How to Use Minitab:

Quality Control

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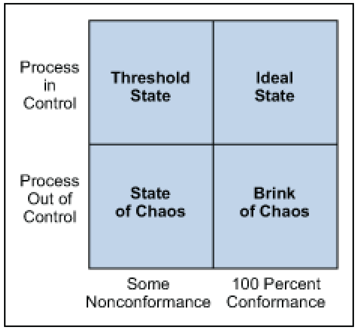
08/27/14

INTRODUCTION

* Click on the links to jump to that page in the presentation. *

Two Major Components:



1. Control Charts
   - Used to monitor a process and show if it's in control
   - Does not indicate if your process is meeting specifications

2. Capability Analysis
   - Indicates whether your process is meeting specifications
   - Does not show if your process is in control or not

For more details, go here:
\\Csdlnet\services\FS5-Projects\MCM-D\PERSONAL FOLDERS\Student Folders\N. Richard\SPC\Statistical Process Control (SPC).pptx

http://www.isixsigma.com/wp-content/uploads/2013/02/four-process-states.gif

Types of Control Charts

* Click on the links to jump to that page in the presentation. *

Chart	Use This Chart When… You have…	You have…	You want to find…
Xbar – R Chart	One Variable- Measurement Data	A sample at each time t. Samples can be different sizes	Out of control signals, **large process shifts** (≥ 1.5σ)
Xbar – S Chart	One Variable- Measurement Data	A sample at each time t. Samples can be different sizes.	Out of control signals**, large process shifts** (≥ 1.5σ)
I – MR Chart	One Variable- Measurement Data	Individual measures (sample size =1) at each time t	Out of control signals**, large process shifts** (≥ 1.5σ)
EWMA Chart	One Variable- Measurement Data	Either samples or individual measures at each time t	Out of control signals, **small process shifts** (< 1.5σ)
CUSUM Chart	One Variable- Measurement Data	Either samples or individual measures at each time t	Out of control signals, **small process shifts** (< 1.5σ)
P Chart	Attribute (Categorical) Data	A sample at each time t. Samples can be different sizes	The fraction of non-conforming units p, **large process shifts** (≥ 1.5σ)
C Chart	Attribute (Categorical) Data	Samples that are all the same size	The # of non-conformities in a sample, **large process shifts** (≥ 1.5σ)
U Chart	Attribute (Categorical) Data	Samples that differ in size	The # of non-conformities per unit in a sample, **large process shifts** (≥ 1.5σ)
T^2 Chart	Several Variables- Measurement Data	A sample at each time t, for each variable- considering variables jointly, rather than separately	Out of control signals, **large process shifts** (≥ 1.5σ),

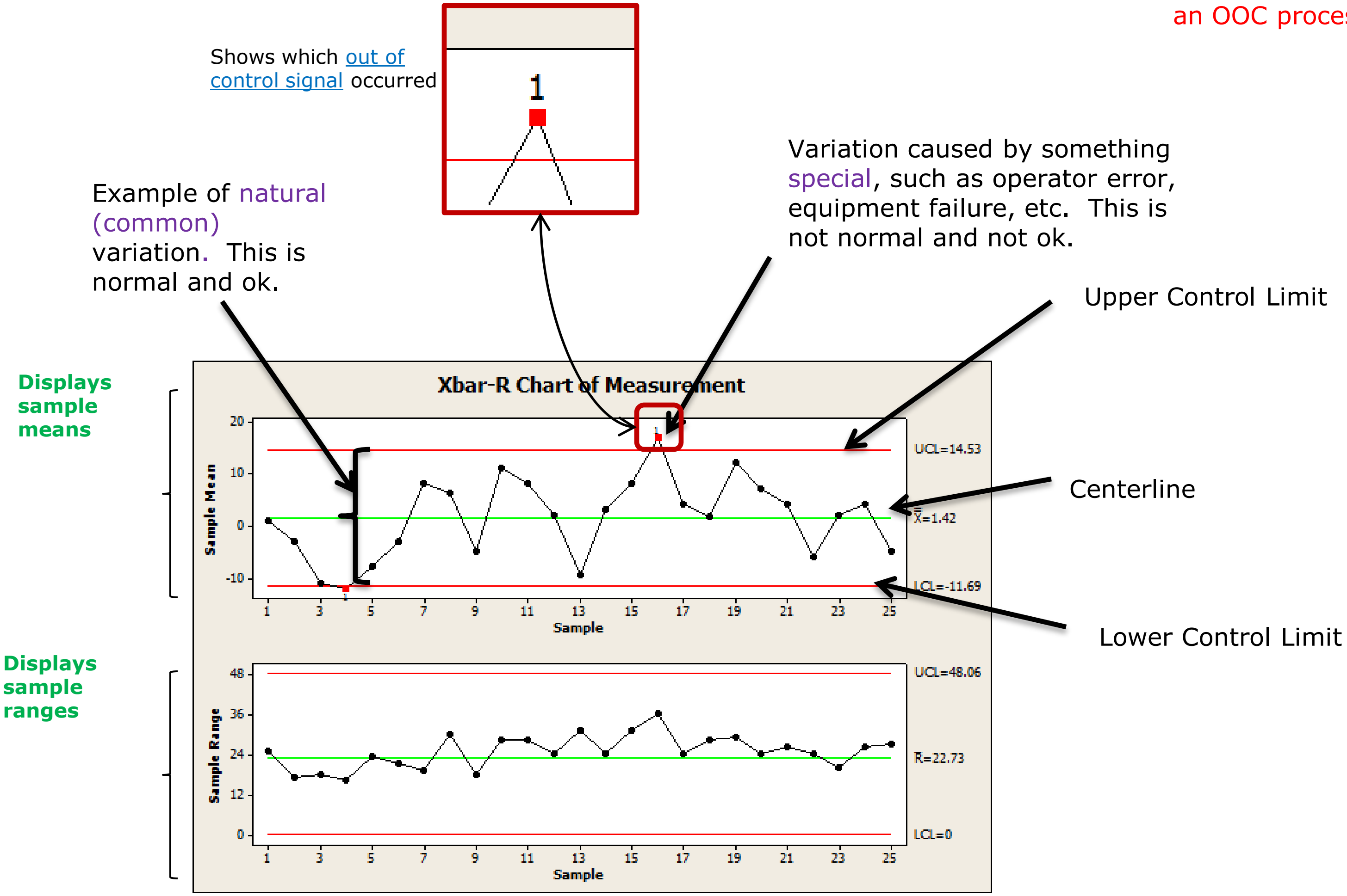
σ = standard deviation

Parts of a Control Chart

Control charts are used to detect special causes of variation.

A process is out of control (OOC) if it is operating with special causes of variation.

See the next slide for signals of an OOC process.



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Out of Control Signals

Your process may be out of control (OOC) if one or more of the following occurs:

1. One or more points beyond 3 sigma from center line
2. 9 points in a row on same side of center line
3. 6 points in a row, all increasing or all decreasing
4. 14 points in a row, alternating up and down
5. 2 out of 3 consecutive points beyond 2 sigma from center line (same side)
6. 4 out of 5 consecutive points beyond 1 sigma from center line (same side)
7. 15 points in a row within 1 sigma of center line (either side)
8. 8 points in a row beyond 1 sigma from center line (either side)

You can change the values in red, but the ones above are standard in practice.

Will show later how to perform these tests.

If you have an in control, normally distributed process, 99.73% of the points will fall within 3 sigma limits. 0.27% will fall outside the limits; these points are called false alarms. They appear to be out of control signals, but they are not.

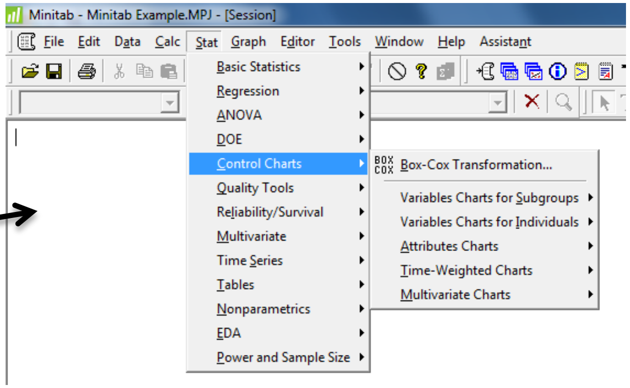
If your data is not normally distributed, you have a greater risk of false alarms. Even more important, you also have the risk of false negatives. This is a point that is out of control, but is not flagged. This is bad!

