# Title

> **QC —** Quality control charts

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## Description

These commands provide standard quality-control charts. cchart draws a c chart; pchart, a p (fraction-defective) chart; rchart, an R (range or dispersion) chart; xchart, an $\overline{X}$ (control line) chart; and shewhart, vertically aligned $\overline{X}$ and R charts.

## Quick start

c chart for dvar defects per unit identified by uvar
    cchart dvar uvar

p chart for dvar defective items out of nvar items inspected from each unit identified by uvar
    pchart dvar uvar nvar

Same as above, but stabilize the p chart for unequal numbers of items inspected per unit
    pchart dvar uvar nvar, stabilized

R chart for the range of measurements m1, m2, m3, and m4
    rchart m1 m2 m3 m4, connect(l)

Same as above, but use known process standard deviation of 0.5 for control limits
    rchart m1 m2 m3 m4, connect(l) std(.5)

$\overline{X}$ chart for measurements m1, m2, m3, and m4
    xchart m1 m2 m3 m4, connect(l)

Same as above, but use known process standard deviation of 0.5 and grand mean of 10 for control limits
    xchart m1 m2 m3 m4, connect(l) std(.5) mean(10)

Shewhart chart with vertically aligned R and $\overline{X}$ charts
    shewhart m1 m2 m3 m4, connect(l) std(.5) mean(10)

# Menu

### cchart

Statistics > Other > Quality control > C chart

### pchart

Statistics > Other > Quality control > P chart

### rchart

Statistics > Other > Quality control > R chart

### xchart

Statistics > Other > Quality control > X-bar chart

### shewhart

Statistics > Other > Quality control > Vertically aligned X-bar and R chart

# Syntax

*Draw a c chart*

cchart *defect_var unit_var* [ , *cchart_options* ]

*Draw a p (fraction-defective) chart*

pchart *reject_var unit_var ssize_var* [ , *pchart_options* ]

*Draw an R (range or dispersion) chart*

rchart *varlist* [ *if* ] [ *in* ] [ , *rchart_options* ]

*Draw an $\overline{X}$ (control line) chart*

xchart *varlist* [ *if* ] [ *in* ] [ , *xchart_options* ]

*Draw vertically aligned $\overline{X}$ and R charts*

shewhart *varlist* [ *if* ] [ *in* ] [ , *shewhart_options* ]

| *cchart_options* | Description |
|---|---|
| **Main** | |
| <u>nog</u>raph | suppress graph |
| **Plot** | |
| *connect_options* | affect rendition of the plotted points |
| *marker_options* | change look of markers (color, size, etc.) |
| *marker_label_options* | add marker labels; change look or position |
| **Control limits** | |
| <u>clo</u>pts(*cline_options*) | affect rendition of the control limits |
| **Add plots** | |
| <u>addp</u>lot(*plot*) | add other plots to the generated graph |
| **Y axis, X axis, Titles, Legend, Overall** | |
| *twoway_options* | any options other than by() documented in [G-3] *twoway_options* |

| *pchart_options* | Description |
|---|---|
| **Main** | |
| <u>stabilized</u> | stabilize the p chart when sample sizes are unequal |
| <u>nograph</u> | suppress graph |
| <u>generate</u>(*newvar$_f$ newvar$_{lcl}$ newvar$_{ucl}$*) | store the fractions of defective elements and the lower and upper control limits |
| **Plot** | |
| *connect_options* | affect rendition of the plotted points |
| *marker_options* | change look of markers (color, size, etc.) |
| *marker_label_options* | add marker labels; change look or position |
| **Control limits** | |
| <u>clopts</u>(*cline_options*) | affect rendition of the control limits |
| **Add plots** | |
| <u>addplot</u>(*plot*) | add other plots to the generated graph |
| **Y axis, X axis, Titles, Legend, Overall** | |
| *twoway_options* | any options other than by() documented in [G-3] *twoway_options* |

