Six Sigma – Q & A

Shift in Business Focus

Business Focus	<1950	1950 to1970's	1980's	1990's	2000's
Productivity	●	● ●	● ●	● ●	● ●
Quality	●	● ●	● ● ●	● ● ●	● ● ●
Customer Satisfaction		●	● ●	● ● ●	● ● ●
Cost	●	●	● ●	● ● ●	● ● ●
Agility/Speed			● ●	● ●	● ● ●
Flexibility				● ●	● ● ●
Adaptability					● ●
Product life cycle			●	● ●	● ● ●

Operating at 99 % Quality

- At least 200,000 wrong drug prescriptions each year;
- Two short or long landings at major airports each day;
- 5000 incorrect surgical procedures per week;
- Unsafe drinking water for almost 15 minutes each day;
- No electricity for almost 7 hours each month;
- 50 dropped newborn babies each day;

Is it Good Enough ?

Source: Six sigma forum

What is Six Sigma?

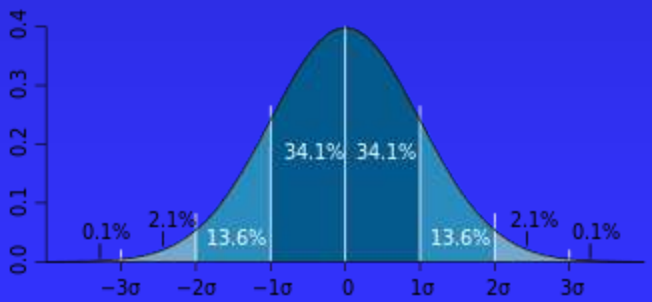
- Born in Motorola in 1992.
- High performance, data driven approach for analyzing the root causes of business processes/ problems and solving them.
- Links Customers, Process improvements with financial results.

What is Six Sigma?

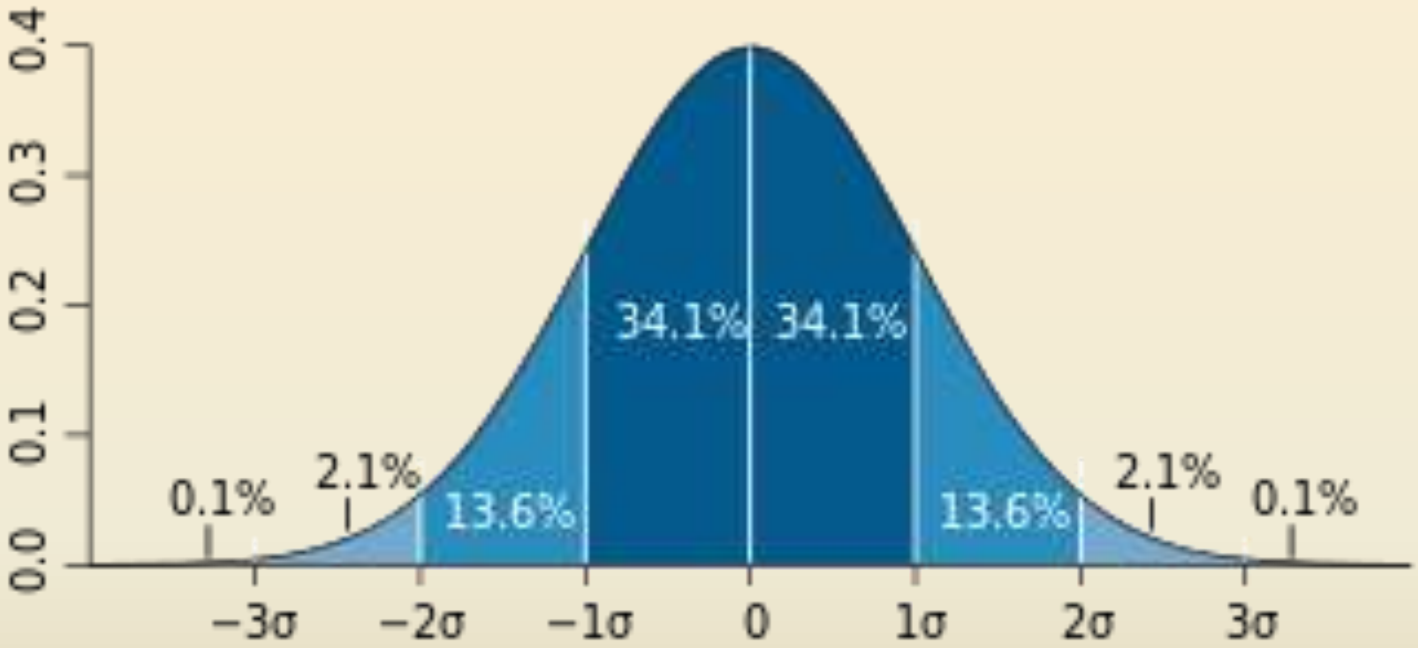
- Greek character used in statistics;
- Measures the capability of the process to perform defect free work i.e. variation - standard deviation – i.e. how far a measured result is from the average;
- Six Sigma – Upper and lower specification limits are 6 standard deviations from the average;
- Defect – anything which leads to customer dissatisfaction

What is Six Sigma?

