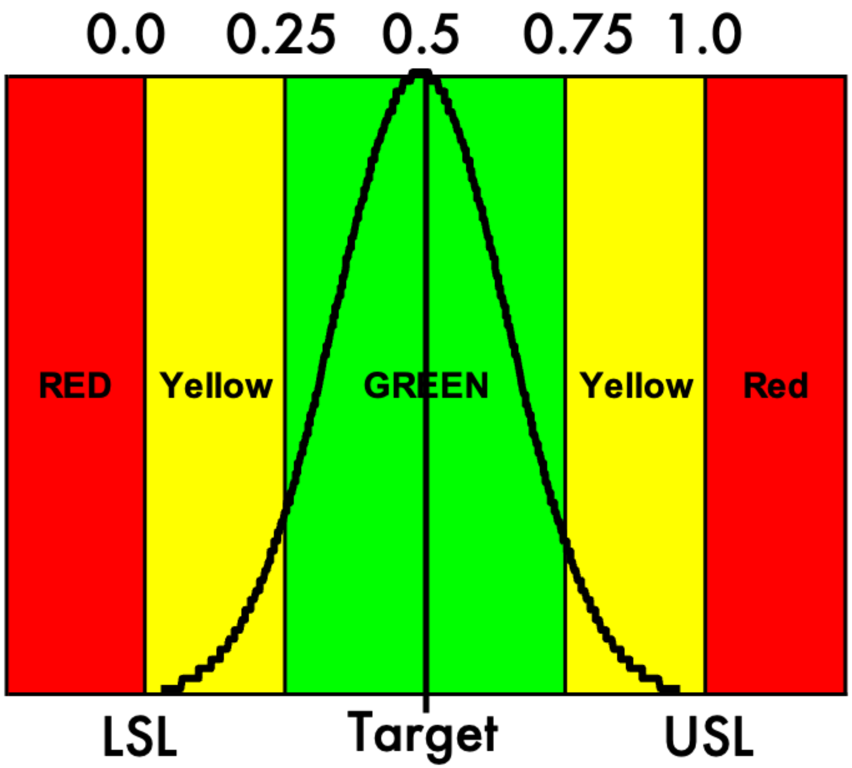
OPEN SOURCE SIX SIGMA

Statistical Process Control



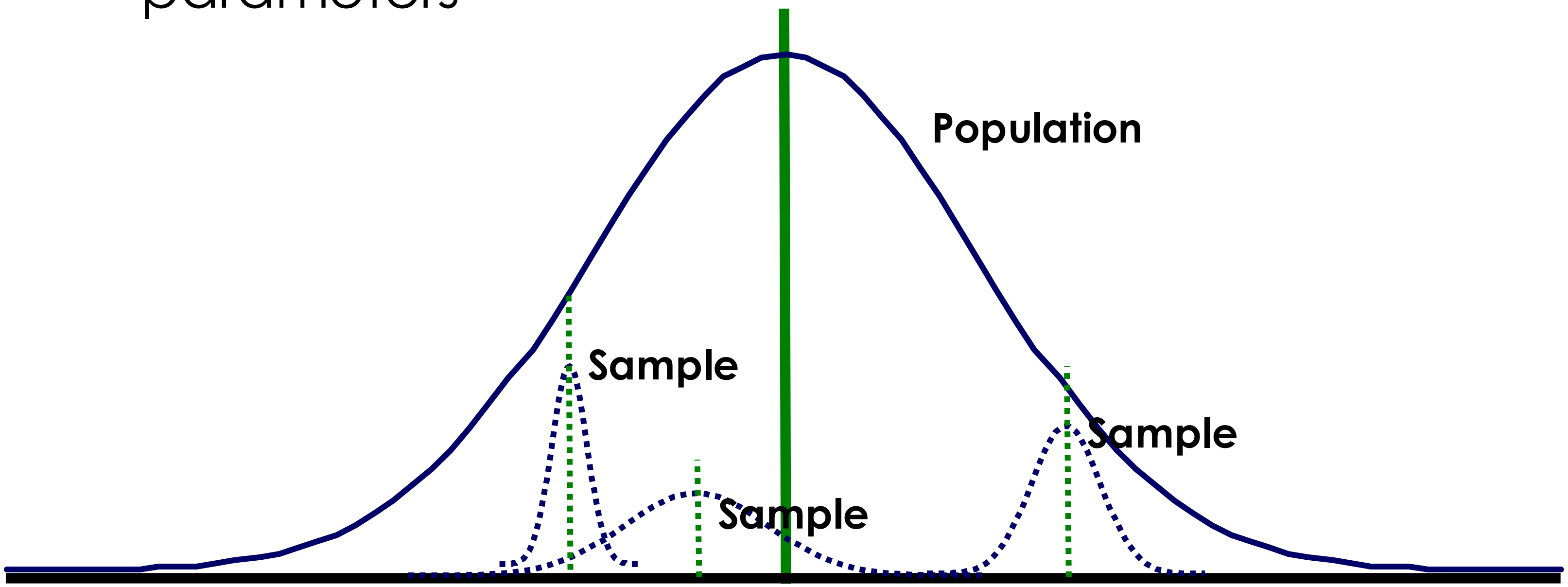
- **Welcome to Control**
- **Lean Controls**
- **Statistical Process Control (SPC)**
  - Elements and Purpose
  - Methodology
  - Special Cause Tests
  - Examples
- **Six Sigma Control Plans**
- **Wrap Up & Action Items**

Population:

- An entire group of objects that have been made or will be made containing a characteristic of interest

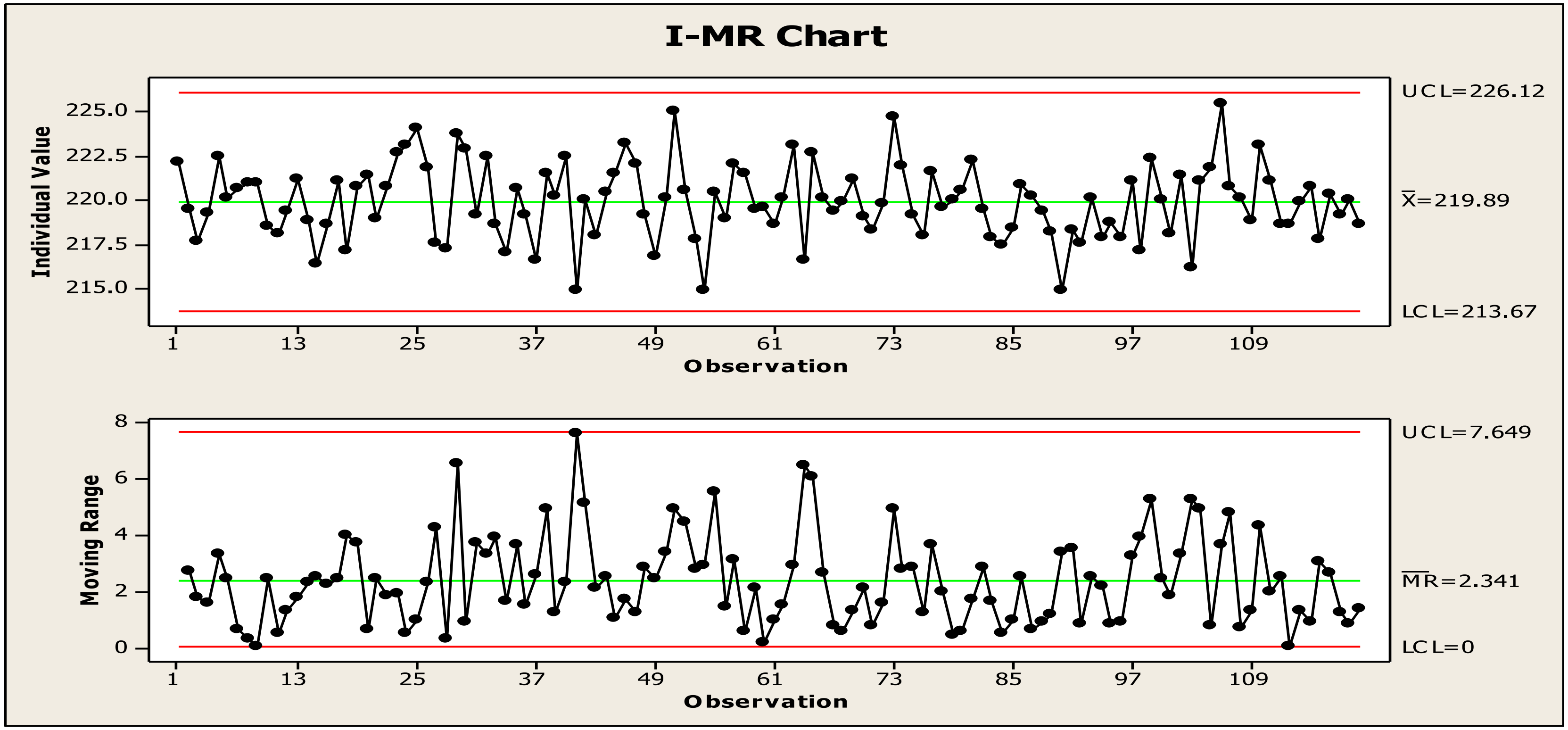
Sample:

- A sample is a subset of the population of interest
- The group of objects actually measured in a statistical study
- Samples are used to estimate the true population parameters



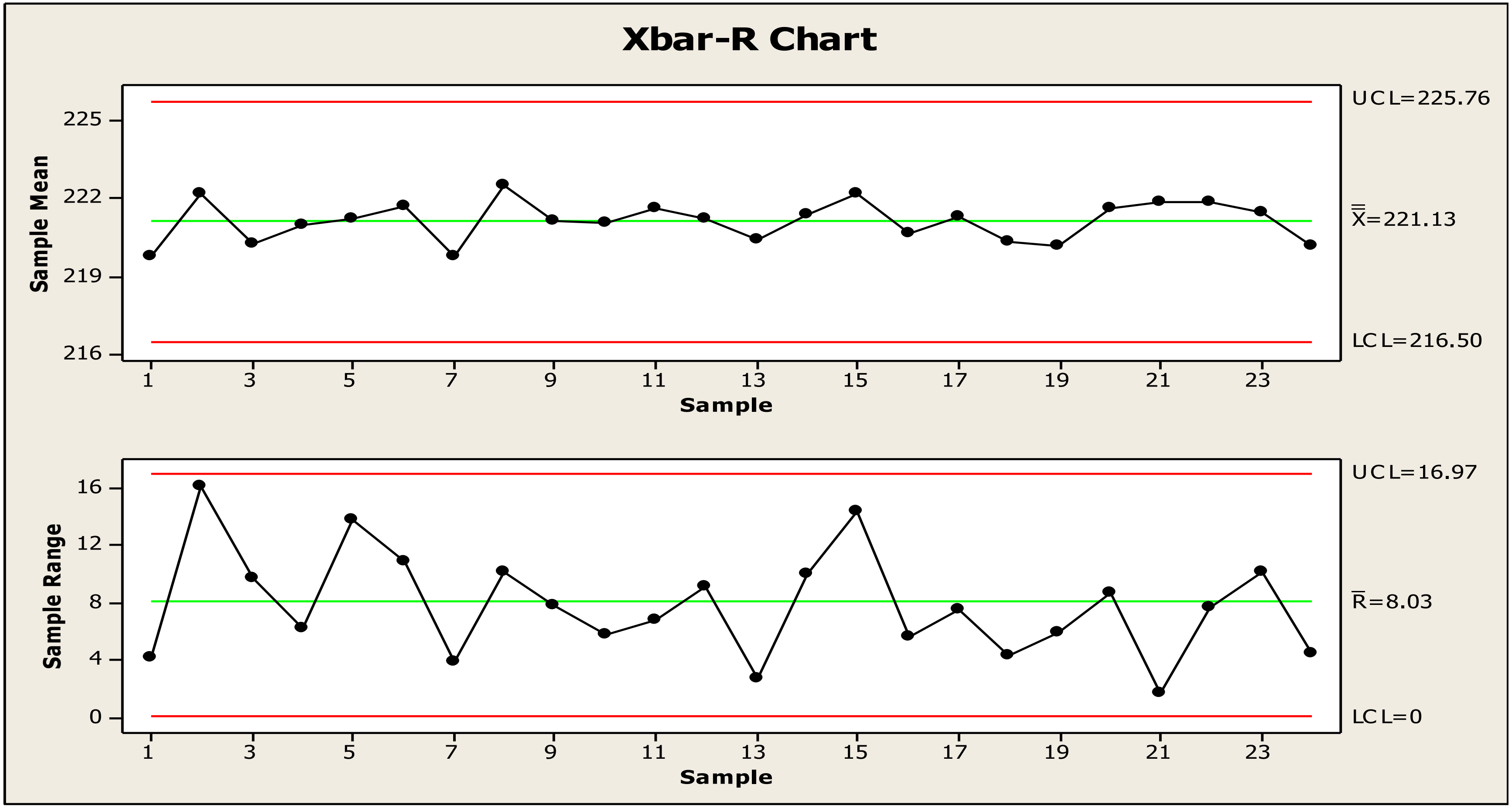
SPC Overview: I-MR Chart

- An I-MR Chart combines a Control Chart of the average moving range with the Individuals Chart.
- You can use Individuals Charts to track the process level and to detect the presence of Special Causes when the sample size is one batch.
- Seeing these charts together allows you to track both the process level and process variation at the same time providing greater sensitivity to help detect the presence of Special Causes.

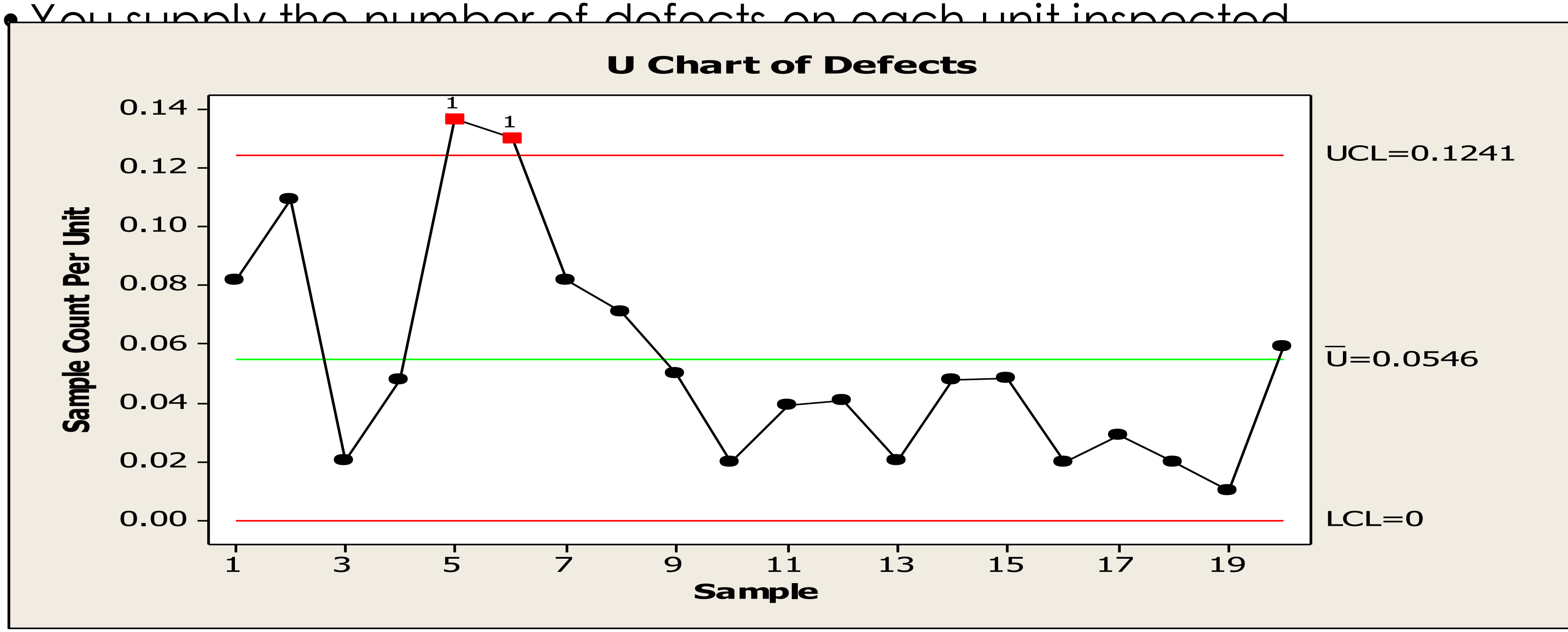


SPC Overview: Xbar-R Chart

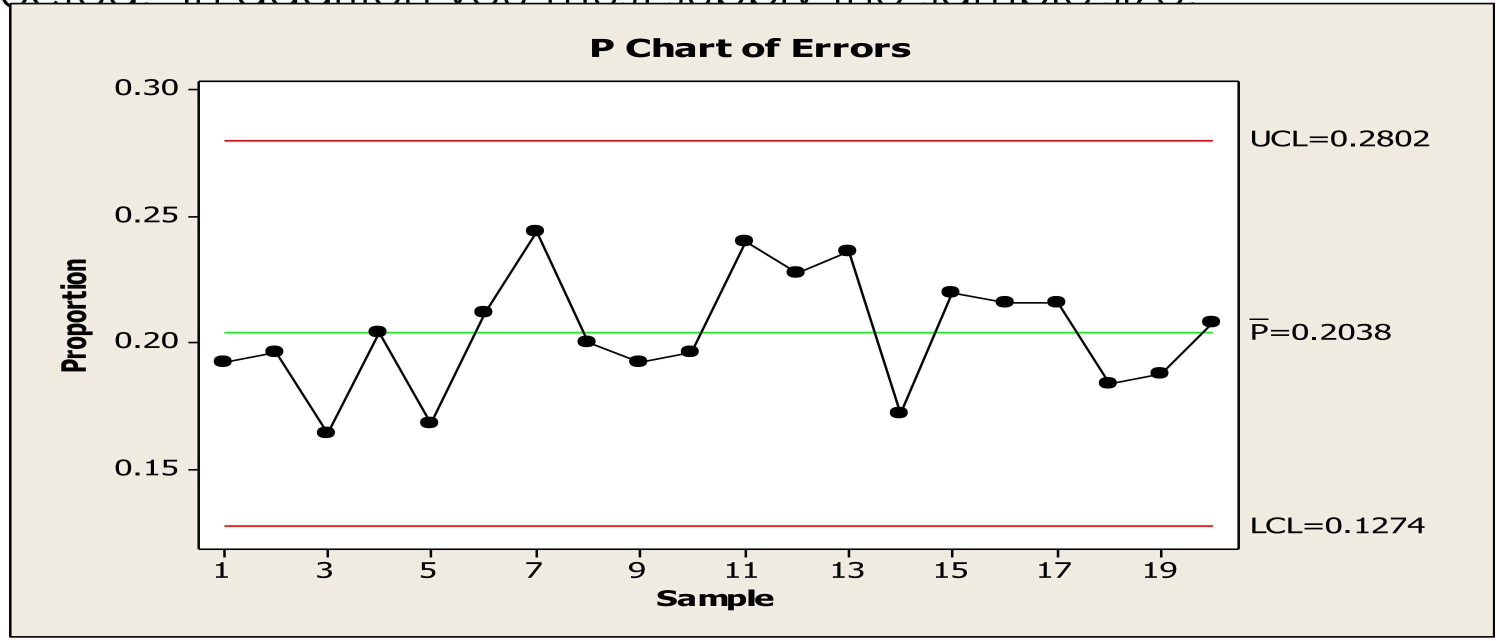
If each of your observations consists of a *subgroup* of data rather than just individual measurements an Xbar-R chart provides greater sensitivity. Failure to form rational subgroups correctly will make your Xbar-R Charts incorrect.



- C Charts and U Charts are for tracking *defects*.
- A U Chart can do everything a C Chart can so we will just learn how to do a U Chart. This chart counts flaws or errors (defects). One “search area” can have more than one flaw or error.
- Search area (unit) can be practically anything we wish to define. We can look for typographical errors per page, the number of paint blemishes on a truck door or the number of bricks a mason drops in a workday.
- You supply the number of defects on each unit inspected.



- NP Charts and P Charts are for tracking *defectives*.
- A P Chart can do everything an NP Chart can so we will just learn how to do a P Chart!
- Used for tracking defectives – the item is either good or bad, pass or fail, accept or reject.
- Center Line is the proportion of "rejects" and is also your Process Capability.
- Input to the P Chart is a series of integers — number bad, number rejected. In addition you must supply the sample size.



SPC Overview: Control Methods/Effectiveness

Type 1 Corrective Action = Countermeasure: improvement made to the process which *will eliminate* the error condition from occurring. The defect will never be created. This is also referred to as a long-term corrective action in the form of Mistake Proofing or design changes.

Type 2 Corrective Action = Flag: improvement made to the process which *will detect* when the error condition has occurred. This flag will shut down the equipment so the defect will not move forward.

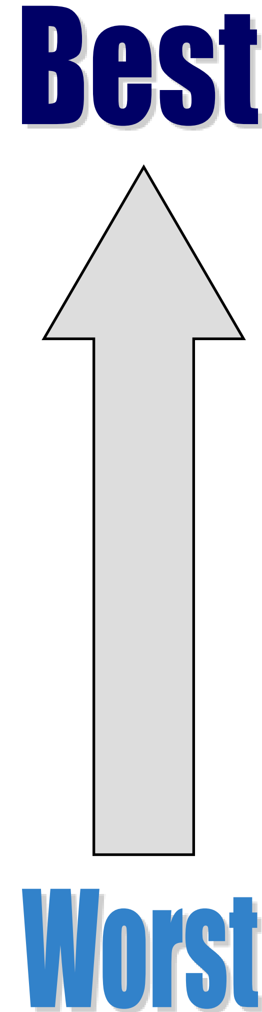
SPC on X's or Y's with fully trained operators and staff who respect the rules. Once a chart signals a problem everyone understands the rules of SPC and agrees to shut down for Special Cause identification. (Cpk > certain level).

Type 3 Corrective Action = Inspection: implementation of a short-term *containment* which is likely to detect the defect caused by the error condition. Containments are typically audits or 100% inspection.

SPC on X's or Y's with fully trained operators. The operators have been trained and understand the rules of SPC, but management will not empower them to stop for investigation.

S.O.P. is implemented to attempt to detect the defects. This action is not sustainable short-term or long-term.

SPC on X's or Y's without proper usage = WALL PAPER.



Every process has Causes of Variation known as:

- ***Common Cause:*** **Natural variability**
- ***Special Cause:*** **Unnatural variability**
    - **Assignable: Reason for detected Variability**
    - **Pattern Change: Presence of trend or unusual pattern**

SPC is a basic tool to monitor variation in a process.

SPC is used to detect Special Cause variation telling us the process is "out of control"… but does NOT tell us why.

SPC gives a glimpse of ongoing process capability AND is a visual management tool.

Not this special cause!!

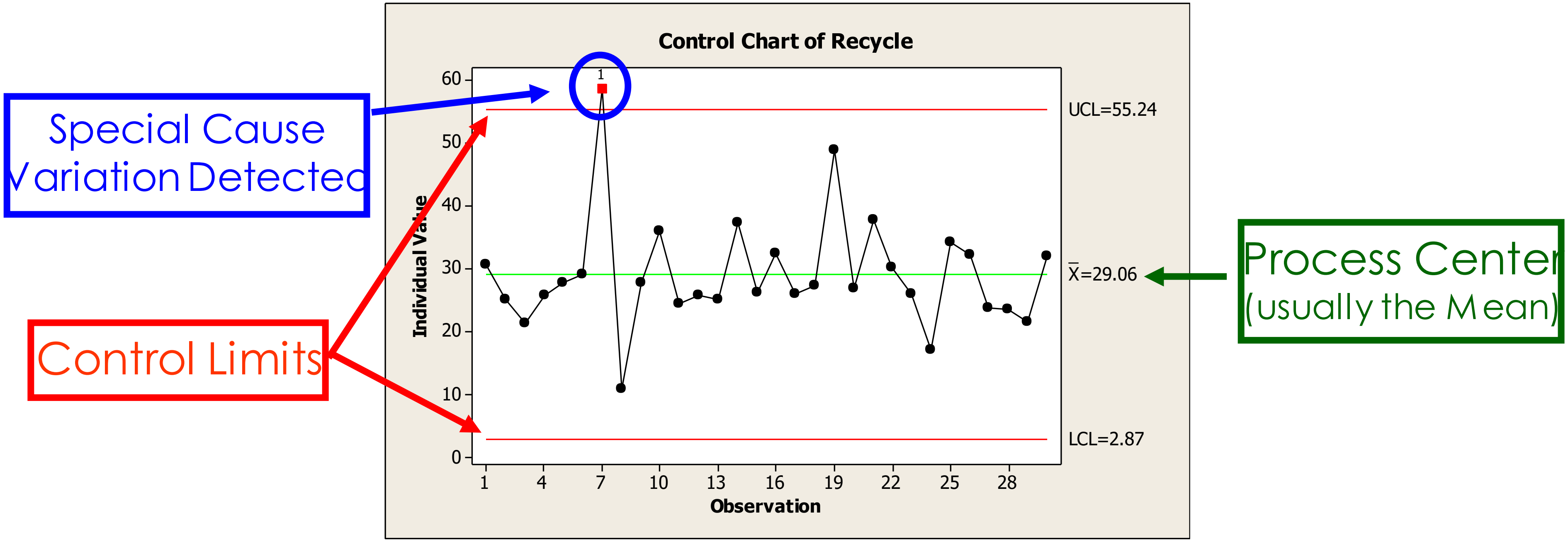
Developed by Dr Walter A. Shewhart of Bell Laboratories from 1924.

Graphical and visual plot of changes in the data over time.

- This is necessary for visual management of your process.

Control Charts were designed as a methodology for indicating change in performance, either variation or Mean/Median.

Charts have a Central Line and Control Limits to detect Special Cause variation.



Understanding the Power of SPC

Control Charts indicate when a process is "out of control" or exhibiting Special Cause variation but NOT why!

SPC Charts incorporate upper and lower Control Limits.

- **The limits are typically +/- 3 σ from the Center Line.**
- **These limits represent 99.73% of natural variability for Normal Distributions.**

SPC Charts allow workers and supervision to maintain improved process performance from Lean Six Sigma projects.

Use of SPC Charts can be applied to all processes.

- **Services, manufacturing and retail are just a few industries with SPC applications.**
- **Caution must be taken with use of SPC for Non-normal processes.**

Control Limits describe the process variability and are unrelated to customer specifications. (Voice of the Process instead of Voice of the Customer)

- **An undesirable situation is having Control Limits wider than customer specification limits. This will exist for poorly performing processes with a Cp less than 1.0**

Many SPC Charts exist and selection must be appropriate for effectiveness.

General Steps for Constructing Control Charts

1. Select characteristic (Critical "X" or CTQ) to be charted.
2. Determine the purpose of the chart.
3. Select data-collection points.
4. Establish the basis for sub-grouping (only for Y's).
5. Select the type of Control Chart.
6. Determine the measurement method/criteria.
7. Establish the sampling interval/frequency.
8. Determine the sample size.
9. Establish the basis of calculating the Control Limits.
10. Set up the forms or software for charting data.
11. Set up the forms or software for collecting data.
12. Prepare written instructions for all phases.
13. Conduct the necessary training.

Stirred or Shaken?

Focus of Six Sigma and the Use of SPC

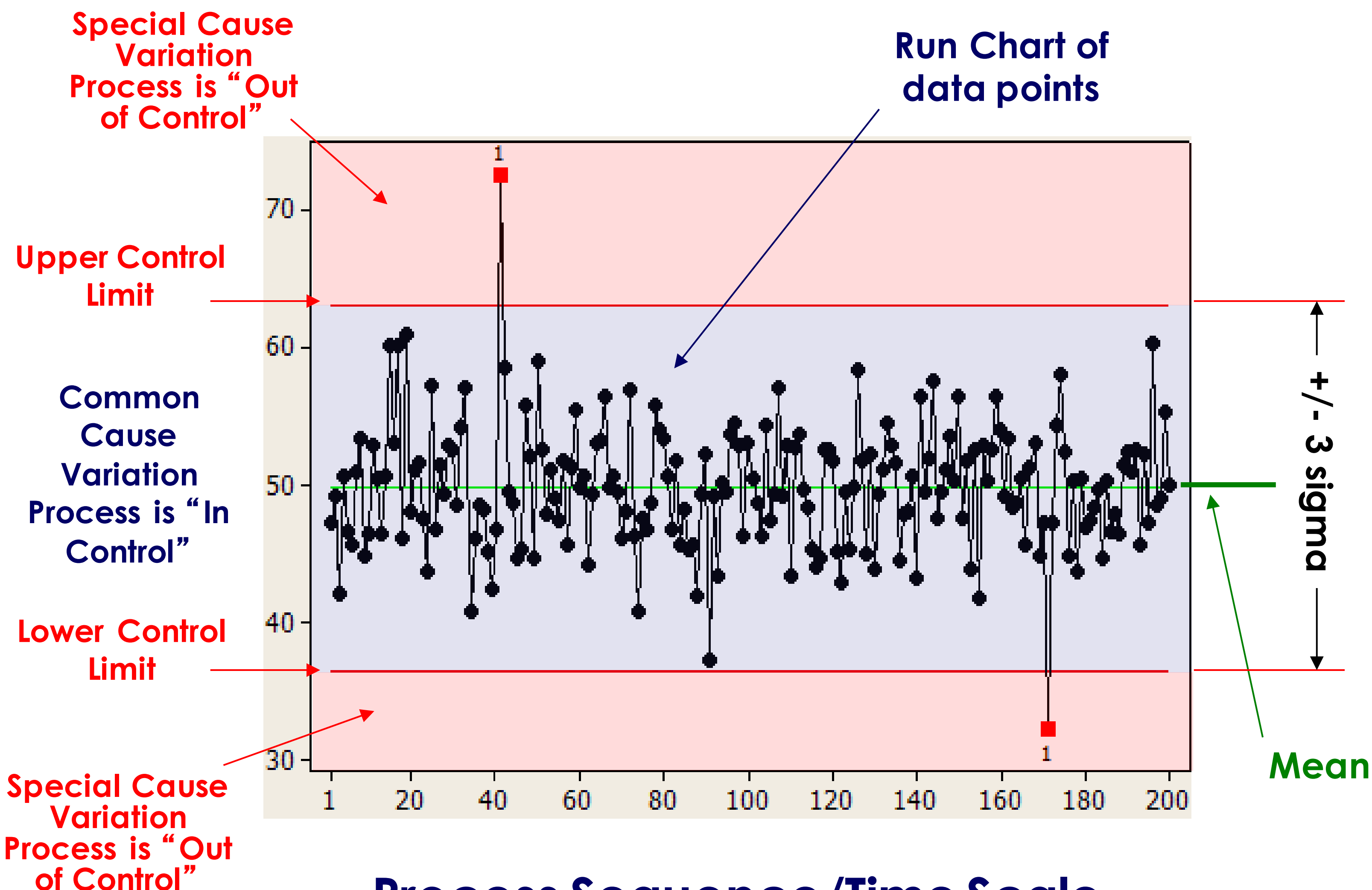
Y = *f*(x)

To get results should we focus our behavior on the Y or X?

Y	$X_1 \ldots X_N$
Dependent	Independent
Output	Input
Effect	Cause
Symptom	Problem
Monitor	Control

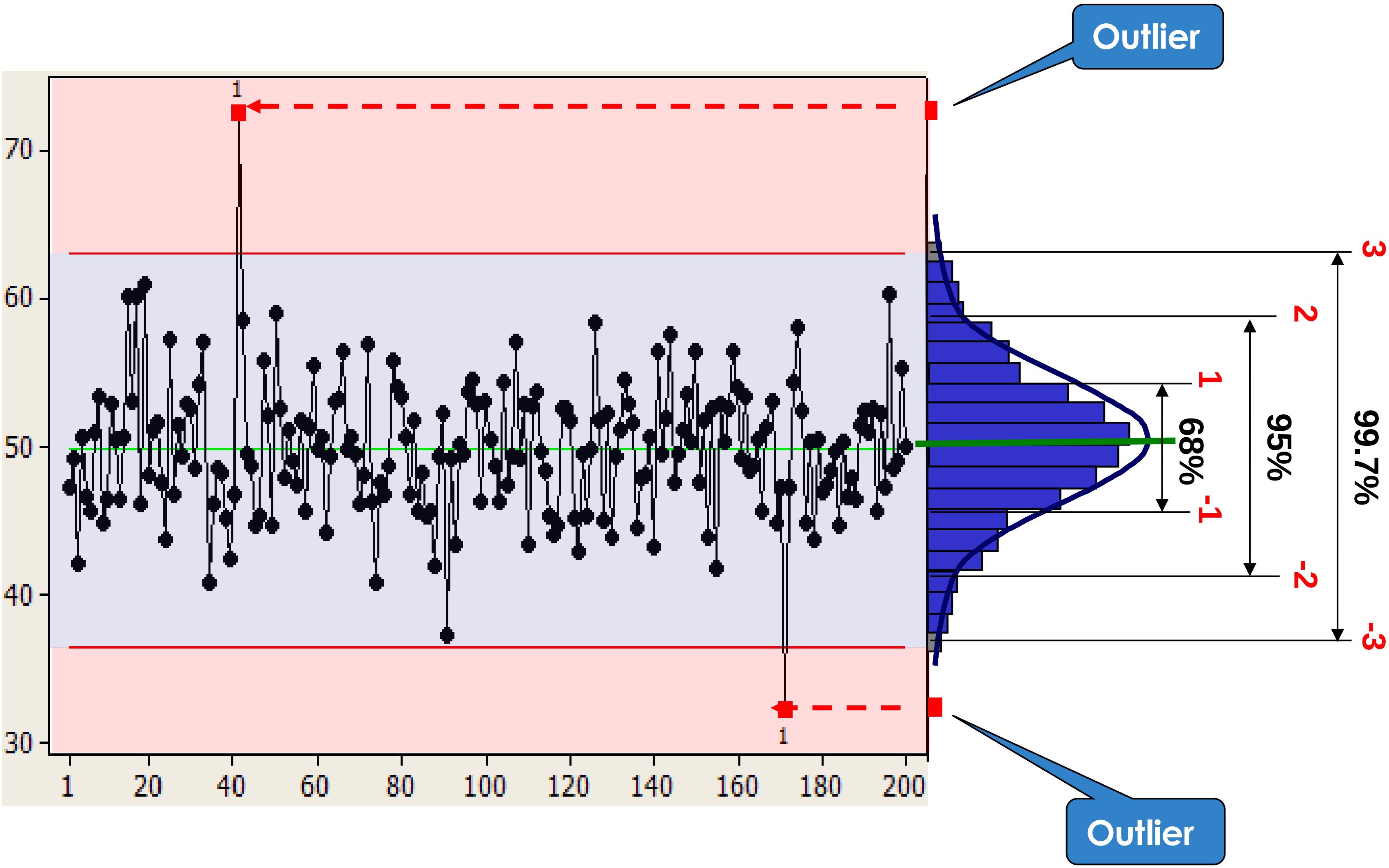
When we find the "vital few" X's first consider using SPC on the X's to achieve

Control Chart Anatomy



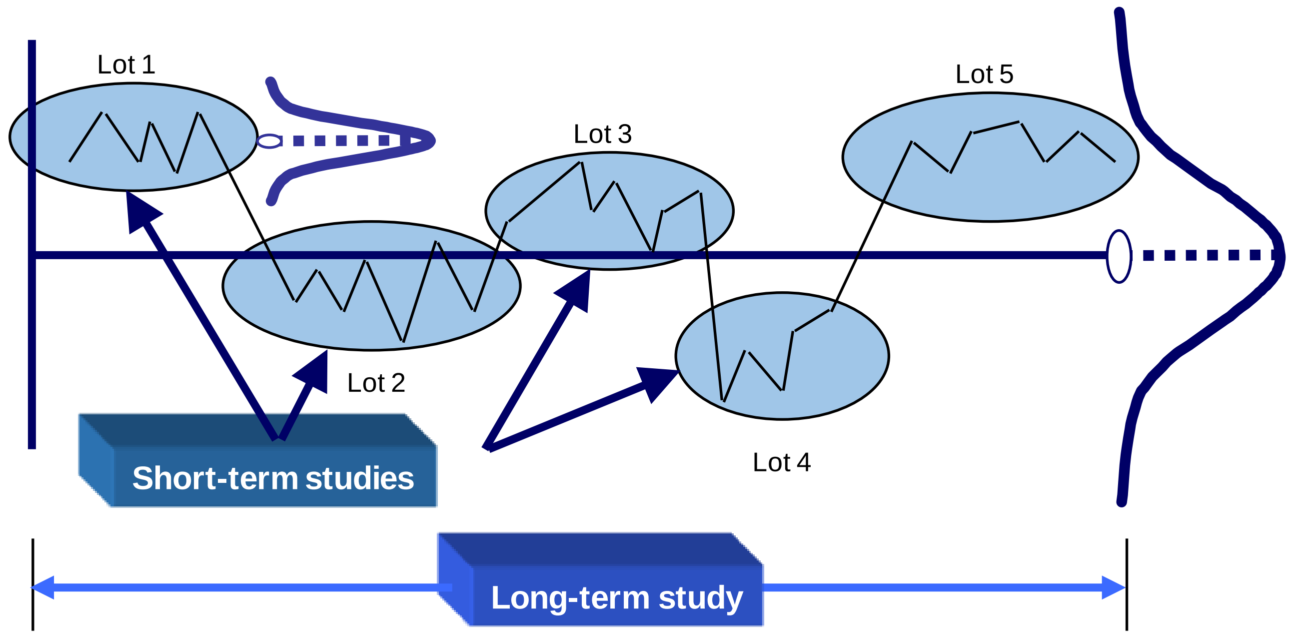
Process Sequence/Time Scale

Control and Out of Control



Typical subgroup sizes are 3-12 for variable data:

- If difficulty of gathering sample or expense of testing exists the size, n, is smaller.
- 3, 5 and 10 are the most common size of subgroups because of ease of calculations when SPC is done without computers.

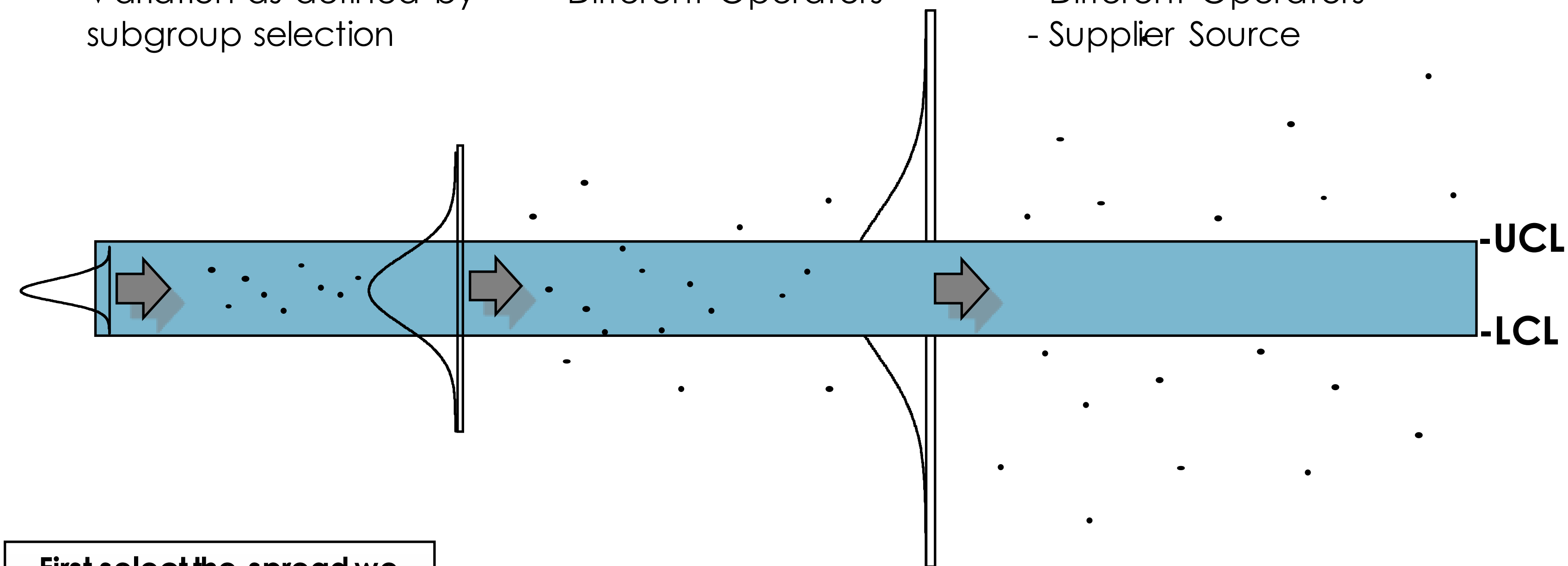


Sources of Variation

- Natural Process Variation as defined by subgroup selection

- Natural Process Variation
- Different Operators

- Natural Process Variation
- Different Operators
- Supplier Source



First select the spread we will declare as the "Natural Process Variation" so whenever any point lands outside these "Control Limits" an alarm will sound

So when a second source of variation appears we will know!

And, of course, if <u>two</u> additional sources of variation arrive we will detect that too!

If you base your limits on all <u>three</u> sources of variation, what will sound the alarm?

Frequency of Sampling

Sampling Frequency **is a balance between the cost of sampling and testing versus the cost of not detecting shifts in Mean or variation.**

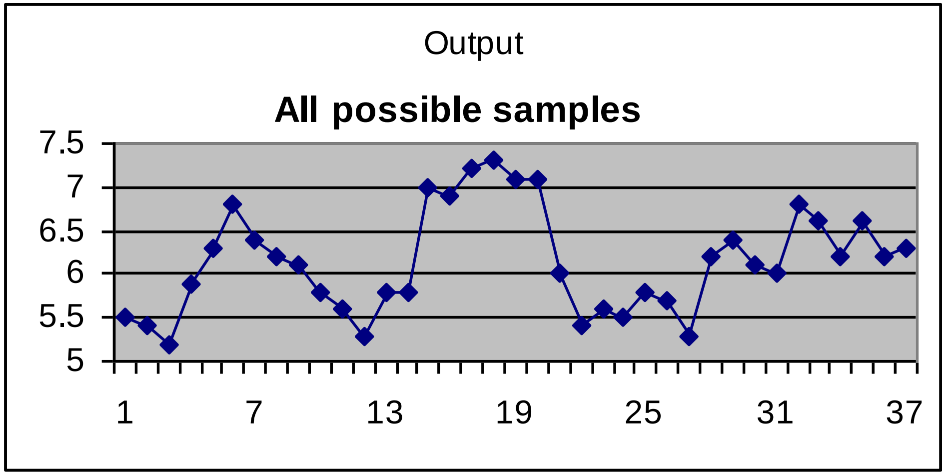
Process knowledge is an input to frequency of samples after the subgroup size has been decided.

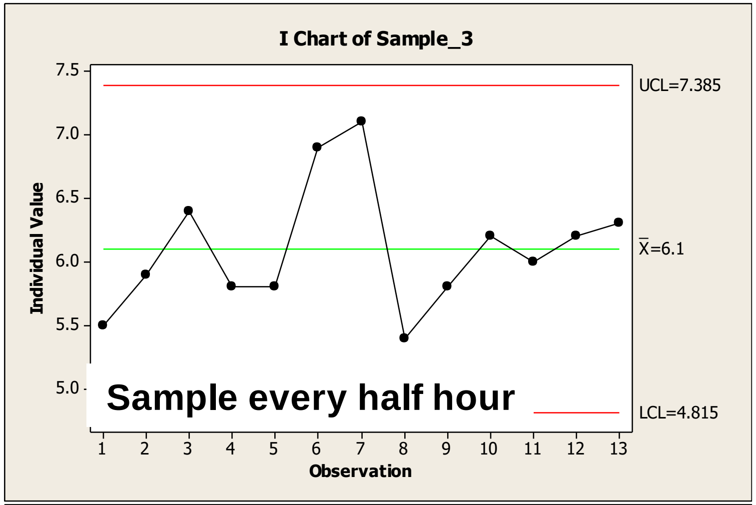
- **If a process shifts but cannot be detected because of too infrequent sampling the customer suffers**
- **If a choice is given between a large subgroup of samples infrequently or smaller subgroups more frequently most choose to get information more frequently.**
- **In some processes with automated sampling and testing frequent sampling is easy.**

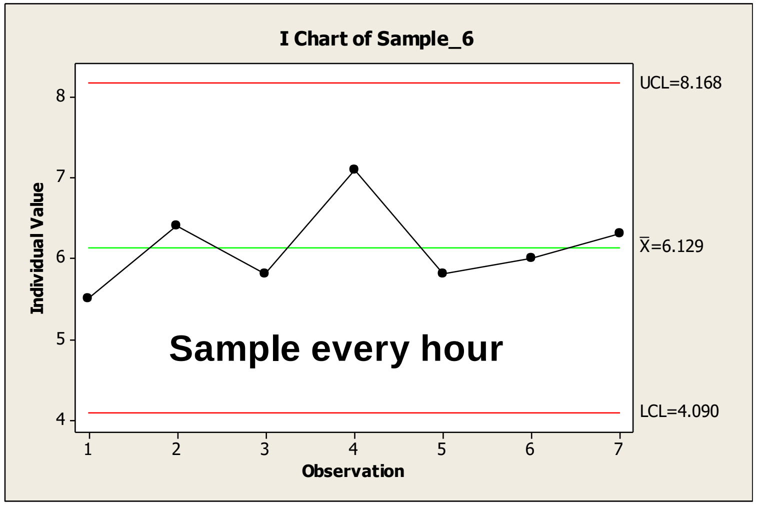
If undecided as to sample frequency, sample more frequently to confirm detection of process shifts and reduce frequency if process variation is still detectable.

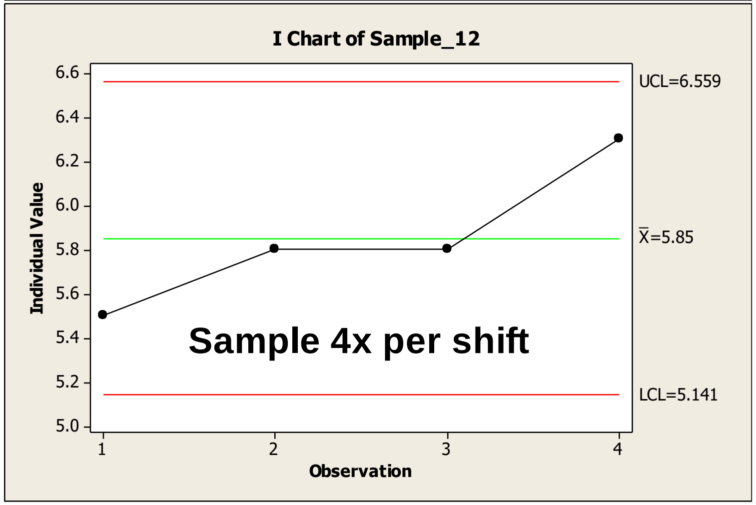
A rule of thumb also states "sample a process at least 10 times more frequent than the frequency of 'out of control' conditions".

Sampling too little will not allow for sufficient detection of shifts in the process because of Special Causes.

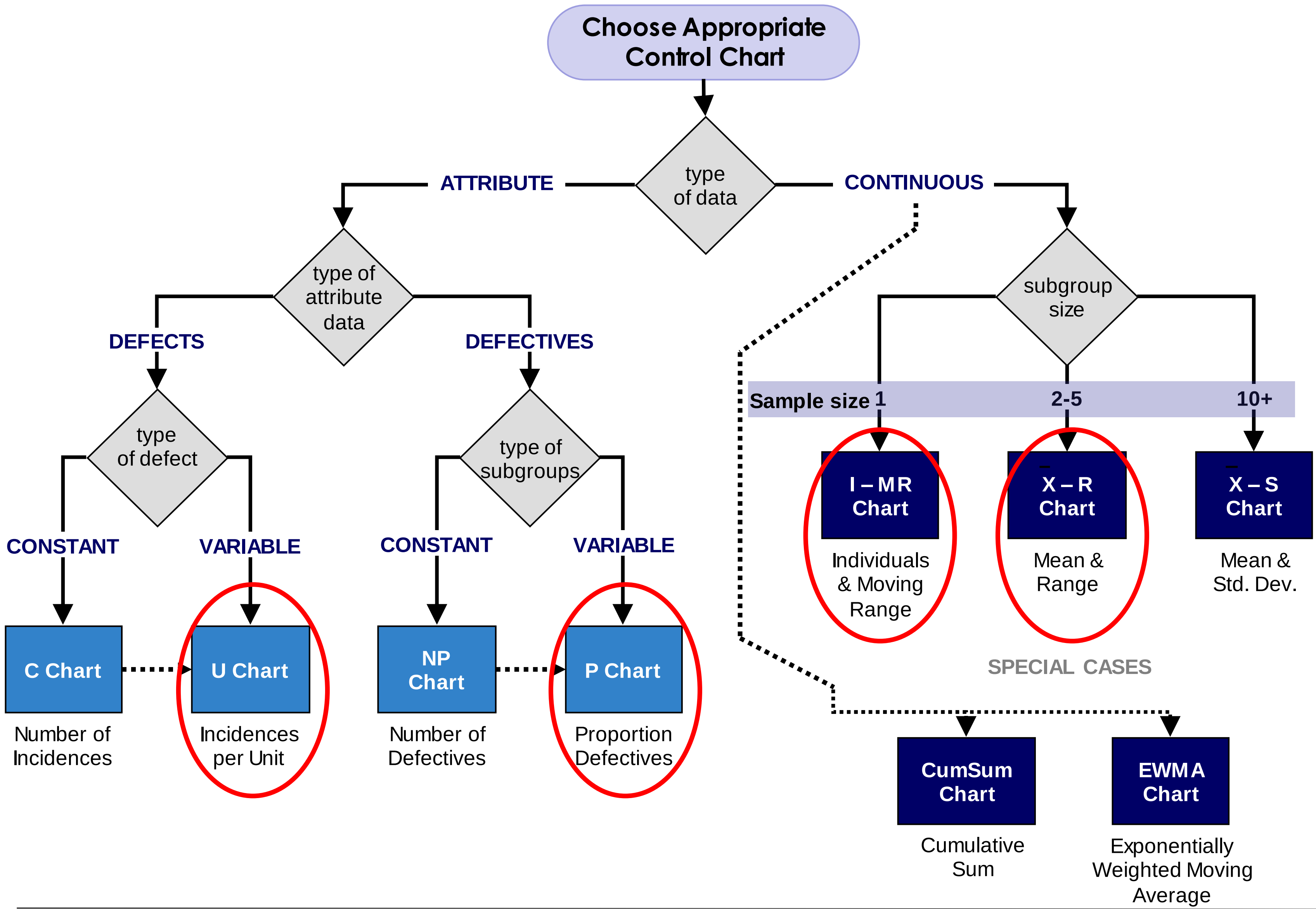








SPC Selection Process



Understanding Variable Control Chart Selection

Type of Chart	When do you need it?
Average & Range or S (Xbar and R or Xbar and S)	Production is higher volume; allows process Mean and variability to be viewed and assessed together; more sampling than with Individuals Chart (I) and Moving Range Charts (MR) but when subgroups are desired. Outliers can cause issues with Range (R) charts so Standard Deviation charts (S) used instead if concerned.
Most Common	
Individual and Moving Range	Production is low volume or cycle time to build product is long or homogeneous sample represents entire product (batch etc.); sampling and testing is costly so subgroups are not desired. Control limits are wider than Xbar Charts. Used for SPC on most inputs.
Pre-Control	Set-up is critical, or cost of setup scrap is high. Use for outputs
Exponentially Weighted Moving Average	Small shift needs to be detected often because of autocorrelation of the output results. Used only for individuals or averages of Outputs. Infrequently used because of calculation complexity.
Cumulative Sum	Same reasons as EWMA (Exponentially Weighted Moving Range) except the past data is as important as present data.
Less Common	

Understanding Attribute Control Chart Selection

Type of Chart	When do you need it?
P	Need to track the fraction of defective units; sample size is variable and usually > 50
nP	When you want to track the number of defective units per subgroup; sample size is usually constant and usually > 50
C	When you want to track the number of defects per subgroup of units produced; sample size is constant
U	When you want to track the number of defects per unit; sample size is variable

Detection of Assignable Causes or Patterns

Control Charts indicate Special Causes being either assignable causes or patterns.

The following rules are applicable for both variable and Attribute Data to detect Special Causes.

These four rules are the only applicable tests for Range (R), Moving Range (MR) or Standard Deviation (S) charts.

- **One point more than 3 Standard Deviations from the Center Line.**
- **6 points in a row all either increasing or all decreasing.**
- **14 points in a row alternating up and down.**
- **9 points in a row on the same side of the center line.**

These remaining four rules are only for variable data to detect Special Causes.

- **2 out of 3 points greater than 2 Standard Deviations from the Center Line on the same side.**
- **4 out of 5 points greater than 1 Standard Deviation from the Center Line on the same side.**
- **15 points in a row all within one Standard Deviation of either side of the Center Line.**
- **8 points in a row all greater than one Standard Deviation of either side of the Center Line.**

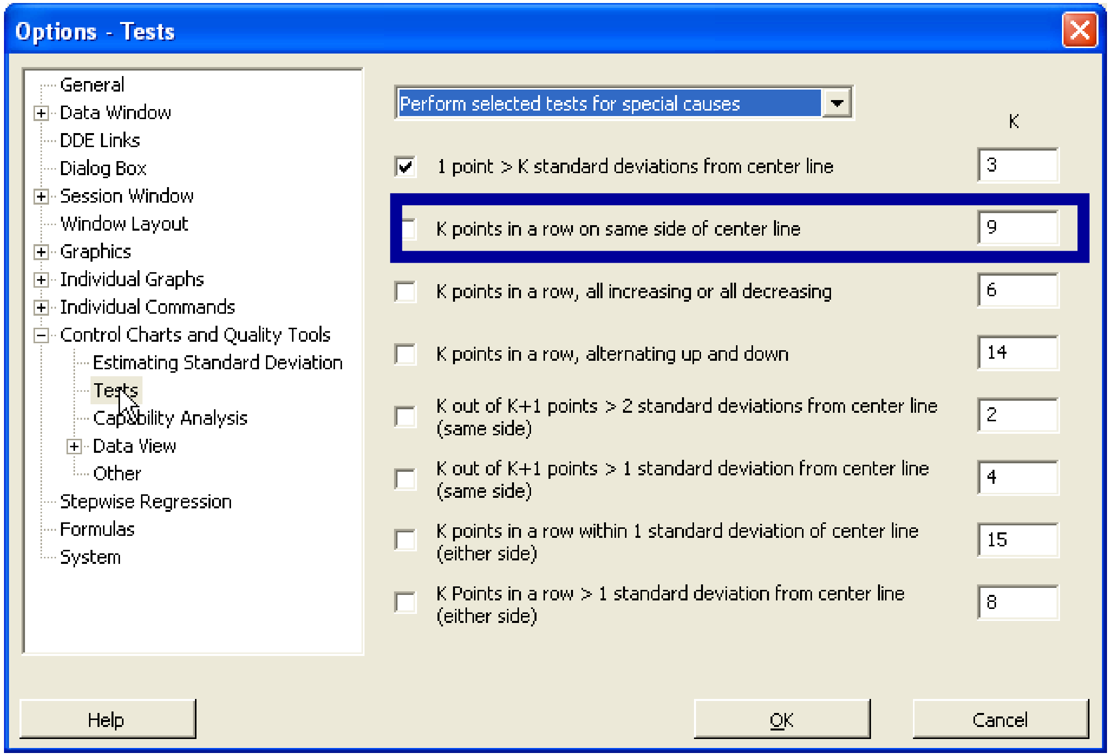
Recommended Special Cause Detection Rules

- If implementing SPC manually without software initially the most visually obvious violations are more easily detected. SPC on manually filled charts are common place for initial use of Defect Prevention techniques.
- These three rules are **visually** the most easily detected by personnel.
  - One point more than 3 Standard Deviations from the Center Line.
  - 6 points in a row all either increasing or all decreasing.
  - 15 points in a row all within one Standard Deviation of either side of the Center Line.
- Dr. Shewhart working with the Western Electric Co. was credited with the following four rules referred to as Western Electric Rules.
  - One point more than 3 Standard Deviations from the Center Line.
  - **8** points in a row on the same side of the Center Line.
  - 2 out of 3 points greater than 2 Standard Deviations from the Center Line on the same side.
  - 4 out of 5 points greater than 1 Standard Deviation from the Center Line on the same side.
- You might notice the Western Electric rules vary slightly. The importance is to be consistent in your organization deciding what rules you will use to detect Special Causes.
- VERY few organizations use all eight rules for detecting Special Causes.

Special Cause Rule Default in MINITAB^{TM}

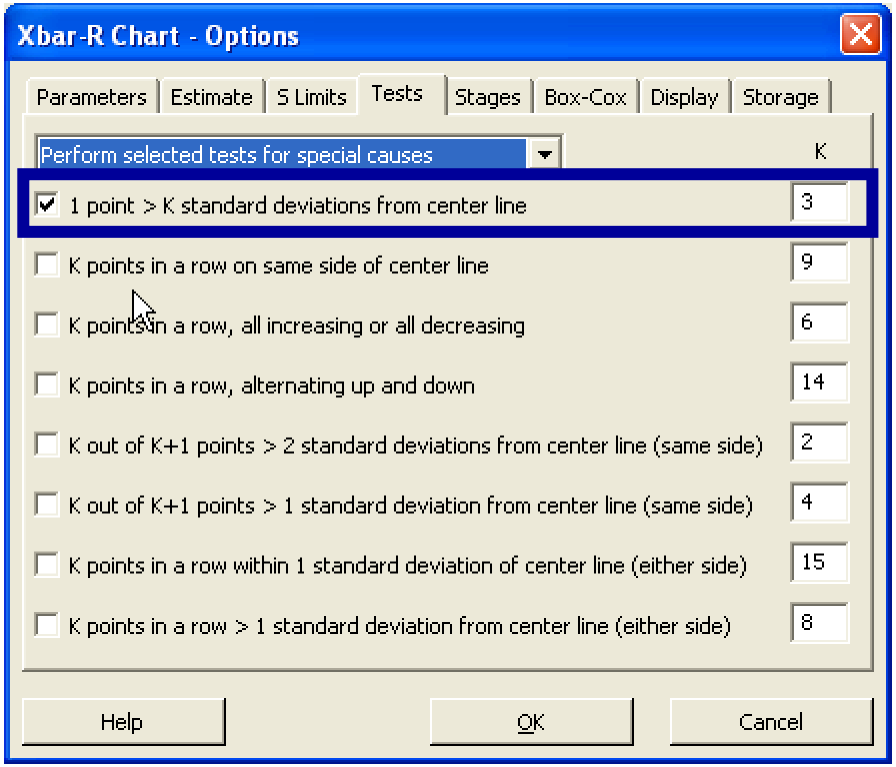
If a Belt is using MINITAB^{TM} she must be aware of the default setting rules. Program defaults may be altered by:

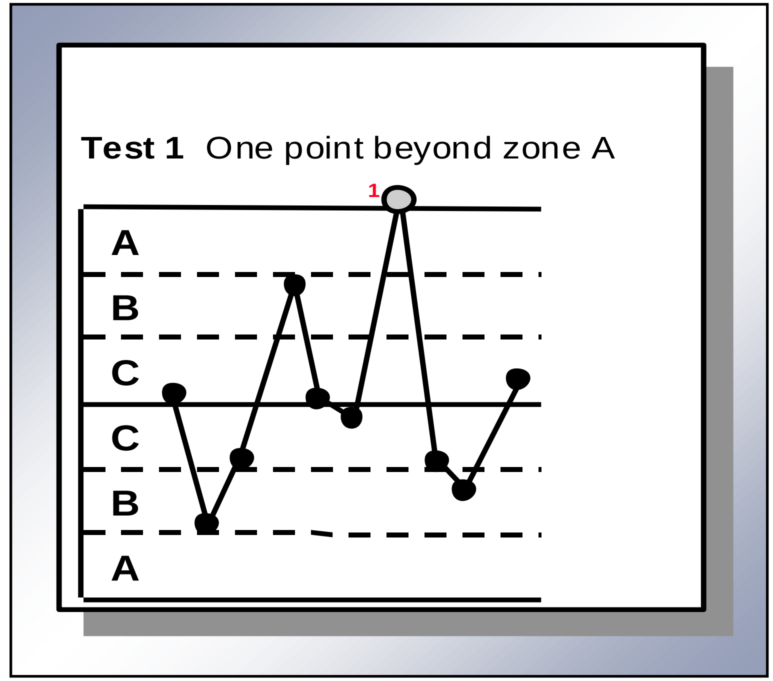
Tools>Options>Control Charts and Quality Tools> Tests



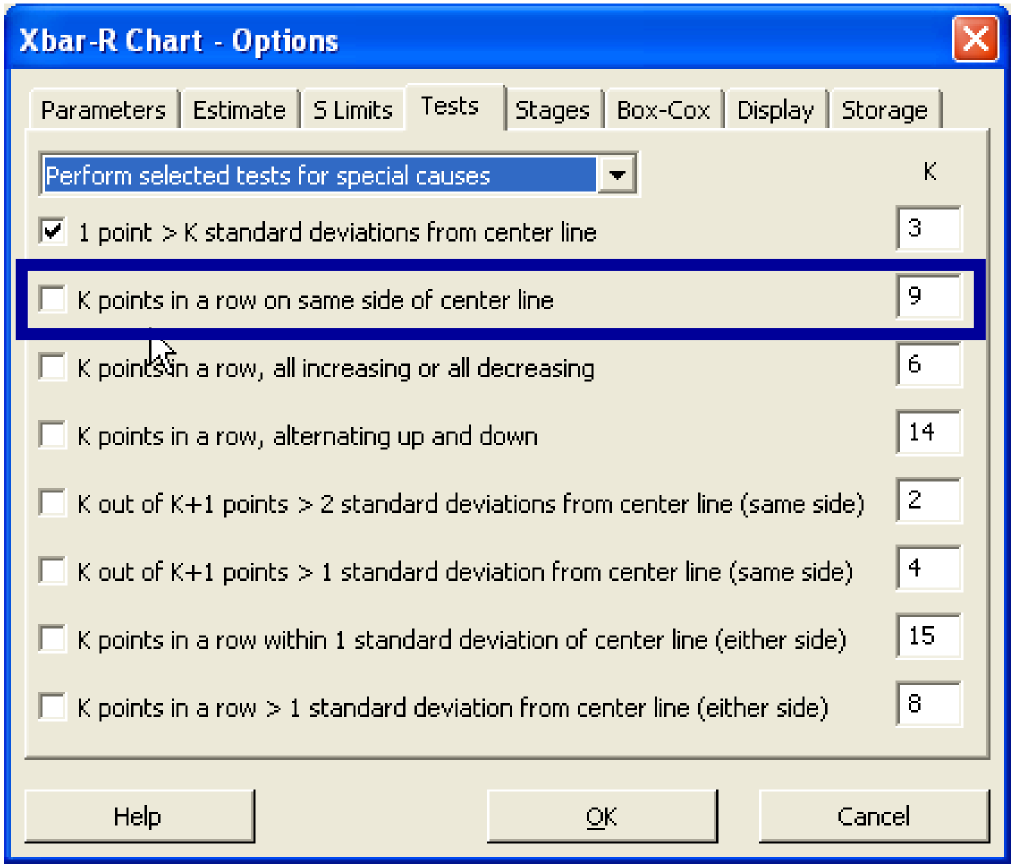
Many experts have commented on the appropriate tests and numbers to be used. Decide, then be consistent when implementing.

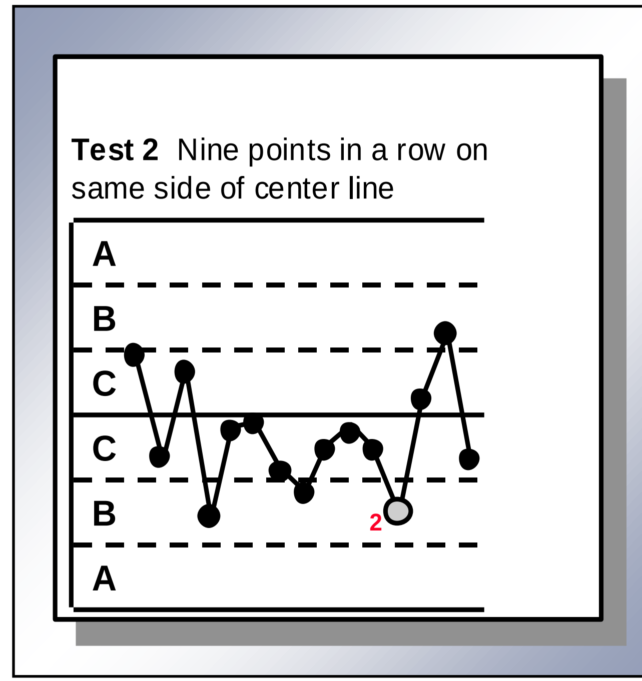
This is the MOST common Special Cause test used in SPC charts.



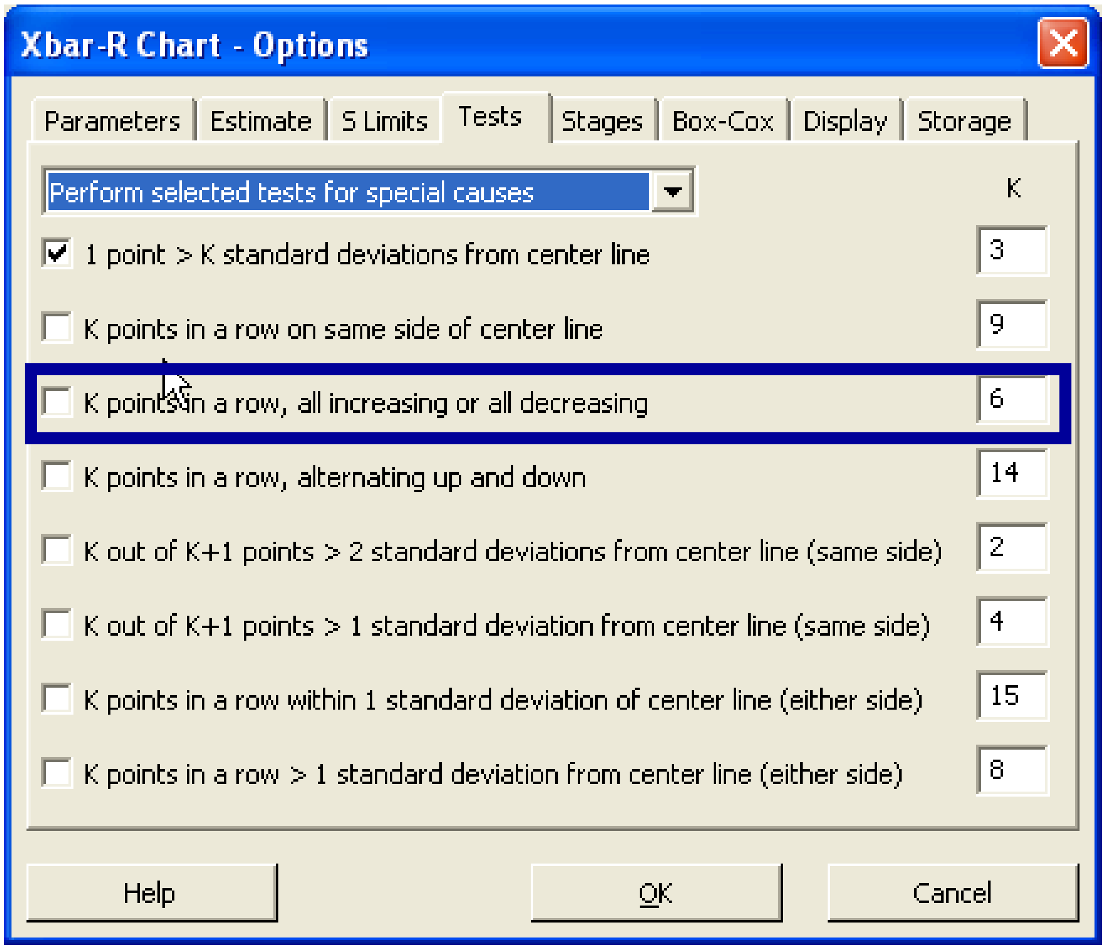


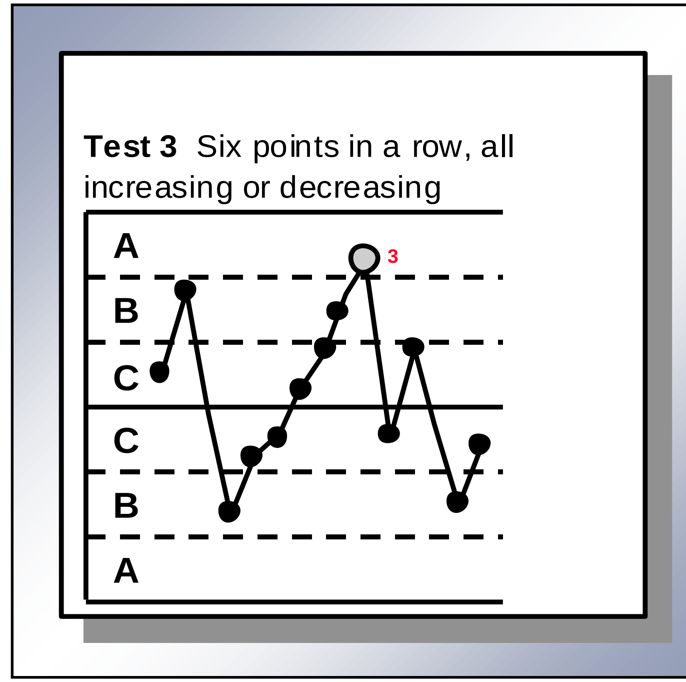
This test is an indication of a shift in the process Mean.



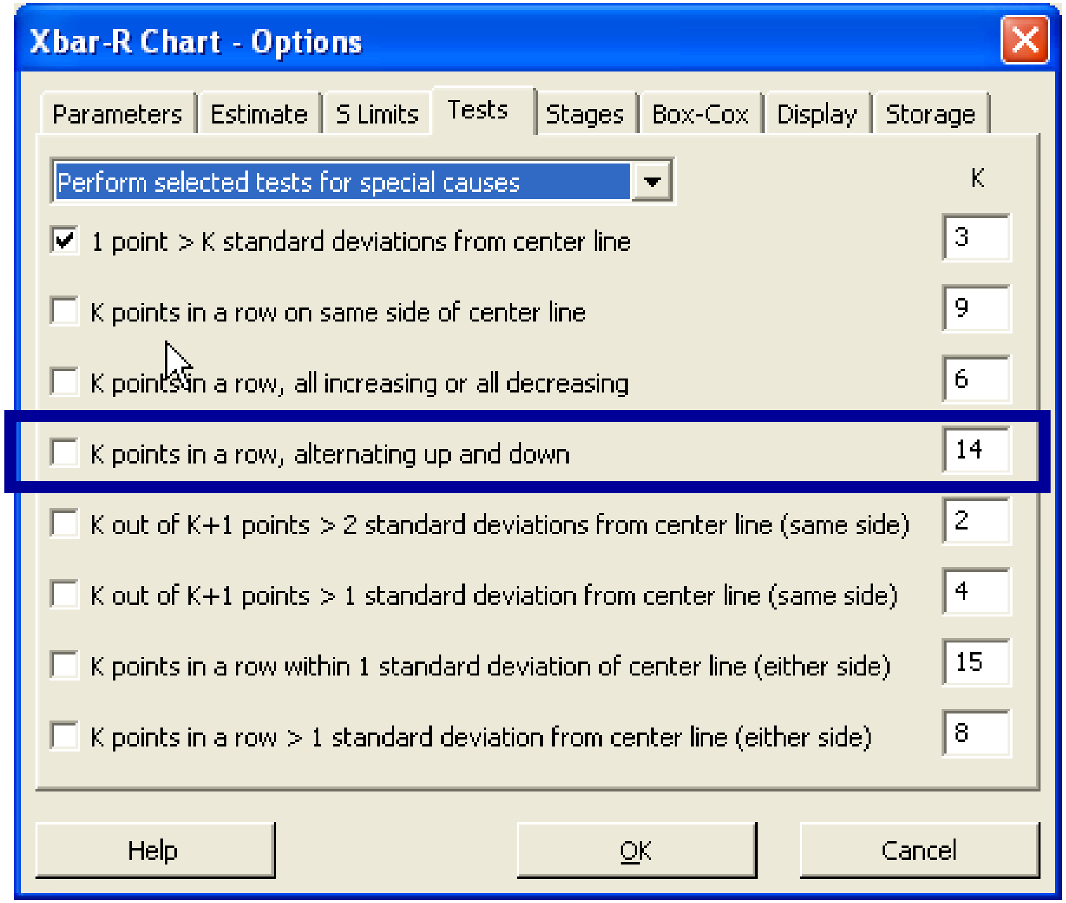


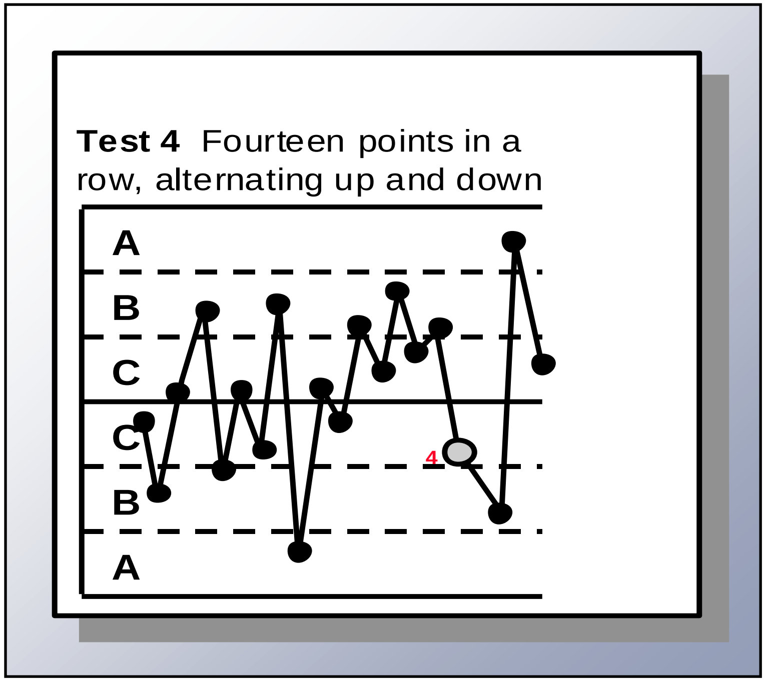
This test is indicating a trend or gradual shift in the Mean.



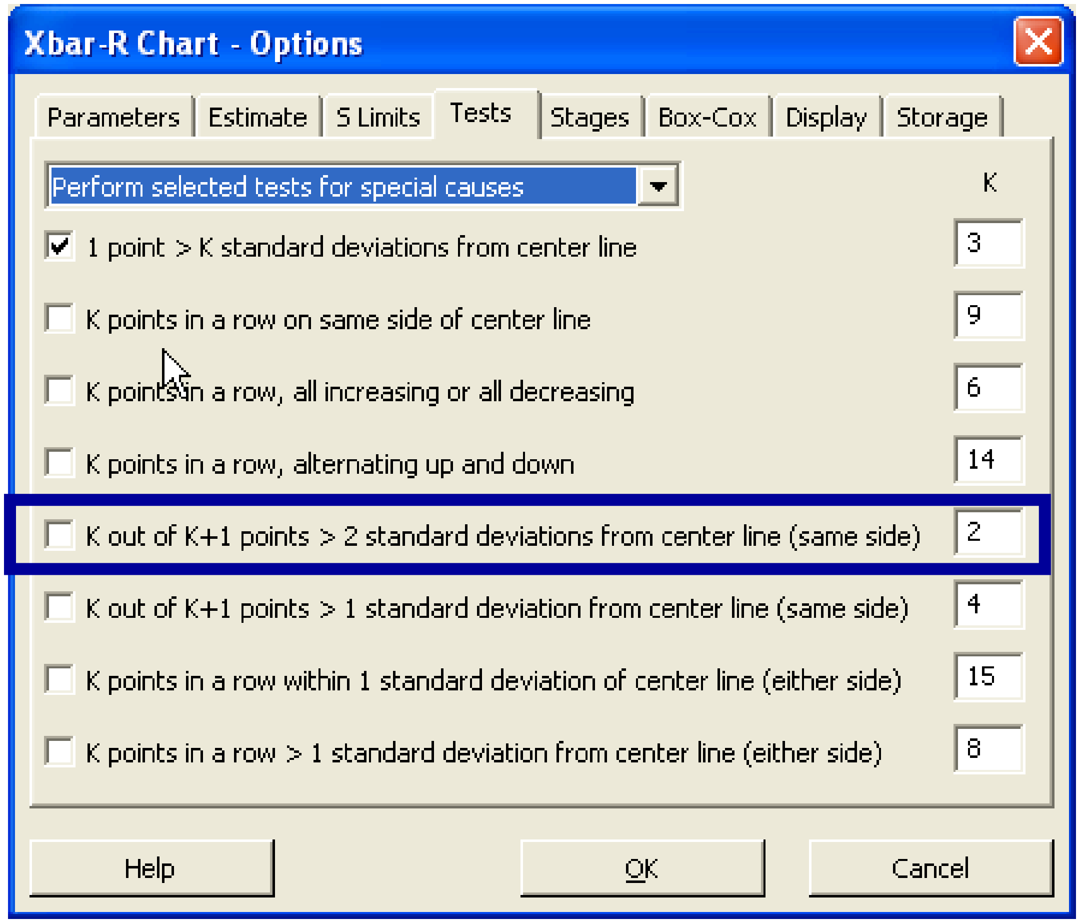


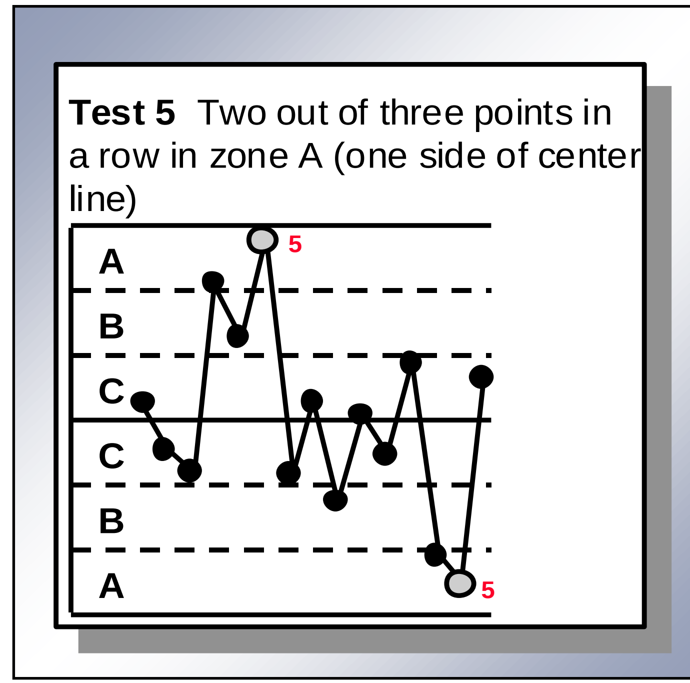
This test is indicating a non-random pattern.



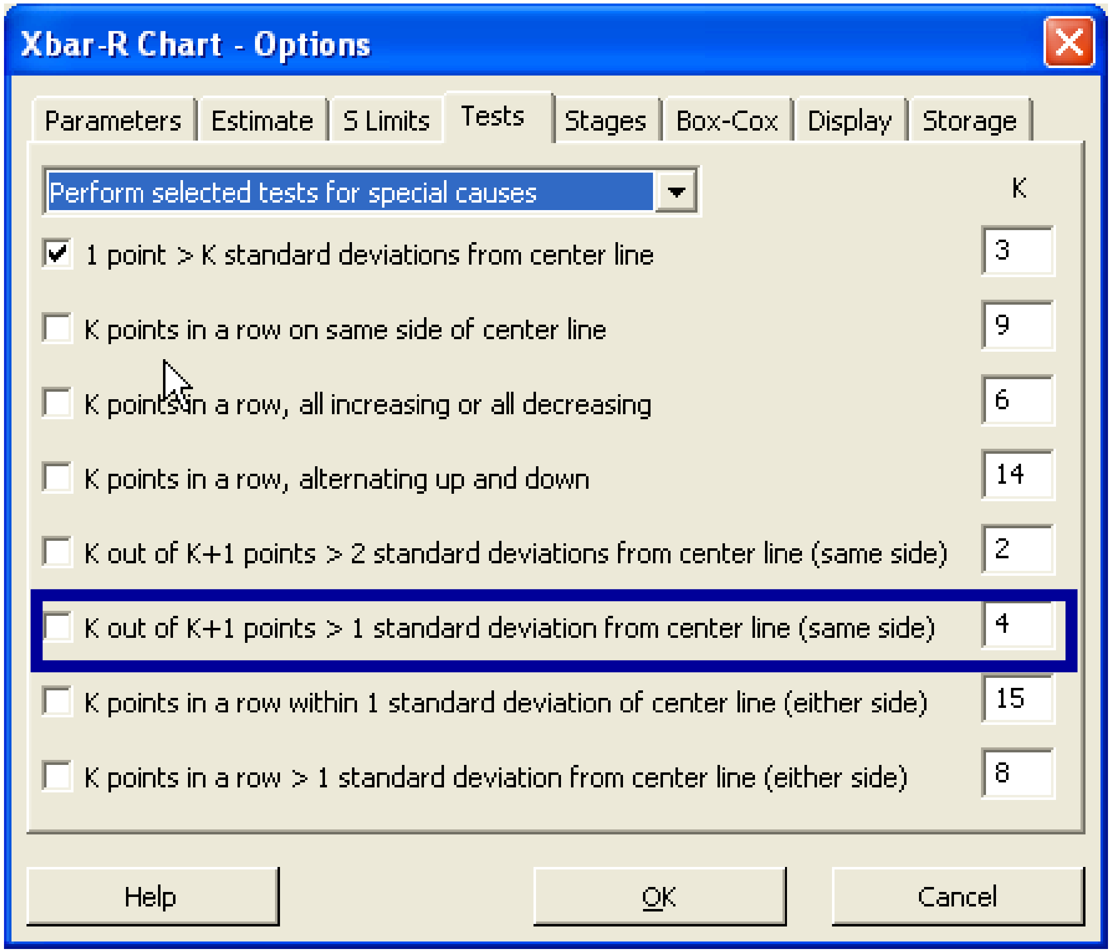


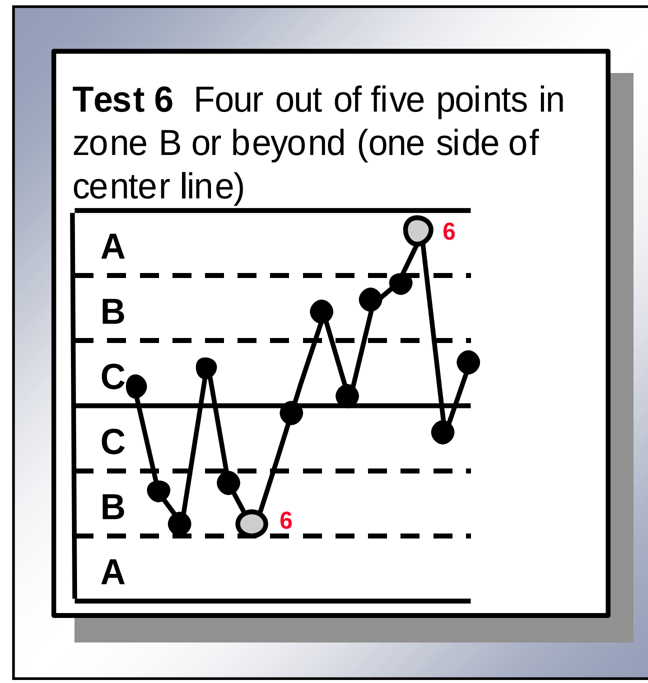
This test is indicating a shift in the Mean or a worsening of variation.



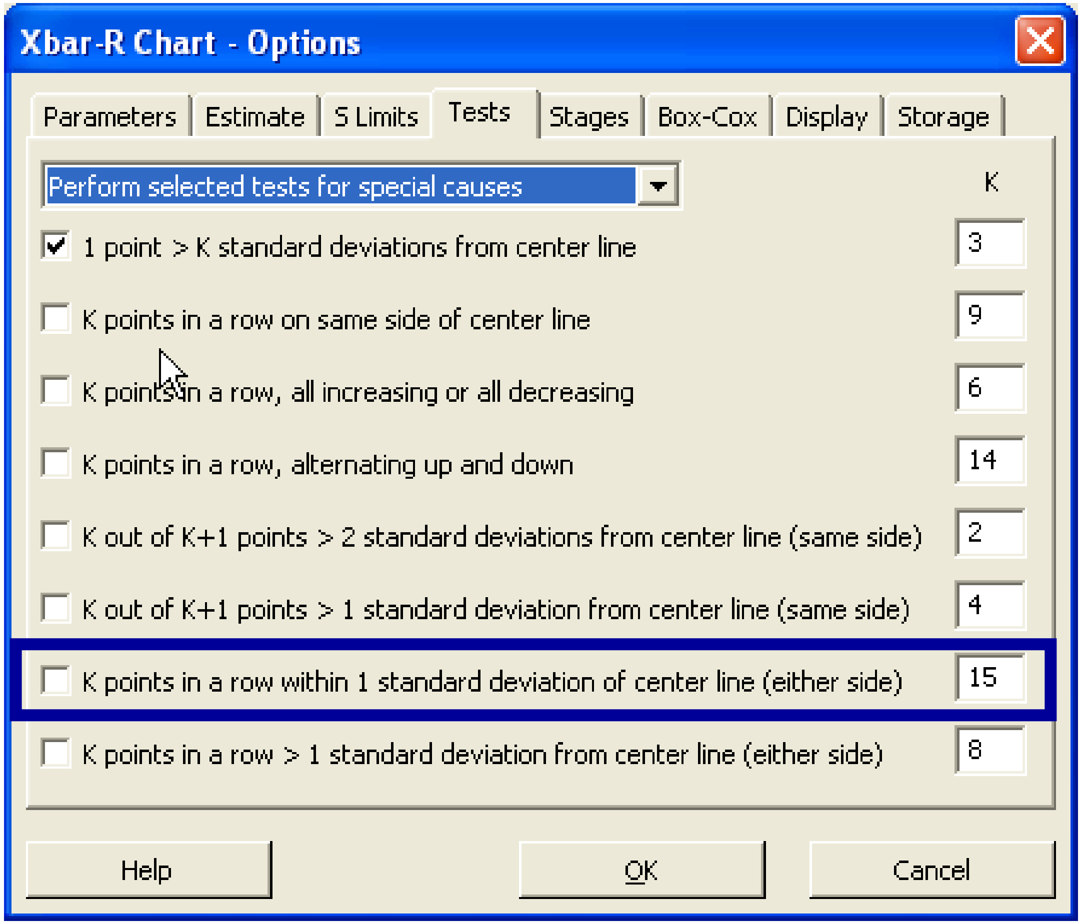


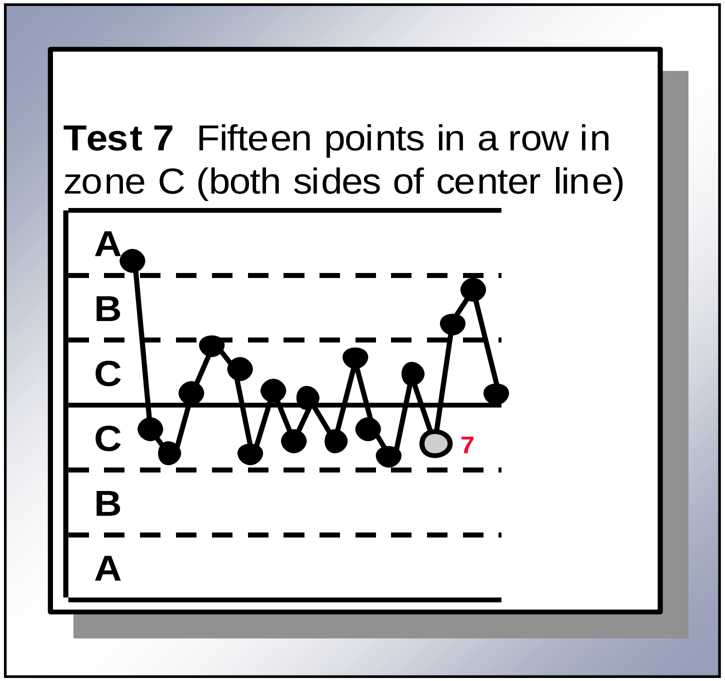
This test is indicating a shift in the Mean or degradation of variation.



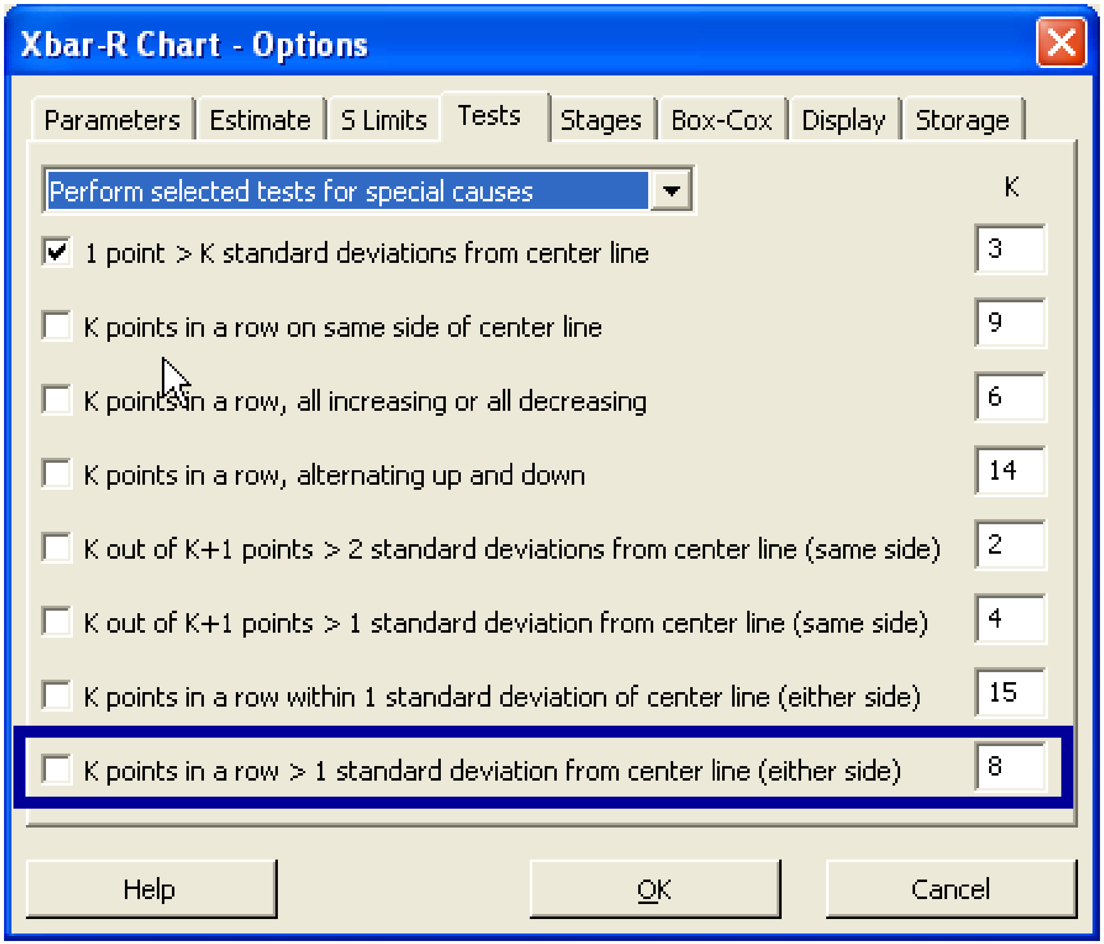


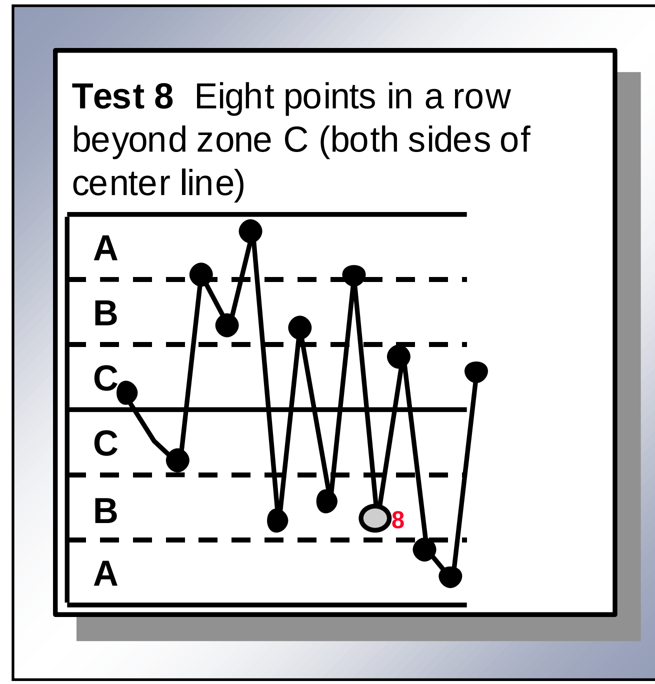
This test is indicating a dramatic improvement of the variation in the process.





This test is indicating a severe worsening of variation.





Calculate the parameters of the Individual and MR Control Charts with the following:

Center Line

$$\overline{X} = \frac{\sum_{i=1}^{k} x_i}{k} \qquad \overline{MR} = \frac{\sum_{i}^{k} R_i}{k}$$

Control Limits

$$UCL_x = \overline{X} + E_2\overline{MR} \qquad UCL_{MR} = D_4\overline{MR}$$

$$LCL_x = \overline{X} - E_2\overline{MR} \qquad LCL_{MR} = D_3\overline{MR}$$

Where ~

Xbar: Average of the individuals becomes the Center Line on the Individuals Chart

Xi: Individual data points

k: Number of individual data points

R_i : Moving range between individuals generally calculated using the difference between each successive pair of readings

MRbar: The average moving range, the Center Line on the Range Chart

UCL_X: Upper Control Limit on Individuals Chart

LCL_X: Lower Control Limit on Individuals Chart

UCL_{MR}: Upper Control Limit on moving range

LCL_{MR} : Lower Control Limit on moving range (does not apply for sample sizes below 7)

E_2, D_3, D_4: Constants that vary according to the sample size used in obtaining the moving range

Calculate the parameters of the Xbar and R Control Charts with the following:

Center Line

$$\bar{\bar{X}} = \frac{\sum_{i=1}^{k} \bar{x}_i}{k} \qquad \bar{R} = \frac{\sum_{i}^{k} R_i}{k}$$

Control Limits

$$UCL_{\bar{x}} = \bar{\bar{X}} + A_2\bar{R} \qquad UCL_R = D_4\bar{R}$$

$$LCL_{\bar{x}} = \bar{\bar{X}} - A_2\bar{R} \qquad LCL_R = D_3\bar{R}$$

Where ~

$\bar{\bar{X}}_i$: Average of the subgroup averages, it becomes the Center Line of the Control Chart

$\bar{X}_i$: Average of each subgroup

k: Number of subgroups

R_i : Range of each subgroup (Maximum observation – Minimum observation)

Rbar: The average range of the subgroups, the Center Line on the Range Chart

UCL_X: Upper Control Limit on Average Chart

LCL_X: Lower Control Limit on Average Chart

UCL_R: Upper Control Limit on Range Chart

LCL_R : Lower Control Limit Range Chart

A_2, D_3, D_4: Constants that vary according to the subgroup sample size

Calculate the parameters of the Xbar and S Control Charts with the following:

Center Line

$$\bar{\bar{X}} = \frac{\sum_{i=1}^{k} \bar{x}_i}{k} \qquad \bar{S} = \frac{\sum_{i=1}^{k} s_i}{k}$$

Control Limits

$$UCL_{\bar{x}} = \bar{\bar{X}} + A_3\bar{S} \qquad UCL_S = B_4\bar{S}$$

$$LCL_{\bar{x}} = \bar{\bar{X}} - A_3\bar{S} \qquad LCL_S = B_3\bar{S}$$

Where ~

$\bar{\bar{X}}_i$: Average of the subgroup averages it becomes the Center Line of the Control Chart

$\bar{X}_i$: Average of each subgroup

k: Number of subgroups

s_i : Standard Deviation of each subgroup

Sbar: The average S. D. of the subgroups, the Center Line on the S chart

UCL_X: Upper Control Limit on Average Chart

LCL_X: Lower Control Limit on Average Chart

UCL_S: Upper Control Limit on S Chart

LCL_S : Lower Control Limit S Chart

A_3, B_3, B_4: Constants that vary according to the subgroup sample size

Calculate the parameters of the P Control Charts with the following:

Center Line

$$\bar{p} = \frac{\text{Total number of defective items}}{\text{Total number of items inspected}}$$

Control Limits

$$UCL_p = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n_i}}$$

$$LCL_p = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n_i}}$$

Where~

- **$\bar{p}$:** Average proportion defective (0.0 – 1.0)
- **n_i:** Number inspected in each subgroup
- **LCL_p:** Lower Control Limit on P Chart
- **UCL_p:** Upper Control Limit on P Chart

Since the Control Limits are a function of sample size they will vary for each

Calculate the parameters of the nP Control Charts with the following:

Center Line

$$\overline{np} = \frac{\text{Total number of defective items}}{\text{Total number of subgroups}}$$

Control Limits

$$UCL_{np} = \bar{n}_i\bar{p} + 3\sqrt{n_i p(1-p)}$$

$$LCL_{np} = \bar{n}_i\bar{p} - 3\sqrt{n_i p(1-p)}$$

Where ~

$\overline{np}$: Average number defective items per subgroup
n_i: Number inspected in each subgroup
LCL_{np}: Lower Control Limit on nP chart
UCL_{np}: Upper Control Limit on nP chart

Since the Control Limits AND Center Line are a function of sample size they will vary for each sample.

Calculate the parameters of the U Control Charts with the following:

Center Line

$$\bar{\mathrm{u}} = \frac{\text{Total number of defects Identified}}{\text{Total number of Units Inspected}}$$

Control Limits

$$\mathrm{UCL}_{\mathrm{u}} = \bar{\mathrm{u}} + 3\sqrt{\frac{\bar{u}}{n_i}}$$

$$\mathrm{LCL}_{\mathrm{u}} = \bar{\mathrm{u}} - 3\sqrt{\frac{\bar{u}}{n_i}}$$

Where ~

$\bar{u}$:	Total number of defects divided by the total number of units inspected.
ni:	Number inspected in each subgroup
LCL_u:	Lower Control Limit on U Chart.
UCL_u:	Upper Control Limit on U Chart.

Since the Control Limits are a function of sample size they will vary for each sample.

Calculate the parameters of the C Control Charts with the following:

Center Line

$$\bar{c} = \frac{\text{Total number of defects}}{\text{Total number of subgroups}}$$

Control Limits

$$UCL_c = \bar{c} + 3\sqrt{\bar{c}}$$

$$LCL_c = \bar{c} - 3\sqrt{\bar{c}}$$

Where ~

$\bar{c}$:	Total number of defects divided by the total number of subgroups.
LCL_c:	Lower Control Limit on C Chart.
UCL_c:	Upper Control Limit on C Chart.

Calculate the parameters of the EWMA Control Charts with the following:

Center Line

$$Z_t = \lambda X_t + (1-\lambda) Z_{t-1}$$

Control Limits

$$UCL = \overline{X} + 3\frac{\sigma}{\sqrt{n}}\sqrt{\left(\frac{\lambda}{2-\lambda}\right)[1-(1-\lambda)^{2t}]}$$

$$LCL = \overline{X} - 3\frac{\sigma}{\sqrt{n}}\sqrt{\left(\frac{\lambda}{2-\lambda}\right)[1-(1-\lambda)^{2t}]}$$

Where ~

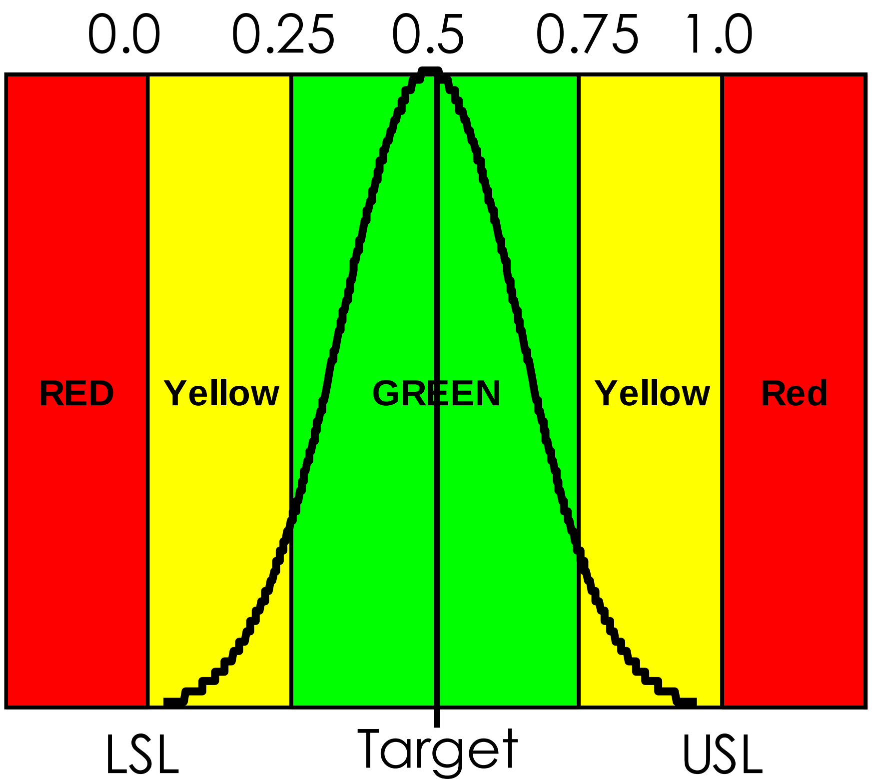
Z_t:	EWMA statistic plotted on Control Chart at time t
Z_{t-1}:	EWMA statistic plotted on Control Chart at time t-1
λ:	The weighting factor between 0 and 1 – suggest using 0.2
σ:	Standard Deviation of historical data (pooled Standard Deviation for subgroups – MRbar/d2 for individual observations)
X_t:	Individual data point or sample averages at time t
UCL:	Upper Control Limit on EWMA Chart
LCL:	Lower Control Limit on EWMA Chart
n:	Subgroup sample size

Calculate the parameters of the CUSUM control charts with MINITAB™ or other program since the calculations are even more complicated than the EWMA charts.

Because of this complexity of formulas execution of either this or the EWMA are not done without automation and computer assistance.

Ah, anybody got a laptop?

Pre-Control Charts use limits relative to the specification limits. This is the first and ONLY chart wherein you will see specification limits plotted for Statistical Process Control. This is the most basic type of chart and unsophisticated use of process control.



Red Zones. Zone outside the specification limits. Signals the process is out-of-control and should be stopped

Yellow Zones. Zone between the PC Lines and the specification limits indicating caution and the need to watch the process closely

Green Zone. Zone lies between the PC Lines, signals the process is in control

Qualifying Process

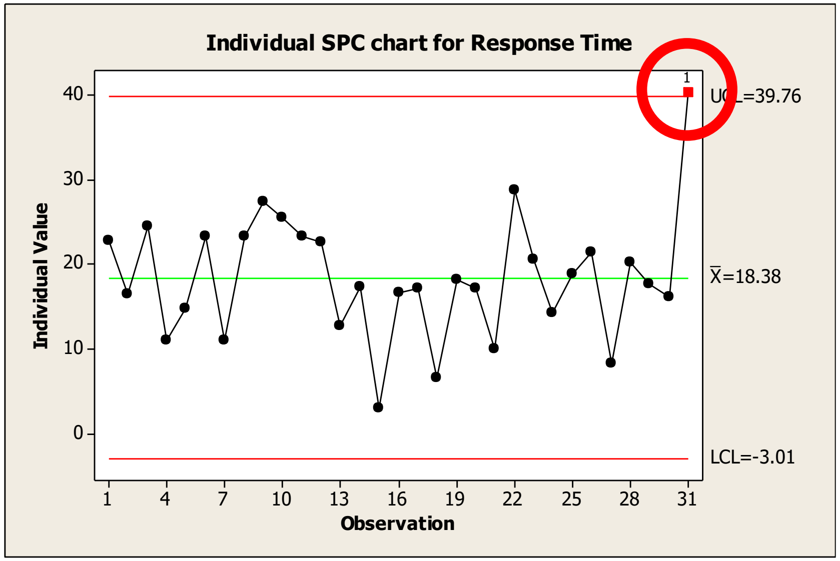
- To qualify a process five consecutive parts must fall within the green zone
  - The process should be qualified after tool changes, adjustments, new operators, material changes, etc.

Monitoring Ongoing Process

- Sample two consecutive parts at predetermined frequency
  - If either part is in the red, stop production and find reason for variation
  - When one part falls in the yellow zone inspect the other and:
    - If the second part falls in the green zone then continue
    - If the second part falls in the yellow zone on the same side make an adjustment to the process
    - If second part falls in the yellow zone on the opposite side or in the red zone the process is out of control and should be stopped
  - If any part falls outside the specification limits or in the red zone the process is out of control and should be stopped

Responding to Out of Control Indications

- The power of SPC is not to find out what the Center Line and Control Limits are.
- The power is to react to the Out of Control (OOC) indications with your Out of Control Action Plans (OCAP) for the process involved. These actions are your corrective actions to correct the output or input to achieve proper conditions.



VIOLATION:
Special Cause is indicated

OCAP
If response time is too high get additional person on phone bank

- SPC requires immediate response to a Special Cause indication.
- SPC also requires no “sub optimizing” by those operating the process.
  - Variability will increase if operators always adjust on every point if not at the Center Line. ONLY respond when an Out of Control or Special Cause is detected.
  - Training is required to interpret the charts and response to the charts.

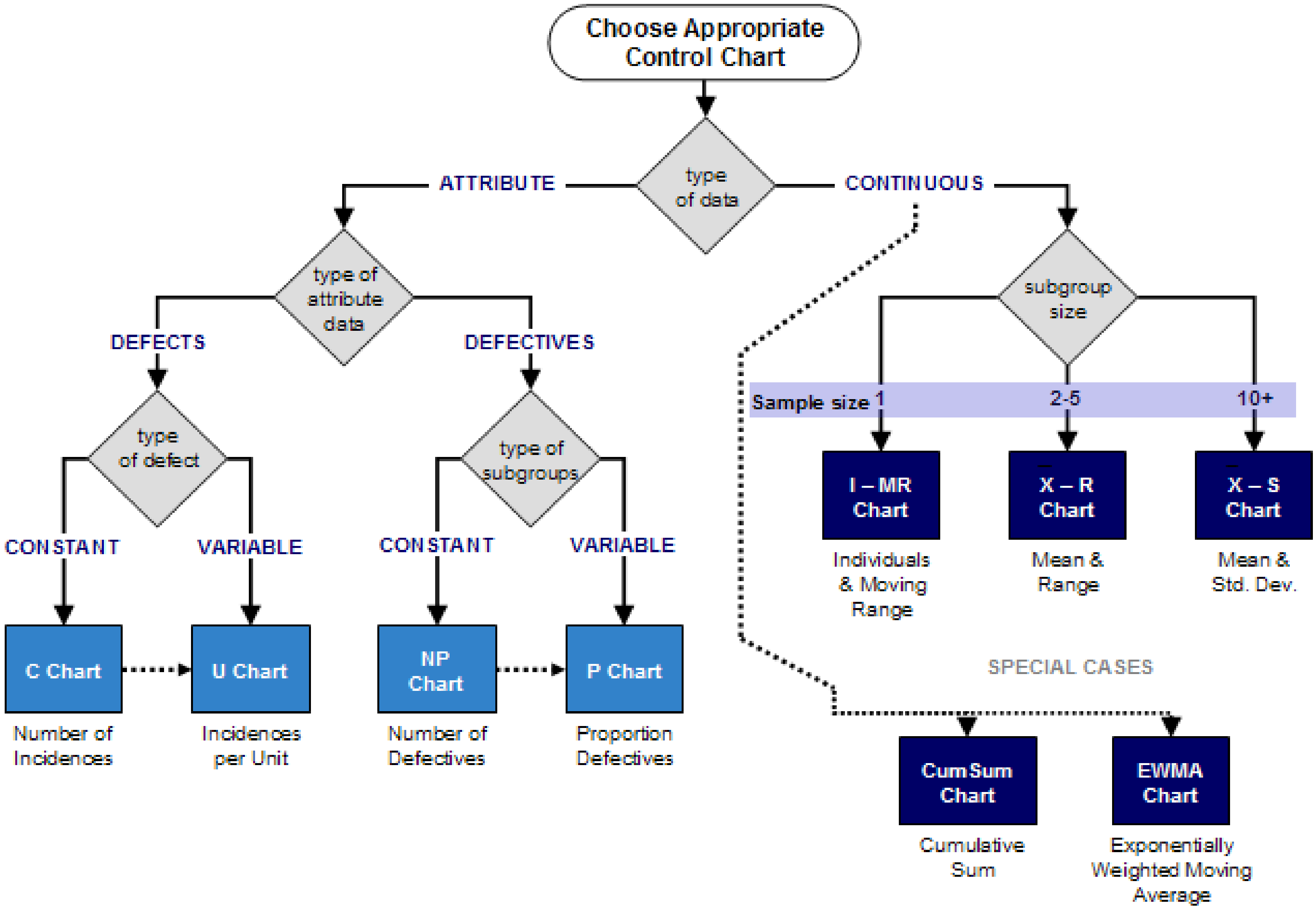
Practical Problem: A project has been launched to get rework reduced to less than 25% of paychecks. Rework includes contacting a manager about overtime hours to be paid. The project made some progress but decides they need to implement SPC to sustain the gains and track % defective. Please analyze the file "*paycheck2.mtw*" and determine the Control Limits and Center Line.

Step 3 and 5 of the methodology is the primary focus for this example.

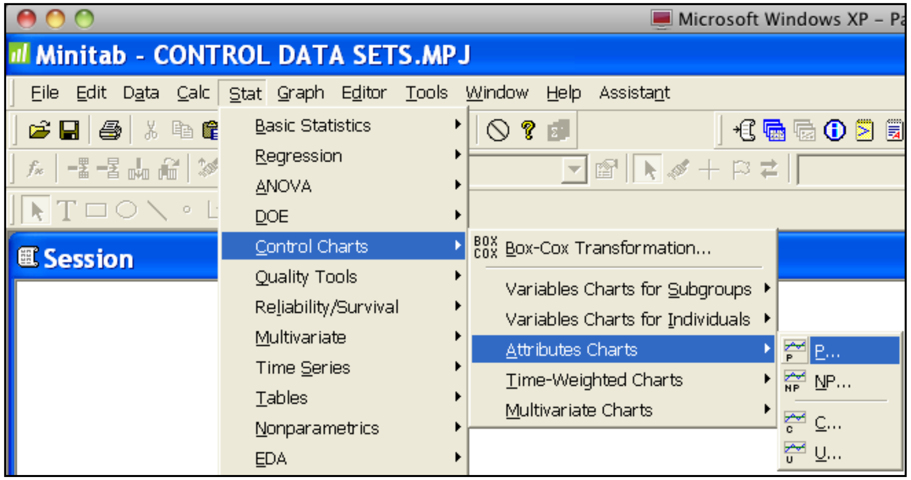
- **Select the appropriate Control Chart and Special Cause tests to employ**
- **Calculate the Center Line and Control Limits**
- Looking at the data set we see 20 weeks of data.
- The sample size is constant at 250.
- The amount of defective in the sample is in column C3.

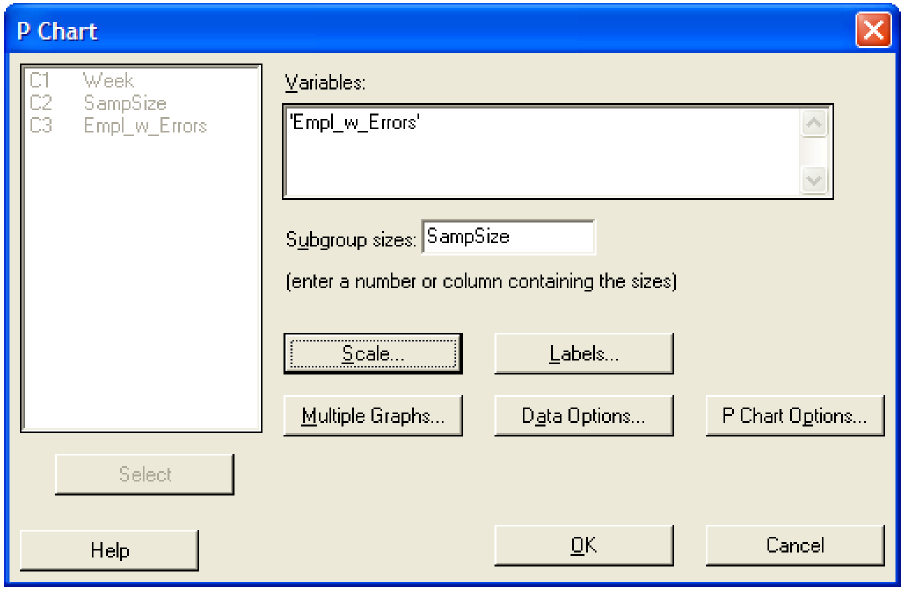
Paycheck2.mtw

Attribute SPC Example (cont.)



Notice specifications were never discussed. Let's calculate the Control Limits and Central Line for this example.

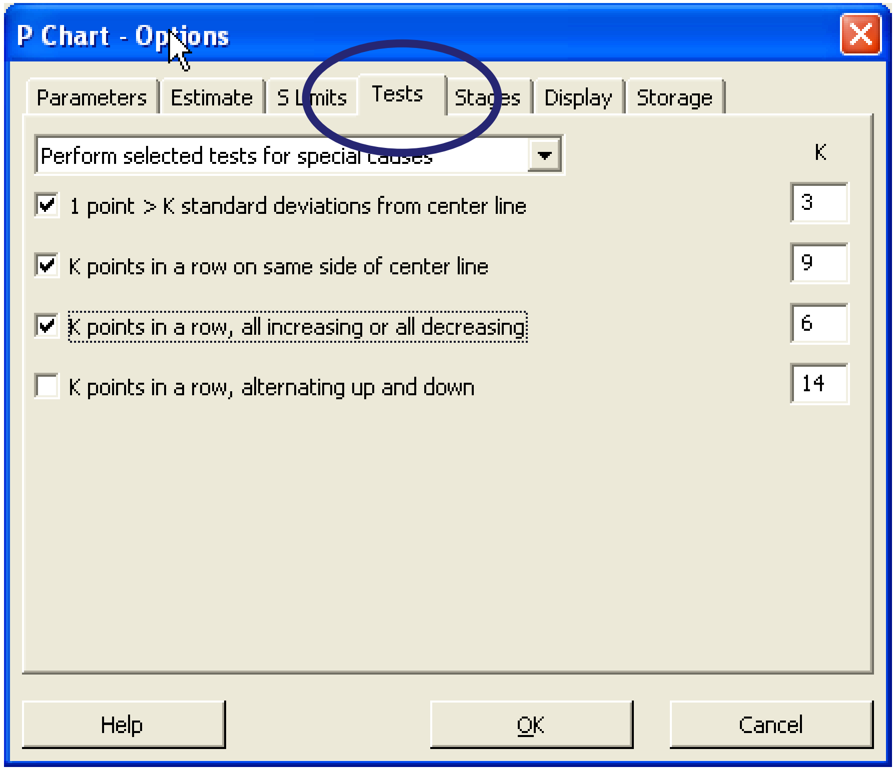




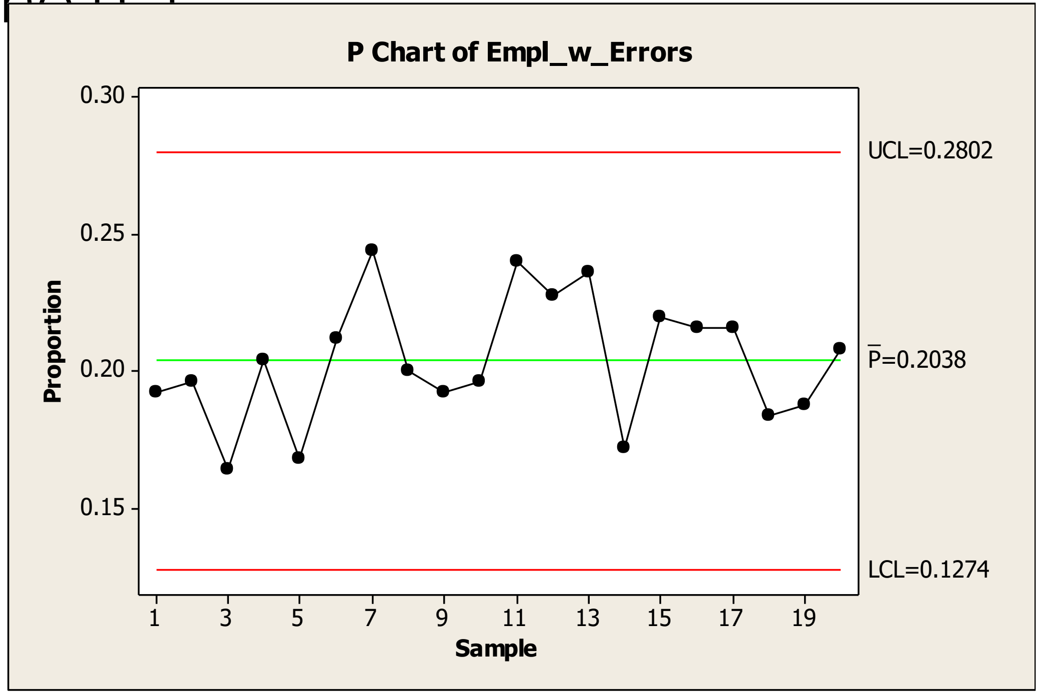
We will confirm what rules for Special Causes are included in our Control Chart analysis.

Remember to click on the "Options…" and "Tests" tab to clarify the rules for detecting Special Causes.

…. Chart Options>Tests



No Special Causes were detected. The average % defective checks were 20.38%. The UCL was 28.0% and 12.7% for the LCL



Now we must see if the next few weeks are showing Special Cause from the results. The sample size remained at 250 and the defective checks were 61, 64, 77.

Let's continue our example:

– **Step 6: Plot process X or Y on the newly created Control Chart**

– **Step 7: Check for Out-Of-Control (OOC) conditions after each point**

– **Step 8: Interpret findings, investigate Special Cause variation & make improvements following the Out of Control Action Plan (OCAP)**

Notice the new 3 weeks of data was entered into the spreadsheet.

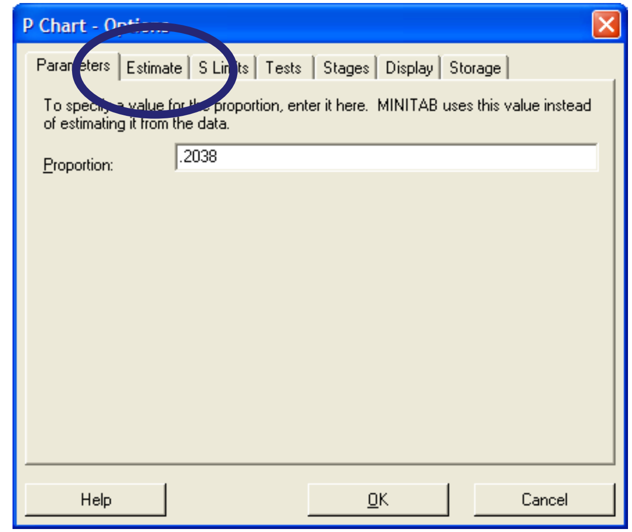
PAYCHECK2.MTW ***

↓	C1	C2	C3
	Week	SampSize	Empl_w_Errors
17	17	250	54
18	18	250	46
19	19	250	47
20	20	250	52
21		250	61
22		250	64
23		250	77
24			
25			
26			

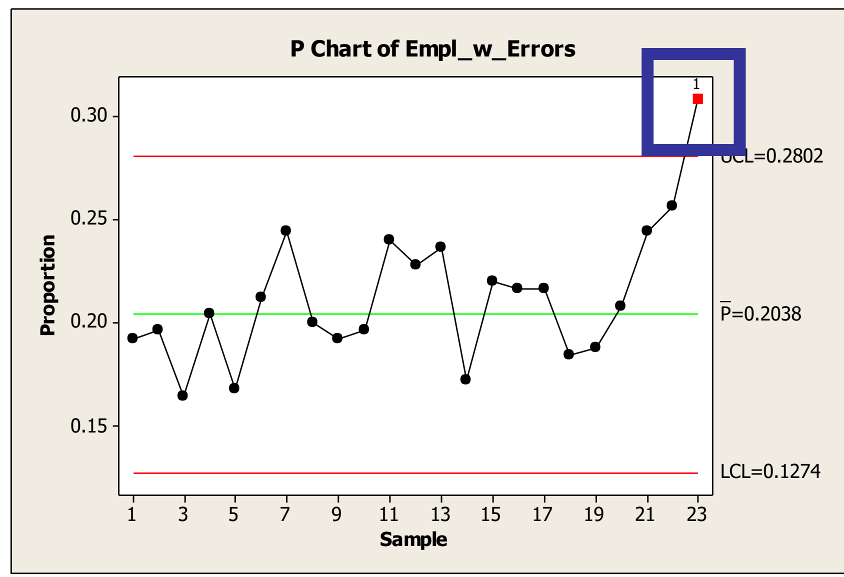
Attribute SPC Example (cont.)

…… Chart Options>Parameters

Place the pbar from the first chart we created in the "Estimate" tab. This will prevent MINITAB™ from calculating new Control Limits which is step 9.

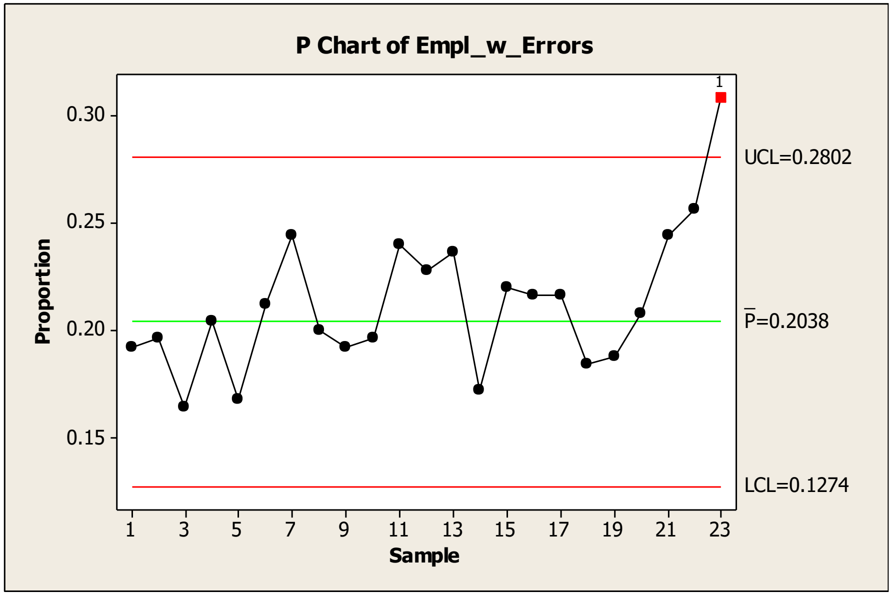


The new updated SPC chart is shown with one Special Cause.



Attribute SPC example (cont.)

Because of the Special Cause the process must refer to the OCAP or Out of Control Action Plan stating what Root Causes need to be investigated and what actions are taken to get the process back in Control.



After the corrective actions were taken wait until the next sample is taken to see if the process has changed to not show Special Cause actions.

- **If still out of control refer to the OCAP and take further action to improve the process. DO NOT make any more changes if the process shows back in control after the next reading.**
  - **Even if the next reading seems higher than the Center Line! Do not cause more variability.**

If process changes are documented after this project was closed the Control Limits should be recalculated as in step 9 of the SPC methodology.

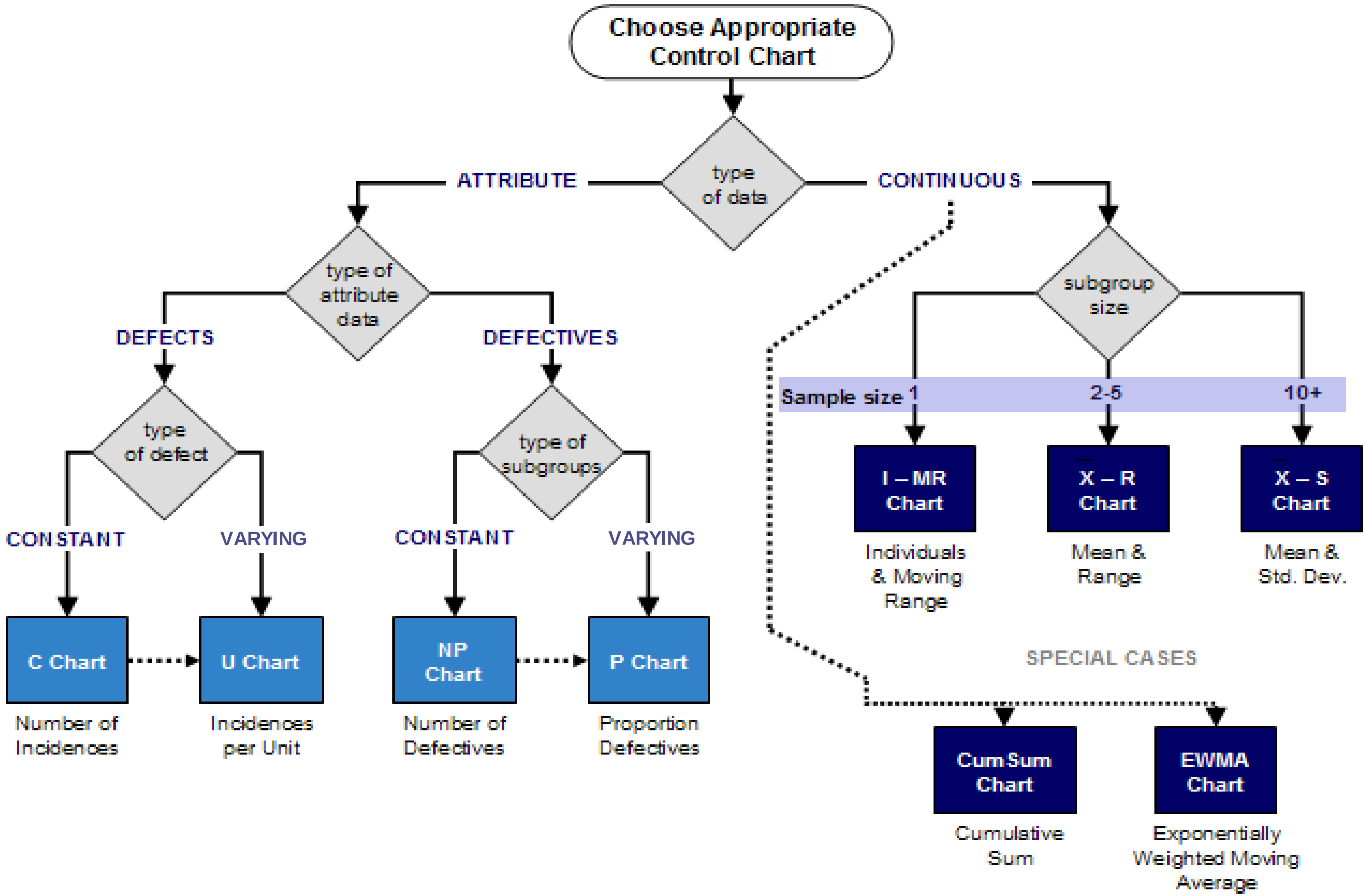
Practical Problem: A job shop drills holes for its largest customer as a final step to deliver a highly engineered fastener. This shop uses five drill presses and gathers data every hour with one sample from each press representing part of the subgroup. You can assume there is insignificant variation within the five drills and the subgroup is across the five drills. The data is gathered in columns C3-C7.

Step 3 and 5 of the methodology is the primary focus for this example.

- **Select the appropriate Control Chart and Special Cause tests to employ**
- **Calculate the Center Line and Control Limits**

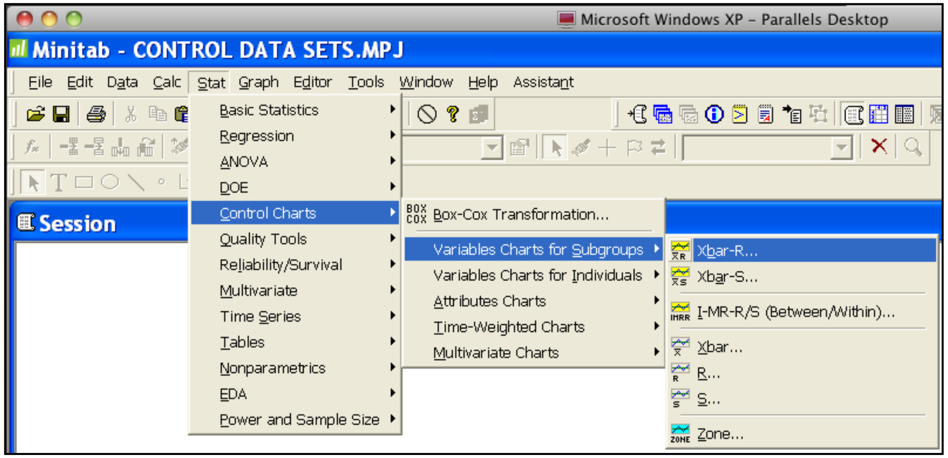
Holediameter.mtw

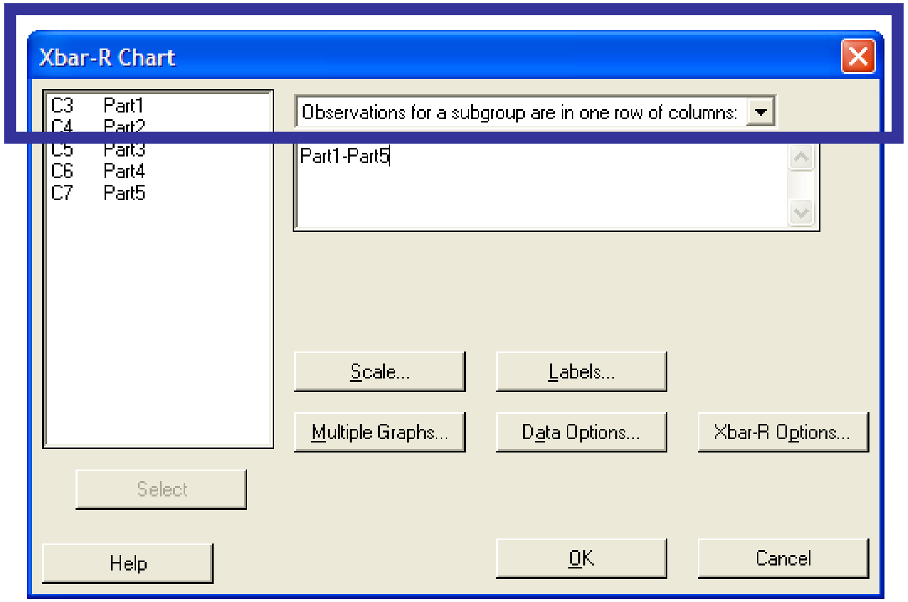
Variable SPC Example (cont.)



Variable SPC Example (cont.)

Specifications were never discussed. Let's calculate the Control Limits and Center Line for this example.

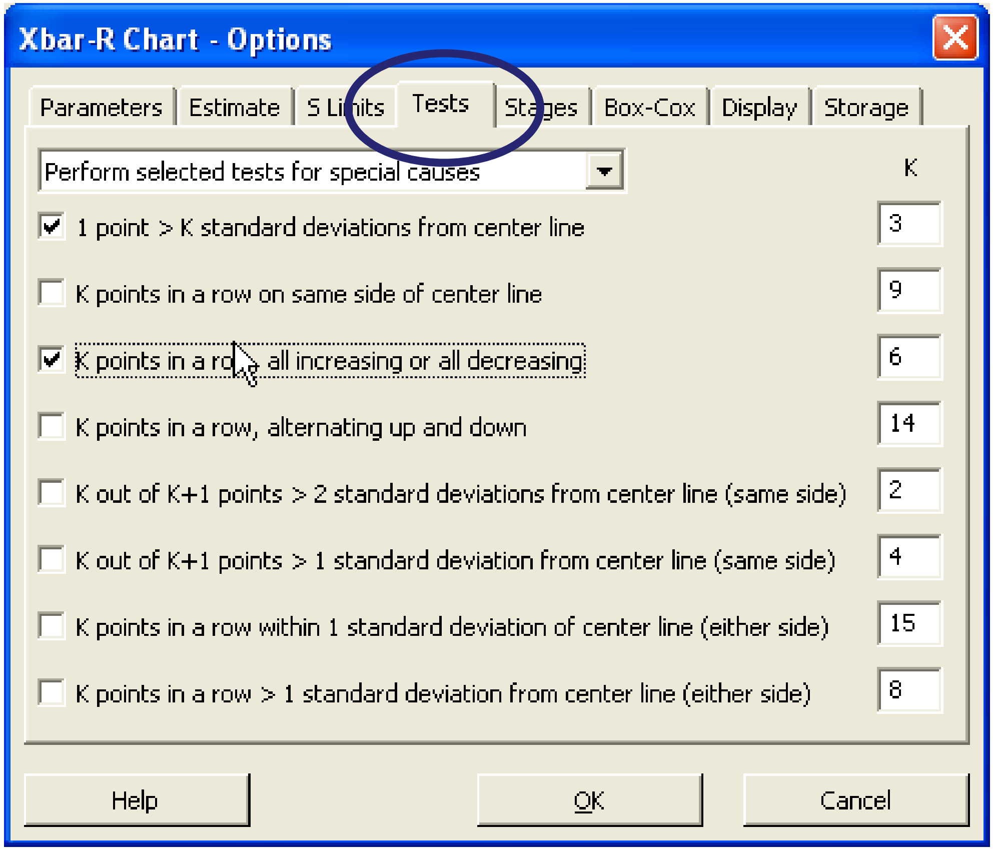




We will confirm what rules for Special Causes are included in our Control Chart analysis.

Remember to click on the "Options…" and "Tests" tab to clarify the rules for detecting Special Causes.

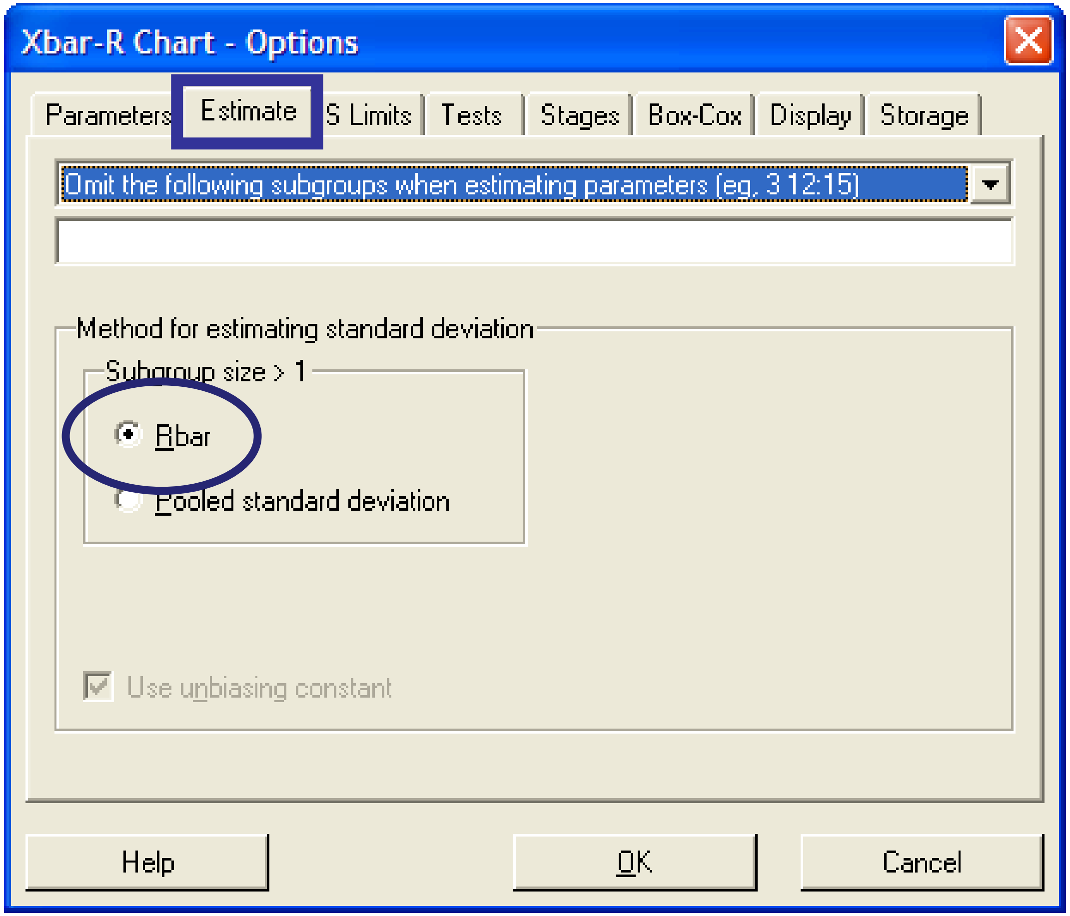
……..Xbar-R Chart Options>Tests



We will confirm what rules for Special Causes are included in our Control Chart analysis. The top 2 of 3 were selected.

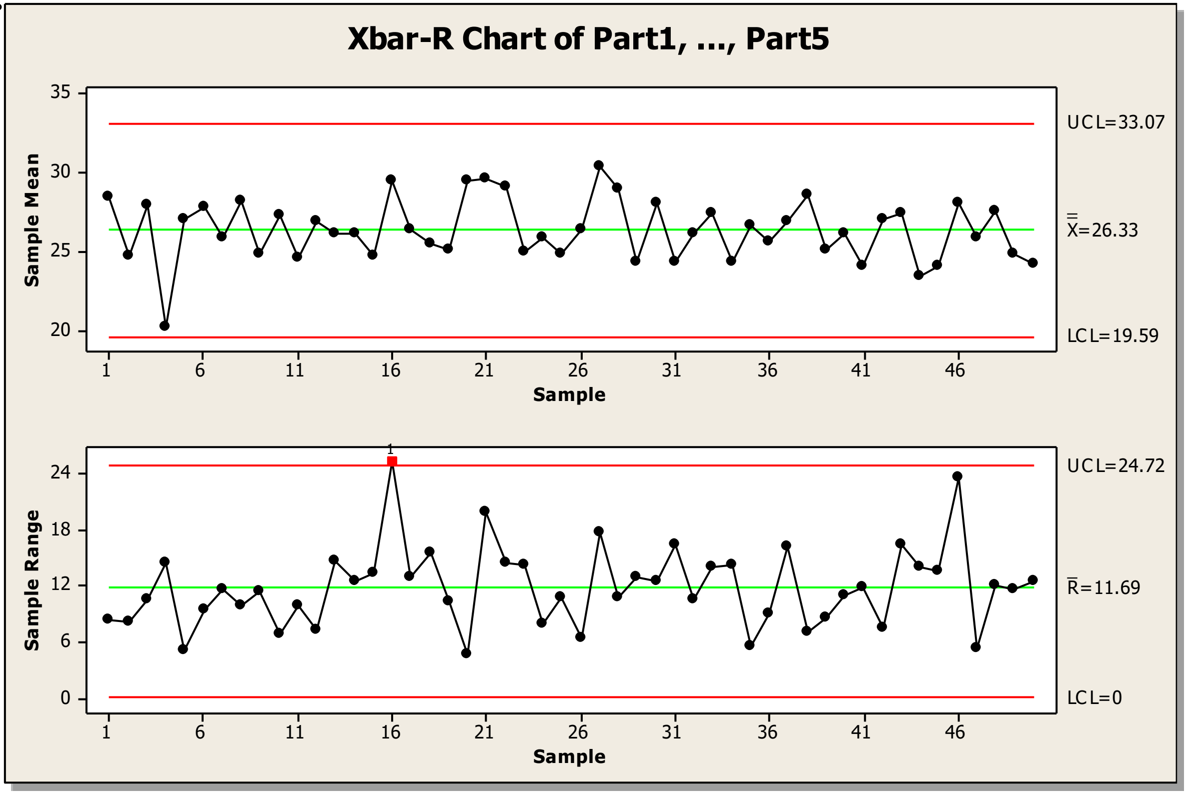
Also confirm the Rbar method is used for estimating Standard Deviation.

Stat>Control Charts>Variable Charts for Subgroups>Xbar-R>Xbar-R Chart Options>Estimate



Variable SPC Example (cont.)

No Special Causes were detected in the Xbar Chart. The average hole diameter was 26.33. The UCL was 33.1 and 19.6 for the LCL.



Now we will use the Control Chart to monitor the next 2 hours and see if we are still in control.

Some more steps….

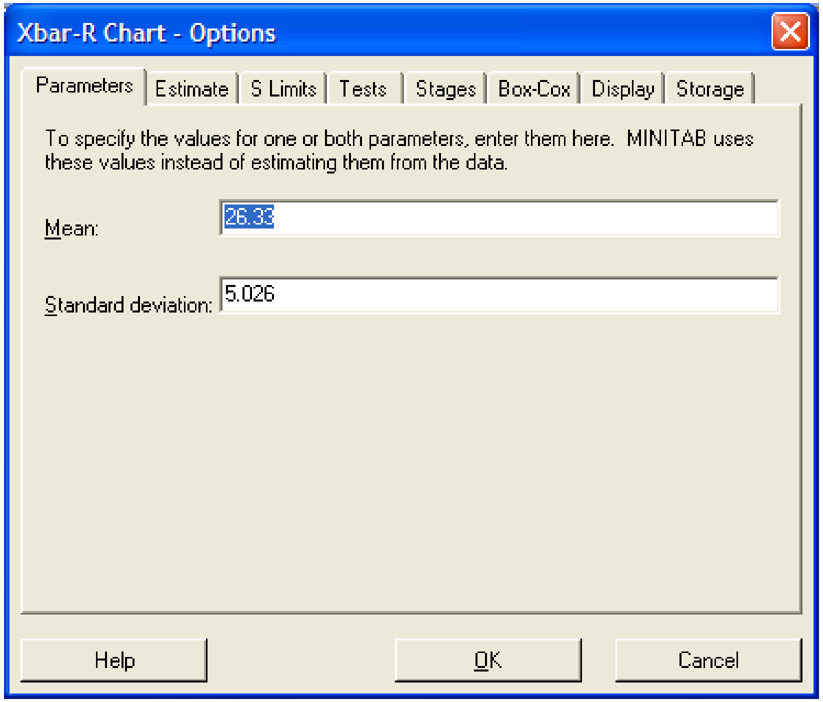
–**Step 6: Plot process X or Y on the newly created Control Chart**

–**Step 7: Check for Out-Of-Control (OOC) conditions after each point**

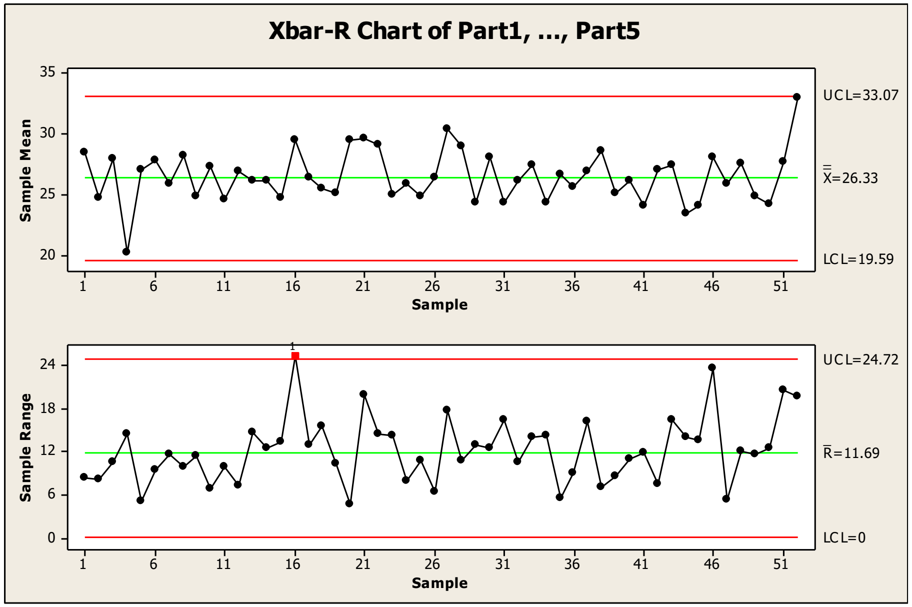
–**Step 8: Interpret findings, investigate Special Cause variation, & make improvements following the Out of Control Action Plan (OCAP)**

	Part1	Part2	Part3	Part4	Part5
	15.1091	26.7913	28.0801	21.9363	28.6757
	22.9919	43.8256	26.9672	26.3525	20.3566
	26.0451	24.9063	29.1935	24.0603	24.8859
	28.4191	33.2059	30.7638	24.0925	21.2145
	24.0519	24.3238	29.7652	18.3506	27.6355
	18.6099	23.7891	31.0655	28.3659	19.4081
	25.3000	40.2000	19.9000	23.9000	29.3000
	24.7000	28.7000	27.2000	39.9000	44.2000

Variable SPC Example (cont.)

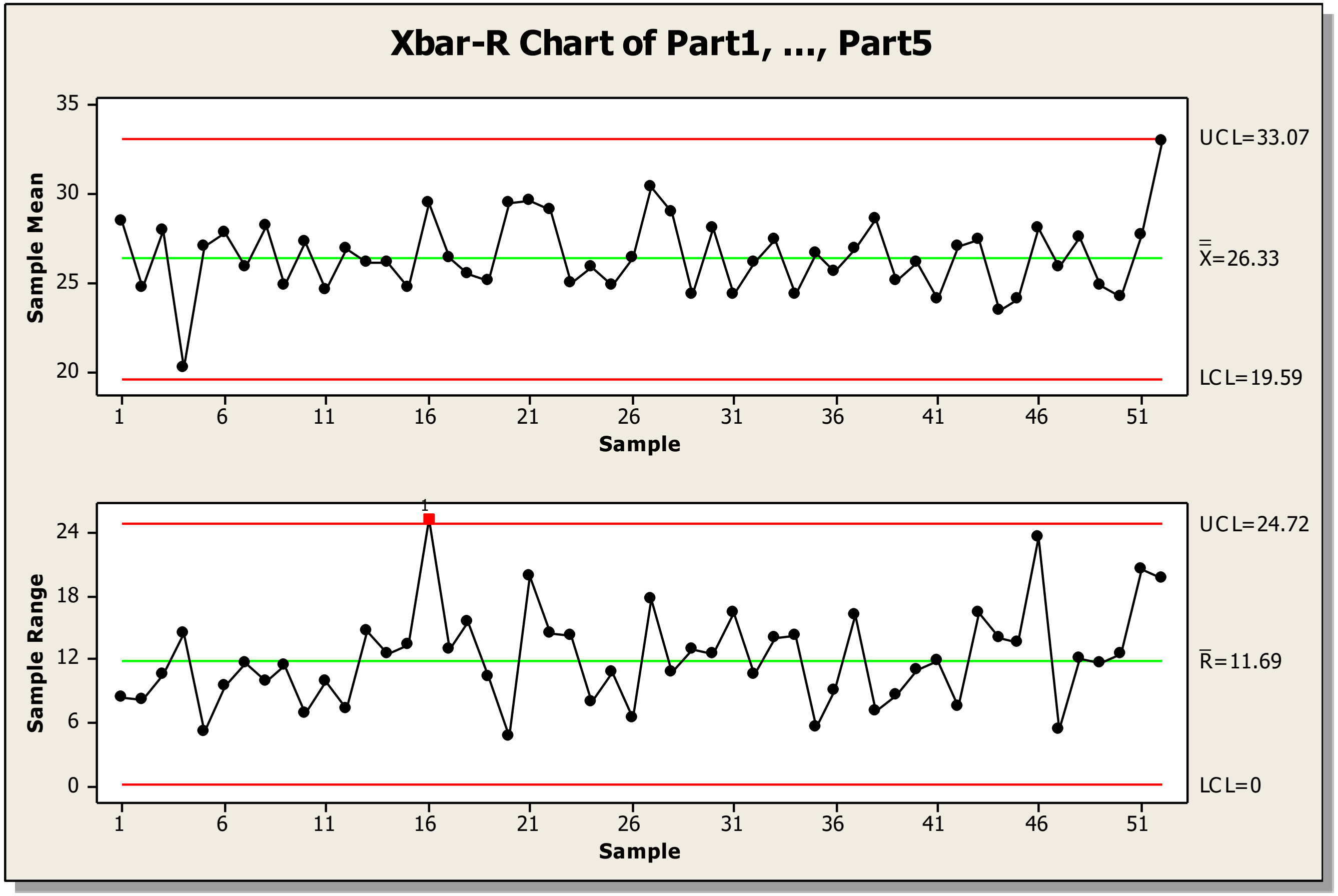


……..Xbar-R Chart Options>Parameters



The updated SPC Chart is shown with no indicated Special Causes in the Xbar Chart. The Mean, UCL and LCL are unchanged because of the completed option .

Because of no Special Causes the process does not refer to the OCAP or Out of Control Action Plan and NO actions are taken.

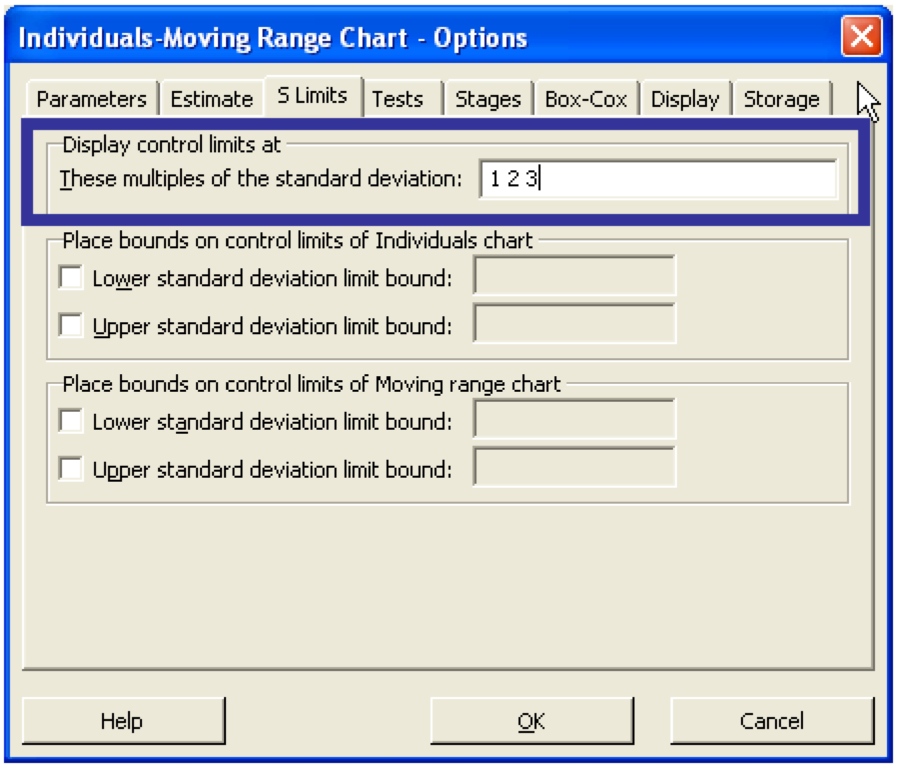


If process changes are documented after this project was closed the Control Limits should be recalculated as in Step 9 of the SPC methodology.

Recalculation of SPC Chart Limits

- Step 9 of the methodology refers to recalculating SPC limits.
- Processes should see improvement in variation after usage of SPC.
- Reduction in variation or known process shift should result in Center Line and Control Limits recalculations.
  - Statistical confidence of the changes can be confirmed with Hypothesis Testing from the Analyze Phase.
- Consider a periodic time frame for checking Control Limits and Center Lines.
  - 3, 6, 12 months are typical and dependent on resources and priorities
  - A set frequency allows for process changes to be captured.
- Incentive to recalculate limits include avoiding false Special Cause detection with poorly monitored processes.
- These recommendations are true for both Variable and Attribute Data

This is possible with ~



Stat>Quality Charts> …..
Options>S Limits "tab"

At this point you should be able to:

- Describe the elements of an SPC Chart and the purposes of SPC
- Understand how SPC ranks in Defect Prevention
- Describe the 13 step route or methodology of implementing a chart
- Design subgroups if needed for SPC usage
- Determine the frequency of sampling
- Understand the Control Chart selection methodology
- Be familiar with Control Chart parameter calculations such as UCL, LCL and the Center Line

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