| *rchart_options* | Description |
|---|---|
| **Main** | |
| <u>std</u>(*#*) | user-specified standard deviation |
| <u>nograph</u> | suppress graph |
| **Plot** | |
| *connect_options* | affect rendition of the plotted points |
| *marker_options* | change look of markers (color, size, etc.) |
| *marker_label_options* | add marker labels; change look or position |
| **Control limits** | |
| <u>clopts</u>(*cline_options*) | affect rendition of the control limits |
| **Add plots** | |
| <u>addplot</u>(*plot*) | add other plots to the generated graph |
| **Y axis, X axis, Titles, Legend, Overall** | |
| *twoway_options* | any options other than by() documented in [G-3] *twoway_options* |

| *xchart_options* | Description |
|---|---|
| **Main** | |
| <u>std</u>(*#*) | user-specified standard deviation |
| <u>mean</u>(*#*) | user-specified mean |
| <u>lower</u>(*#*) <u>upper</u>(*#*) | lower and upper limits of the X-bar limits |
| <u>nograph</u> | suppress graph |
| **Plot** | |
| *connect_options* | affect rendition of the plotted points |
| *marker_options* | change look of markers (color, size, etc.) |
| *marker_label_options* | add marker labels; change look or position |
| **Control limits** | |
| clopts(*cline_options*) | affect rendition of the control limits |
| **Add plots** | |
| addplot(*plot*) | add other plots to the generated graph |
| **Y axis, X axis, Titles, Legend, Overall** | |
| *twoway_options* | any options other than by() documented in [G-3] *twoway_options* |

| *shewhart_options* | Description |
|---|---|
| **Main** | |
| <u>std</u>(*#*) | user-specified standard deviation |
| <u>mean</u>(*#*) | user-specified mean |
| <u>nograph</u> | suppress graph |
| **Plot** | |
| *connect_options* | affect rendition of the plotted points |
| *marker_options* | change look of markers (color, size, etc.) |
| *marker_label_options* | add marker labels; change look or position |
| **Control limits** | |
| clopts(*cline_options*) | affect rendition of the control limits |
| **Y axis, X axis, Titles, Legend, Overall** | |
| *combine_options* | any options documented in [G-2] **graph combine** |

collect is allowed with all QC commands; see [U] **11.1.10 Prefix commands**.

## Options

> **Main**

stabilized stabilizes the p chart when sample sizes are unequal.

std(*#*) specifies the standard deviation of the process. The R chart is calculated (based on the range) if this option is not specified.

mean(*#*) specifies the grand mean, which is calculated if not specified.

lower(*#*) and upper(*#*) must be specified together or not at all. They specify the lower and upper limits of the $\overline{X}$ chart. Calculations based on the mean and standard deviation (whether specified by option or calculated) are used otherwise.

nograph suppresses the graph.

generate(*newvar*$_f$ *newvar*$_{lcl}$ *newvar*$_{ucl}$) stores the plotted values in the p chart. *newvar*$_f$ will contain the fractions of defective elements; *newvar*$_{lcl}$ and *newvar*$_{ucl}$ will contain the lower and upper control limits, respectively.

> ### Plot

*connect_options* affect whether lines connect the plotted points and the rendition of those lines; see [G-3] *connect_options*.

*marker_options* affect the rendition of markers drawn at the plotted points, including their shape, size, color, and outline; see [G-3] *marker_options*.

*marker_label_options* specify if and how the markers are to be labeled; see [G-3] *marker_label_options*.

> ### Control limits

clopts(*cline_options*) affects the rendition of the control limits; see [G-3] *cline_options*.

> ### Add plots

addplot(*plot*) provides a way to add other plots to the generated graph. See [G-3] *addplot_option*.

> ### Y axis, X axis, Titles, Legend, Overall

*twoway_options* are any of the options documented in [G-3] *twoway_options*, excluding by(). These include options for titling the graph (see [G-3] *title_options*) and for saving the graph to disk (see [G-3] *saving_option*).

*combine_options* (shewhart only) are any of the options documented in [G-2] **graph combine**. These include options for titling the graph (see [G-3] *title_options*) and for saving the graph to disk (see [G-3] *saving_option*).

