SPC: Statistical Process Control

AGENDA

1. SPC (Statistical Process Control)
   - Control Chart
   - Advantages
   - Disadvantages
   - Structure
2. Basic Statistic
3. Control Charts
4. Control Charts – Minitab 18

SPC

All processes have a natural variations (due to common causes) and unnatural variations (due to special causes).

- The right use of SPC can detect the **special causes** using signal of non controlled process.
- The control charts can not tell us why the process is out of control.

The **Control Chart** is a tool that we can use to track statistically a process or its parameters along time.

- The Control chart introduce a new concept that we will call natural limits (random) of the process variation.

Control Chart

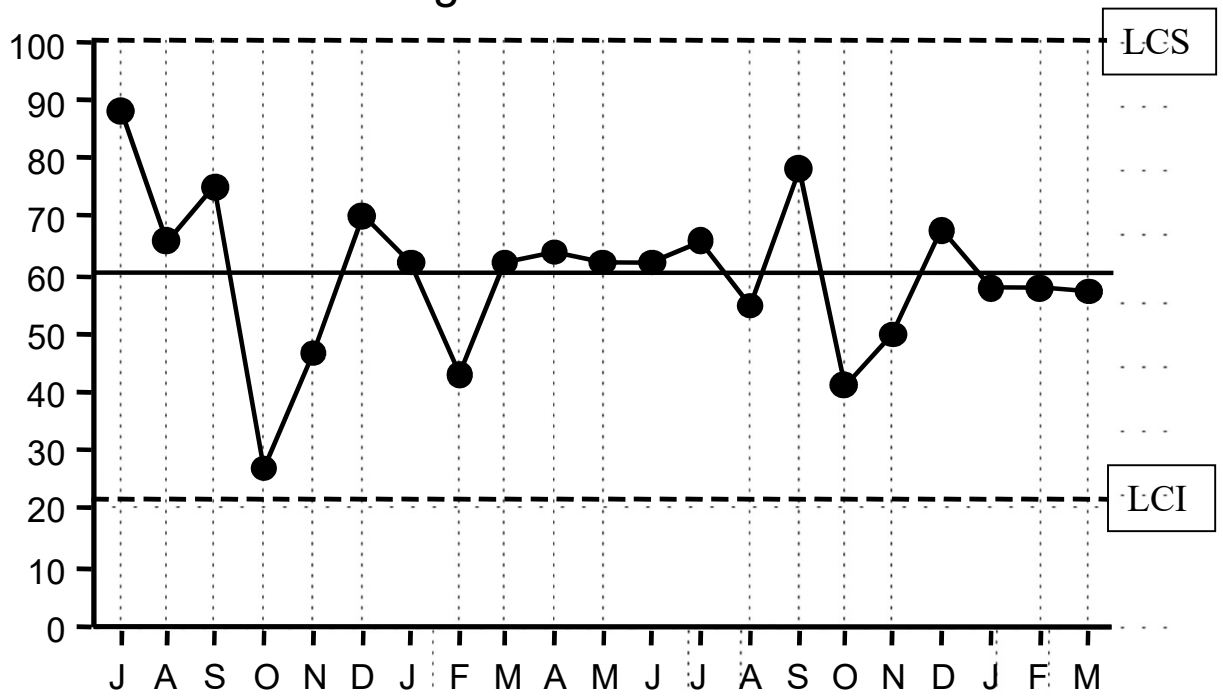
D M A I C R

Structure.

The result ordered in time in one plane (exactly as time traces)

The control limits are establish statisticaly and drawn in the plane has not has nothing related to the specification limits.

The central line use the average +/- 3σ for the limits.



Advantages

- Guaranteed technique to quality improvement
- Effective for deffect prevention
- Preventive for unnecesary process adjustmen
- Provides a diagnostic for the information
- Provides information about process capability
- It can be use for variables data or atributes data

Disadvantages

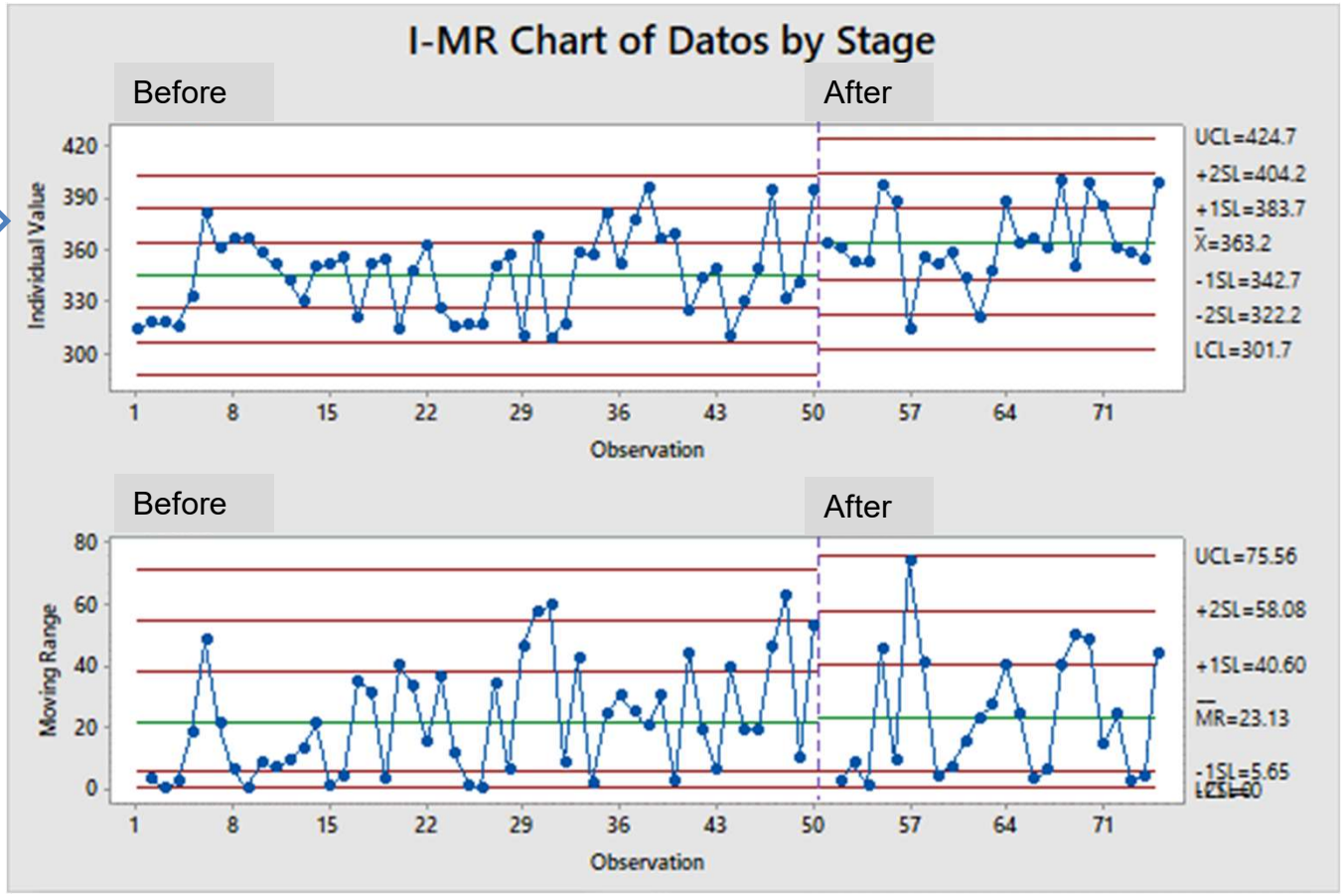
- All participants must be trained
- All calculations of mean, range, standard deviation must be properly calculated.
- All the information must be true
- All the charts must be filled properly
- All the charts must be analyzed properly

Structure

D M A I C R

Trend

Control



+/1σ **Normal** Variation Zone

+/- 2σ **Control** Zone

+/- 3σ **Correction or adjustment** zone

Basic Statistic

Why is measuring so important?

D M A I C R

If we can not measure something with precision

- **Then**

We don not know enough about their behavior

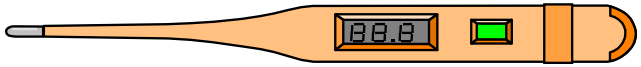
- **Then**

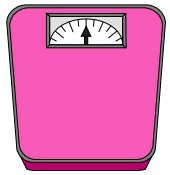
We can not control it

Data Type

Continuous Data (Quantitative)

Continuous Data: They use a measurement scale as temperature, time, width, pressure, etc.

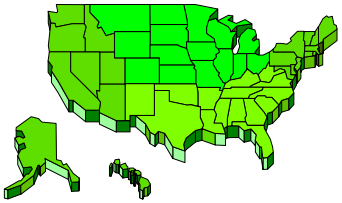




Atribute Data (Qualitative)

Discrete Data: Good/Bad, Yes/No, Ok/Not Ok

Innocent or guilty



Region

Statistic Analysis

- **Descriptive Statistics:**

  Descriptive statistics are used to describe the basic features of the data in a study. They provide simple summaries about the sample and the measures. Together with simple graphics analysis, they form the basis of virtually every quantitative analysis of data.

- **Probability:**

  Means possibility. It is a branch of mathematics that deals with the occurrence of a random event.

Population based on the sample.

- In statistics, a **population** is the entire pool from which a statistical sample is drawn. A population may refer to an entire group of people, objects, events, hospital visits, or measurements.
- A **sample** is just a part of a population. For example, let's say your population was every American, and you wanted to find out how much the average person earns.
- A **random sample** is a sample that is chosen randomly. It could be more accurately called a randomly chosen sample. Random samples are used to avoid bias and other unwanted effects.

Resume

D M A I C R

- **Measures of central tendency**
  - Mean
  - Median
  - Mode
- **Measures of Variability**
  - Range
  - Variance
  - Standard Deviation

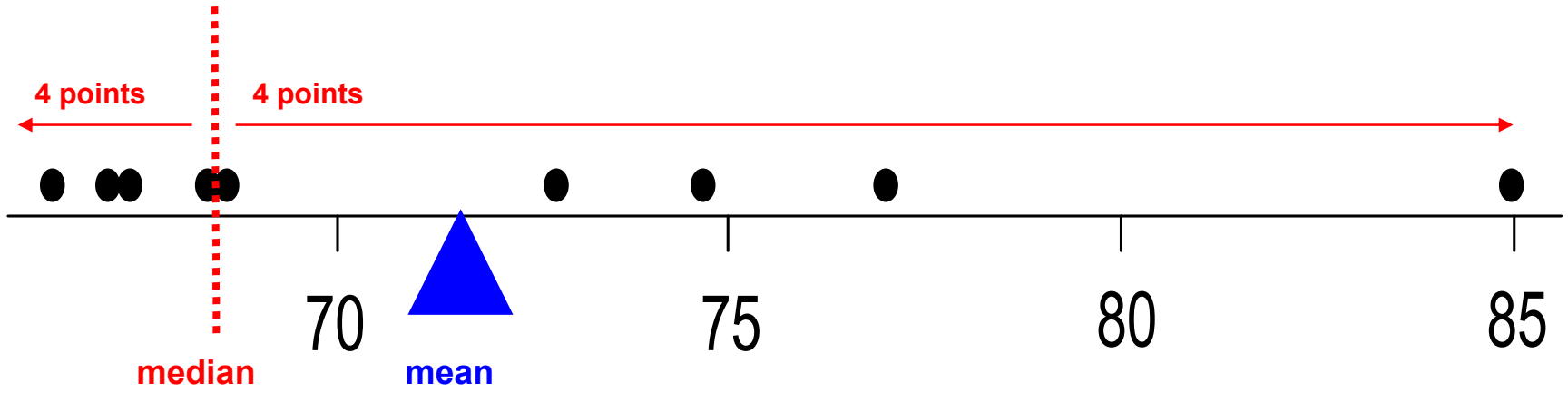
Measures of central tendency

- The **mean** describes an entire sample with a single number that represents the center of the data. The mean is the arithmetic average.

