**SIX SIGMA**

**Six Sigma** is a business management strategy, initially implemented by Motorola, that today enjoys widespread application 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 variation in manufacturing and business processes. It uses a set of quality management methods, including statistical, and creates a special infrastructure of people within the organization ("Black Belts" etc.) who are experts in these methods. Each Six Sigma project carried out within an organization follows a defined sequence of steps and has quantified financial targets (cost reduction or profit increase).

**Quality management tools and methodologies used in Six Sigma**

Six Sigma makes use of a great number of established quality management methods that are also used outside of Six Sigma. The following table shows an overview of the main methods used.

|  |  |
| --- | --- |
| * [5 Whys](http://www.answers.com/topic/5-whys) * [Analysis of variance](http://www.answers.com/topic/analysis-of-variance) * [ANOVA Gauge R&R](http://www.answers.com/topic/anova-gage-r-r) * [Axiomatic design](http://www.answers.com/topic/axiomatic-design) * [Business Process Mapping](http://www.answers.com/topic/business-process-mapping) * Catapult exercise on variability * Cause & effects diagram (also known as fishbone or [Ishikawa diagram](http://www.answers.com/topic/ishikawa-diagram)) * [Chi-square test](http://www.answers.com/topic/chi-square-test) of independence and fits * [Control chart](http://www.answers.com/topic/control-chart) * [Correlation](http://www.answers.com/topic/correlation) * [Cost-benefit analysis](http://www.answers.com/topic/cost-benefit-analysis) * [CTQ tree](http://www.answers.com/topic/ctq-tree) * [Quantitative marketing research](http://www.answers.com/topic/quantitative-marketing-research) through use of [Enterprise Feedback Management](http://www.answers.com/topic/enterprise-feedback-management)(EFM) systems * [Design of experiments](http://www.answers.com/topic/design-of-experiments) * [Failure mode and effects analysis](http://www.answers.com/topic/failure-mode-and-effects-analysis-1) * [General linear model](http://www.answers.com/topic/general-linear-model) | * [Histograms](http://www.answers.com/topic/histogram) * [Homoscedasticity](http://www.answers.com/topic/homoscedasticity) * [Quality Function Deployment](http://www.answers.com/topic/quality-function-deployment) (QFD) * [Pareto chart](http://www.answers.com/topic/pareto-chart) * [Pick chart](http://www.answers.com/topic/pick-chart) * [Process capability](http://www.answers.com/topic/process-capability) * [Regression analysis](http://www.answers.com/topic/regression-analysis) * [Root cause analysis](http://www.answers.com/topic/root-cause-analysis) * [Run charts](http://www.answers.com/topic/run-chart-2) * [SIPOC](http://www.answers.com/topic/sipoc) analysis (**S**uppliers, **I**nputs, **P**rocess,**O**utputs, **C**ustomers) * Stratification * [Taguchi methods](http://www.answers.com/topic/taguchi-methods) * [Taguchi Loss Function](http://www.answers.com/topic/taguchi-loss-function) * [Thought process map](http://www.answers.com/topic/thought-process-map) * [TRIZ](http://www.answers.com/topic/triz) |

CONTROL CHARTS

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.

 A statistical tool used to detect excessive process variability due to specific assignable causes that can be corrected. It serves to determine whether a process is in a state of statistical control, that is, the extent of variation of the output of the process does not exceed that which is expected based on the natural statistical variability of the process.

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, one expects to be signaled approximately once out of every 370 points on average, just due to common-causes.

**Types of charts**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Chart** | **Process observation** | **Process observations relationships** | **Process observations type** | **Size of shift to detect** |
| XbarR chart | Quality characteristic measurement within one subgroup | Independent | Variables | Large (≥ 1.5σ) |
| [p-chart](http://www.answers.com/topic/p-chart) | Fraction nonconforming within one subgroup | Independent | Attributes | Large (≥ 1.5σ) |
| [c-chart](http://www.answers.com/topic/c-chart-1) | Number of non-conformances within one subgroup | Independent | Attributes | Large (≥ 1.5σ) |

**Chart Details**

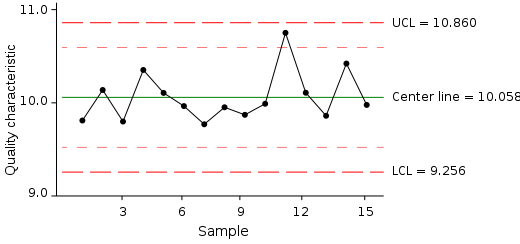
A control chart consists of the following:

* Points representing measurements of a quality characteristic in samples taken from the process at different times [the data]
* A centre line, drawn at the process characteristic [mean](http://www.answers.com/topic/mean-8) which is calculated from the data
* Upper and lower control limits (sometimes called "natural process limits") that indicate the threshold at which the process output is considered statistically 'unlikely'

The chart may contain other optional features, including:

* Upper and lower warning limits, drawn as separate lines, typically two standard deviations above and below the centre 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

However in the early stages of use the inclusion of these items may confuse inexperienced chart interpreters.

