LEAN SOLUTIONS ACADEMY

Lean Six Sigma Training

Black Belt – Day 3

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PATRICK ADAMS CONSULTING

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Hypothesis Testing

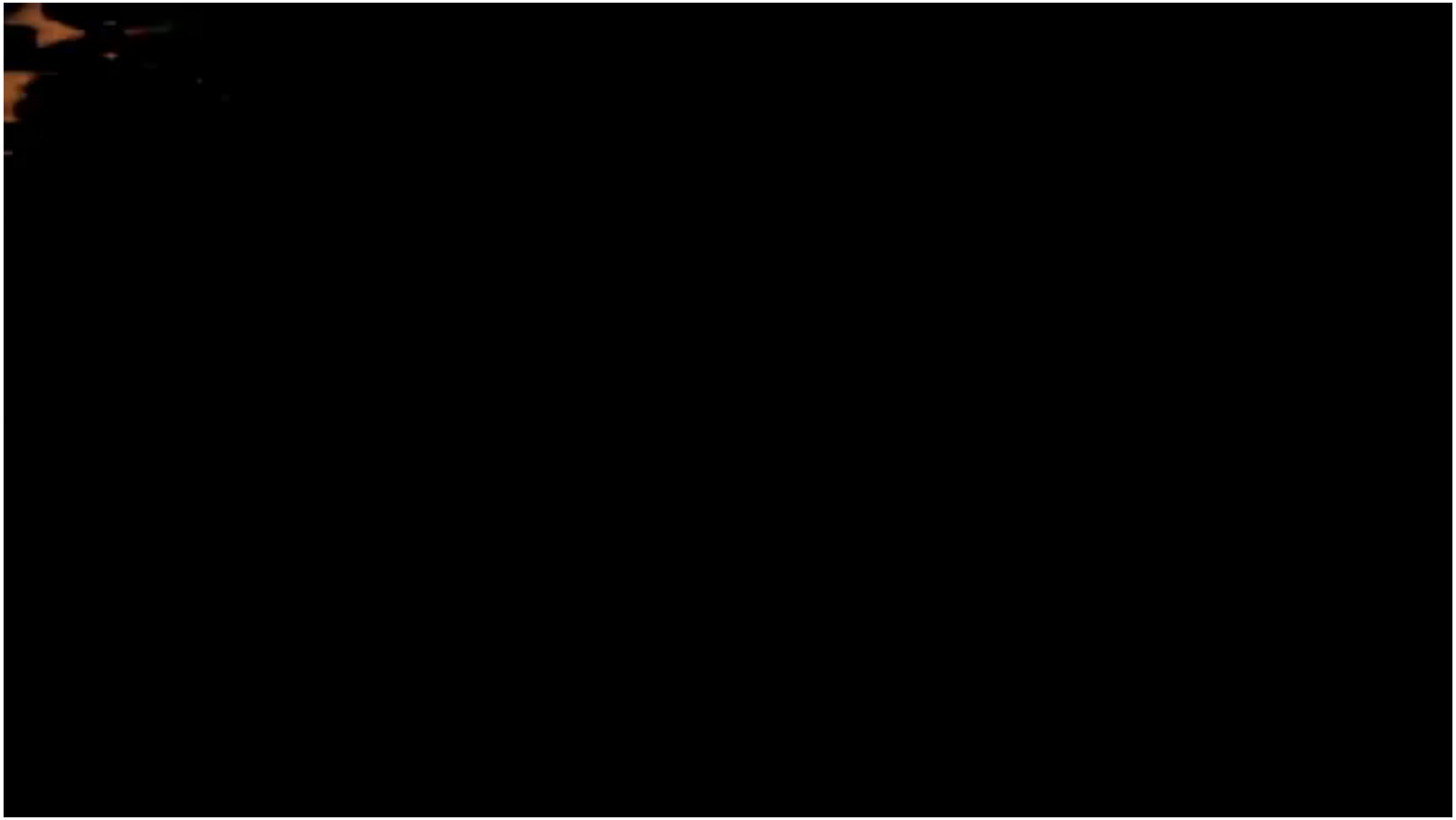
using ‘t-tests’

The History of the Statistical t-test

- In 1895 William Gosset, a student of Cambridge University, started working at the Guinness Brewing Company in Dublin, Ireland. He was presented with the problem of determining how large a sample of testers should be used in the taste-testing of beer to ensure that each vat of beer was of consistent quality.

- In 1908 Gosset published his findings in the journal Biometrika under the pseudonym 'student.' This is why the *t*-test is often called the 'student's t.'

Guinness Brewery Statistics Video



Test of Means (t-tests)

t-tests are used:

- With continuous data that is approximately Normal
- To compare a Mean against a target (1-sample t-test).

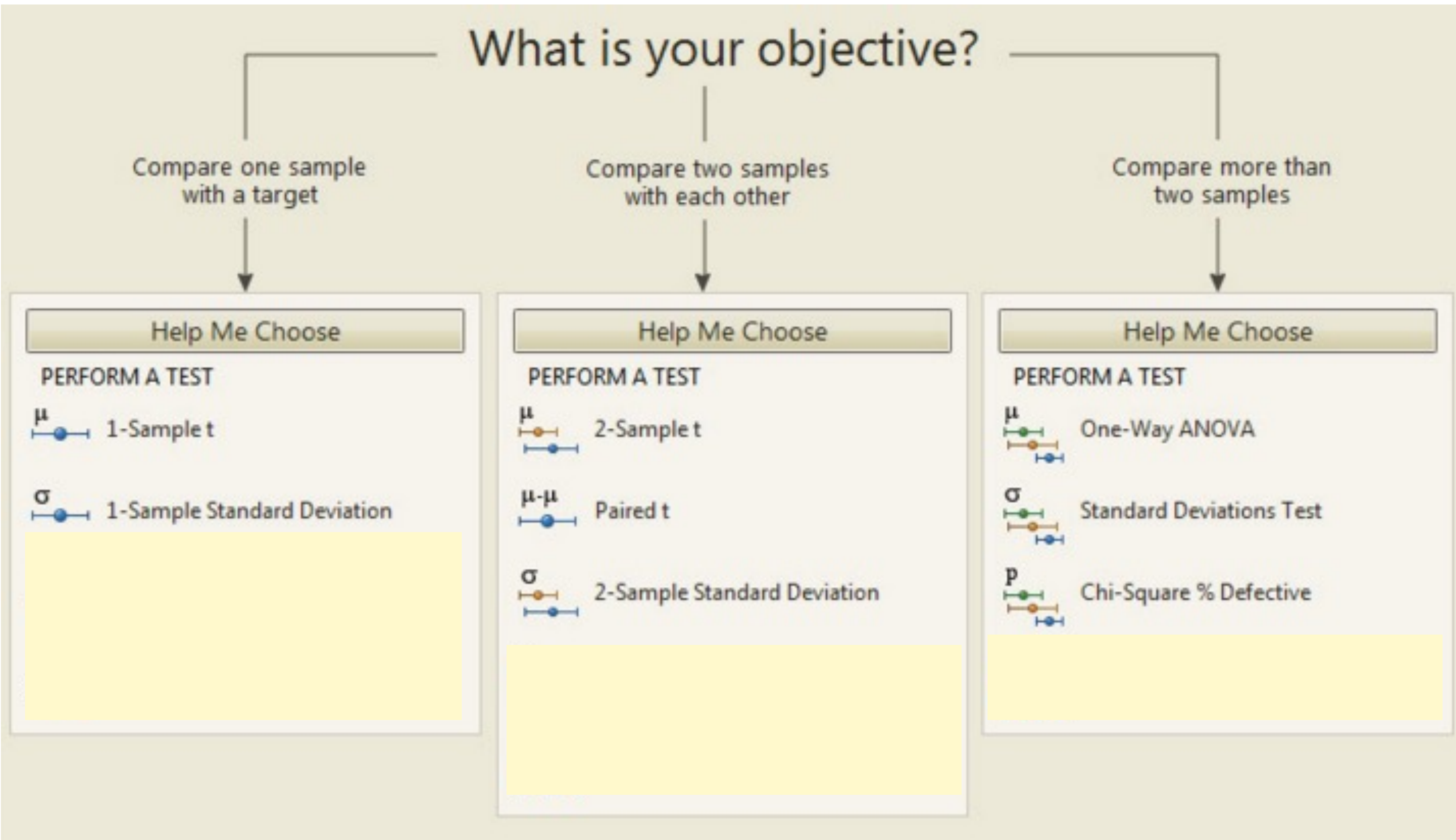
OR

- To compare Means from two **independent** samples (2-sample t-test).

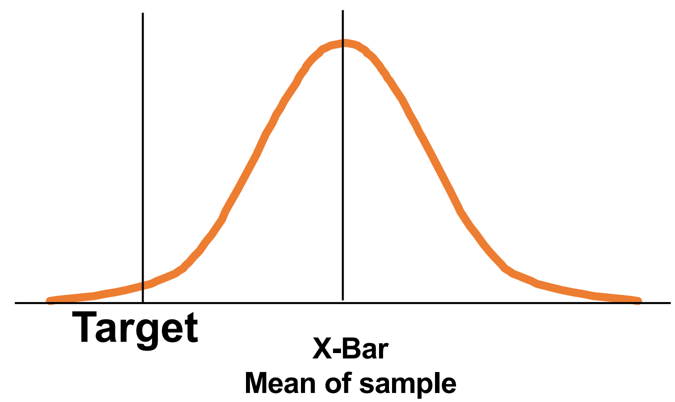
OR

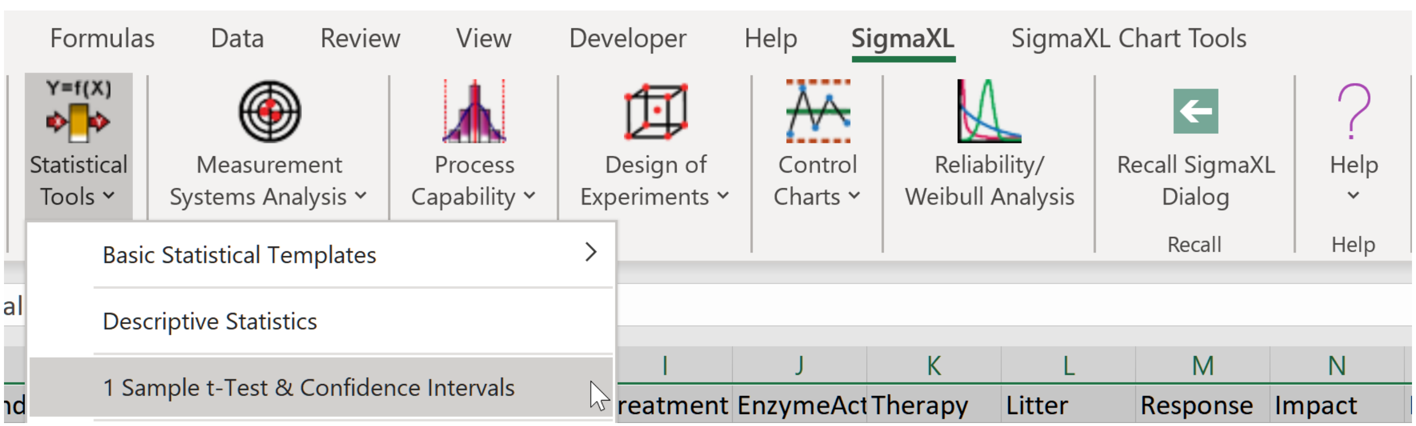
- To compare Means from two **dependent** samples (paired t-test).

t-Testing Decision Chart - Minitab



1 Sample t


Target
X-Bar
Mean of sample


Formulas
Data
Review
View
Developer
Help
SigmaXL
SigmaXL Chart Tools
Y=f(X)
Statistical Tools
Measurement Systems Analysis
Process Capability
Design of Experiments
Control Charts
Reliability/ Weibull Analysis
Recall SigmaXL Dialog
Help
Recall
Help
Basic Statistical Templates
Descriptive Statistics
1 Sample t-Test & Confidence Intervals
I
J
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reatment
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Litter
Response
Impact

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1-Sample t Example

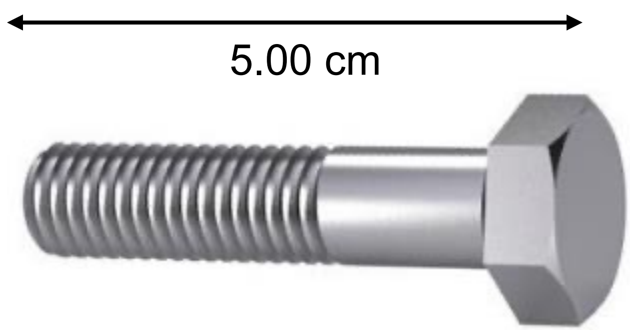
1. Practical Problem:

- We are considering changing to a new supplier of a bolt we use in our production process.
- The proposed new supplier has provided us with a sample of their product. They have stated they can maintain a mean average length of 5.00cm for their product.
- We want to test the samples to determine if their claim is accurate.

2. Statistical Problem:

$H_o: \mu = 5.00$

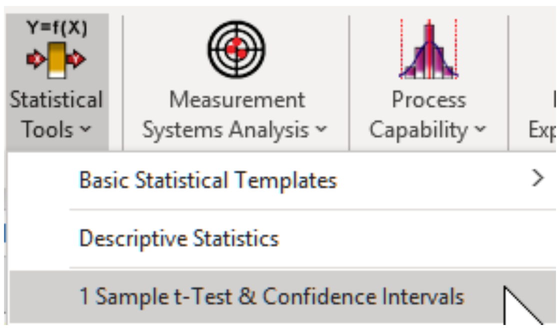
$H_a: \mu \neq 5.00$



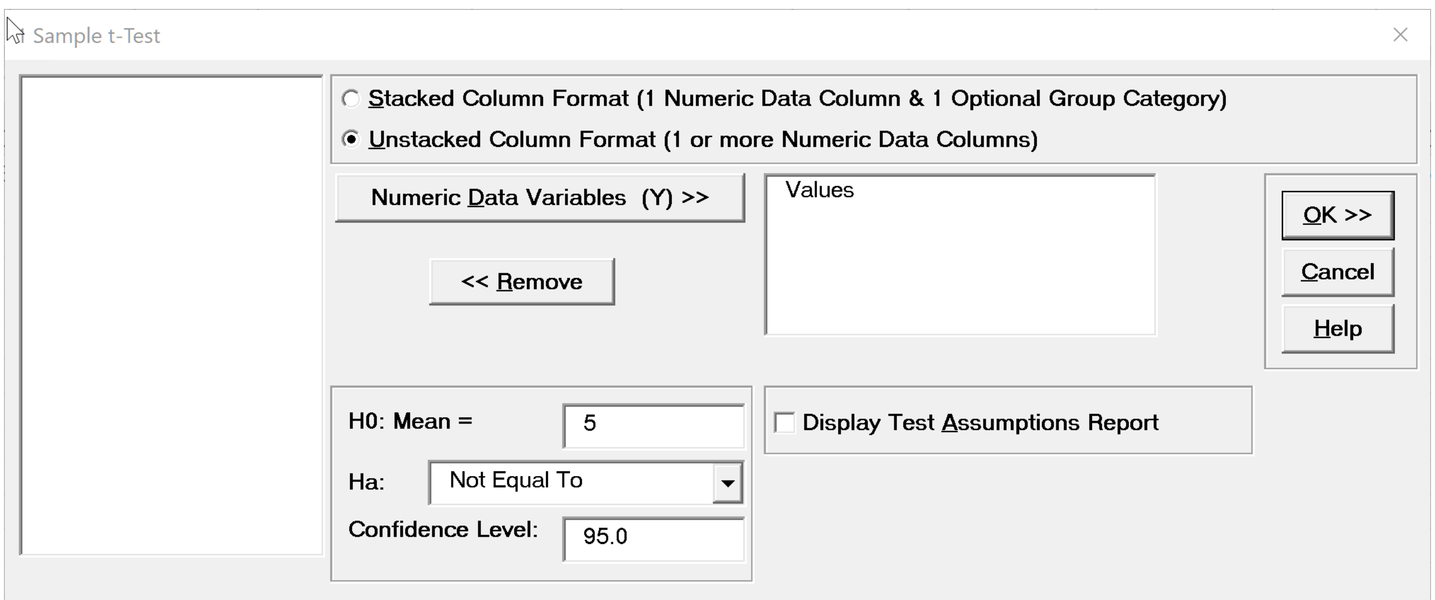
μ is the mean of the population of all bolt lengths from new suppiler

1-Sample t Example   Exh_stat.xlsx

Run Hypothesis test on the data



Select column: Values
Compare with a HO: Mean = 5.00
Select Ha: Not Equal To
In Confidence level enter '95.0'
Uncheck Display Test Assumptions Report



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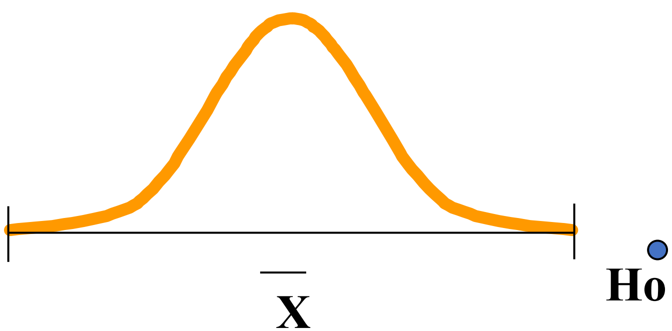
Stating Conclusions

State Statistical Conclusions

Since the P-value of 0.034 is less than 0.05 reject the null hypothesis.

Based on the samples given there is a difference between the average of the sample and the desired target.



1 Sample t-Test	
Test Information	
H_0: Mean (Mu) = 5	
H_a: Mean (Mu) Not Equal To 5	
Results:	**Values**
Count	9
Mean	4.789
StDev	0.247207
SE Mean	0.082402205
t	-2.562
P-Value (2-sided)	**0.0335**
UC (2-sided, 95%)	4.979
LC (2-sided, 95%)	4.599

7. State Practical Conclusions

The new supplier's claim they can meet the target of 5.00cm for the bolt length is not correct.

Improve Phase

Improve Phase Overview - The Goal

The goals of the Improve Phase are to:

- Come to a Consensus to Select the best and most appropriate solution
- Pilot or Prototype the solution to test and evaluate its effectiveness
- Implement the improvements into production using good project management techniques

Implementing Solutions in Your Organization

Implementation plans should emphasize the need to:

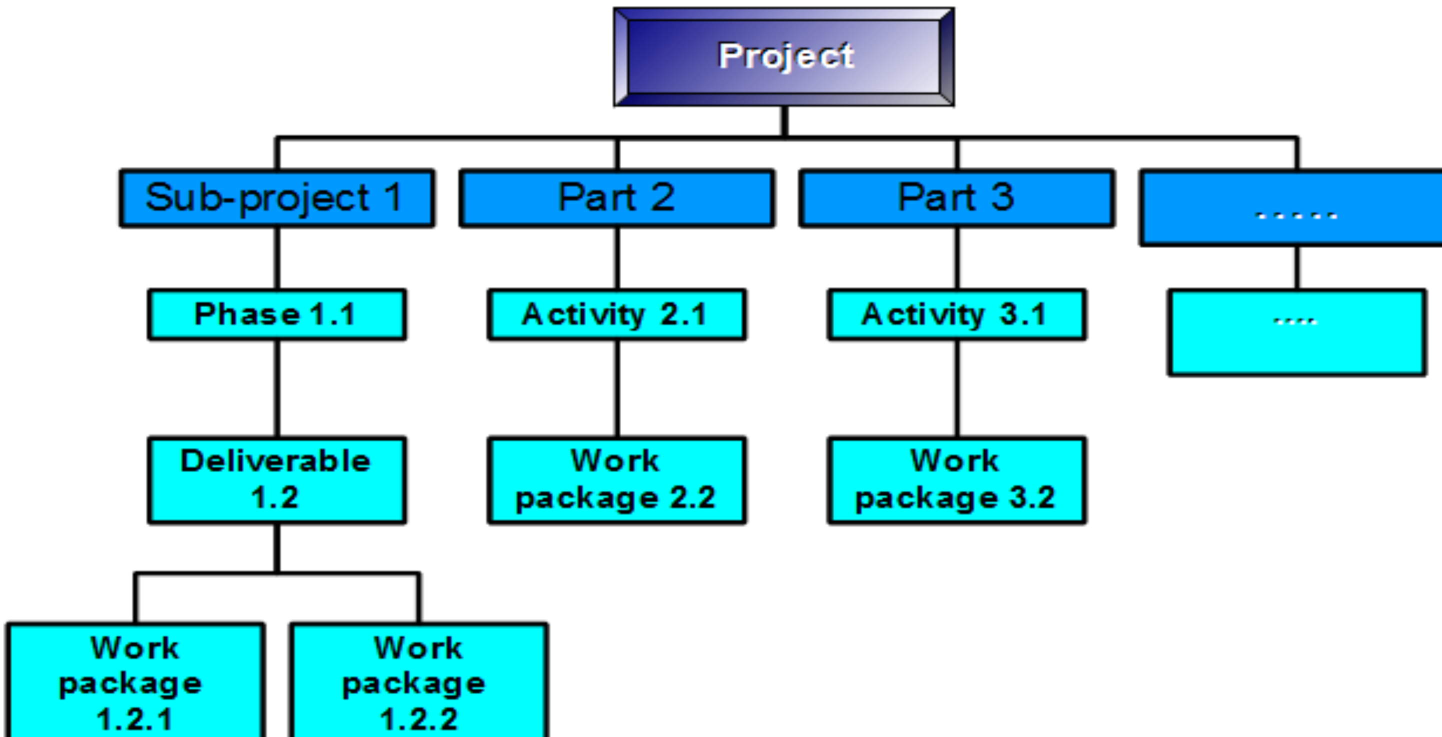
- Organize the tasks and resources
- Establish realistic time frames and deadlines
- Identify actions necessary to ensure success

Components of an implementation plan include:

- Work breakdown structure (WBS)
- Gantt Charts
- Stakeholder management
- Change management
- Issue Management
- Risk Management (FMEA)

Implementing Solutions in Your Organization

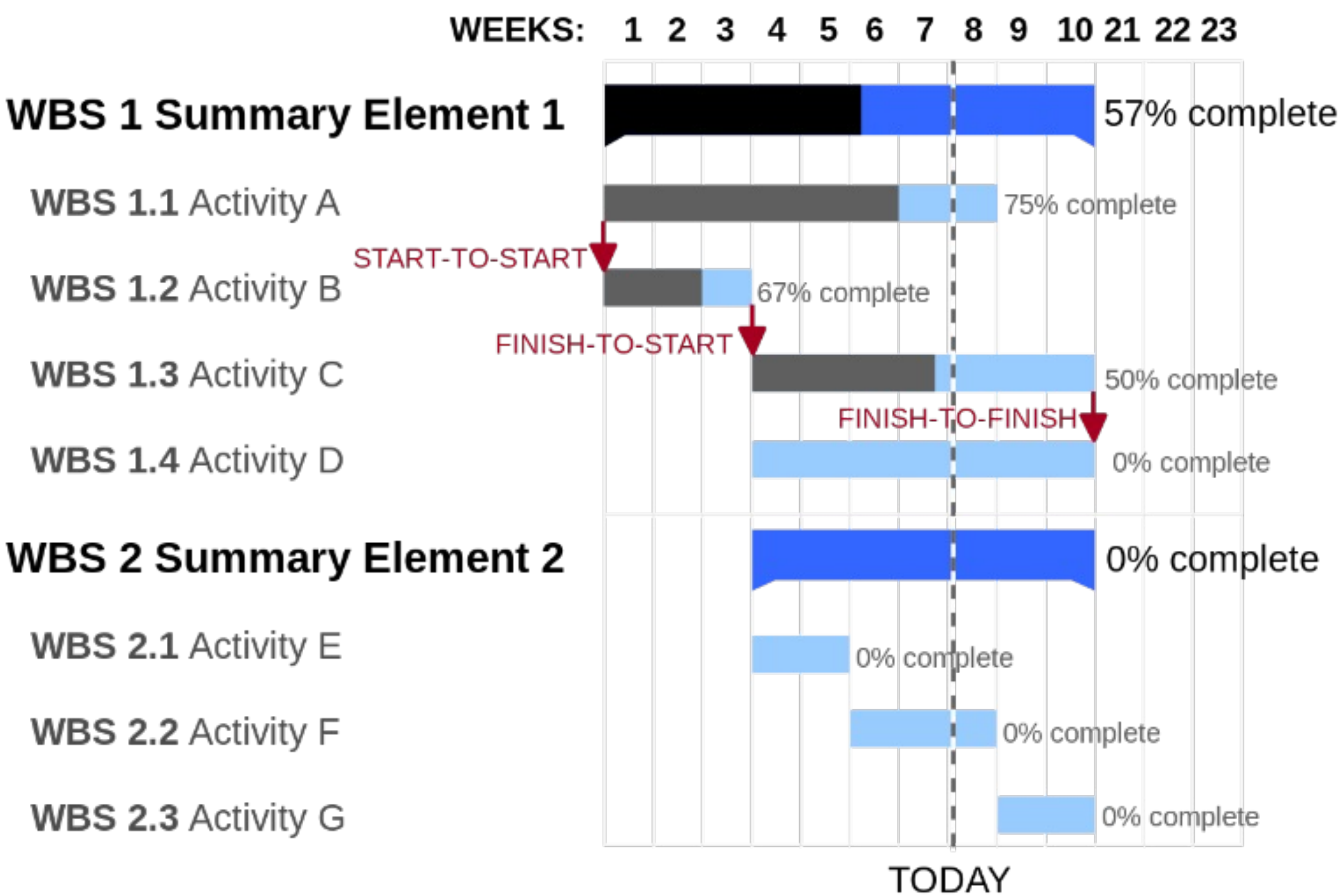
- Work Breakdown Structure (WBS) Chart
- Commonly now called ‘Tree Diagram’.



(Example of WBS)

Implementing Solutions in Your Organization

– Gantt Chart Example



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Control Phase

Lean Six Sigma Control

What is a Control Plan?

A Control Plan is:

- **Written summary describing systems used for monitoring/controlling process or product variation**

- **A Living document to be updated as new measurement systems and control methods are added for continuous improvement**

- **Often includes concise operator instructions (SOPs , SWIs, OCAPs)**
  - **OCAP = Out of Control Action Plan**
  - **SWI =Standard Work Instructions**
  - **SOP = Standard Operating Instruction**

- **Made in conjunction with the final project report**
  - **Lessons Learned**
  - **Actual Gains vs Planned Gains**

Control Plan Elements

Control Plan

4 Elements of a Control Plan

1. Training
2. Documentation
3. Monitoring
4. Response

Monitoring with SPC

Statistical Process Control (SPC):

- SPC is used for monitoring of a process to make sure it is ‘ in control’
- The most common method of SPC is a **Control Chart**
- SPC was first introduced in the 1930 by **Walter Shewhart** and then popularized in the 1960 and 1970 by **Joseph Juran** and was the basis of the Motorola ‘**Six Sigma**’ Quality program.

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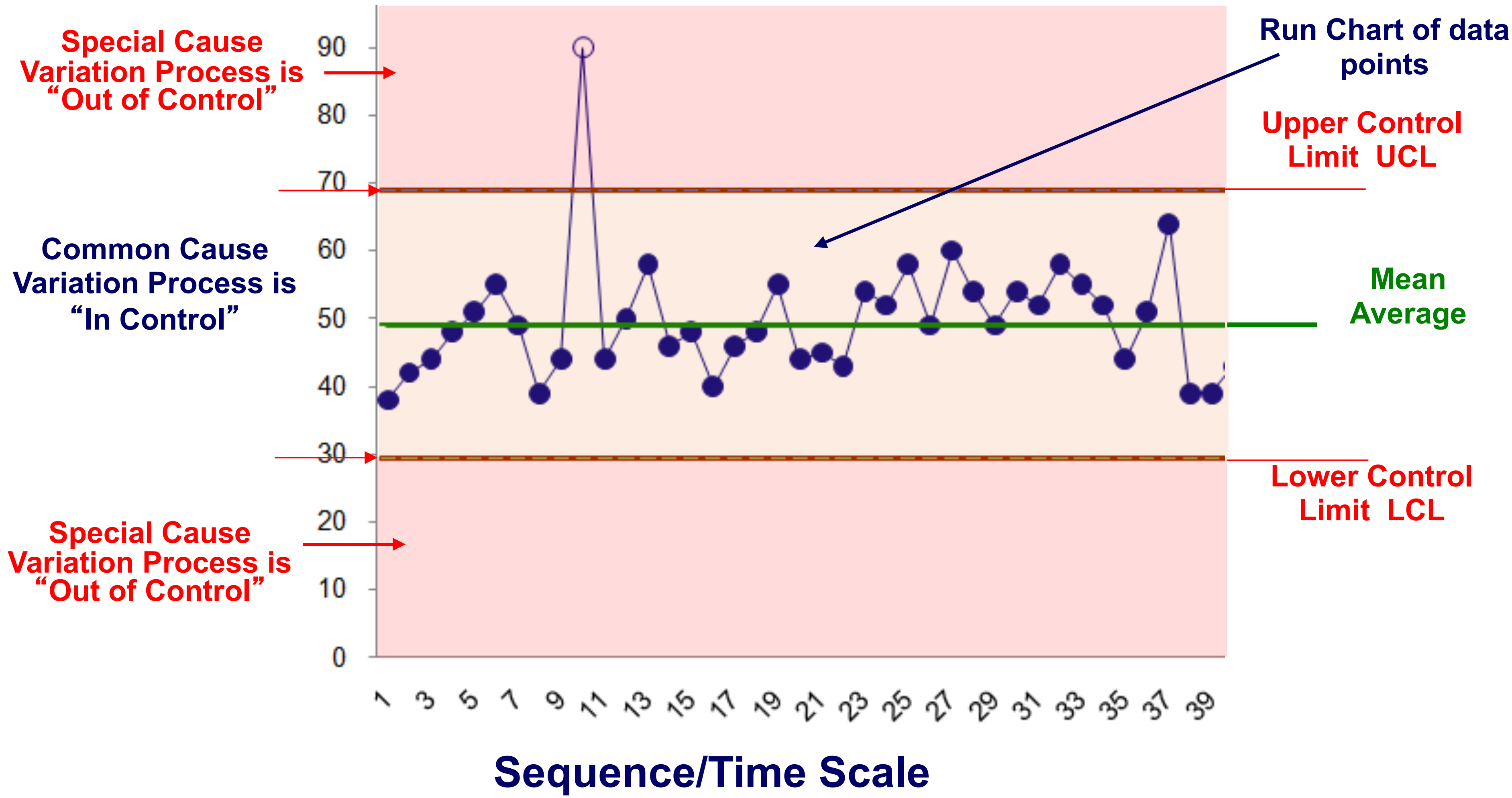
A Control Chart



2 types of Variation shown on Control Chart

1. Common Cause Variation

Expected, natural and inherent in every process. Due to random small changes in the process inputs. Small changes in temperature, vibration, wait time or worker energy level are examples. ‘Chronic’ variation

2. Special Cause Variation / Assignable Cause Variation

Unexpected, not part of the process. Often due to external influences out of our control such as accidents, mechanical or electrical failures. ‘Sporadic’ variation. Can be either an **‘Outlier’** or an unusual **‘Pattern or Trend’** in the data. See the ‘Western Electric’ tests for Special Causes.

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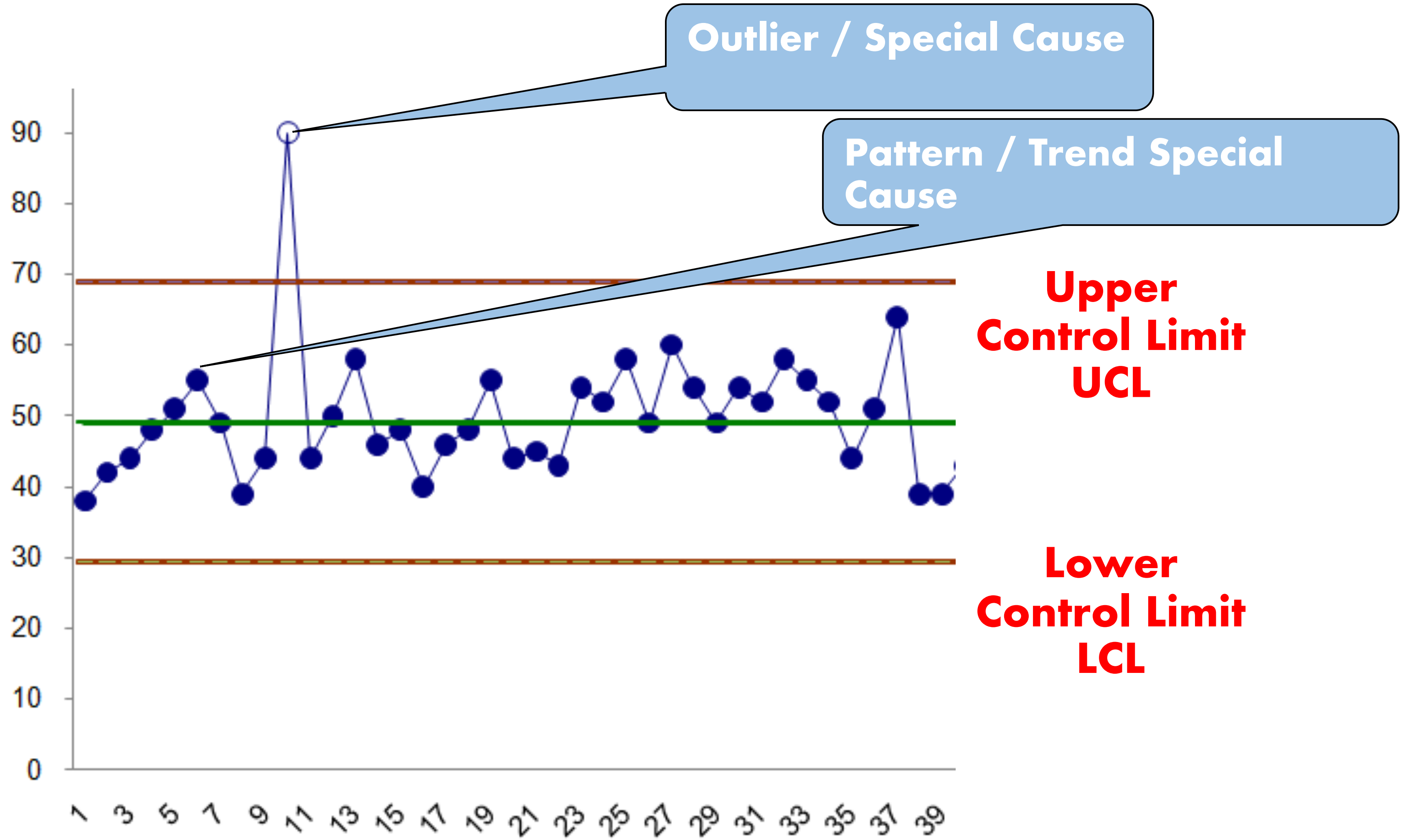
Control and Out of Control



Control Charts

- Control Charts indicate when a process is "out of control" or exhibiting Special Cause variation.
- Control 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.
- Use of Control Charts can be applied to all processes.
  - Services, manufacturing and retail are just a few industries with SPC applications.
- Control Limits are used to define the limits that the business is setting for the process.
  - Ideally Control Limits should be narrower than customer specs.

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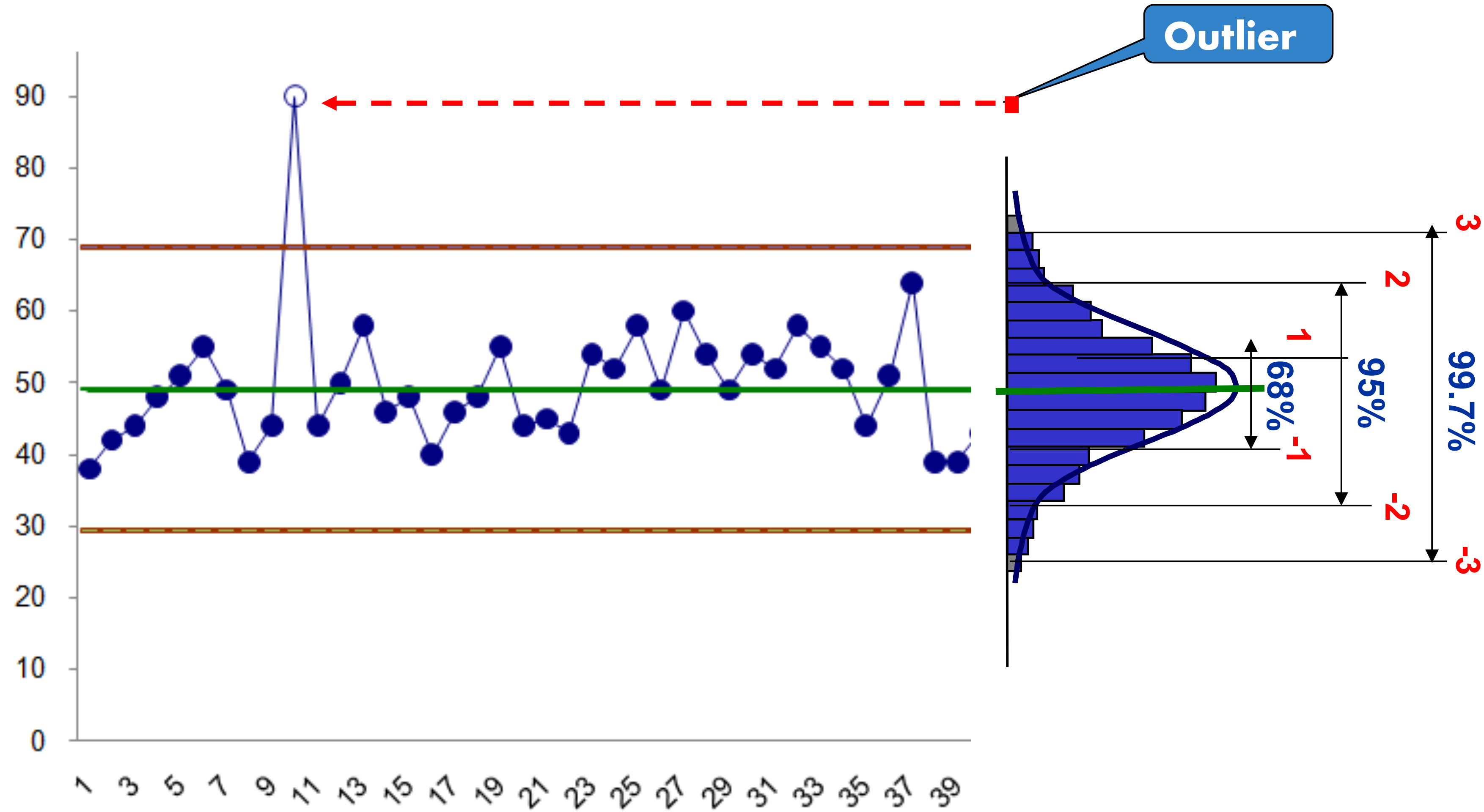
Control and Out of Control



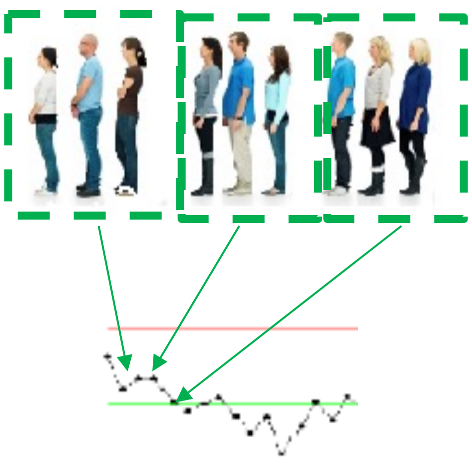
WESTERN ELECTRIC ZONES

WESTERN ELECTRIC special cause tests

- Test 1. One Point Beyond Zone A
- Test 2. Nine Points in a Row on One Side of the Centre Line
- Test 3. Six Points in a Row Steadily Increasing or Decreasing
- Test 4. Fourteen Points in a Row Alternating Up and Down
- Test 5. Two Out of Three Points in a Row in Zone A or Beyond
- Test 6. Four Out of Five Points in a Row in Zone B and Beyond
- Test 7. Fifteen consecutive Points within Zone C
- Test 8. Eight Points in a Row on Both Sides of Centreline with None in Zone C

Samples and Subgroups

- A sample is a (representative) part of the population
- When Control Charting a sample is often called a “subgroup”
- “Sample Size” is called a “Subgroup Size”



3 subgroups for plotting
Weights of patients

Subgroups plotted on chart

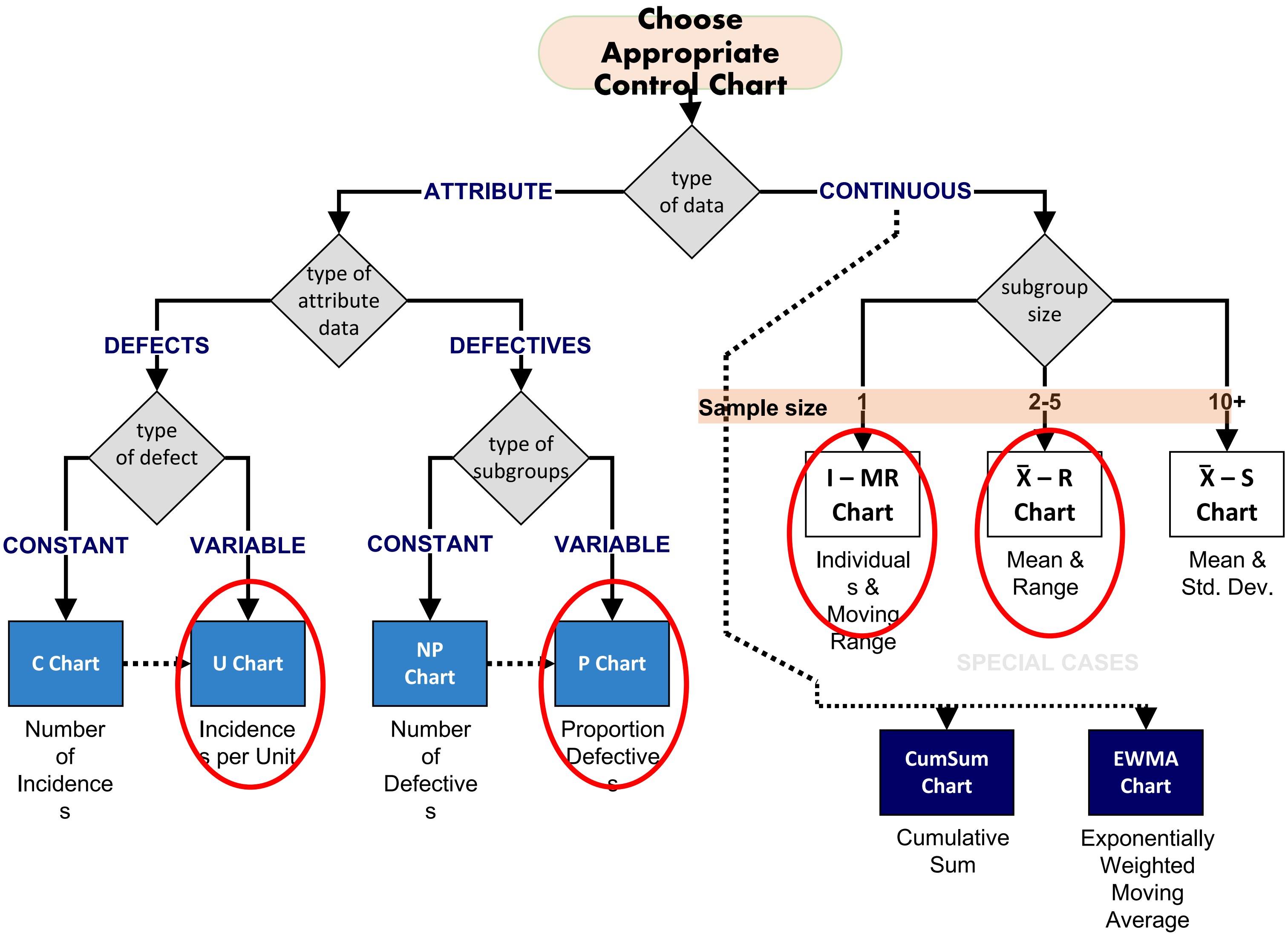
Considerations when selecting a control chart

There are over 10 different types of Control Chart !

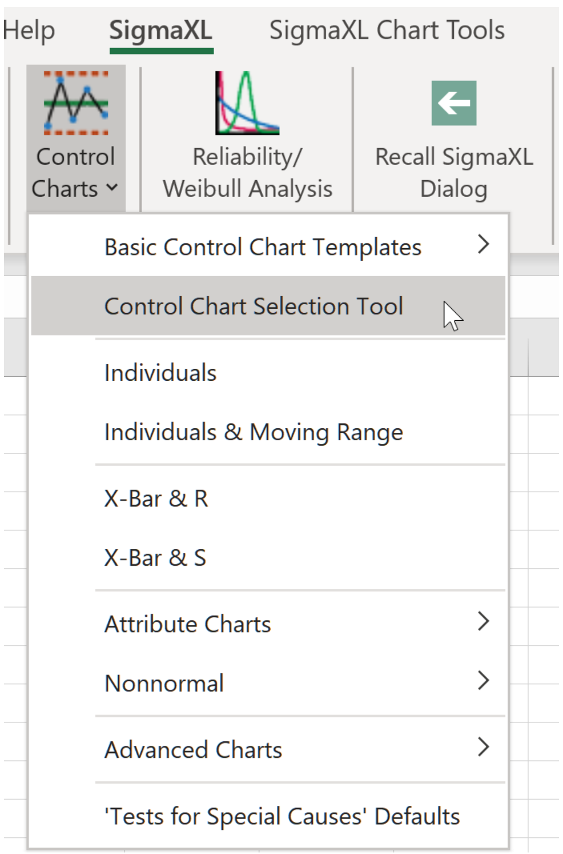
Many factors influence the choice of which control chart to use. These include:

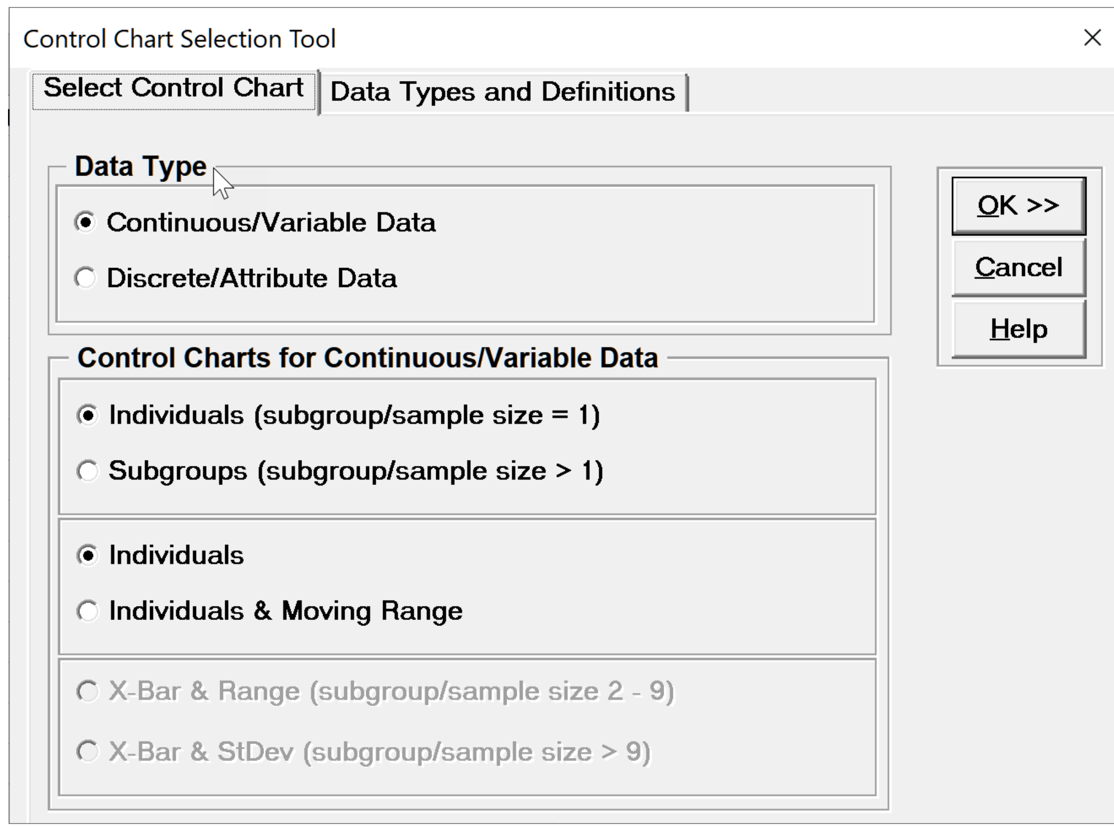
1. The type of data being charted (Variable or Attribute)
2. The required sensitivity (size of the change to be detected) of the chart
3. The subgroup size / sample size
4. The ease and cost of sampling
5. Production volumes

SPC Selection Process



SigmaXL Control Chart Selection Tool





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Control Chart summary

Chart	Data type	Feature
I	Variable	Plots individual reading (subgroup = 1)
MR	Variable	Plots the difference between the current plot and the last one (Moving Range)
X Bar	Variable	Plots the mean of each subgroup
R	Variable	Plots the range (largest – smallest value) of each subgroup
S	Variable	Plots the Standard Deviation of each subgroup
U	Attribute	Plots the total number of defects on a unit (sample size from 1)
C	Attribute	Same as U but requires constant sample size
P	Attribute	Plots the number of units defective in a subgroup
NP	Attribute	As P but requires constant sample size
CUSUM EWMA	Continuous Continuous	Useful for illustrating very small changes Calculates the moving average using complex formula

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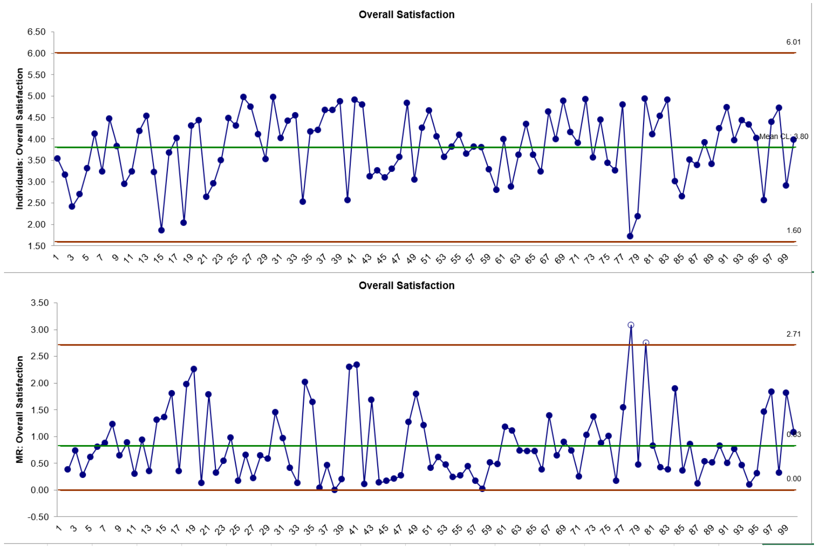
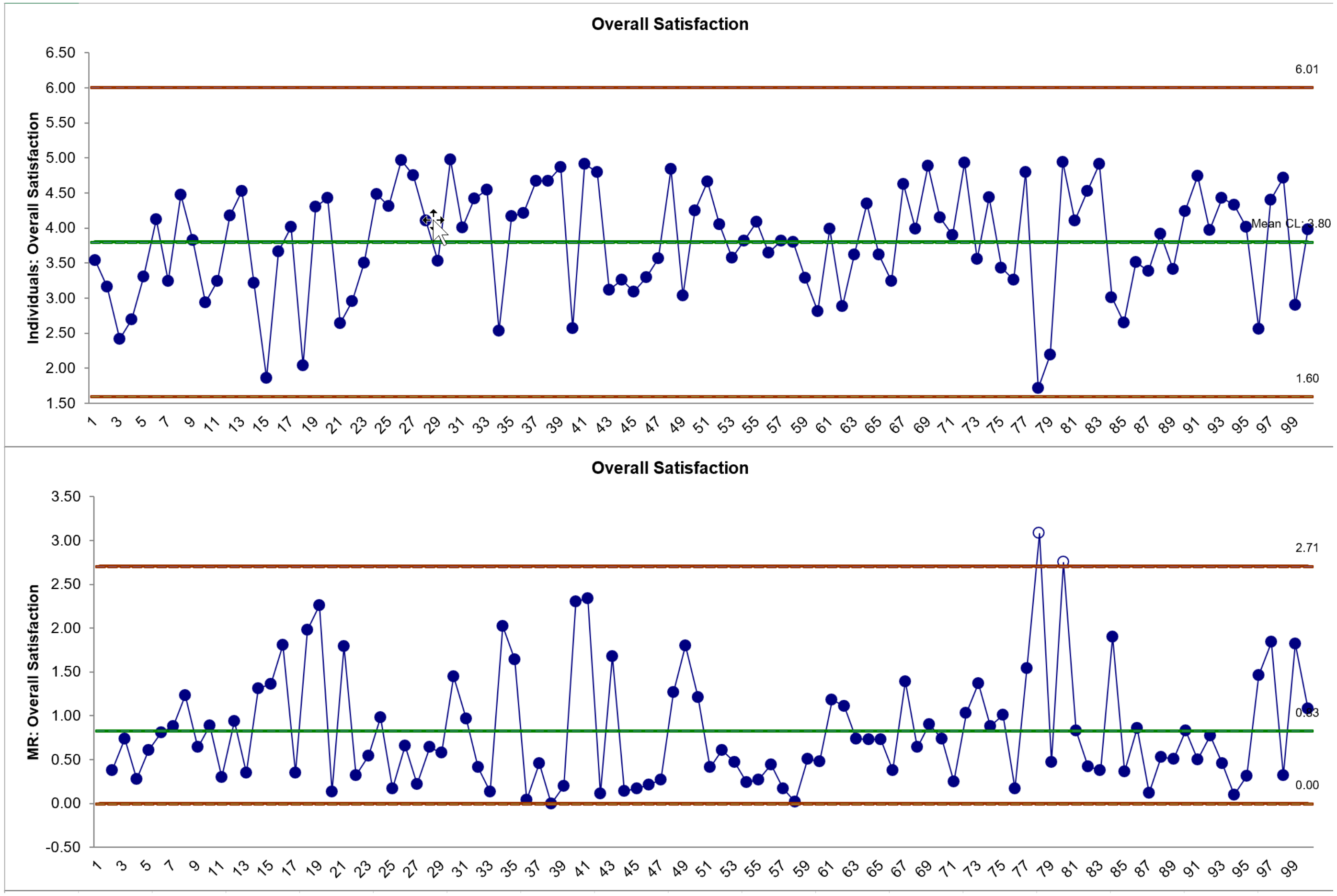
Combining charts

- Often a single chart will not allow us to model a process in a way that gives us the needed understanding
- In such cases we will use 2 charts drawing from the same data
- For example we may need to understand how the mean of a process changes over time but also how each sample varies from the one before.
- In such a case we use two charts such as:
  - X-BAR & R chart
  - I-MR chart



Variables control charts

- I-MR
- X BAR-R
- X BAR-S



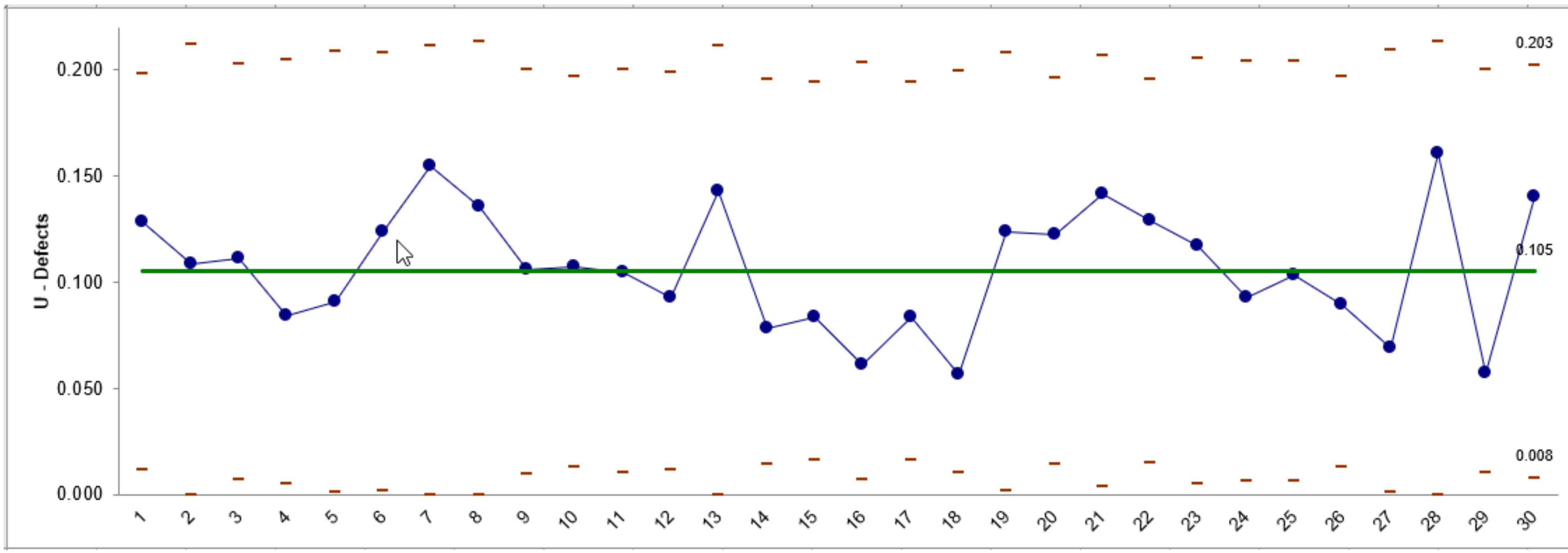
Attribute control charts

Attribute , Discrete, Binary data

- **P charts**
- **NP charts**
- **C charts**
- **U charts**

Dynamic Control Limits for U and P Charts

U-Chart example



Both P and U charts can have variable subgroup sizes therefore SigmaXL computes the Control Limits dynamically (based on subgroup size)

NP and P Charts

- NP Charts and P Charts are for tracking *defectives*.
- A NP Chart is used when the sample size is constant. A P Chart is used when the sample size is changing.
- Center Line is the proportion of "rejects" and is also your Process Capability.
- Input to the P Chart is a ratio, percentage or proportion. The number bad or number rejected as a proportion of total number in sample.
- Based on **BINOMIAL DISTRIBUTION**

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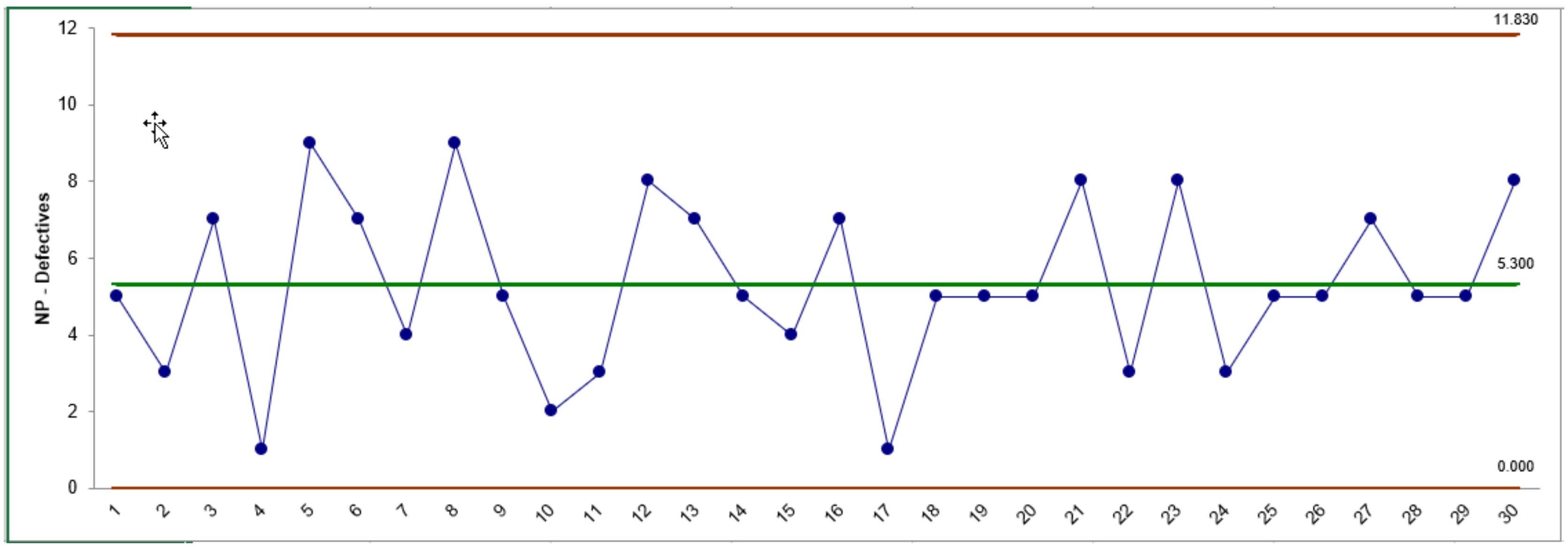
NP – Charts: Defectives

Control Charts > Attribute Charts > NP



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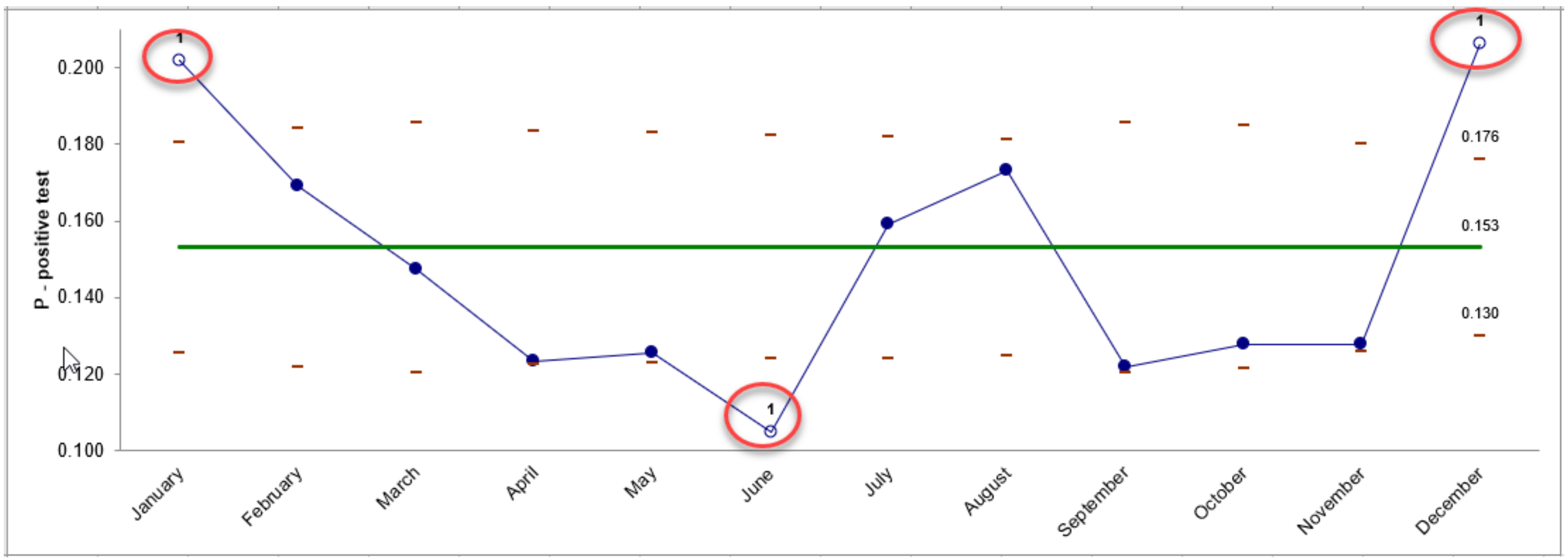
Dynamic Control Limits - P -charts

Control Charts > Attribute Charts > P

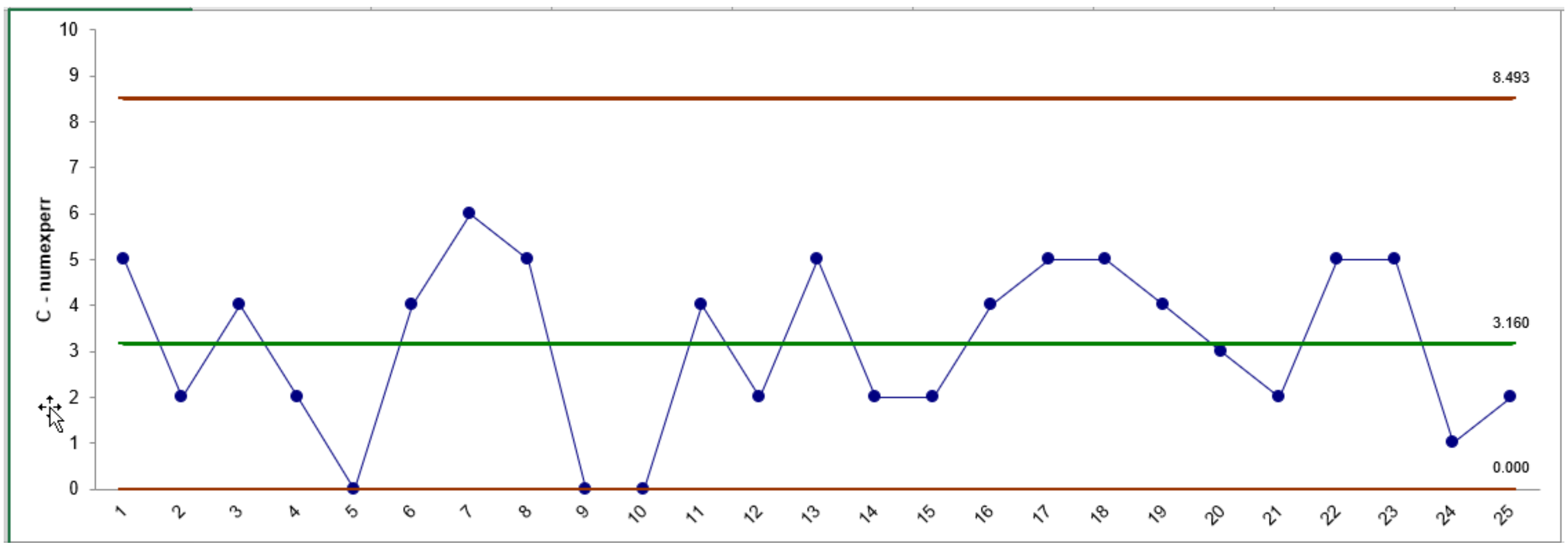


C Charts and U Charts

- C Charts and U Charts are for tracking *Defects.*
- A C Chart is used when the sample size is constant and we plot the raw count of defects found each time we take a sample.
- A U Chart is used when the sample size is changing and we plot the number of defects as a proportion of the sample size. (Defect per Unit)
- Search area (unit) must be defined. We can look for number of scratches per square meter , the number of paint blemishes on a truck door or the number of returned invoices in a week.
- You take a sample of product and count the number of defects on each unit inspected.
- Based on **POISSON DISTRIBUTION**

C Charts

Control Charts > Attribute Charts > C



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U Charts

Control Charts > Attribute Charts > U