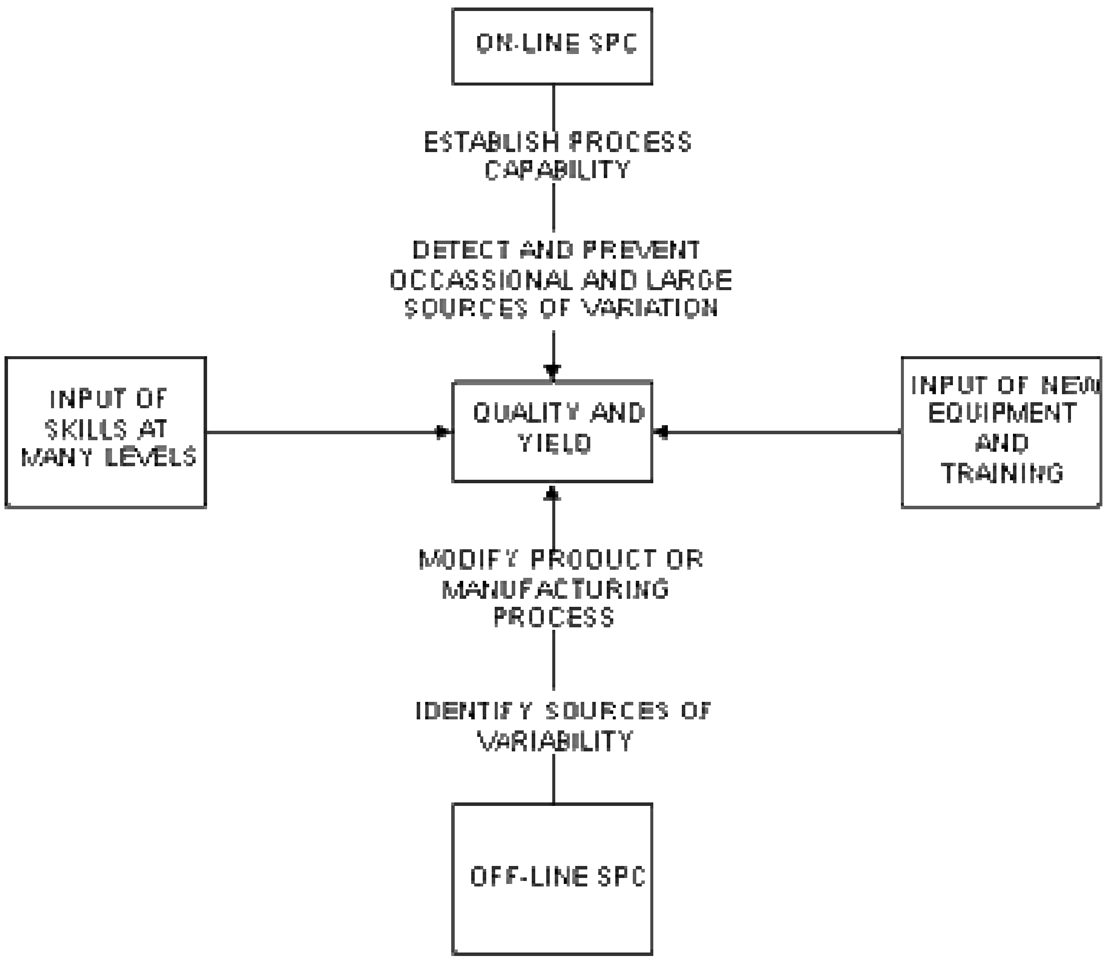
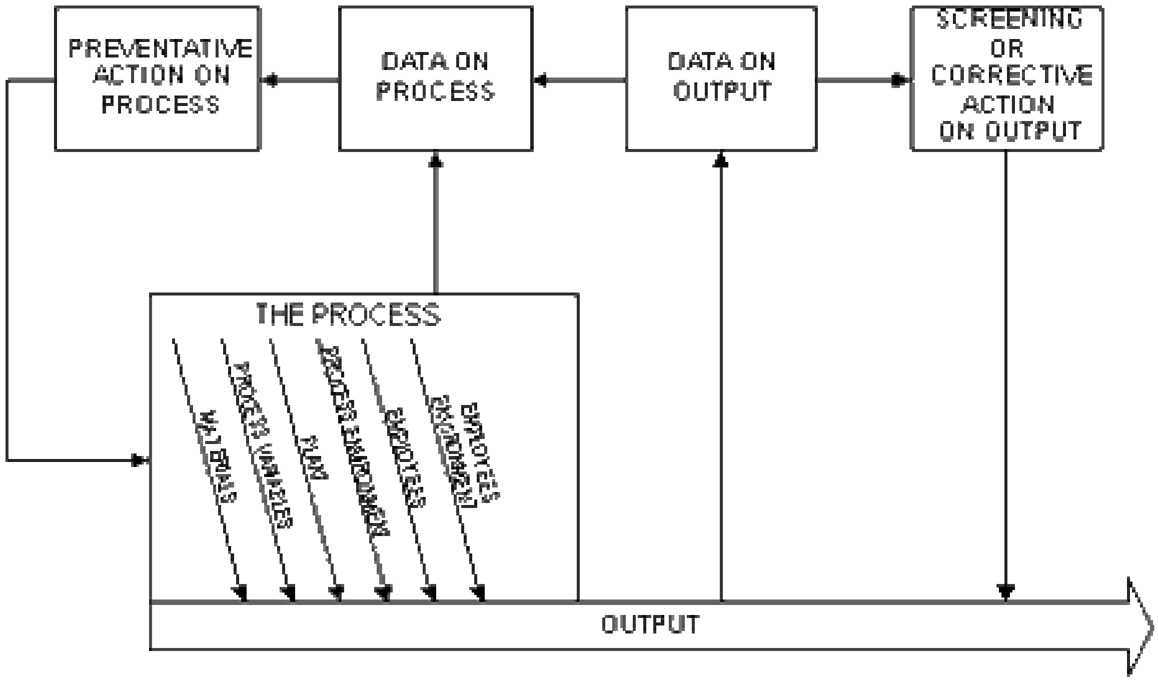
Ensuring the Success of SPC

