SPC

Statistical Process Control

Zihe ZHOU
Sibish Ragul BHARATHI
Jihene Ouled Sghaier
Vincent RENDU
Sai Hemanth
Shubham JAISWAL

Statistical Process Control

Statistical process control is a quality control methodology that uses statistics to predict variations in processes. It is used for the control step of a Six Sigma project. The goal is to predict how a process will behave in the future.

It is impossible to avoid variation in a process. However, the idea is to recognize in a sample if the variation are small enough to ensure that the rest of the products will be within the required engineering specifications. The quality of this tool is due to the fact that it is based upon objective analysis, not subjective opinions.

Statistical Process Control objectives

One of the main objective of every company is to deliver an high level of quality and consistency. SPC is an important tool in controlling quality by accomplishing the following activities:

- Determine process capability
- Monitor a process as it happens
- Compare process performances to the expectations
- Identify changes in a process
- Determine if, and what action is necessary to correct for the change
- Measure and reduce variations
- Gain knowledge of processes
- Improve processes

Detection VS Inspection

Before tools like Statistical process control were available, the only way to know if products were within the required specifications was to physically inspect them **after** the process was completed. This is post-process inspection. The problem with this method is that it doesn't prevent defect from occurring.

Using SPC, processes are monitored to detect any changes the moment they occur, finding problem the moment they occur and minimizes the amount of nonconforming products produced.

The three basis of SPC

Statistical Process control can be broken down into three sets of activities:

The first step of a successful SPC implementation is to measure the amount of variation within the process. Then, you can determine if a variation is normal or not for this specific process.

Determining the causes of Variation

One can cause more variation in a process by continually making changes or adjustments is often called over-adjusting.

1.Common Cause

- Common Cause variation is inherent in a process and is predictable
- Common-Cause variation arises from a multitude of small factors that invariably affect any process.

1. Inconsistency in measurement
2. Poorly designed process
3. Machine operator differences.

Special Cause

- Special-cause variation is variation that occurs outside of the known common cause variation.
- Special-cause variation is also considered as ‘Unexpected’ Variation.

1. Poor adjustment of equipment.
2. Faulty controllers
3. Computer crashes

Eliminating the variation

- If the variation is excessive, time must be spent identifying and correcting the problem that are causing the variations.
- Some sources of variation may be obvious, while others may be very difficult to locate.
- Process variation may come from a single problem or it may be caused by multiple issues that must be corrected on by one.

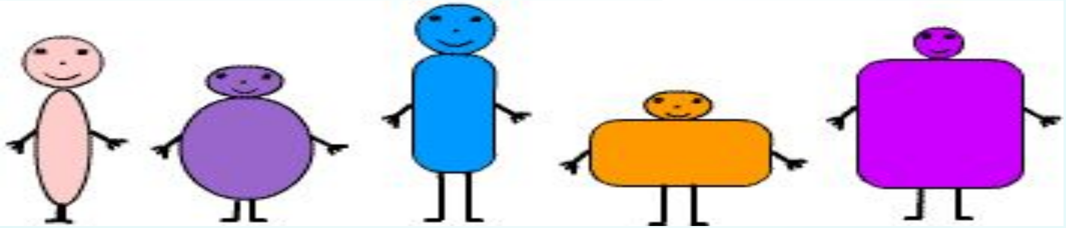
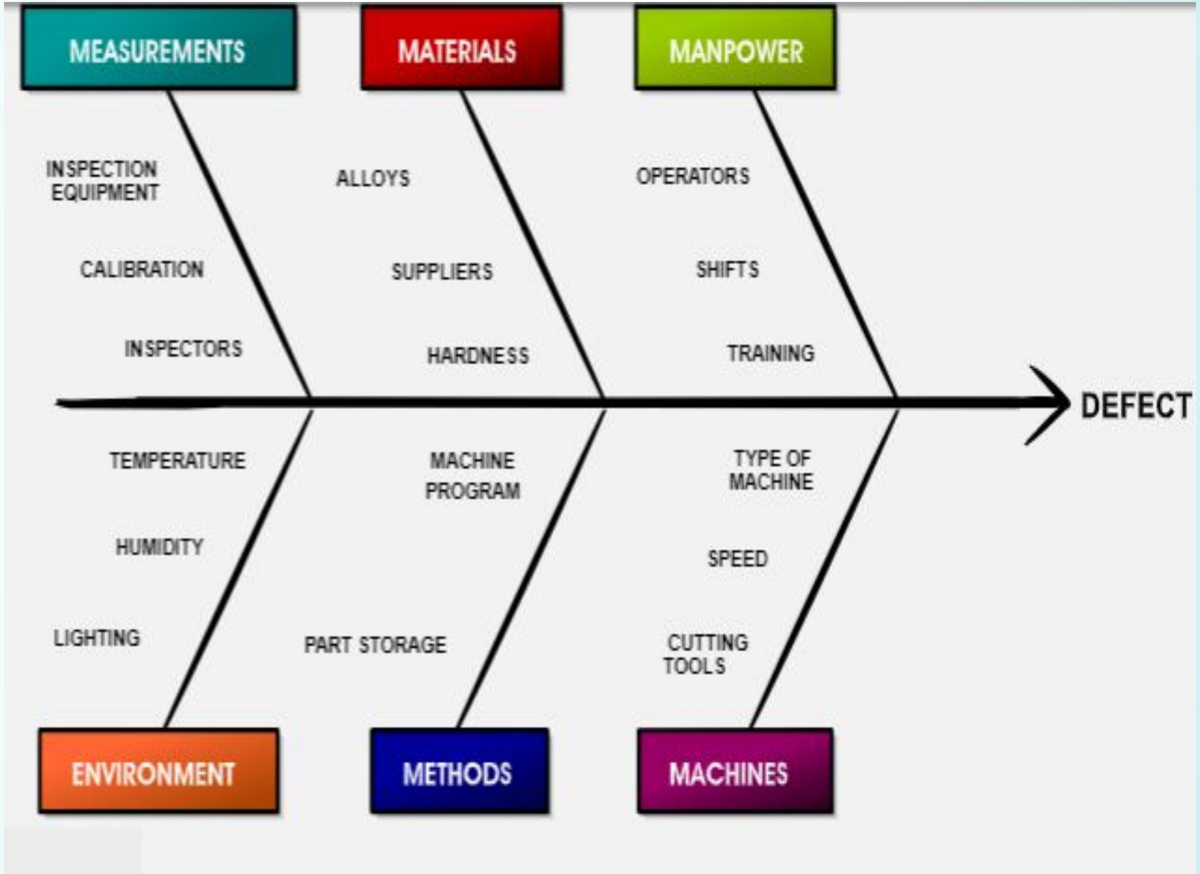


Image Source: Google image,S-cool

Sources of variation in a process

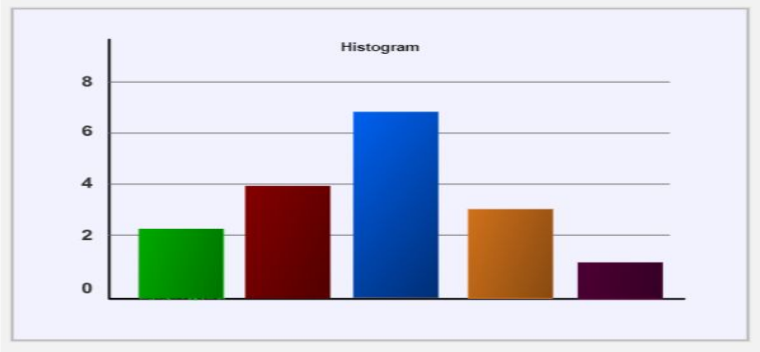
- Identifying the source of variation in a process can be a daunting task.
- In 1968, Kaoru Ishikawa developed a simple tool to simplify this task called **Fishbone Diagram.**
- The tool places the most common causes of variation into six categories:

1. Measurements
2. Materials
3. Manpower
4. Machines
5. Methods
6. Environment

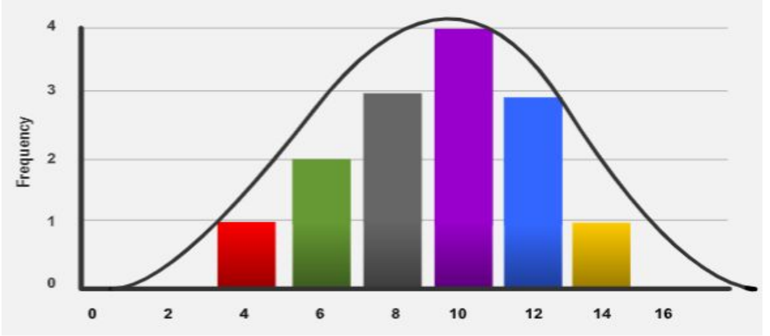


The fishing Bone diagram is used to group potential causes into major categories, Once the causes are grouped you can begin to identify or eliminate each one methodically.

Measuring variations



Histogram



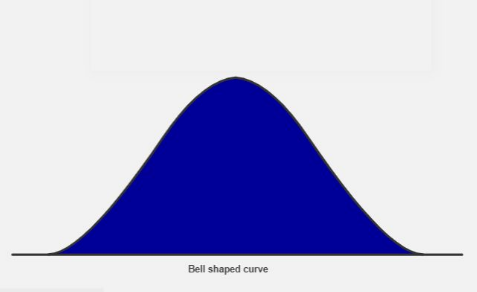
Normal Distribution

- A **histogram** has rectangle that represents the frequency of an occurrence of an event.
- The taller the rectangle the more times an event has occurred.
- The location of the histogram represents the numeric value of the occurrence.

- The histogram allows you to see the distribution of the data samples.
- If the variation you are measuring is ‘Common-cause’ the histogram will usually begin to take the shape of a bell curve.
- This is called a **normal distribution**
- A normal distribution is the pattern of a data set which follows the bell shaped curve.

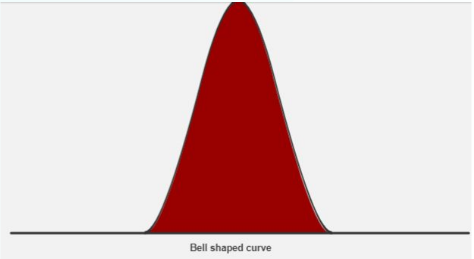
The Bell Shaped Curves

- Normal distribution curves can take many shapes, The closer the data points fall to the centre, the less variation there will be in your process.
- When data points fall further from the centre the process will have more variation.
- Curves with less variation will be taller in the centre.



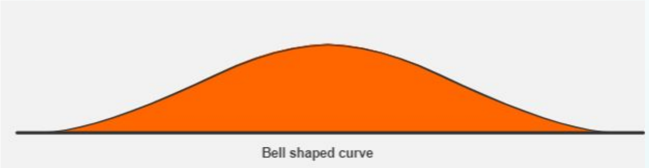
Bell Shaped curve

If the variation we are measuring is "Common cause" the histogram will usually begin to take the shape of Bell curve



Tall/Narrow curve

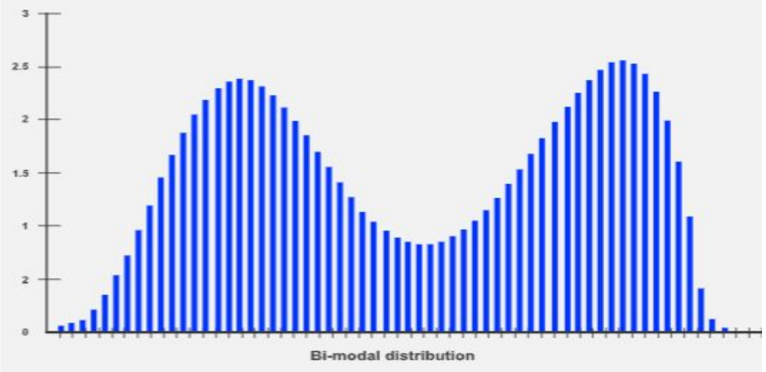
A tall narrow data set will show us that there is little variation in the process. Most of the occurrence are in the centre of the curve.



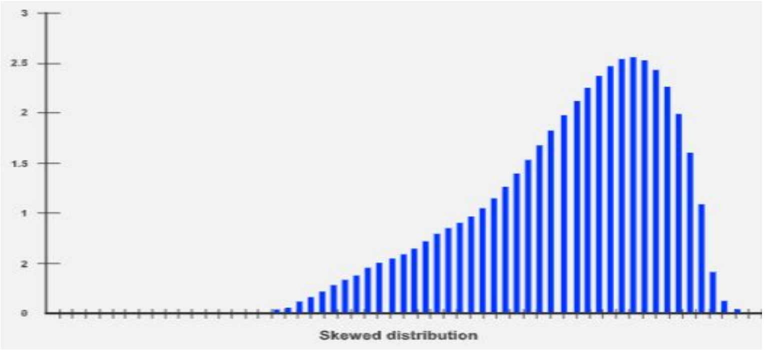
Wide/Flat curve

This kind of curve will show that there is more variation in our process.

Other types of Variations



BI-Model



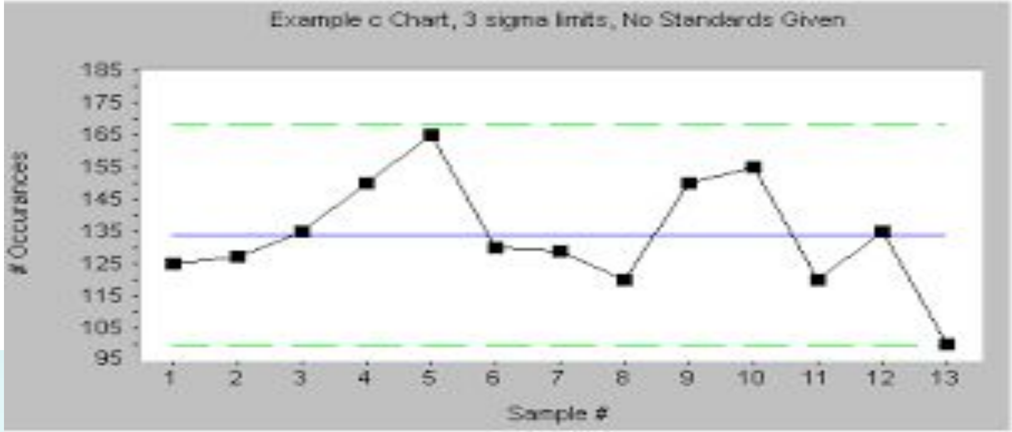
Skewed

- A BI-Model distribution is a non-normal distribution that has two or more high points in the curve.
- A BI-Model distribution would indicate that special-cause variation has occurred. Something has changed that has caused the normal curve to change

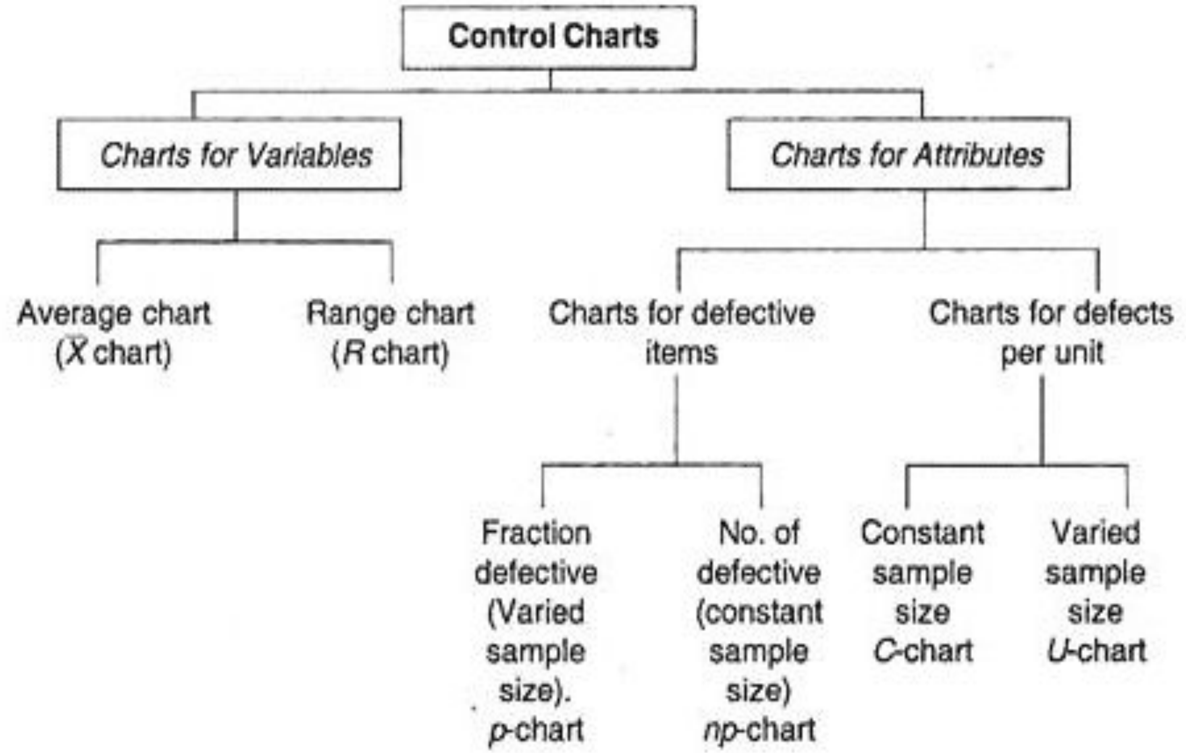
- A Skewed curve is a normal distribution that indicates that your process mean has shifted away from centre.
- A skewed distribution shows that the mean of distribution has shifted to one side of the curve.
- The graph is required to move back to the centre.

Control Charts

A Six Sigma control chart is a simple yet powerful tool for evaluating the stability of a process or operation over time. Creating a control chart requires a graph that covers a period of time, a center line that shows the results of a process during that time, upper and lower control limits that indicate whether process variation is within an accepted range



Types Of Control Charts



Control Charts for Variables:

A number of samples of component coming out of the process are taken over a period of time. Each sample must be taken at random and the size of sample is generally kept as 5 but 10 to 15 units can be taken for sensitive control charts.

Control Charts for Attributes:

In manufacturing, sometime it is required to control burns, cracks, voids, dents, scratches, missing and wrong components, rust etc. Here, we inspect products only as good or bad but not how much good or how much bad. Furthermore, there are many quality characteristics that come under the category of measurable variables but direct measurement is not taken for reasons of economy.

These products are inspected with GO and NOT GO gauges. Again under this type also, our aim is to tell that whether product confirms or does not confirm to the specified values. Quality characteristics expressed in this way are known as attributes.

Difference Between Variable and Attribute

What Are Rational Subgroups?

A rational subgroup is a group of units produced under the same set of conditions. Rational subgroups are meant to represent a "snapshot" of the process. They also reflect how your data are collected, and represent the inherent (common cause) variation in your process at any given time

For many processes, you can form rational subgroups by sampling multiple observations that are close together in time, but still independent of each other. For example, a die cut machine produces 100 plastic parts per hour. The quality engineer measures five randomly selected parts at the beginning of every hour. Each sample of five parts is a subgroup

Methods Of Sub Grouping

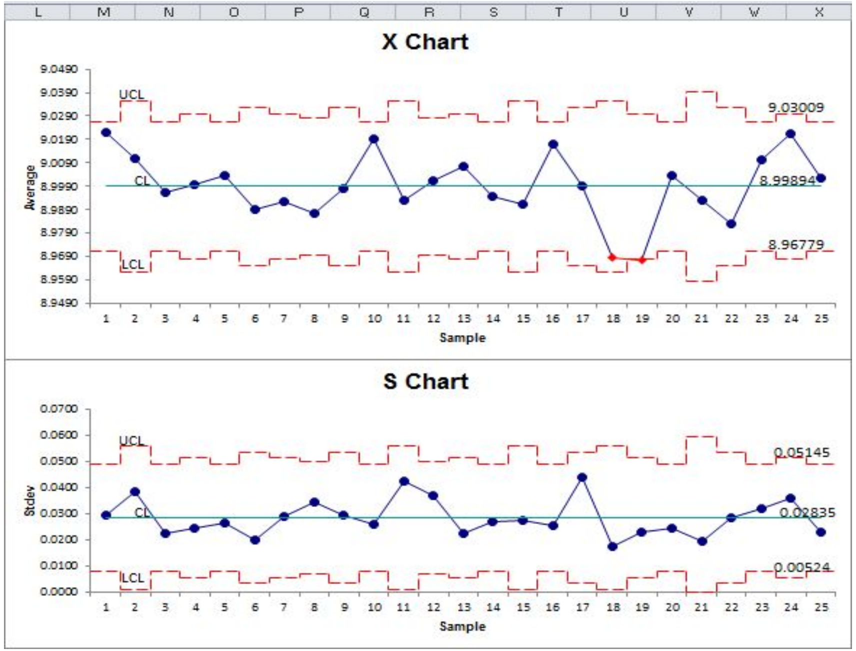
A process involves the filling of one-gallon cans of an expensive liquid using a machine with three filling heads. The operator has taken some initial data on the process and is trying to decide how to organize it into a process control chart. The initial data is given below. The characteristic being measured is fill volume (in gallons).

Filling head	8 a.m.	9 a.m.	10 a.m.	11 a.m.	12 noon
1	1.02	1.04	1.00	1.01	0.99
2	1.03	1.04	1.01	1.02	1.03
3	1.02	1.02	1.00	1.01	1.03

X-Bar and S control chart

- It is used to examine the **process mean and standard deviation** over the time. These charts are used when the subgroups have large sample size and S chart provides better understanding of the spread of subgroup data than range.

- X bar S charts are also similar to **X Bar R Control chart**, the basic difference is that X bar S charts plots the subgroup standard deviation whereas R charts plots the subgroup range.



These combination charts helps to understand the stability of processes and also detects the presence of special cause variation.

Control limits for average

Sample Measurements	1	1.2605	1.2602	1.2596	1.2597	1.2607	1.2603	1.2607	1.2600	1.2592	1.2601
	2	1.2602	1.2603	1.2599	1.2601	1.2604	1.2609	1.2604	1.2605	1.2599	1.2598
	3	1.2606	1.2610	1.2607	1.2603	1.2602	1.2609	1.2598	1.2608	1.2603	1.2599
	4	1.2598	1.2598	1.2604	1.2590	1.2600	1.2598	1.2597	1.2602	1.2601	1.2593
	5	1.2601	1.2602	1.2598	1.2602	1.2603	1.2605	1.2601	1.2592	1.2597	1.2602
SUM		6.3012	6.3015	6.3004	6.2993	6.3016	6.3024	6.3007	6.3007	6.2992	6.2993
Average $\bar{X}$		1.2602	1.2603	1.2601	1.2599	1.2603	1.2605	1.2601	1.2601	1.2598	1.2599
Standard Deviation - s		0.0003	0.0004	0.0005	0.0005	0.0003	0.0005	0.0004	0.0006	0.0004	0.0004
Grand Average $\bar{\bar{X}}$		1.2601	$UCL_{\bar{x}}$	1.26073		UCL_s					
sigma average						LCL_s					

Upper control limit of standard deviations

The control limits for the standard deviations are calculated using the product of the standard deviation average and different control limit constants. The control limit constants are from the same table as the control limit constant for the average.

Lower control limit of standard deviations

$$UCL_s = B_4\bar{s} \qquad LCL_s = B_3\bar{s}$$

Control limits for standard deviations

Sample Measurements	1	1.2605	1.2602	1.2596	1.2597	1.2607	1.2603	1.2607	1.2600	1.2592	1.2601
	2	1.2602	1.2603	1.2599	1.2601	1.2604	1.2609	1.2604	1.2605	1.2599	1.2598
	3	1.2606	1.2610	1.2607	1.2603	1.2602	1.2609	1.2598	1.2608	1.2603	1.2599
	4	1.2598	1.2598	1.2604	1.2590	1.2600	1.2598	1.2597	1.2602	1.2601	1.2593
	5	1.2601	1.2602	1.2598	1.2602	1.2603	1.2605	1.2601	1.2592	1.2597	1.2602
SUM		6.3012	6.3015	6.3004	6.2993	6.3016	6.3024	6.3007	6.3007	6.2992	6.2993
Average $\bar{X}$		1.2602	1.2603	1.2601	1.2599	1.2603	1.2605	1.2601	1.2601	1.2598	1.2599
Standard Deviation - s		0.0003	0.0004	0.0005	0.0005	0.0003	0.0005	0.0004	0.0006	0.0004	0.0004
Grand Average $\bar{\bar{X}}$		1.2601	UCL_x	1.26073		UCL_s	.00089				
sigma average - $\bar{s}$		0.0004	LCL_x	1.25952		LCL_s					

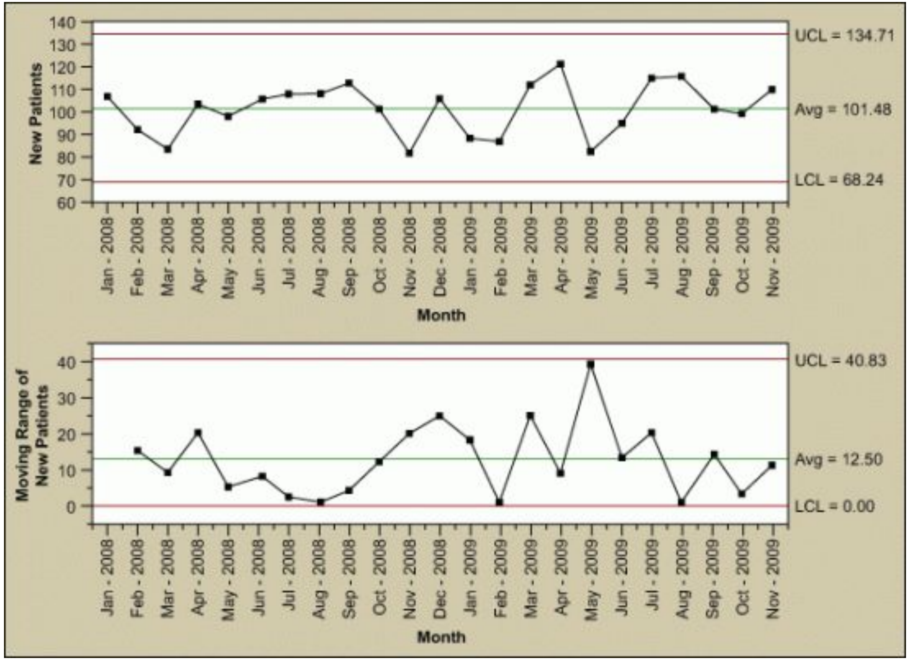
The upper control limit for the standard deviations is calculated as .00089. The lower control limit is calculated as zero because there is no control limit constant for this sample size.

$$UCL_s = (2.089)(.0004) = .00089 \quad LCL_s = (0)(.0004) = 0$$

Individuals and moving range control chart

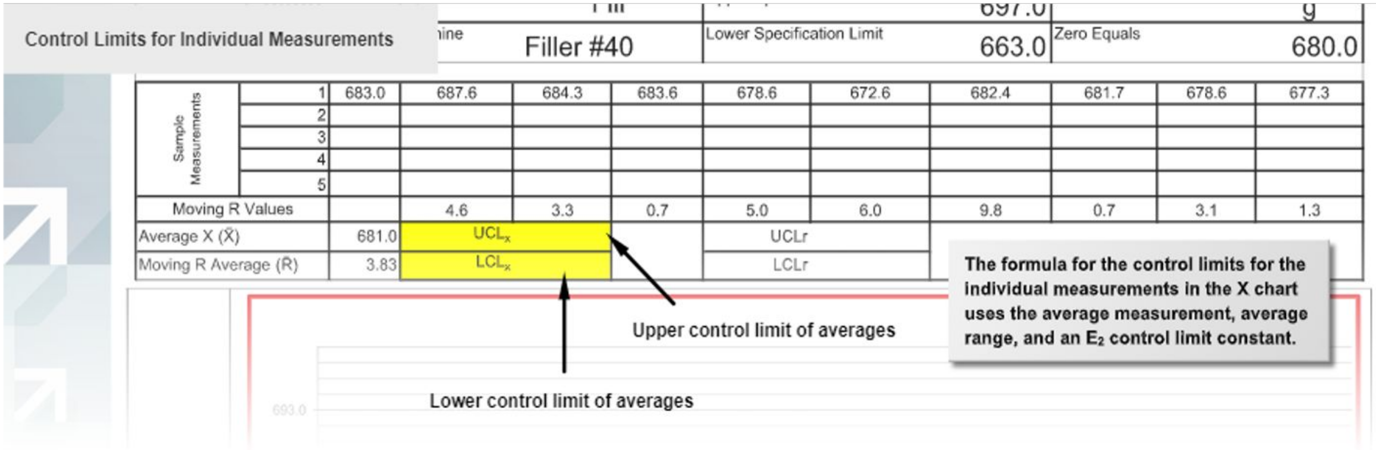
- The individuals and moving range (I-MR) chart is one of the most commonly used control charts for continuous data; it is applicable when one data point is collected at each point in time.

- The individuals and moving range chart consists of a data field and heading sections and two charts areas: X chart, Moving range chart.



It is often used for subgroups of single sample

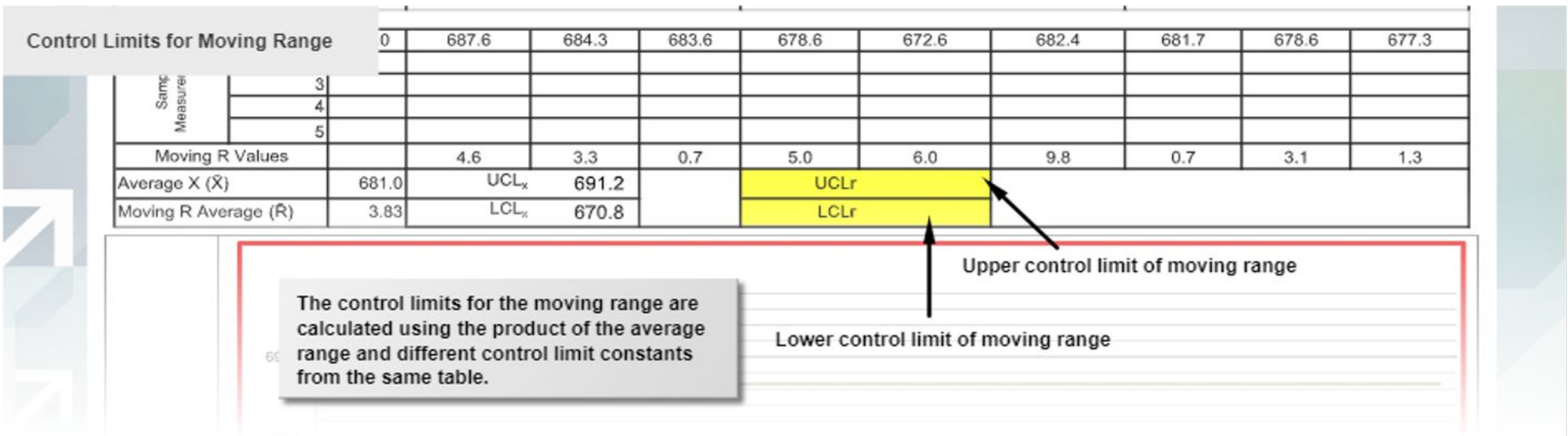
Control limits for individual measurements



Sample Measurements	1	683.0	687.6	684.3	683.6	678.6	672.6	682.4	681.7	678.6	677.3
	2										
	3										
	4										
	5										
Moving R Values			4.6	3.3	0.7	5.0	6.0	9.8	0.7	3.1	1.3
Average X ($\bar{X}$)		681.0	UCL_x			UCL_r					
Moving R Average ($\bar{R}$)		3.83	LCL_x			LCL_r					

$$UCL_X = \overline{X} + E_2\overline{R} \qquad LCL_X = \overline{X} - E_2\overline{R}$$

Control limits for moving range



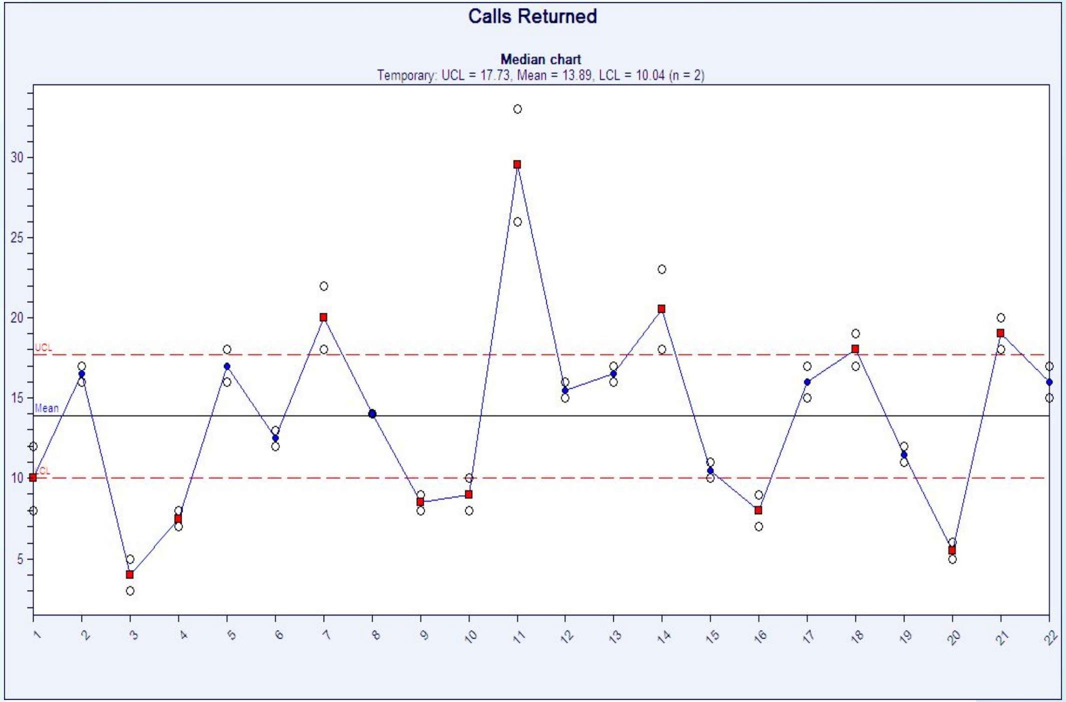
$$UCL_r = D_4\overline{R}$$

$$LCL_r = D_3\overline{R}$$

Median control chart

- This type of chart plots all the data points which illustrate both median and range of each sample.

- A median control chart usually only contains a section for plotting the median values. Some median charts may also have sections for plotting other values, such as the range.



Another variable control chart monitors the median of measurements of samples within a subgroup

Control limits for medians

Control Limits for Medians

fee	Operation # Fill	Upper Specification Limit 697.0	Unit of Measure g
:1.5CC	Machine Filler #40	Lower Specification Limit 663.0	Zero Equals 680.0

Sample Measurements	1	683.0	687.6	684.3	683.6	678.6	678.0	682.4	681.7	678.6	677.3
	2	682.0	688.6	686.2	678.9	682.5	678.0	680.0	678.9	678.5	679.9
	3	681.5	687.5	681.6	682.5	685.0	680.2	681.0	680.8	686.2	681.0
	4	676.3	682.3	687.2	683.7	681.6	682.3	681.7	681.6	681.0	682.1
	5	678.8	687.9	690.1	678.9	682.0	684.1	681.3	683.3	678.0	681.8
Median		681.5	687.6	686.2	682.5	682.0	680.2	681.3	681.6	678.6	681.0
Range		6.7	6.3	8.5	4.8	6.4	6.1	2.4	4.4	8.2	4.8
Average Median ($\bar{X}'$)		682.3	$UCL_{x'}$								
Average Range ($\bar{R}$)		5.86	$LCL_{x'}$								

Upper control limit of medians

Lower control limit of medians

693.0

688.0

The control limits for the medians chart uses a formula containing the average median, average range, and a special control limit constant.

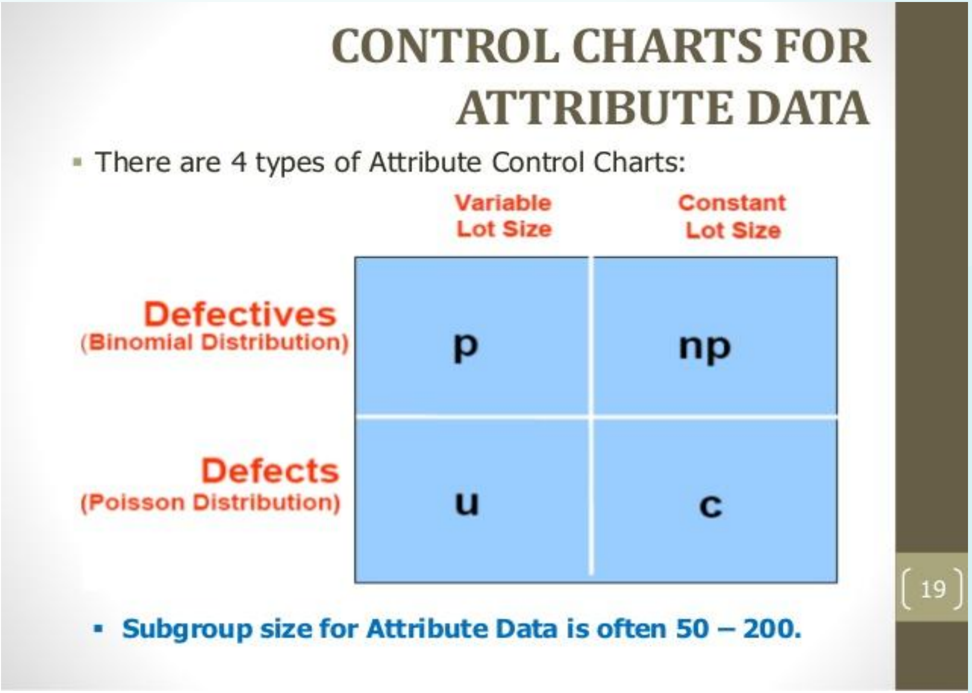
$$UCL_x = X' + A'_2\bar{R}$$

$$LCL_x = X' - A'_2\bar{R}$$

Attributes control chart

- They are a set of **control charts** specifically designed for tracking defects (also called non-conformities). These types of defects are binary in nature (yes/no), where a part has one or more defects, or it doesn't. ... This affects the way the control limits for each chart are calculated

- Attribute control charts require larger subgroups than variable control charts. An attribute chart often requires subgroups with 50 to 200 samples.



Two common attribute control charts for monitoring one of two or more conditions are p chart and np chart

Two common charts for counting the number of occurrences of multiple conditions are c chart and u chart

P & Np Control Chart
U & C Control Chart

1) The P Chart and Np Chart are used to monitor characteristics that can be separated into two classifications including:

   Good or Bad.
   On or Off.
   Male or Female.
   Positive or Negative.

2) The U Chart and C Chart are used to monitor the number of total defects in the samples. The defects could include any type of defects, including:

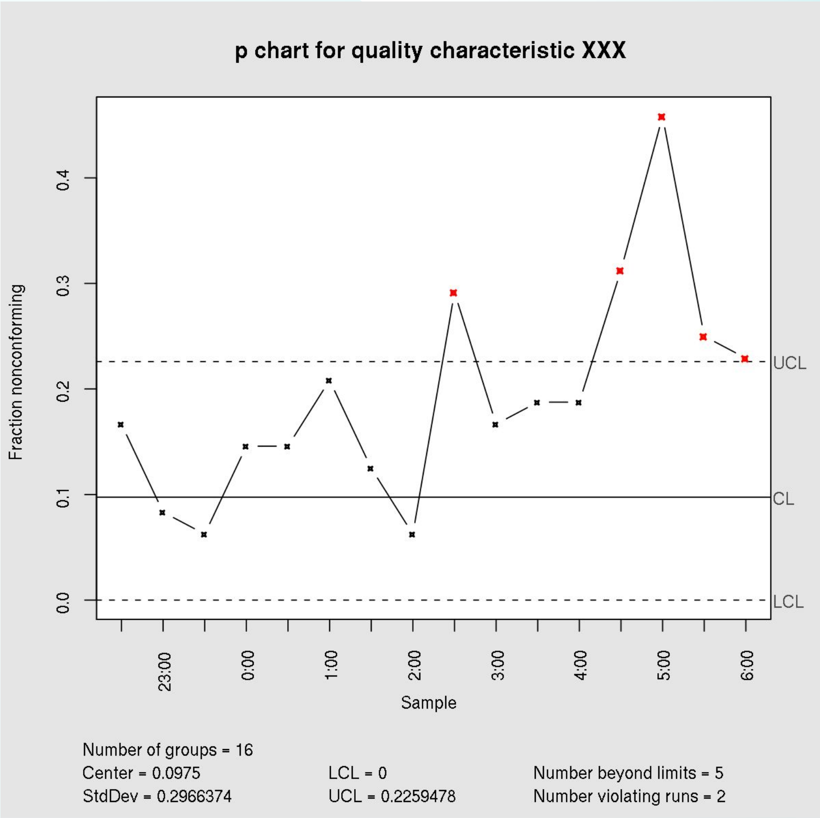
   Overweight.
   Underweight.
   Loose lids.
   Scratches.

P Control Chart

In statistical quality control, the **p-chart** is a type of control **chart** used to monitor the proportion of nonconforming units in a sample, where the sample proportion nonconforming is defined as the ratio of the number of nonconforming units to the sample size, n.

$$LCL = \overline{p} - m\sqrt{\frac{\overline{p}(1-\overline{p})}{n_i}}$$

$$UCL = \overline{p} + m\sqrt{\frac{\overline{p}(1-\overline{p})}{n_i}}$$

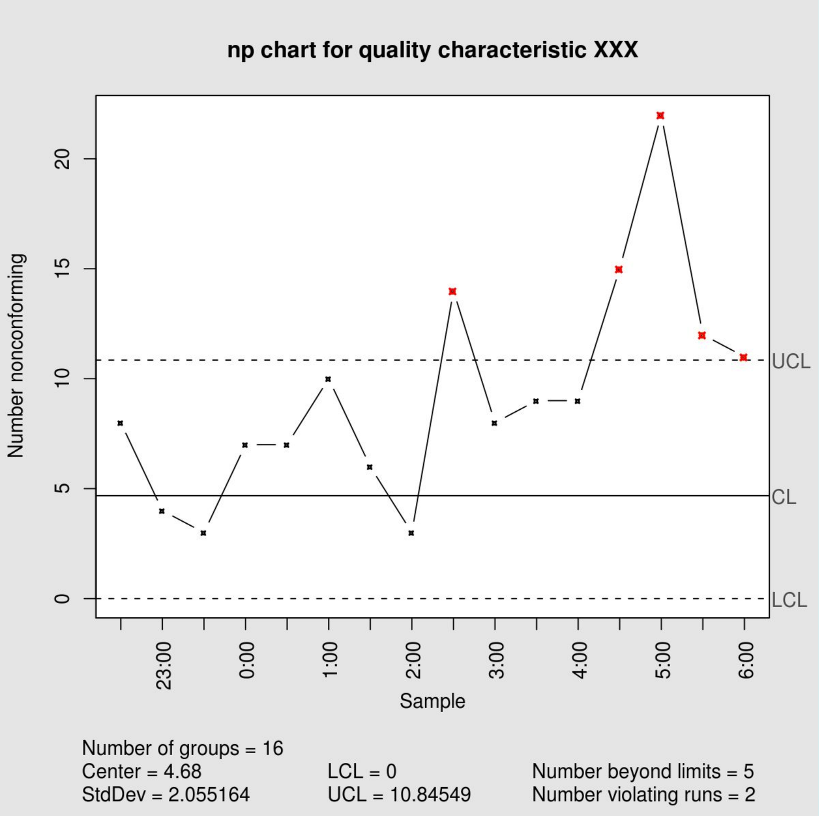


Np Control Chart

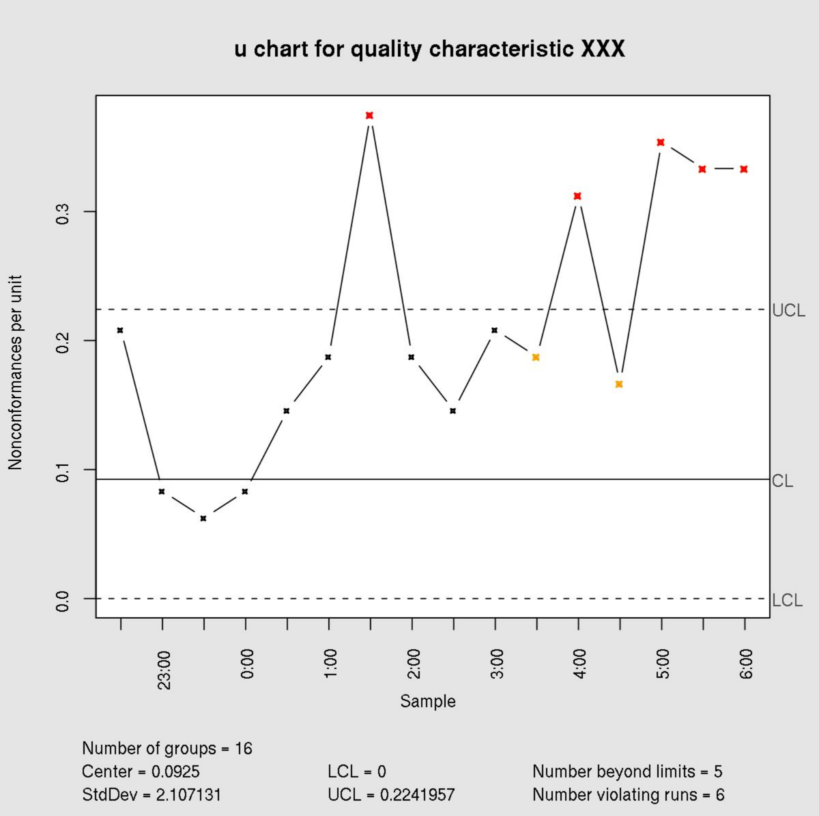
An **np-chart** is an attributes control **chart** used with data collected in subgroups that are the same size. **Np-charts** show how the process, measured by the number of nonconforming items it produces, changes over time.

$$LCL = n\bar{p} - m\sqrt{n\bar{p}(1-\bar{p})}$$

$$UCL = n\bar{p} + m\sqrt{n\bar{p}(1-\bar{p})}$$



U Control Chart

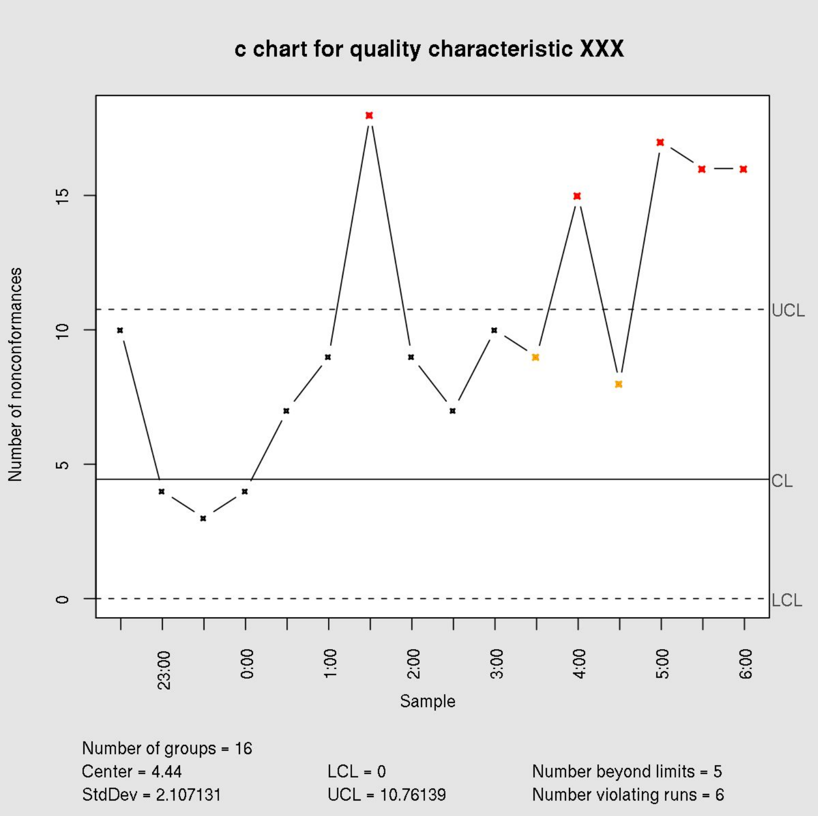


A **u-chart** is an attributes control **chart** used with data collected in subgroups of varying sizes. **U-charts** show how the process, measured by the number of nonconformities per item or group of items, changes over time. Nonconformities are defects or occurrences found in the sampled subgroup.

$$LCL = \bar{u} - m\sqrt{\frac{\bar{u}}{n_i}}$$

$$UCL = \bar{u} + m\sqrt{\frac{\bar{u}}{n_i}}$$

C Control Chart



A **c-chart** is an attributes **control chart** used with data collected in subgroups that are the same size. **C-charts** show how the process, measured by the number of nonconformities per item or group of items, changes over time. Nonconformities are defects or occurrences found in the sampled subgroup.

$$LCL = \bar{c} - m\sqrt{\bar{c}}$$

$$UCL = \bar{c} + m\sqrt{\bar{c}}$$

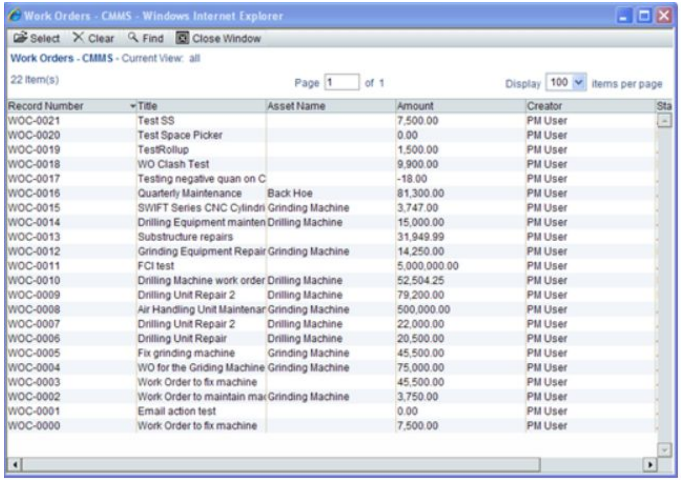
Process Log

Every control chart should be analyzed both as the process runs and when the process is completed.

A critical tool in the analysis of a control chart is a process log.

The log documents process changes or special environmental occurrences made during the process run.

The log may be separate document, part of the control chart, or simple notes on the graph.

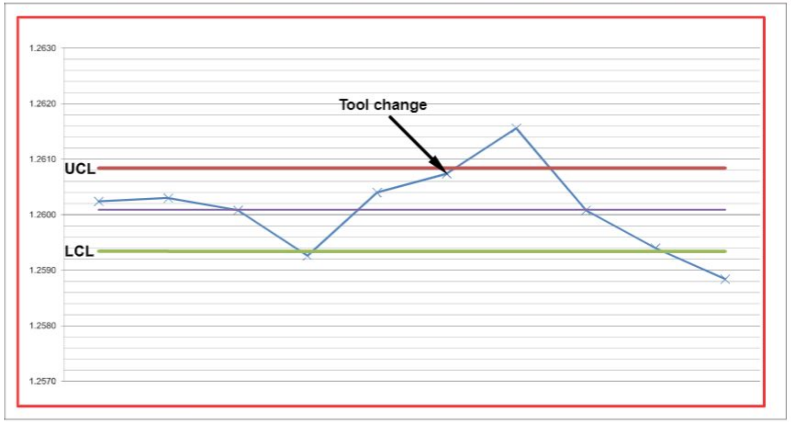

Work Orders - CMMS - Windows Internet Explorer

Select Clear Find Close Window

Work Orders - CMMS - Current View: all

22 Item(s) Page 1 of 1 Display 100 items per page

Record Number	Title	Asset Name	Amount	Creator	Sta
WOC-0021	Test SS		7,500.00	PM User	
WOC-0020	Test Space Picker		0.00	PM User	
WOC-0019	TestRollup		1,500.00	PM User	
WOC-0018	WO Clash Test		9,900.00	PM User	
WOC-0017	Testing negative quan on C		-18.00	PM User	
WOC-0016	Quarterly Maintenance	Back Hoe	81,300.00	PM User	
WOC-0015	SWIFT Series CNC Cylindri	Grinding Machine	3,747.00	PM User	
WOC-0014	Drilling Equipment mainten	Drilling Machine	15,000.00	PM User	
WOC-0013	Substructure repairs		31,949.99	PM User	
WOC-0012	Grinding Equipment Repair	Grinding Machine	14,250.00	PM User	
WOC-0011	FCI test		5,000,000.00	PM User	
WOC-0010	Drilling Machine work order	Drilling Machine	52,504.25	PM User	
WOC-0009	Drilling Unit Repair 2	Drilling Machine	79,200.00	PM User	
WOC-0008	Air Handling Unit Maintenar	Grinding Machine	500,000.00	PM User	
WOC-0007	Drilling Unit Repair 2	Drilling Machine	22,000.00	PM User	
WOC-0006	Drilling Unit Repair	Drilling Machine	20,500.00	PM User	
WOC-0005	Fix grinding machine	Grinding Machine	45,500.00	PM User	
WOC-0004	WO for the Griding Machine	Grinding Machine	75,000.00	PM User	
WOC-0003	Work Order to fix machine		45,500.00	PM User	
WOC-0002	Work Order to maintain mac	Grinding Machine	3,750.00	PM User	
WOC-0001	Email action test		0.00	PM User	
WOC-0000	Work Order to fix machine		7,500.00	PM User	



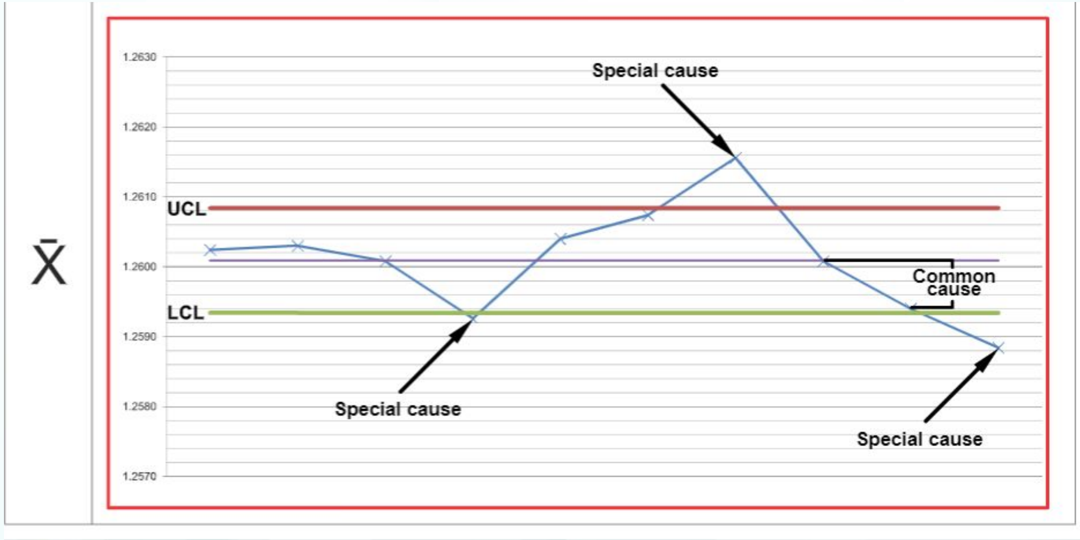
Analysis of Control charts

Goals:

⇨ Distinguish between special and common causes of variation

⇨ Determine if the process is in control.A process is in control when both the average and the variation are stable

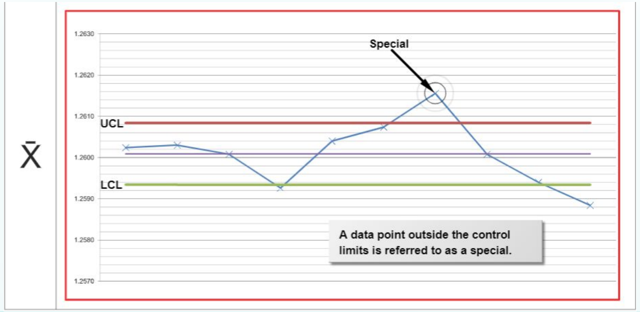
1. Special causes of variation are identified as points above and below the control limits
2. Common causes of variation are more difficult to identify because they are part of the normal variation within the process



Interpretation of the Control charts

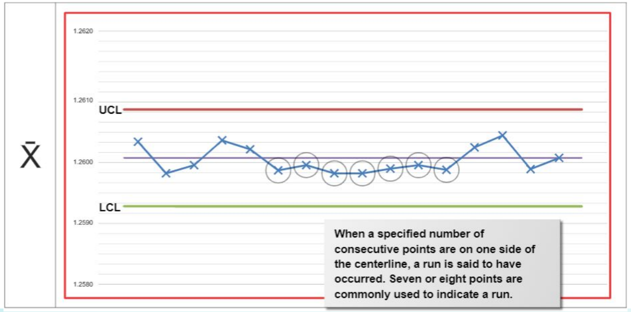
Data points in the different areas of the control chart may indicate process conditions such as:

Specials

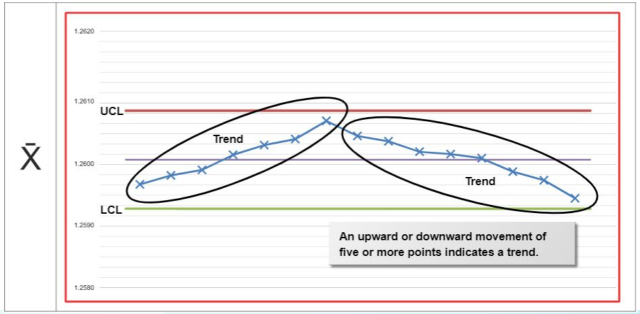


1 in 20

Run



Trend



Conclusion

Statistical Process Control (SPC) is an industry-standard methodology for measuring and controlling quality during the manufacturing process. Quality data in the form of Product or Process measurements are obtained in real-time during manufacturing.