 and written by W. Chan Kim and Renée Mauborgne of The Blue Ocean Strategy Institute [2] at INSEAD. The book illustrates what the authors believe is the high growth and profits an organization can generate by creating new demand in an uncontested market space, or a "Blue Ocean", rather than by competing head-to-head with other suppliers for known customers in an existing industry.[3]

Book layout and highlight

The book is divided into five parts: The first part presents key concepts of blue ocean strategy, including Value Innovation – the simultaneous pursuit of differentiation and low cost – and key analytical tools and frameworks such as the strategy canvas, the four actions framework and the eliminate-reduce-raise-create grid. The second part describes the four principles of blue ocean strategy formulation: how to create uncontested market space by reconstructing market boundaries, focusing on the big picture, reaching beyond existing demand and getting the strategic sequence right. These four formulation principles address how an organization can create blue oceans by looking across the six conventional boundaries of competition (Six Paths Framework), reduce their planning risk by following the four steps of visualizing strategy, create new demand by unlocking the three tiers of noncustomers and launch a commercially-viable blue ocean idea by aligning unprecedented utility of an offering with strategic pricing and target costing and by overcoming adoption hurdles. The book uses many examples across industries to demonstrate how to break out of traditional competitive (structuralist) strategic thinking and to grow demand and profits for the company and the industry by using blue ocean (reconstructionist) strategic thinking. The third and final part describes the two key implementation principles of blue ocean strategy including tipping point leadership and fair process. These implementation principles are essential for leaders to overcome the four key organizational hurdles that can prevent even the best strategies from being executed. The four key hurdles comprise the cognitive, resource, motivational and political hurdles that prevent people involved in strategy execution from understanding the need to break from status quo, finding the resources to implement the new strategic shift, keeping your people committed to implementing the new strategy, and from overcoming the powerful vested interests that may block the

change.

In the book the authors draw the attention of their readers towards the correlation of success stories across industries and the formulation of strategies that provide a solid base create unconventional success − a strategy termed as "*Blue Ocean Strategy*". Unlike the "*Red Ocean Strategy*", the conventional approach to business of beating competition derived from the military organization, the "*Blue Ocean Strategy*" tries to align innovation with utility, price and cost positions. The book mocks at the phenomena of conventional choice between product/service differentiation and lower cost, but rather suggests that both differentiation and lower costs are achievable simultaneously.

The authors ask readers "*What is the best unit of analysis of profitable growth? Company? Industry?*" − a fundamental question without which any strategy for profitable growth is not worthwhile. The authors justify with original and practical ideas that neither the company nor the industry is the best unit of analysis of profitable growth; rather it is the strategic move that creates "*Blue Ocean*" and sustained high performance. The book examines the experience of companies in areas as diverse as watches, wine, cement, computers, automobiles, textiles, coffee makers, airlines, retailers, and even the circus, to answer this fundamental question and builds upon the argument about "*Value Innovation*" being the cornerstone of a blue ocean strategy. Value Innovation is necessarily the alignment of innovation with utility, price and cost positions. This creates uncontested market space and makes competition irrelevant. The following section discusses the concept behind the book in detail.

Concept

Cirque du Soleil − an example of creating a new market space, by blending opera and ballet with the circus format while eliminating star performer and animals

The metaphor of **red and blue oceans** describes the market universe.

Red Oceans are all the industries in existence today − the known market space. In the red oceans, industry boundaries are defined and accepted, and the competitive rules of the game are known. Here companies try to outperform their rivals to grab a greater share of product or service demand. As the market space gets crowded, prospects for profits and growth are reduced. Products become commodities or niche, and cutthroat competition turns the ocean bloody. Hence, the term *red oceans*.[4]

Blue oceans, in contrast, denote all the industries not in existence today − the unknown market space, untainted by competition. In blue oceans, demand is created rather than fought over. There is ample opportunity for growth that is both profitable and rapid. In blue oceans, competition is irrelevant because the rules of the game are waiting to be set. Blue ocean is an analogy to describe the wider, deeper potential of market space that is not yet explored.[4]

The cornerstone of Blue Ocean Strategy is 'Value Innovation'. A blue ocean is created when a company achieves value innovation that creates value simultaneously for both the buyer and the company. The *innovation* (in product, service, or delivery) must raise and create value for the market, while simultaneously reducing or eliminating features or services that are less valued by the current or future market. The authors criticize Michael Porter's idea that successful businesses are either low-cost providers or niche-players. Instead, they propose finding value that

crosses conventional market segmentation and offering value *and* lower cost. Educator Charles W. L. Hill proposed this idea in 1988 and claimed that Porter's model was flawed because differentiation can be a means for firms to achieve low cost. He proposed that a combination of differentiation and low cost might be necessary for firms to achieve a sustainable competitive advantage.