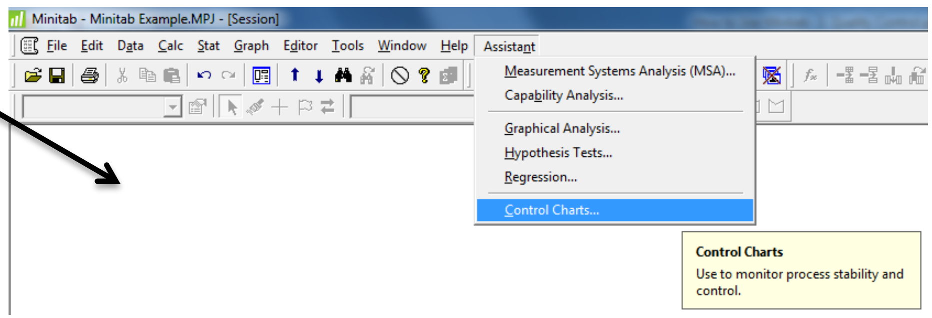
Return to Types of Control Chart

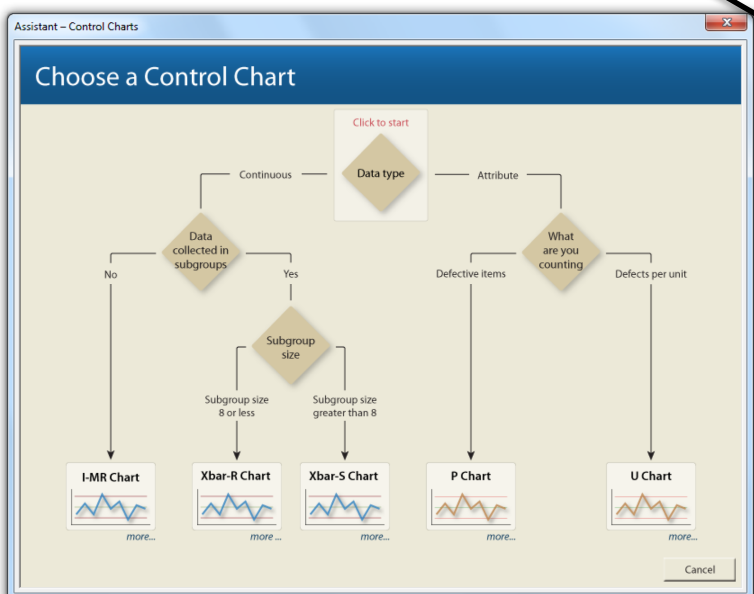
CREATING CONTROL CHARTS

Two ways to create control charts in Minitab

1. Stat → Control Charts
2. Assistant → Control Charts







Note: Assistant only performs tests 1, 2, and 7 from page 5

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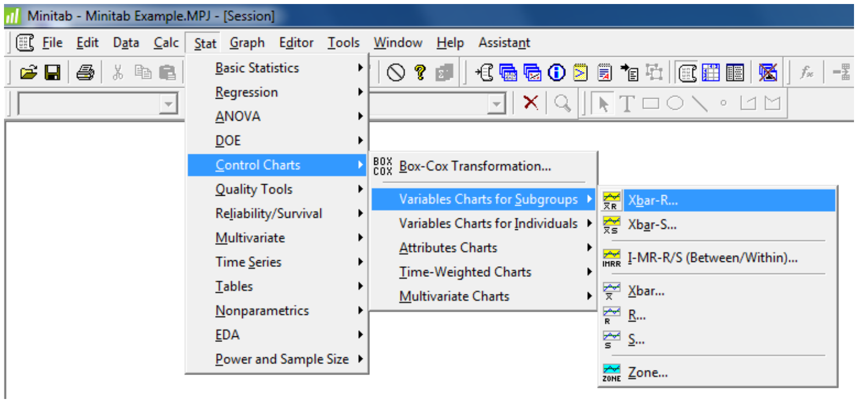
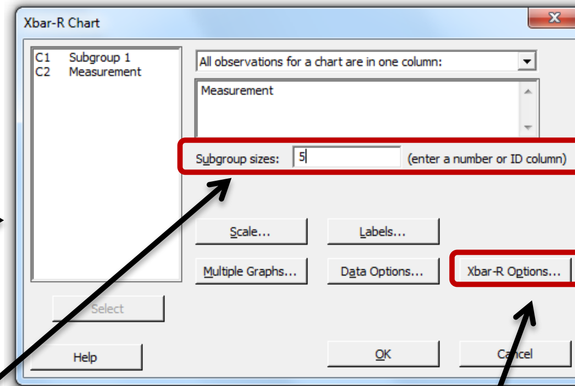
XBAR-R CHART

Graphs subgroup means and ranges

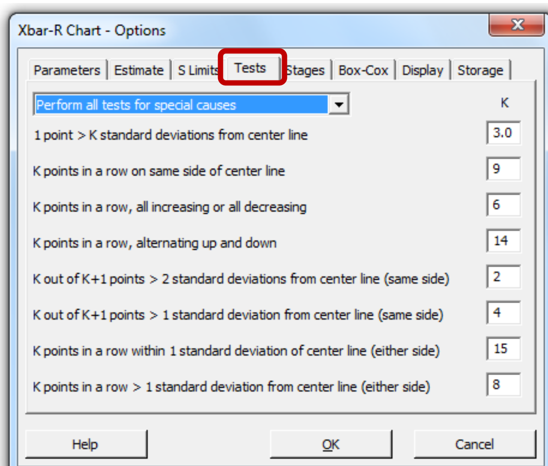
Subgroup size: the number of data points in each of your samples.





If all your samples are the same size, you can enter in the number here.

If samples are not the same size, create a "Subgroup" column in your data. The subgroup column should indicate what sample a data point belongs to.



To select which tests (for out of control signals) to perform, click Options.

Then, click the Tests tab.

Select which tests you want to perform, or use the drop-down to select "Perform all tests for special causes"

Change the values if you wish.

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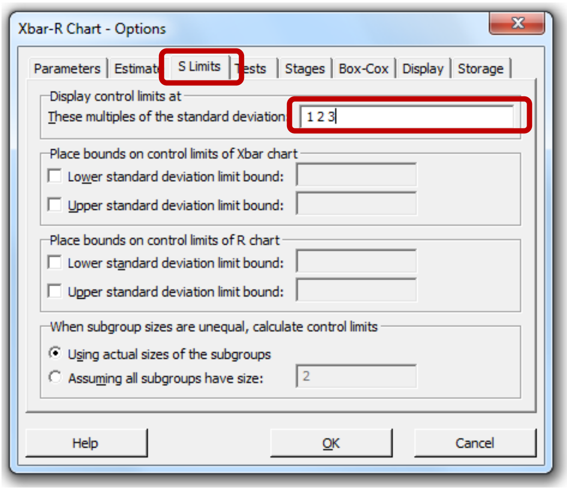
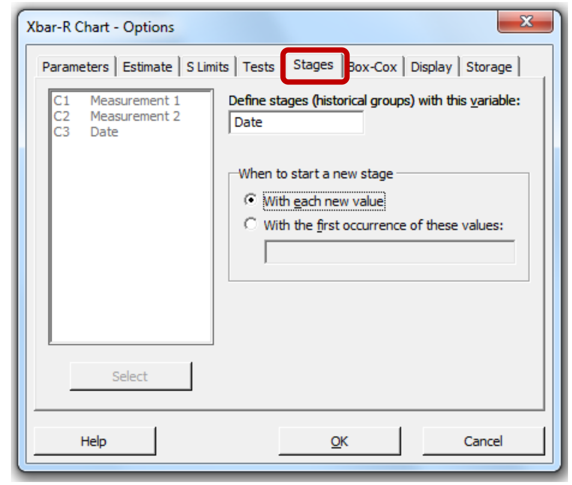
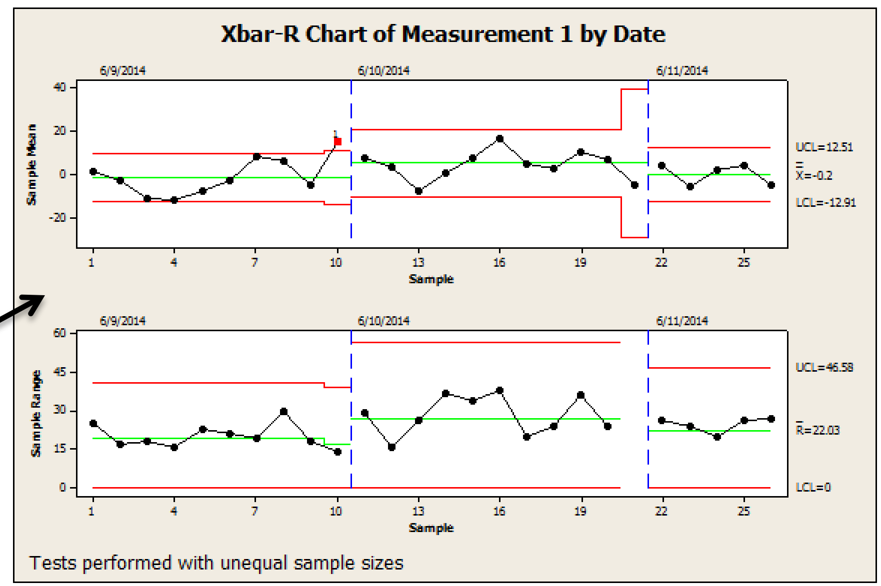
XBAR-R CHART