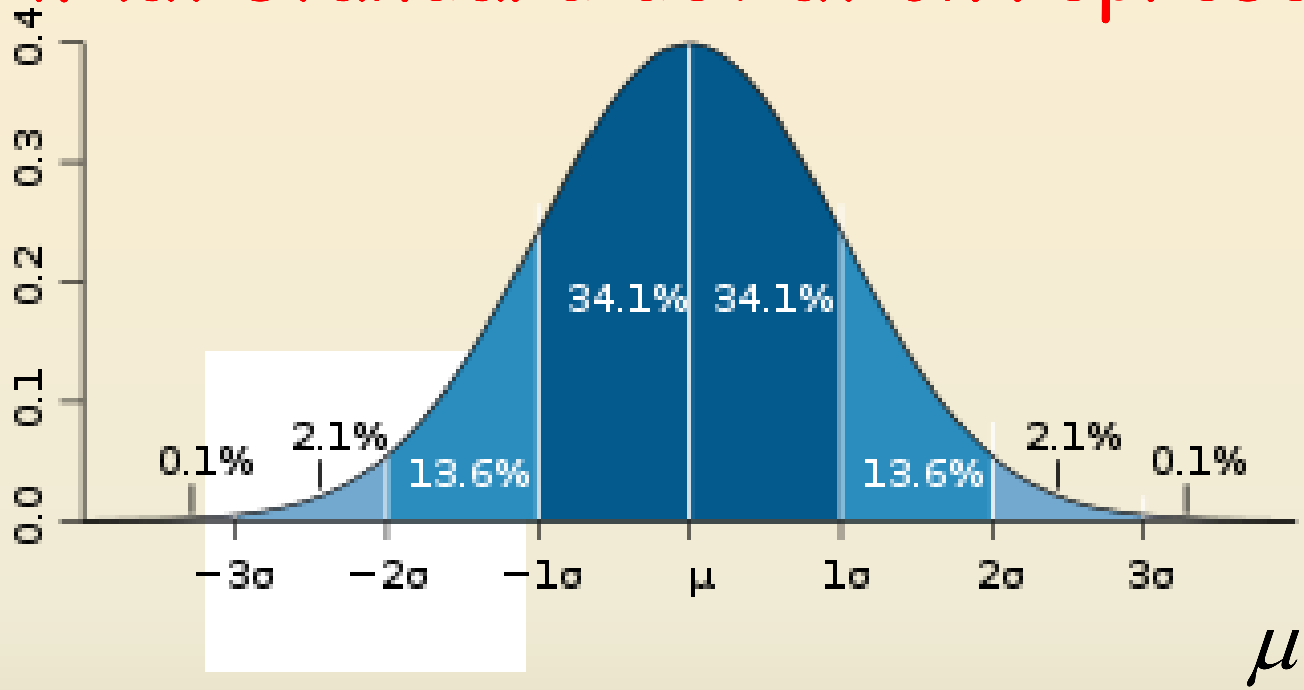
- Sigma value indicates how often defects are likely to occur.
- As sigma increases, cost goes down while profitability, productivity and customer satisfaction go up.



What is Six Sigma?



The **bell curve** which represents a normal distribution of data shows what standard deviation represents.



One standard deviation away from the mean (μ) in either direction on the horizontal axis accounts for around 68 percent of the data. Two standard deviations away from the mean accounts for roughly 95 percent of the data with three standard deviations representing about 99 percent of the data.

Six Sigma Failure Rates

Sigma Level	Defects per Million Opportunities
1	697,672
2	*308,770*
3	*66,810*
4	6,209
5	232
6	3.4

Who All are Using Six Sigma ?

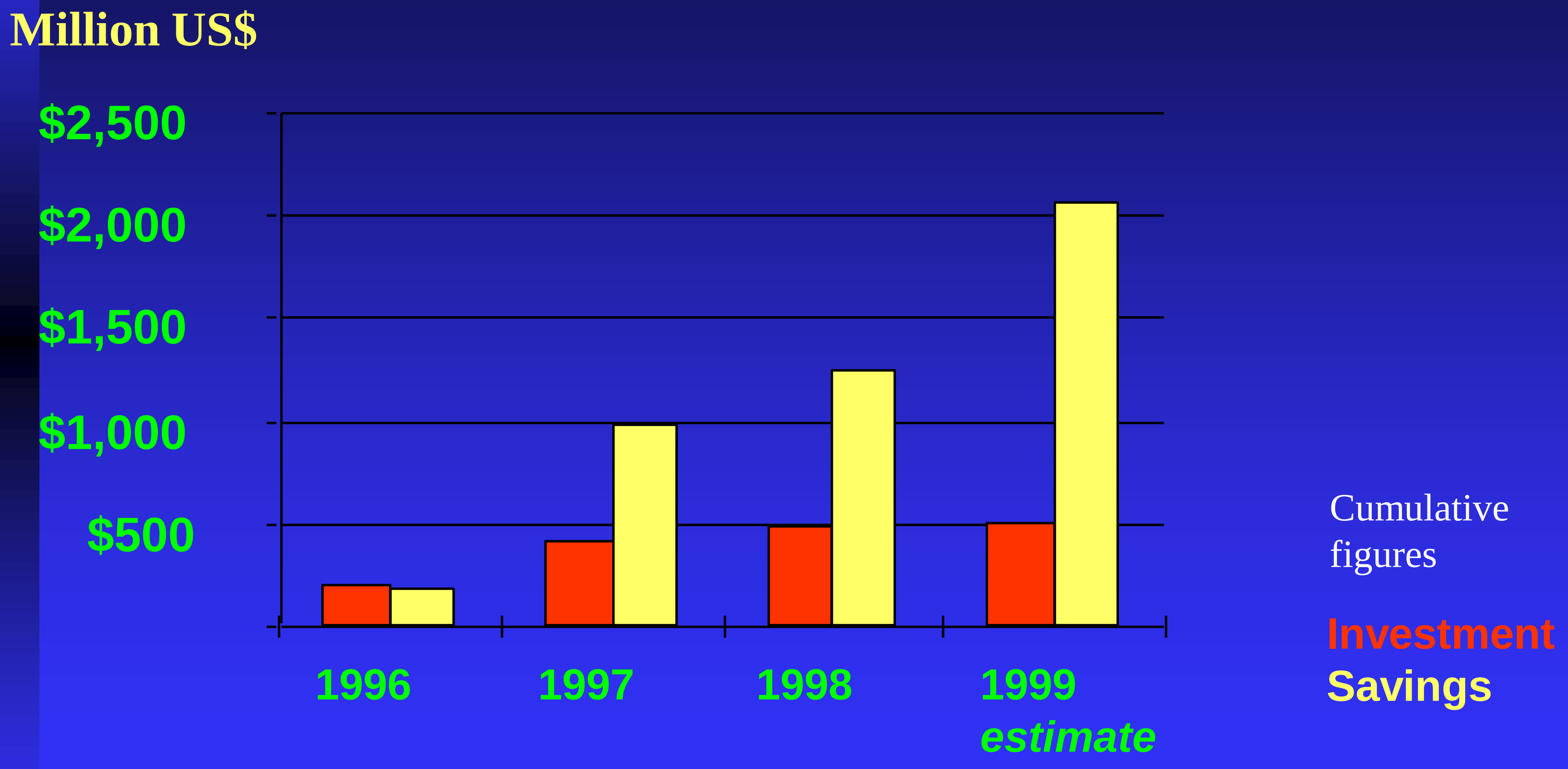
3M, Alcoa, GE , Abbott Pharmaceuticals, Johnson Controls , Ford, Pratt & Whitney , Northrop Grumann , BP, Air France, Lufthansa, Conoco, Halliburton, Ferrari , Morelli, Boeing, Motorola, TRW, Wipro, Tata Group, Singapore Airlines, Honeywell, Sun Microsystems, Citigroup, Jaguar, Rolls Royce, Bombardier, Home Depot , Amazon.com, Sprint, Apple Computer , IBM, Sony, Ericsson, Nokia, Canon, Hitachi , Maytag, Polaroid, Lockheed Martin, Dupont

+ hundreds of other companies worldwide.