- Off-line SPC
  - is the next stage on from on-line SPC
  - should ideally be built into the design an operating procedures of the process
  - aims to reduce or remove the effect of potential causes of process variability





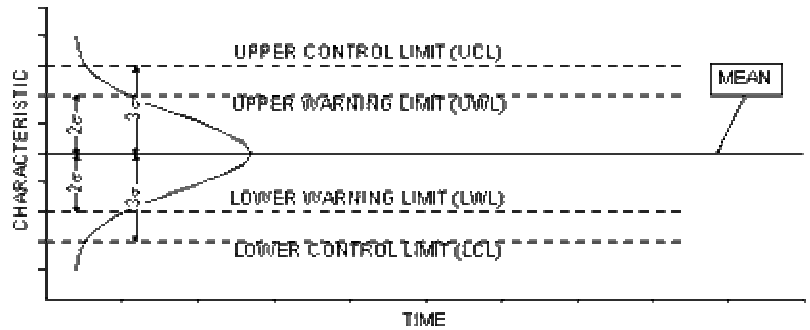
SPC - the philosophy

"*It is good management to reduce the variation of any quality characteristic (say thickness or measure of performance), whether this characteristic be in a state of control or not, and even when few or no defectives are being produced*" - Deming

- Zero defects is not sufficient - *aim for continuous process improvement*
- Technical expertise itself is not good enough and should pay attention to
    - training
    - capital
    - equipment
    - management philosophy and structure that encourages workers to strive for quality products

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:

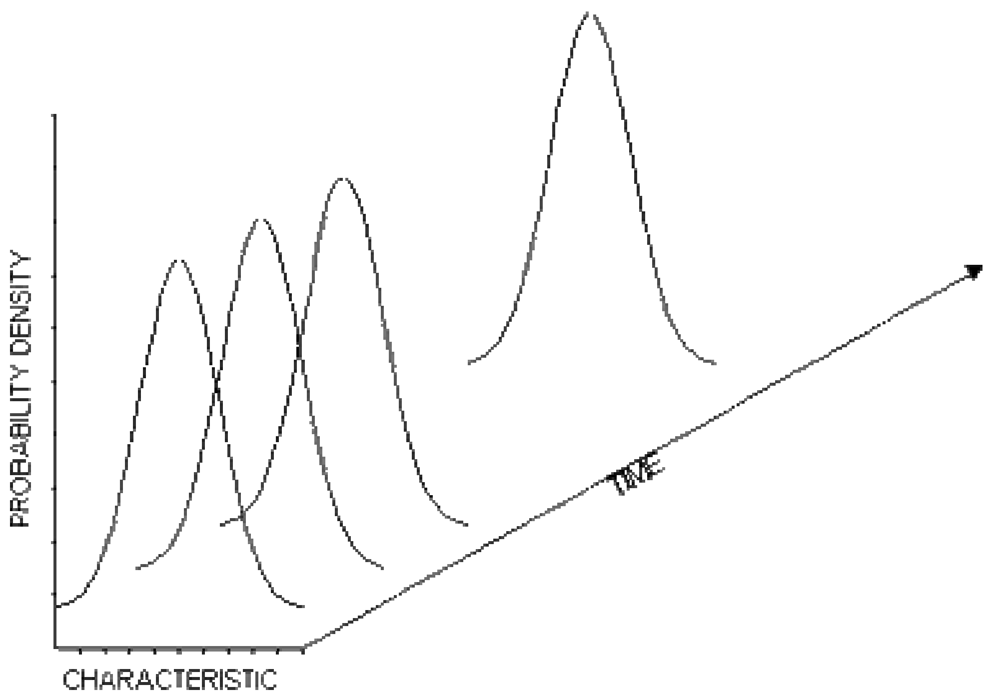
- the variation is due to an assignable cause or;
- the process is out-of-statistical control.