- The **median** is the middle of the data. Half of the observations are less than or equal to it and half of the observations are greater than or equal to it.

- The **mode** is the value that occurs most frequently in a set of observations. You can find the mode simply by counting the number of times each value occurs in a data set.

Mean vs. median



Imagine 1 pound balls on a thin rod

- The mean is the gravity center.
- The median has a half of the balls to the left and the other half to the right.

Measures of Variability

- The **range** of a dataset is the difference between the largest and smallest values in that dataset.

- **Variance** is the average squared difference of the values from the mean, the variance includes all values in the calculation by comparing each value to the mean.

- **The standard deviation** is the standard or typical difference between each data point and the mean.

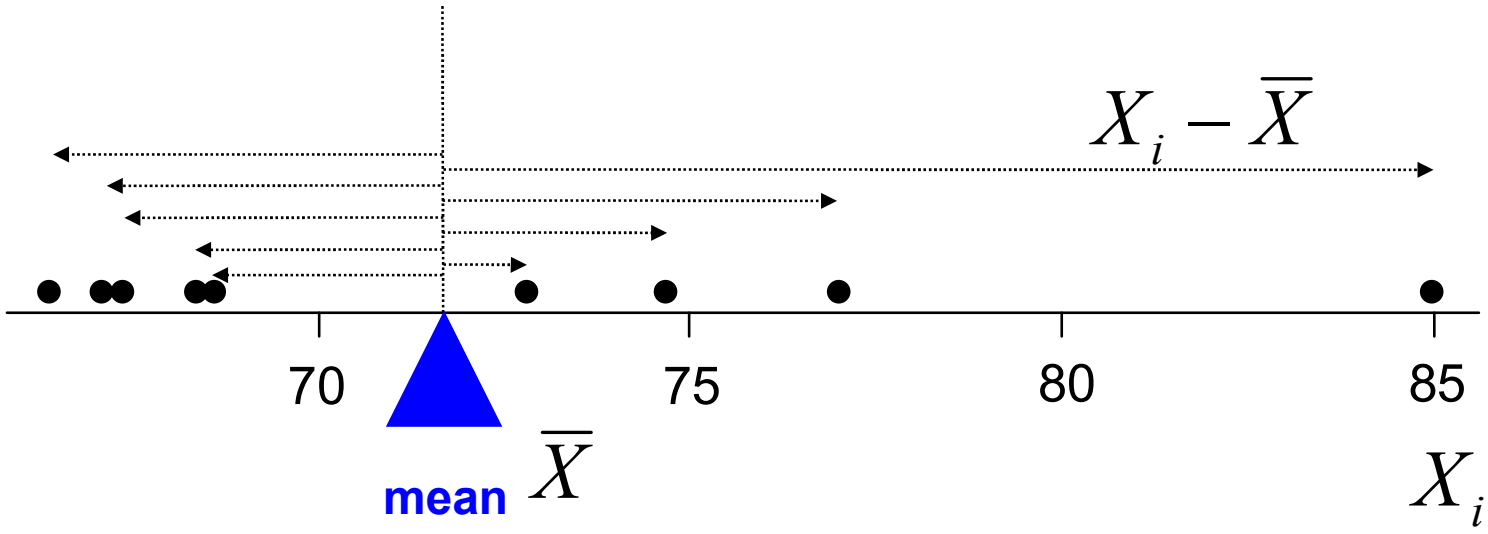
Standard deviation

Formula:

$$\sigma = \sqrt{\sum_{i=1}^{N} \frac{(X_i - \mu)^2}{N}} \qquad s = \sqrt{\sum_{i=1}^{n} \frac{(x_i - \bar{x})^2}{n - 1}}$$

- Conveniently, the standard deviation uses the original units of the data, which makes interpretation easier. Consequently, the standard deviation is the most widely used measure of variability.

Standard deviation



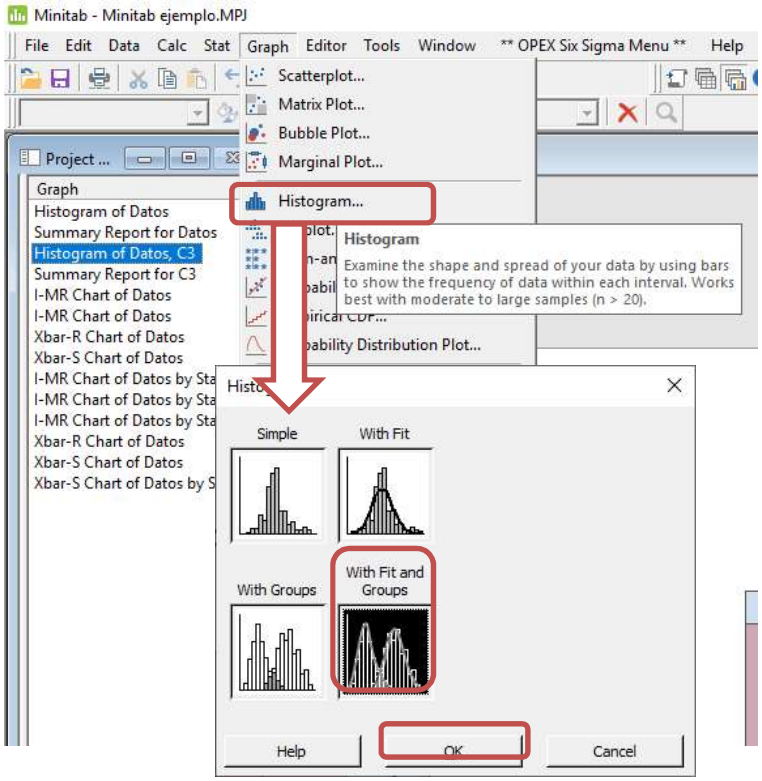
Steps for calculation:

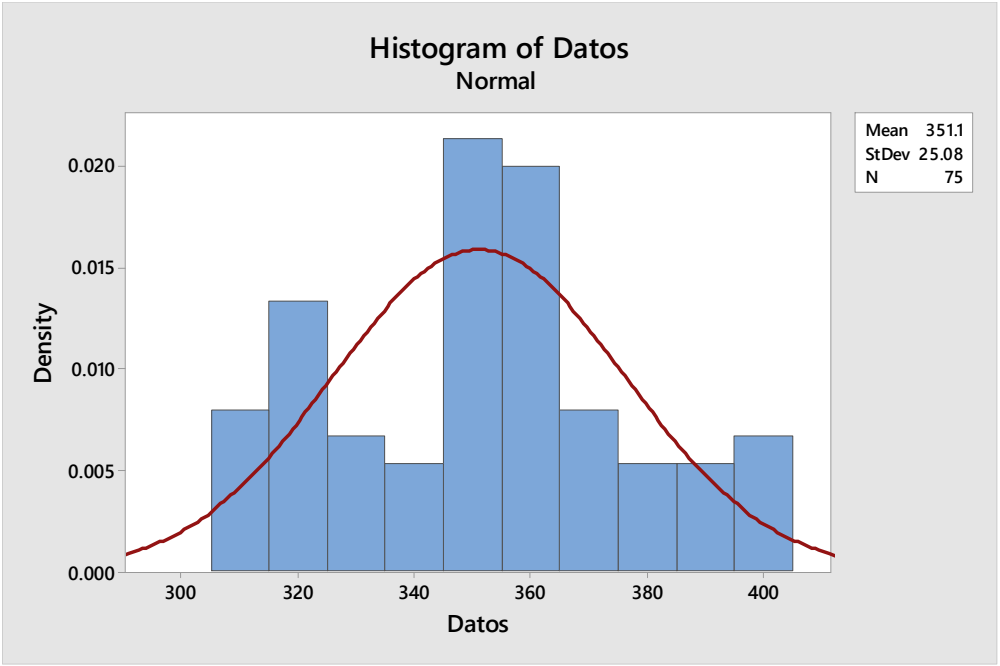
- Take the length of each row and square them
- Calculate the average of the squares (using "*n*-1" as divider for a simple)
- Extract the square root

Basic Statistic in Minitab

D M A I C R

- **Histogram:** A frequency distribution shows how often each different value in a set of data occurs. A histogram is the most commonly used graph to show frequency distributions. It looks very much like a bar chart, but there are important differences between them. This helpful data collection and analysis tool is considered one of the seven basic quality tools.