Many others have proposed similar strategies. For example, Swedish educators Jonas Ridderstråle and Kjell Nordström in their 1999 book *Funky Business* follow a similar line of reasoning. For example, "competing factors" in Blue Ocean Strategy are similar to the definition of "finite and infinite dimensions" in *Funky Business*. Just as Blue Ocean Strategy claims that a Red Ocean Strategy does not guarantee success, *Funky Business* explained that "Competitive Strategy is the route to nowhere". *Funky Business* argues that firms need to create "Sensational Strategies". Just like Blue Ocean Strategy, a Sensational Strategy is about "playing a different game" according to Ridderstråle and Nordström. Ridderstråle and Nordström also claim that the aim of companies is to create temporary monopolies. Kim and Mauborgne explain that the aim of companies is to create blue oceans, that will eventually turn red. This is the same idea expressed in the form of an analogy. Ridderstråle and Nordström also claimed in 1999 that "in the slow-growth 1990s overcapacity is the norm in most businesses". Kim and Mauborgne claim that blue ocean strategy makes sense in a world where supply exceeds demand.

Preceding work

The contents of the book are based on research and a series of Harvard Business Review articles as well as academic articles on various dimensions of the topic.

Kim and Mauborgne studied about one hundred fifty positions made from 1880 to 2000 in more than thirty industries and closely examined the relevant business players in each. They analyzed the winning business players as well as the less successful competitors. Studied industries included hotels, cinemas, retail stores, airlines, energy, construction, Publishing, automotive and steel. They searched for convergence among the more and less successful players. Divergence across the two groups was also studied to discover the common factors leading to strong growth and the key differences separating those winners from the mere survivors and the losers. Kim and Mauborgne defined a consistent and common pattern across all the seemingly idiosyncratic success stories and first called it value innovation, and then Blue Ocean Strategy.

Research results were first published in 1997 in a Harvard Business Review article by Kim and Mauborgne titled "Value Innovation: The Strategic Logic of High Growth".[5] The ideas, tools and frameworks were tested and refined over the years in corporate practice in Europe, the United States and Asia and presented in the following eight additional articles, before being published in the form of a book in 2005.

- 1997. "Value Innovation – The Strategic Logic of High Growth". Harvard Business Review 75, January–February, 103–112.
- 1998. Procedural Justice, Strategic Decision Making and the Knowledge Economy." Strategic Management Journal, April.
- 1999. "Creating New Market Space." Harvard Business Review 77, January–February, 83–93.
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- 2000. "Knowing a Winning Business Idea When You See One." Harvard Business Review 78, September–October, 129–141.
- 2002. "Charting Your Company's Future." Harvard Business Review 80, June, 76–85.
- 2003. "Tipping Point Leadership." Harvard Business Review 81, April, 60–69.
- 2004. "Blue Ocean Strategy." Harvard Business Review, October, 76–85.

The name "Blue Ocean Strategy" was introduced in the Harvard Business Review article published in October 2004.[6] The book builds on and extends the work presented in these articles by providing a narrative arc that draws all these ideas together to offer a unified framework for creating and capturing blue oceans.

Subsequent work

- 2009. "How Strategy Shapes Structure." Harvard Business Review, September, pp. 73–80.

In this latest HBR article, Kim and Mauborgne present the importance of alignment across the value, profit and people propositions regardless of whether one takes the structuralist (traditional competitive) or the reconstructionist (blue ocean) approach to strategy.