All types of businesses – manufacturing, service,

e-business, process – in all types of processes/ functions.

GE – Investments Vs. Returns



Six Sigma Sample Results

Company	**Annual Savings**
General Electric	$2.0+ billion
JP Morgan Chase	$1.5 billion
Texas Instruments	$600 million
Johnson & Johnson	$500 million
Honeywell	$600 million

Six Sigma Methodology

- Based on Dr. Deming & Dr. Juran philosophy;
- Dr. Deming's PDSA cycle to continually improve the process in terms of quality, cost and delivery.
- Dr. Juran - improvement is achieved project by project.
- US $ 100,000 to 250,000 savings per Six Sigma project.

Process Efficiency and Effectiveness

- Process Effectiveness: The process is effective if the output meets customer needs e.g. % of orders delivered on time to the customers.
- Process Efficiency: Process is efficient when it is effective at the least cost e.g. time taken to deliver goods to customer on time.
- Maximizing effectiveness and efficiency together means that process produces high quality at low cost i.e. providing most value to customer.

Six Sigma Methodology

- DMAIC process :
  - Define;
  - Measure;
  - Analyse;
  - Improve;
  - Control.

Six Sigma Methodology - Define

- Poorly performing areas are identified and prioritized through use of data;
- Use of 7 QC tools like Check sheets, Pareto diagram, Cause & Effect.
- Make a business case for improvement;
- Form teams & issue charter.

Six Sigma Methodology - Measure

- Identify suspected problem process;
- Is the process aligned with organisations strategic goals?
- How will we know we are successful?
- What is the capability of the process?
- Use of process flow charts, FMEA etc.

Six Sigma Methodology - Analyze

- When, where and why do defects occur i.e. understand exactly what is happening within a process and why defects are occurring;
- Use of statistical tools like Input/ Output matrices, Scatter plots, Hypothesis testing

Six Sigma Methodology

- Improve
  - Vital factors in the process are identified;
  - Experiments systematically designed to focus on factors which can be modified to achieve target goals.
  - Use of Design of Experiments techniques.
- Control:
  - Process capability and controls;
  - Use of SPC tools to manage processes on continual basis

The Players

- Project Champions;
- Master Black Belts;
- Black Belts;
- Green Belts;
- Yellow Belts

The Players – Project Champions

Project Champions are involved in:

- selecting projects;
- identifying Black and Green Belt candidates;
- Set improvement targets
- Provide resources;
- Review the projects on regular basis and
- Remove any road blocks to programs success.

The Players – Master Black Belts

Master Black Belts are:

- Technical leaders of Six Sigma;
- Serve as instructors for Black & Green Belts;
- Provide ongoing coaching and support to project teams to assure the appropriate application of statistics;
- Provide assistance to Project Champions;
- Deploy Six Sigma program.

The Players – Black Belts

Black Belts are:

- Backbone of Six Sigma deployment;
- Highly qualified;
- Lead teams;
- Attack chronic problems;
- Manage projects;
- “ Drive “ teams for solutions that work;
- Responsible for bottom line results.

The Players – Green Belts

Green Belts:

- Provide team support to Black Belts;
- Assist in data collection, input;
- Analyse data using software;
- Prepare reports for management.

The Players – Yellow Belts

Yellow Belts:

- Represent large percentage of work force;
- Trained with basic skills;
- Assist GB & BB on large projects;
- Assist in build and sustain Six Sigma culture

Conclusion

- Six sigma provides the desired speed, accuracy and agility to organisation to be in the digital age of tomorrow.

- “ I do not believe you can do today’s job with yesterday’s methods and be in business tomorrow “ - *Mr. Nelson Jackson*.

What is SPC?

- SPC stands for Statistical Process Control
- SPC *does not* refer to a particular technique, algorithm or procedure
- SPC is an *optimisation philosophy* concerned with *continuous process improvements*, using a collection of (statistical) tools for
    - data and process analysis
    - making inferences about process behaviour
    - decision making
- SPC is a key component of Total Quality initiatives
- Ultimately, SPC seeks to *maximise profit* by
    - improving product quality
    - improving productivity
    - streamlining process
    - reducing wastage
    - reducing emissions
    - improving customer service, etc.

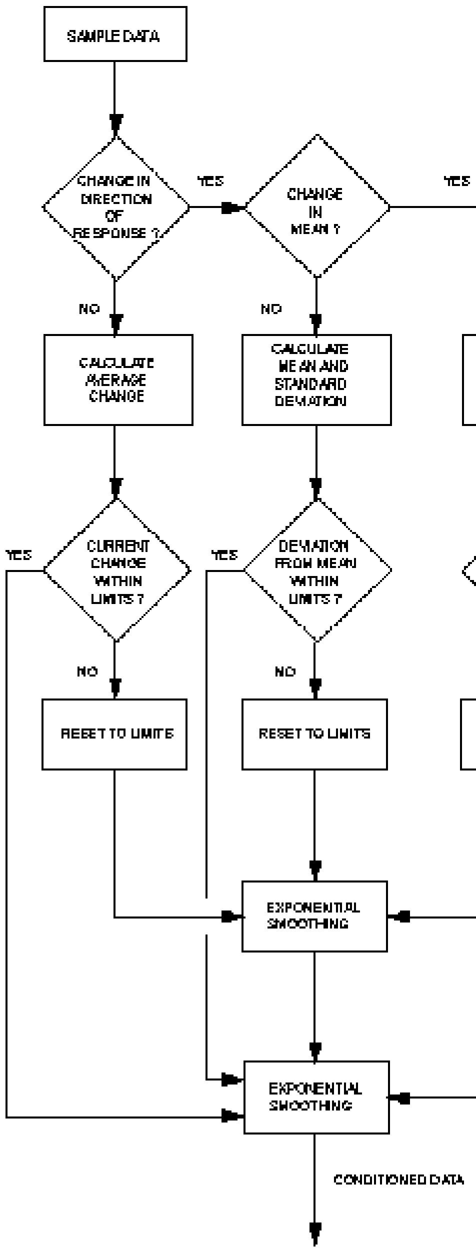
Tools for SPC

- Commonly used tools in SPC include
    - Flow charts
    - Run charts
    - Pareto charts and analysis
    - Cause-and-effect diagrams
    - Frequency histograms
    - Control charts
    - Process capability studies
    - Acceptance sampling plans
    - Scatter diagrams
- Each tool is simple to implement
- These tools are usually used to complement each other, rather than employed as stand-alone techniques