To display ±1, ±2, ±3, etc. standard deviations on your graph, go to the S-Limits tab





Sometimes, you will have data taken on different days. You may want to see separate analysis for each day.

Or, you purposely shift a process. The control limits should be re-evaluated, and you may want to see the change in limits.

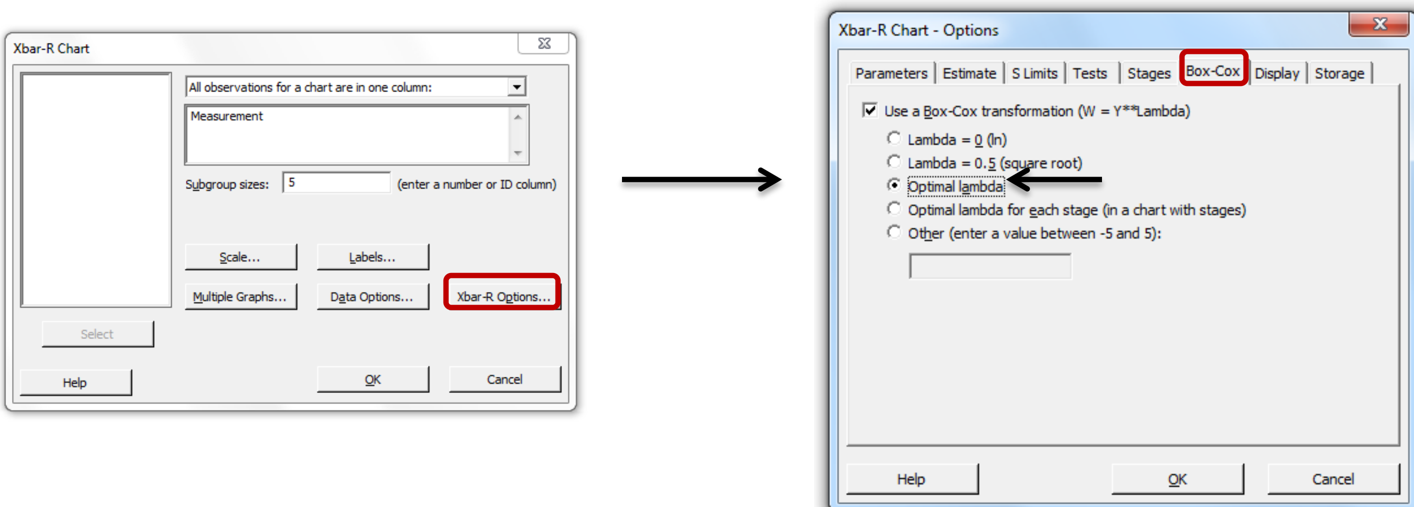
Or, you want to monitor short production runs (frequent product changeover, or, a part going through several processes)

Using stages will allow you to do this. Control limits will be re-evaluated at the beginning of a new stage.

Return to Types of Control Chart

Box-Cox Transformation

- Xbar – R control charts perform well when the data is normally distributed (Why? See bottom of page 5).
- But what if it's not?
  - You can try a Box-Cox Transformation
  - Raises your data points to a power ex. ½ (square root), 2 (squared), etc.
  - Box-Cox can select the "best" power for the data
  - Caution: Box Cox transformations don't always work. If it doesn't try a chart robust for non-normality (see EWMA, for example)



Note: All data must be positive when using the Box-Cox transformation.

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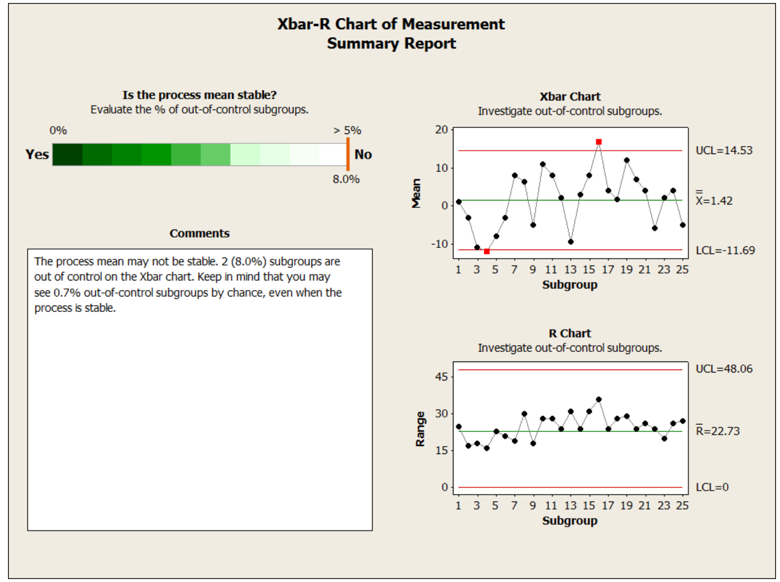
XBAR-R CHART

Remember: Assistant only performs tests 1, 2, and 7 from page 5

Output from Assistant for an Xbar – R Chart



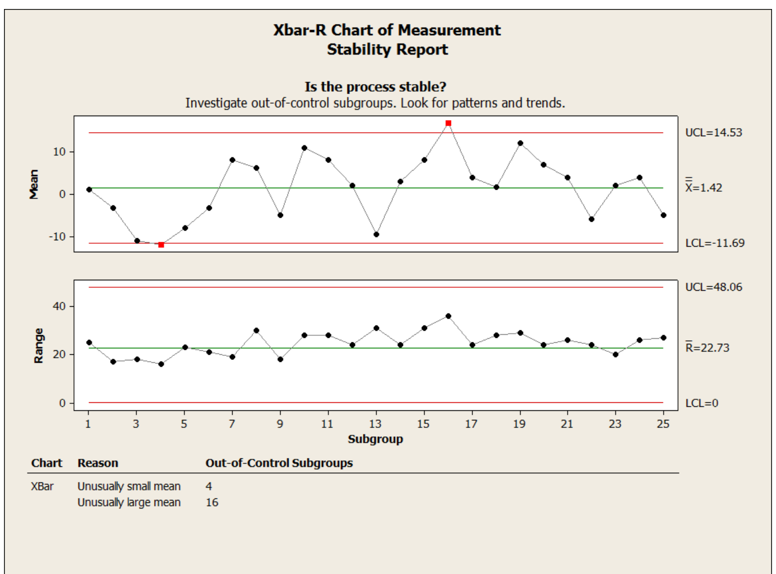
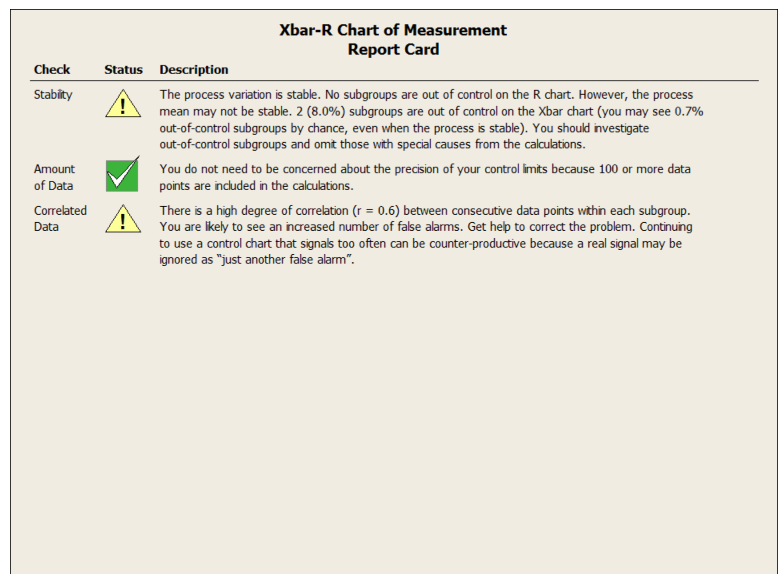