Blue Ocean Strategy vs. competition based strategies

Kim and Mauborgne argue that while traditional competition-based strategies (red ocean strategies) are necessary, they are not sufficient to sustain high performance. Companies need to go beyond competing. To seize new profit and growth opportunities they also need to create blue oceans.[7]

The authors argue that competition based strategies assume that an industry's structural conditions are given and that firms are forced to compete within them, an assumption based on what academics call the structuralist view, or environmental determinism.[8] To sustain themselves in the marketplace, practitioners of red ocean strategy focus on building advantages over the competition, usually by assessing what competitors do and striving to do it better. Here, grabbing a bigger share of the market is seen as a zero-sum game in which one company's gain is achieved at another company's loss. Hence, competition, the supply side of the equation, becomes the defining variable of strategy. Here, cost and value are seen as trade-offs and a firm chooses a distinctive cost or differentiation position. Because the total profit level of the industry is also determined exogenously by structural factors, firms principally seek to capture and redistribute wealth instead of creating wealth. They focus on dividing up the red ocean, where growth is increasingly limited.

Blue ocean strategy, on the other hand, is based on the view that market boundaries and industry structure are not given and can be reconstructed by the actions and beliefs of industry players. This is what the authors call "reconstructionist view". Assuming that structure and market boundaries exist only in managers' minds, practitioners who hold this view do not let existing market structures limit their thinking. To them, extra demand is out there, largely untapped. The crux of the problem is how to create it. This, in turn, requires a shift of attention from supply to demand, from a focus on competing to a focus on value innovation – that is, the creation of innovative value to unlock new demand. This is achieved via the simultaneous pursuit of differentiation and low-cost. As market structure is changed by breaking the value/cost tradeoff, so are the rules of the game. Competition in the old game is therefore rendered irrelevant. By expanding the demand side of the economy new wealth is created. Such a strategy therefore allows firms to largely play a non–zero-sum game, with high payoff possibilities.[9]

Tools and frameworks

Blue Ocean Strategy has introduced a number of practical tools, methodologies and frameworks to formulate and execute blue ocean strategies, attempting to make creation of blue oceans a systematic, repeatable process. Some of these are listed below:

> ***Summary of Blue Ocean Strategy Frameworks, Tools and Methodologies***
> *For blue ocean strategy formulation*
>
> - The Strategy Canvas
> - The initial litmus test for BOS: focus, divergence, compelling tagline
> - The Four Actions Framework
> - Eliminate-Reduce-Raise-Create Grid
> - The Six Paths Framework
> - Buyer Utility Map
> - Buyer Experience Cycle
> - Price Corridor of the Mass model
> - Four Steps of Visualizing Strategy Process
> - Pioneer-Migrator-Settler Map
> - Three Tiers of Noncustomers Framework
> - The Sequence of Blue Ocean Strategy
>
> *For blue ocean strategy execution*
>
> - Tipping Point Leadership
> - Four Key Organizational Hurdles:
>   - Riding the "Electric Sewer" to break the Cognitive Hurdle
>   - Redirecting from cold spots to hot spots and horse trading to overcome the Resource Hurdle
>   - Placing Kingpins in a Fishbowl and atomize the change to jump over the Motivational Hurdle
>   - Leverage your angels and consigliere to overcome the Political Hurdle
> - 3 E principles of Fair Process: engagement, explanation, clarity of expectations

Criticisms

While Kim and Mauborgne propose approaches to finding uncontested market space, at the present there are few success stories of companies that applied their theories in advance. One success story that does exist is Nintendo, who first applied the Blue Ocean Strategy to create the Nintendo DS handheld game system which was the first portable gaming system to offer dual screen gaming and a touch screen. In 2006 Nintendo released Wii, which redefined who video games are played by. The 3DS is Nintendo's third endeavour for its blue ocean strategy. Its first two attempts, the Nintendo DS and Wii, were wildly successful, becoming some of the biggest selling platforms in history. Nintendo revealed their Blue Ocean Strategy during an E3 press conference during the hype build-up of the Wii.

However with just one case study, this hole in their data persists despite the publication of Value Innovation concepts since 1997. Hence, a critical question is whether this book and its related ideas are *descriptive* rather than *prescriptive*.[10] The authors present many examples of successful innovations, and then explain from their Blue Ocean perspective – essentially interpreting success through their lenses.[11]

The research process followed by the authors has been criticized[12] on several grounds. Criticisms include claims that no control group was used, that there is no way to know how many companies using a Blue Ocean Strategy failed and the theory is thus unfalsifiable, that a deductive process was not followed, and that the examples in the book were selected to "tell a winning story."