SPC Tools - Flow Charts

- Flow charts
    - have no statistical basis
    - are excellent visualisation tools
- Flow charts show
    - the progress of work
    - the flow of material or information through a sequence of operations
- Flow charts are useful in an initial process analysis
- Flow charts should be complemented by process flow sheets or process flow diagrams (more detailed) if available
- Everyone involved in the project should draw a flow chart of the process being studied so as to reveal the different perceptions of how the process operates

Example flow chart of a procedure to ensure data quality

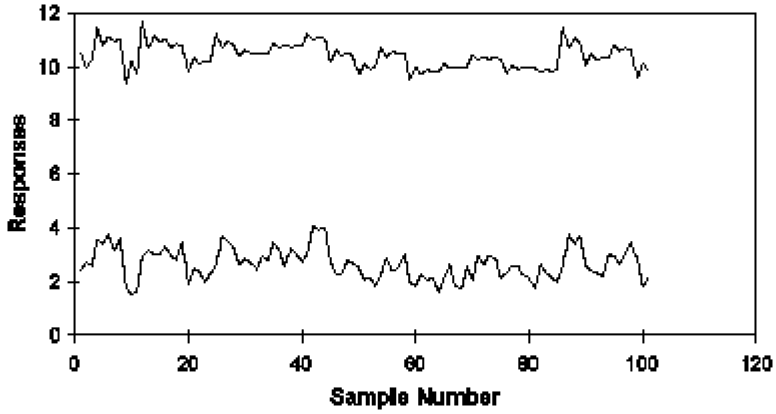


SPC Tools - Run charts

Run charts are simply plots of process characteristics against time or in chronological sequence. They do not have statistical basis, but are useful in revealing

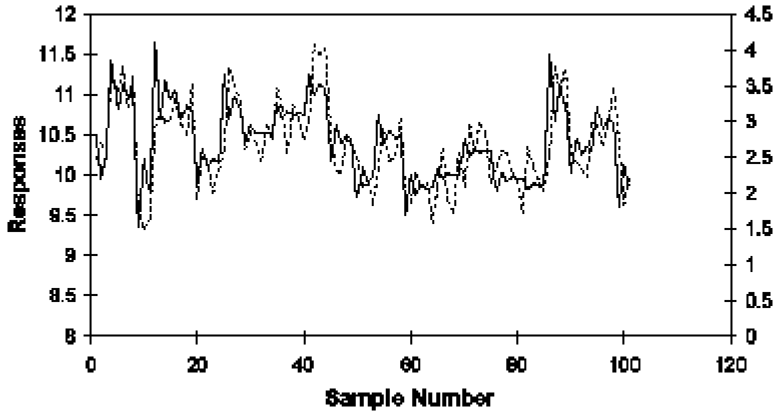
- trends
- relationships between variables

Example of Run Chart with two responses



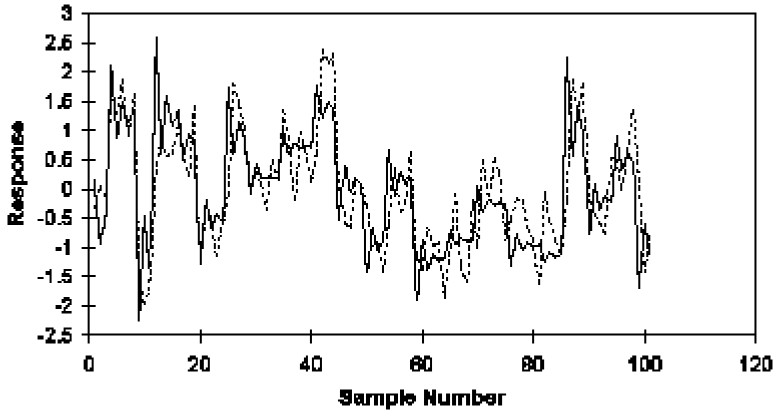
Run charts can be used to study relationships between variables. For example, in the above chart, the relationship between the 2 variables is difficult to discern. To facilitate this, appropriate scalings for the plots should be chosen. If each plotted variable has its own y-axis scale, the above run chart then becomes,

Run chart for two variables with independent y-axis scales



Now, the relationship between the two becomes much clearer. Obviously this method will fail when there are more than two variables. However, if the variables are standardised before plotting, only a single common axis is necessary, and the results are just as clear as the previous.

Run chart for two standardised variables



SPC Tools - Pareto charts

The 20% Rule

Vilfredo Pareto (1848-1923) discovered that:

- 80% of the wealth in Italy was held by 20% of the population;
- 20% of customers accounted for 80% of sales;
- 20% of parts accounted for 80% of cost, etc.

These observations were confirmed by Juran (1960) and resulted in what is known as the Pareto Principle.

