Applying Statistical Techniques to implement High Maturity Practices At North Shore Technologies (NST)

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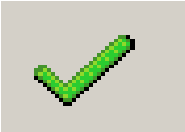
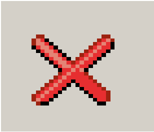
December 2015

For our audience some Key Features



Say “Yes” when you understand



Say “No” when you don’t understand

Indicate laughter

Indicate applause

Participate

The Dairy Story

Delighting the customer

A memorable breakfast?

Two men decide to go to a restaurant for breakfast
Find the waiter to be attentive; food to be nice
The manager, stopped by to say hello and to ask whether we liked our meal

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And..

While leaving, they ask for a few cookies as takeaway

But on reaching home…

They find a small box of chocolates with an accompanying ‘Thank You’ note from the manager

The dining experience delighted the customers, and the thoughtfulness of the manager, simply astounded them

Analysis…

Basic Needs

- The two had certain expectations for the meal before they even arrived at the restaurant.
- For instance, the two must have expected that the service would be prompt and friendly, the food good and reasonably priced, and that the restaurant be clean.

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Basic Needs

If these needs go unfilled, customers will certainly be dissatisfied. Total absence or poor performance in any of these attributes could result in extreme dissatisfaction.

However, even if these are completely fulfilled, there is no guarantee that customers will be particularly satisfied or return for subsequent meals at the establishment.

Performance Attributes

Linear effect on customer satisfaction
Additionally, the price customers are willing to pay for goods and services is closely tied to these attributes.
The better the restaurant is in meeting these, the more are customers are satisfied with the total dining experience.

Delighters

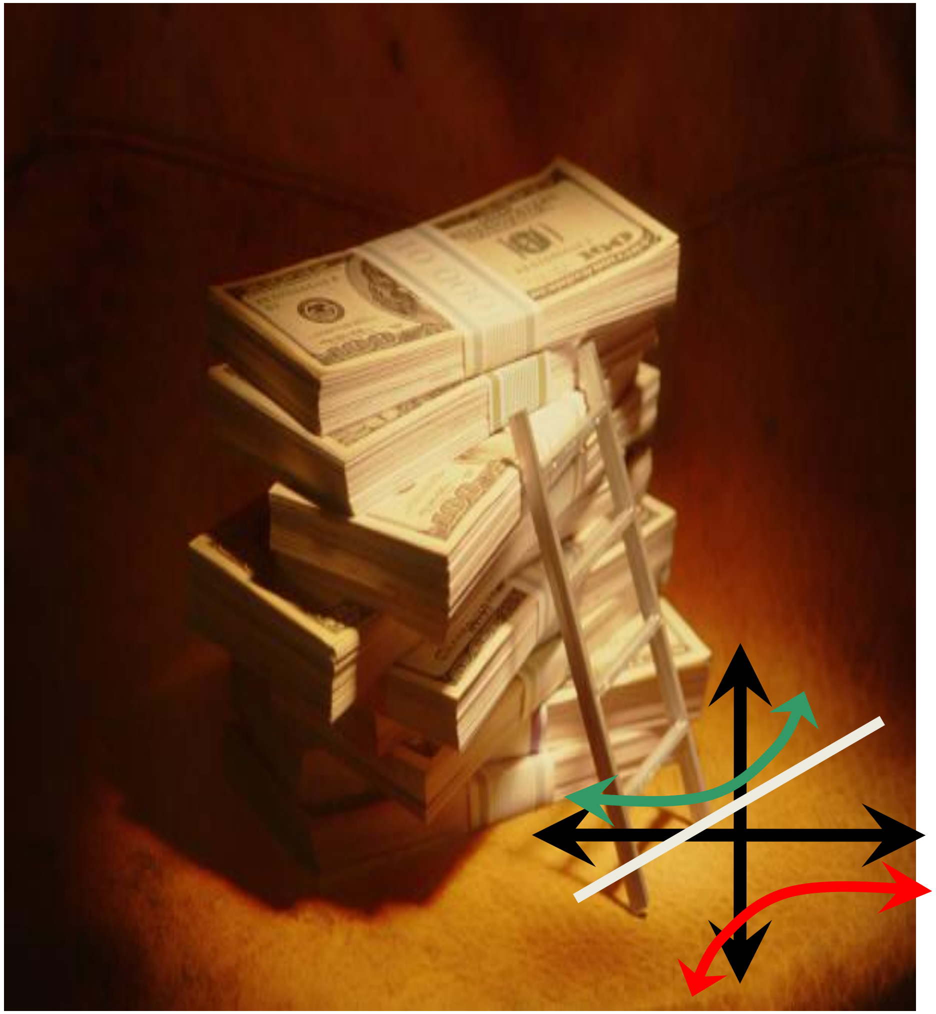
- These are unexpected by the customer, but when present can result in high levels of customer satisfaction or customer "wows."

Delighters

- Take for example, the box of chocolates that was tucked into the cookies' box. Then there was the personal note of thanks from the manager. This personal touch was certainly unexpected and a delighter that ensured that the two would return to be delighted again.

In short…

Provide the basics, and then deliver outstanding customer service and you will create customer loyalty translating into better business.



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1 Fundamental of Statistical Thinking

Fundamentals of Statistical Thinking

- All product development and services are a series of interconnected processes.

- All processes have variation in their results

- Understanding variation is the basis for management by fact and systematic improvement:

Understand the past quantitatively
Control the present quantitatively
Predict the future quantitatively

What is Statistics

- A summary or characterization of a distribution (i.e. a set of numbers)
- A characterization of a central tendency (e.g. mean, median and mode)
- A characterization of dispersion (e.g. variance, standard deviation, inter-quartile range and range

Basic Statistics

- Type of Data
- Measure of the center if the data
  - Mean
  - Median
  - Mode
- Measure of the Spread of the Data
  - Range
  - Variation
  - Standard Deviation
- Normal Distribution and Normal Probabilities
- Process Stability and Process Capabilities
- A characterization of dispersion (e.g. variance, standard deviation, inter quartile range.

What sorts of data do you see being collected around your area?

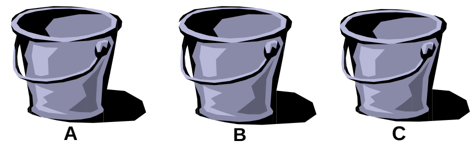
Types of Data

Placing observations into categories

Examples

Attribute

(a.k.a., nominal, categorical, digital)



Defect counts by type

Job titles

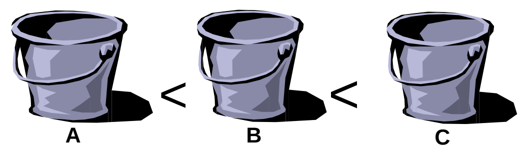
Ordinal

Attribute data, with > or < relationships among the categories

Satisfaction ratings: *unsatisfied, neutral, delighted*

Risk estimates: *low, med, high*

CMM maturity levels



Increasing Information Content

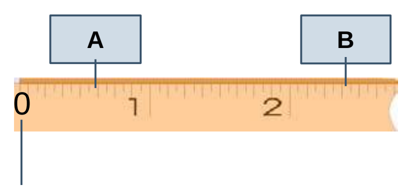
Variables

(a.k.a., measures, continuous, analog)

Assignment of observations to points on a scale … enabling determination of interval sizes and differences