Chart	Reason	Out-of-Control Subgroups
XBar	Unusually small mean	4
	Unusually large mean	16



Xbar-R Chart of Measurement
Report Card

Check	Status	Description
Stability	!	The process variation is stable. No subgroups are out of control on the R chart. However, the process mean may not be stable. 2 (8.0%) subgroups are out of control on the Xbar chart (you may see 0.7% out-of-control subgroups by chance, even when the process is stable). You should investigate out-of-control subgroups and omit those with special causes from the calculations.
Amount of Data	✓	You do not need to be concerned about the precision of your control limits because 100 or more data points are included in the calculations.
Correlated Data	!	There is a high degree of correlation (r = 0.6) between consecutive data points within each subgroup. You are likely to see an increased number of false alarms. Get help to correct the problem. Continuing to use a control chart that signals too often can be counter-productive because a real signal may be ignored as "just another false alarm".

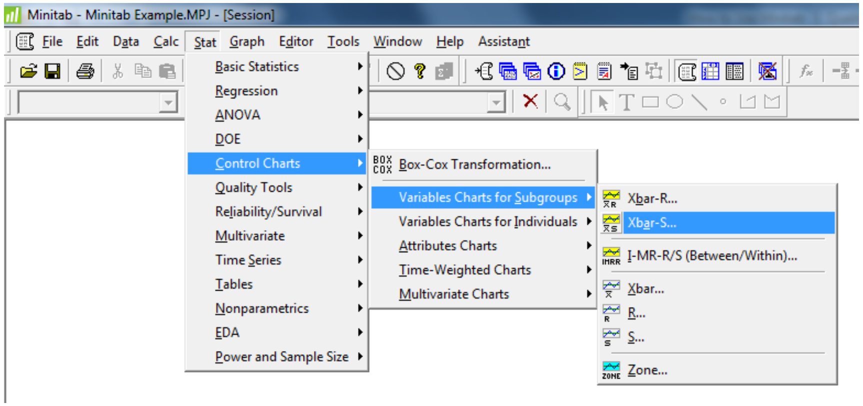
Return to Types of Control Chart

XBAR – S CHART

* Click on the link to jump to that page in the presentation. *

Graphs subgroup means and standard deviation.

More robust than Xbar – R charts. If you can, use this one over Xbar – R



Go through same steps as [Xbar-R chart]

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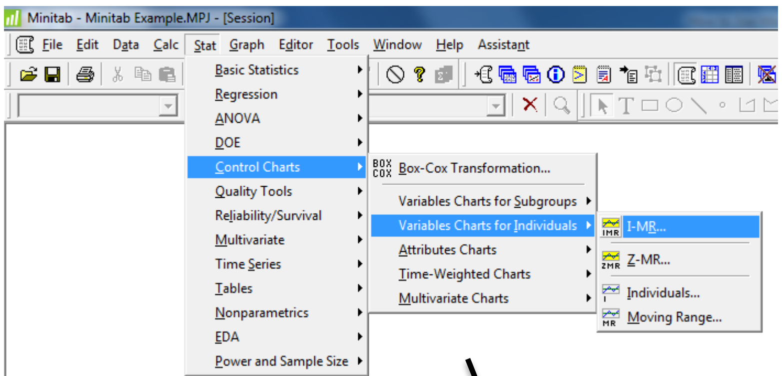
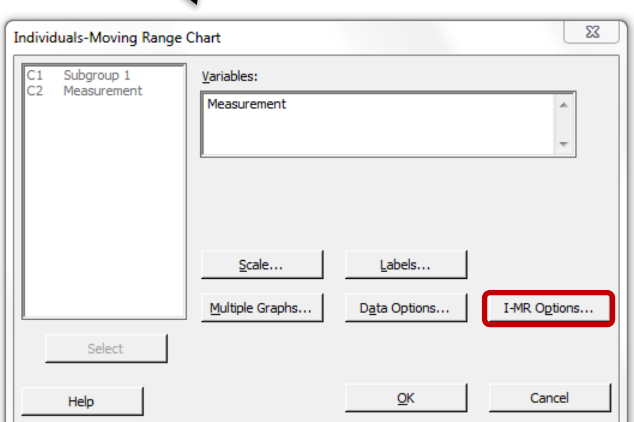
I-MR Chart

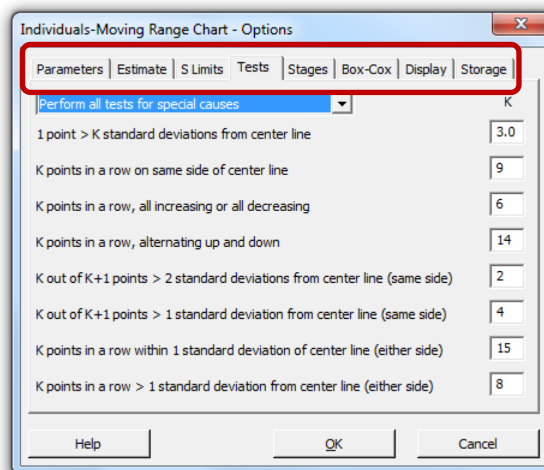
Individuals and Moving Range Chart

Graphs individual data points and the difference between consecutive data points (moving range)



Same options as Xbar – R and Xbar – S charts. Just no option for sample size, because it's automatically = 1





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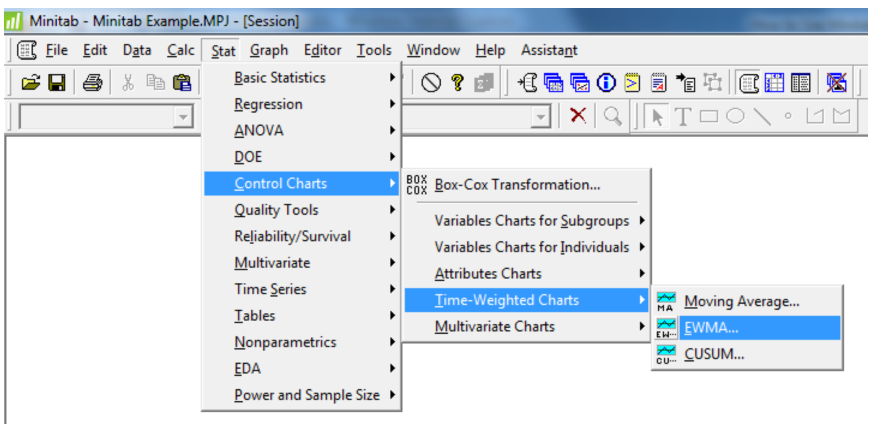
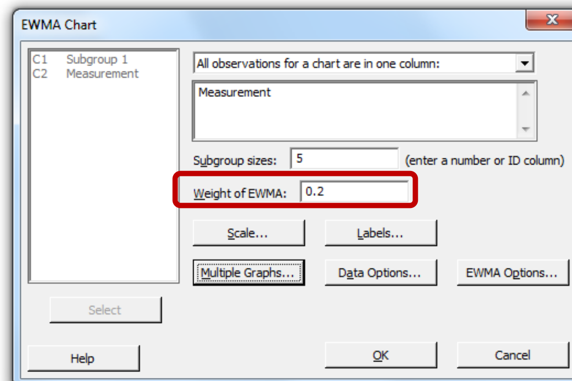
EWMA Chart

Exponentially-Weighted Moving Average Chart

Xbar – R and Xbar – S charts use information from the present sample only.
EWMA charts use both past and present information.

Robust for non-normal data





$$z_i = \lambda \bar{x}_i + (1 - \lambda) z_{i-1}$$

z_i: current EWMA value
λ: EWMA weight
$\bar{x}_i$: current data value (individual value or sample mean)
z_{i-1}: previous EWMA value
$\lambda = 1$ means that the current EWMA value = current data value
(same as a Xbar – R or Xbar – S chart)

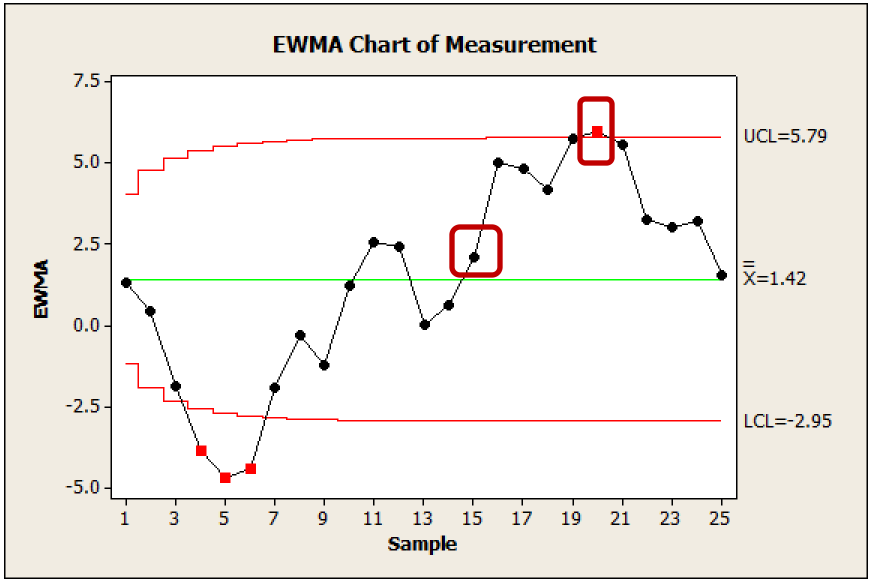
Weight values within (0.05, 0.25) work well.

For 3σ charts, use a weight > 0.1

Return to Types of Control Chart

EWMA Chart

Output:



Only have one chart for EWMA.

Looking mostly at points outside the control limits or trends.

Great for identifying small process shifts

Interpretation:

If a point is above the UCL, scan to the left of that point. Find the last positive point. This is where the process shift began.

ex. In the figure above, sample 20 is an out of control point. Scanning to the left, sample 15 is the last positive point. Thus, the shift began at sample 15.

Return to Types of Control Chart

CUSUM Chart

Cumulative Sum Chart

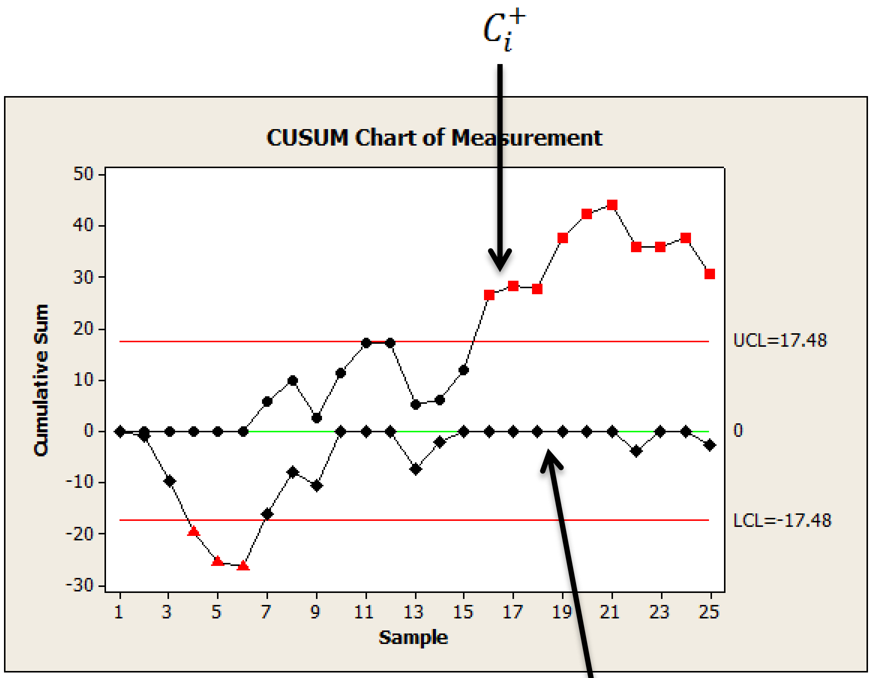
Plots cumulative sums of deviations from a target

$$C_i^+ = \max[0, x_i - (\mu_0 + k) + C_{i-1}^+]$$
$$C_i^- = \max[0, (\mu_0 + k) - x_i + C_{i-1}^-]$$

$$k = \frac{\mu_1 - \mu_0}{2}$$

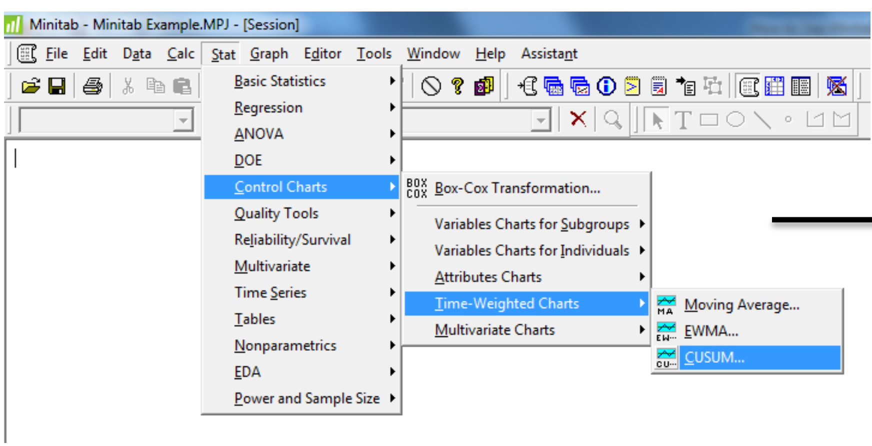
μ_0: a target value

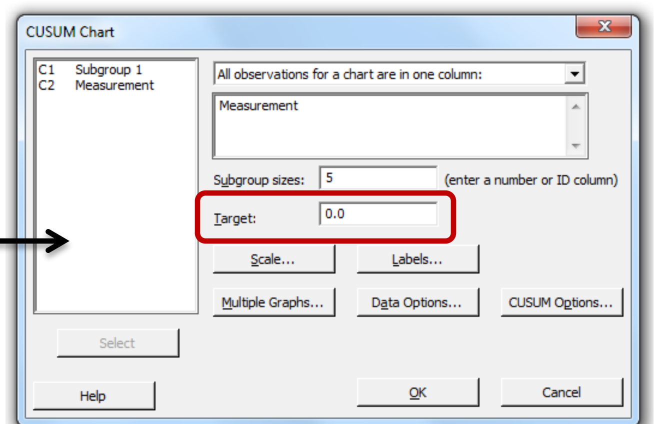
μ_1: the out of control value we wish to detect



C_i^-

Like with EWMA, looking for OOC points or trends





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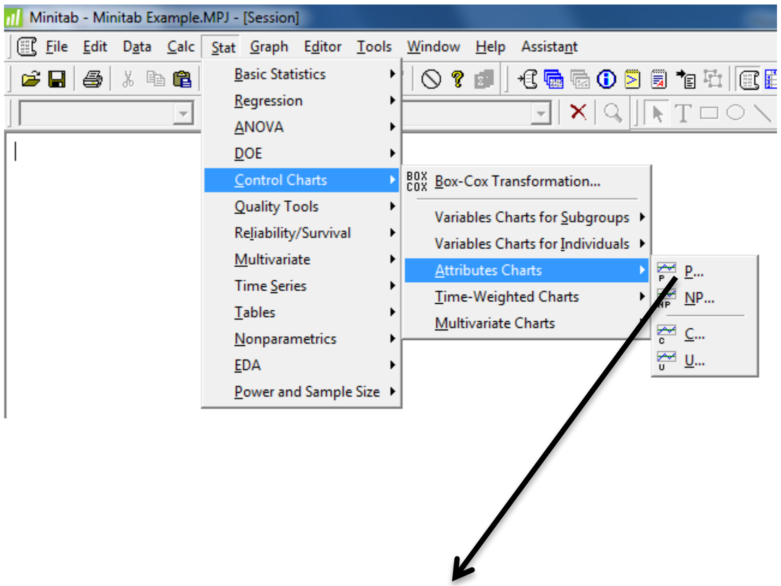
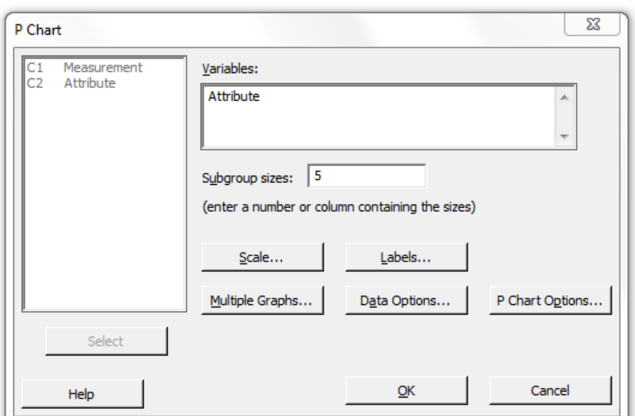
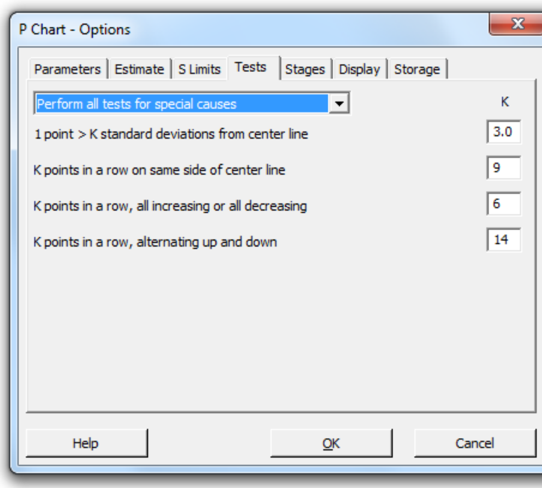
P, C, AND U CHARTS



The previous charts were applicable for "measurement" data.

P, C, and U charts are applicable when you have a count of the # of nonconforming units, # nonconformities on a unit, etc.





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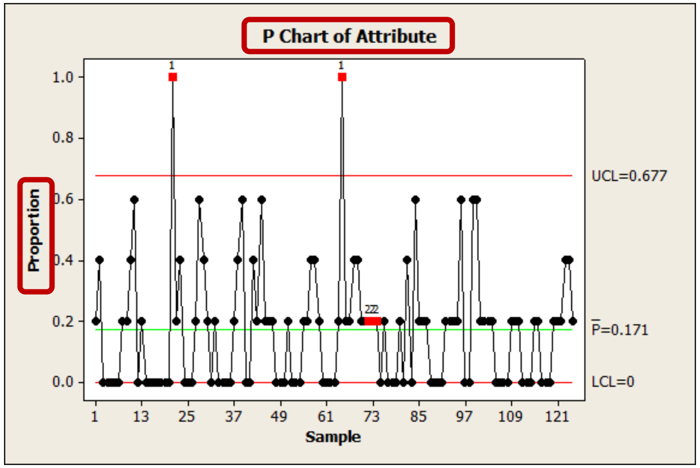
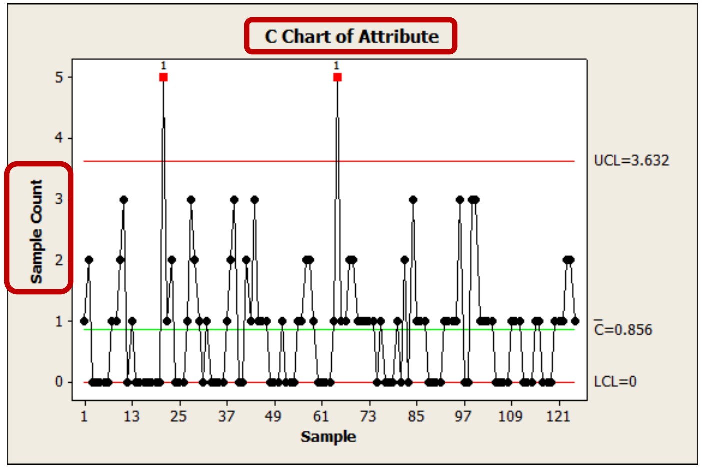
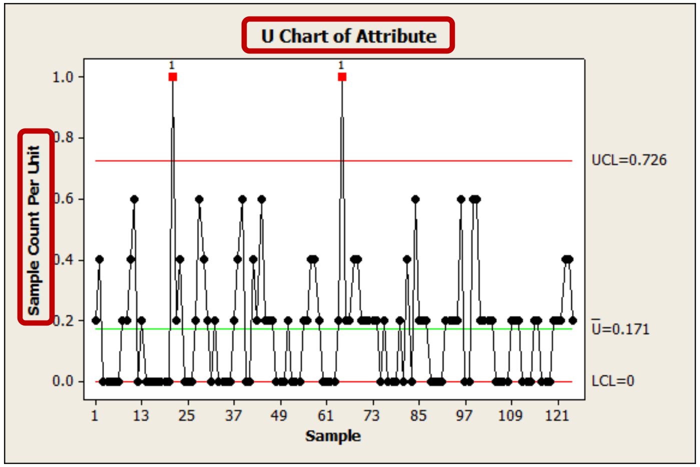
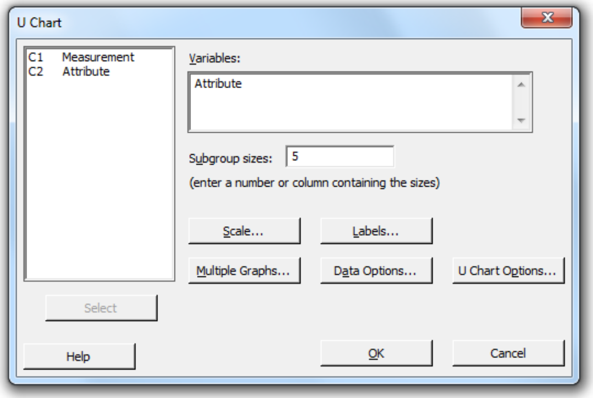
P, C, and U Charts









P Chart	A sample at each time t. Samples can be different sizes	The fraction of non-conforming units p, large process shifts (≥ 1.5σ)
C Chart	Samples that are all the same size	The # of non-conformities in a sample, large process shifts (≥ 1.5σ)
U Chart	Samples that differ in size	The # of non-conformities per unit in a sample, large process shifts (≥ 1.5σ)

Return to Types of Control Chart

T² CHART

T² – Generalized Variance Chart

Used when you have several process variables simultaneously measured on the same process/product

Assume J observations and p variables being monitored
Sample size = 1

1. Find the overall mean = $\bar{\boldsymbol{X}}$
   (a p – dimensional vector, where each entry is the overall mean of that variable)

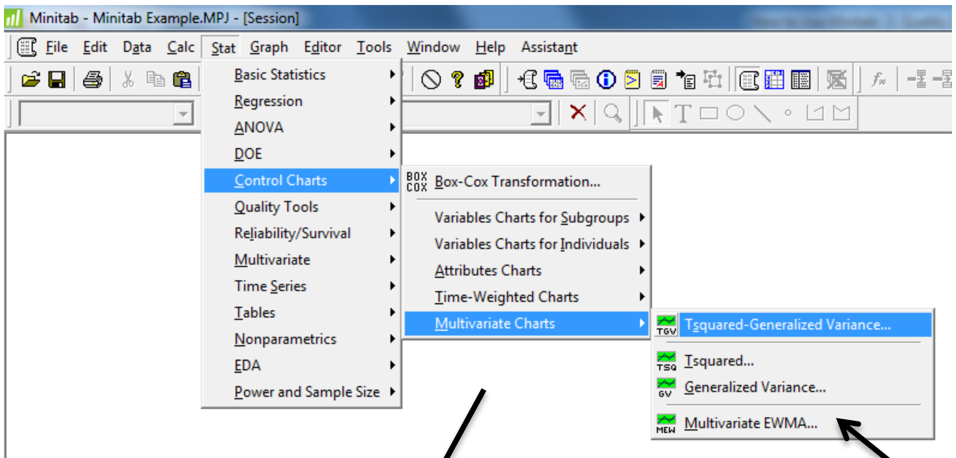
2. Find the variance – covariance matrix (p x p) = $\boldsymbol{S}$
   (estimated variance of each variable is on the diagonal, covariance on off – diagonals)

3. Then, $T_i^2 = (\boldsymbol{X}_i - \bar{\boldsymbol{X}})' \boldsymbol{S}^{-1} (\boldsymbol{X}_i - \bar{\boldsymbol{X}})$

First chart plots T_i^2 versus observation (to monitor process mean)

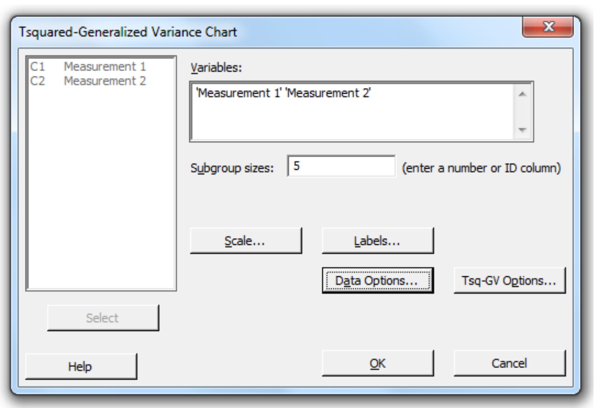
Second chart plots det$|\boldsymbol{S}|$ to (monitor process variation)

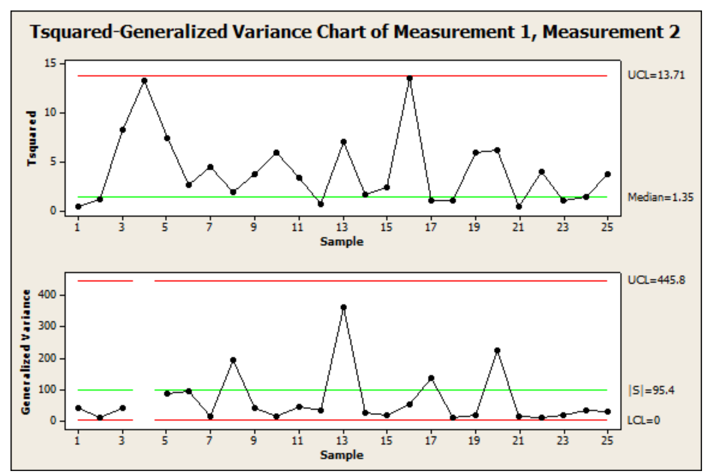
→ Similar process for sample sizes > 1



Can also perform multivariate EWMA

Look for points outside the control limits or trends





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Capability Analysis

- Are products/processes meeting specifications?
  - Can use process capability ratios (PCRs) to determine this

$$C_p = \frac{Upper\ Spec. - Lower\ Spec.}{Natural\ Tolerance\ Range} = \frac{USL - LSL}{6\sigma}$$

Two-sided limits

$$C_{PU} = \frac{USL - \mu}{3\sigma}$$

$$C_{PL} = \frac{\mu - LSL}{3\sigma}$$

One-sided limits

$$C_{PK} = \min\left(C_{PU}\ ,\ C_{PL}\right)$$

These assume your process is centered, and works best for normally distributed data.

$$C_{PM} = \frac{\mathrm{USL} - \mathrm{LSL}}{6\sqrt{\sigma^2 + (\mu - \mathrm{T})^2}}$$

Accounts for a process being off-target. T is the target. Usually, T is the midpoint between USL and LSL

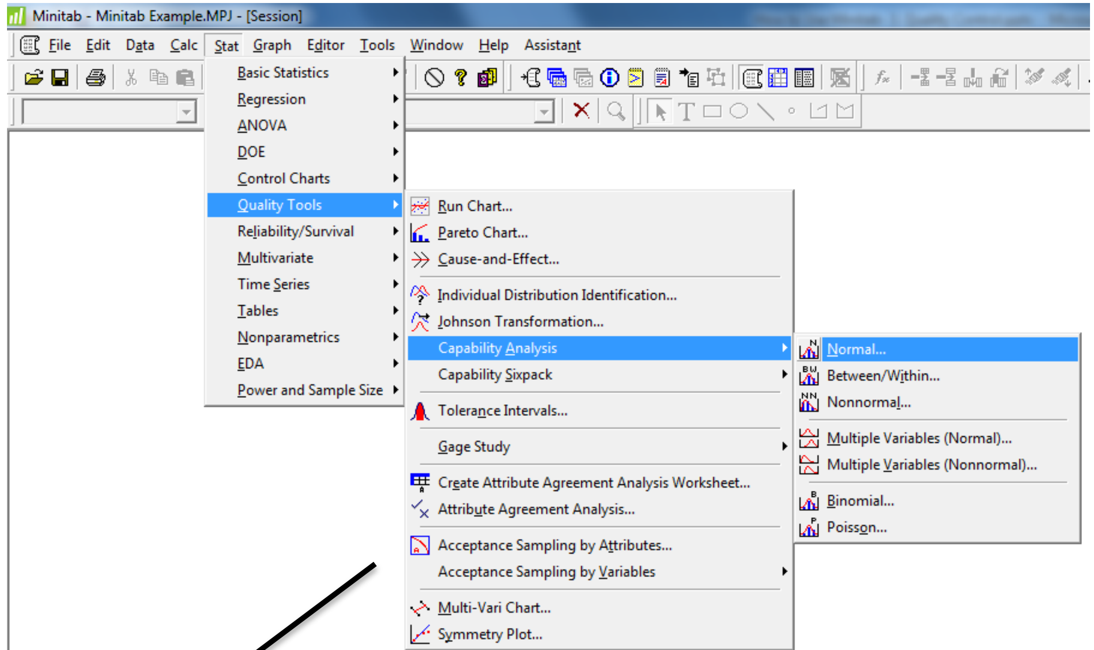
Works best for normally distributed data

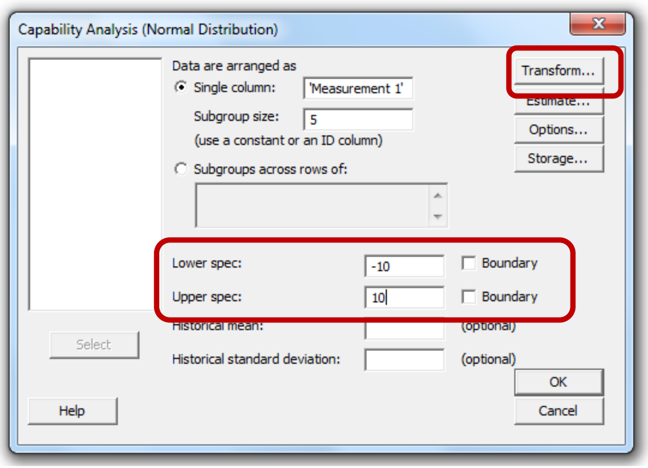
If data not normally distributed, try a Box-Cox transformation.

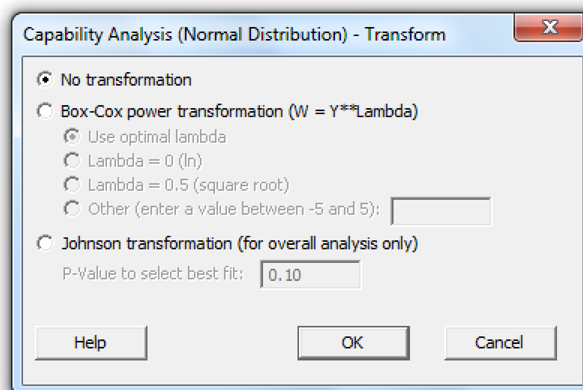
CAPABILITY ANALYSIS

You must specify USL, LSL, or both.

If data not normally distributed, you can use a transformation







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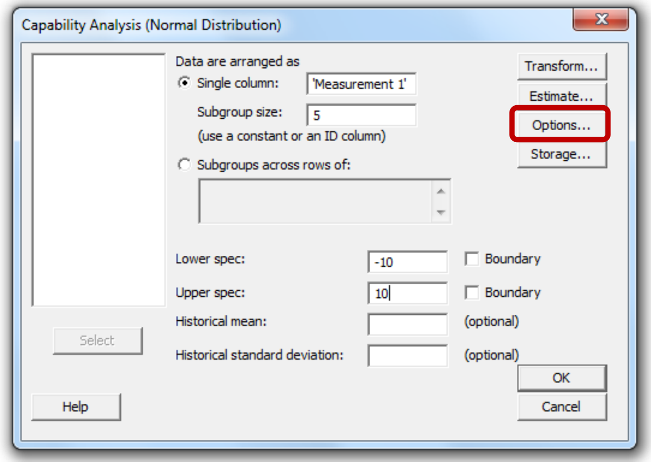
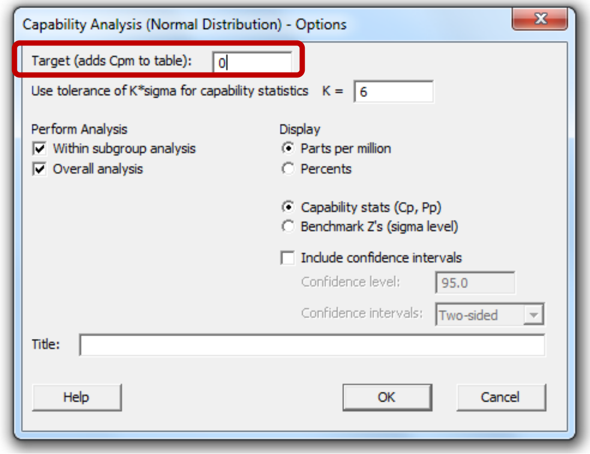
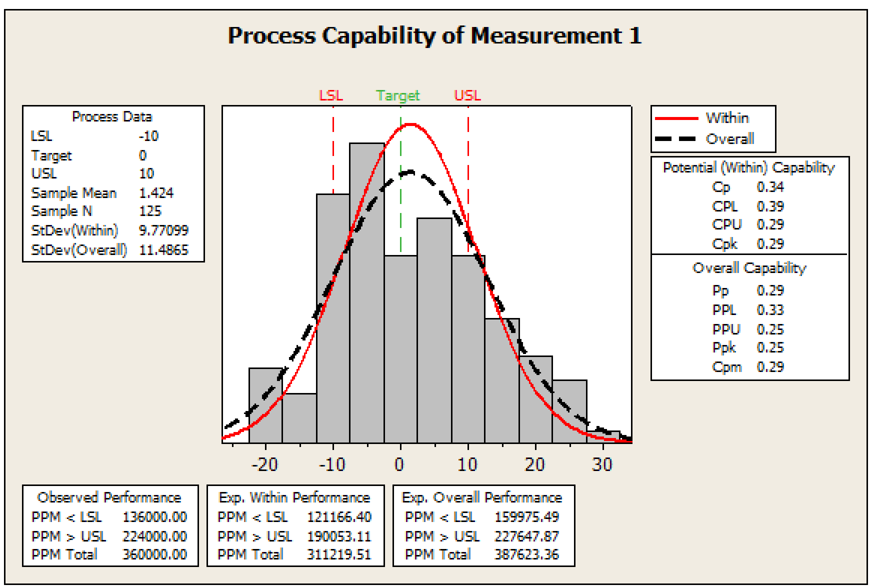
CAPABILITY ANALYSIS

Use "Options" to add a target. Can change the natural tolerance limits, but 6 is most common.







Interpretation:

(two-sided)

$C_P \geq 2$ excellent
$C_P = 1.33$ good
Same for C_{PK} and C_{PM}

(one-sided)

C_{PU} or $C_{PL} = 1.25$ good

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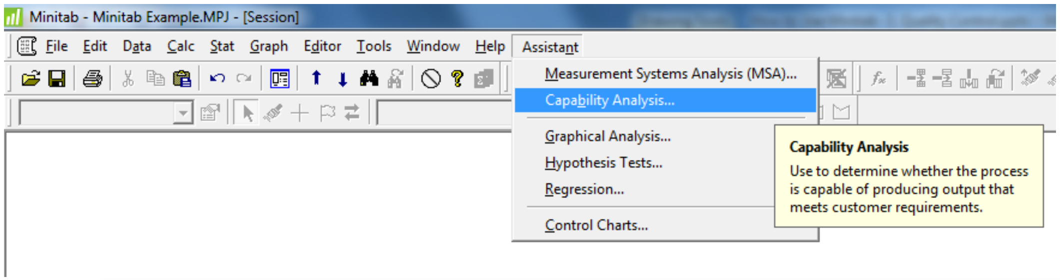
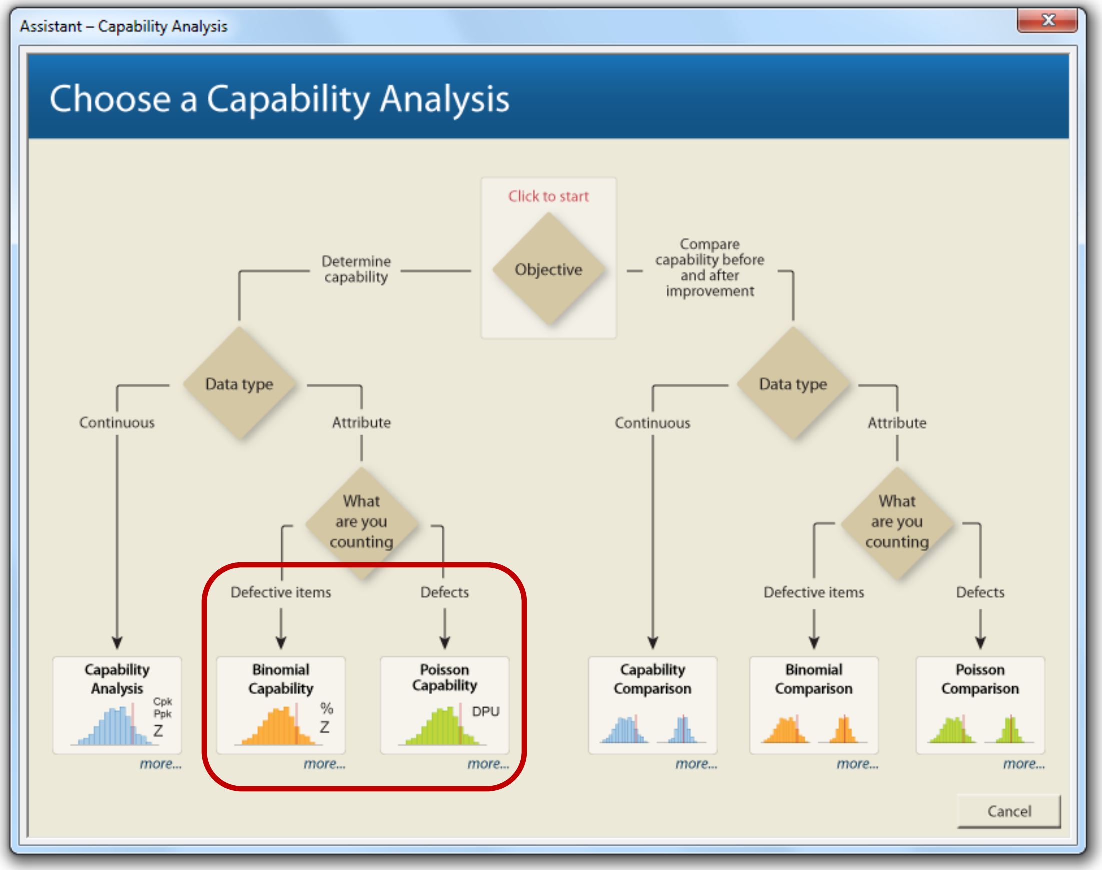
CAPABILITY ANALYSIS



Can also perform capability analysis using Assistant



Use these options with the P, C, and U Charts.

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REFERENCES

- Khan, R. M. (2013). *Problem solving and data analysis using minitab: A clear and easy guide to six sigma methodology* (1st ed.). West Sussex, United Kingdom: Wiley.
- http://en.wikipedia.org/wiki/Control_chart
- http://www.isixsigma.com/tools-templates/control-charts/a-guide-to-control-charts/