Brand and communication are taken for granted and do not represent a key for success. Kim and Maubourgne take the marketing of a value innovation as a given, assuming the marketing success will come as a matter of course.[10]

It is argued that rather than a theory, Blue Ocean Strategy is an extremely successful attempt to brand a set of already existing concepts and frameworks with a highly "sticky" idea.[13] The blue ocean/red ocean analogy is a powerful

and memorable metaphor, which is responsible for its popularity. This metaphor can be powerful enough to stimulate people to action. However, the concepts behind the Blue Ocean Strategy (such as the competing factors, the consumer cycle, non-customers, etc.) are not new. Many of these tools are also used by Six Sigma practitioners and proposed by other management theorists.

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External links

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- Blue Ocean Strategy − A Review (http://www.technoparktoday.com/blue-ocean-strategy/)

TRIZ

TRIZ (🔊 /ˈtriːz/; Russian: теория решения изобретательских задач, *teoriya resheniya izobretatelskikh zadatch*) is "a problem-solving, analysis and forecasting tool derived from the study of patterns of invention in the global patent literature".[1] It was developed by the Soviet inventor and science fiction author Genrich Altshuller and his colleagues, beginning in 1946. In English the name is typically rendered as "the **theory of inventive problem solving**",[2][3] and occasionally goes by the English acronym **TIPS**.

Following Altshuller's insight, the theory developed on a foundation of extensive research covering hundreds of thousands of inventions across many different fields to produce a theory which defines generalisable patterns in the nature of inventive solutions and the distinguishing characteristics of the problems that these inventions have overcome.

An important part of the theory has been devoted to revealing patterns of evolution and one of the objectives which has been pursued by leading practitioners of TRIZ has been the development of an algorithmic approach to the invention of new systems, and the refinement of existing ones.

The theory includes a practical methodology, tool sets, a knowledge base, and model-based technology for generating new ideas and solutions for problem solving. It is intended for application in problem formulation, system analysis, failure analysis, and patterns of system evolution.

There are three primary findings of this research. The first is that problems and solutions are repeated across industries and sciences, the second that patterns of technical evolution are also repeated across industries and sciences, and the third and final primary finding is that the innovations used scientific effects outside the field in which they were developed. In the application of TRIZ all these findings are[4] applied to create and to improve products, services, and systems.

History

TRIZ in its classical form was developed by the Soviet inventor and science fiction writer Genrich Altshuller and his associates. He started developing TRIZ in 1946 while working in the "Inventions Inspection" department of the Caspian Sea flotilla of the Soviet Navy. His job was to help with the initiation of invention proposals, to rectify and document them and prepare applications to the patent office. During this time he realised that a problem requires an inventive solution if there is a unresolved contradiction in the sense that improving one parameter impacts negatively on another. He later called these "technical contradictions".

His work on what later resulted in TRIZ was interrupted in 1950 by his arrest and sentencing to 25 years in the Gulag. According to one source the arrest was partially triggered by letters which he and Raphael Shapiro sent to Stalin, ministers and newspapers about certain decisions made by the Soviet Government, which they believed were erroneous.[5] Altshuller and Shapiro were freed following Stalin's death in 1953[6] and returned to Baku.

The first paper on TRIZ titled "On the psychology of inventive creation" was published in 1956 in "Issues in Psychology" (Voprosi Psichologii) journal.[7]

By 1969 Altshuller had reviewed about 40,000 patent abstracts in order to find out in what way the innovation had taken place and developed the concept of technical contradictions, the concept of ideality of a system, contradiction matrix, and 40 principles of invention. In the years that followed he developed the concepts of physical contradictions, SuField analysis (structural substance-field analysis), standard solutions, several laws of technical systems evolution, and numerous other theoretical and practical approaches.

In 1971 Altshuller convinced The Inventors Society to establish in Baku the first TRIZ teaching facility called the Azerbaijan Public Institute for Inventive Creation and the first TRIZ research lab called The Public Lab for Inventive Creation. Altshuller was appointed the head of the lab by the society. The lab incubated the TRIZ movement and in the years that followed other TRIZ teaching institutes were established in all major cities of the USSR. In 1989 the

TRIZ Association was formed, with Altshuller chosen as President.

Following the end of the cold war, the waves of emigrants from the former Soviet Union brought TRIZ to other countries and drew attention to it overseas.[8] In 1995 the Altshuller Institute for TRIZ Studies was established in Boston, USA.

