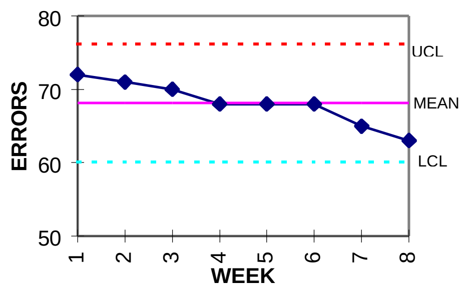
CONTROL CHART

X bar and R chart



Purpose

A **Control Chart** is used to analyze and monitor the variability of a process over time. This is accomplished by observing how the variability within the process causes the trend line to fluctuate in relation to a pair of calculated control limits.

When the fluctuations within the process occur in a non-random pattern or go beyond a control limit, the process is “out of statistical control.” Non-random variation represents an opportunity to improve the process and bring it into “statistical control.”

A process is said to be in a state of statistical control when the variation within the process is consistently random and within predictable limits.
Control charts can help a group or individual:

- Understand and recognize variability and how to control it.
- Identify the presence of "special causes" of variation or changes in performance of a process, i.e., a shift in the process average, change in the variance, cyclic behavior, etc.
- Stop trying to fix a process that is varying consistently over time and objectively determine the root causes of the problem.

Attribute Control Charts

Attribute data require a good/bad or go/no go decision and counting, e.g., type of defects (non-defects), percent late or defective (not late), etc. The formulas for developing these charts are not given in this toolbox. If you need to use this type of control chart, consult a statistical reference book or contact the DOT Productivity Management Section for assistance.

Variable Control Charts

X bar and R chart is a two-part **Control Chart** used to monitor processes with variable type data. In general, variable data requires some form of measurement, e.g., length, temperature, time, volume, pressure, etc. This is the most common of all control charts.

Interpretation of Control Charts

There are situations that indicate when a process may be out of control and the situation should be investigated to determine the problem.

Points Outside of the Limit - Control limits are drawn to represent the boundary of the natural variability of the process.

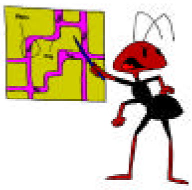
Run - A run is a series of seven or more consecutive points that occur on one side of the center line. Other runs include 10 out of 11, 12 out of 14, or 16 out of 20 points on one side of the center line.

Trend - A trend is a series of seven or more consecutive points that steadily increase or decrease.

Hugging the Center Line - Hugging is where 15 or more consecutive points occur within the center third of the control region. This may indicate a mixing of data from different populations which results in control limits that are too wide. The populations must be separated before any interpretation is possible.

Cycling - A cycle is a consistent repeating pattern of variation over time.

Approaching Control limits - Two of three consecutive points lying in the outer third of the control region.

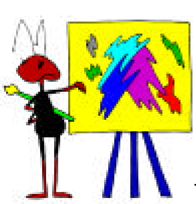


Process

Construction of an X bar and R chart where data values are variable:

1. Set up a distribution table of variable data.

2. Prepare a standard run chart to display the data collected.

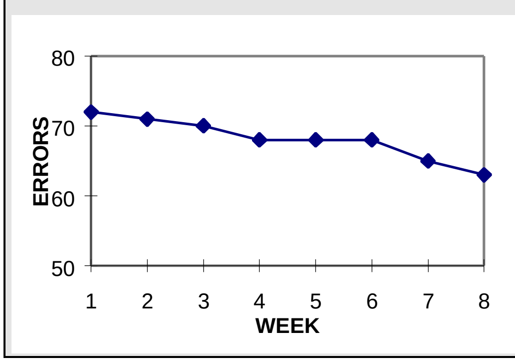


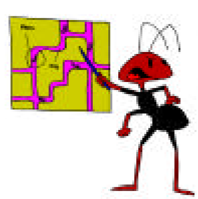
Example

1. Data collected was for data entry errors counted during quality control inspections.

Week	Errors
1	72
2	71
3	70
4	68
5	68
6	68
7	65
8	63
Total	545

2. Run chart for data collected:





Process

3. Calculate the mean for the data collected. The mean is equal to the sum of all values divided by the number of samples. The formula used:

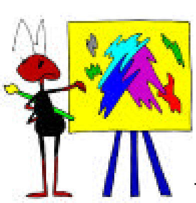
$$\bar{X} = \frac{\sum X}{N}$$

Where $\bar{X}$ = mean
$\sum X$ = sum of values
N = number of values

4. Calculate the standard deviation for the data collected. The standard deviation is equal to the square root of the difference between the sum of the raw values squared, which is divided by the number of values, less the mean squared. The formula used:

$$SD = \sqrt{\frac{\sum X^2}{N} - \bar{X}^2}$$

Where $\bar{X}^2$ = mean squared
$\sum X^2$ = the sum of the square of each value



Example

3. The mean for the data collected is as follows:

$\sum X$ = 545 defects counted
N = 8 weeks of data

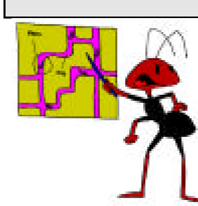
$$\bar{X} = \frac{545}{8} = 68.13$$

4A. Calculate the sum of the values squared:

X	X^2
72	5184
71	5041
70	4900
68	4624
68	4624
68	4624
65	4225
63	3691
545= $\sum X$	37191= $\sum X^2$

4B. Calculate for mean squared:

68.13 x 68.13 = 4641.7

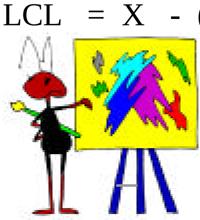


Process

5. Calculate upper control limits and lower control limits. The formulas are:

UCL = X + (3 x SD)

LCL = X - (3 x SD)



Example

4C. Solve for standard deviation using numbers solved above:

$$SD = \sqrt{\frac{\sum X^2}{N} - X^2}$$

$$SD = \sqrt{\frac{37191}{8} - 4641.7}$$

$$SD = \sqrt{4648.9 - 4641.7}$$

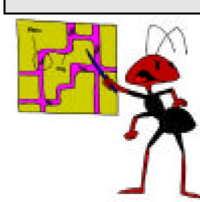
$$SD = \sqrt{7.2}$$

$$SD = 2.68$$

5. Upper and lower control limits plugged into equations and solved:

UCL = 68.13 + (3 x 2.68)= 76.17

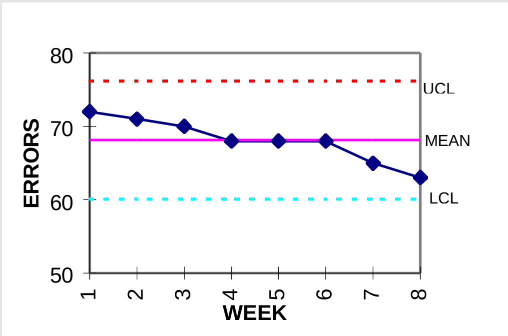
LCL = 68.13 - (3 x 2.68) = 60.09

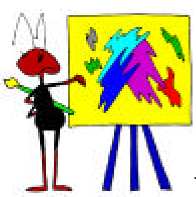


Process

6. Draw control limits on the chart in addition to the mean.

6. Complete new chart:





Example

Key Points

- A **Control Chart** is used to track the trend or the performance of a process over time.

- A **Control Chart** can be used to determine if a process is "out of statistical control."

- A **Control Chart** cannot tell you **WHY** a process is out of control. A cause and effect diagram, supported by data, can help you identify the special cause which is affecting the process.

- A **Control Chart** helps you to identify the normal process variation, which is system variation or random variation. Thus, two processes with widely different ranges of variation can both be in control. This does not mean both processes are equally good. The process with the least variation always will produce more predictable, dependable results and therefore is a better process.