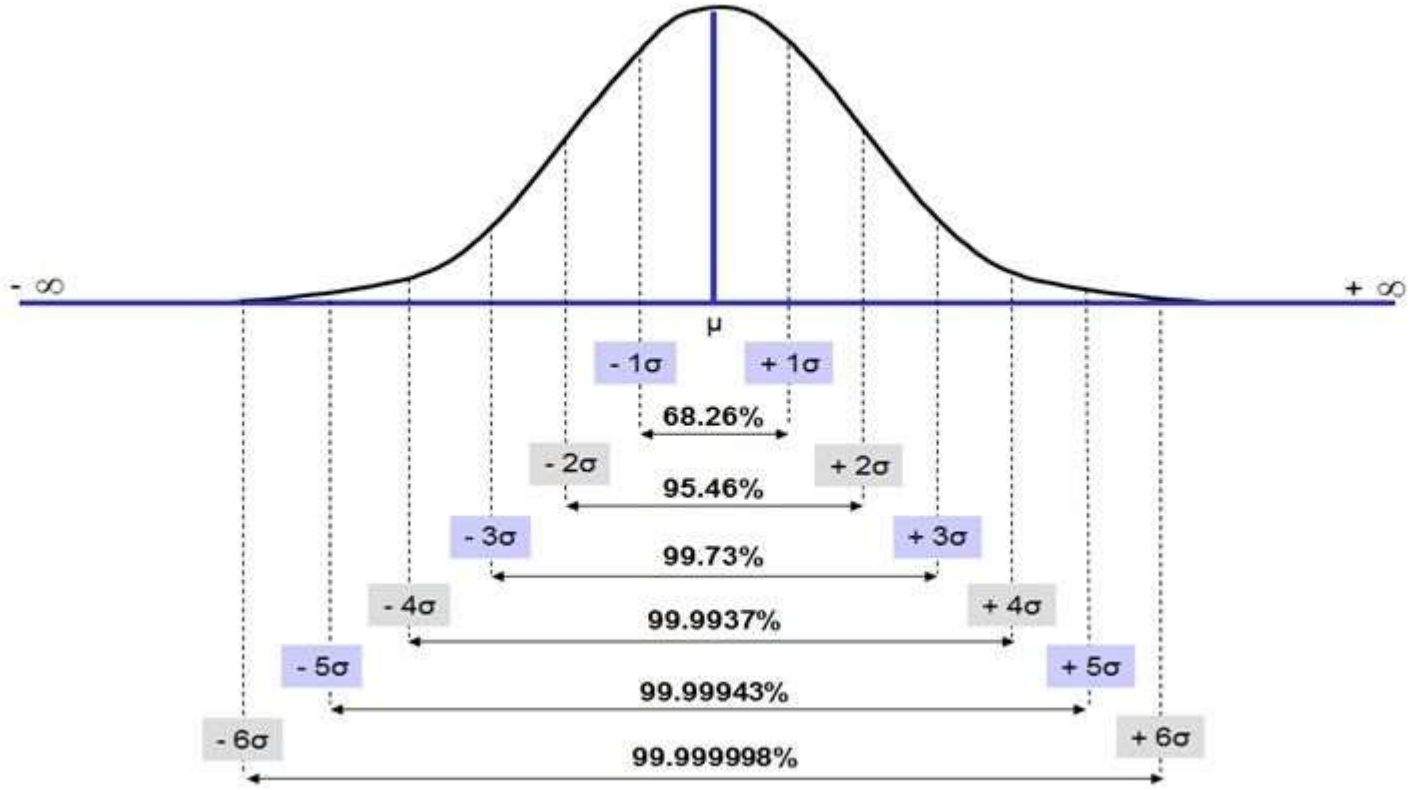




SixSigma

Normal Distribution in Six Sigma

D M A I C R



Control Charts

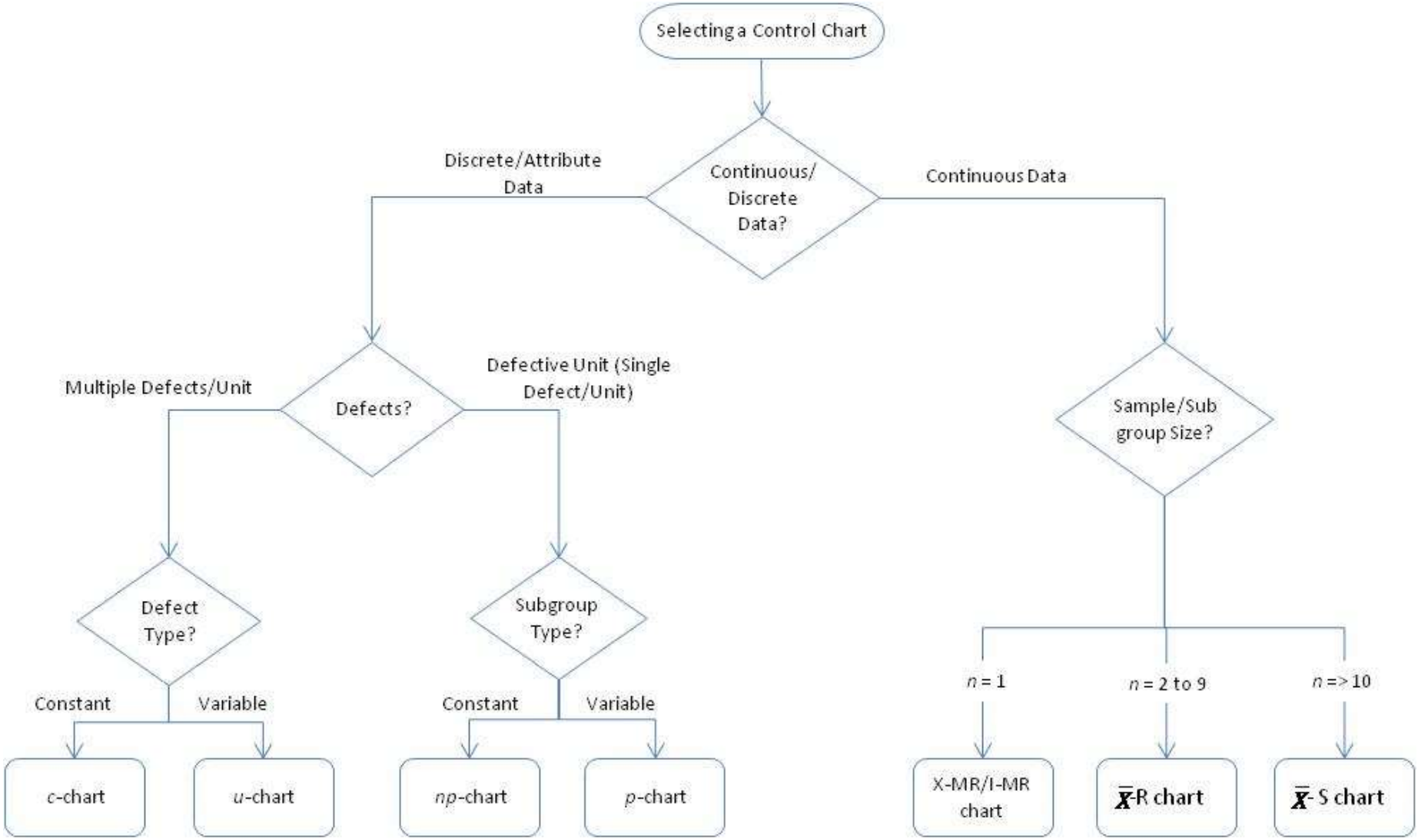
https://www.youtube.com/watch?v=QjEsp9ppfIA

Planning for an effective SPC

- Bases for a Control Chart implementation

  - **Characterize the Process in its limits**
    - Max; Min, Mean & Histogram.
    - Stablish and prove the critical variables for the process.
  - **Determine the variation limits (1σ, 2σ, 3σ).**
  - **Stablish the reference setting**
  - **Record the special causes located at 3σ**
  - Remove unnecesary graphs
  - Update charts periodically if necessary.
  - Decisions based on control charts must be agreed by the Team.

Selecting a control chart



Control Charts Types

X Bar R Control Charts

X-bar chart: The mean or average change in process over time from subgroup values. The control limits on the X-Bar brings the sample's mean and center into consideration.

R-chart: The range of the process over the time from subgroups values. This monitors the spread of the process over the time.

X Bar S Control Charts

X-bar chart: The mean or average change in process over time from subgroup values. The control limits on the X-Bar brings the sample's mean and center into consideration.

S-chart: The standard deviation of the process over the time from subgroups values. This monitors the process **standard deviation** (as approximated by the sample moving range)

I-MR Chart

I-Chart: Individual chart displays the individual data points and monitors mean and shifts in the process when the data points collected at regular intervals of time. This chart will help to identify the common and assignable causes in the process, if any.

MR Chart: While Individual chart monitors the process mean, the Moving Range chart monitors the process variation when the data points collected at regular intervals of time. In other words the moving range chart tracks the absolute difference of each measurement to its previous measurement.

Control Charts Types

D M A I C R

Np Chart.

It is generally used to monitor the number of non-conforming or defective items in the measurement process.

$$n\bar{p} = \frac{Total\ number\ of\ defectives}{Number\ of\ lots\ sampled}$$

P Chart.

P chart is also known as the control chart for proportions. It is generally used to analyze the proportions of non-conforming or defective items in a process.

$$\bar{p} = \frac{Total\ number\ of\ defectives}{Total\ number\ of\ items\ sampled}$$

C Chart.

C chart is also known as the control chart for defects (counting of the number of defects). It is generally used to monitor the number of defects in constant size units.

$$\bar{c} = \frac{Total\ number\ of\ defects}{Number\ of\ samples}$$

U Chart .

U chart is an attributes control chart used with data collected in subgroups of varying sizes. U-charts show how the process, measured by the number of nonconformities per item or group of items, changes over time.

Steps in constructing an X-R chart

D M A I C R

1. Calculate the average of each subgroup

$$\bar{x} = \frac{1}{5}(10.0 + 1.0 + 4.0 + 9.0 + 8.0) = 6.4$$

2. Calculate the range of each supgroup

$$R = 10.0 - 1.0 = 9.0$$

Muestra #	8:00	8:30	9:00	9:30	10:00	10:30	11:00
1	10.0	7.0	5.0	9.0	2.0	2.0	5.0
2	1.0	4.0	2.0	3.0	4.0	4.0	6.0
3	4.0	10.0	6.0	7.0	2.0	8.0	4.0
4	9.0	2.0	2.0	3.0	6.0	8.0	10.0
5	8.0	8.0	3.0	1.0	1.0	6.0	3.0
Promedio	6.4	6.2	3.6	4.6	3.0	5.6	5.6
Rango	9.0	8.0	4.0	8.0	5.0	6.0	7.0

Steps in constructing an X-R chart

D M A I C R

3. Calculate the average of the average

$$\overline{\overline{X}} = \frac{1}{7}(6.4 + 6.2 + 3.6 + 4.6 + 3.0 + 5.6 + 5.6) = 5.0$$

4. Calculate the average of the range

$$\overline{R} = \frac{1}{7}(9.0 + 8.0 + 4.0 + 8.0 + 5.0 + 6.0 + 7.0) = 6.7$$

Muestra #	8:00	8:30	9:00	9:30	10:00	10:30	11:00
1	10.0	7.0	5.0	9.0	2.0	2.0	5.0
2	1.0	4.0	2.0	3.0	4.0	4.0	6.0
3	4.0	10.0	6.0	7.0	2.0	8.0	4.0
4	9.0	2.0	2.0	3.0	6.0	8.0	10.0
5	8.0	8.0	3.0	1.0	1.0	6.0	3.0
Promedio	6.4	6.2	3.6	4.6	3.0	5.6	5.6
Rango	9.0	8.0	4.0	8.0	5.0	6.0	7.0

Steps in constructing an X-R chart

D M A I C R

5. Calculate the control limits

Muestra #	8:00	8:30	9:00	9:30	10:00	10:30	11:00
1	10.0	7.0	5.0	9.0	2.0	2.0	5.0
2	1.0	4.0	2.0	3.0	4.0	4.0	6.0
3	4.0	10.0	6.0	7.0	2.0	8.0	4.0
4	9.0	2.0	2.0	3.0	6.0	8.0	10.0
5	8.0	8.0	3.0	1.0	1.0	6.0	3.0
Promedio	6.4	6.2	3.6	4.6	3.0	5.6	5.6
Rango	9.0	8.0	4.0	8.0	5.0	6.0	7.0