# Remarks and examples

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Control charts may be used to define the goal of a repetitive process, to control that process, and to determine if the goal has been achieved. Walter A. Shewhart of Bell Telephone Laboratories devised the first control chart in 1924. In 1931, Shewhart published *Economic Control of Quality of Manufactured Product.* According to Burr, "Few fields of knowledge have ever been so completely explored and charted in the first exposition" (1976, 29). Shewhart states that "a phenomenon will be said to be controlled when, through the use of past experience, we can predict, at least within limits, how the phenomenon may be expected to vary in the future. Here it is understood that prediction within limits means that we can state, at least approximately, the probability that the observed phenomenon will fall within given limits" (1931, 6).

For more information on quality-control charts, see Burr (1976), Duncan (1986), Harris (1999), or Ryan (2011).

▷ Example 1: cchart

cchart graphs a c chart showing the number of nonconformities in a unit, where *defect_var* records the number of defects in each inspection unit and *unit_var* records the unit number. The unit numbers need not be in order. For instance, consider the following example dataset from Ryan (2011, 186):

```
. use https://www.stata-press.com/data/r18/ncu

. describe

Contains data from https://www.stata-press.com/data/r18/ncu.dta
 Observations:            30
    Variables:             2                          2 Dec 2022 15:15
```

| Variable name | Storage type | Display format | Value label | Variable label |
|---|---|---|---|---|
| day | byte | %9.0g | | Day in April |
| defects | byte | %9.0g | | Number of nonconforming units |

```
Sorted by:

. list in 1/5
```

|  | day | defects |
|---|---|---|
| 1. | 1 | 7 |
| 2. | 2 | 5 |
| 3. | 3 | 11 |
| 4. | 4 | 13 |
| 5. | 5 | 9 |

```
. cchart defects day, title(c chart for nonconforming transistors)
```
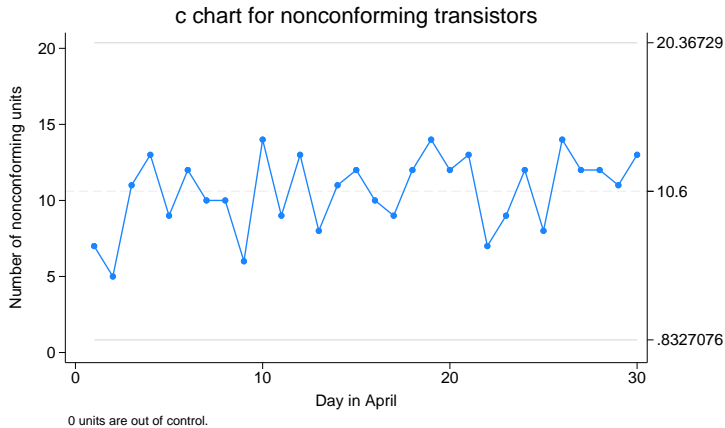


The expected number of defects is 10.6, with lower and upper control limits of 0.8327 and 20.37, respectively. No units are out of control.

◁

▷ Example 2: pchart

pchart graphs a p chart, which shows the fraction of nonconforming items in a subgroup, where *reject_var* records the number rejected in each inspection unit, *unit_var* records the inspection unit number, and *ssize_var* records the number inspected in each unit.

Consider the example dataset from Ryan (2011, 186) of the number of nonconforming transistors out of 1,000 inspected each day during the month of April:

```
. use https://www.stata-press.com/data/r18/ncu2
. describe

Contains data from https://www.stata-press.com/data/r18/ncu2.dta
 Observations:              30
    Variables:               3                     2 Dec 2022 15:16
─────────────────────────────────────────────────────────────────────────
Variable      Storage   Display    Value
    name         type    format    label      Variable label
─────────────────────────────────────────────────────────────────────────
day             byte    %9.0g                 Day in April
rejects         byte    %9.0g                 Number of nonconforming units
ssize            int    %9.0g                 Sample size
─────────────────────────────────────────────────────────────────────────

Sorted by:
. list in 1/5
```

|     | day | rejects | ssize |
|-----|-----|---------|-------|
| 1.  | 1   | 7       | 1000  |
| 2.  | 2   | 5       | 1000  |
| 3.  | 3   | 11      | 1000  |
| 4.  | 4   | 13      | 1000  |
| 5.  | 5   | 9       | 1000  |

```
. pchart rejects day ssize
```



