

C Chart

Summary

The **C Chart** procedure creates a control chart for data that describes the number of nonconformities recorded as the result of inspecting m samples. The samples could represent a group of n items, a fixed period of time, a specified number of square meters of fabric, or some other sampling unit of fixed size. Unlike the data plotted using a p chart or np chart, the inspection of an item within the sample does not result in simply an acceptable or unacceptable rating. Rather, it results in a count of the total number of defects or problems observed with that item. The chart may be constructed in either *Initial Study* (Phase 1) mode, where the current data determine the control limits, or in *Control to Standard* (Phase 2) mode, where the limits come from either a known standard or from prior data.

The data for this analysis consist of m samples from a population detailing:

$$c_j = \text{number of nonconformities observed in sample } j$$

Many of the options for the C chart are the same as those of the P chart. This document highlights the differences between the 2 charts. For information on options such as runs test and ARL curves, consult the *P Chart* documentation.

Sample StatFolio: *cchart.sgp*

Sample Data:

The file *boards.sgd* contains the information on $m = 26$ samples, each consisting of $n = 100$ printed circuit boards. The data is taken from Montgomery (2005). Each board was inspected and the number of defects on the board was tabulated. The table below shows a partial list of the data in that file:

Sample	Defects
1	21
2	24
3	16
4	12
5	15
6	5
7	28
8	20
9	31
10	25
11	20
12	24
13	16
14	19
15	10

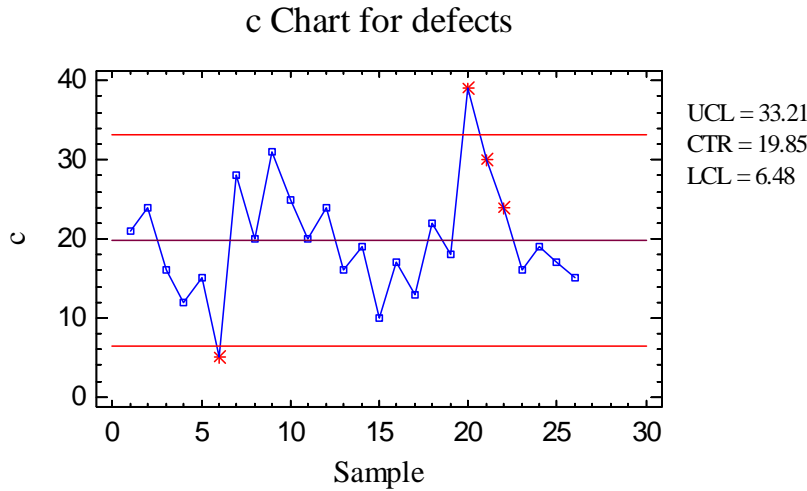
Data Input

The data required by this procedure is a numeric column containing the number of nonconformities in each of m samples.

- **Counts:** a column containing the number of nonconformities in each sample.
- **Labels:** optional labels for each sample.
- **LSL, Nominal, USL:** optional lower specification limit, nominal (target) value, and upper specification limit.
- **Select:** subset selection.

C Chart

The *C Chart* plots the numbers of nonconformities c_j .



In Phase 1 (*Initial Studies*) mode, the centerline and control limits are determined from the data. The centerline is located at:

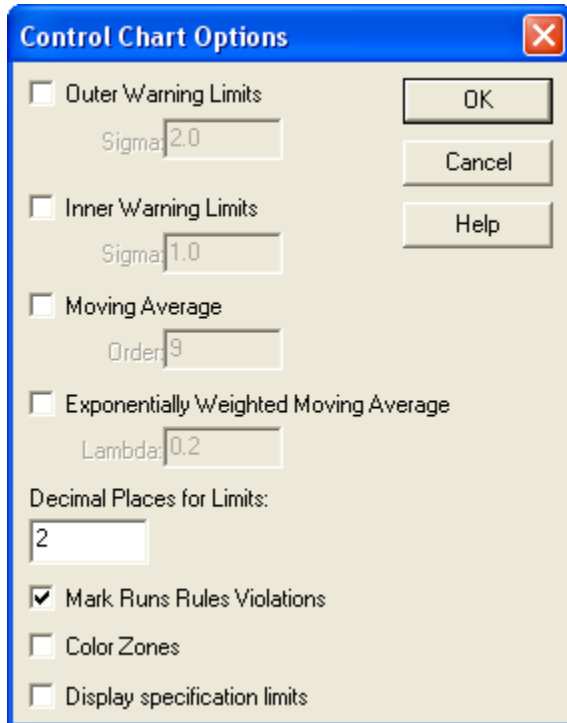
$$\bar{c} = \frac{\sum_{j=1}^m c_j}{m} \tag{1}$$

where m equals the number of samples. The control limits are placed above and below the centerline at:

$$\bar{c} \pm k\sqrt{\bar{c}} \tag{2}$$

where k is the sigma multiple specified on the *Control Charts* tab of the *Preferences* dialog box ($k = 3$ except in rare cases). All sample sizes are assumed to be equal. If this is not true, then a U chart should be used instead of a C chart.