Pareto Principle

The Pareto Principle states that:

"Not all of the causes of a particular phenomenon occur with the same frequency or with the same impact"

Such characteristics can be highlighted using Pareto Charts

Pareto charts and analysis

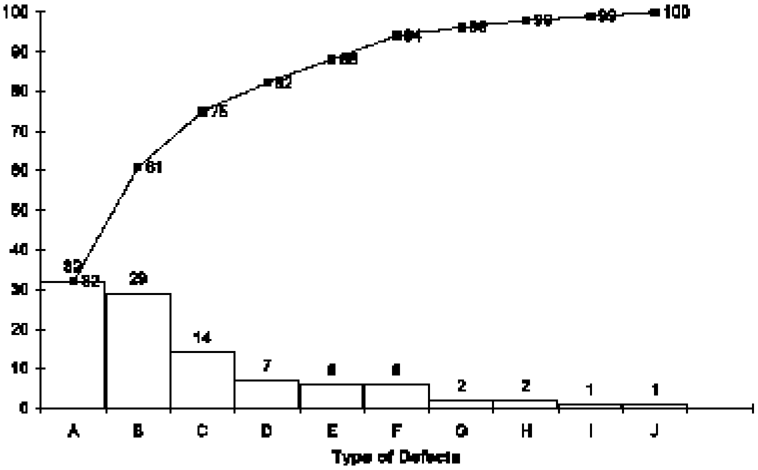
- Pareto charts show the most frequently occurring factors
- Analysis of Pareto charts help to make best use of limited resources by targeting the most important problems to tackle

For example,

- Products may suffer from different defects, but
  - the defects occur at different frequency
  - only a few account for most of the defects present
  - different defects incur different costs

So a product line may experience a range of defects (A, B, C ... J). Plotting the percentage contribution of each type to total number of faults, gives the bar-plots in the following diagram. Next if, each of these contributions are sequentially summed, a cummulative line plot is obtained. These two plots together make up the Pareto Chart.

ample of Pareto Chart



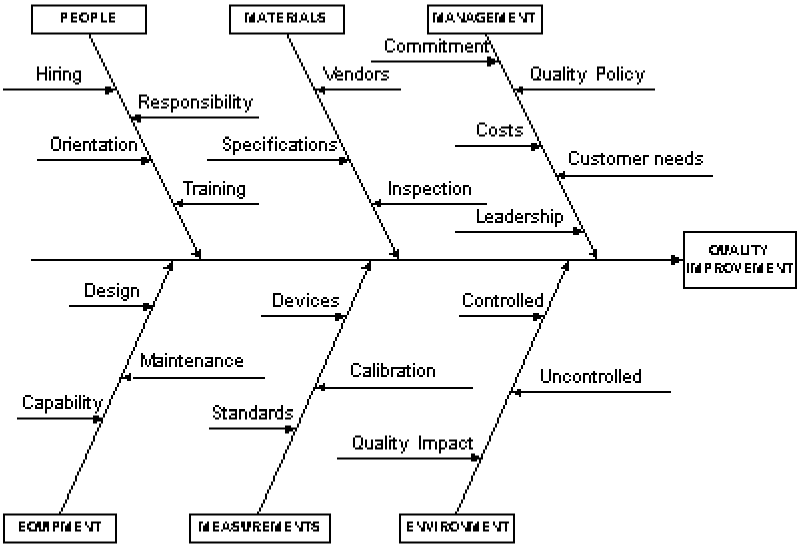
From the information on the chart, the manufacturer could for example,

- concentrate on reducing defects A, B and C since they make up 75% of all defects
- focus on eliminating defect E, if defect E causes 40% of monetary loss

SPC Tools - Cause-and-effect diagrams

- Cause-and-effect diagrams are also called:
  - Ishikawa diagrams (Dr. Kaoru Ishikawa, 1943)
  - fishbone diagrams
- Cause-and -effect diagrams do not have a statistical basis, but are excellent aids for problem solving and trouble-shooting
- Cause-and-effect diagrams can
  - reveal important relationships among various variables and possible causes
  - provide additional insight into process behaviour

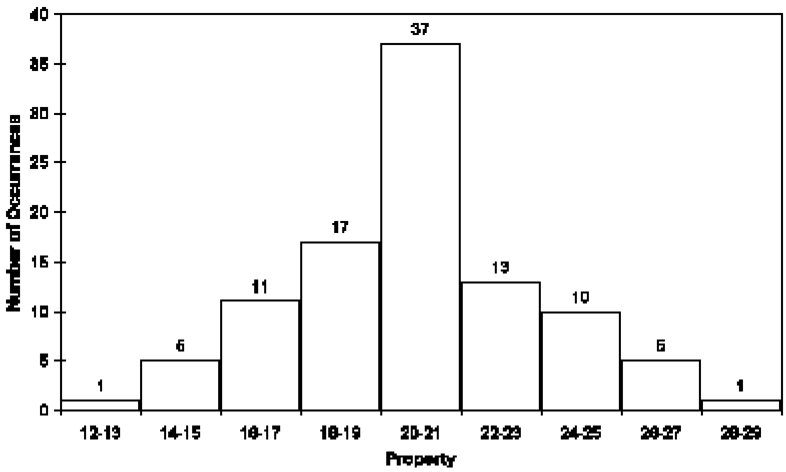
Example of a Cause-and-effect diagram



SPC Tools - Frequency histograms

- The frequency histogram is a very effective graphical and easily interpreted method for summarising data
- The frequency histogram is a fundamental statistical tool of SPC
- It provides information about:
  - the average (mean) of the data
  - the variation present in the data
  - the pattern of variation
  - whether the process is within specifications

Example frequency histogram

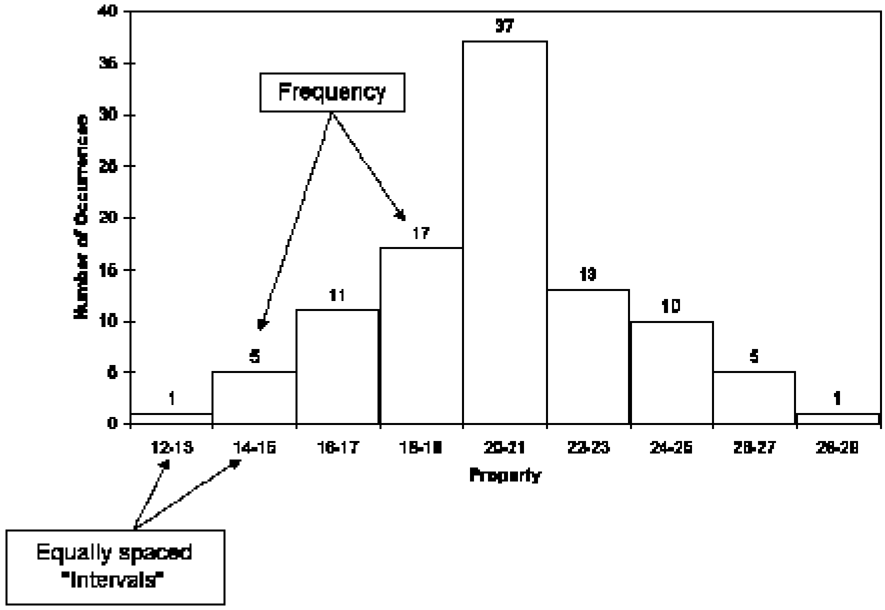


Drawing Frequency Histograms

In drawing frequency histograms, bear in mind the following rules:

- Intervals should be equally spaced
- Select intervals to have convenient values
- Number of intervals is usually between 6 to 20

- Small amounts of data require fewer intervals
- 10 intervals is sufficient for 50 to 200 readings



SPC Tools - Control charts

Processes that are *not* in a state of *statistical control*

- show excessive variations
- exhibit variations that change with time

A process in a state of statistical control is said to be statistically stable. Control charts are used to detect whether a process is *statistically stable*. Control charts differentiates between variations

- that is normally expected of the process due *chance* or *common* causes
- that change over time due to *assignable* or *special* causes

Control charts: common cause variations

Variations due to common causes

- have small effect on the process
- are inherent to the process because of:
  - the nature of the system
  - the way the system is managed
  - the way the process is organised and operated
- can only be removed by
  - making modifications to the process
  - changing the process
- are the responsibility of higher management

Control charts: special cause variations

Variations due to special causes are

- localised in nature
- exceptions to the system
- considered abnormalities
- often specific to a
    - certain operator
    - certain machine
    - certain batch of material, etc.

Investigation and removal of variations due to special causes are key to process improvement

Note: Sometimes the delineation between common and special causes may not be very clear

Control charts: how they work

The principles behind the application of control charts are very simple and are based on the combined use of

- run charts
- hypothesis testing

The procedure is

- sample the process at regular intervals
- plot the *statistic* (or some measure of performance), e.g.
    - mean
    - range
    - variable
    - number of defects, etc.
- check (graphically) if the process is under statistical control
- if the process is not under statistical control, do something about it

Control charts: types of charts

Different charts are used depending on the nature of the charted data Commonly used charts are:

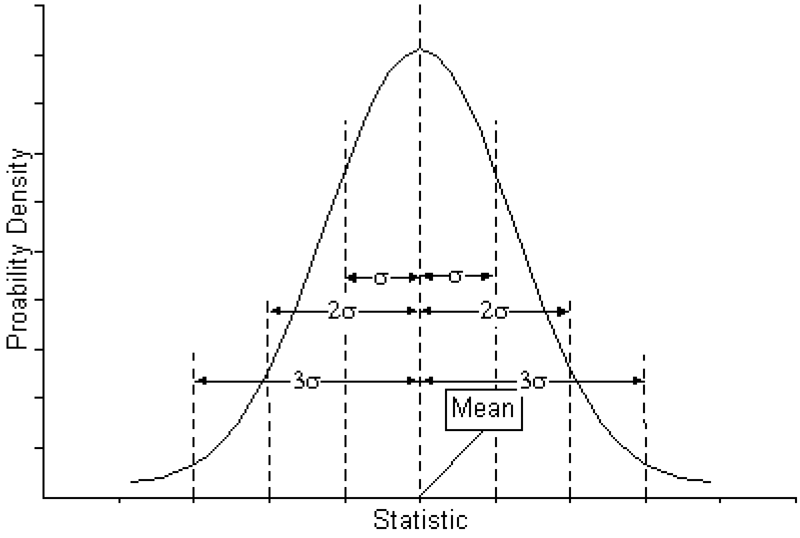
- for *continuous* (variables) data
    - Shewhart sample mean ($\overline{X}$-chart)
    - Shewhart sample range (*R*-chart)
    - Shewhart sample (*X*-chart)
    - Cumulative sum (CUSUM)
    - Exponentially Weighted Moving Average (EWMA) chart
    - Moving-average and range charts
- for *discrete* (attributes and countable) data
    - sample proportion defective (*p*-chart)
    - sample number of defectives (*np*-chart)
    - sample number of defects (*c*-chart)
    - sample number of defects per unit (*u*-chart or $\overline{c}$-chart)

Control charts: assumptions

Control charts make assumptions about the plotted statistic, namely

- it is *independent*, i.e. a value is not influenced by its past value and will not affect future values
- it is *normally* distributed, i.e. the data has a normal probability density function

Normal Probability Density Function



The assumptions of normality and independence enable predictions to be made about the data.

Control charts: properties of the normal distribution

The normal distribution $N(\mu,\sigma^2)$ has several distinct properties:

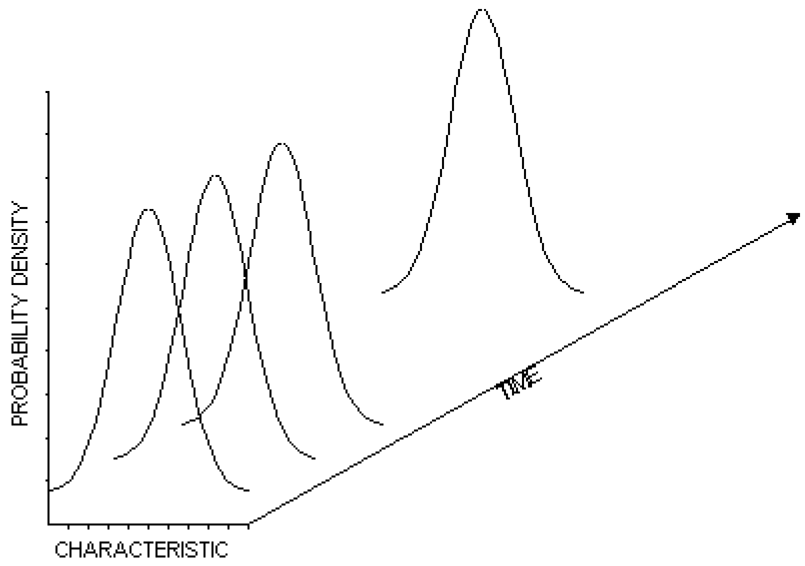
- The normal distribution is bell-shaped and is symmetric
- The mean, μ, is located at the centre

- The probabilities that a point, x, lies a certain distance beyond the mean are:
  - $Pr(x > \mu + 1.96\sigma) = Pr(x > \mu - 1.96\sigma) = 0.025$
  - $Pr(x > \mu + 3.09\sigma) = Pr(x > \mu - 3.09\sigma) = 0.001$