Basic principles of TRIZ

TRIZ presents a systematic approach for analysing the kind of challenging problems where inventiveness is needed and provides a range of strategies and tools for finding inventive solutions. One of the earliest findings of the massive research on which the theory is based is that the vast majority of problems that require inventive solutions typically reflect a need to overcome a dilemma or a trade-off between two contradictory elements. The central purpose of TRIZ-based analysis is to systematically apply the strategies and tools to find superior solutions that overcome the need for a compromise or trade-off between the two elements.

By the early 1970s two decades of research covering hundreds of thousands of patents had confirmed Altshuller's initial insight about the patterns of inventive solutions and one of the first analytical tools was published in the form of 40 inventive principles, which could account for virtually all of those patents that presented truly inventive solutions. Following this approach the "Typical solution" shown in the diagram can be found by defining the contradiction which needs to be resolved and

TRIZ process for creative problem solving

systematically considering which of the 40 principles may be applied to provide a specific solution which will overcome the "contradiction" in the problem at hand, enabling a solution that is closer to the "ultimate ideal result".
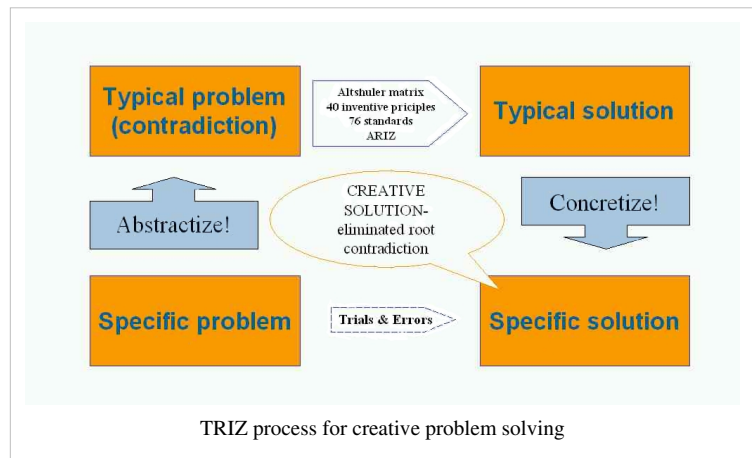
The combination of all of these concepts together – the analysis of the contradiction, the pursuit of an ideal solution and the search for one or more of the principles which will overcome the contradiction, are the key elements in a process which is designed to help the inventor to engage in the process with purposefulness and focus.

One of the tools which evolved as an extension of the 40 principles was a contradiction matrix in which the contradictory elements of a problem were categorized according to a list of 39 factors which could impact on each other. The combination of each pairing of these 39 elements is set out in a matrix (for example, the weight of a stationary object, the use of energy by a moving object, the ease of repair etc.) Each of the 39 elements is represented down the rows and across the columns (as the negatively affected element) and based upon the research and analysis of patents: wherever precedent solutions have been found that resolve a conflict between two of the elements, the relevant cells in the matrix typically contain a sub-set of three or four principles that have been applied most frequently in inventive solutions which resolve contradictions between those two elements.

The main objective of the contradiction matrix was to simplify the process of selecting the most appropriate Principle to resolve a specific contradiction. It was the core of all modifications of ARIZ till 1973. But in 1973, after introducing the concept of physical contradictions and creating SuField analysis, Altshuller realized that the contradiction matrix was comparatively an inefficient tool and stopped working on it. Beginning ARIZ-71c contradiction matrix ceased to be the core of ARIZ and therefore was not a tool for solving inventive problems that Altshuller believed should be pursued. Physical contradictions and separation principles as well as SuField analysis, etc. became the core. Despite this, the 40 principles has remained the most popular tool taught in introductory seminars and has consistently attracted the most attention amongst the tens of thousands of individuals who visit

TRIZ-focused web sites in a typical month. Therefore, many of those who learn TRIZ or have attended seminars are taught quite wrongly that TRIZ is primarily composed of the 40 principles and contradiction matrix, the truth is ARIZ is the core methodology of TRIZ.

ARIZ is an algorithmic approach to finding inventive solutions by identifying and resolving contradictions. This includes the "system of inventive standards solutions" which Altshuller used to replace the 40 principles and contradiction matrix, it consists of SuField modeling and the 76 inventive standards. A number of TRIZ-based computer programs have been developed whose purpose is to provide assistance to engineers and inventors in finding inventive solutions for technological problems. Some of these programs are also designed to apply another TRIZ methodology whose purpose is to reveal and forecast emergency situations and to anticipate circumstances which could result in undesirable outcomes.