0 units are out of control.
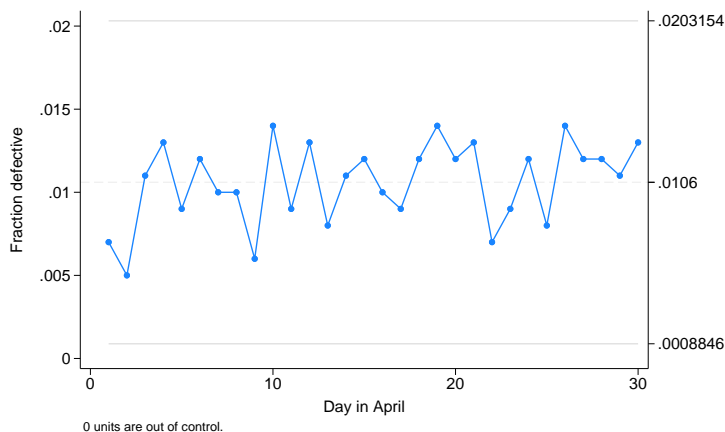
All the points are within the control limits, which are 0.0009 for the lower limit and 0.0203 for the upper limit.

Here the sample sizes are fixed at 1,000, so the `ssize` variable contains 1,000 for each observation. Sample sizes need not be fixed, however. Say that our data were slightly different:

```
. use https://www.stata-press.com/data/r18/ncu3
. list in 1/5
```
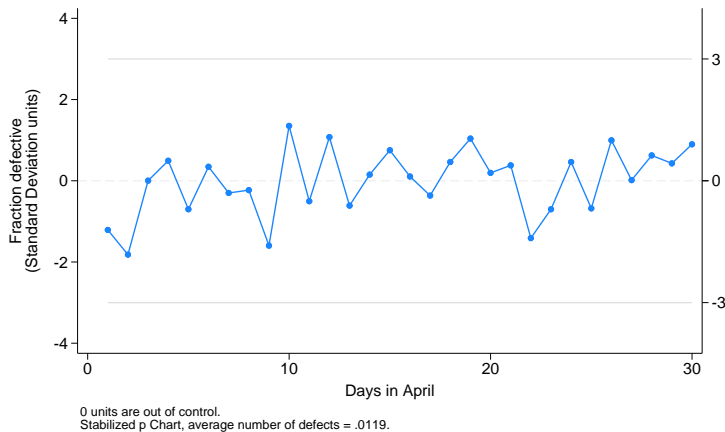
|     | day | rejects | ssize |
|-----|-----|---------|-------|
| 1.  | 1   | 7       | 920   |
| 2.  | 2   | 5       | 920   |
| 3.  | 3   | 11      | 920   |
| 4.  | 4   | 13      | 950   |
| 5.  | 5   | 9       | 950   |

```
. pchart rejects day ssize
```



0 units are out of control.
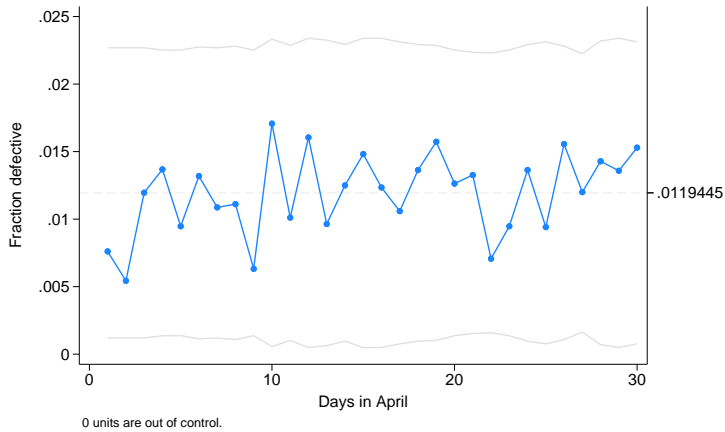
Here the control limits are, like the sample size, no longer constant. The `stabilize` option will stabilize the control chart:

```
. pchart rejects day ssize, stabilize
```