Interval

deg. F, C



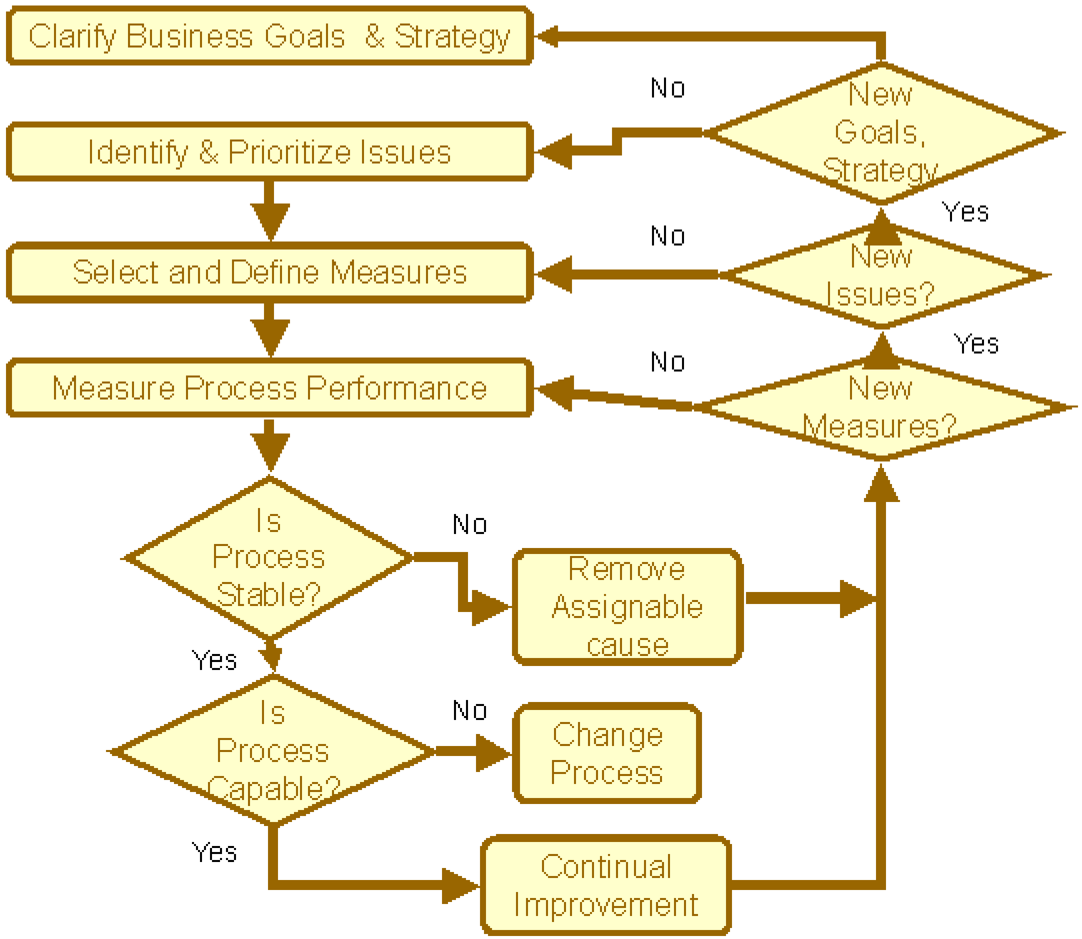
Ratio

Time
Cost
Code size

Which type of data is it?

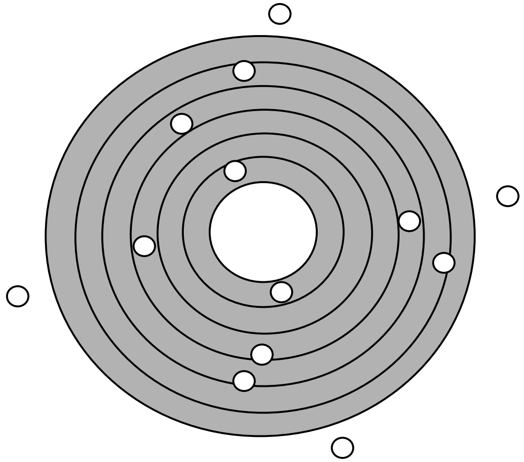
- Percent defect parts in hourly production
- Percent cream content in milk bottles
- Amount of time it takes to respond to a request
- Daily test of water acidity
- Number of accidents per month
- Number of defective parts in lots of size 100
- Number of employees who had an accident

Which type of data is it?



Progressive Journey of Improvements

QUANTITATIVE MEASUREMENT:



Progressive Journey of Improvements

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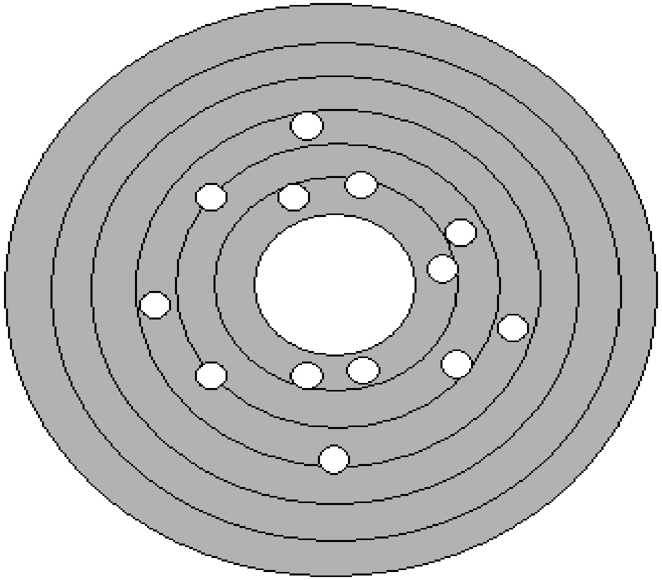
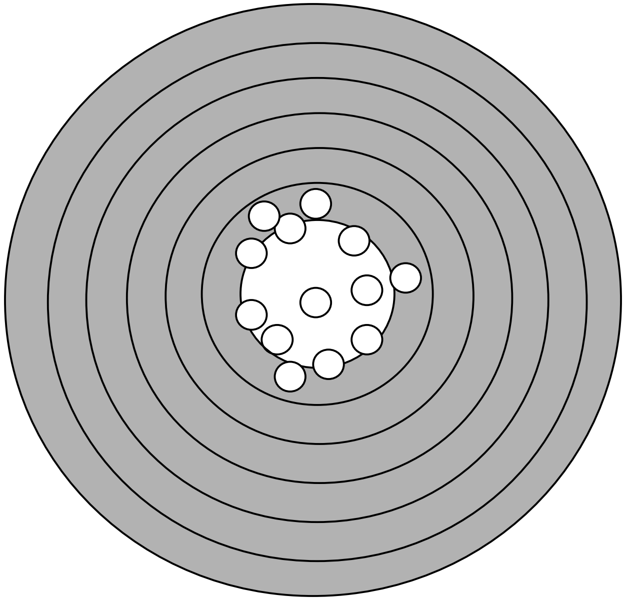
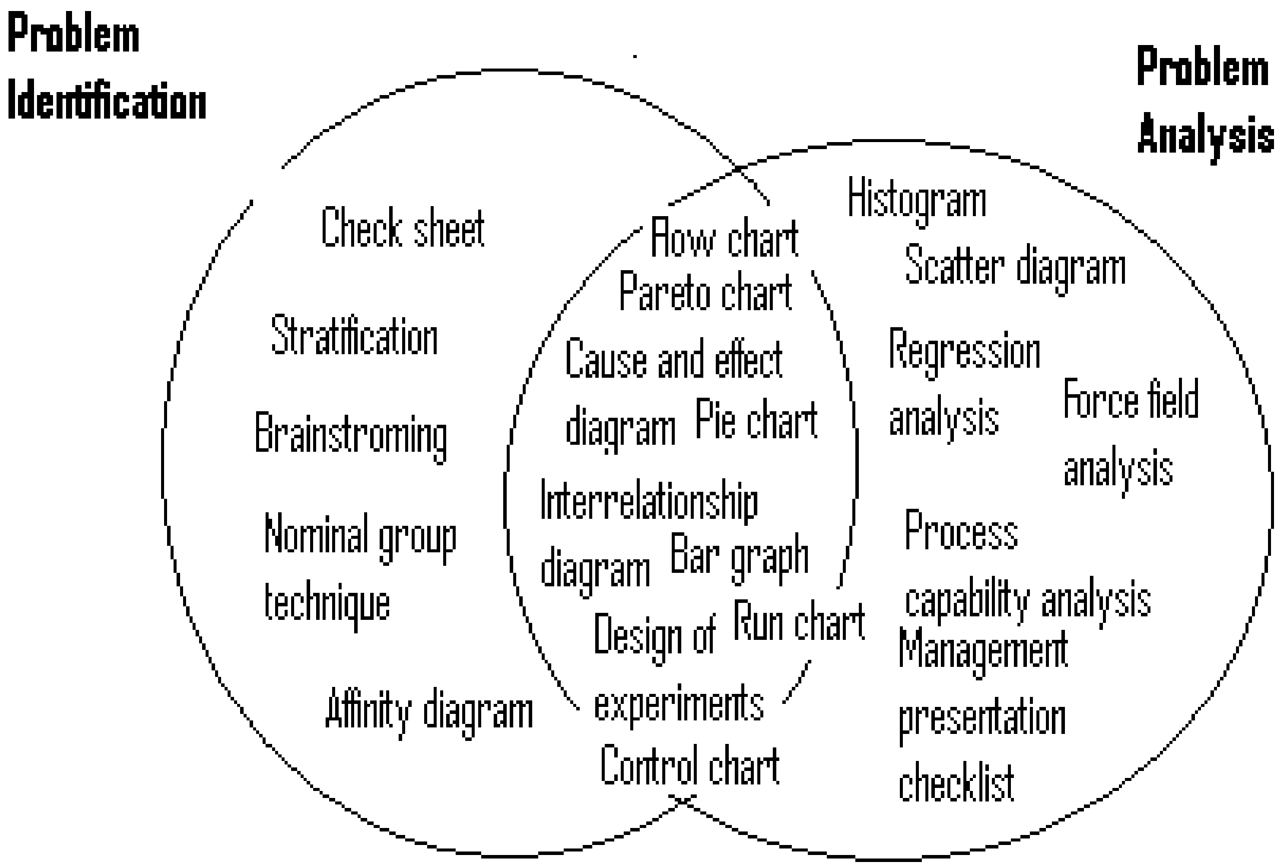