One of the important branches of TRIZ is focused on analysing and predicting trends of evolution in the characteristics that existing solutions are likely to develop in successive generations of a system.

Essentials

Basic terms

- *Ideal final result* (IFR) - the ultimate idealistic solution of a problem when the desired result is achieved by itself;
- *Administrative contradiction* - contradiction between the needs and abilities;
- *Technical contradiction* - an inverse dependence between parameters/characteristics of a machine or technology;
- *Physical contradiction* - opposite/contradictory physical requirements to an object;
- *Separation principle* - a method of resolving physical contradictions by separating contradictory requirements;
- *VePol* or *SuField* - a minimal technical system consisting of two material objects (substances) and a "field". "Field" is the source of energy whereas one of the substances is "transmission" and the other one is the "tool";
- *FePol* - a sort of VePol where "substances" are ferromagnetic objects;
- *Level of invention*;
- *Standard solution* - a standard inventive solution of a higher level;
- *Laws of technical systems evolution*;
- *Algorithm of inventive problems solving* (ARIZ), which combines various specialized methods of TRIZ into one universal tool;

Identifying a problem: contradictions

Altshuller believed that inventive problems stem from contradictions (one of the basic TRIZ concepts) between two or more elements, such as, "If we want more acceleration, we need a larger engine; but that will increase the cost of the car," that is, more of something desirable also brings more of something less desirable, or less of something else also desirable.

These are called *technical contradictions* by Altshuller. He also defined so-called physical or inherent contradictions: More of one thing and less of the same thing may both be desired in the same system. For instance, a higher temperature may be needed to melt a compound more rapidly, but a lower temperature may be needed to achieve a homogeneous mixture.

An *inventive situation* which challenges us to be inventive, might involve several such contradictions. Conventional solutions typically "trade" one contradictory parameter for another; no special inventiveness is needed for that. Rather, the inventor would develop a creative approach for resolving the contradiction, such as inventing an engine that produces more acceleration without increasing the cost of the engine.

Inventive principles and the matrix of contradictions

Altshuller screened patents in order to find out what kind of contradictions were resolved or dissolved by the invention and the way this had been achieved. From this he developed a set of 40 inventive principles and later a matrix of contradictions. Rows of the matrix indicate the 39 system features that one typically wants to improve, such as speed, weight, accuracy of measurement and so on. Columns refer to typical undesired results. Each matrix cell points to principles that have been most frequently used in patents in order to resolve the contradiction.

For instance, Dolgashev mentions the following contradiction: increasing accuracy of measurement of machined balls while avoiding the use of expensive microscopes and elaborate control equipment. The matrix cell in row "accuracy of measurement" and column "complexity of control" points to several principles, among them the Copying Principle, which states, "Use a simple and inexpensive optical copy with a suitable scale instead of an object that is complex, expensive, fragile or inconvenient to operate." From this general invention principle, the following idea might solve the problem: Taking a high-resolution image of the machined ball. A screen with a grid might provide the required measurement. As mentioned above, Altshuler abandoned this method of defining and solving "technical" contradictions in the mid 1980's and instead used SuField modeling and the 76 inventive standards and a number of other tools included in the algorithm for solving inventive problems, ARIZ

Laws of technical system evolution

Altshuller also studied the way technical systems have been developed and improved over time. From this, he discovered several trends (so called Laws of Technical Systems Evolution) that help engineers predict what the most likely improvements that can be made to a given product are. The most important of these laws involves the ideality of a system.

Substance-field analysis

One more technique that is frequently used by inventors involves the analysis of substances, fields and other resources that are currently not being used and that can be found within the system or nearby. TRIZ uses non-standard definitions for substances and fields. Altshuller developed methods to analyze resources; several of his invention principles involve the use of different substances and fields that help resolve contradictions and increase ideality of a technical system. For instance, videotext systems used television signals to transfer data, by taking advantage of the small time segments between TV frames in the signals.

SuField analysis produces a structural model of the initial technological system, exposes its characteristics, and with the help of special laws, transforms the model of the problem. Through this transformation the structure of the solution that eliminates the shortcomings of the initial problem is revealed. SuField analysis is a special language of formulas with which it is possible to easily describe any technological system in terms of a specific (structural) model. A model produced in this manner is transformed according to special laws and regularities, thereby revealing the structural solution of the problem.

