

The Six Sigma System – <http://www.bes-llc.com/sixsig.htm>

The core of the Six Sigma methodology is a data-driven, systematic approach to problem solving that focuses on customer impact and product quality. An acceptable Six Sigma project can be started with only rudimentary statistical tools. The widely accepted definition of a Six Sigma process is one that produces 3.4 defective parts per million opportunities.

The Six Sigma philosophy is dictated by statistical analysis of processes and production numbers. More information on the mathematical basis is available here.

When organizations strive for perfection in their production processes, their defective to acceptable part ratio drops dramatically. Six Sigma is a process by which the defect rate is related to the company's manufacturing methods, so the number of rejected parts can be decreased (ideally, to 3.4 defective parts per million), and the material and labor costs of the business can be reduced as a result.

At its core, Six Sigma revolves around a few key concepts.

Critical to Quality - Attributes most important to the customer

Defect - Failing to deliver what the customer wants

Process Capability - What your process can deliver

Variation - What the customer sees and feels

Stable Operations - Ensuring consistent, predictable processes to improve what the customer sees and feels

Design for Six Sigma - Designing to meet customer needs and process capability

Six Sigma identifies five key roles for its successful implementation

Executive Leadership - includes CEO and other key top management team members. They are responsible for setting up a vision for Six Sigma implementation.

Champions - responsible for the Six Sigma implementation across the organization in an integrated manner.

Master Black Belts - identified by champions, act as in-house expert coaches for the organization on Six Sigma. They devote 100% of their time to Six Sigma.

Experts - this level of skill is used primarily within Aerospace and Defense Business Sectors. Experts work across company boundaries, improving services, processes, and products for their suppliers, their entire campuses, and for their customers.

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.

Green Belts - the employees who take up Six Sigma implementation along with their other job responsibilities

Mathematics Behind The Six Sigma System

Six Sigma Statistical Analysis

Sigma (the lower-case Greek letter s) is used to represent standard deviation (a measure of variation) of a population (lower-case 's', is an estimate, based on a sample). The term "six sigma process" comes from the notion that if one has six standard deviations between the mean of a process and the nearest specification limit, he will make practically no items that exceed the specifications. This is the basis of the Process Capability Study, often used by quality professionals. The term "Six Sigma" has its roots in this tool, rather than in simple process standard deviation, which is also measured in sigmas. Criticism of the tool itself, and the way that the term was derived from the tool, often sparks criticism of Six Sigma.

The widely accepted definition of a six sigma process is one that produces 3.4 defective parts per million opportunities (DPMO).[9] 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). This implies that 3.4 DPMO corresponds to 4.5 sigmas, not six as the process name would imply. This can be confirmed by running on QuikSigma or Minitab a Capability Study on data with a mean of 0, a standard deviation of 1, and an upper specification limit of 4.5. The 1.5 sigmas added to the name Six Sigma are arbitrary and they are called "1.5 sigma shift" (SBTI Black Belt material, ca 1998). Dr. Donald Wheeler dismisses the 1.5 sigma shift as "goofy".[10]

In a Capability Study, sigma refers to the number of standard deviations between the process mean and the nearest specification limit, rather than the standard deviation of the process, which is also measured in "sigmas". As process standard deviation goes up, or the mean of the process moves away from the center of the tolerance, the Process Capability sigma number goes down, because fewer standard deviations will then fit between the mean and the nearest specification limit (see Cpk Index). The notion that, in the long term, processes usually do not perform as well as they do in the short term is correct. That requires that Process Capability

sigma based on long term data is less than or equal to an estimate based on short term sigma. However, the original use of the 1.5 sigma shift is as shown above, and implicitly assumes the opposite.

As sample size increases, the error in the estimate of standard deviation converges much more slowly than the estimate of the mean (see confidence interval). Even with a few dozen samples, the estimate of standard deviation often drags an alarming amount of uncertainty into the Capability Study calculations. It follows that estimates of defect rates can be very greatly influenced by uncertainty in the estimate of standard deviation, and that the defective parts per million estimates produced by Capability Studies often ought not to be taken too literally.

Estimates for the number of defective parts per million produced also depends on knowing something about the shape of the distribution from which the samples are drawn. Unfortunately, there are no means for proving that data belong to any particular distribution. One can only assume normality, based on finding no evidence to the contrary. Estimating defective parts per million down into the 100s or 10s of units based on such an assumption is wishful thinking, since actual defects are often deviations from normality, which have been assumed not to exist.

The ± 1.5 Sigma Drift

The ± 1.5 sigma drift is the drift of a process mean, which occurs in all processes in a six sigma program.[citation needed] If a product being manufactured measures 100 ± 3 cm (97 – 103 cm), over time the ± 1.5 sigma drift may cause the average to range up to 98.5 - 104.5 cm or down to 95.5 - 101.5 cm. This could be of significance to customers.

The ± 1.5 shift was introduced by Mikel Harry. Harry referred to a paper about tolerancing, the overall error in an assembly is affected by the errors in components, written in 1975 by Evans, "Statistical Tolerancing: The State of the Art. Part 3. Shifts and Drifts". Evans refers to a paper by Bender in 1962, "Benderizing Tolerances – A Simple Practical Probability Method for Handling Tolerances for Limit Stack Ups". He looked at the classical situation with a stack of disks and how the overall error in the size of the stack, relates to errors in the individual disks. Based on "probability, approximations and experience", Bender suggests:

Harry then took this a step further. Supposing that there is a process in which 5 samples are taken every half hour and plotted on a control chart, Harry considered the "instantaneous" initial 5 samples as being "short term" (Harry's $n=5$) and the samples throughout the day as being "long term" (Harry's $g=50$ points). Due to the random variation in the first 5 points, the mean of the initial sample is different to the overall mean. Harry derived a relationship between the short term and long term capability, using the equation above, to produce a capability shift or "Z shift"

of 1.5. Over time, the original meaning of "short term" and "long term" has been changed to result in "long term" drifting means.

Harry has clung tenaciously to the "1.5" but over the years, its derivation has been modified. In a recent note from Harry "We employed the value of 1.5 since no other empirical information was available at the time of reporting." In other words, 1.5 has now become an empirical rather than theoretical value. A further softening from Harry: "... the 1.5 constant would not be needed as an approximation".

Despite this, industry has fixed on the idea that it is impossible to keep processes on target. No matter what is done, process means will drift by ± 1.5 sigma. In other words, if a process has a target value of 10.0, and control limits work out to be 13.0 and 7.0, over the long term the mean will drift to 11.5 (or 8.5), with control limits changing to 14.5 and 8.5.

In truth, any process where the mean changes by 1.5 sigma, or any other amount, is not in statistical control. Such a change can often be detected by a trend on a control chart. A process that is not in control is not predictable. It may begin to produce defects, no matter where specification limits have been set.