Progressive Journey of Improvements

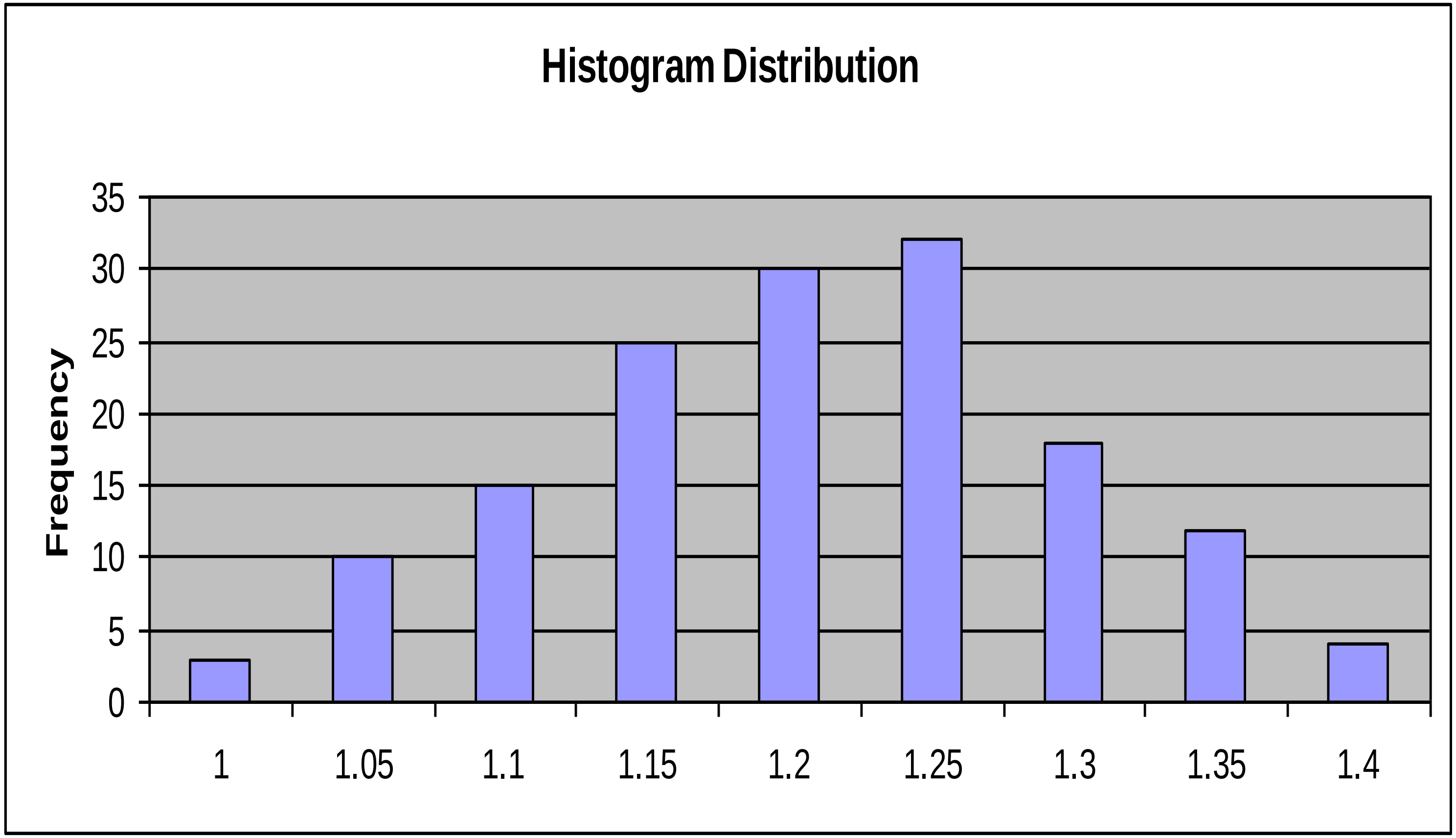
QUANTITATIVE MEASUREMENT:



Problem Identification and Analysis



Distribution of Data

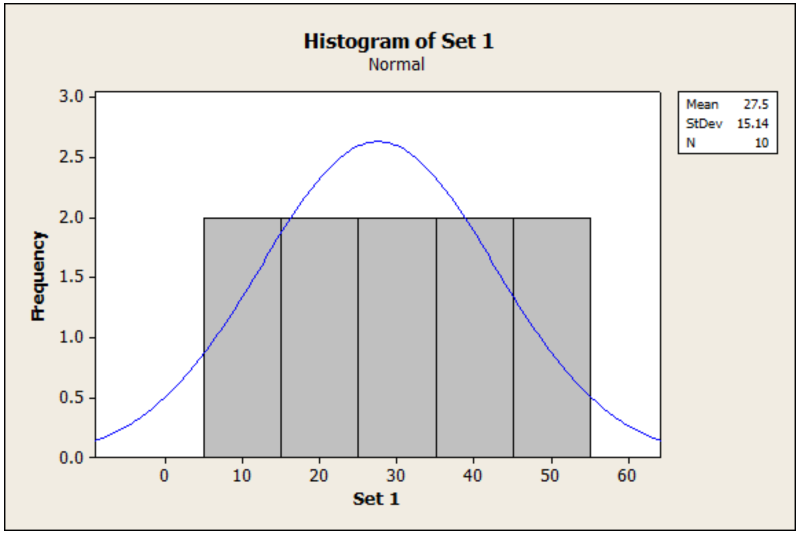


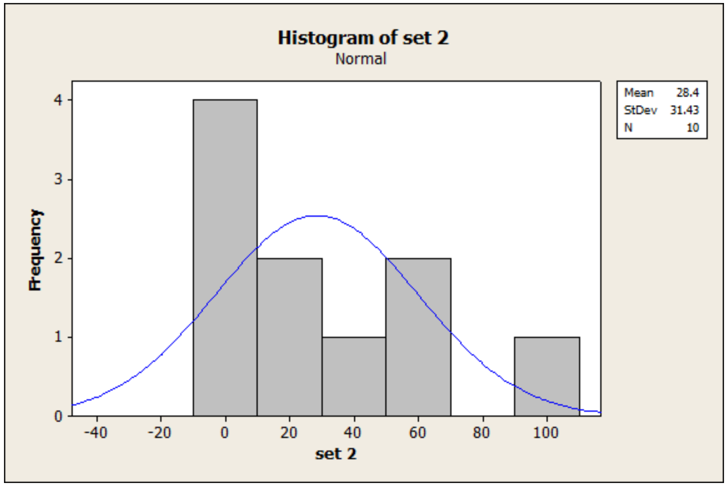
The Normal Distribution

- The Normal Distribution is a distribution of data which has certain consistent properties
- These properties are very useful in our understanding of the characteristics of the underlying process from which the data were obtained
- Most natural phenomena and man-made processes are distributed normally, or can be represented as normally distributed