[](http://en.wikipedia.org/wiki/File:ControlChart.svg)

X BAR R CHART

An **X-bar/R chart** is a specific member of a family of control charts. A control chart is a tool used in quality control, specifically SPC or statistical process control, as originally developed by Walter A. Shewhart at Western Electric in 1924 to improve the quality of telephones.

A control chart is a plot of measurements of a product on two special scales, usually located above and below each other and running horizontally. X-Bar/R charts consist of two charts, both with the same horizontal axis denoting the sample number.

The vertical axis on the top chart depicts the sample means (X-Bar) for a series of lots or subgroup samples. It has a centreline represented by Xdoublebar, which is simply the overall process average, as well as two horizontal lines, one above and one below the centreline, known as the upper control limit or UCL and lower control limit or LCL, respectively. These lines are drawn at a distance of plus and minus three standard deviations (that is, standard deviations of the sampling distribution of sample means) from the process average. In practice, tabulated constants are available to determine the control limits, or they are automatically calculated by the SPC software used.

The bottom chart has the range (R) of each subgroup plotted on the vertical axis. Like an X-Bar chart, R charts have a centreline and two control limits. However, for sample sizes below 7, the LCL is zero.

The purpose of any control chart is to help determine if variations in measurements of a product are caused by small, normal variations that cannot be acted upon ("common causes"), or by some larger "special cause" that can be acted upon or fixed. The type of chart to be used is based on the nature of the data.

The X-bar/R chart is normally used for numerical data that is captured in subgroups in some logical manner – for example 3 production parts measured every hour. A special cause such as a broken tool will then show up as an abnormal pattern of points on the chart.

P CHART

In industrial [statistics](http://www.answers.com/topic/statistics), the **p-chart** is a type of [control chart](http://www.answers.com/topic/control-chart) that monitors the proportion of nonconforming units in a [sample](http://www.answers.com/topic/sample-4). The appropriate data for p-charts are attribute data (conform or non-conform, yes or no, etc.). The subgroup size should ideally be equal, although unequal sample sizes can be accommodated.

p-chart

1. The "p" comes from use of the proportion of nonconforming items
2. Need a good definition of nonconforming items – usually a categorical definition
3. Can be of equal or unequal subgroups
4. Normally need large subgroups – can even be up to total for the period

Control limits for the p-chart are calculated on the basis of the binomial distribution and an approximation based on the central limit theorem.

The control limits for this chart type can be determined by the formula: \bar p \pm 3\sqrt{\frac{\bar p(1-\bar p)}{n}}

C CHART

In industrial [statistics](http://www.answers.com/topic/statistics), the **c-chart** is a type of [control chart](http://www.answers.com/topic/control-chart) used to monitor "count"-type data, typically total number of nonconformities per unit.[[1]](http://www.answers.com/topic/c-chart-1#cite_note-0) It is also occasionally used to monitor the total number of events occurring in a given unit of time.

The c-chart differs from the [p-chart](http://www.answers.com/topic/p-chart) in that it accounts for the possibility of more than one nonconformity per inspection unit. The p-chart models "pass"/"fail"-type inspection only. Nonconformities may also be tracked by type or location which can prove helpful in tracking down assignable.

Examples of processes suitable for monitoring with a c-chart include:

* Monitoring the number of voids per inspection unit in [injection molding](http://www.answers.com/topic/injection-molding) or [casting](http://www.answers.com/topic/casting) processes
* Monitoring the number of discrete components that must be re-[soldered](http://www.answers.com/topic/solder) per [printed circuit board](http://www.answers.com/topic/circuit-board)
* Monitoring the number of product returns per day

The [Poisson distribution](http://www.answers.com/topic/poisson-distribution) is the basis for the chart and requires the following assumptions[[2]](http://www.answers.com/topic/c-chart-1#cite_note-1):

* The number of opportunities or potential locations for nonconformities is very large
* The probability of nonconformity at any location is small and constant
* The inspection procedure is same for each sample and is carried out consistently from sample to sample

The control limits for this chart type are \bar c \pm 3\sqrt{\bar c} where \bar c is the estimate of the long-term process mean established during control-chart setup.

### Chart usage

If the process is in control, all points will plot within 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 "signalling" 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 behaviour and have no intrinsic relationship to any specification targets or engineering tolerance. In practice, the process mean (and hence the centre line) may not coincide with the specified value (or target) of the quality characteristic because the process' design simply can't deliver the process characteristic at the desired level.

Control charts omit 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 centre 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.

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