0 units are out of control.
Stabilized p Chart, average number of defects = .0119.

▷ Example 3: rchart

rchart displays an R chart showing the range for repeated measurements at various times. Variables within observations record measurements. Observations represent different samples.

For instance, say that we take five samples of 5 observations each. In our first sample, our measurements are 10, 11, 10, 11, and 12. The data are
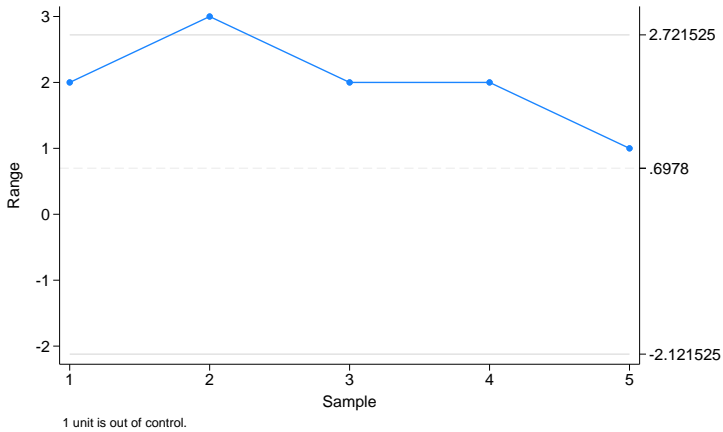
```
. list
```

|    | m1 | m2 | m3 | m4 | m5 |
|----|----|----|----|----|----|
| 1. | 10 | 11 | 10 | 11 | 12 |
| 2. | 12 | 10 | 9  | 10 | 9  |
| 3. | 10 | 11 | 10 | 12 | 10 |
| 4. | 9  | 9  | 9  | 10 | 11 |
| 5. | 12 | 12 | 12 | 12 | 13 |

```
. rchart m1-m5, connect(l)
```



0 units are out of control.
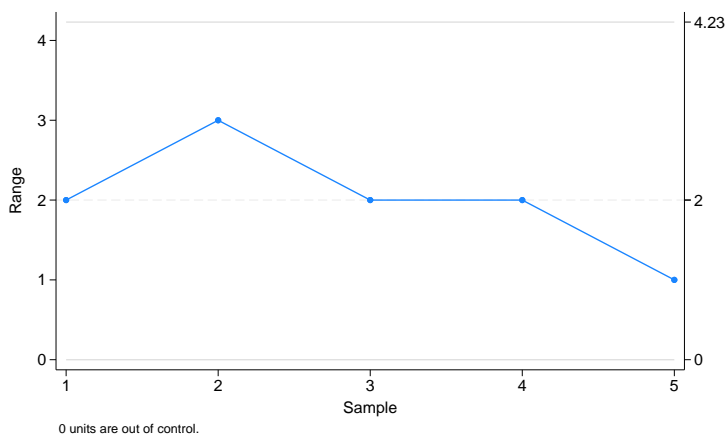
The expected range in each sample is 2 with lower and upper control limits of 0 and 4.23, respectively. If we know that the process standard deviation is 0.3, we could specify
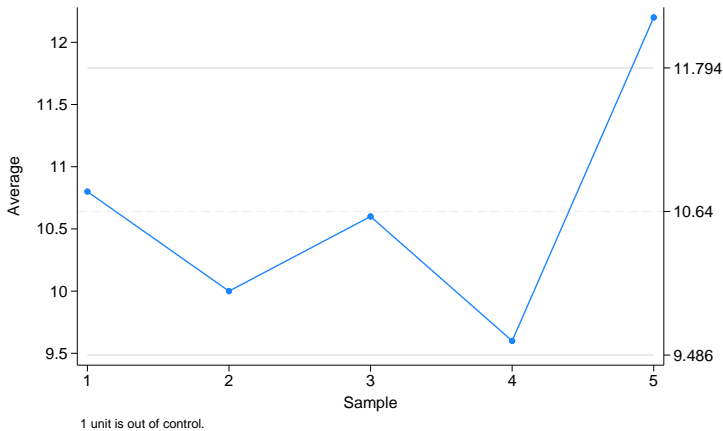
```
. rchart m1-m5, connect(l) std(.3)
```