Check of Normal Distribution - 1

	Set 1	Set 2
	5	1
	10	20
	15	50
	20	30
	25	5
	30	100
	35	50
	40	1
	45	2
	50	25
Total	**275**	**284**
Average	**27.5**	**28.4**





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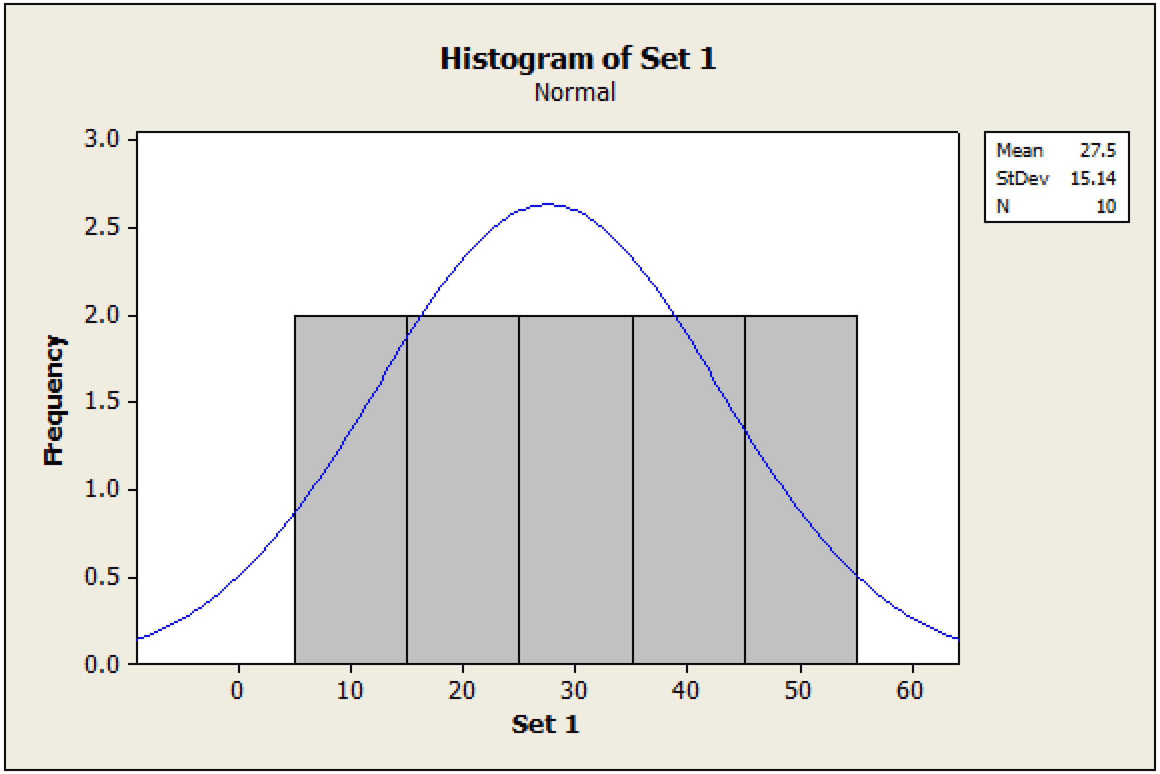
Check of Normal Distribution - 2



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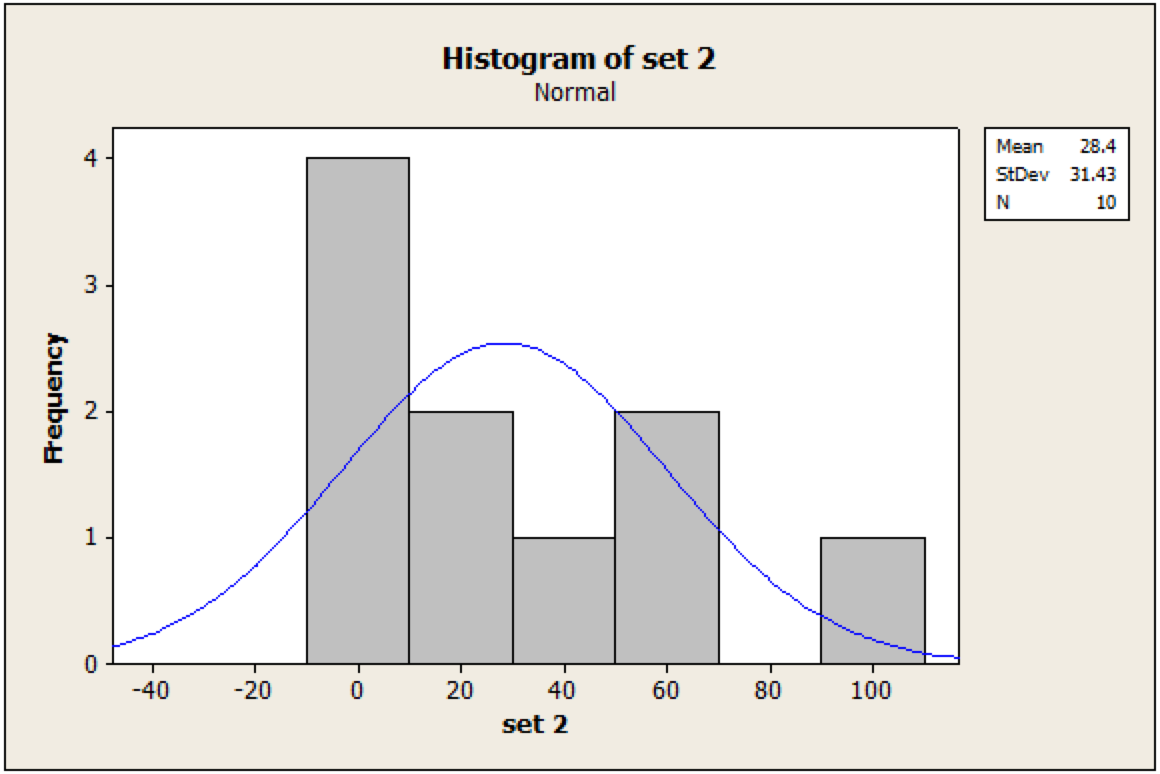
Check of Normal Distribution - 3



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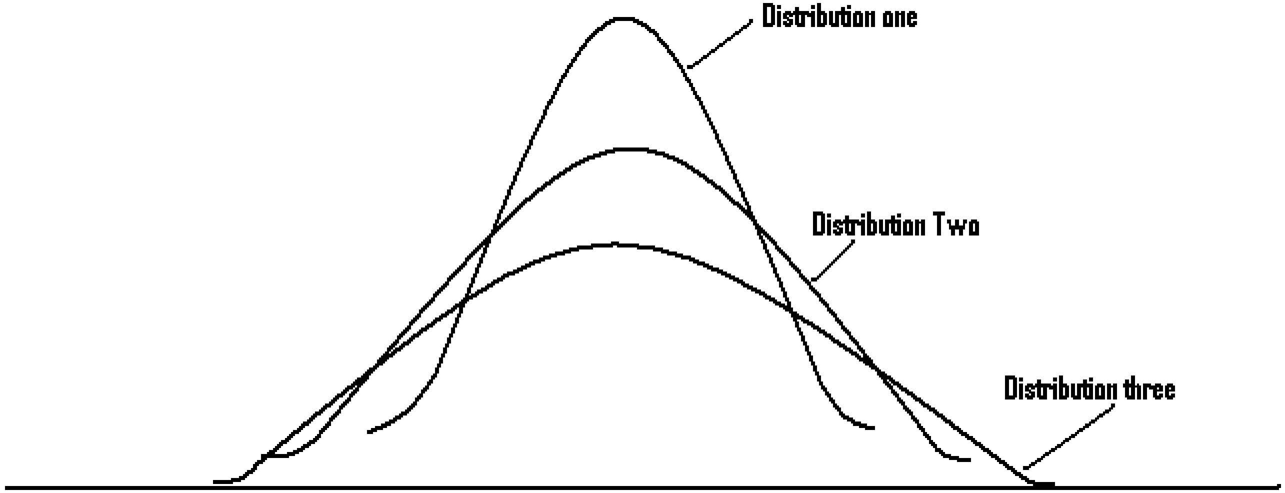
The Normal Distribution