ARIZ - algorithm of inventive problems solving

ARIZ (Russian acronym of алгоритм решения изобретательских задач - АРИЗ) (algorithm of inventive problems solving) is a list of about 85 step-by-step procedures to solve complicated invention problems, where other tools of TRIZ alone (Sufield analysis, 40 inventive principles, etc.) are not sufficient.

Various TRIZ software (see invention machine, ideation international, and southbeach modeller) is based on this algorithm (or an improved one).

Starting with an updated matrix of contradictions, semantic analysis, subcategories of inventive principles and lists of scientific effects, some new interactive applications are other attempts to simplify the problem formulation phase and the transition from a generic problem to a whole set of specific solutions.

(see External links for details)

Use of TRIZ methods in industry

It has been reported that car companies Ford and Daimler-Chrysler, Johnson & Johnson, aeronautics companies Boeing, NASA, technology companies Hewlett Packard, Motorola, General Electric, Xerox, IBM, LG, Samsung, Procter and Gamble and Kodak have used TRIZ methods in some projects.[6][9][10][11]

Approaches which are modifications/derivatives of TRIZ

1. Systematic Inventive Thinking (systematic inventive thinking)
2. ASIT (advanced systematic inventive thinking)
3. USIT (unified structured inventive thinking)
4. JUSIT (Japanese version of unified systematic inventive thinking)
5. TRIZICS (A methodology for the systematic application of TRIZ)

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• Altshuller, Genrich (1984). *Creativity as an Exact Science*. New York, NY: Gordon & Breach. ISBN 0-677-21230-5.

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External links

- Official G.S. Altshuller foundation (http://www.altshuller.ru/)
- The Altshuller Institute for TRIZ Studies, Worcester, MA, USA (http://www.aitriz.org)
- TRIZ-Research journal (http://www3.sympatico.ca/karasik) (Alternative journal on TRIZ.)
- Dmitry Kucharavy website sharing publications and materials for educational purposes (http://www.seecore.org/id11.htm)
- Open Source TRIZ (http://www.opensourcetriz.com/main/page_home.html)

Lean Six Sigma

Lean Six Sigma is a synergized managerial concept of Lean and Six Sigma that results in the elimination of the seven kinds of wastes/muda (classified as Defects, Overproduction, Transportation, Waiting, Inventory, Motion and Over-Processing) and provision of goods and service at a rate of 3.4 defects per million opportunities (DPMO) .

The Lean Six Sigma concepts were first published in the book titled "Lean Six Sigma: Combining Six Sigma with Lean Speed" authored by Michael George in the year 2002. Lean Six Sigma utilises the DMAIC phases similar to that of Six Sigma. The Lean Six Sigma projects comprise the Lean's waste elimination projects and the Six Sigma projects based on the critical to quality characteristics. The DMAIC toolkit of Lean Six Sigma comprises all the Lean and Six Sigma tools. The training for Lean Six Sigma is provided through the belt based training system similar to that of Six Sigma. The belt personnel are designated as White Belts, Yellow Belts, Green Belts, Black Belts and Master Black Belts.

Lean Six Sigma Group is the largest online networking group of Lean Six Sigma Professionals Internationally. http://www.linkedin.com/groups/Lean-Six-Sigma-37987.

Lean Six Sigma Tollgate Templates, developed by Master Black Belt Steven Bonacorsi, President of the International Standard for Lean Six Sigma, and Founder of the Lean Six Sigma Group. The Lean Six Sigma project templates are used by Green Belt, Black Belt, and Master Black Belts in documenting Lean Six Sigma Projects, Case Studies, Certification Projects, Kaizen, and Overall Project Summary Results.

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An Alternative Approach

Appreciative inquiry

Appreciative Inquiry (sometimes shortened to "AI") is primarily an organizational development method which focuses on increasing what an organization does well rather than on eliminating what it does badly. Through an *inquiry* which *appreciates* the positive and engages all levels of an organization (and often its customers and suppliers) it seeks to renew, develop and build on this. Its proponents view it as being applicable to organizations facing rapid change or growth.[1] David Cooperrider is generally credited with coining the term 'Appreciative Inquiry'.