1 unit is out of control.

◁

▷ Example 4: xchart

xchart graphs an $\overline{X}$ chart for repeated measurements at various times. Variables within observations record measurements, and observations represent different samples. Using the same data as in the previous example, we type

```
. xchart m1-m5, connect(l)
```



1 unit is out of control.

The average measurement in the sample is 10.64, and the lower and upper control limits are 9.486 and 11.794, respectively. Suppose that we knew from prior information that the mean of the process is 11. Then, we would type
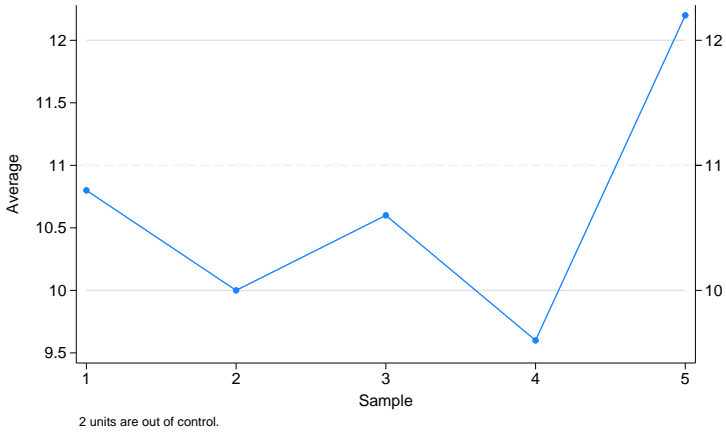
```
. xchart m1-m5, connect(l) mean(11)
```



2 units are out of control.
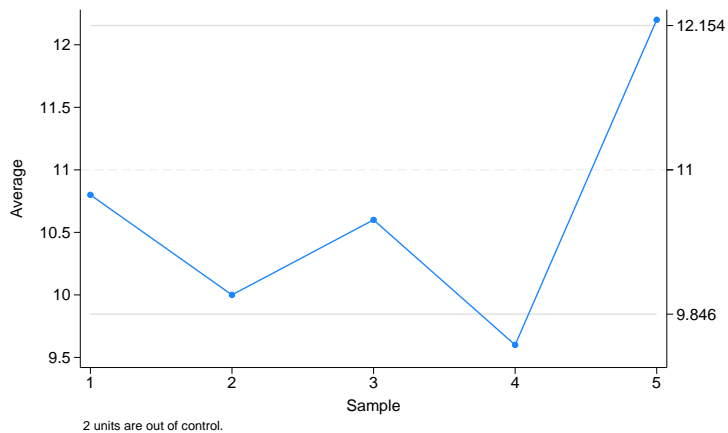
If we also know that the standard deviation of the process is 0.3, we could type

```
. xchart m1-m5, connect(l) mean(11) std(.3)
```