For X Bar chart:

$$UCL_{\bar{x}} = \bar{\bar{X}} + A_2\bar{R}$$
$$UCL_{\bar{x}} = 5.0 + (0.577 \times 6.7) = 8.9$$
$$LCL_{\bar{x}} = \bar{\bar{X}} - A_2\bar{R}$$
$$LCL_{\bar{x}} = 5.0 - (0.577 \times 6.7) = 1.1$$

For R chart:

$$UCL_R = D_4\bar{R}$$
$$UCL_R = 2.114 \times 6.7 = 14.2$$
$$LCL_R = D_3\bar{R}$$
$$LCL_R = 0.000 \times 6.7 = 0.0$$

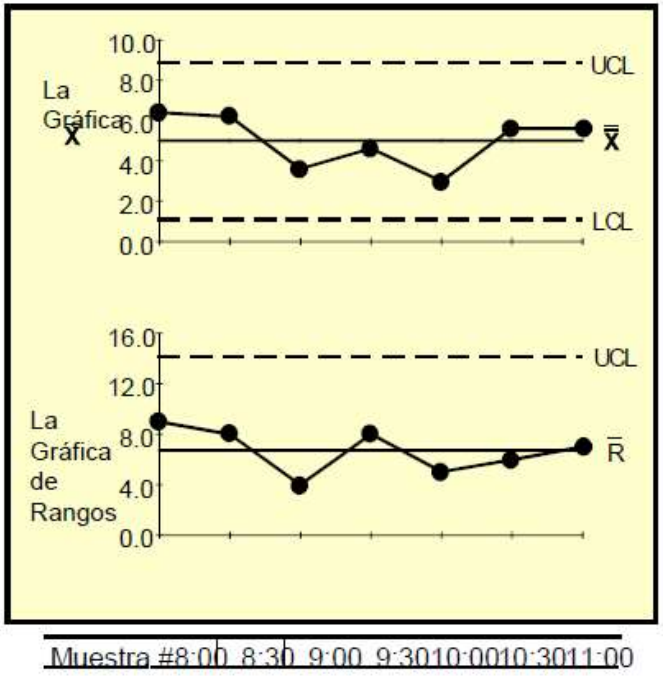
Table of d_2, A_2, D_3, and D_4 values as a Function of the subgroup sample size, n

n	d_2	A_2	D_3	D_4
2	1.128	1.880	0	3.267
3	1.693	1.023	0	2.574
4	2.059	0.729	0	2.282
5	2.326	0.577	0	2.114
6	2.534	0.483	0	2.004
7	2.704	0.419	0.076	1.924

Table 4

Steps in constructing an X-R chart

D M A I C R

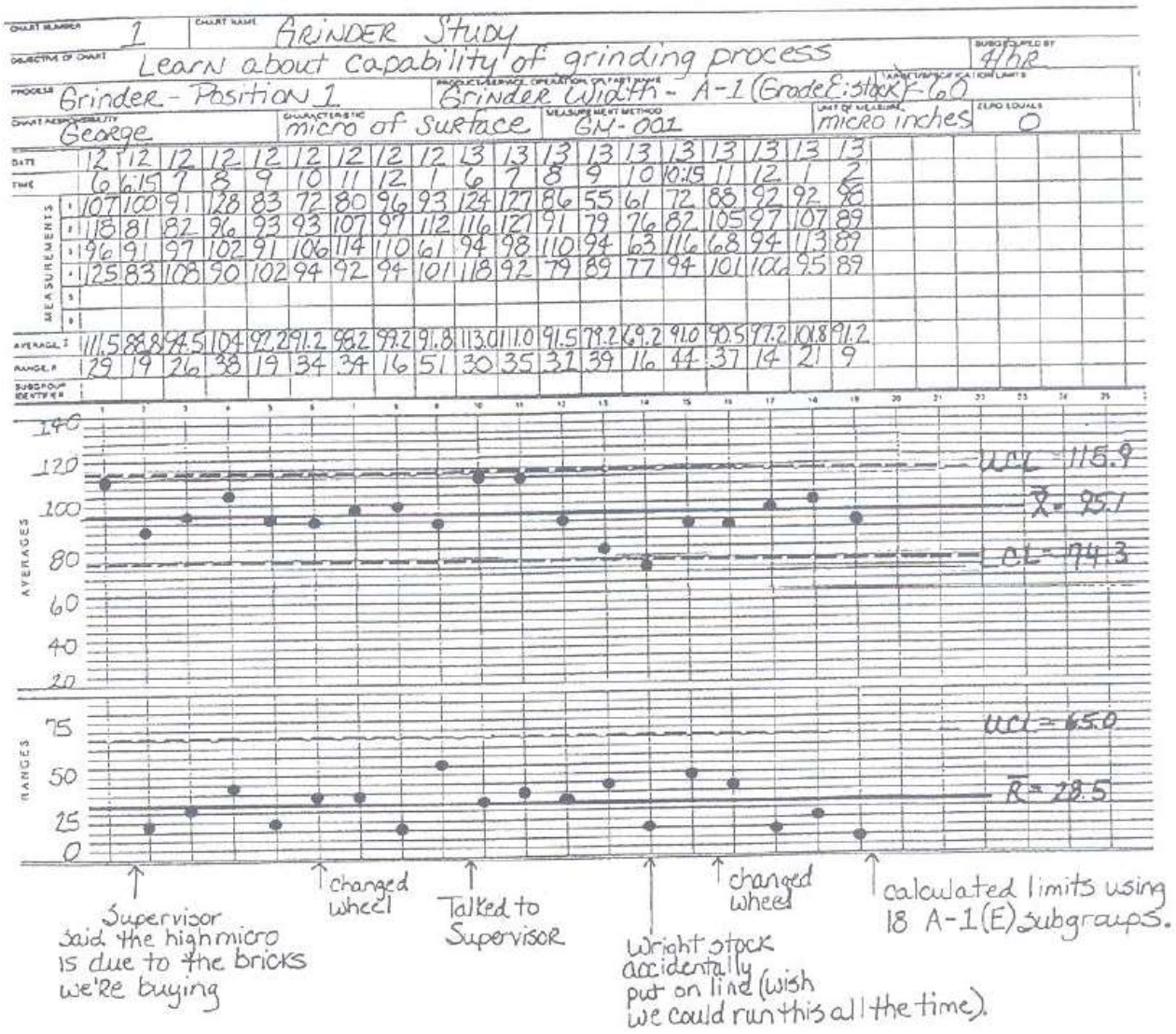


6. Build the graph

1	10.0	7.0	5.0	9.0	2.0	2.0	5.0
2	1.0	4.0	2.0	3.0	4.0	4.0	6.0
3	4.0	10.0	6.0	7.0	2.0	8.0	4.0
4	9.0	2.0	2.0	3.0	6.0	8.0	10.0
5	8.0	8.0	3.0	1.0	1.0	6.0	3.0
Promedio	6.4	6.2	3.6	4.6	3.0	5.6	5.6
Rango	9.0	8.0	4.0	8.0	5.0	6.0	7.0

X Bar R Control Charts Example

D M A I C R



SixSigma

Data Collection to X-R chart

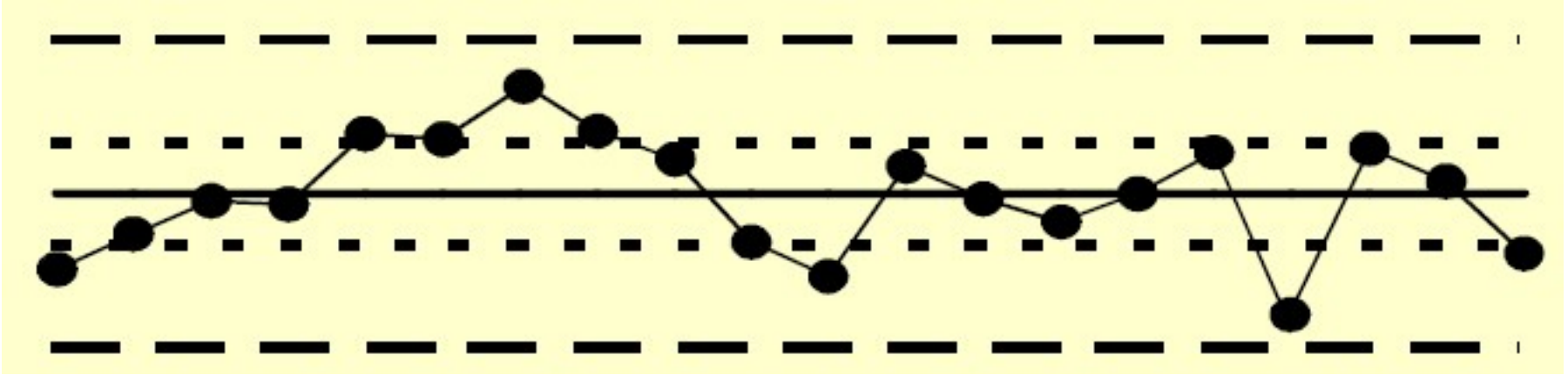
Basic Rules:

1. At least 20 subgroups of approximately n = 5 data are required.

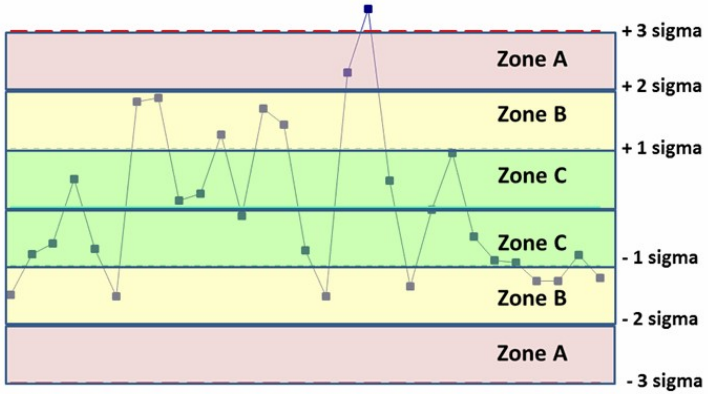
2. Data within a subgroup should be collected in close time periods (for example, 5 parts produced consecutively).

3. Between subgroups longer time intervals are used. (Depending on the process and the objective of the study, these time intervals can be 15 min., 30 min., 1 hr., 2 hr., or more).

Normal Pattern



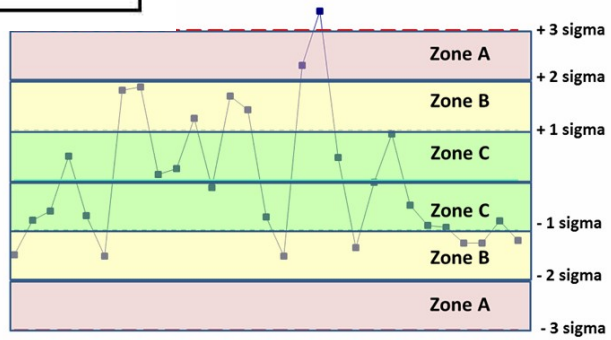
- Random pattern, non repetitive
- There are no trends or erratic changes
- All points are inside the UCL and LCL
- 66% of the points are in zone C



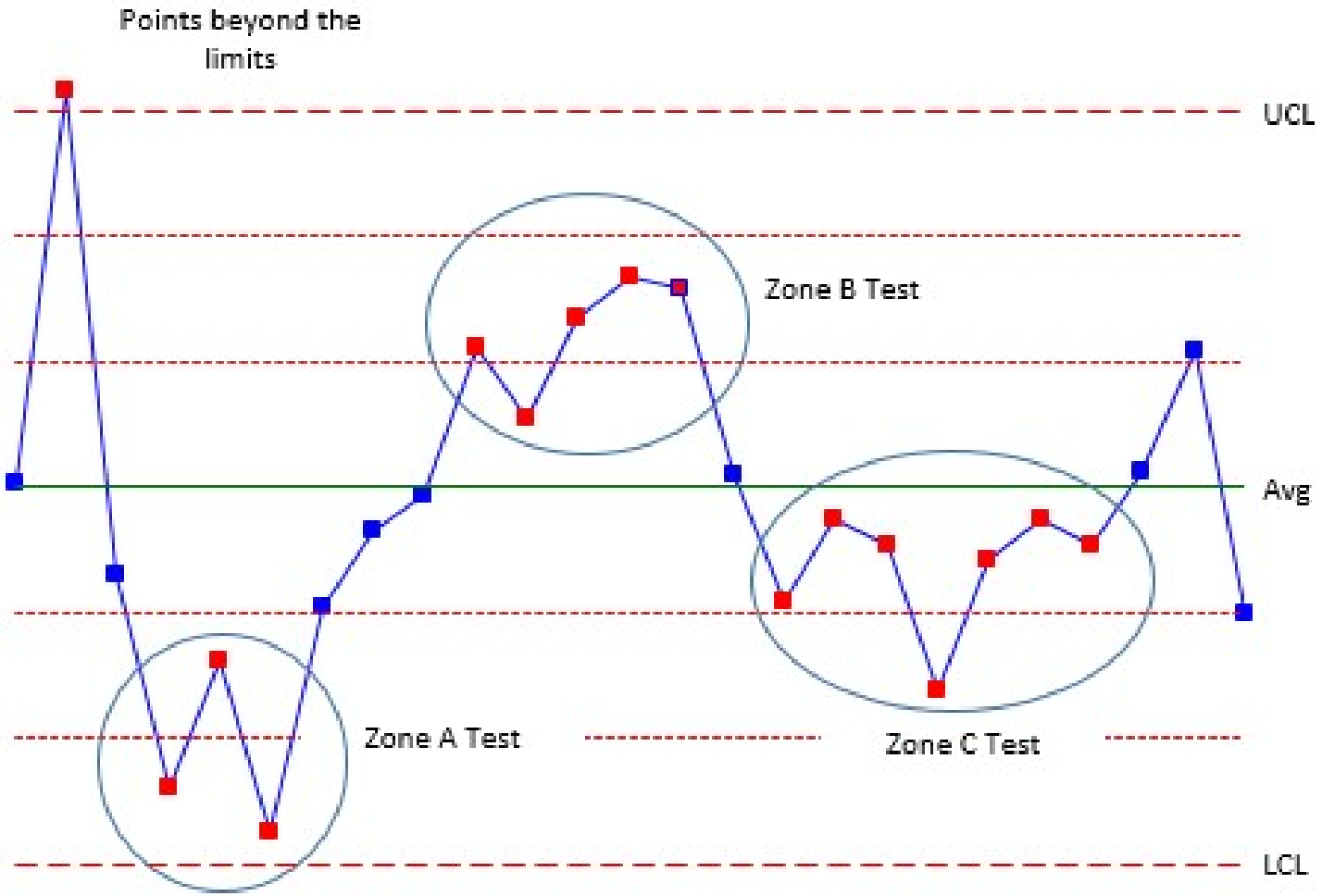
Control Charts Rules

D M A I C R

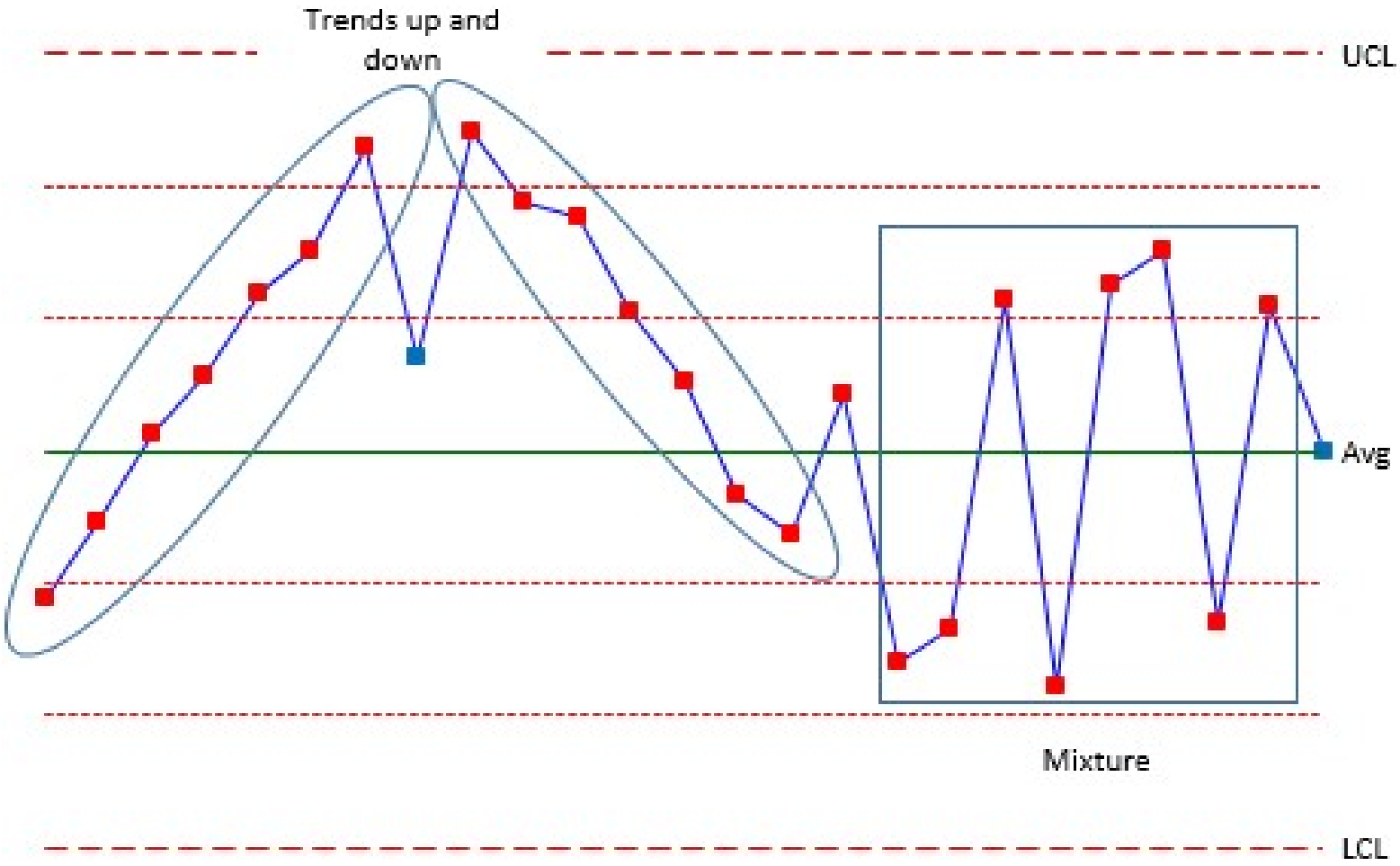
Rule	Rule Name	Pattern
1	Beyond Limits	One or more points beyond the control limits
2	Zone A	2 out of 3 consecutive points in Zone A or beyond
3	Zone B	4 out of 5 consecutive points in Zone B or beyond
4	Zone C	7 or more consecutive points on one side of the average (in Zone C or beyond)
5	Trend	7 consecutive points trending up or trending down
6	Mixture	8 consecutive points with no points in Zone C
7	Stratification	15 consecutive points in Zone C
8	Over-control	14 consecutive points alternating up and down



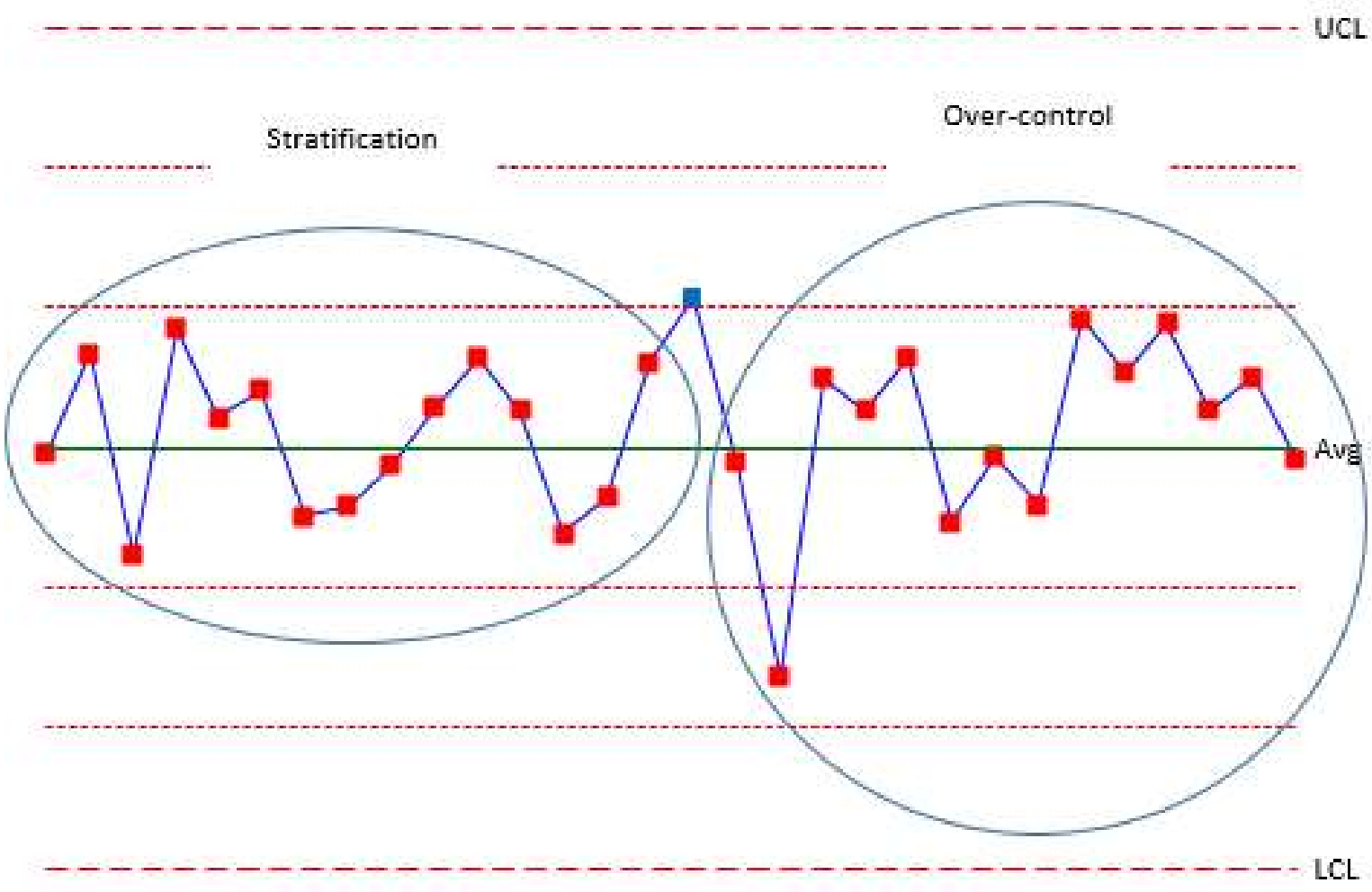
Control Charts Rules



Control Charts Rules



Control Charts Rules

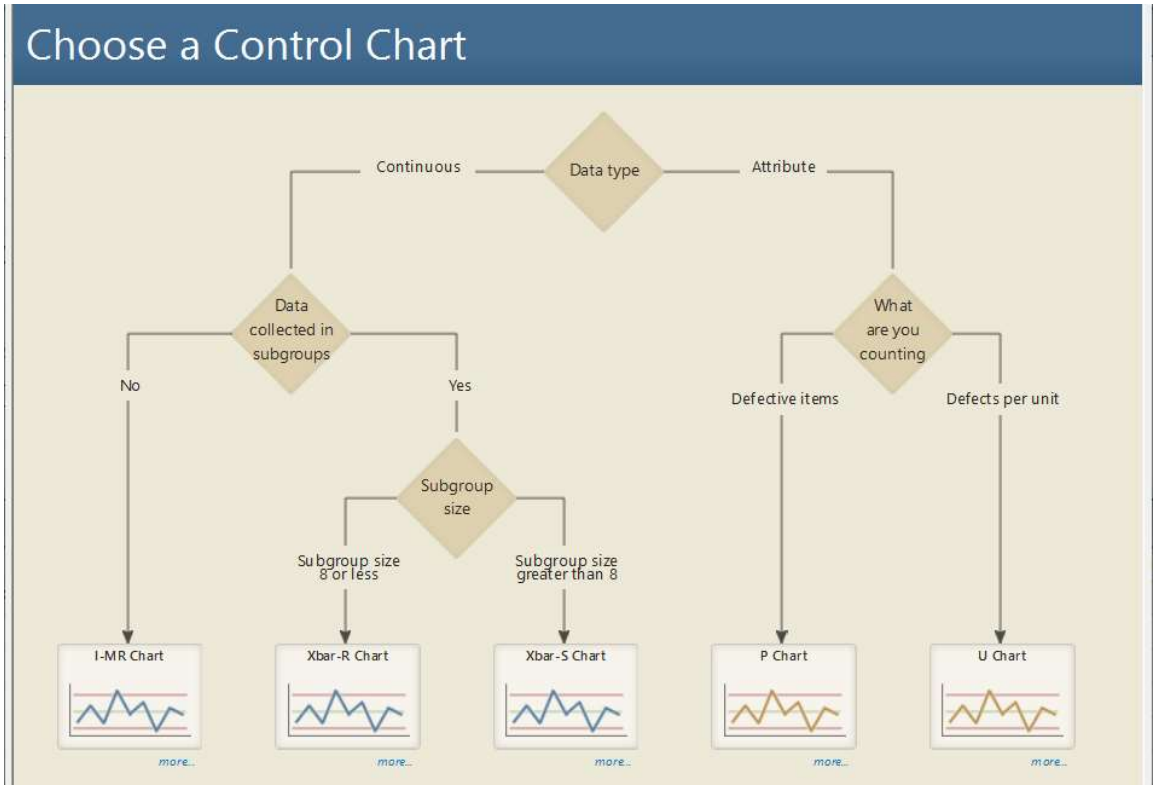


Possible causes by pattern

D M A I C R

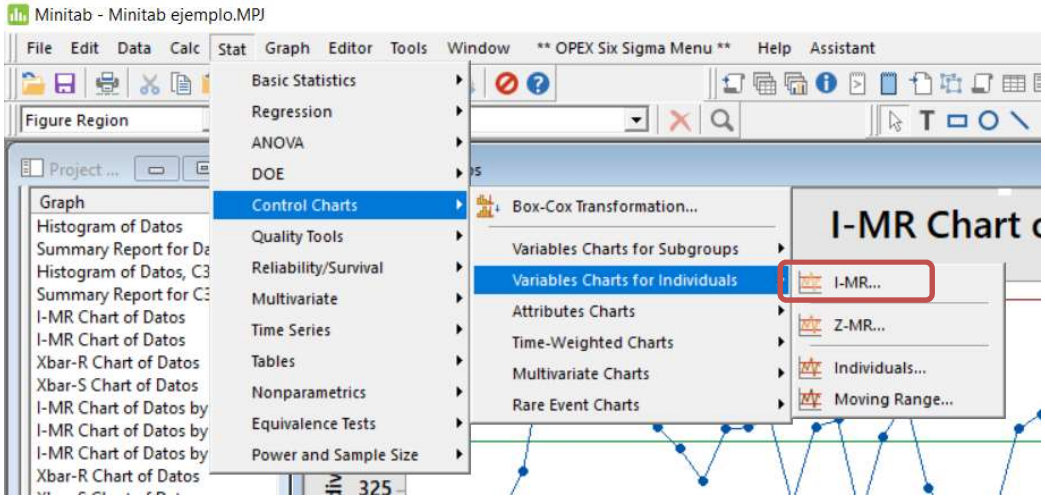
Pattern Description	Rules	Possible Causes
Large shifts from the average	1, 2	New person doing the job Wrong setup Measurement error Process step skipped Process step not completed Power failure Equipment breakdown
Small shifts from the average	3, 4	Raw material change Change in work instruction Different measurement device/calibration Different shift Person gains greater skills in doing the job Change in maintenance program Change in setup procedure
Trends	5	Tooling wear Temperature effects (cooling, heating)
Mixtures	6	More than one process present (e.g. shifts, machines, raw material.)
Stratifications	7	More than one process present (e.g. shifts, machines, raw materials)
Over-control	8	Tampering by operator Alternating raw materials

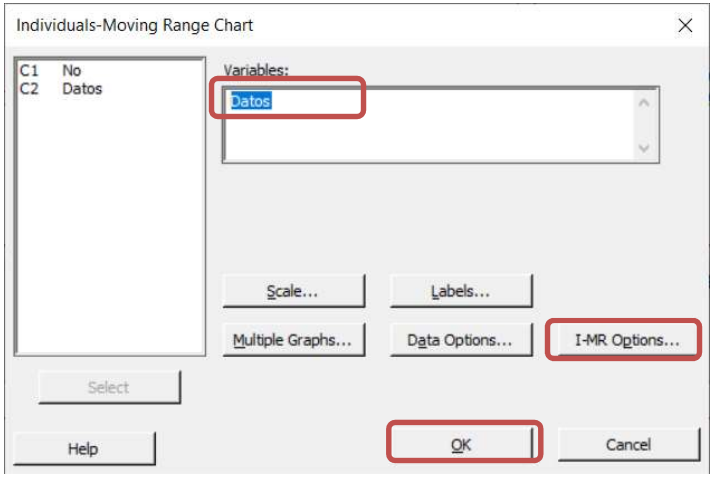
https://youtu.be/MhMR2hBt4Kg

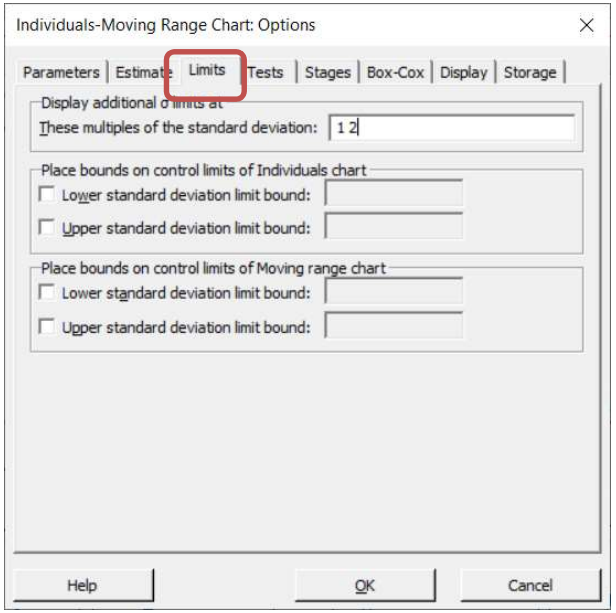


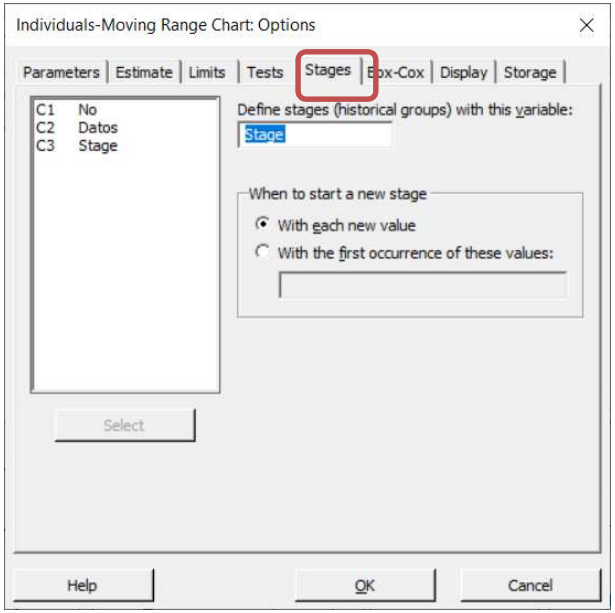
Control Charts Minitab 18

I-MR Chart

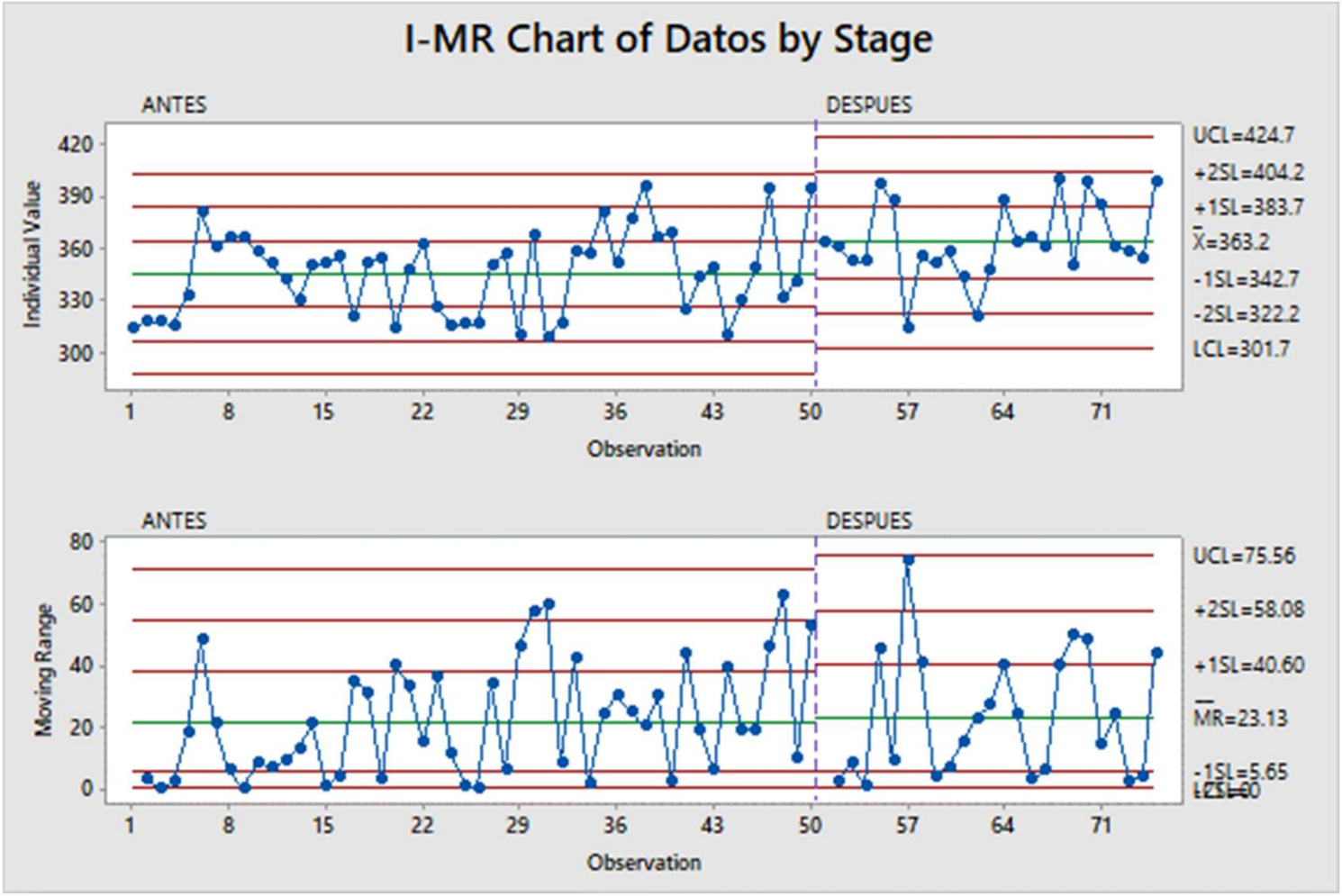

Minitab - Minitab ejemplo.MPJ
File Edit Data Calc Stat Graph Editor Tools Window ** OPEX Six Sigma Menu ** Help Assistant
Basic Statistics
Regression
ANOVA
DOE
Control Charts
Quality Tools
Reliability/Survival
Multivariate
Time Series
Tables
Nonparametrics
Equivalence Tests
Power and Sample Size
Box-Cox Transformation...
Variables Charts for Subgroups
Variables Charts for Individuals
Attributes Charts
Time-Weighted Charts
Multivariate Charts
Rare Event Charts
I-MR...
Z-MR...
Individuals...
Moving Range...
I-MR Chart
Graph
Histogram of Datos
I-MR Chart of Datos
Xbar-R Chart of Datos
Xbar-S Chart of Datos


Individuals-Moving Range Chart
C1 No
C2 Datos
Variables:
Datos
Scale...
Labels...
Multiple Graphs...
Data Options...
I-MR Options...
Select
Help
OK
Cancel

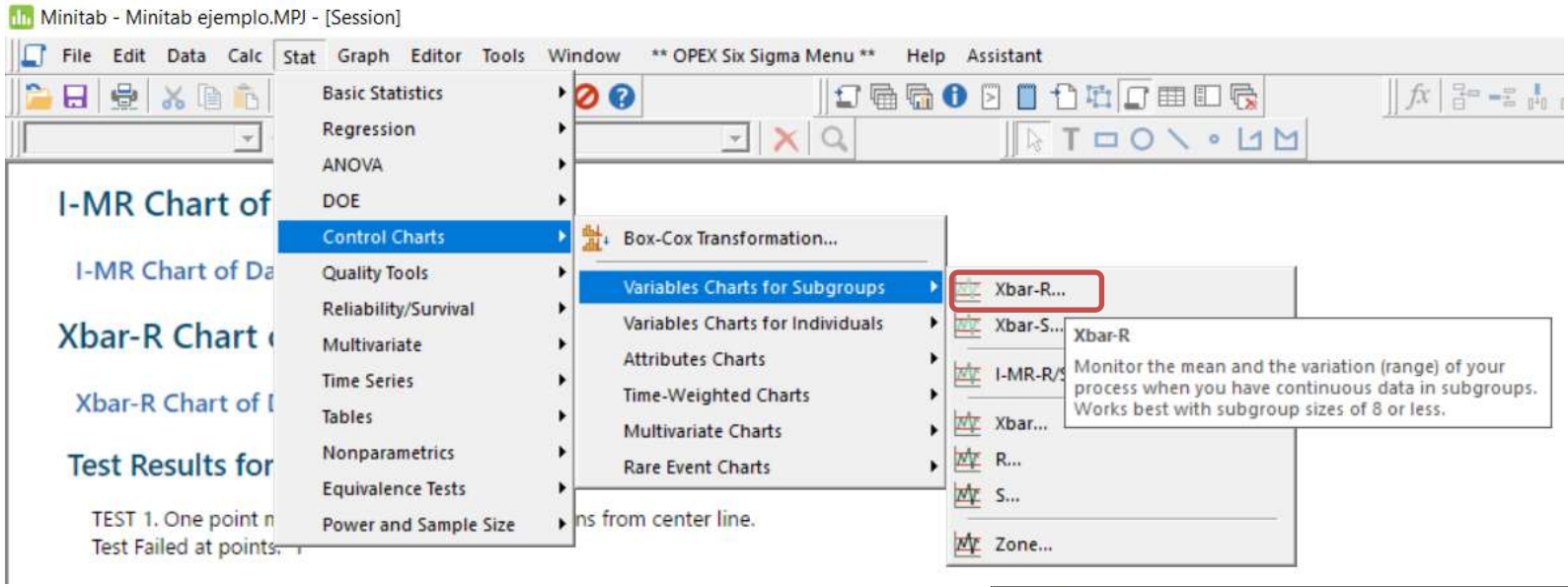

Individuals-Moving Range Chart: Options
Parameters Estimate Limits Tests Stages Box-Cox Display Storage
These multiples of the standard deviation: 1 2
Place bounds on control limits of Individuals chart
Lower standard deviation limit bound:
Upper standard deviation limit bound:
Place bounds on control limits of Moving range chart
Lower standard deviation limit bound:
Upper standard deviation limit bound:
Help
OK
Cancel

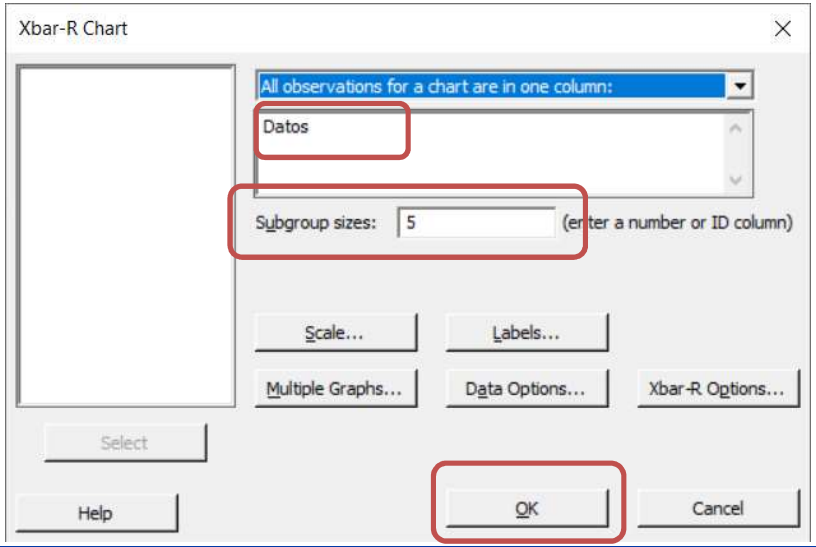

Individuals-Moving Range Chart: Options
Parameters Estimate Limits Tests Stages Box-Cox Display Storage
C1 No
C2 Datos
C3 Stage
Define stages (historical groups) with this variable:
Stage
When to start a new stage
With each new value
With the first occurrence of these values:
Select
Help
OK
Cancel

I-MR Chart

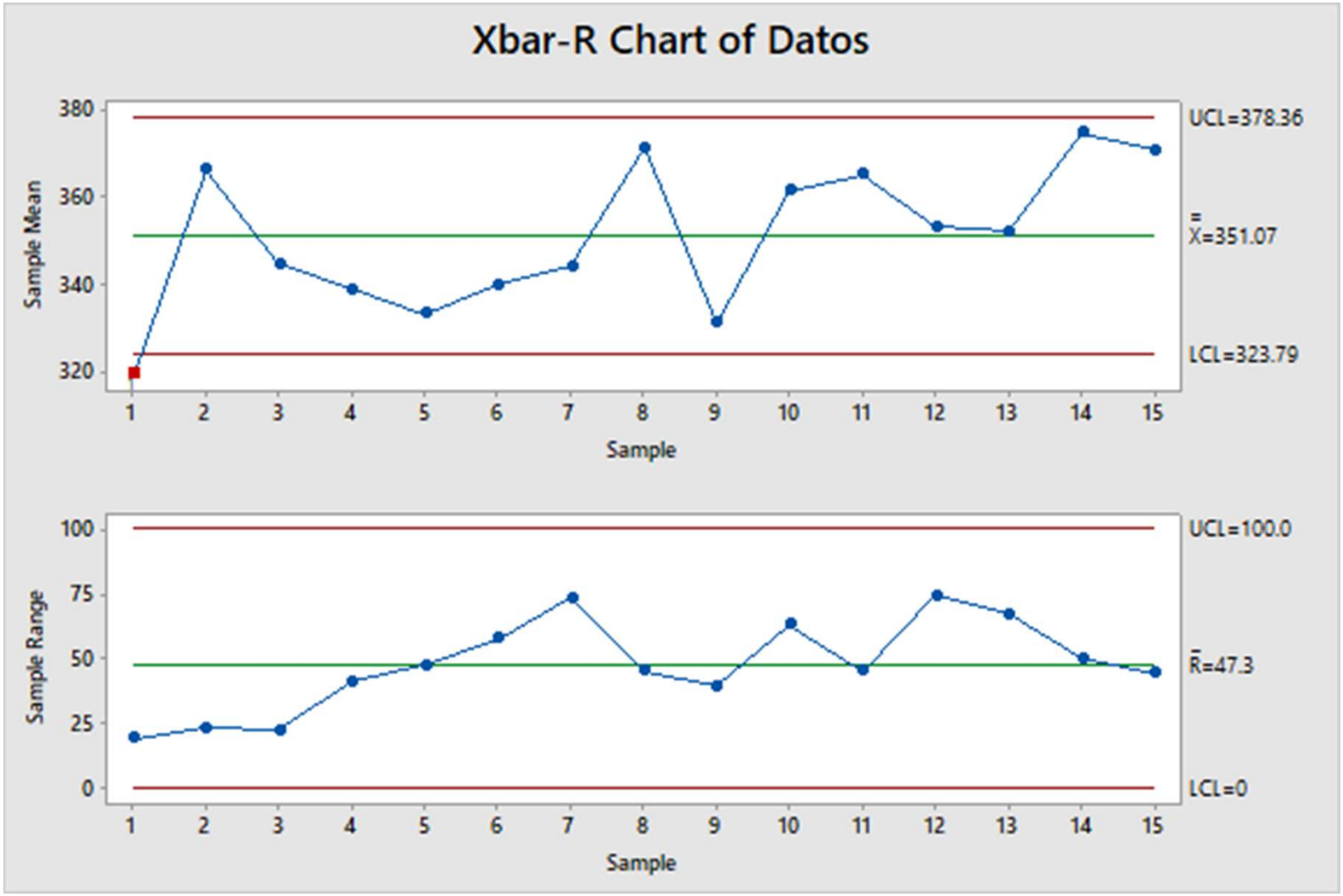

I-MR Chart of Datos by Stage
ANTES
DESPUES
Individual Value
420
390
360
330
300
UCL=424.7
+2SL=404.2
+1SL=383.7
X=363.2
-1SL=342.7
-2SL=322.2
LCL=301.7
1
8
15
22
29
36
43
50
57
64
71
Observation
ANTES
DESPUES
Moving Range
80
60
40
20
0
UCL=75.56
+2SL=58.08
+1SL=40.60
MR=23.13
-1SL=5.65
1
8
15
22
29
36
43
50
57
64
71
Observation

X Bar R Control Charts

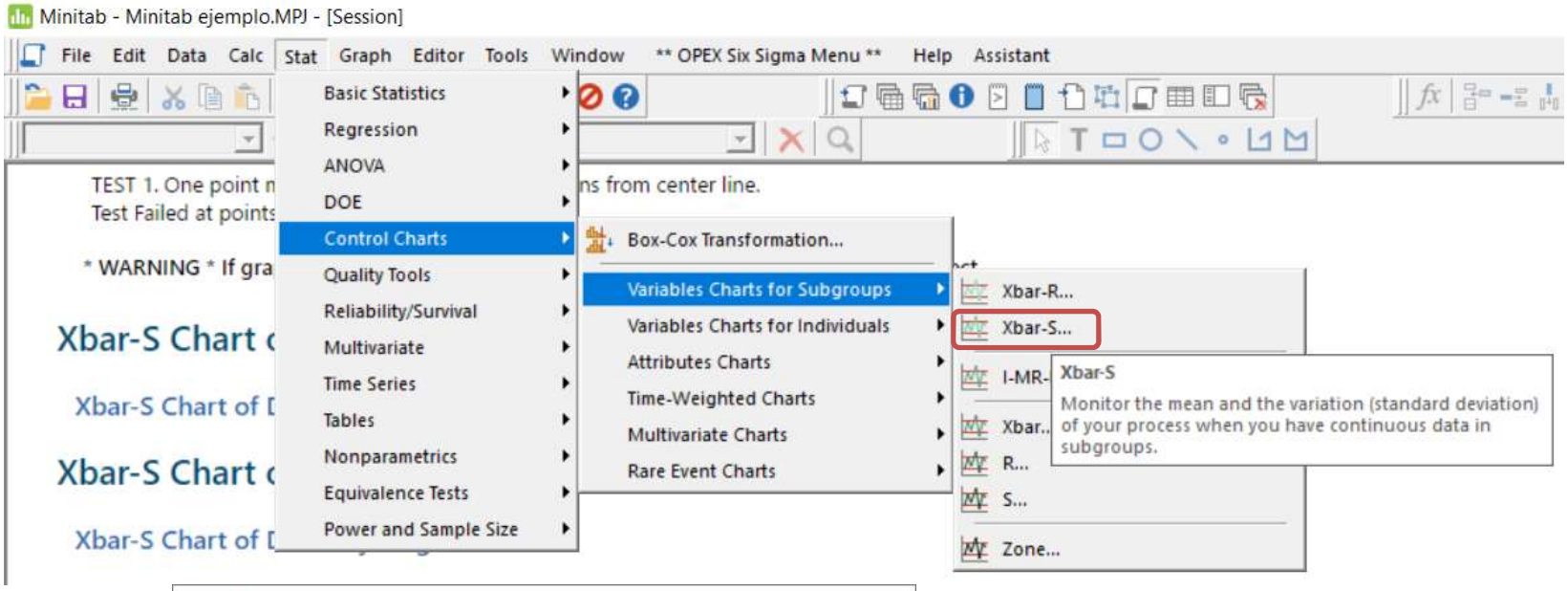


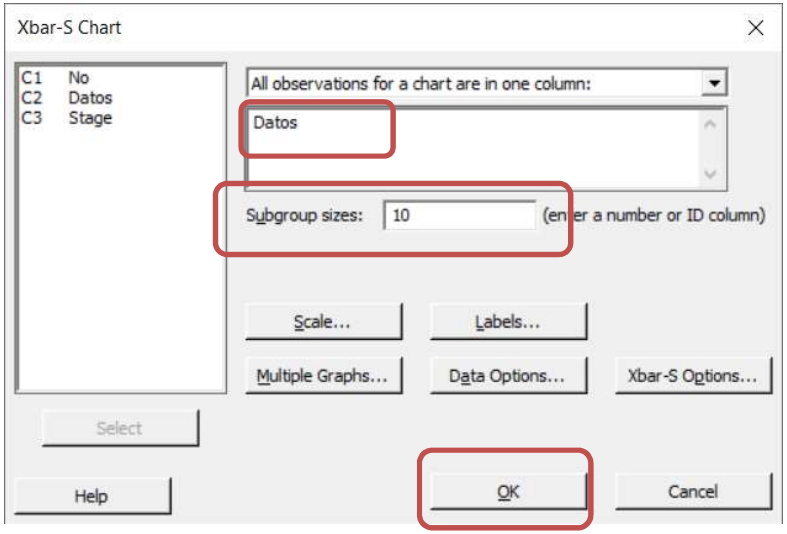


X Bar R Control Charts

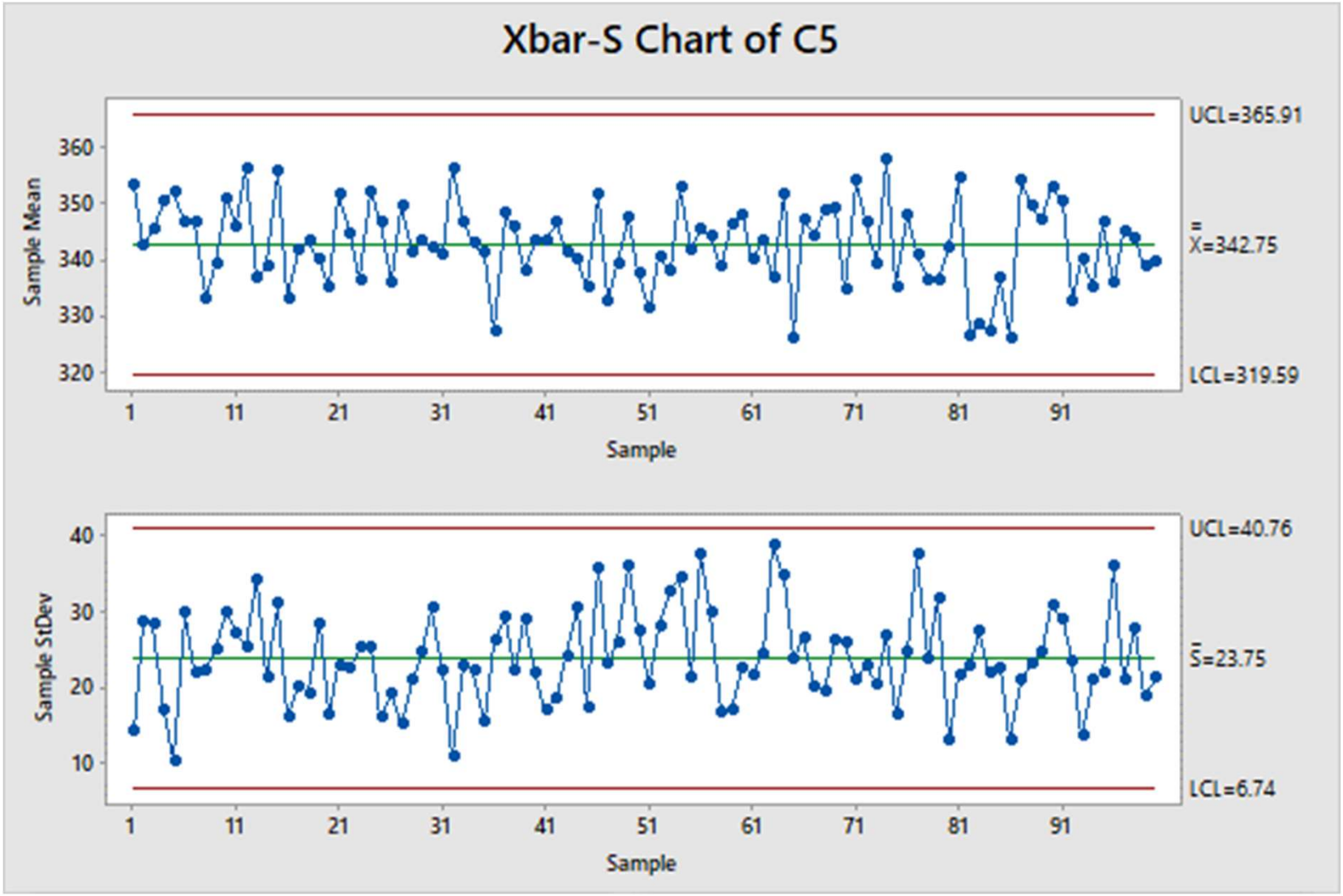


X Bar S Control Charts





X Bar S Control Charts



Thanks for your participation !!!