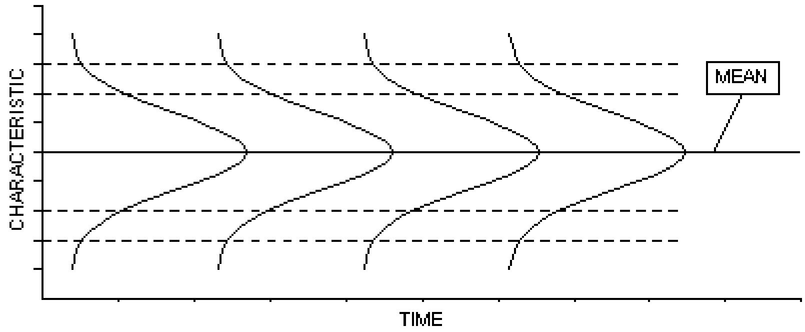
σ is the standard deviation of the data

Control charts: interpretation

- *Control charts are normal distributions with an added time dimension*

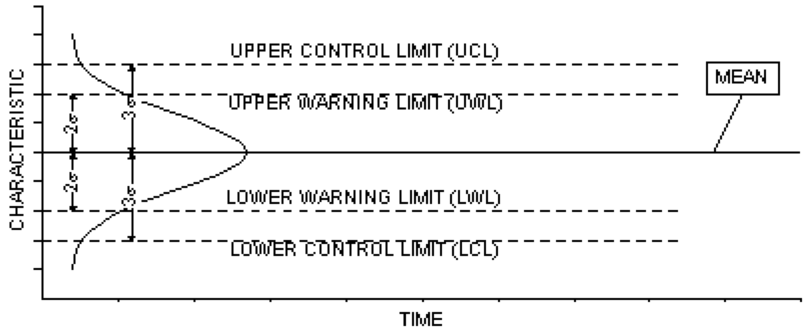


- *Control charts are run charts with superimposed normal distributions*



Control charts: a graphical means for hypothesis testing

Control charts provide a graphical means for testing hypotheses about the data being monitored. Consider the commonly used Shewhart Chart as an example.



Shewhart X-chart with control and warning limits

The probability of a sample having a particular value is given by its location on the chart. Assuming that the plotted statistic is normally distributed, the probability of a value lying beyond the:

- *warning limits* is approximately 0.025 or 2.5% chance
- *control limits* is approximately 0.001 or 0.1% chance, this is rare and indicates

that

- the variation is due to an assignable cause
- the process is out-of-statistical control

Control charts: run rules for Shewhart charts

Run rules *are rules that are used to indicate out-of-statistical control situations.* Typical run rules for Shewhart X-charts with control and warning limits are:

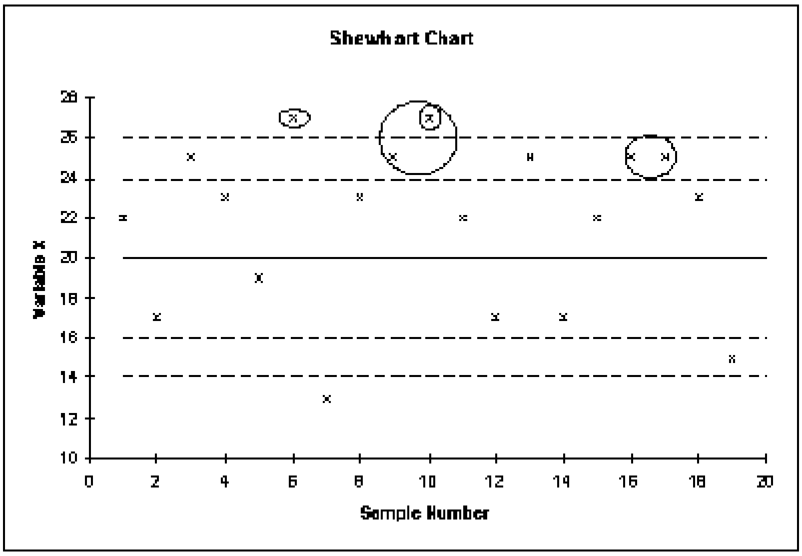
- a point lying beyond the control limits
- 2 consecutive points lying beyond the warning limits (0.025x0.025x100 = 0.06% chance of occurring)
- 7 or more consecutive points lying on one side of the mean (0.5^7x100 = 0.8% chance of occurring and indicates a shift in the mean of the process)
- 5 or 6 consecutive points going in the same direction (indicates a trend)
- Other run rules can be formulated using similar principles

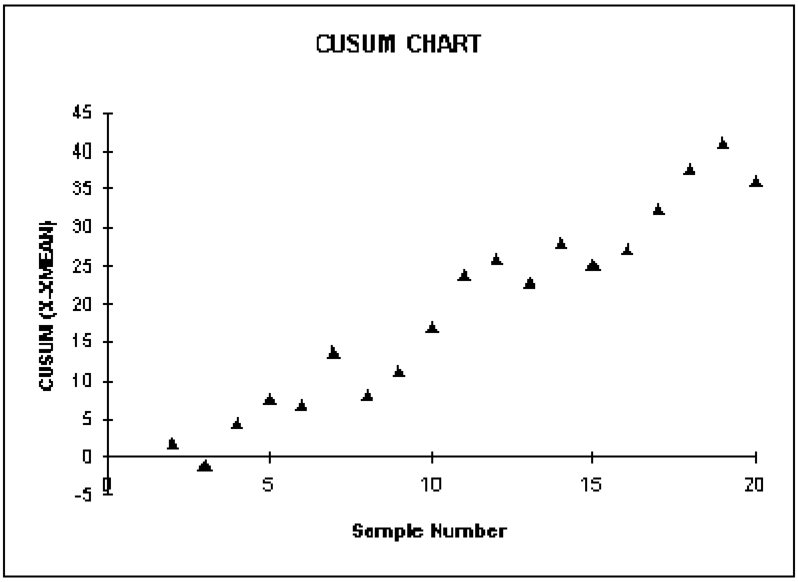
Control charts: CuSum charts

CUSUM Charts are excellent for detecting changes in means. A CUSUM Chart is simply a plot of the sum of some process characteristic against time. Examples of typical characteristics that are plotted are:

- the raw variable X_i
- difference between the raw variable and a target $X_i - X_{target}$
- difference between the raw variable and its mean $X_i - \mu$
- difference between successive variables $X_i - X_{i-1}$

Control charts: examples





Control charts: relative merits

Different control charts have different capabilities. The table below shows the relative merits of different chart types when applied to detect the changes listed in the first column.