Summary

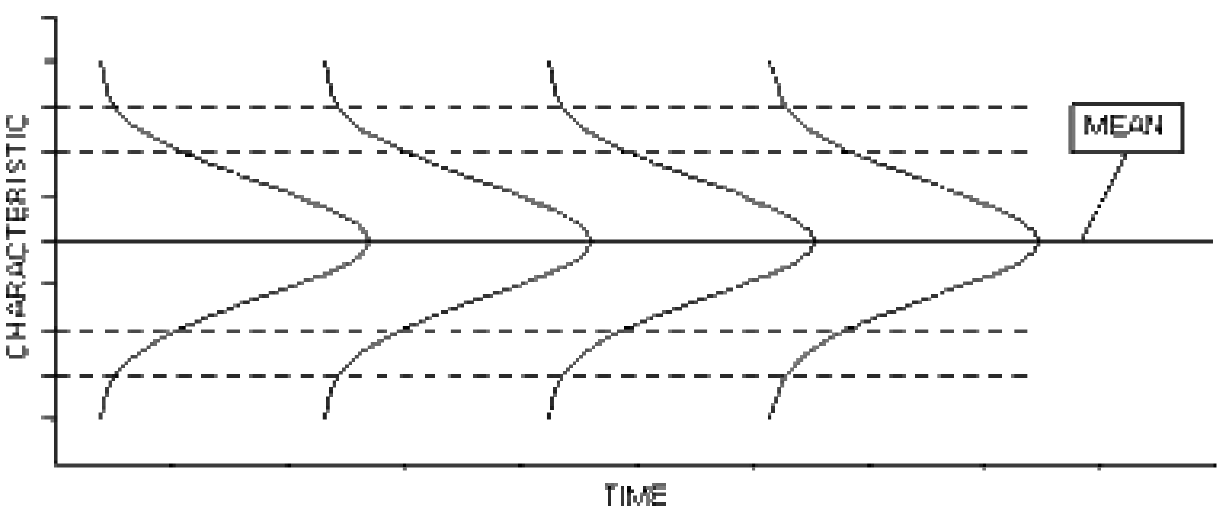
- On-line SPC
  - *screening* - the output is inspected and if the quality is not acceptable, the substandard items are
    - recycled for re-work
    - sold at reduced price
    - scrapped
  - *preventative* -attempts to avoid production of defective items by applying process control methods