Any points beyond the control limits will be flagged using a special point symbol. Any point excluded from the analysis, usually by clicking on a point on the chart and pressing the *Exclude/Include* button, will be indicated by an X. If so indicated on the *Pane Options* dialog box, unusual sequences of points may also be flagged. In the current chart, 2 samples are beyond the upper control limit, while 2 others display runs rules signals due to 2 out of 3 consecutive samples being more than two standard deviation above the centerline.

Pane Options

- **Outer Warning Limits:** check this box to add warning limits at the specified multiple of sigma, usually at 2 sigma.
- **Inner Warning Limits:** check this box to add warning limits at the specified multiple of sigma, usually at 1 sigma.
- **Moving Average:** check this box to add a moving average smoother to the chart. In addition to the sample counts, the average of the most recent q points will also be displayed, where q is the *order* of the moving average. The default value $q = 9$ since the 1-sigma inner warning limits for the original counts are equivalent to the 3-sigma control limits for that order moving average.
- **Exponentially Weighted Moving Average:** check this box to add an EWMA smoother to the chart. In addition to the sample counts, an exponentially weighted moving average of the sample counts will also be displayed, where λ is the smoothing parameter of the EWMA. The default value $\lambda = 0.2$ since the 1-sigma inner warning limits for the original counts are equivalent to the 3-sigma control limits for that EWMA.
- **Decimal Places for Limits:** the number of decimal places used to display the control limits.
- **Mark Runs Rules Violations:** flags with a special point symbol any unusual sequences or runs. The runs rules applied by default are specified on the *Runs Tests* tab of the *Preferences* dialog box.
- **Color Zones:** check this box to display green, yellow and red zones.

- **Display Specification Limits:** whether to add horizontal lines to the chart displaying the location of the specification limits (if any).

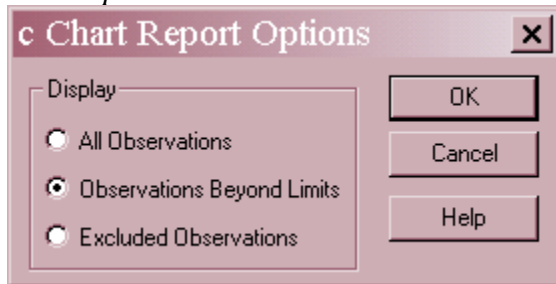
C Chart Report

This pane tabulates the values plotted on the control chart:

c Chart Report	
Samples Beyond Limits	
X = Excluded * = Beyond Limits	
Sample	c
6	* 5.0
20	* 39.0

Out-of-control points are indicated by an asterisk. Points excluded from the calculations are indicated by an X.

Pane Options



- **Display:** specify the samples (observations) to display in the report.

Analysis Summary

The *Analysis Summary* summarizes the data and the control chart.

<u>c Chart - defects</u>	
Number of samples = 26	
0 samples excluded	
c Chart	
<i>Period</i>	#1-26
UCL: +3.0 sigma	33.2109
Centerline	19.8462
LCL: -3.0 sigma	6.48145
2 beyond limits	
Estimates	
<i>Period</i>	#1-26
Mean c	19.8462
Sigma	4.4549

Included in the table are:

- **Sample Information:** the number of samples m . If any samples have been excluded from the calculations, that number is also displayed.
- **c Chart:** a summary of the centerline and control limits for the c chart. Using *Analysis Options*, separate limits may be calculated for different periods (sets of samples).
- **Estimates:** estimates of the mean number of nonconformities:

$$\hat{\mu} = \bar{c} \tag{3}$$

and the process sigma

$$\hat{\sigma} = \sqrt{\bar{c}} \tag{4}$$

Analysis Options

- **Type of Study:** determines how the control limits are set. For an *Initial Study* (Phase 1) chart, the limits are estimated from the current data. For a *Control to Standard* (Phase 2) chart, the control limits are determined from the information in the *Control to Standard* section of the dialog box.
- **Normalize:** if selected, all statistics will be normalized by calculating Z-scores and the Z-scores plotted on the charts. The centerline on such a chart is always located at 0, and the control limits are always located at $\pm k$.
- **Use Zone Format:** if checked, the statistics will be plotted using a zone chart rather than the usual format. See the example in the *P Chart* documentation.
- **Recalculate at:** the control limits of the chart may be recalculated at up to 4 locations along the X axis by specifying the sample numbers at which new estimates are to be initiated. Separate estimates of the mean number of nonconformities will be obtained using the data in the different sections. In such cases, the control limits will be adjusted at the start of each new period.
- **C Chart Control Limits:** specify the multiple k to use in determining the upper and lower control limits on the c chart. To suppress a limit completely, enter 0.
- **Control to Standard:** to perform a Phase 2 analysis, select *Control to Standard* for the *Type of Study* and then enter either of the following:

Specify Parameters: specify the established standard mean number of nonconforming items.

Specify Control Limits: specify the location of the centerline and control limits exactly where you wish them to be placed.

- **Exclude:** use this button to exclude specific samples from the calculations.

Save Results

The following results can be saved to the datasheet:

1. *Counts* – the sample counts.
2. *Labels* – the sample labels.
3. *Mean c* – the estimated mean number of nonconformities.
4. *Sigma* – the estimated standard deviation of the counts.