Property 1: A normal distribution can be described completely by knowing only “mean” and “standard deviation”

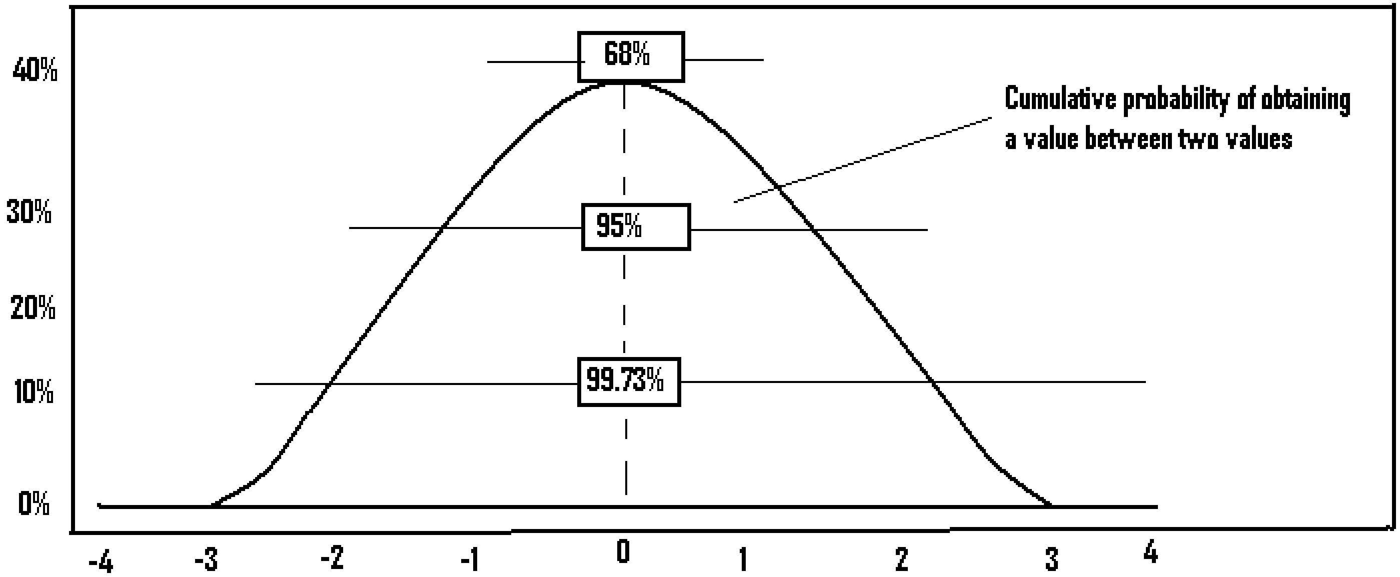


What is the difference among these three normal distributions?

The Normal Distribution

The Normal Curve and Probability Areas Associated with the Standard Deviation

Property 2: The area under sections of the curve can be used to estimate the cumulative probability of a certain "event" occurring



Number of standard deviations from the mean

Empirical Rule of Standard Deviation

The previous rules of cumulative probability apply even when a set of data is not perfectly normally distributed. Let's compare the values for a theoretical (perfect) normal distributions to other (skewed) distributions

Number of		
Standard	Theoretical	Empirical
Deviations	Normal	Non Normal
+/- 1σ	68%	60-75%
+/- 2σ	95%	90-98%
+/- 3σ	99.7%	99-100%

Where is the Center of the Data ?

Mean = The average value (the "Center of Gravity"	Median = the 50% point (or the "middle number"

$$\bar{X} = \frac{\text{Sum of the data points}}{\text{Number of data points}}$$

- Uses all data points	To find the median of a data set (1) arrange data in order from smallest to largest (2) the middle number is the median
- Heavily influenced by extreme values	1,2,3,14,85 The median is 3
	- Not heavily influenced by extreme values