Control Chart Interpretation

Control charts are normal distributions with an added time dimension



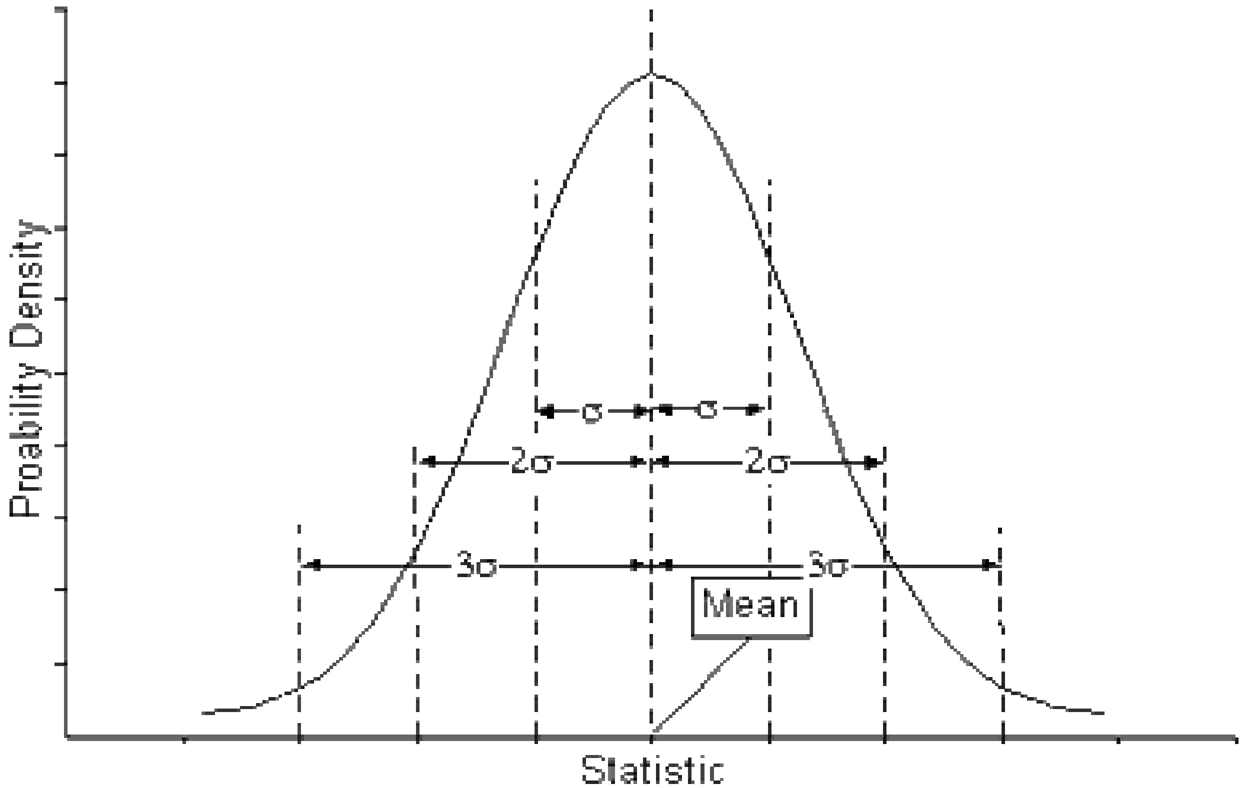
- *Control charts are run charts with superimposed normal distributions*



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.

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

How Control Charts 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

Types of Control 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

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

1 - Variations due to common causes are the responsibility of higher management and

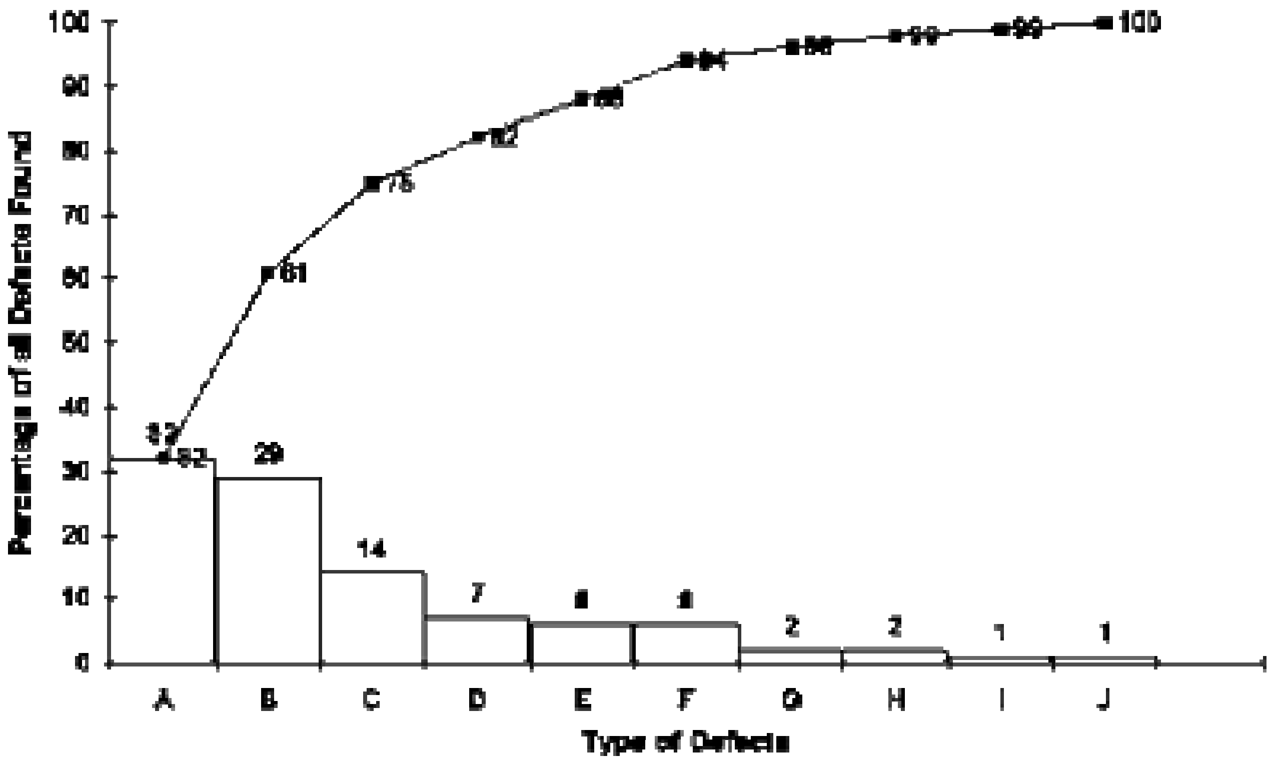
- have small effect on the process
- are inherent to the process because of:
  - the nature of the system
  - the way the system is managed
  - the way the process is organised and operated
- can only be removed by
  - making modifications to the process
  - changing the process

2 - 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



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 or
- focus on eliminating defect E, if defect E causes 40% of monetary loss

Pareto Charts

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**.

The Pareto Principle states that:

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

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

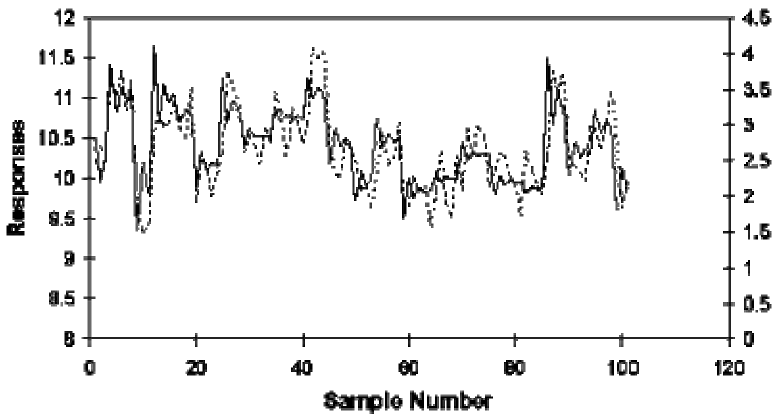
For example, - Products may suffer from different defects, but

- 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 cumulative line plot is obtained. These two plots together make up the Pareto Chart.

Run charts can be used to study relationships between variables. For example, in the above chart, the relationship between the 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.

Flow Charts

Flow charts are excellent visualisation tools but have no statistical basis

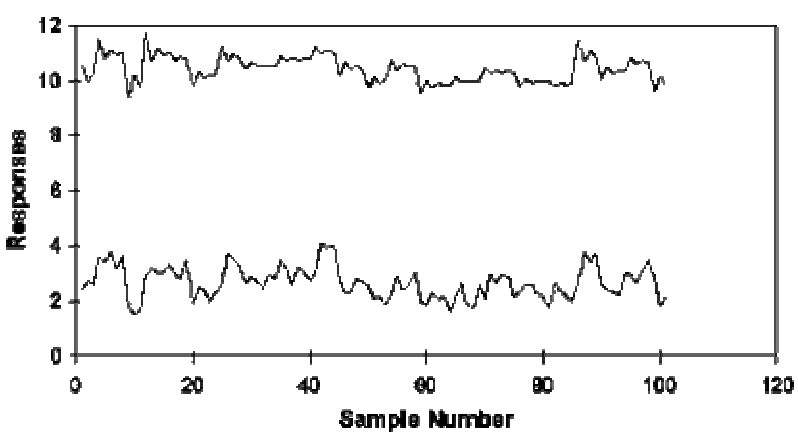
- Flow charts show
  - the progress of work
  - the flow of material or information through a sequence of operations
- Flow charts are useful in an initial process analysis
- Flow charts should be complemented by process flow sheets or process flow diagrams (more detailed) if available
- Everyone involved 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

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



What is SPC – 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 That Can Be Used for SPC

- Commonly used tools 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