Cause of Change	Chart Type			
	Mean	Range	Standard Deviation	CUSUM
Gross Error	✓✓✓	✓✓		✓
Shifts in Mean	✓✓		✓	✓✓✓
Shifts in Variability		✓✓✓		
Slow Fluctuation	✓✓			✓✓✓
Rapid Fluctuation		✓✓✓	✓✓	

SPC Tools - Process Capability

Process Capability is also another important concept in SPC. Process capability examines

- the variability in process characteristics
- whether the process is capable of producing products which conforms to specifications

Process capability studies distinguish between conformance to ***control limits*** *and conformance to* ***specification limits*** *(also called* ***tolerance limits***)

- if the process mean is in control, then virtually all points will remain within control limits
- staying within control limits does not necessarily mean that specification limits are satisfied
- specification limits are usually dictacted by customers

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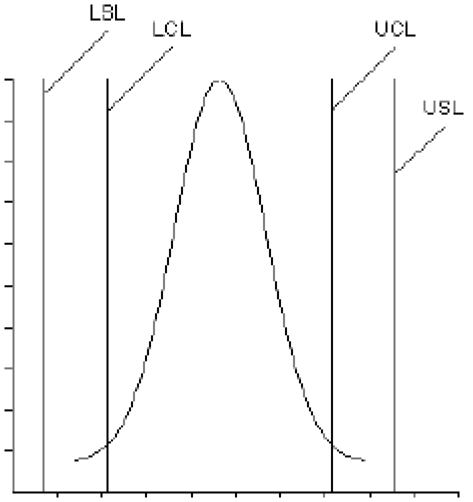
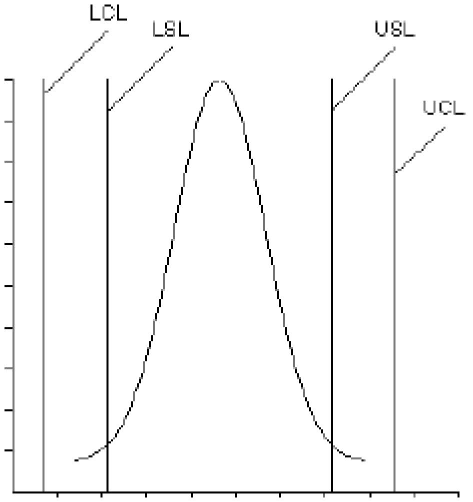
Process capability: concepts

The following distributions show different process scenarios. Note the relative positions of the control limits and specification limits.



In control and product meets specifications.

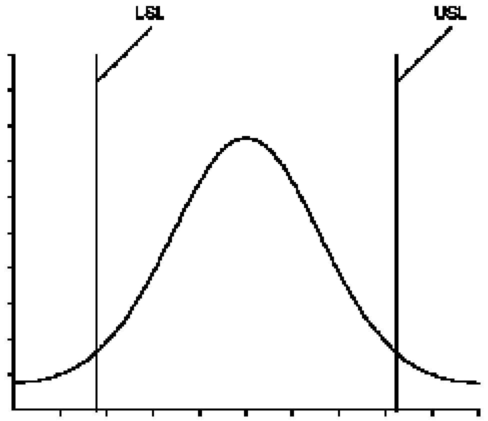
Control limits are within specification limits



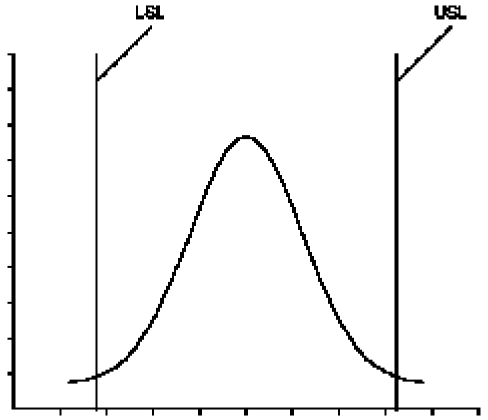
In control but some products do not meet specifications.

Specification limits are within control limits

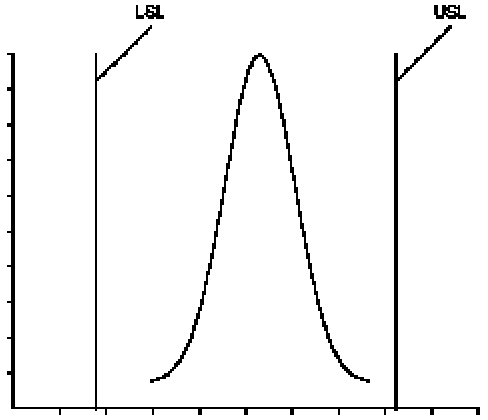
Process capability: relative capability



Data from process with low capability



Data from process with medium capability



Data from process with high capability

Process capability: capability index

The capability index is defined as:

$$C_p = (\text{allowable range})/6\sigma = (USL - LSL)/6\sigma$$

The capability index show how well a process is able to meet specifications. The higher the value of the index, the more capable is the process:

- $C_p < 1$ (process is unsatisfactory)
- $1 < C_p < 1.6$ (process is of medium relative capability)

- $C_p > 1.6$ (process shows high relative capability)

Process capability: process performance index

The capability index

- considers only the spread of the characteristic in relation to specification limits
- assumes two-sided specification limits

The product can be bad if the mean is not set appropriately. The process performance index takes account of the mean (μ) and is defined as:

$$C_{pk} = \min[\ (USL - \mu)/3\sigma,\ (\mu - LSL)/3s\sigma\ ]$$

The process performance index can also accommodate one sided specification limits

- for upper specification limit: $C_{pk} = (USL - \mu)/3\sigma$
- for lower specification limit: $C_{pk} = (\mu - LSL)/3\sigma$

Process capability: the message

The message from process capability studies is:

- first reduce the variation in the process
- then shift the mean of the process towards the target

This procedure is illustrated in the diagram below: