

Anexas Consultancy Services

Part 1: Introduction to Minitab

Introduction to Minitab

- Minitab is a statistical analysis and graphing program that uses data stored in its worksheet
- We will use follow-along activities, exercises, and brief practices to:
 - Demonstrate how Minitab works
 - Show Minitab output
 - Let you try out the commands and menus

Minitab Follow-Along: Open Minitab, Get Data, Save Files

1. Open Minitab from Windows (follow the four steps listed below)

The screenshot shows the Windows search interface. The search bar at the top contains the text "Type here to search". Below the search bar, the results are categorized into "Best match", "Search the web", "Folders", and "Documents". Under "Best match", "Minitab Statistical Software" is listed as an App. A context menu is open over this result, showing options: "Open", "Run as administrator", "Open file location", "Pin to Start", "Pin to taskbar", and "Uninstall".

Step 1: Click "Start" - A callout box with an arrow pointing to the search bar.

Step 2: Type Minitab - A callout box with an arrow pointing to the search results area.

Step 3: Click "MINITAB Statistical Software." - A callout box with an arrow pointing to the "Minitab Statistical Software" app result.

Minitab Follow-Along: Open Minitab, Get Data, Save Files, cont.

Your screen should look like this:

The screenshot shows the Minitab software interface. On the left, there are four callout boxes with arrows pointing to specific parts of the interface:

- Menu Bar:** Use the menus to do calculations and make plots. (Points to the menu bar at the top of the window.)
- Toolbar:** Go here for easy access to frequently used tools. (Points to the toolbar below the menu bar.)
- Session Window:** Displays text output, such as tables of statistics. (Points to the Navigator pane on the left side.)
- Data Window:** Where you enter, edit, and view the data. (Points to the worksheet grid at the bottom.)

The Minitab window itself shows the title bar "Minitab - Untitled" and the user name "Gopi Krishna Dontha - Trial". The menu bar includes File, Edit, Data, Calc, Stat, Graph, View, Help, Assistant, and Additional Tools. The toolbar contains various icons for file operations, editing, and data analysis. The Navigator pane is empty. The main workspace displays the Minitab logo and keyboard shortcuts: Open (Ctrl+O), New Project (Ctrl+Shift+N), and New Worksheet (Ctrl+N). Below this is a worksheet grid with columns labeled C1 through C21 and rows numbered 1 through 13. The cell at the intersection of column C7 and row 3 is selected.

Minitab Follow-Along: The Standard Toolbar

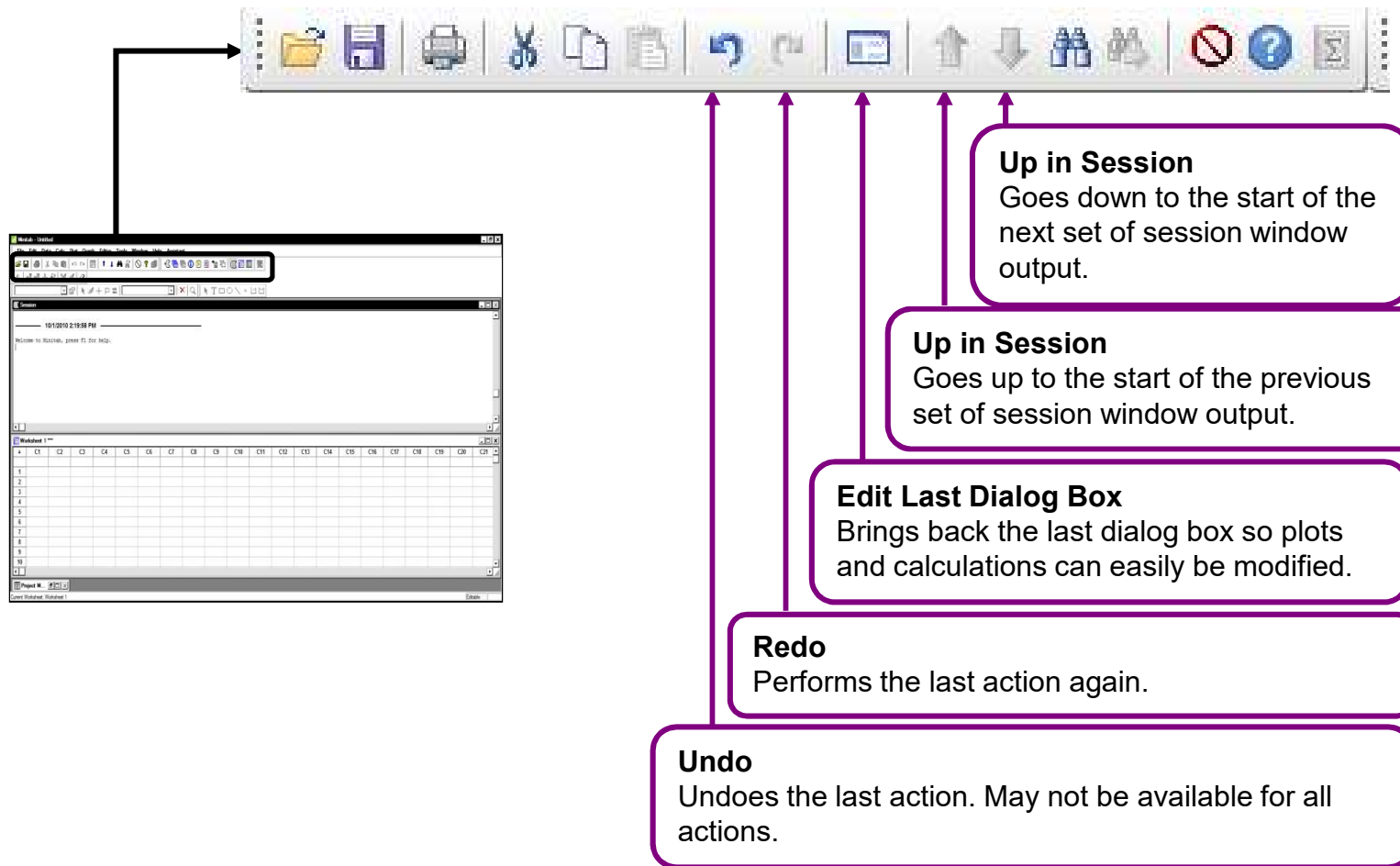
2. Get familiar with the toolbars: The Standard Toolbar

The image shows a screenshot of the Minitab Standard Toolbar. A purple arrow points from the toolbar to a callout box. Below the toolbar, six callout boxes are arranged in a descending staircase pattern, each with an arrow pointing to a specific icon in the toolbar. The callout boxes contain the following text:

- Open**
Opens a project, but not a worksheet.
- Save**
Saves a project, but not a worksheet.
- Print**
Prints contents of the active window.
- Cut**
Cuts the highlighted selection.
- Copy**
Copies the highlighted selection.
- Paste**
Pastes the copied text.

Minitab Follow-Along: The Standard Toolbar, cont.

2. Get familiar with the toolbars: The Standard Toolbar (cont.)



The image shows a screenshot of the Minitab Standard Toolbar with five callout boxes explaining specific icons. The callout boxes are:

- Undo**
Undoes the last action. May not be available for all actions.
- Redo**
Performs the last action again.
- Edit Last Dialog Box**
Brings back the last dialog box so plots and calculations can easily be modified.
- Up in Session**
Goes up to the start of the previous set of session window output.
- Up in Session**
Goes down to the start of the next set of session window output.

Minitab Follow-Along: The Standard Toolbar, cont.

2. Get familiar with the toolbars: The Standard Toolbar (cont.)

The image shows a screenshot of the Minitab Standard Toolbar with five callout boxes explaining specific icons. The callout boxes are:

- Find in Data or Session**
Finds the first occurrence of entered string.
- Find Next**
Finds the next occurrence of the string entered in the Find dialog box.
- Cancel Command or Calculation**
Used to cancel a command that is taking too long to run.
- Help**
Launches the online help function.
- Stat Guide**
Explains some common statistical procedures after they are performed.

Minitab Follow-Along: The Project Manager Toolbar, cont.

2. Get familiar with the toolbars: The Project Manager Toolbar (cont.)

Assign Formula to Column
Assigns a selected formula to a column.
New Feature

Close All Graphs
Used to permanently get rid of all graphs.

Show Project Manager
Enter project manager view of active plot or worksheet.

Go to Data Window
Toggle between or among all data windows.

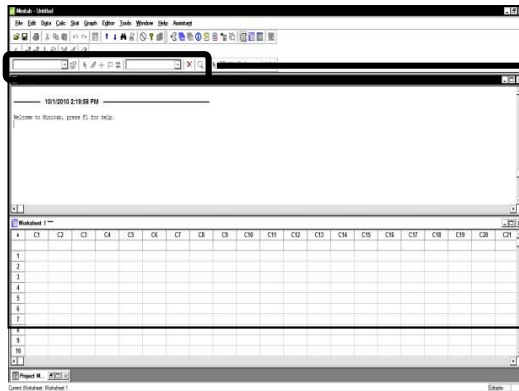
Go to Session Window
Go to the session window.

Show Experimental Design
If the worksheet is a designed experiment, shows its properties.

Minitab Follow-Along: The Graph Editing Toolbar

3. Review another useful toolbar: The Graph Editing Toolbar

Use the Tools > Toolbars menu command to select Graph



Add List
Used to add a graph element, such as a fitted line.

Crosshair Mode
Get the coordinates of any point on a graph.

Brush Mode
Used to identify points on a graph.

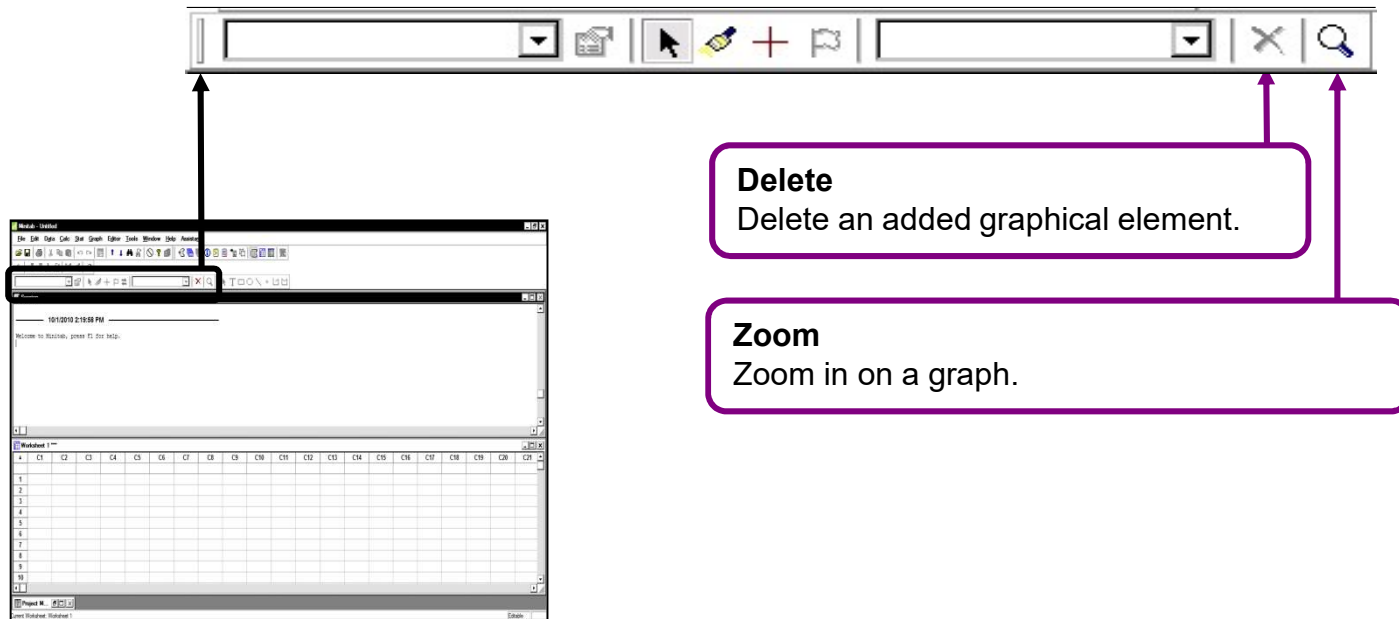
Select Mode
Activates select mode so you can click on graph elements.

Edit Selected Graph Element
Brings up the dialog box for editing the selected graph element.

Select a Graph Element List
Select a part of the plot (e.g., X scale) by name.

Minitab Follow-Along: The Graph Editing Toolbar, cont.

3. Review another useful toolbar: The Graph Editing Toolbar (cont.)



Minitab Follow-Along: Open Minitab, Get Data, Save Files

4. Type data into the worksheet

a. Name the columns:

Click a column name cell and type the column names:

Quarter (C1)

Date (C2)

Sales (\$k) (C3)

column name cell column number active cell

data direction arrow

row number

The active cell moves down after pressing Enter. Click on the data direction arrow if you wish to change directions so the active cell moves across after pressing Enter.

	C1	C2	C3	C4	C5
	Quarter	Date	Sales (\$k)		
1					
2					
3					
4					
5					
6					
7					
8					

Minitab Follow-Along: Open Minitab, Get Data, Save Files, cont.

b. Place the cursor where you want it; enter the following data:

<u>Quarter</u>	<u>Date</u>	<u>Sales (\$k)</u>
Q1	3/30	100
Q2	6/30	78
Q3	9/30	99
Q4	12/30	103

Minitab Follow-Along: Open Minitab, Get Data, Save Files, cont.

c. Your worksheet should look like this

The D means this is a date/time column.

The T means this is a text column.

This is a numerical column.

Be sure to press Enter after filling in the last value.

	C1-T	C2-D	C3	C4	C5
	Quarter	Date	Sales (\$k)		
1	Q1	3/30	100		
2	Q2	6/30	78		
3	Q3	9/30	99		
4	Q4	12/30	103		
5					
6					

Minitab Follow-Along: Open Minitab, Get Data, Save Files, cont.

5. Save the worksheet

Select the Save Current Worksheet from the file menu

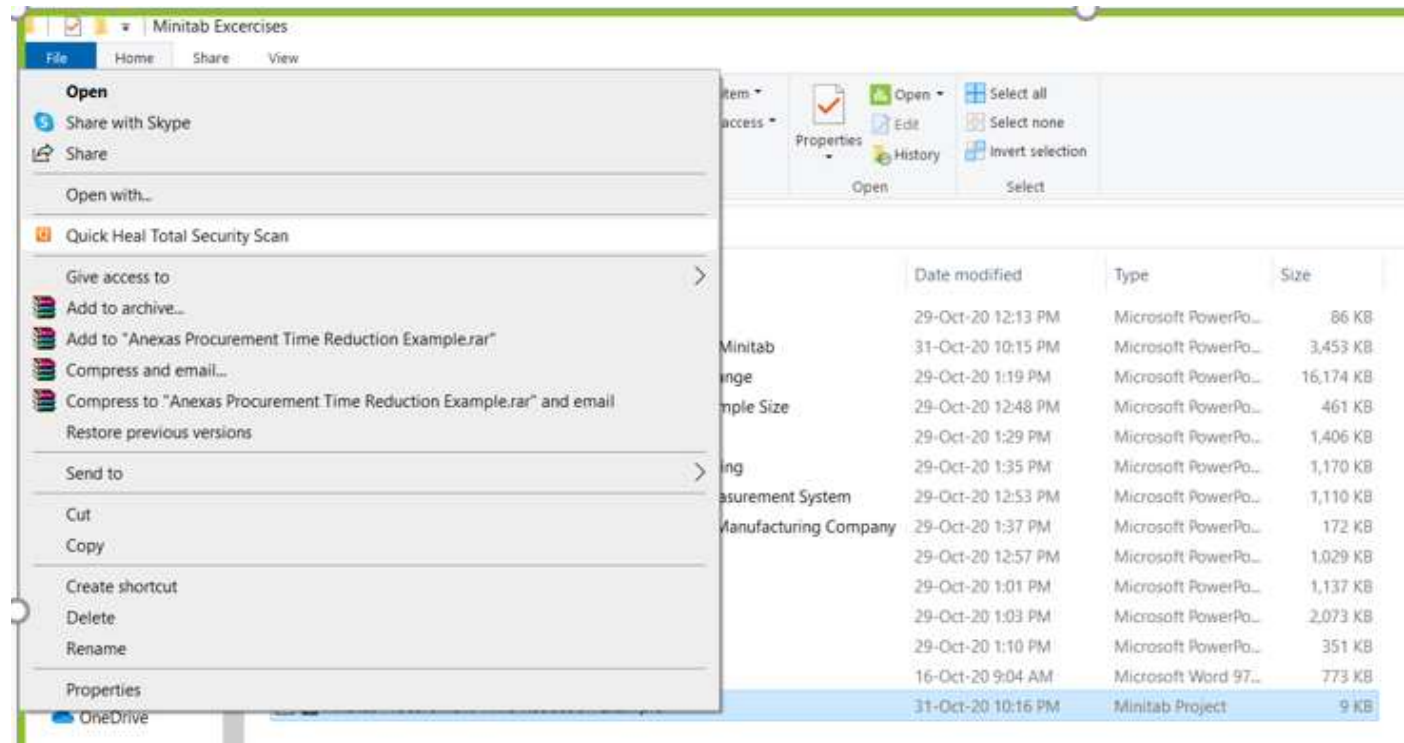
(From now on, we will abbreviate menu commands like this:

File > Save Current Worksheet)

Minitab Follow-Along: Open Minitab, Get Data, Save Files, cont.

6. Open file “Anexas Procurement case study”

- a. Right Click on the file name
- b. Click Open



Minitab Follow-Along: Open Minitab, Get Data, Save Files, cont.

7. Save a Minitab project

- A Minitab project contains all your work: data worksheet(s), text output, graphs, and more
- To save your project:
File > Save Project
- Name your file:
Anexas Procurement case study
(Minitab automatically assigns projects the extension **.MPJ**, e.g., File Name.MPJ)

Minitab Follow-Along: Open Minitab, Get Data, Save Files, cont.

8. If you need help:

Help > (Choose a topic)

9. Close Minitab:

File > Exit

Three Minitab Column Formats

Column formats

■ Text

- Combination of letters or numbers
- Denoted as **T** in the column heading (e.g., C1T)

■ Date/Time

- Time in seconds, minutes, hours, days, months, or years
- Denoted as **D** in the column heading (e.g., C2D)

■ Numerical

- A positive or negative number expressed as a decimal or integer
 - **Not flagged** in column heading (e.g., C3)

Three Minitab Column Formats, cont.

Using the formats

- Minitab automatically chooses a format based on the data entered in the column
- You can change the column format if you wish
Data > Change data type > ...
- Missing values appear as:
 - Blanks [] in Text columns
 - Asterisks [*] in Date/Time or Numerical columns

Introduction to Minitab Follow-Along Exercises: Using the Basic Tools

Background:

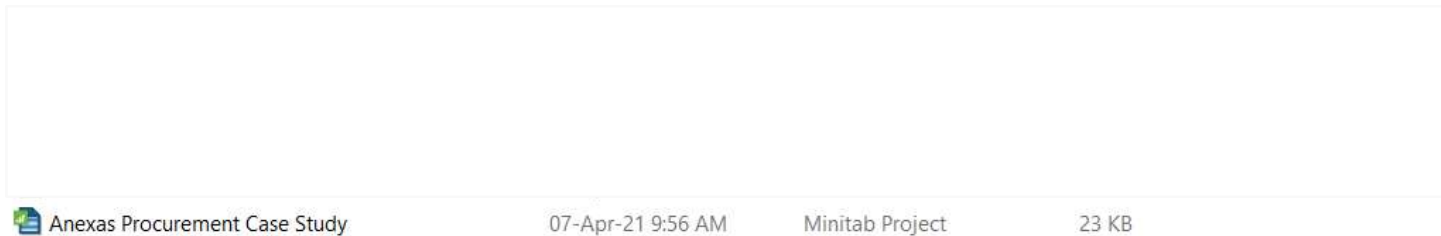
- You work in Procurement Department in Anexas Engineering Company
- Green Belt has collected a Procurement data given in the file *Anexas Procurement case study*
- Conduct Preliminary Minitab Statistical Analysis
- Make the Graphical Summary, Histogram and Time Series Plot

Minitab Follow-Along: Get Familiar with the Data

1. Open Minitab and retrieve the data set

File > Open worksheet >

Anexas Procurement case study.mpx > Open



Minitab Follow-Along: Get Familiar with the Data, cont.

2. Examine the data in the worksheet

- a. How many columns are there?
 - What are their names?
 - What format: Text, Date/Time, or Numerical?
 - What type of data: discrete or continuous?
 - What are the units for the Procurement Time: Days or Hours?

C23	C24	C25	C26-T	C27-T	C28
PO no.	Delivery Time	Vendor Selection Time	Clarity	Approval Delay	Procurement Time
654375	10	6	Medium	No	121
456789	14	3	Medium	No	125
987654	18	4	Low	No	130
567867	11	5	High	No	123
987654	9	3	High	Yes	122
234569	16	4	Medium	Yes	126
987654	12	5	Medium	Yes	124
345678	11	3	High	Yes	123
345678	10	4	High	No	122
567899	8	5	High	No	119
789034	14	6	Medium	No	124
123987	15	3	Medium	No	126
235468	14	4	Medium	Yes	124
987654	13	5	Low	Yes	124
234567	17	6	Low	Yes	129

Minitab Follow-Along: Get Familiar with the Data, cont.

2. Examine the data in the worksheet (cont.)

b. How many rows are there?

– What is the time span?

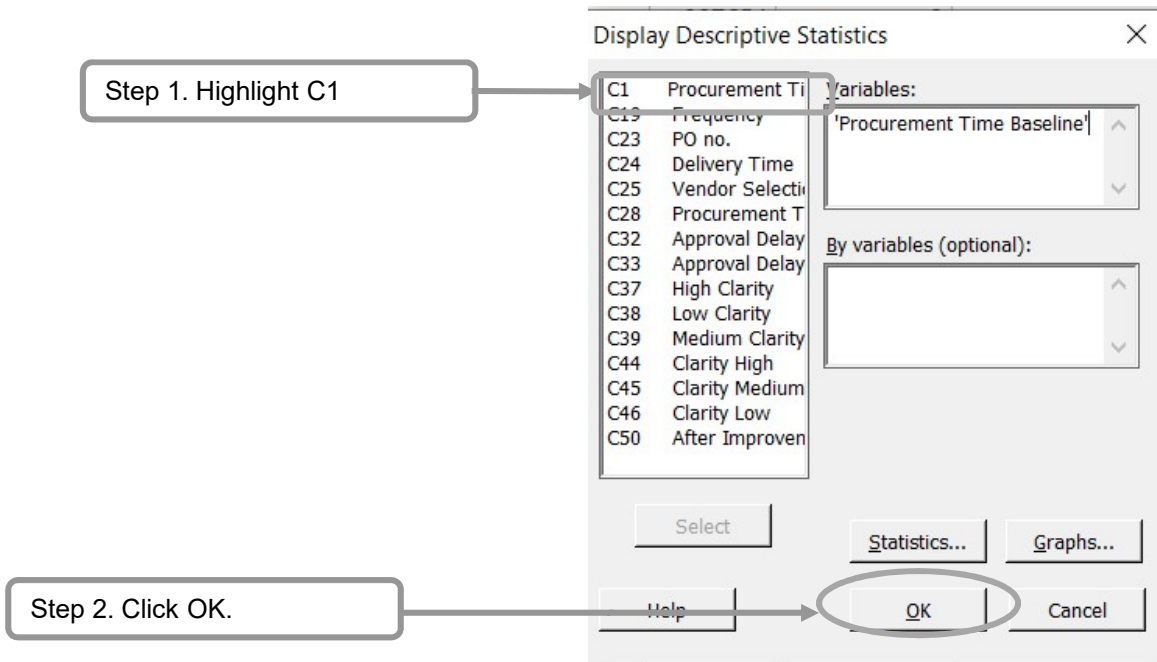
c. Is there a problem with the format of any of the columns?

C23	C24	C25	C26-T	C27-T	C28
PO no.	Delivery Time	Vendor Selection Time	Clarity	Approval Delay	Procurement Time
654375	10		6 Medium	No	121
456789	14		3 Medium	No	125
987654	18		4 Low	No	130
567867	11		5 High	No	123
987654	9		3 High	Yes	122
234569	16		4 Medium	Yes	126
987654	12		5 Medium	Yes	124
345678	11		3 High	Yes	123
345678	10		4 High	No	122
567899	8		5 High	No	119
789034	14		6 Medium	No	124
123987	15		3 Medium	No	126
235468	14		4 Medium	Yes	124
987654	13		5 Low	Yes	124
234567	17		6 Low	Yes	129

Minitab Follow-Along: Get Familiar with the Data, cont.

3. Compare the means and standard deviations Procurement Time column

Stat > Basic Statistics > Display Descriptive Statistics >
(Select C1) > OK



Minitab Follow-Along: Get Familiar with the Data, cont.

The session window holds the output from this command

Statistics

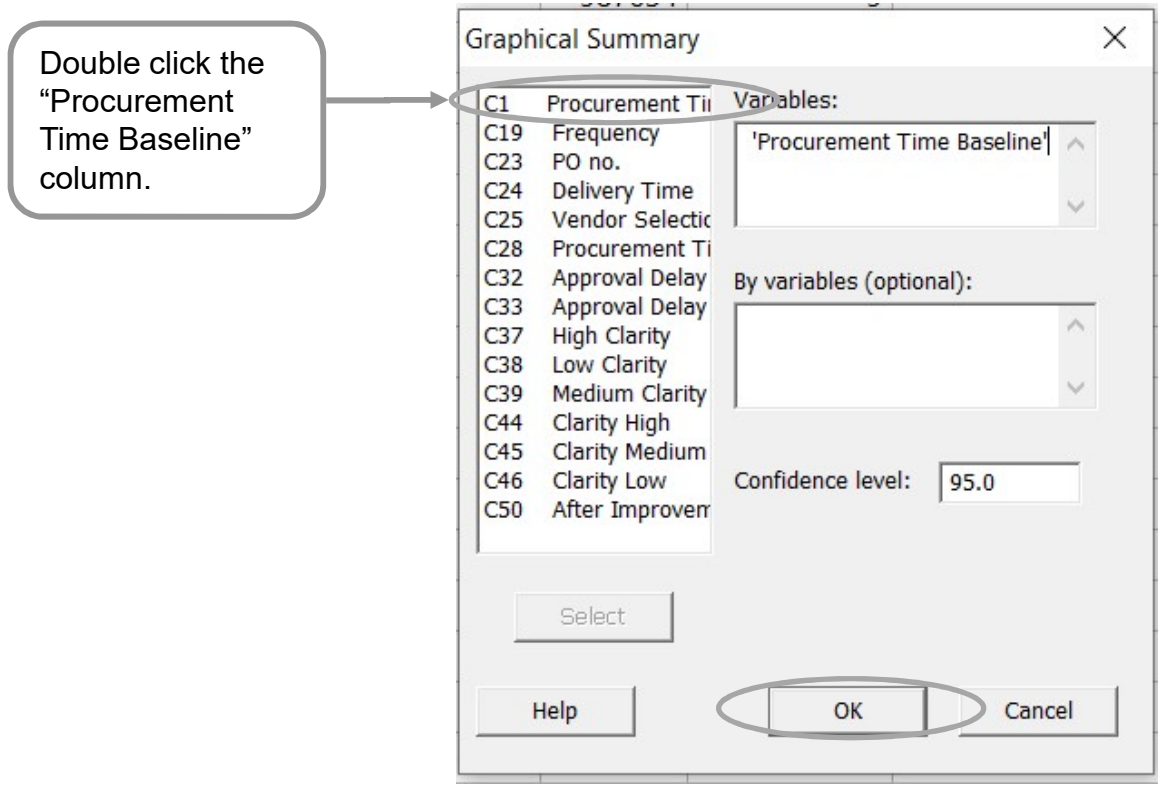
Variable	Mean	StDev	Variance	Minimum	Q1	Median	Q3	Maximum	Range
Procurement Time	124.13	2.85	8.12	119.00	122.00	124.00	126.00	130.00	11.00

Variable	IQR	Mode	N for Mode
Procurement Time	4.00	124	4

Minitab Follow-Along: Get Familiar with the Data, cont.

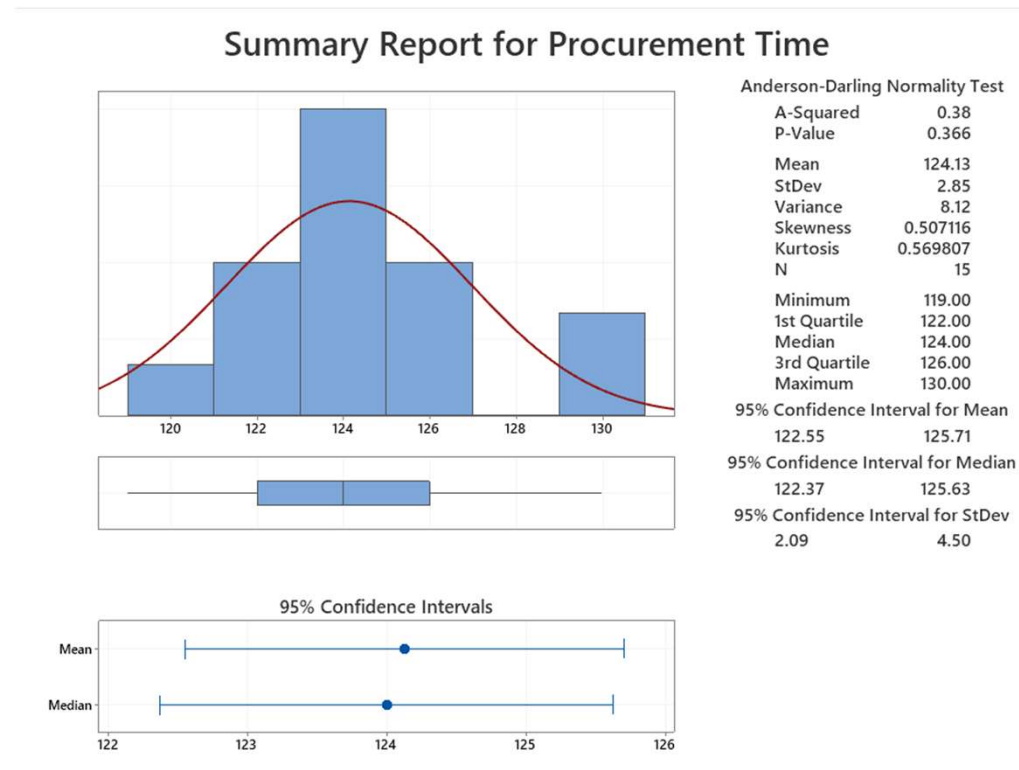
4. Request a graphical summary of the data

Stat > Basic Statistics > Graphical Summary...



Minitab Follow-Along: Get Familiar with the Data, cont.

A plot window holds the mean and standard deviation along with other output



Minitab Follow-Along: Make Time Plots

Data: Anexas Procurement case study

1. Get a time series plot of “Procurement Time”

Graph > Time Series Plot > Simple > (Select “Procurement Time” in Y Box) > OK

The image shows two screenshots from the Minitab software interface, illustrating the steps to create a time series plot.

Step 1: Choose Simple Time Plot. The first screenshot shows the 'Time Series Plots' dialog box. The 'Simple' option is selected and circled. The 'OK' button at the bottom is also circled.

Step 2: Click “OK.” This step is indicated by an arrow pointing from the 'OK' button in the first screenshot to the 'OK' button in the second screenshot.

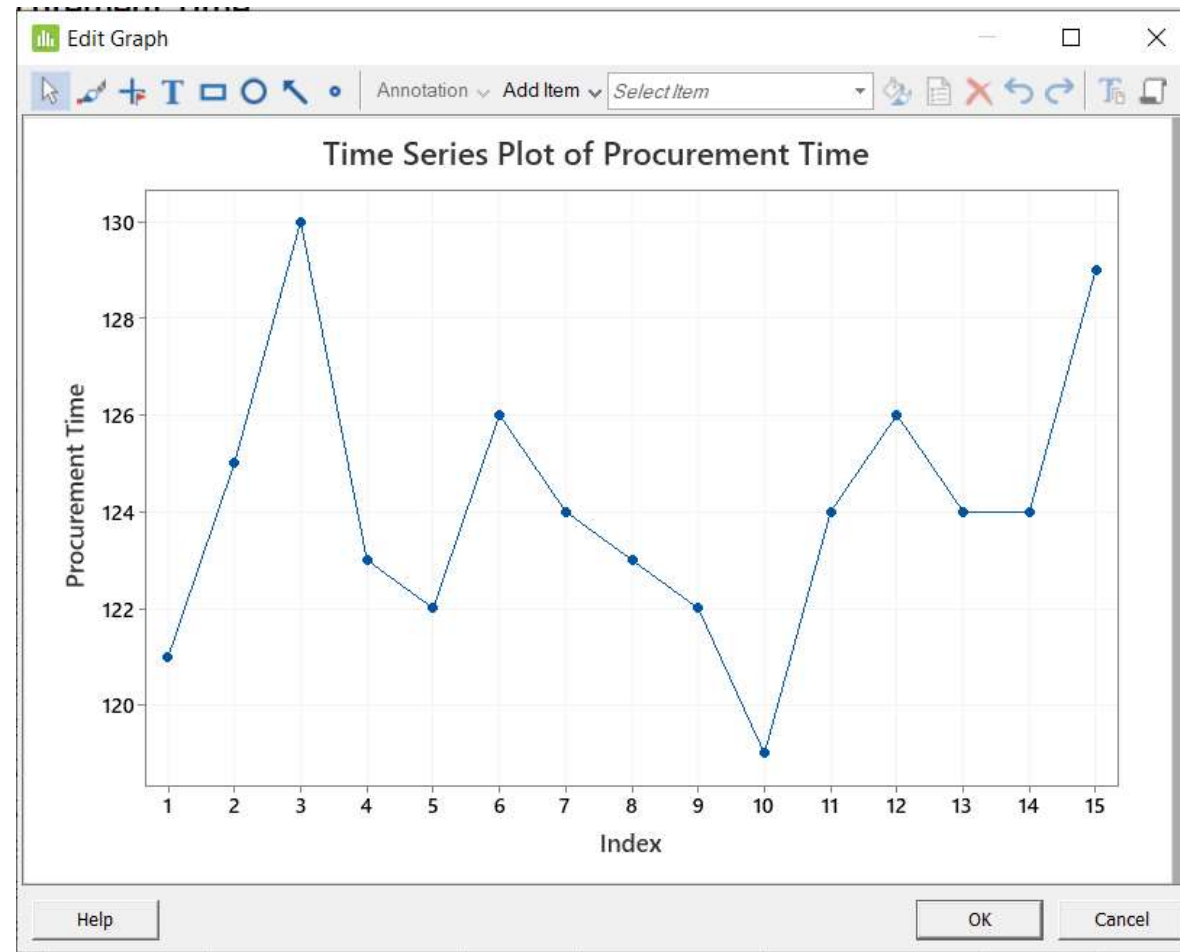
Step 3: Double Click the “Procurement Time” column. The second screenshot shows the 'Variables' list. The 'Procurement Time' column (C28) is double-clicked and circled. The 'OK' button at the bottom is also circled.

Step 4: Click “OK.” This step is indicated by an arrow pointing from the 'OK' button in the second screenshot to the 'OK' button in the third screenshot.

The third screenshot shows the 'Variables' list with 'Procurement Time' selected in the 'Variables' box. The 'OK' button at the bottom is circled.

Minitab Follow-Along: Make Time Plots, cont.

Result:



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Part 2: Data Analysis

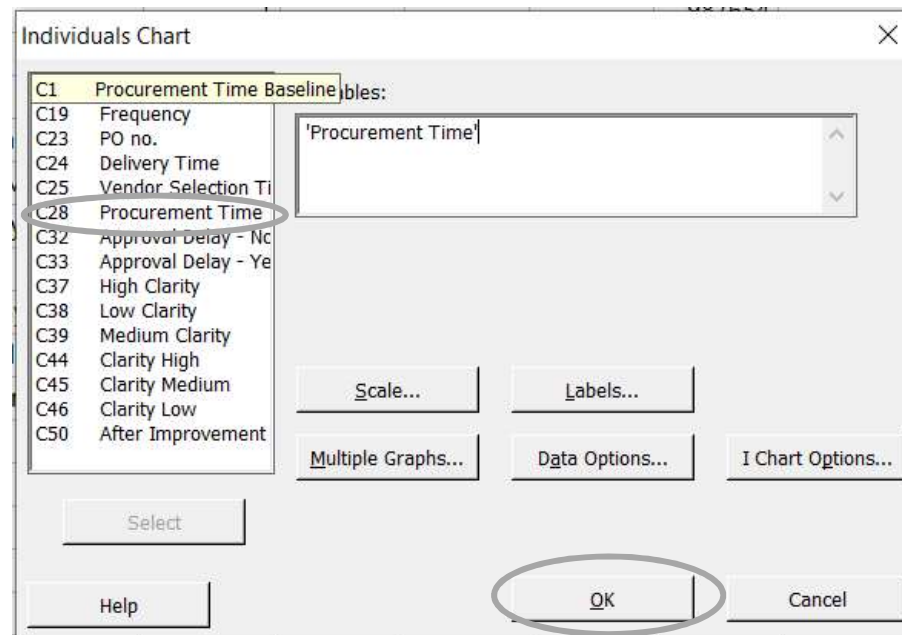
Minitab Follow-Along: Control Charts for Individuals

Data: Anexas Procurement case study

Part 1: Create charts for Procurement Time

1. Make an individuals control chart for the Procurement time

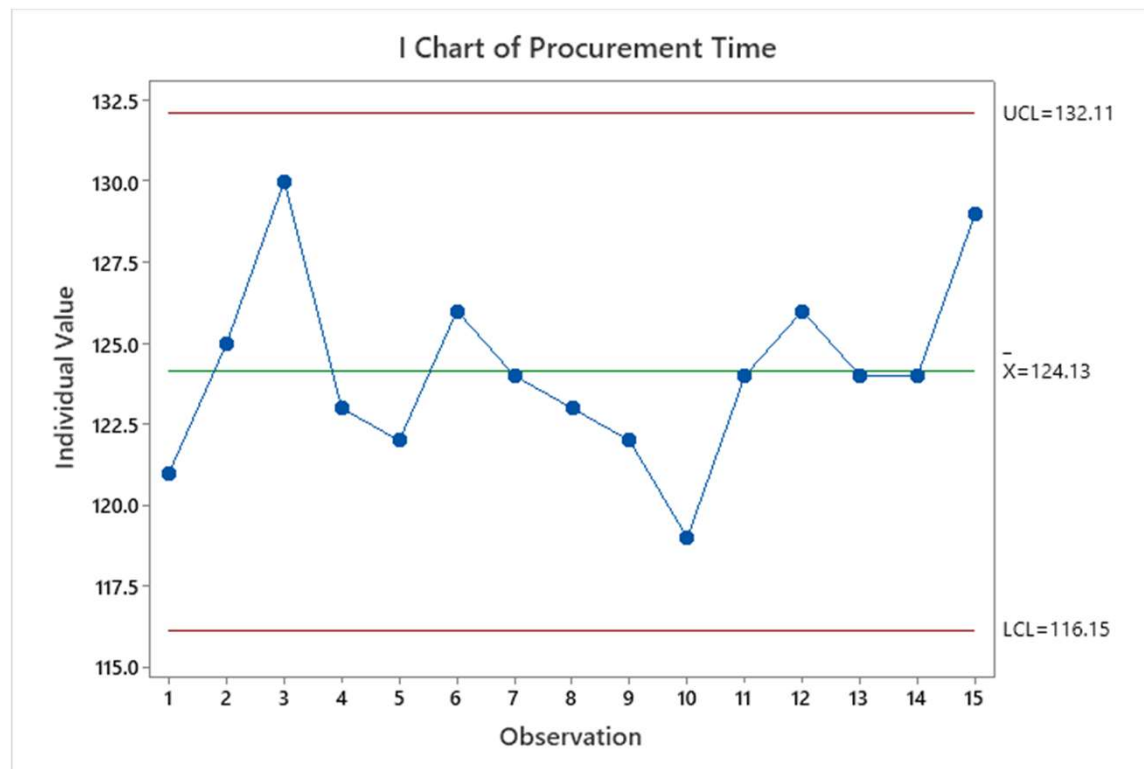
Stat > Control Charts > Variables Charts for Individuals > Individual > (Select 'procurement Time') > OK



Minitab Follow-Along: Control Charts for Individuals, cont.

2. Turn on more special cause signals

Stat > Control Charts > Variables Charts for Individuals > Individuals > (Select 'I chart options...', Tests Tab) > (Select 'Perform the following tests for special causes') > (Check the first 4 boxes) > OK >



Stratified Control Charts

Definition

- A stratified control chart shows the data points coded by the categories of another variable; they are commonly used to compare “before” and “after” results
 - Make a separate control chart for each category, ensuring that both axes are scaled the same, and compare charts side by side
 - Plot all the data on one control chart, but compute and draw control limits separately for each “before” and “after” time period

Minitab Exercise: “Before” and “After” Individuals Control Charts

Objective: Practice making and editing control charts for individuals in Minitab

Data: Anexas Procurement case study

Project update:

- We can create Improved Procurement Time in the same case study after implementing solutions.

Time: 15 minutes

Minitab Exercise: “Before” and “After” Individuals Control Charts, cont.

Instructions:

- Answer the following questions:
 1. **What is the Average of Improved Procurement Time** Look at the created column and determine whether any improvement has happened or not ?
 2. **Make individuals control charts** look for special cause signals—can you verify the results of the new process?
 3. **What are the control limits and average** for the new process only?
 4. **Create Time Series plot for the Improved Procurement Time**
 5. **(Optional) Edit the control charts** any way you'd like

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Histograms, Dot Plots,
Box Plots

Minitab Follow-Along: Histograms and Dot Plots

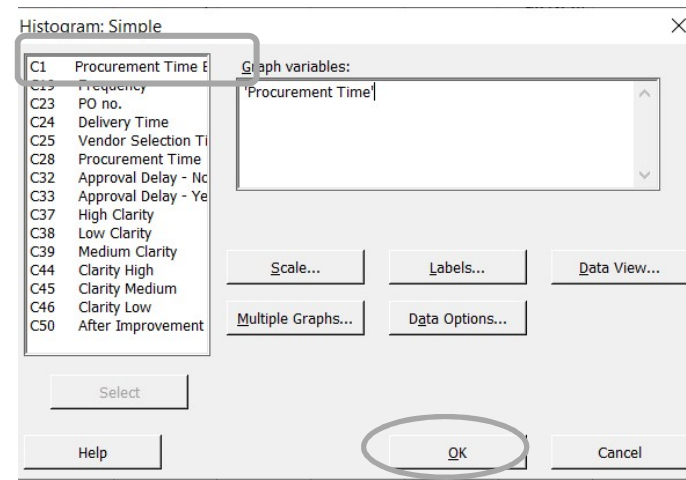
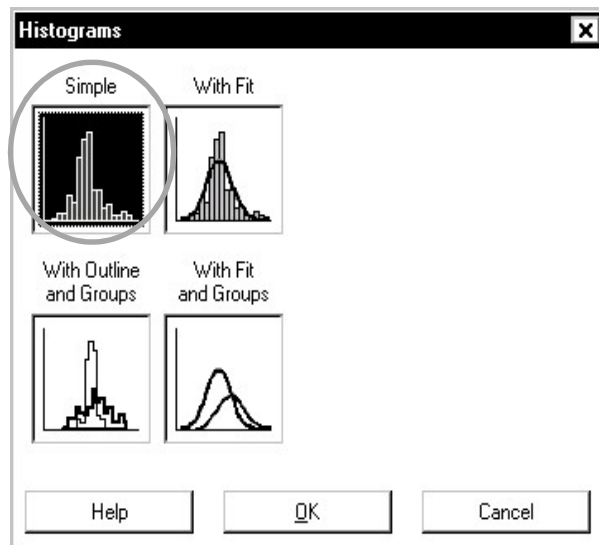
1. Use the Minitab data set:

Anexas Procurement case study

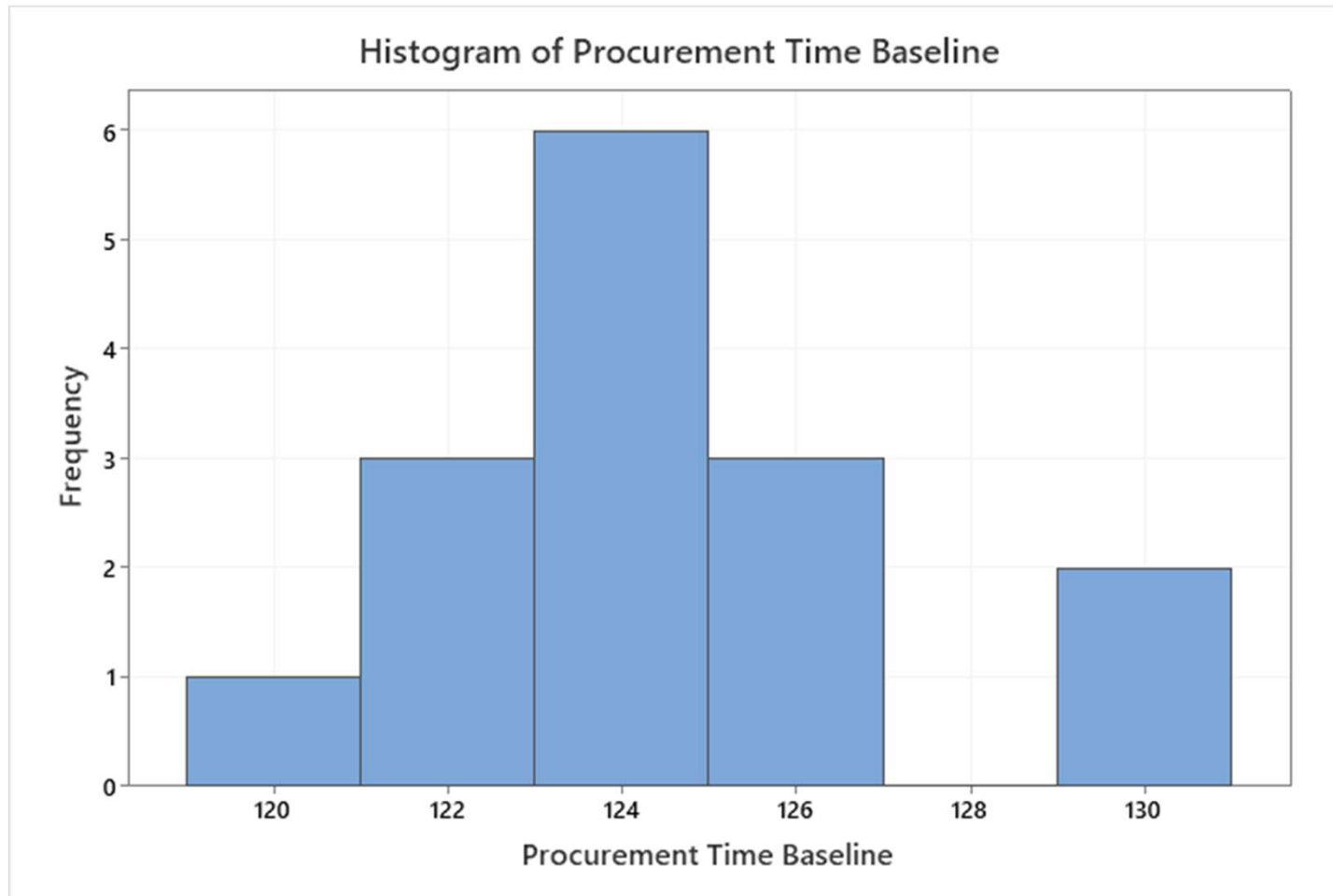
2. Make histograms of Procurement Time Baseline

Graph > Histogram > Simple > OK >

Double click the variable, Procurement Time Baseline> OK



Minitab Follow-Along: Histograms, Dot Plots, and Box Plots

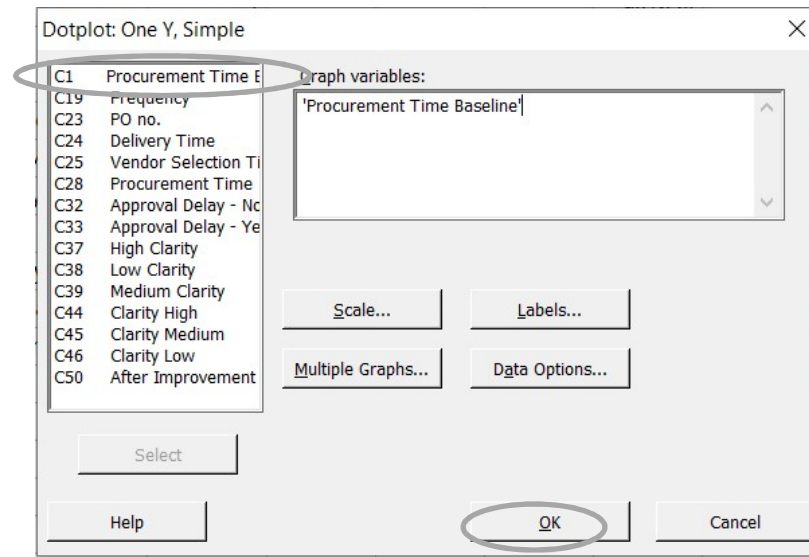
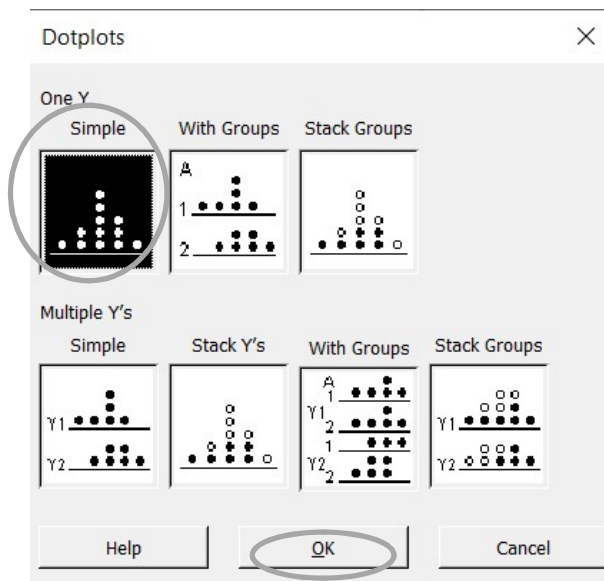


Minitab Follow-Along: Histograms, Dot Plots, and Box Plots, cont.

3. Make a Dotplot of the Procurement Time Baseline

Close all graphs before continuing on

Graph > Dotplot > One Y > Simple > OK
(Select Procurement Time Baseline) > OK

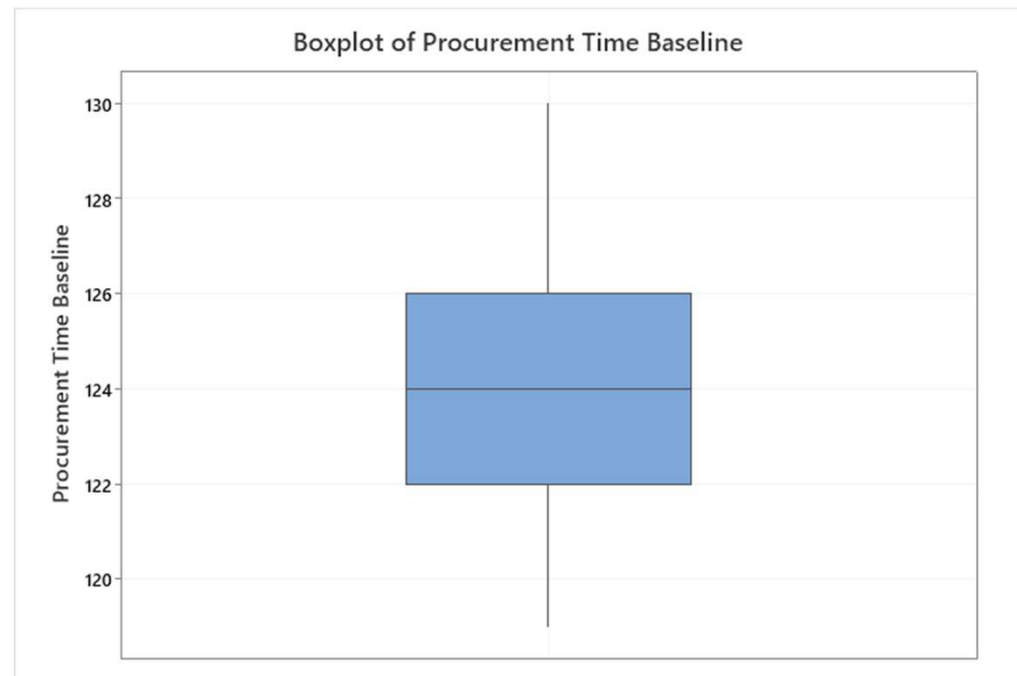
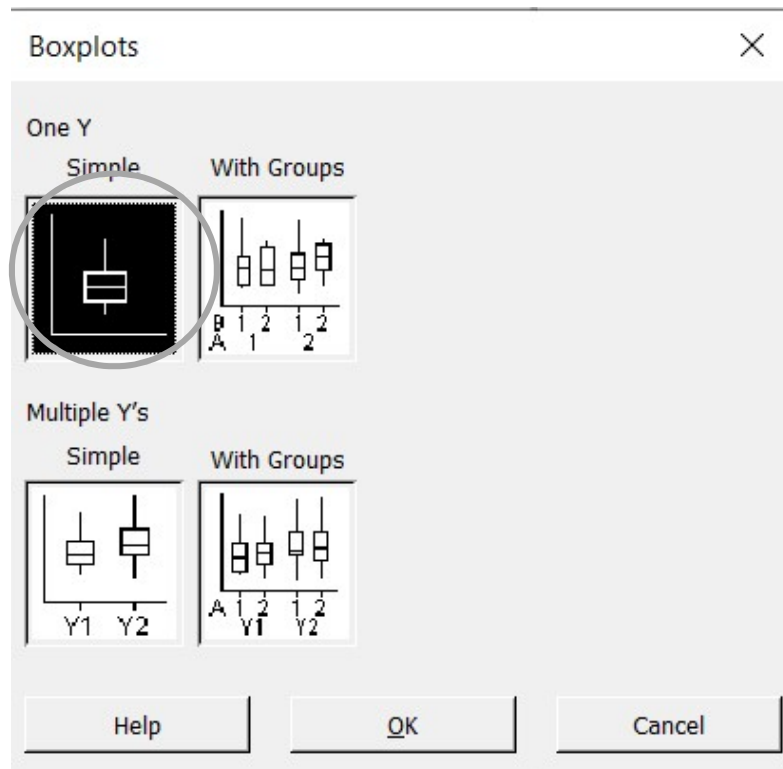


Minitab Follow-Along: Histograms, Dot Plots, and Stratified Box Plots, cont.

4. Make a simple boxplot of Procurement Time Baseline

Graph > Boxplot > One Y > Simple > OK >

(Select Procurement Time Baseline) > OK



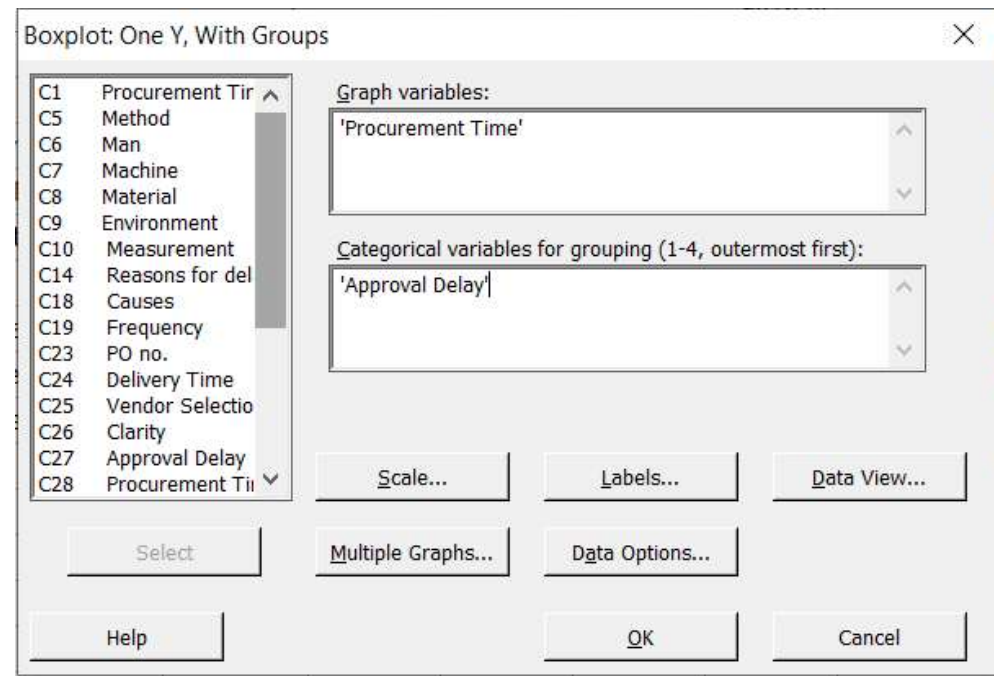
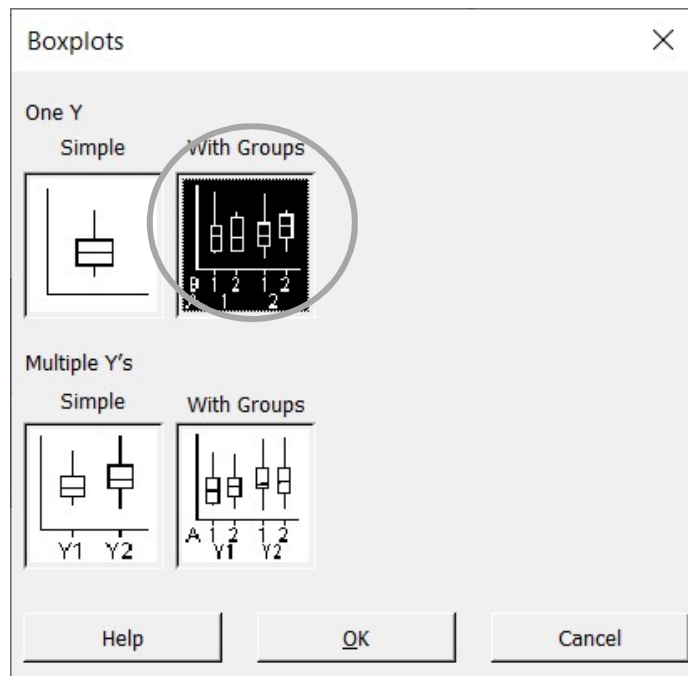
Minitab Follow-Along: Histograms, Dot Plots, and Stratified Box Plots, cont.

5. Make a stratified boxplot of Procurement Time Baseline

Graph > Boxplot > One Y > With Groups > OK >

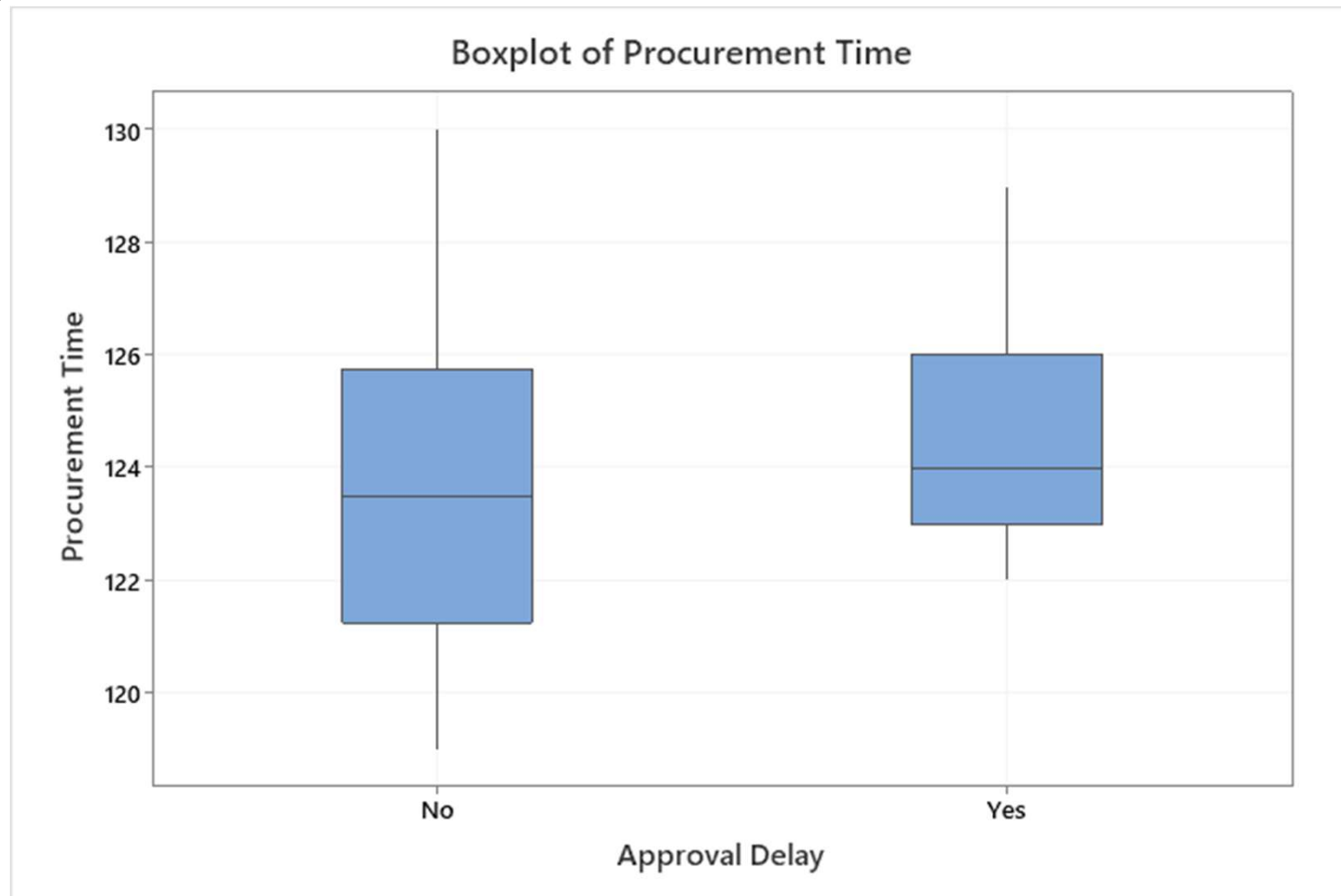
(Select Procurement Time Baseline) > OK

(Select under Graph variable, Procurement Time and categorical variable, Approval Delay)



Minitab Follow-Along: Histograms, Dot Plots, and Stratified Box Plots, cont.

Result:



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Pareto Charts

Minitab Follow-Along: Pareto Charts

- Project update: possible reasons for Delay in Procurement were collected and which is given in column C14 (Reasons for Delay). Prepare a Pareto and list down the root causes.

- Open the data file:**

Anexas Procurement case study

2. Examine the data:

What does column 14 contain?

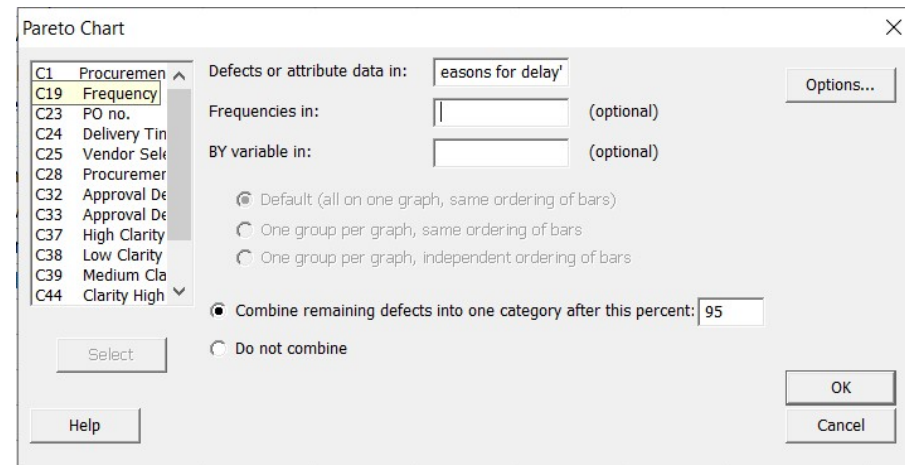
3. Make a Pareto chart

Stat > Quality Tools >

Pareto Chart >

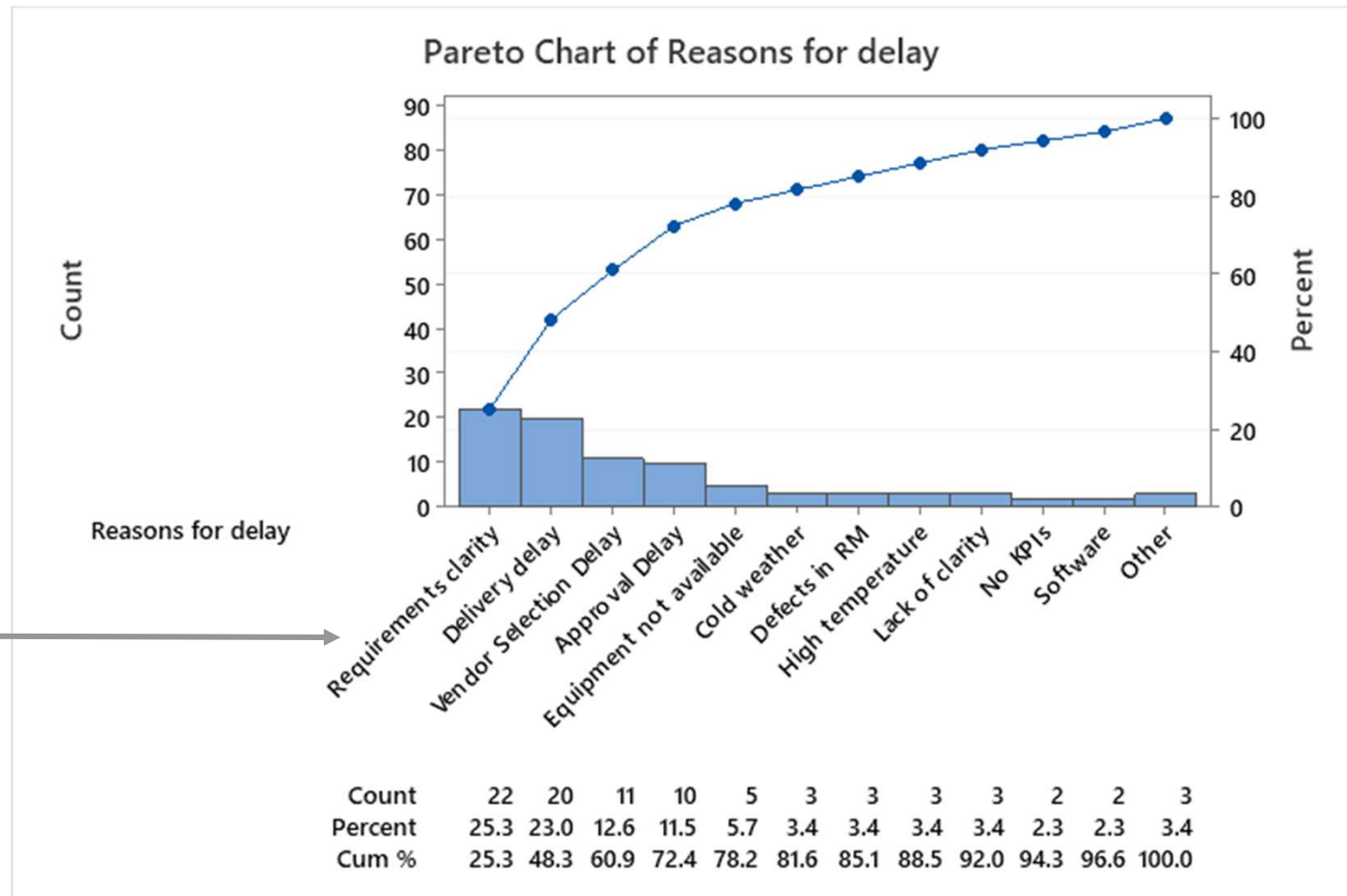
(Select “Reasons for Delay”)

> OK



Minitab Follow-Along: Pareto Charts, cont.

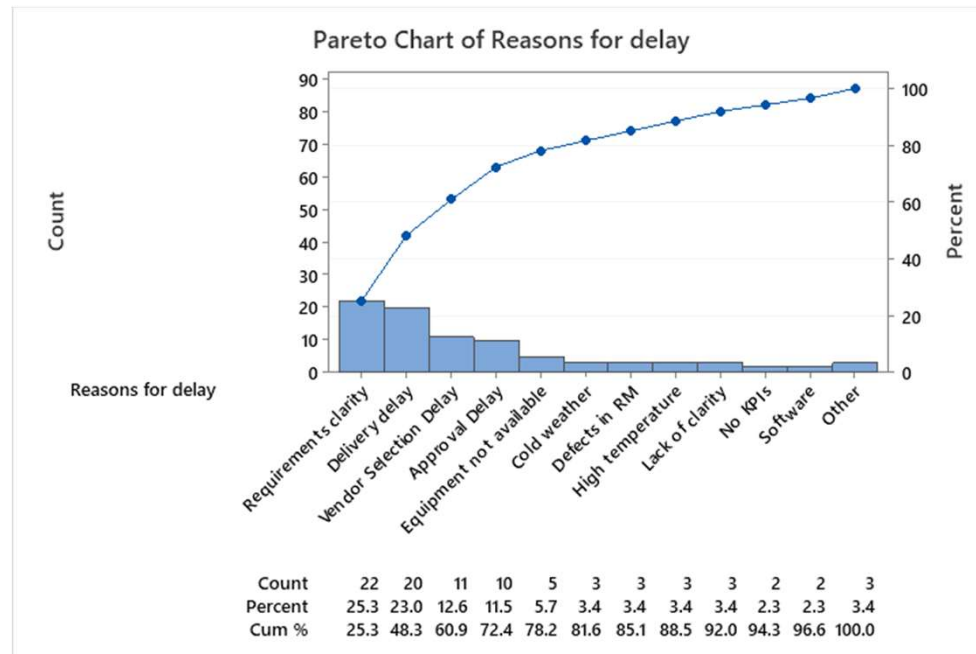
Result:



Note:
Different reasons for the delay are listed

Exercise Answers: Pareto Charts

Conclusions



- Requirements Clarity is the biggest single contributor to Procurement Delays
- Together, the top five categories (Requirements Clarity, Delivery Delay, Vendor Selection Delay, Approval Delay and Equipment not available) account for almost 80% of the problem

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Part 3: Verify Causes

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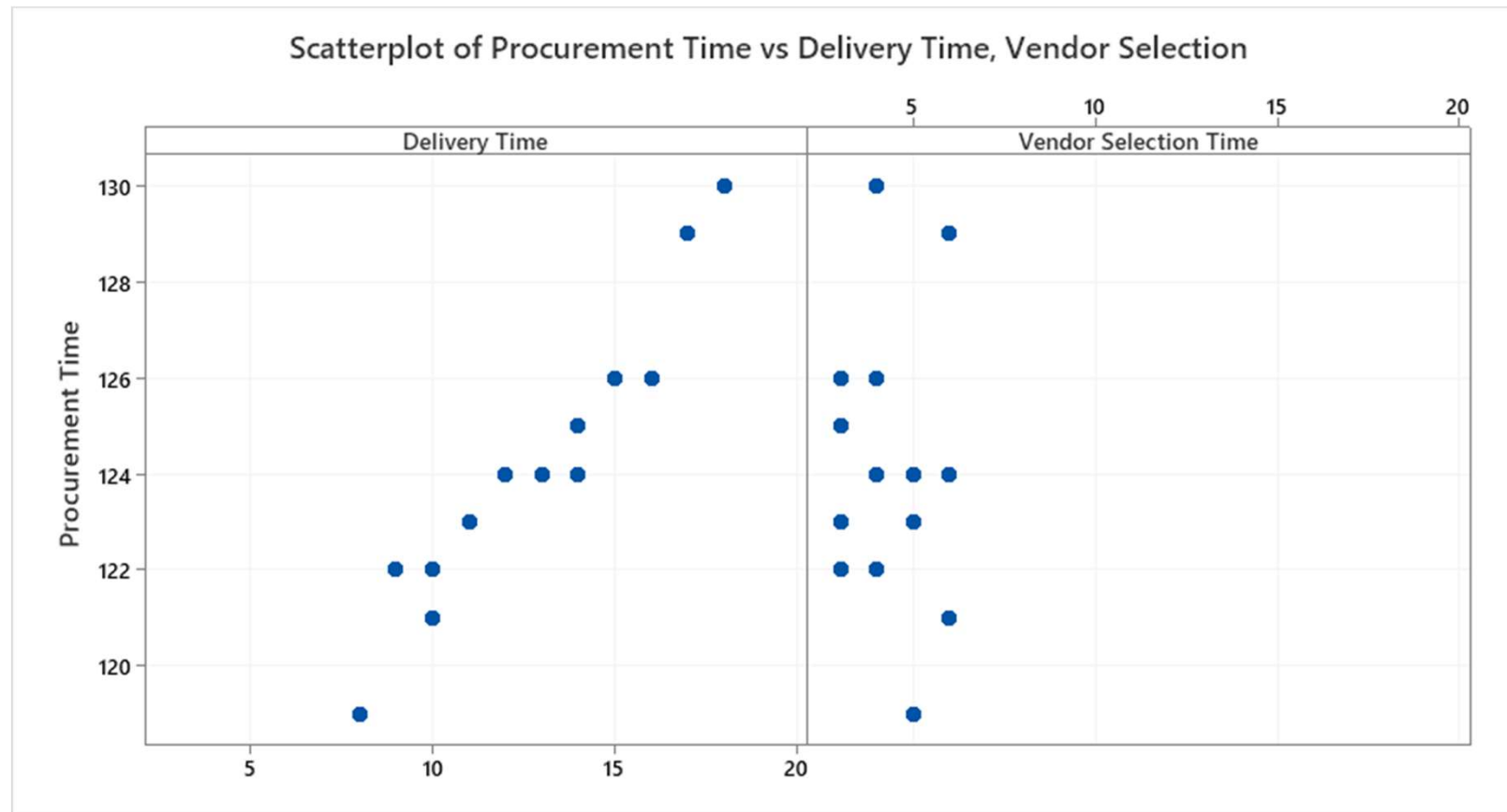
Scatter Plots

Minitab Follow-Along: Scatter Plots

1. **Use Anexas Procurement case study Minitab worksheet:**
2. **Make a scatter plot of Procurement Time versus Delivery Time and Vendor Selection Time:**
 - a. Determine which is X and Y:
 - Delivery Time and Vendor Selection Time (input) affects Procurement Time (output)
 - Y = Procurement Time
 - X = Delivery Time and Vendor Selection Time
 - b. Graph > Scatter plot > Simple > OK:
(Select “Procurement Time” for Y1 and “Delivery Time” for X1) >
(Select “Procurement Time” for Y2 and “Vendor Selection Time” for X2) >
Multiple Graphs > (Select “In separate panels of the same graphs”) >
(Select “Same Y” and “Same X”) > OK > OK

Minitab Follow-Along: Scatter Plots, cont.

Result:



Follow-Along: Scatter Plots, cont.

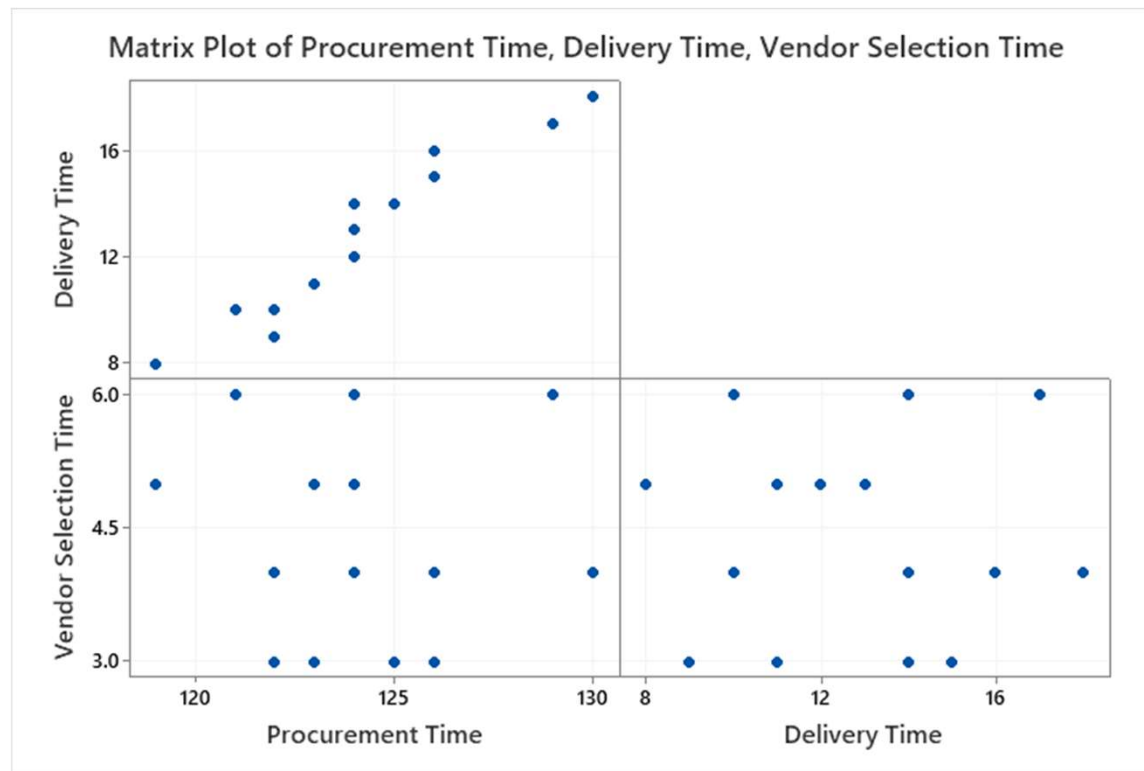
3. Other ways to make multiple scatter plots:

Graph > Matrix Plot > Simple > OK

(Select 3 variables: Delivery Time, Vendor Selection Time, Procurement Time) >

(Click on “Matrix Options...”) > (Select “Lower left”) (Select “Boundary”) >

OK > OK

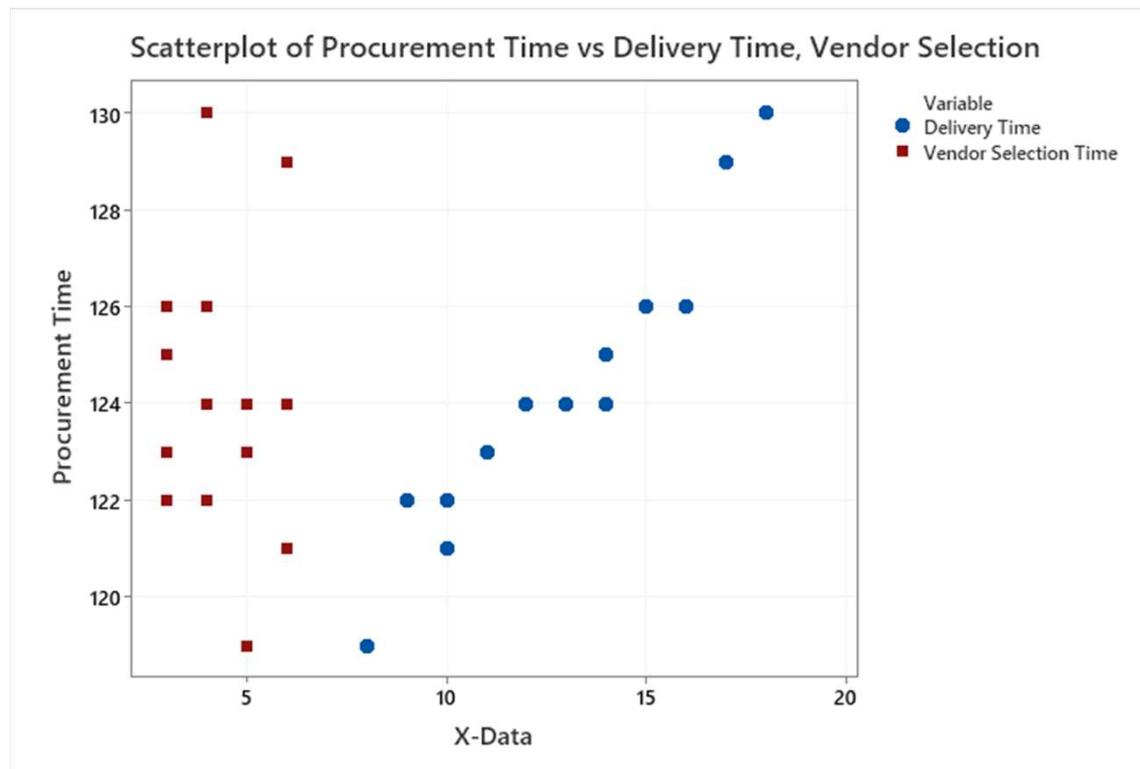


Follow-Along: Scatter Plots, cont.

4. Make a stratified scatter plot by queue:

Graph > Scatter plot > Simple > OK > (same variables as before)

Multiple Graphs... > (Select "Overlaid on the same graph") > OK > OK



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Part 4: Process Monitoring

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Statistical Process Control
for Variables Data
(SPC)

Module Objectives

By the end of this module, the participant will be able to:

- Apply SPC rules
- Interpret run and trend patterns in control charts
- Create and interpret
 - Xbar-R Charts
 - I-MR charts
 - Target I-MR charts

Why Learn About SPC for Variables?

SPC for variable data will:

- Keep process centered
- Minimize variation
- Reduce excursions
- Validate improvements
- Focus six sigma process activity

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Introduction to SPC

SPM and SPC

Statistical Process Control before six sigma

- *Statistical Process Monitoring*
 - Usual focus of SPC tools
 - Looks at output
 - Corrective action after output is out of control

Statistical Process Control after six sigma

- Same tools, additional focus
 - Focus on inputs
- Corrective action on inputs prior to output out of control

SPC Defined

Statistical Process Control

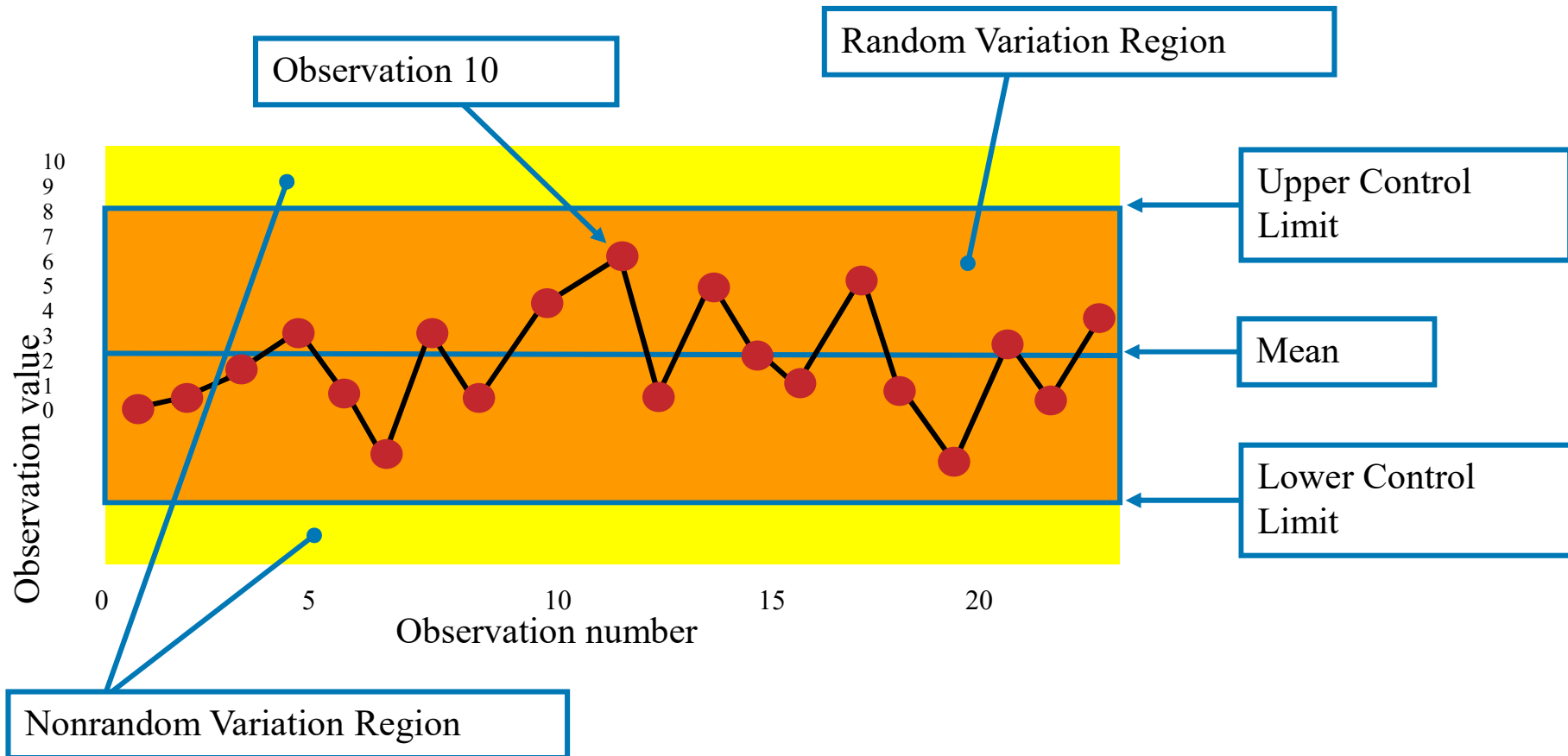
- Is application of statistical tools and methods to provide feedback
- Sets limits of variation
- Provides trigger for action

SPC Function

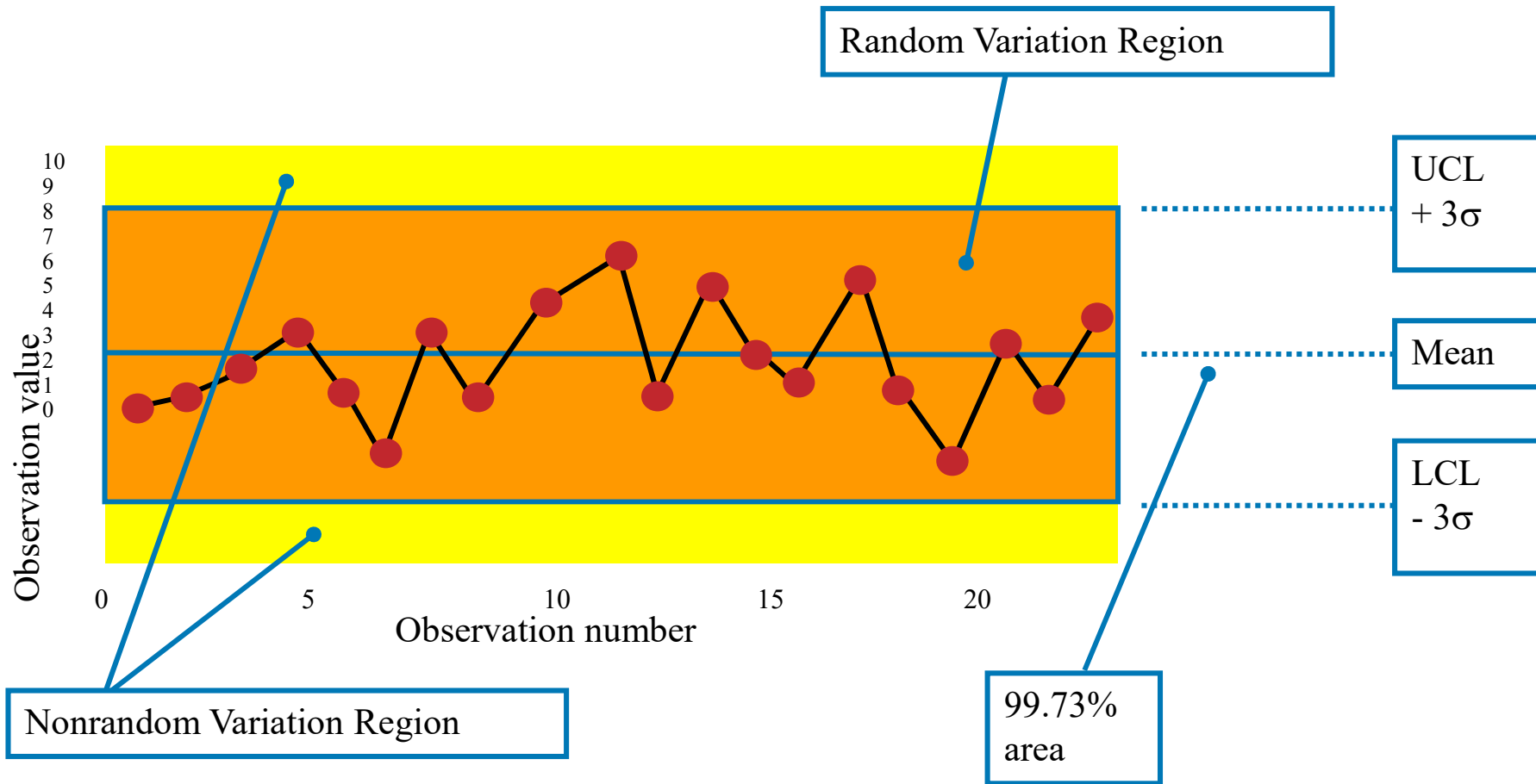
SPC Charts

- Used to monitor and control process under local responsibility
- Require process owners to
 - take measurements
 - Plot and interpret data
 - Take action
- Provide a history of the process

Components of a Control Chart



Statistics of a Control Chart



Establishing Process Control Limits

Control limits are

- Are statistical limits set +/- 3 standard deviations from the mean
- Set when process is in control
 - Fixed at baseline value
 - Adjusted for improvements
 - Never widened
- Control limits are not related to specification limits

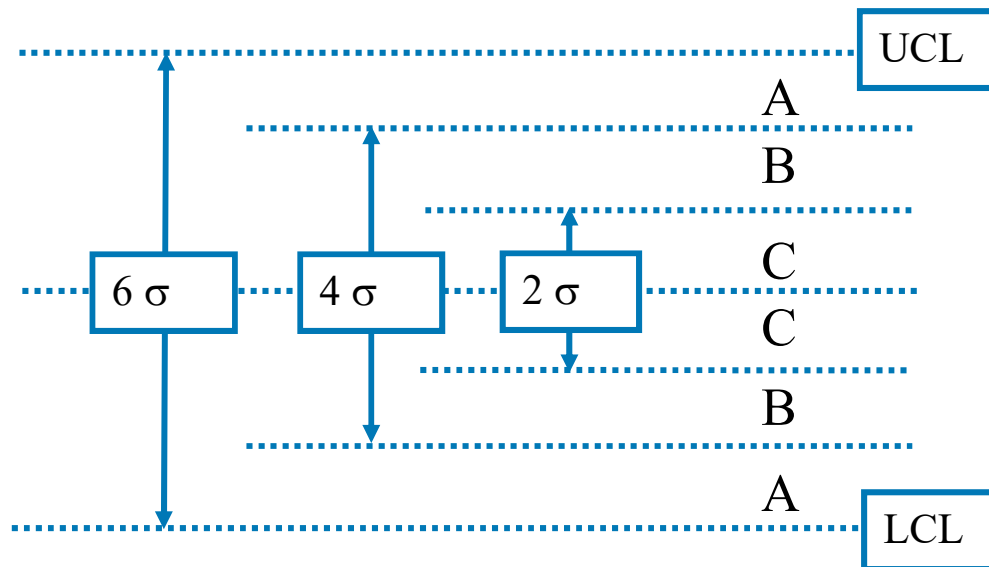
Control Limits are not specification limits

Definition of Control

In control is

- A statistical term for process variation
 - Within three standard deviations of the mean
 - That is random without cause
 - That does not show run patterns
 - That does not show trend patterns
- No assignable cause variation

Western Electric Rules for Control Overview

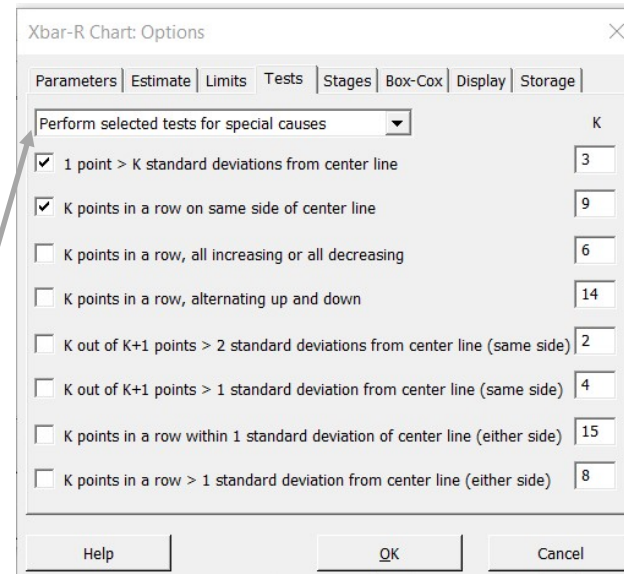
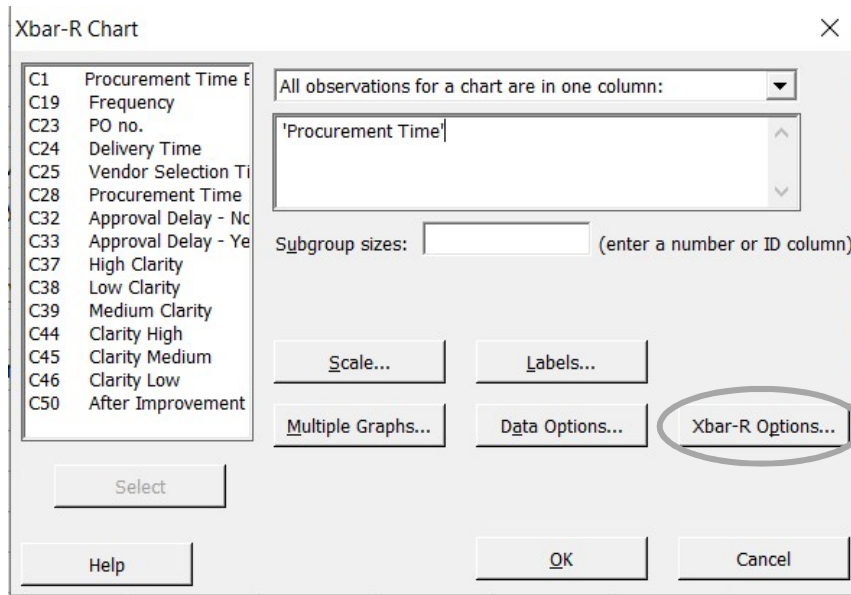


1. Any point outside control limits
2. 7 consecutive points on same side of centerline
3. 7 consecutive points increasing or decreasing
4. 2 of 3 points in same zone A or beyond
5. 4 of 5 points in same zone B or beyond
6. 14 consecutive points alternating up and down
7. 14 consecutive points in either zone C

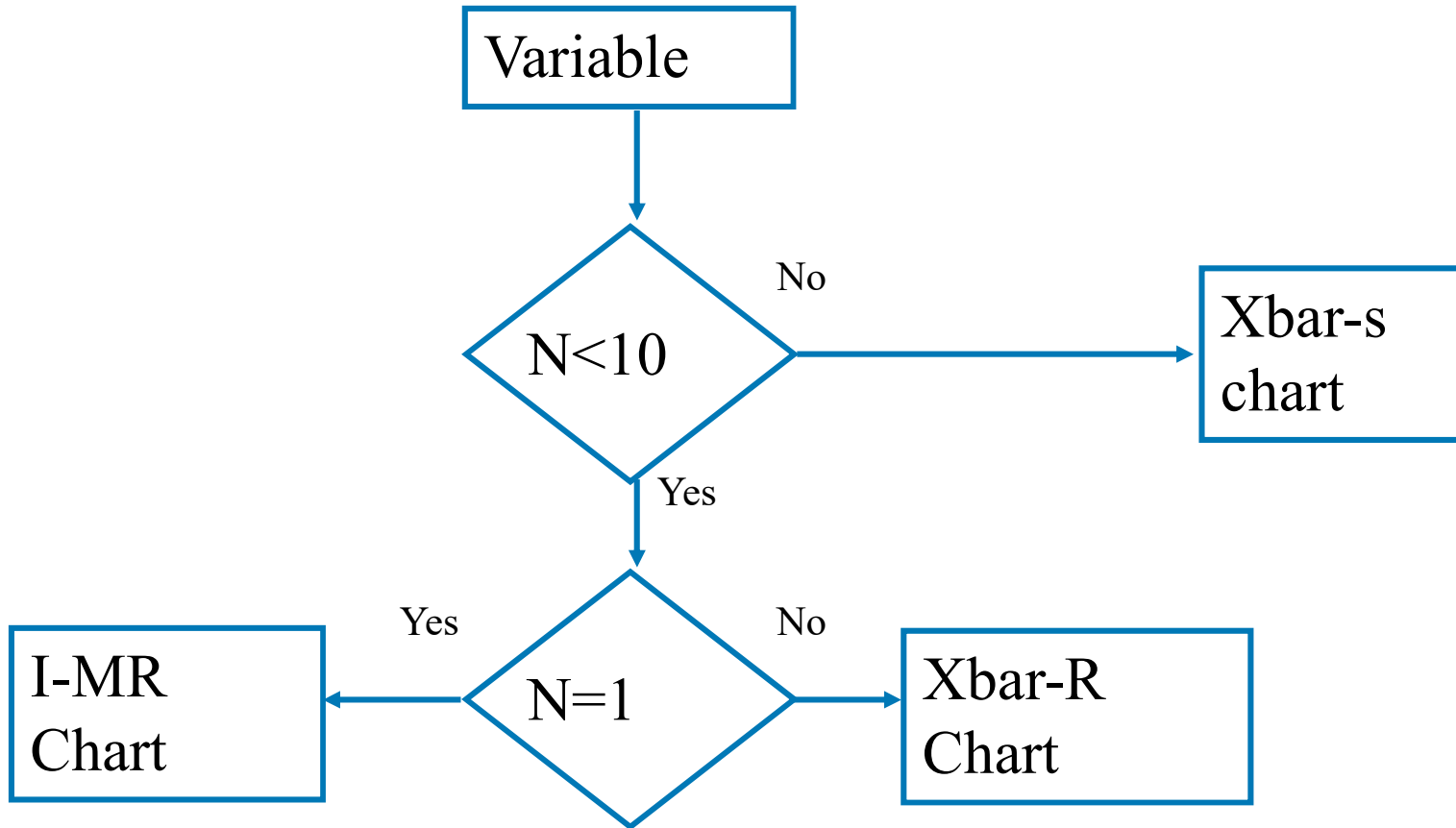
Established rules for run and trend analysis

Western Electric Rules in Minitab®

Stat>Control Charts>Xbar-R



Control Chart Roadmap



Anexas Consultancy Services

Xbar-R: Average, Range Charts

Xbar-R Chart Principles

Xbar-R Charts (and Xbar-s) are two separate charts of the same subgroup data

- Xbar chart is a plot of the subgroup means
- R chart is a plot of the subgroup ranges (or if s , plot of subgroup standard deviation)
- Most sensitive charts for tracking and identifying assignable cause of variation
- Based on control chart factors that assume a normal distribution within subgroups
- Establish three sigma process limits

Xbar-R and Subgroup Data

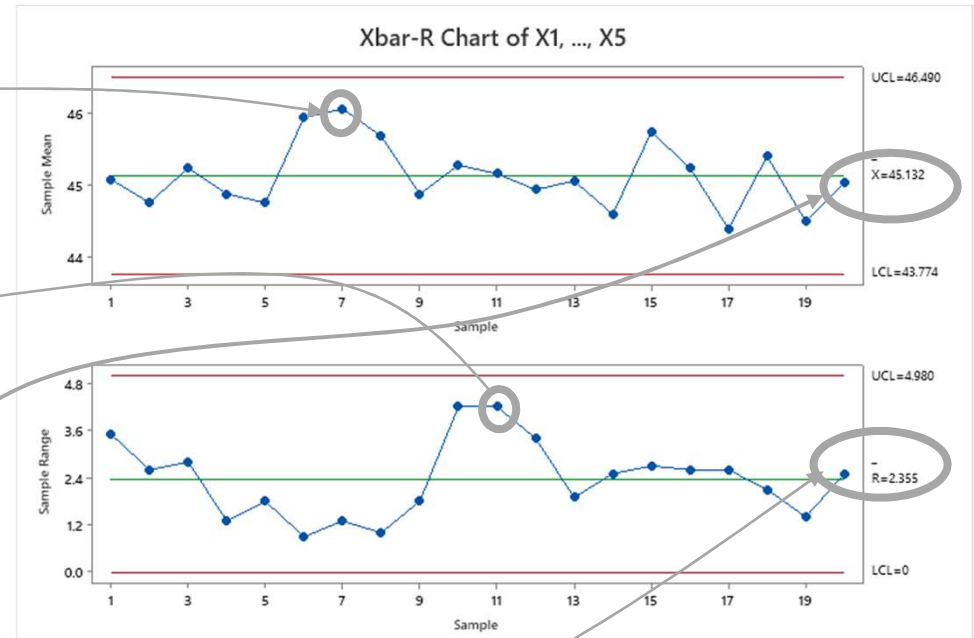
	X1	X2	X3	X4	X5
SG 1	43.8	43.7	47.2	46.3	44.4
SG 2	44.7	43.2	45.7	45.8	44.4
SG 3	45.3	43.8	44.3	46.2	46.6
SG 4	45.4	44.1	44.6	45.3	45.0
SG 5	43.8	45.6	44.6	44.8	45.0
SG 6	45.7	46.0	45.6	45.9	46.5
SG 7	46.5	45.6	45.7	46.9	45.6
SG 8	46.1	45.8	45.5	45.9	45.1
SG 9	44.5	44.0	45.4	45.8	44.7
SG 10	47.8	43.6	44.5	46.0	44.5
SG 11	45.5	45.4	42.8	47.0	45.1
SG 12	46.8	43.5	43.4	46.0	45.0
SG 13	44.2	44.7	46.1	44.5	45.8
SG 14	44.6	44.7	45.2	43.0	45.5
SG 15	46.0	46.0	45.0	44.5	47.2
SG 16	46.3	43.7	44.8	46.0	45.4
SG 17	43.2	43.0	45.6	44.8	45.4
SG 18	45.2	45.1	46.9	45.0	44.8
SG 19	44.6	44.5	44.6	43.7	45.1
SG 20	45.6	44.2	46.0	43.5	45.9

The QC department measures the percent transmission of 560 nanometer light through a tinted glass product. Is the process in control?

Since the data is subgroup data an Xbar-R chart will be used

Constructing an Xbar-R Chart Graph

	X1	X2	X3	X4	X5	Xbar	Range	
SG 1	43.8	43.7	47.2	46.3	44.4	45.1	3.5	
SG 2	44.7	43.2	45.7	45.8	44.4	44.8	2.6	
SG 3	45.3	43.8	44.3	46.2	46.6	45.2	2.8	
SG 4	45.4	44.1	44.6	45.3	45.0	44.9	1.3	
SG 5	43.8	45.6	44.6	44.8	45.0	44.8	1.8	
SG 6	45.7	46.0	45.6	45.9	46.5	45.9	0.9	
SG 7	46.5	45.6	45.7	46.9	45.6	46.1	1.3	
SG 8	46.1	45.8	45.5	45.9	45.1	45.7	1.0	
SG 9	44.5	44.0	45.4	45.8	44.7	44.9	1.8	
SG 10	47.8	43.6	44.5	46.0	44.5	45.3	4.2	
SG 11	45.5	45.4	42.8	47.0	45.1	45.2	4.2	
SG 12	46.8	43.5	43.4	46.0	45.0	44.9	3.4	
SG 13	44.2	44.7	46.1	44.5	45.8	45.1	1.9	
SG 14	44.6	44.7	45.2	43.0	45.5	44.6	2.5	
SG 15	46.0	46.0	45.0	44.5	47.2	45.7	2.7	
SG 16	46.3	43.7	44.8	46.0	45.4	45.2	2.6	
SG 17	43.2	43.0	45.6	44.8	45.4	44.4	2.6	
SG 18	45.2	45.1	46.9	45.0	44.8	45.4	2.1	
SG 19	44.6	44.5	44.6	43.7	45.1	44.5	1.4	
SG 20	45.6	44.2	46.0	43.5	45.9	45.0	2.5	
						Average	45.13	2.36



Xbar-R Charts in Minitab®

Step 1

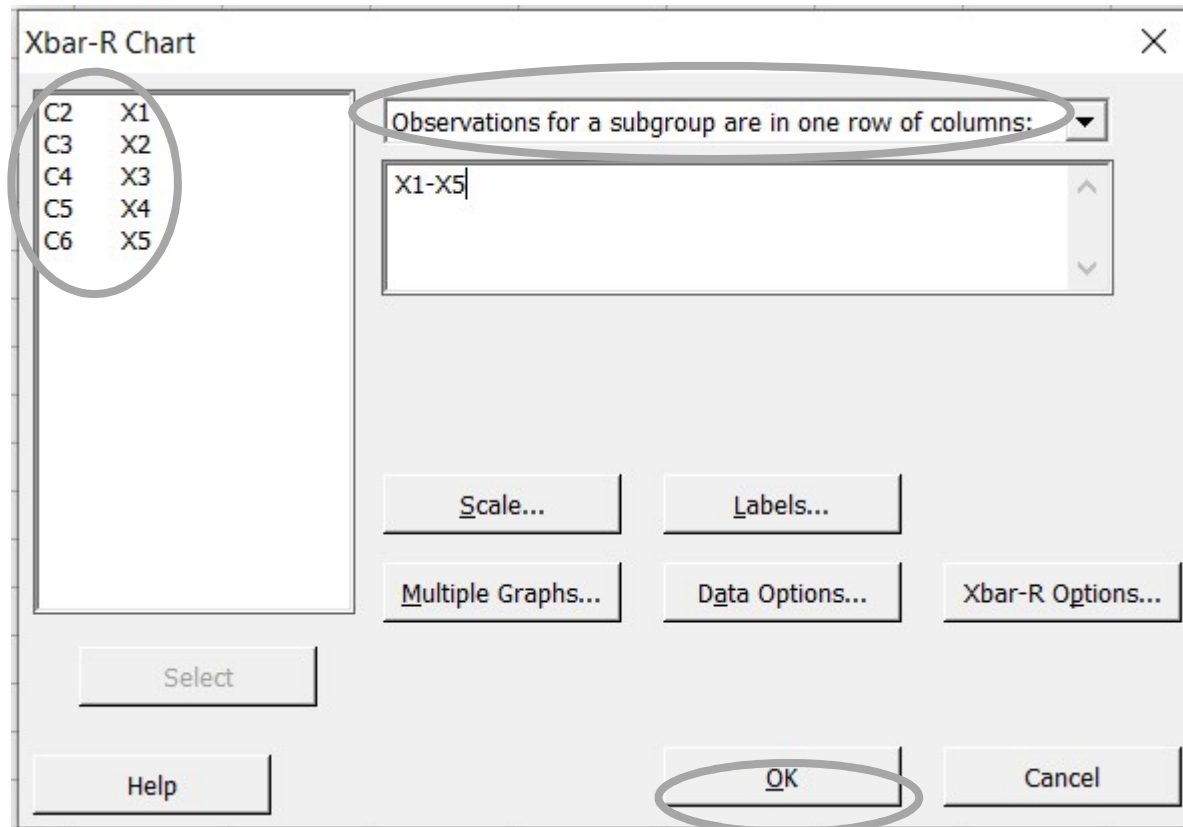
Copy or enter the data by subgroups into the worksheet
Open file *SPC VARIABLE XBAR*

↓	C1-T	C2	C3	C4	C5	C6
		X1	X2	X3	X4	X5
4	SG 4	45.4	44.1	44.6	45.3	45.0
5	SG 5	43.8	45.6	44.6	44.8	45.0
6	SG 6	45.7	46.0	45.6	45.9	46.5
7	SG 7	46.5	45.6	45.7	46.9	45.6
8	SG 8	46.1	45.8	45.5	45.9	45.1
9	SG 9	44.5	44.0	45.4	45.8	44.7
10	SG 10	47.8	43.6	44.5	46.0	44.5
11	SG 11	45.5	45.4	42.8	47.0	45.1
12	SG 12	46.8	43.5	43.4	46.0	45.0
13	SG 13	44.2	44.7	46.1	44.5	45.8
14	SG 14	44.6	44.7	45.2	43.0	45.5
15	SG 15	46.0	46.0	45.0	44.5	47.2
16	SG 16	46.3	43.7	44.8	46.0	45.4
17	SG 17	43.2	43.0	45.6	44.8	45.4
18	SG 18	45.2	45.1	46.9	45.0	44.8
19	SG 19	44.6	44.5	44.6	43.7	45.1
20	SG 20	45.6	44.2	46.0	43.5	45.9

Xbar-R Charts in Minitab®

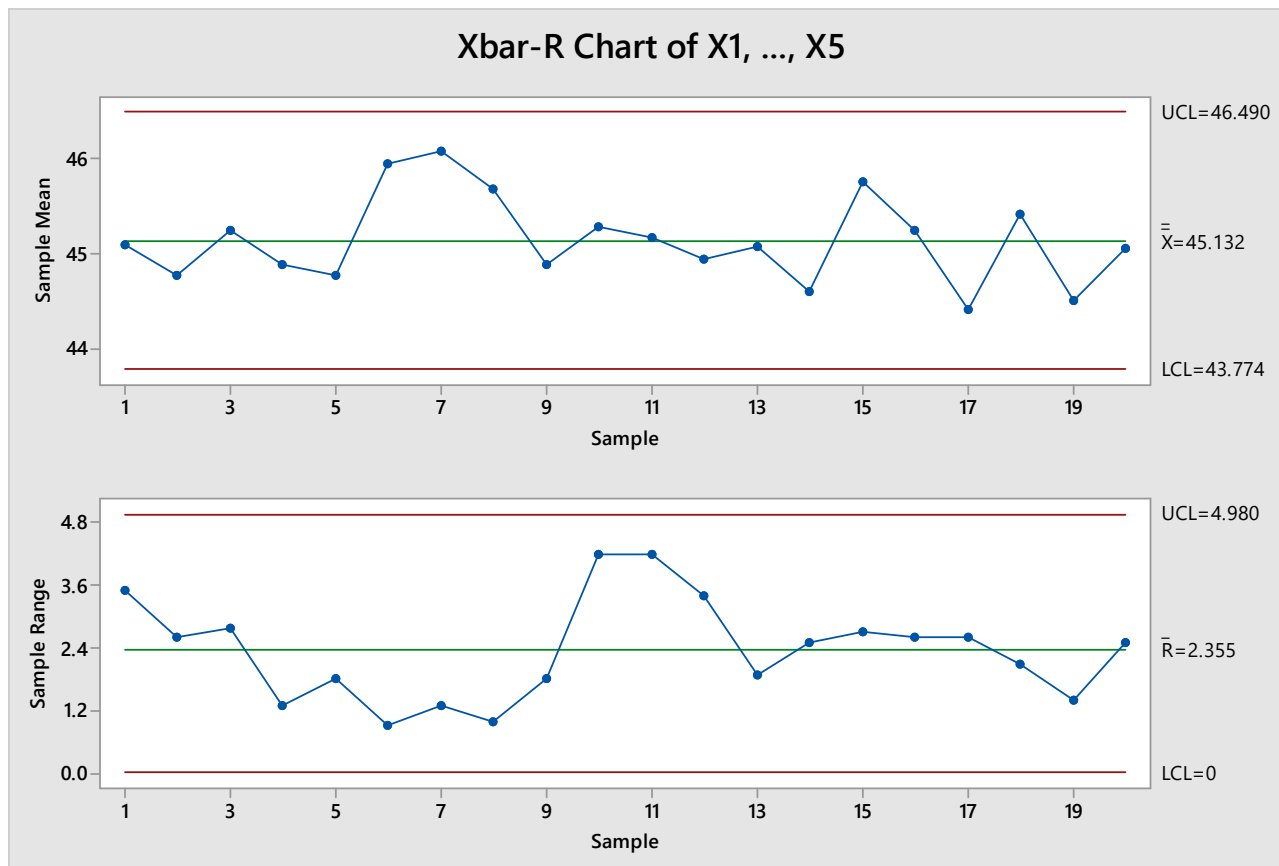
Step 2

Stat>Control Charts>Xbar-R



Xbar-R Charts in Minitab®

Step 3



Xbar-R Class Exercise

Using “Xbar Charts Data” tab of file *SPC Variable Class Exercises*

1. Find Xbars, Xdbar and Rbar
2. Determine applicable Shewhart constants
3. Calculate UCL and LCL for Xbar and R
4. Copy the data into Minitab®
5. Stack the data
6. Verify your calculations
7. Determine if process is in control

Anexas Consultancy Services

I-MR: Individual, Moving Range
Charts

Also called X-MR

I-MR Chart Principles

I-MR Charts are two separate charts of the same data

- I chart is a plot of the individual data
- MR chart is a plot of the moving range of the previous individuals
- I-MR charts are sensitive to trends, cycles and patterns
- Used when subgroup variation is zero or no subgroups exist
 - Destructive testing
 - Batch processing

I-MR and Individual Data

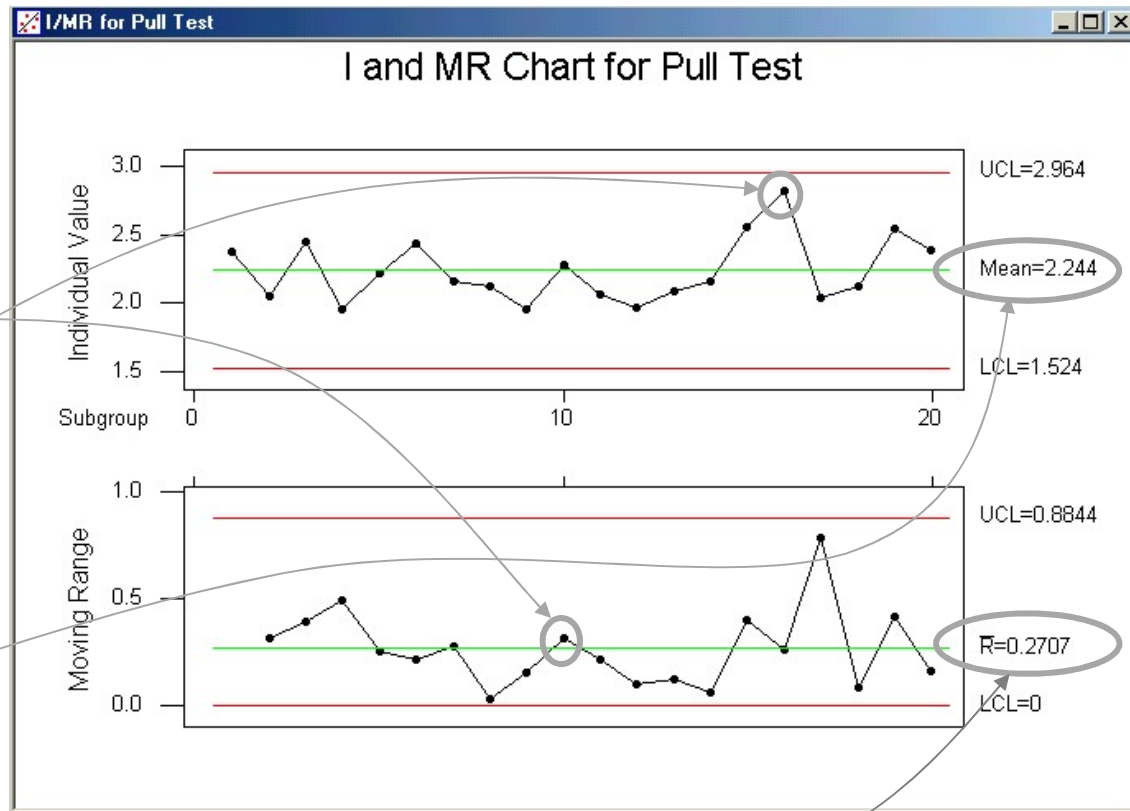
Pull Test
2.38
2.06
2.46
1.96
2.22
2.44
2.16
2.13
1.97
2.29
2.07
1.97
2.09
2.16
2.57
2.83
2.04
2.13
2.55
2.39

Once an hour the QC department measures peel strength of welds on clips for plate glass mounts.
Is the process in control?

Since the data is individual data an I-MR chart will be used. This is an example of a destructive test.

Constructing an I-MR Chart Graph

	Pull Test	MR (2)
1	2.38	
2	2.06	0.32
3	2.46	0.40
4	1.96	0.50
5	2.22	0.26
6	2.44	0.22
7	2.16	0.28
8	2.13	0.03
9	1.97	0.16
10	2.29	0.32
11	2.07	0.22
12	1.97	0.10
13	2.09	0.12
14	2.16	0.07
15	2.57	0.41
16	2.83	0.26
17	2.04	0.79
18	2.13	0.09
19	2.55	0.42
20	2.39	0.16
Ave	2.244	0.270



I-MR Charts in Minitab®

Step 1

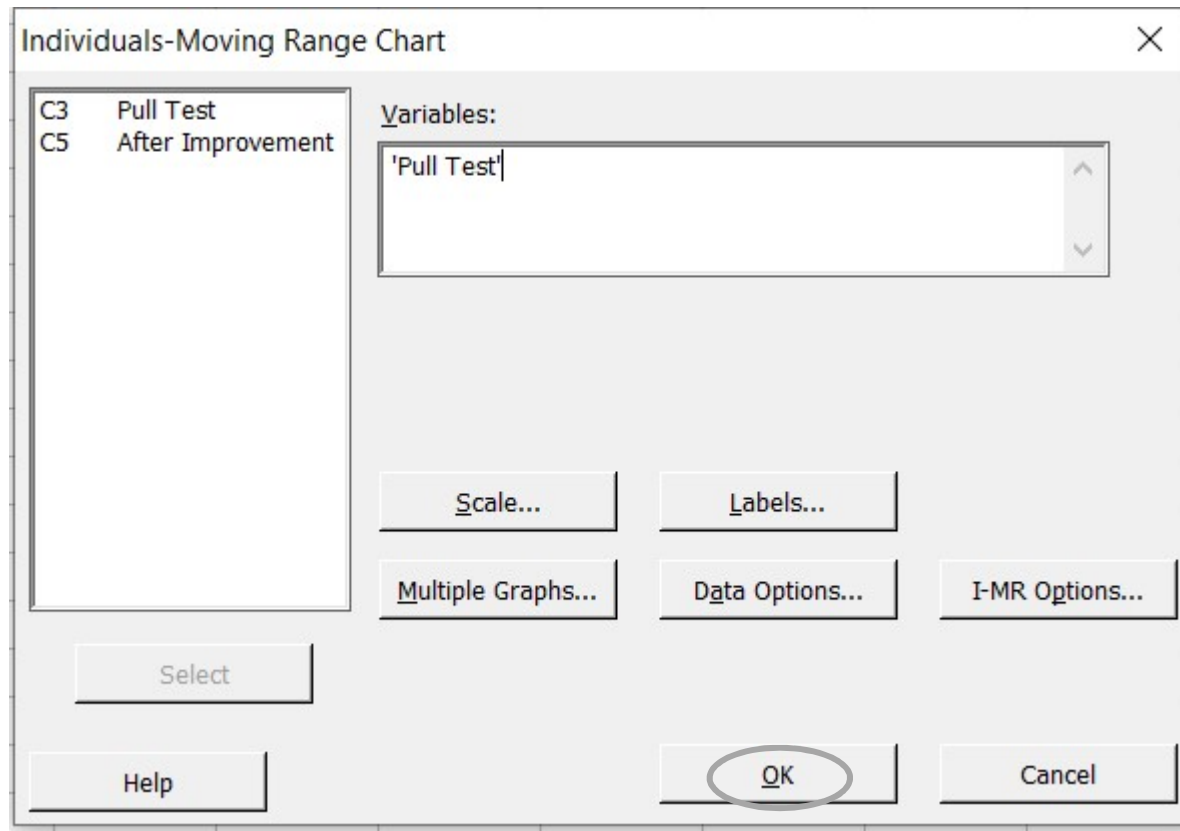
Copy or enter the data by subgroups into the worksheet
 Open file **SPC VARIABLE IMR**

SPC VARIABLE IMR.MTW ***					
	C1	C2	C3	C4	C5
			Pull Test		After Improvement
1			2.38159		2.785
2			2.06106		3.142
3			2.45871		2.7011
4			1.96439		3.132
5			2.22114		2.971
6			2.44221		2.841
7			2.16163		3.270
8			2.12563		2.993
9			1.96588		

I-MR Charts in Minitab®

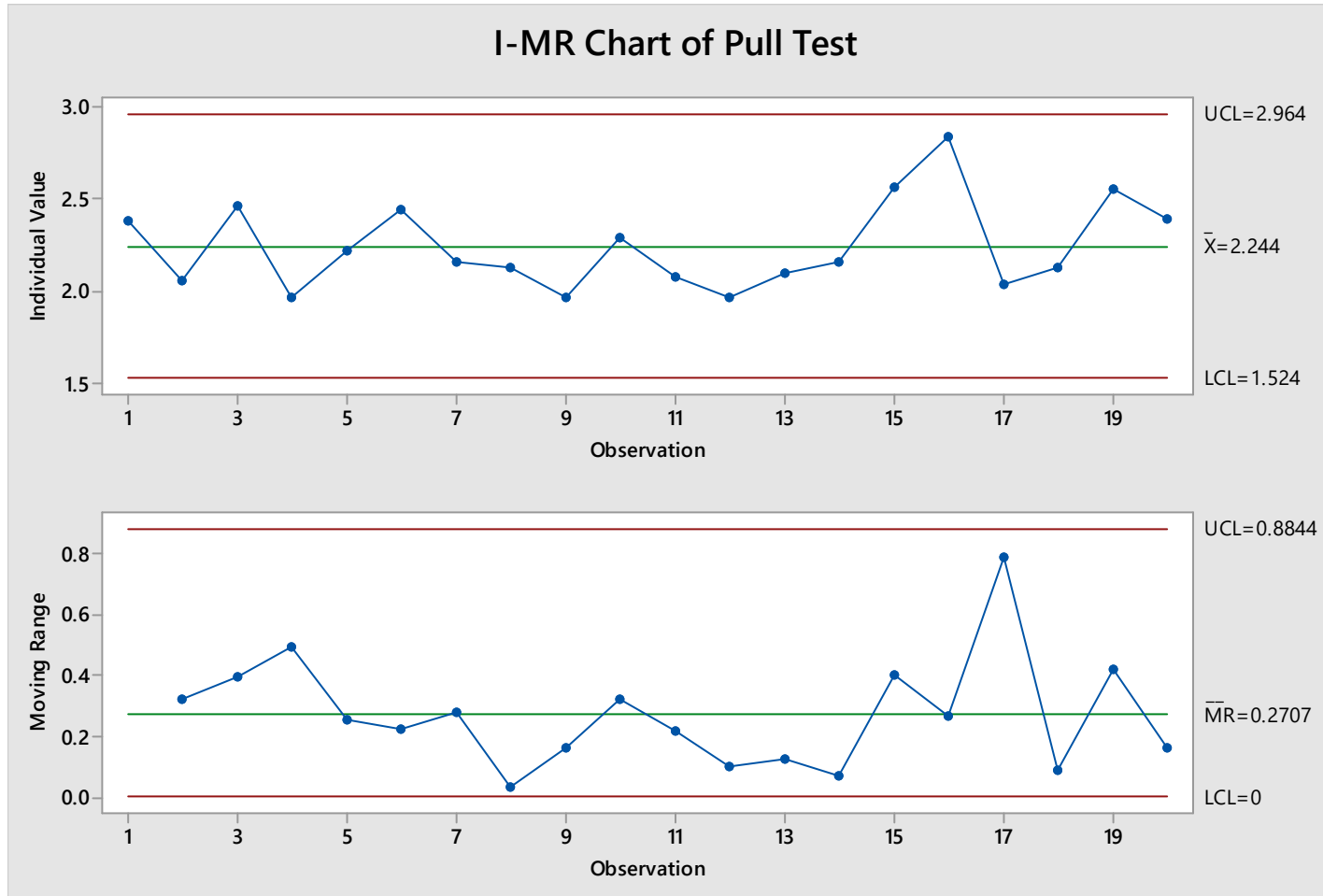
Step 2

Stat>Control Charts>Control Charts for Individuals> I-MR



I-MR Charts in Minitab®

Step 3



I-MR Charting an Improvement in Process

A process “improvement” has been made to increase peel strength. Is it real?

C3	C4	C5	C6	C7	C8-T
Pull Test		After Improvement		Stacked	
2.38159		2.78571		2.38159	Pull Test
2.06106		3.14213		2.06106	Pull Test
2.45871		2.70162		2.45871	Pull Test
1.96439		3.13228		1.96439	Pull Test
2.22114		2.97127		2.22114	Pull Test
2.44221		2.84115		2.44221	Pull Test
2.16163		3.27077		2.16163	Pull Test
2.12563		2.99385		2.12563	Pull Test
1.96588				1.96588	Pull Test
2.28996				2.28996	Pull Test
2.07185				2.07185	Pull Test
1.96902				1.96902	Pull Test
2.09350				2.09350	Pull Test
2.16213				2.16213	Pull Test
2.56520				2.56520	Pull Test
2.83337				2.83337	Pull Test
2.04062				2.04062	Pull Test
2.12954				2.12954	Pull Test
2.55237				2.55237	Pull Test
2.39008				2.39008	Pull Test
				2.78571	After Improvement
				3.14213	After Improvement
				2.70162	After Improvement
				3.13228	After Improvement
				2.97127	After Improvement
				2.84115	After Improvement
				3.27077	After Improvement
				2.99385	After Improvement

Stack the data

Descriptive Statistics: After Improvement

Variable	N	Mean	Median	TrMean	StDev
After Im	8	2.9798	2.9826	2.9798	0.1960

Individuals-Moving Range Chart

Individuals-Moving Range Chart

Variables:
Stacked

Scale... Labels...
Multiple Graphs... Data Options... I-MR Options...

Select

Help OK Cancel

Individuals-Moving Range Chart: Options

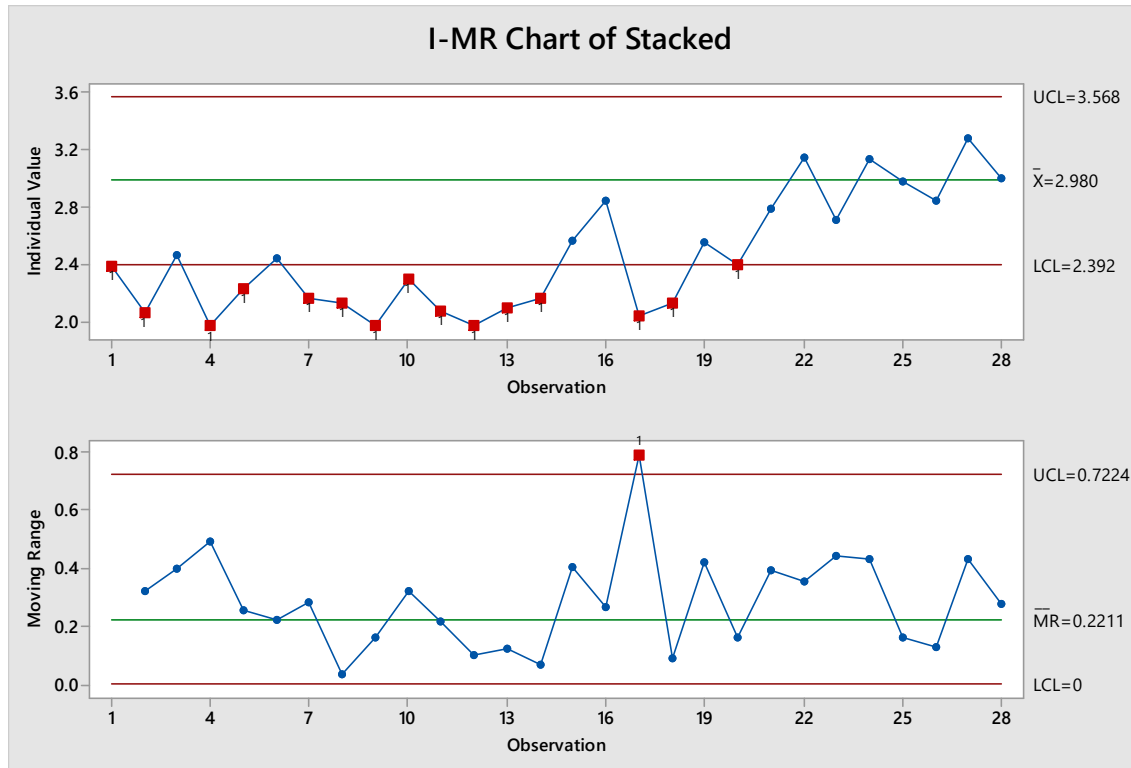
Parameters | Estimate | Limits | Tests | Stages | Box-Cox | Display | Storage

To specify the values for one or both parameters, enter them here. Minitab uses these values instead of estimating them from the data.

Mean: 2.9798
Standard deviation: 0.196

Help OK Cancel

I-MR Shows Two Populations



Recalculating limits based upon improved statistics show clearly that “old” process is significantly different. Peel strength is higher.

Anexas Consultancy Services

p- and np-charts

Anexas Consultancy Services

P-charts

Varying Subgroup Size

p-chart Principles

p-charts

- Measure the proportion non-conforming
 - Uses binomial distribution
 - Good/bad, accept/reject, yes/no
- Each proportion is a subgroup of samples
 - Large subgroups required (50 minimum)
- Subgroup size does not have to be constant
- Control limits may vary from subgroup to subgroup based upon subgroup size
- 20 or more subgroups suggested for analysis

p-charts and Varying Subgroup Size

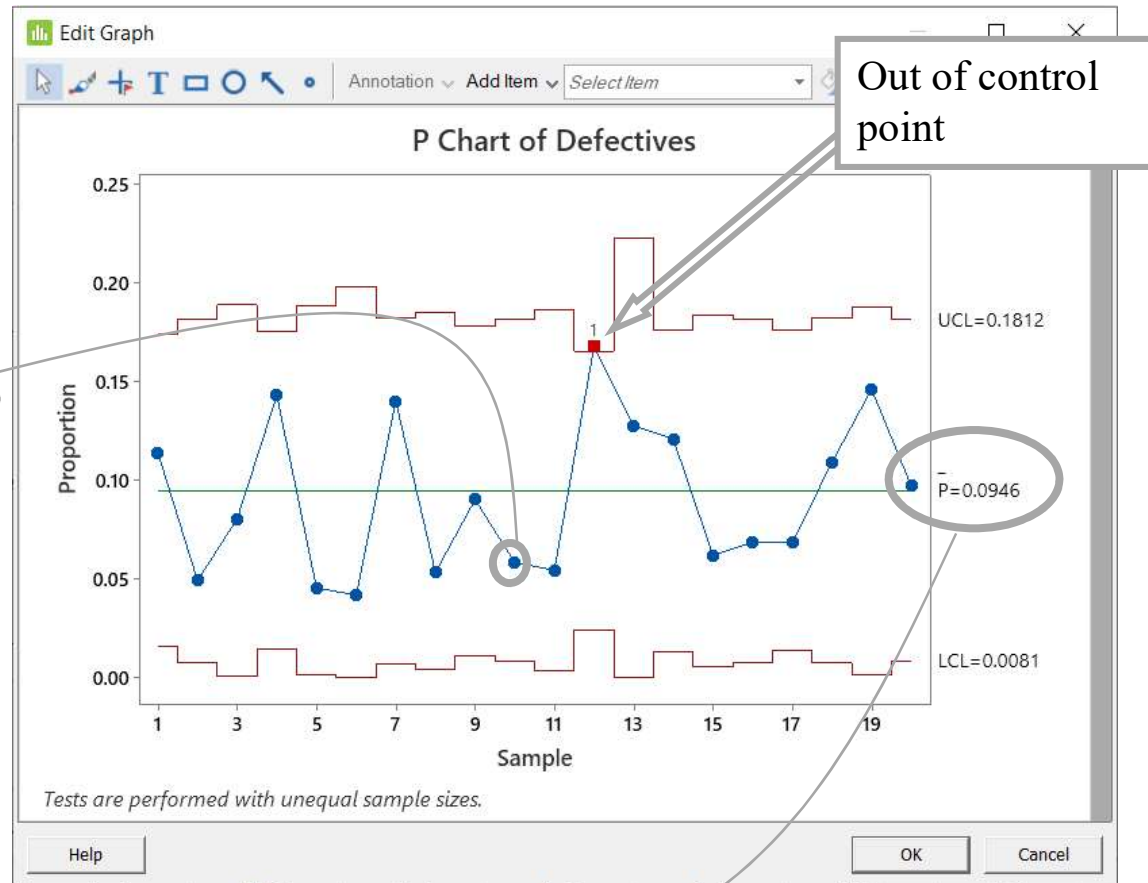
Day	Orders	Defectives
1	123	14
2	102	5
3	87	7
4	119	17
5	88	4
6	72	3
7	100	14
8	94	5
9	111	10
10	103	6
11	92	5
12	155	26
13	47	6
14	116	14
15	97	6
16	102	7
17	117	8
18	101	11
19	89	13
20	103	10

The sourcing department measures the number of entry errors on a daily basis. Is the order entry process in control?

Since the data has varying subgroup sizes (orders processed) of defectives (error/no error) a p-chart will be used

Constructing a p-chart Graph

Day	Orders	Defectives	Prop
1	123	14	0.114
2	102	5	0.049
3	87	7	0.080
4	119	17	0.143
5	88	4	0.045
6	72	3	0.042
7	100	14	0.140
8	94	5	0.053
9	111	10	0.090
10	103	6	0.058
11	92	5	0.054
12	155	26	0.168
13	47	6	0.128
14	116	14	0.121
15	97	6	0.062
16	102	7	0.069
17	117	8	0.068
18	101	11	0.109
19	89	13	0.146
20	103	10	0.097
Total	2018	191	0.0946



p-charts in Minitab® Step 1

Day	Orders	Defectives
1	123	14
2	102	5
3	87	7
4	119	17
5	88	4
6	72	3
7	100	14
8	94	5
9	111	10
10	103	6
11	92	5
12	155	26
13	47	6
14	116	14
15	97	6
16	102	7
17	117	8
18	101	11
19	89	13
20	103	10

Copy or enter the data by subgroups into the worksheet
 Open file ***SPC Attribute p-chart***

Stat>Control Charts>p

P Chart

Variables: Defectives

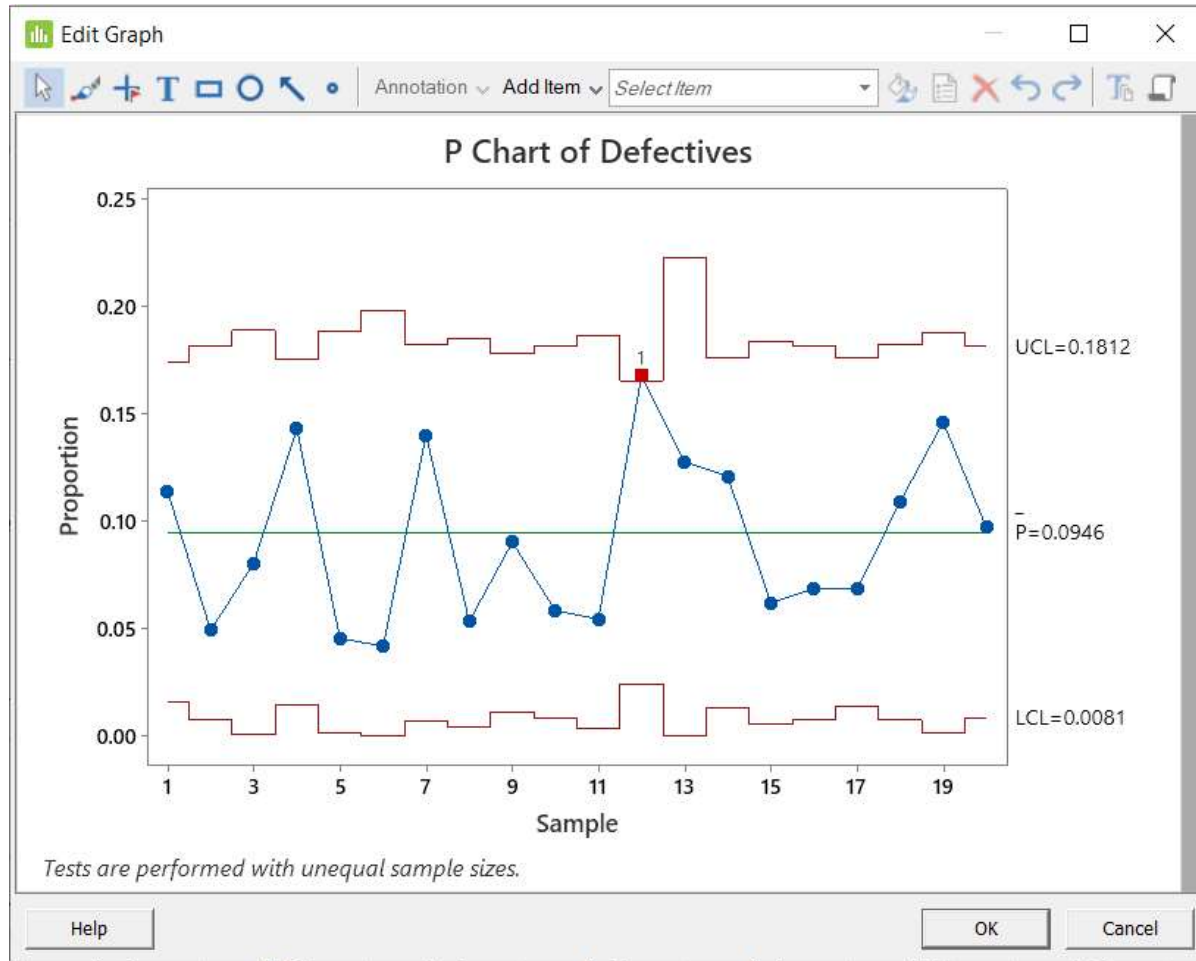
Subgroup sizes: Orders
 (enter a number or column containing the sizes)

Scale... Labels...
 Multiple Graphs... Data Options... P Chart Options...

Select

Help OK Cancel

p-charts in Minitab® Step 2



Anexas Consultancy Services

np-charts

Constant subgroup size

np-chart Principles

np-charts

- Measure the proportion non-conforming
 - uses binomial distribution
 - good/bad, accept/reject, yes/no
- Each proportion is a subgroup of samples
 - large subgroups required (50 minimum)
- Subgroup size must be constant
- Control limits will be constant
- 20 or more subgroups suggested for analysis

np-charts and Uniform Subgroup Size

Day	Orders	Defective orders
1	125	14
2	125	5
3	125	7
4	125	17
5	125	4
6	125	3
7	125	14
8	125	5
9	125	10
10	125	6
11	125	5
12	125	26
13	125	6
14	125	14
15	125	6
16	125	7
17	125	8
18	125	11
19	125	13
20	125	10

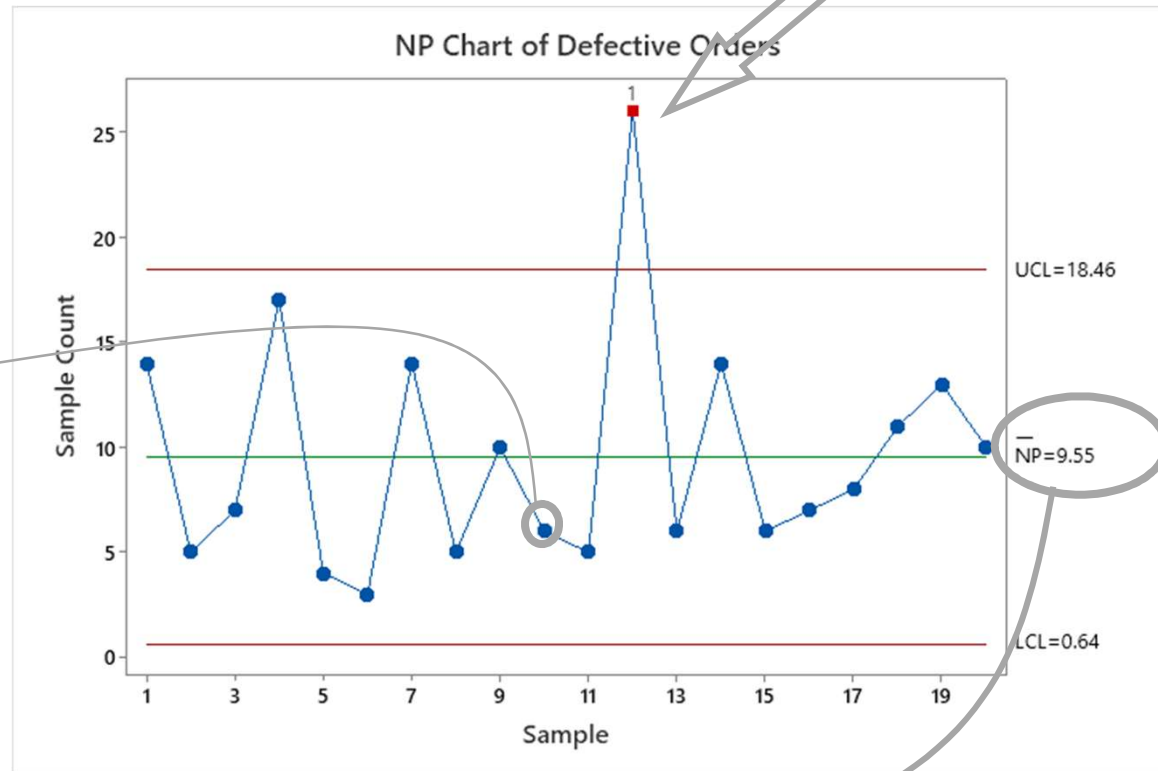
The sourcing department measures 125 purchase orders daily and records the number of entry errors.

Is the order entry process in control?

Since the data has a constant subgroup size (orders processed) of defectives (error/no error) an np-chart will be used

Constructing an np-chart Graph

Day	Orders	Defective Orders	Prop	np
1	125	14	0.112	14
2	125	5	0.040	5
3	125	7	0.056	7
4	125	17	0.136	17
5	125	4	0.032	4
6	125	3	0.024	3
7	125	14	0.112	14
8	125	5	0.040	5
9	125	10	0.080	10
10	125	6	0.048	6
11	125	5	0.040	5
12	125	26	0.208	26
13	125	6	0.048	6
14	125	14	0.112	14
15	125	6	0.048	6
16	125	7	0.056	7
17	125	8	0.064	8
18	125	11	0.088	11
19	125	13	0.104	13
20	125	10	0.080	10
Total		191		
		pbar	0.076	
		npbar	9.55	



np-charts in Minitab®

Step 1

Day	Orders	Defective orders
1	125	14
2	125	5
3	125	7
4	125	17
5	125	4
6	125	3
7	125	14
8	125	5
9	125	10
10	125	6
11	125	5
12	125	26
13	125	6
14	125	14
15	125	6
16	125	7
17	125	8
18	125	11
19	125	13
20	125	10

Copy or enter the data by subgroups into the worksheet

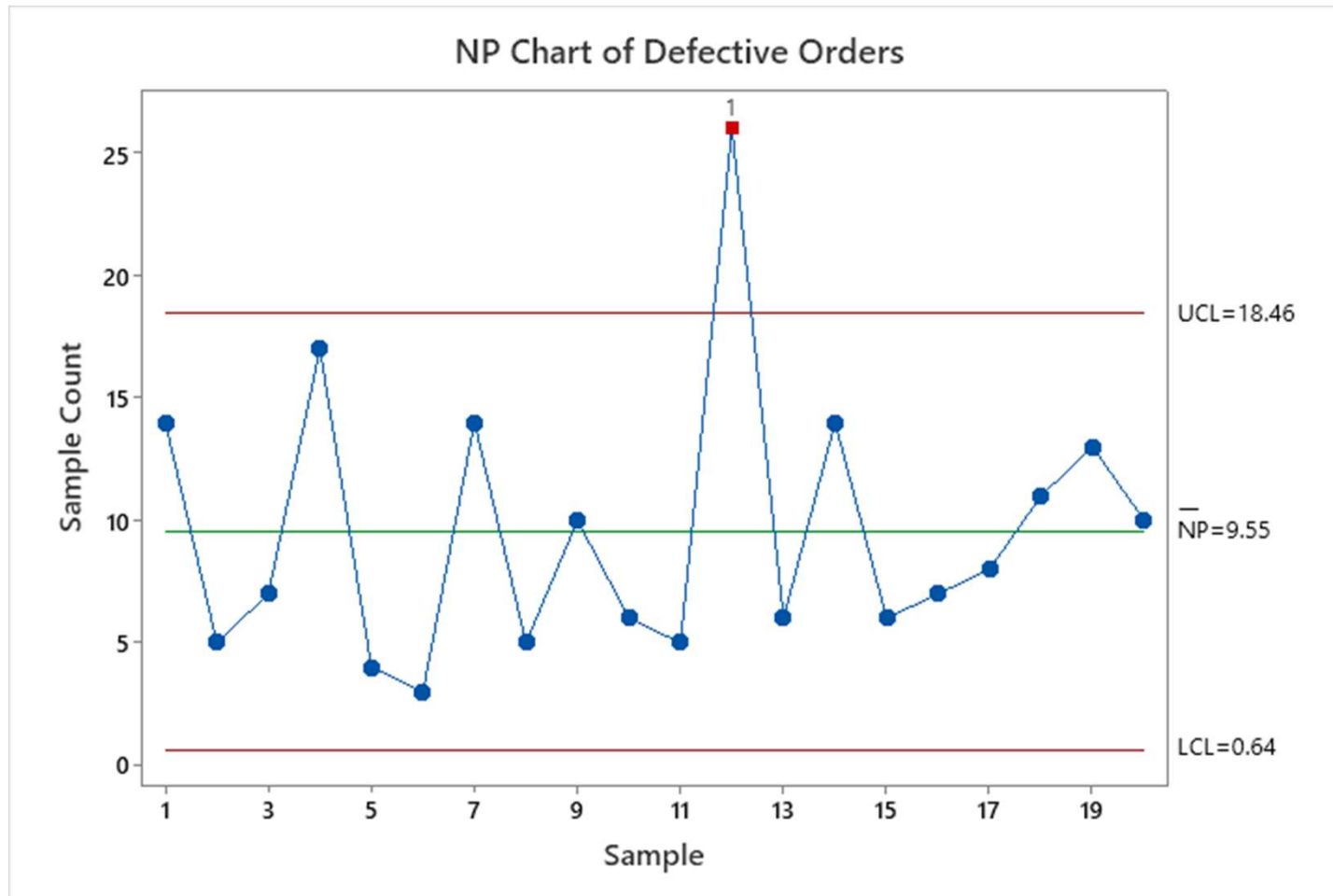
Open file ***SPC Attribute np-chart***

Stat>Control Charts>Attribute Charts>NP

The screenshot shows the 'NP Chart' dialog box in Minitab. On the left, a list of variables includes 'C1 Day', 'C2 Orders', and 'C3 Defective Orders'. The 'Variables' field on the right contains 'Defective Orders'. Below this, the 'Subgroup sizes' field is set to 'Orders', with a note '(enter a number or column containing the sizes)'. At the bottom, there are buttons for 'Scale...', 'Labels...', 'Multiple Graphs...', 'Data Options...', 'NP Chart Options...', 'Select', 'Help', 'OK', and 'Cancel'. The 'Scale...' button is highlighted with a dashed border.

np-charts in Minitab®

Step 2



np-chart Class Exercise

Using “np-chart Data” tab of file *SPC Attribute Class Exercises*

For Shipment Number subgroups

1. Calculate UCL and LCL
2. Copy the data into Minitab®
3. Verify your calculations.
4. Determine if process is in control
5. If you have done SPC Variables Data module run an I-MR chart on this data
 - What does I-MR show?
 - Why is it wrong?
6. Prepare for discussion

Anexas Consultancy Services

c- and u-Charts

c-chart Principles

c-charts

- Measure the count of non-conforming defects
 - uses Poisson distribution
 - good/bad, accept/reject, yes/no
- Each count is a subgroup of samples
- Area of opportunity must be constant
 - lot, unit, invoice
- Control limits will be constant
- 20 or more subgroups suggested for analysis

c-chart Subgroups

PaneNo	White Specs
1	31
2	39
3	38
4	5
5	22
6	34
7	10
8	23
9	11
10	36
11	25
12	4
13	4
14	11
15	25
16	4
17	38
18	36
19	36
20	17
Average	22.45

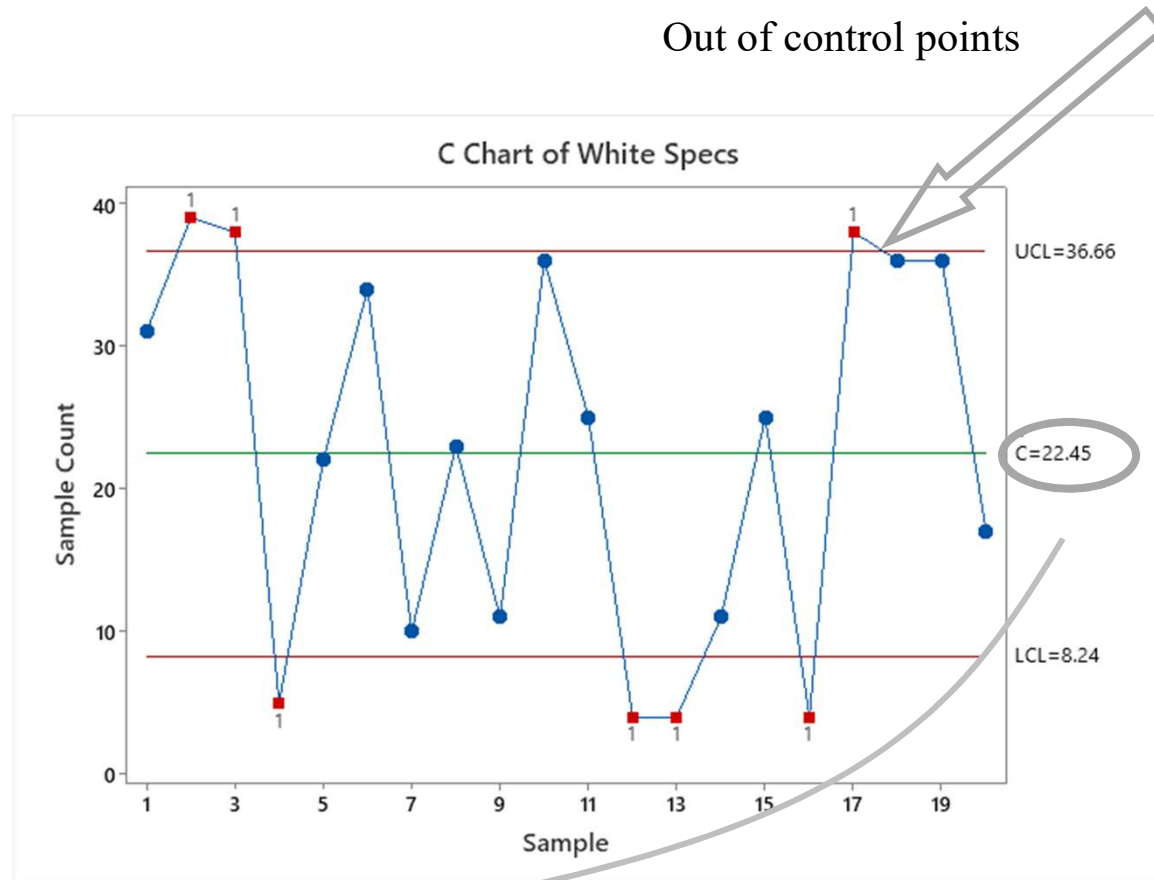
Final inspection grades the tinted glass on the number of “white specs.” Product is priced by grade.

Is the process in control?

White specs are defects, not defectives, and are measured over a constant sample area; a c-chart will be used

Constructing a c-chart Graph

PaneNo	White Specs
1	31
2	39
3	38
4	5
5	22
6	34
7	10
8	23
9	11
10	36
11	25
12	4
13	4
14	11
15	25
16	4
17	38
18	36
19	36
20	17
Average	22.45

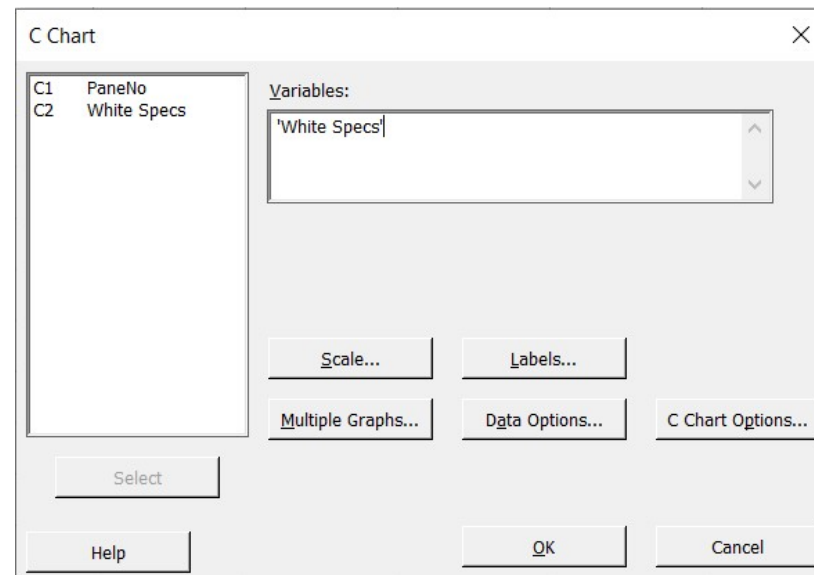


c-charts in Minitab® Step 1

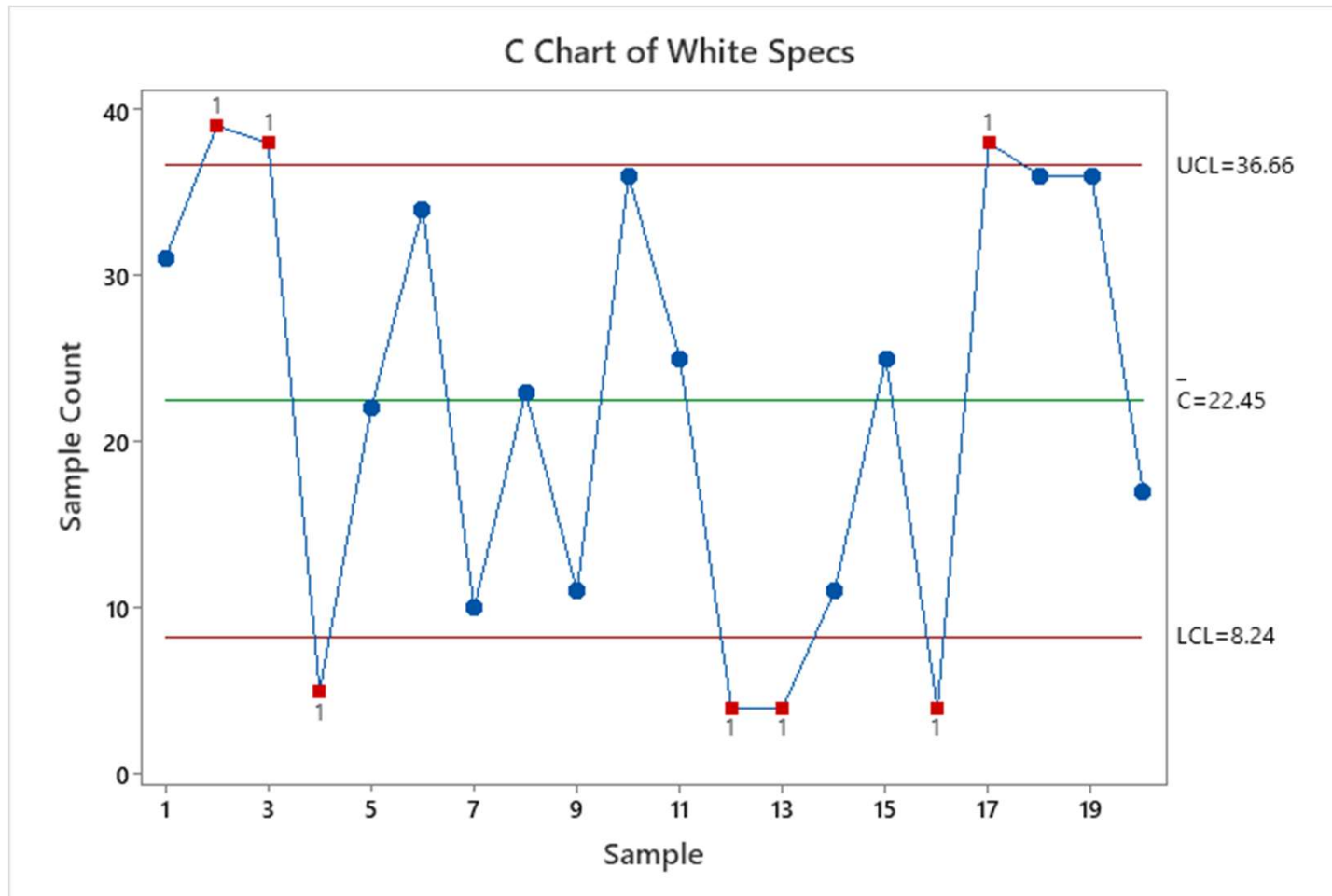
SPC Attribute c-chart.MTW ***		
↓	C1	C2
	PaneNo	White Specs
1	1	31
2	2	39
3	3	38
4	4	5
5	5	22
6	6	34
7	7	10
8	8	23
9	9	11
10	10	36
11	11	25
12	12	4
13	13	4
14	14	11
15	15	25
16	16	4
17	17	38
18	18	36
19	19	36
20	20	17
21		

Copy or enter the data by subgroups into the worksheet
 Open file ***SPC Attribute c-chart***

Stat>Control Charts>c



c-charts in Minitab® Step 2



c-chart Class Exercise

Using “c-chart Data” tab of file *SPC Attribute Class Exercises*

For CSR subgroups of complaints

1. Calculate UCL and LCL
2. Copy the data into Minitab®
3. Verify your calculations
4. Determine if process is in control
5. Prepare for discussion

Anexas Consultancy Services

u-charts

Varying Area of Opportunity

u-chart Principles

u-charts

- Measure the count of non-conforming defects
 - Uses Poisson distribution
 - Good/bad, accept/reject, yes/no
- Each count is a subgroup of samples
- Area of opportunity may vary
 - Lot, unit, invoice
- Control limits may vary
- 20 or more subgroups suggested for analysis

u-chart Subgroups

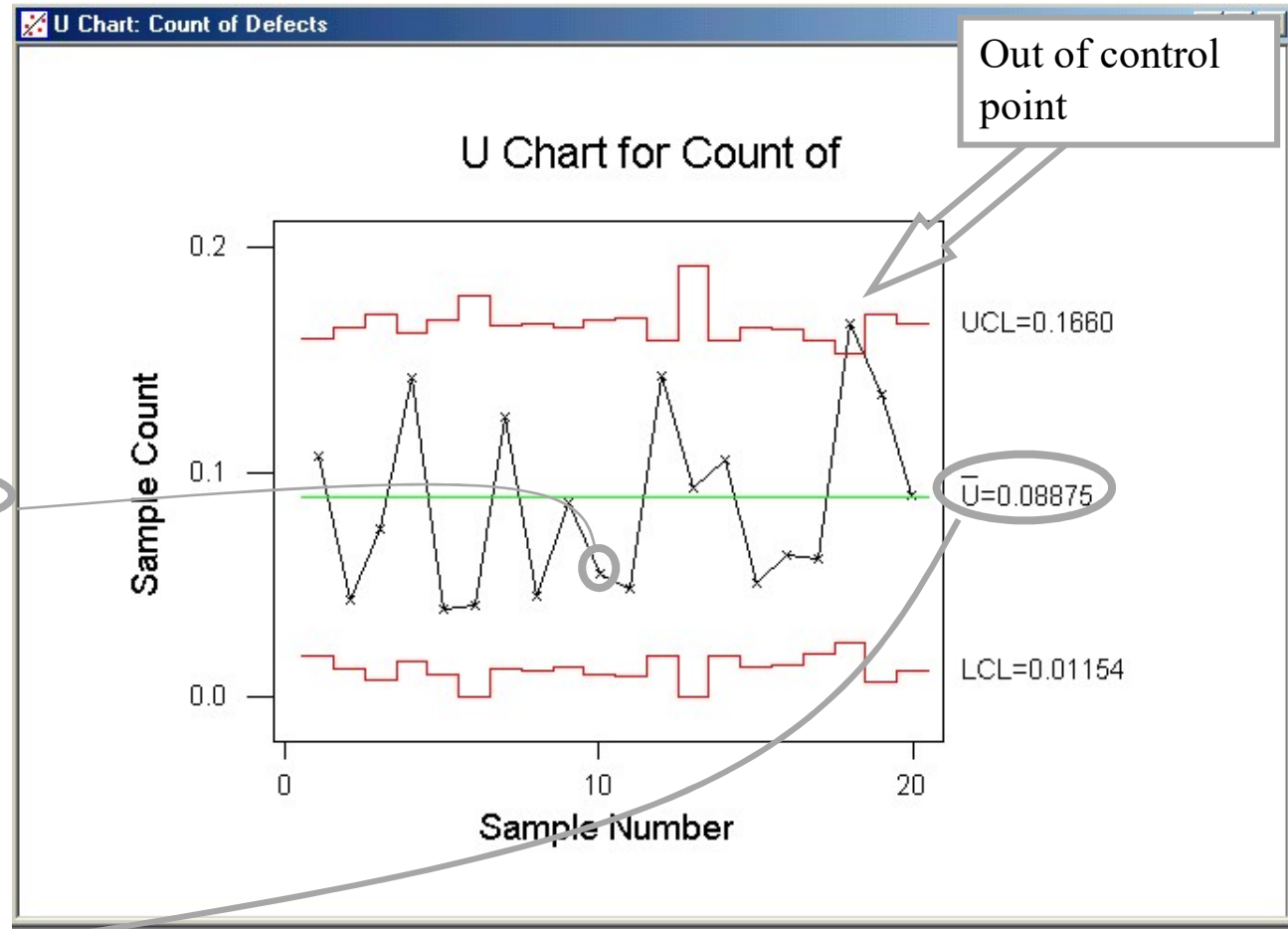
Run	Produced	Count of Defects
1	159	17
2	138	6
3	120	9
4	148	21
5	127	5
6	98	4
7	136	17
8	134	6
9	139	12
10	127	7
11	125	6
12	161	23
13	75	7
14	161	17
15	139	7
16	143	9
17	163	10
18	192	32
19	119	16
20	134	12
Total	2738	243
	Ubar	0.08875

The plastics operation counts defects after a “run”, which is undetermined in length (once started continues until all material is used).
Is the process in control?

The count of defect has a varying area of opportunity since the lengths of runs are not constant. A u-chart will be used.

Constructing a u-chart Graph

Run	Produced	Count of Defects	Count/area
1	159	17	0.107
2	138	6	0.043
3	120	9	0.075
4	148	21	0.142
5	127	5	0.039
6	98	4	0.041
7	136	17	0.125
8	134	6	0.045
9	139	12	0.086
10	127	7	0.055
11	125	6	0.048
12	161	23	0.143
13	75	7	0.093
14	161	17	0.106
15	139	7	0.050
16	143	9	0.063
17	163	10	0.061
18	192	32	0.167
19	119	16	0.134
20	134	12	0.090
Total	2738	243	
Ubar			0.088751



u-charts in Minitab® Step 1

SPC Attribute U-chart ***			
↓	C1	C2	C3
	Run	Produced	Count of Defects
1	1	159	17
2	2	138	6
3	3	120	9
4	4	148	21
5	5	127	5
6	6	98	4
7	7	136	17
8	8	134	6
9	9	139	12
10	10	127	7
11	11	125	6
12	12	161	23
13	13	75	7
14	14	161	17
15	15	139	7
16	16	143	9
17	17	163	10
18	18	192	32
19	19	119	16
20	20	134	12

Copy or enter the data by subgroups into the worksheet
 Open file ***SPC Attribute u-chart***

Stat>Control Charts>U

U Chart

Variables: 'Count of Defects'

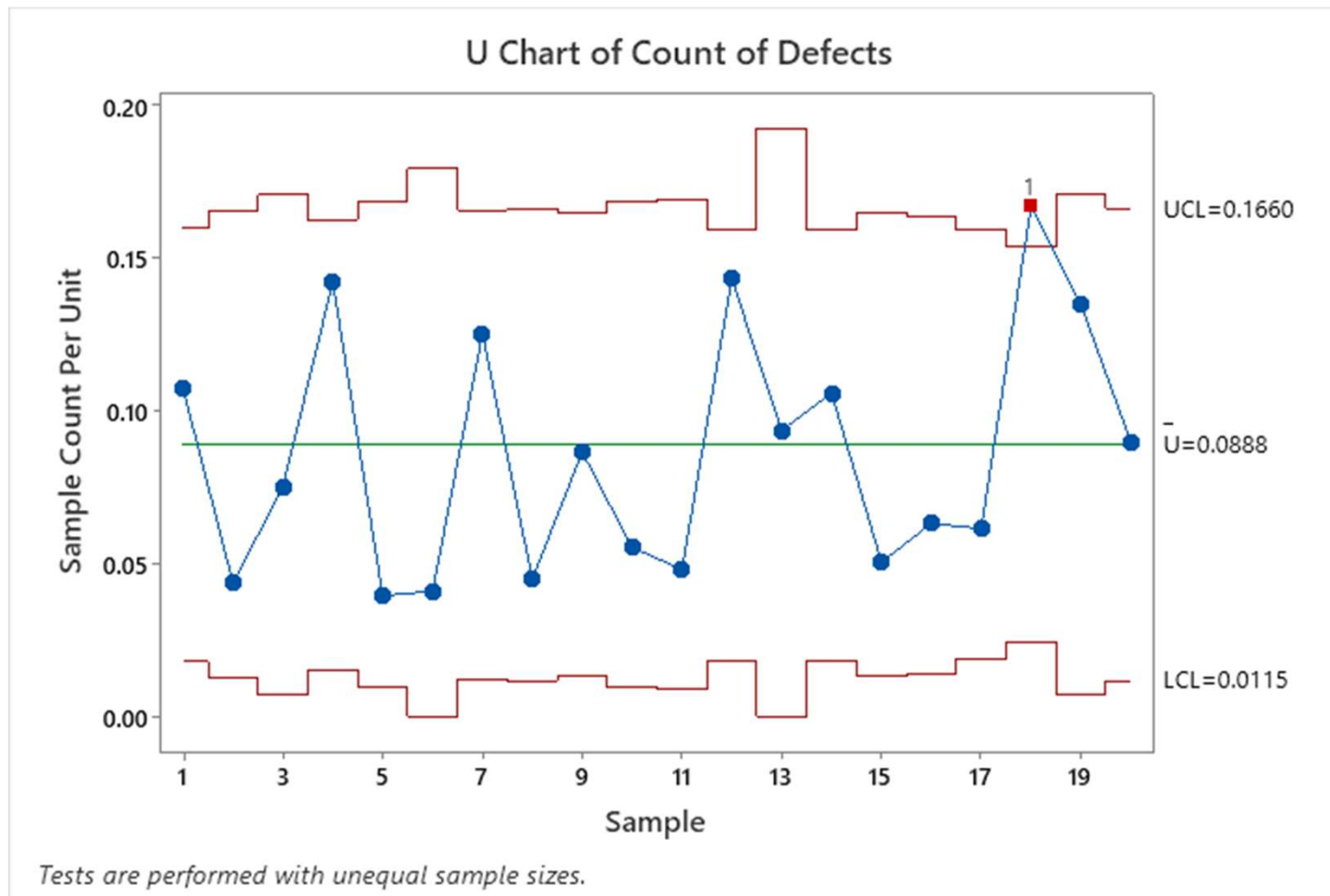
Subgroup sizes: Produced
 (enter a number or column containing the sizes)

Scale... Labels...
 Multiple Graphs... Data Options... U Chart Options...

Select

Help OK Cancel

u-charts in Minitab® Step 2

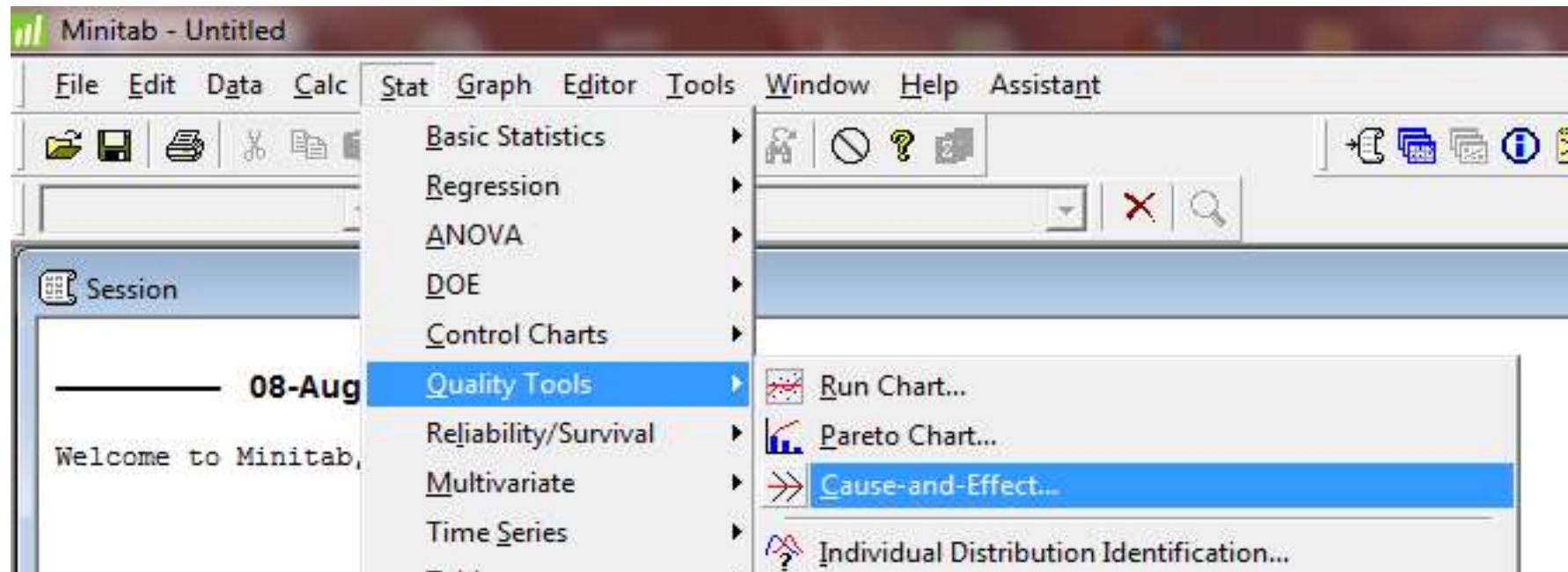


Anexas Consultancy Services

Cause & Effect Diagram

C and E Tool in Minitab

Stat>Quality Tools>Cause-and-Effect



List of Causes (X's)

Category	Cause	Sub - cause	Sub - cause
Man	Shifts		
Man	Supervisors		
Man	Training	Mentors	Testing
Man	Operators		
Machine	Sockets		
Machine	Bits		
Machine	Lathes		
Machine	Speed	Too slow	Erratic
Machine	Alloys		
Machine	Lubricants		
Machine	Suppliers		
Material	Angle		
Material	Engager		
Material	Brake		
Measure	Micrometers	Accuracy	Condition
Measure	Microscopes		
Measure	Inspectors		
Environment	Moisture%		
Environment	Condensation		

List of Causes (X's)

↓	C1-T	C2-T	C3-T	C4-T	C5-T	C6-T	C7-T	C8-T	C9-T
	Man	Machine	Material	Method	Measure	Enviro	Training	Speed	Micrometers
1	Shifts	Sockets	Alloys	Angle	Micrometers	Moisture%	Mentors	Too slow	Accuracy
2	Supervisors	Bits	Lubricants	Engager	Microscopes	Condensation	Testing	Erratic	Condition
3	Training	Lathes	Suppliers	Brake	Inspectors				
4	Operators	Speed							
5									

Under Causes, enter Man, Machine, Material, Method, Measure, and Enviro in columns 1 through 6, respectively.

Sub-causes should be given separate columns, or branches (columns 7 -9)

Entering Causes

Cause-and-Effect Diagram

Branch	Causes	Label	
1	In column	Man	Personnel Sub...
2	In column		Machines Sub...
3	In column		Material Sub...
4	In column		Methods Sub...
5	In column		Measurements Sub...
6	In column		Environment Sub...
7	In column		Sub...
8	In column		Sub...
9	In column		Sub...
10	In column		Sub...

Effect:

Title:

Do not label the branches

Do not display empty branches

Select

Help

OK

Cancel

Enter the fields under *Causes* section from the corresponding field list on the left

Entering Sub-causes - Man

The screenshot shows two dialog boxes in Minitab. The main dialog, 'Cause-and-Effect Diagram', has a list of causes on the left and a table on the right. The table has columns for Branch, Causes, and Label. The sub-dialog, 'Cause-and-Effect Diagram - Sub-Branches', is open over the main dialog, showing a table for sub-causes. An arrow points to the 'Sub...' button in the main dialog with the text 'Click Here'.

Branch	Causes	Label
1	In column ▼ Man	Personnel
2	In column ▼	Machines

Sub-Branch	Causes	Label
1	In column ▼	Shifts
2	In column ▼	Supervisors
3	In column ▼ Training	Training
4	In column ▼	Operators

For Man, click on Sub. Under Causes, enter *Training* which is in Column 7. Click OK.

Entering Sub-causes - Man

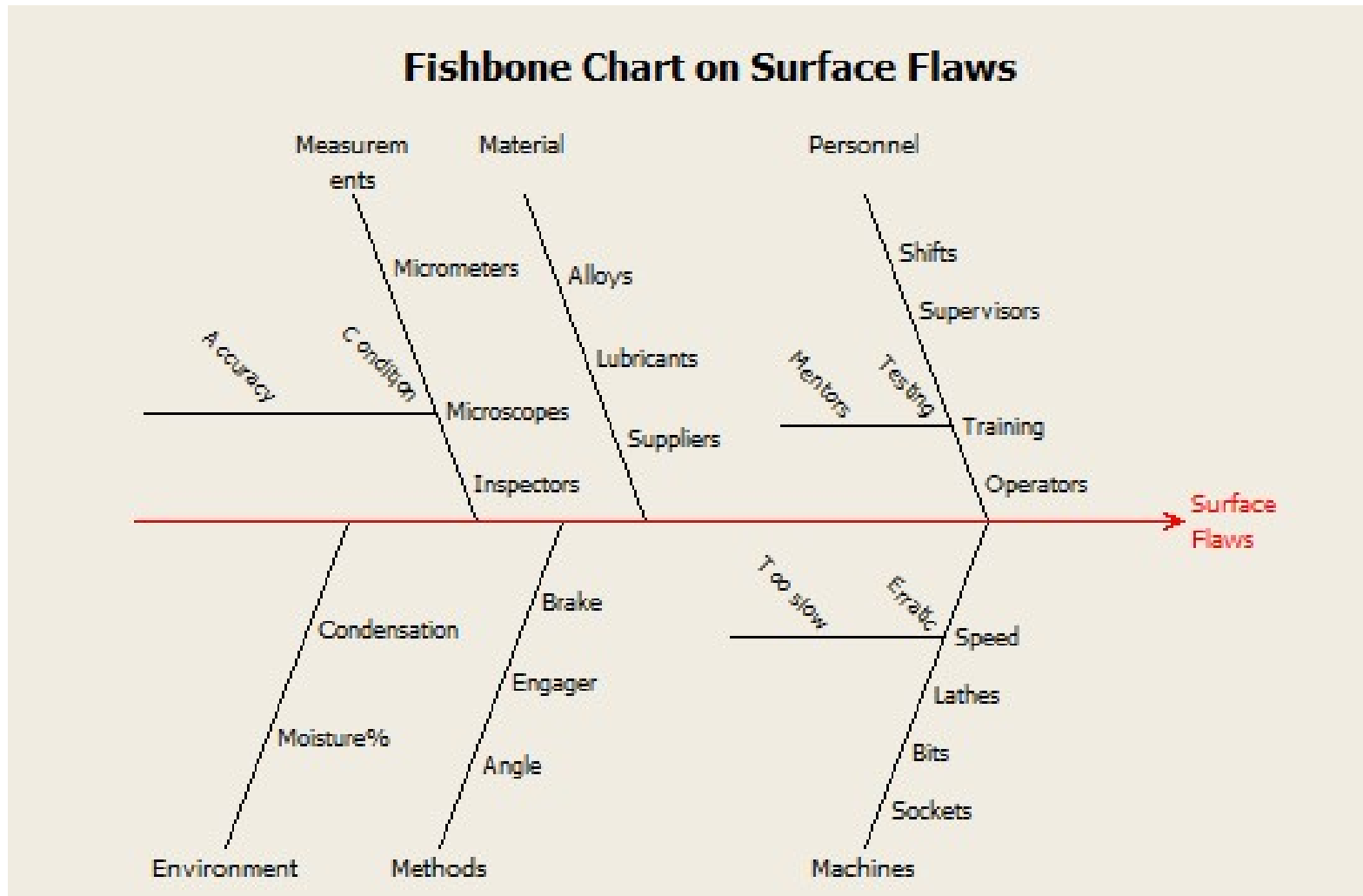
The screenshot shows the Minitab Cause-and-Effect Diagram dialog box. On the left is a list of causes: C1 Man, C2 Machine, C3 Material, C4 Method, C5 Measure, C6 Enviro, C7 Training, C8 Speed, and C9 Micrometers. The main dialog has a table with columns: Branch, Causes, and Label. The table contains five rows, each with a branch number (1-5), a dropdown menu set to 'In column', and a cause name (Man, Machine, Material, Method, Measure). The 'Label' column contains 'Personnel', 'Machines', 'Material', 'Methods', and 'Measurements', each followed by a 'Sub...' button. A red arrow points to the 'Sub...' button for Branch 5. A secondary dialog, 'Cause-and-Effect Diagram - Sub-Branches', is open, showing a list of causes with 'C9 Micrometers' selected. This dialog has a table with columns: Sub-Branch, Causes, and Label. The table contains three rows: Sub-Branch 1 with Cause 'In column' and Label 'Micrometers'; Sub-Branch 2 with Cause 'In column' and Label 'Microscopes'; and Sub-Branch 3 with Cause 'In column' and Label 'Inspectors'.

Branch	Causes	Label
1	In column ▼ Man	Personnel Sub...
2	In column ▼ Machine	Machines Sub...
3	In column ▼ Material	Material Sub...
4	In column ▼ Method	Methods Sub...
5	In column ▼ Measure	Measurements Sub...

Sub-Branch	Causes	Label
1	In column ▼	Micrometers
2	In column ▼	Micrometers
3	In column ▼	Inspectors

For Measure, click on Sub. Under Causes, enter *Micrometers* which is in Column 9. Click OK.

Output



Thank You!

Thank You