The Basis of the AI approach

The Appreciative Inquiry model is based on the assumption that the questions we ask will tend to focus our attention in a particular direction. Some other methods of assessing and evaluating a situation and then proposing solutions are based on a *deficiency* model. Some other methods ask questions such as "What are the problems?", "What's wrong?" or "What needs to be fixed?".

Instead of asking "What's the problem?", some other methods couch the question in terms of challenges, which AI argues maintains a basis of deficiency, the thinking behind the questions assuming that there is something wrong, or that something needs to be fixed or solved.[2]

Appreciative Inquiry takes an alternative approach. As a self defined "asset-based approach" it starts with the belief that every organisation, and every person in that organisation, has positive aspects that can be built upon. It asks questions like "What's working well?", "What's good about what you are currently doing?"[3]

Some researchers believe that excessive focus on dysfunctions can actually cause them to become worse or fail to become better[4]. By contrast, AI argues, when all members of an organization are motivated to understand and value the most favourable features of its culture, it can make rapid improvements.[5]

Strength-based methods are used in the creation of organizational development strategy and implementation of organizational effectiveness tactics.[6] The *appreciative* mode of inquiry often relies on interviews to qualitatively understand the organization's potential strengths by looking at an organization's experience and its potential; the objective is to elucidate the assets and personal motivations that are its strengths.

What distinguishes AI

The following table illustrates how AI supporters describe some of the distinctions between Appreciative Inquiry and approaches to organizational development not based on what they call positive potential[7]:

Problem Solving	Appreciative inquiry
Felt need, identification of problem(s)	Appreciating, valuing the Best of What Is
Analysis of Causes	Envisioning what might be
Analysis of possible solutions	Engaging in dialogue about what should be
Action Planning (treatment)	Innovating, what will be

Appreciative Inquiry attempts to use ways of asking questions and envisioning the future in-order to foster positive relationships and build on the present potential of a given person, organisation or situation. Applied research has demonstrated that this method can enhance an organisation's internal capacity for collaboration and change.[8] Appreciative Inquiry utilises a cycle of 4 processes, which focuses on what it calls:

1. **DISCOVER:** The identification of organizational processes that work well.
2. **DREAM:** The envisioning of processes that would work well in the future.
3. **DESIGN:** Planning and prioritizing processes that would work well.
4. **DESTINY** (or **DELIVER**): The implementation (execution) of the proposed design.[9]

The basic idea is then to build - or rebuild - organisations around what works, rather than trying to fix what doesn't. AI practitioners try to convey this approach as the opposite of problem-solving. They take a positive focus on how to increase exceptional performance instead of improving poor skills and practices. AI assumes that this line of reasoning is motivational. Progress does not stop when one problem is solved: it naturally leads on to continuous improvement. The method draws from stories of success in an attempt to create meaning.

Implementing AI

There are a variety of approaches to implementing Appreciative Inquiry, including mass-mobilised interviews and a large, diverse gathering called an Appreciative Inquiry Summit[10]. Both approaches involve bringing large, diverse groups of people together to study and build upon the best in an organization or community.

Associations with other approaches

The philosophy of AI is also found in other positively oriented approaches to individual change as well as organizational change. The principles behind A.I. are based in the science of Positive Psychology. Building on strengths, rather than just focusing on faults and weakness is used in mentoring and coaching programs. It is the basic idea behind teaching "micro-affirmations" as well as teaching about micro-inequities. (See Microinequity[11])

AI's Uses

AI is used in organizational development and as a management consultancy tool to identify and move towards, needed change. It has been applied in businesses, health care bodies, social non-profit organizations, educational institutions, and government operations[12]. Although originating in the United States, it is also used in the United Kingdom, for example in the National Support Teams.

In Vancouver, AI is being used by the Dalai Lama Center for Peace and Education. The Center, which was founded by the Dalai Lama and Victor Chan, is using AI to facilitate compassionate communities. [13]

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- Appreciative Inquiry Commons (http://appreciativeinquiry.case.edu/) at Case Western Reserve University

- Appreciative Inquiry (http://hbswk.hbs.edu/item.jhtml?id=3684&t=innovation) at Harvard Business School

- Inquérito Apreciativo (http://inqueritoapreciativo.atspace.com/) **(Portuguese)**

- Appreciative Inquiry Conference 2007 (http://appreciativeinquiry.case.edu/intro/conference.cfm/) The Power of Positive Change

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