3 units are out of control.
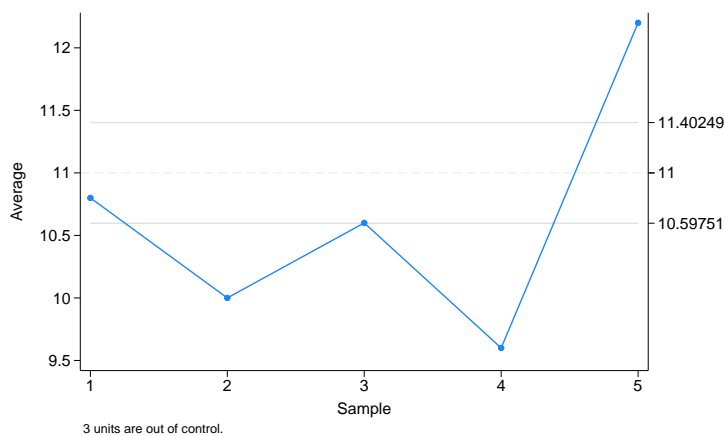
Finally, xchart allows us to specify our own control limits:

```
. xchart m1-m5, connect(l) mean(11) lower(10) upper(12)
```



2 units are out of control.

◁

▷ Example 5: shewhart

shewhart displays a vertically aligned $\overline{X}$ and R chart in the same image. To produce the best-looking combined image possible, you will want to use the xchart and rchart commands separately and then combine the graphs. shewhart, however, is more convenient.

Using the same data as previously, but realizing that the standard deviation should have been 0.4, we type

```
. shewhart m1-m5, connect(l) mean(11) std(.4)
```



3 units are out of control.

0 units are out of control.

◁
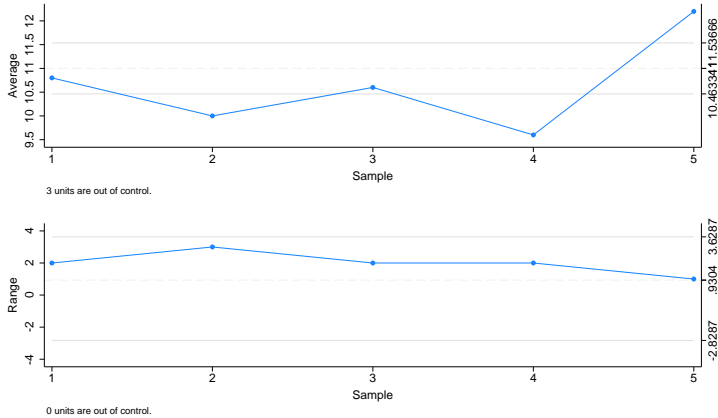
Walter Andrew Shewhart (1891–1967) was born in Illinois and educated as a physicist, with degrees from the Universities of Illinois and California. After a brief period teaching physics, he worked for the Western Electric Company and (from 1925) the Bell Telephone Laboratories. His name is most associated with control charts used in quality controls, but his many other interests ranged generally from quality assurance to the philosophy of science.

## Stored results

cchart stores the following in r():

Scalars
| | |
|---|---|
| r(cbar) | expected number of nonconformities |
| r(lcl_c) | lower control limit |
| r(ucl_c) | upper control limit |
| r(N) | number of observations |
| r(out_c) | number of units out of control |
| r(below_c) | number of units below the lower limit |
| r(above_c) | number of units above the upper limit |

pchart stores the following in r():

Scalars
| | |
|---|---|
| r(pbar) | average fraction of nonconformities |
| r(lcl_p) | lower control limit |
| r(ucl_p) | upper control limit |
| r(N) | number of observations |
| r(out_p) | number of units out of control |
| r(below_p) | number of units below the lower limit |
| r(above_p) | number of units above the upper limit |

rchart stores the following in r():

Scalars
| | |
|---|---|
| r(central_line) | ordinate of the central line |
| r(lcl_r) | lower control limit |
| r(ucl_r) | upper control limit |
| r(N) | number of observations |
| r(out_r) | number of units out of control |
| r(below_r) | number of units below the lower limit |
| r(above_r) | number of units above the upper limit |

xchart stores the following in r():

Scalars
| | |
|---|---|
| r(xbar) | grand mean |
| r(lcl_x) | lower control limit |
| r(ucl_x) | upper control limit |
| r(N) | number of observations |
| r(out_x) | number of units out of control |
| r(below_x) | number of units below the lower limit |
| r(above_x) | number of units above the upper limit |

shewhart stores in r() the combination of stored results from xchart and rchart.

# Methods and formulas

For the c chart, the number of defects per unit, $C$, is taken to be a value of a random variable having a Poisson distribution. If $k$ is the number of units available for estimating $\lambda$, the parameter of the Poisson distribution, and if $C_i$ is the number of defects in the $i$th unit, then $\lambda$ is estimated by $\overline{C} = \sum_i C_i / k$. Then

$$\text{central line} = \overline{C}$$
$$\text{UCL} = \overline{C} + 3\sqrt{\overline{C}}$$
$$\text{LCL} = \overline{C} - 3\sqrt{\overline{C}}$$

Control limits for the p chart are based on the sampling theory for proportions, using the normal approximation to the binomial. If $k$ samples are taken, the estimator of $p$ is given by $\overline{p} = \sum_i \widehat{p}_i / k$, where $\widehat{p}_i = x_i / n_i$, and $x_i$ is the number of defects in the $i$th sample of size $n_i$. The central line and the control limits are given by

$$\text{central line} = \overline{p}$$
$$\text{UCL} = \overline{p} + 3\sqrt{\overline{p}(1-\overline{p})/n_i}$$
$$\text{LCL} = \overline{p} - 3\sqrt{\overline{p}(1-\overline{p})/n_i}$$

Control limits for the R chart are based on the distribution of the range of samples of size $n$ from a normal population. If the standard deviation of the process, $\sigma$, is known,

$$\text{central line} = d_2\sigma$$
$$\text{UCL} = D_2\sigma$$
$$\text{LCL} = D_1\sigma$$

where $d_2$, $D_1$, and $D_2$ are functions of the number of observations in the sample and are obtained from the table published in Beyer (1976).

When $\sigma$ is unknown,

$$\text{central line} = \overline{R}$$
$$\text{UCL} = (D_2/d_2)\overline{R}$$
$$\text{LCL} = (D_1/d_2)\overline{R}$$

where $\overline{R} = \sum_i R_i / k$ is the range of the $k$ sample ranges $R_i$.

Control limits for the $\overline{\text{X}}$ chart are given by

$$\text{central line} = \overline{x}$$
$$\text{UCL} = \overline{x} + (3/\sqrt{n})\sigma$$
$$\text{LCL} = \overline{x} - (3/\sqrt{n})\sigma$$

if $\sigma$ is known. If $\sigma$ is unknown,

$$\text{central line} = \overline{x}$$
$$\text{UCL} = \overline{x} + A_2\overline{R}$$
$$\text{LCL} = \overline{x} - A_2\overline{R}$$

where $\overline{R}$ is the average range as defined above and $A_2$ is a function (op. cit.) of the number of observations in the sample.

> Isobel Loutit (1909–2009) is known for her work during World War II to improve the accuracy of targeting for anti-aircraft guns and as a contributor to the field of quality control. Loutit was born in Selkirk Manitoba, Canada. She graduated from the University of Manitoba in 1929 with a degree in mathematics and was one of the first women to work as a professional statistician in Canada. After graduation, she obtained a job teaching French. However, because of her training, she served as a substitute math teacher when needed.
>
> When World War II started, Loutit took a job as a quality control statistician at Northern Electric. Shortly after that, the Canadian government advertised for women with technical training to fill jobs that had been vacated by men who had gone to war. She took a position testing equipment for the military. This job eventually returned her to Northern Electric, this time as a government employee verifying the accuracy of Northern Electric's Vickers anti-aircraft gun predictor, which was used to aim artillery at incoming planes. Recognizing the quality of her work, the CEO of Northern Electric rehired Loutit as an engineer, the only position for which her pay would not be capped as a woman. She later became the first female manager at Northern Electric and the first woman to chair the Montreal Section of the American Society for Quality Control.

# References

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# Also see

[R] **serrbar** — Graph standard error bar chart

For suggested citations, see the FAQ on citing Stata documentation.