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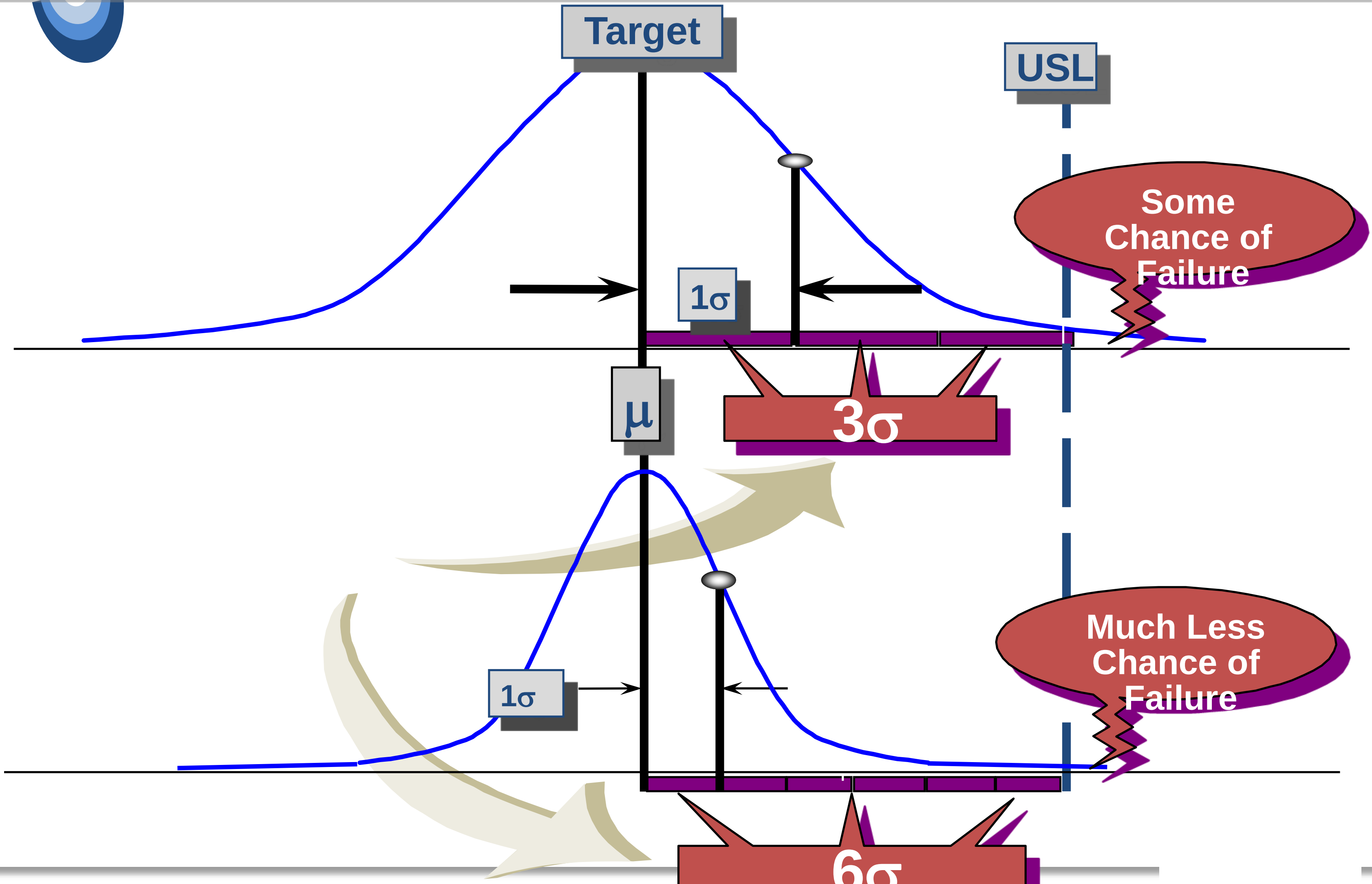
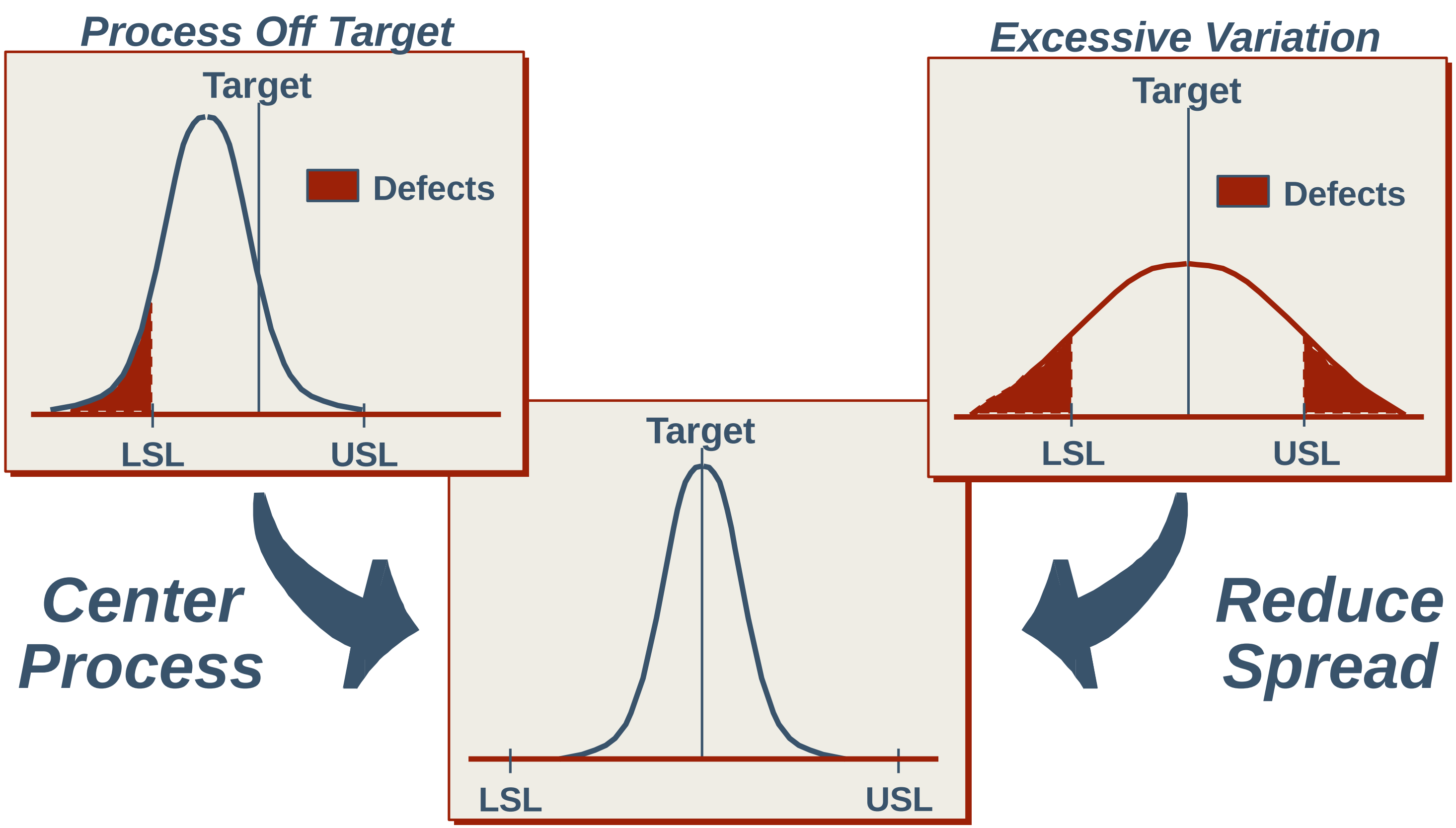
Where is the Center of the Data ?



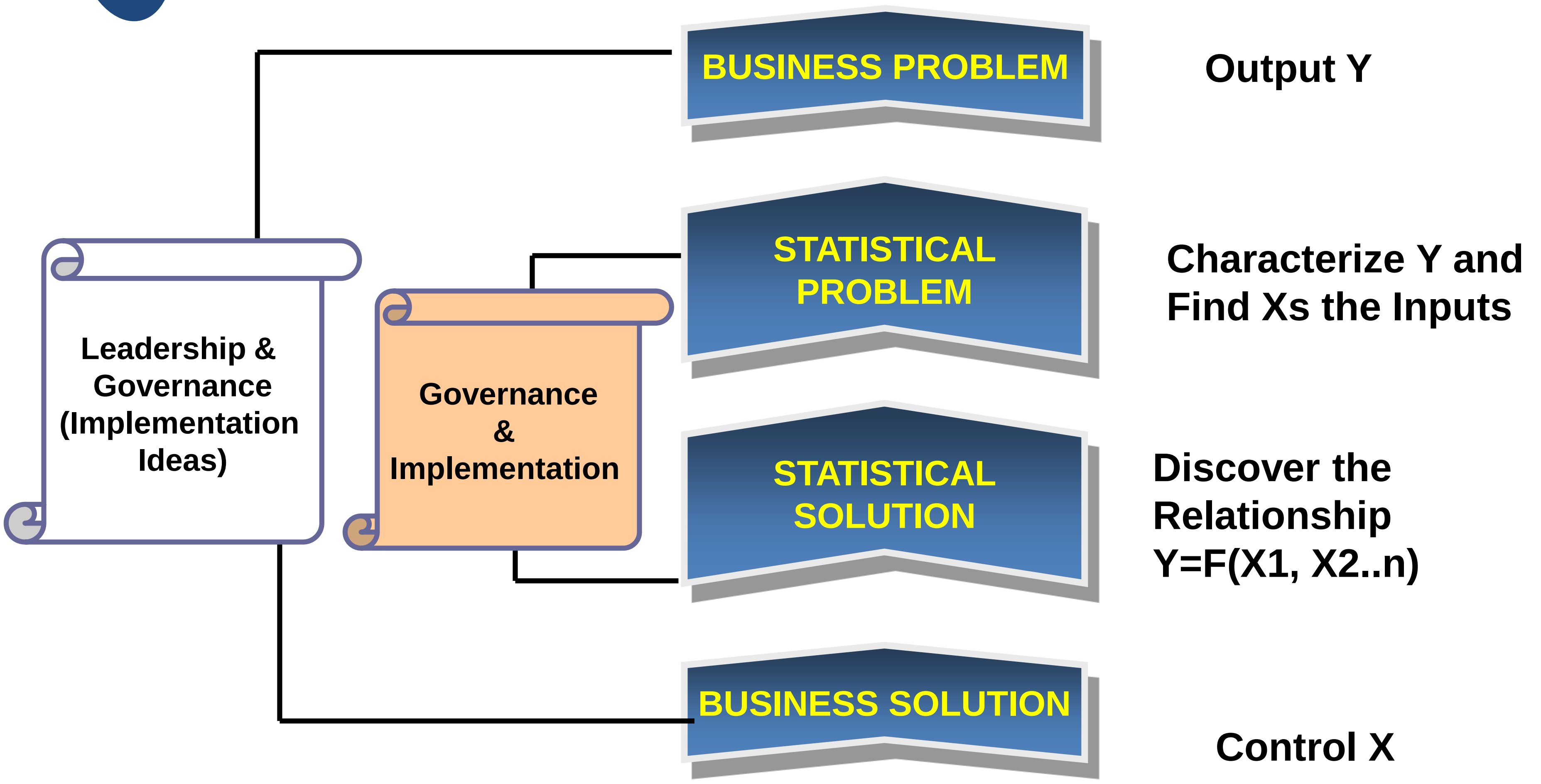
Normal distribution characterstics

- Smooth and continuous
- Bell shaped and symmetrical
- Both tails are asymptotic to the x-axis
- The total area under the distribution curve equals 1
- The mean, median, and mode have the same value

Way to Improve Process



High Maturity Philosophy



Six Sigma Methodology

Control

How do we ensure we never ever have the pain?

Define

Where is the pain?

Measure

Measure

What is the extent of the pain?

Improve

What is the prescription for the pain?

Analyze

What are the causes of the pain?

Measure..Measure..Measure..

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Interpreting Six Sigma

Sigma	Parts per Million (PPM)	Yield (%)
1.5	500,000	50
2	308,537	69.1463
2.5	158,650	84.135
3	66,807	93.3193
3.5	22,700	97.73
4	6,210	99.379
4.5	1,350	99.865
5	233	99.9767
5.5	32	99.9968
6	3.4	99.99966
Process capability	**DPMO**	
3.4 Defects in a Million Defect Making Opportunities.		

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Fruit Tree analogy view

3 sigma = Logic/intuition= ground fruit

4 sigma = Seven Basic tools = Low hanging fruit

5 sigma = process Characterization = Bulk of fruit

6 sigma = Process Innovation = Sweet fruit

- *Center process*
- *Reduce Spread*

Control Chart

A time-ordered plot of process data points with a centerline based on the average and control limits that bound the expected range of variation

Control charts are one of the most useful quantitative tools for understanding variation

Control Charts

- Plots of value in time sequence
- To check if the behavior of the process is changing
- Determine common cause and assignable causes of variance

Why Control Charts?

Show the **capability** of the process (what your process can do) so that you can set achievable goals

Identify unusual events so that you can fix to improve the process

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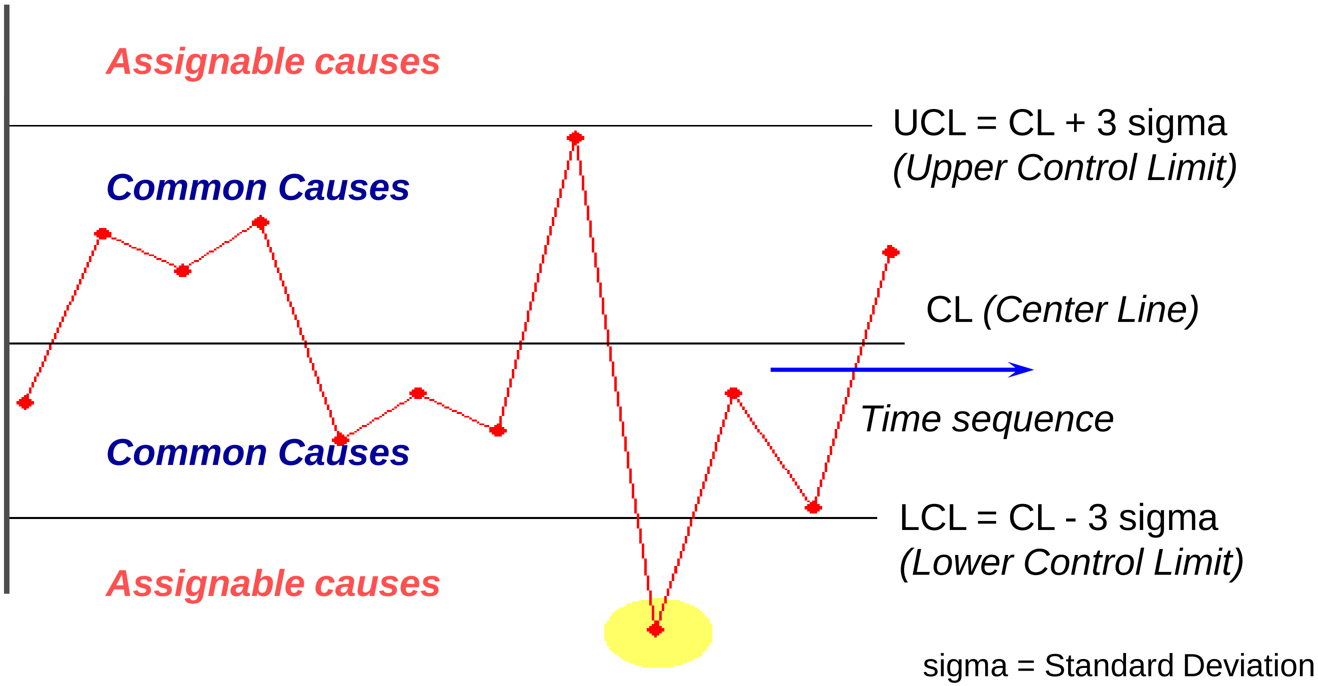
Control Charts Structure

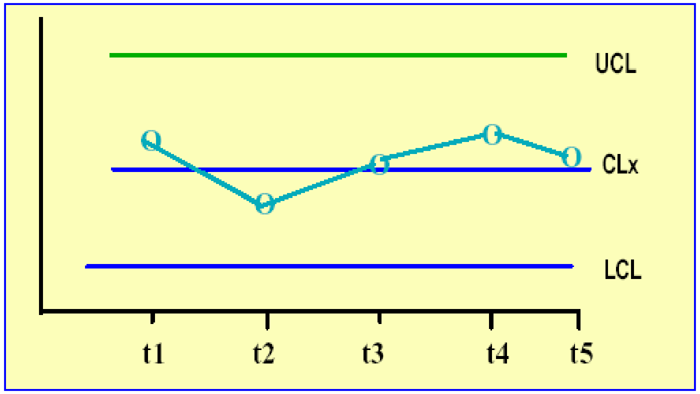


Common causes → in the process
Assignable causes → outside

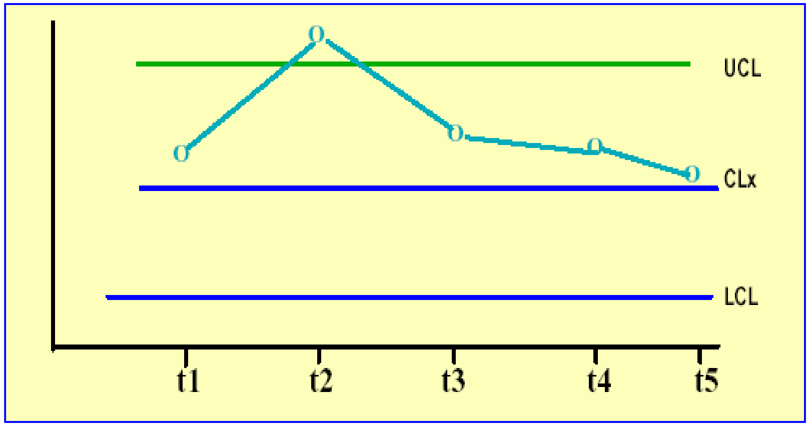
FTR SVC 6 sigma case

Stable Process

Process is stable



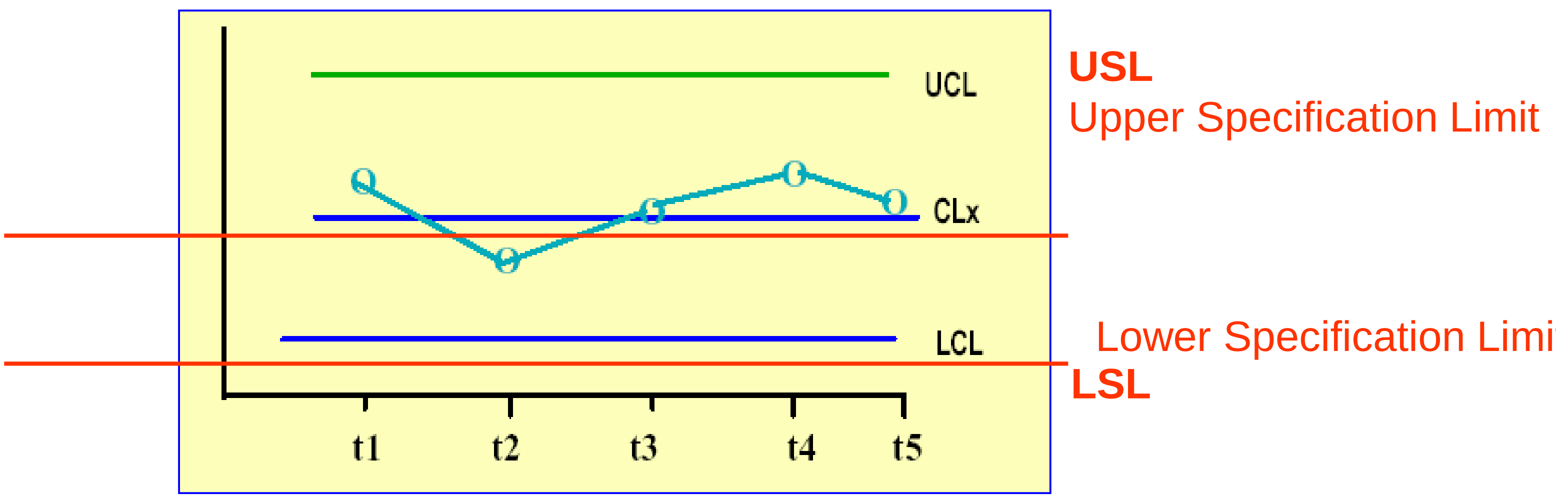
Process is not stable
("Out-of-control" Process)



Capable Process

- Process must be stable
- The capability of the process must meet or exceed the specifications that have to be satisfied to meet the organization/customer expectations

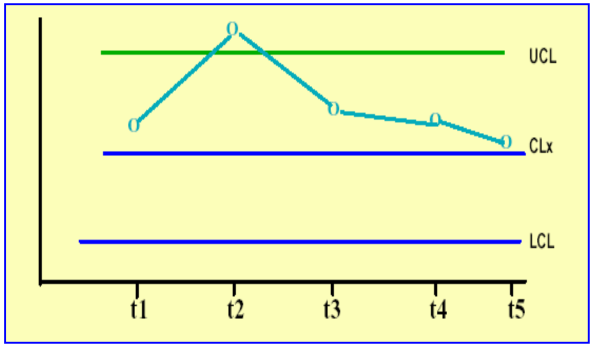
Process is capable



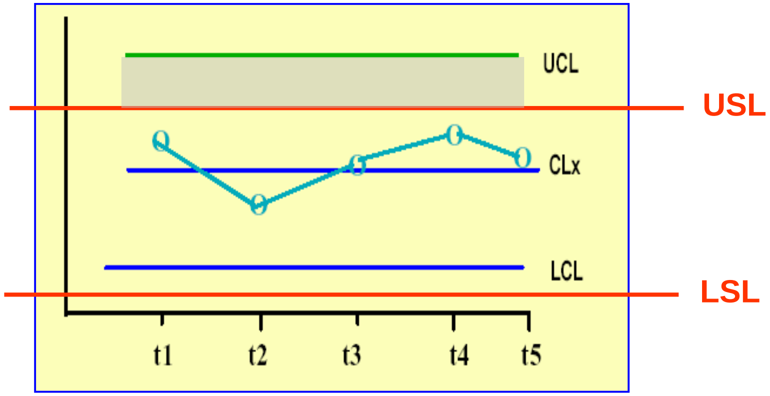
Capable Process - Example

- **Example of Process Is Not Capable**

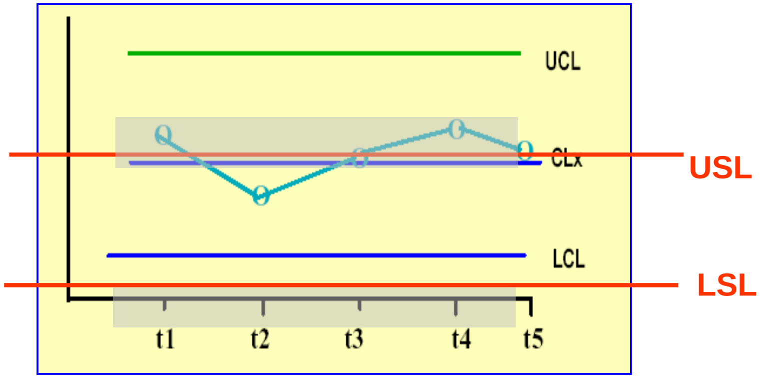
Process is not stable, and of course... not capable



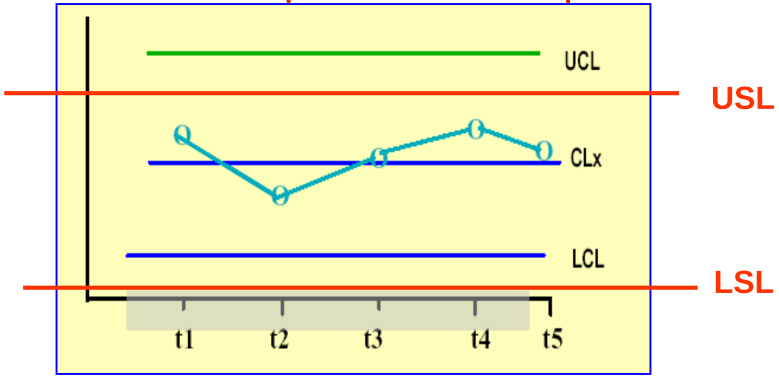
Some data points over spec



Some data points over spec, under spec



Some data points under spec



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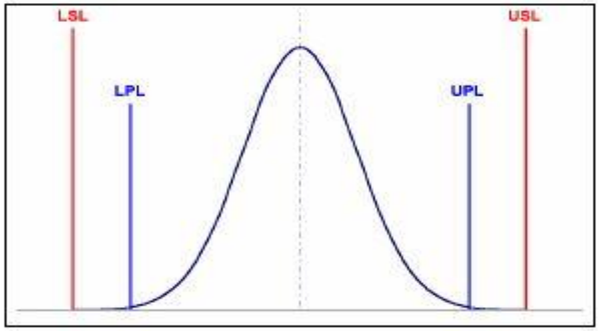
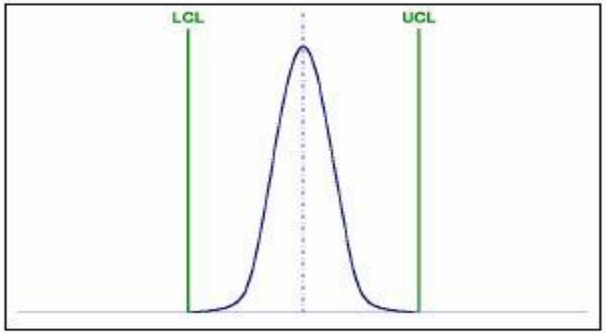
Three Types of Limits

Distribution of Individual Values



Distribution of Sample Averages



Process Capability Indices

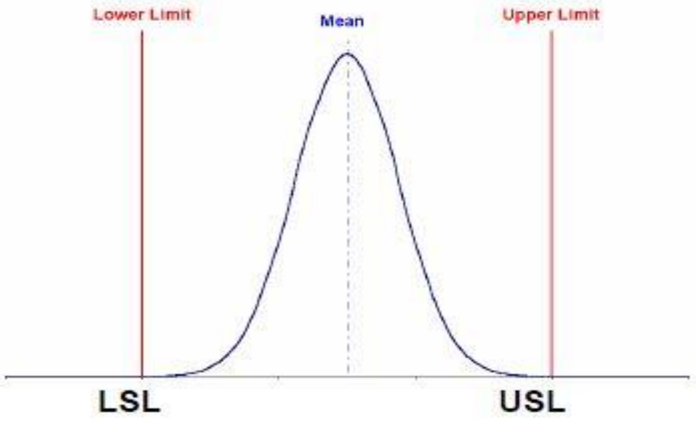
Two measures of process capability

- **Process Potential**
  - C_p
- **Process Performance**
  - C_{pu}
  - C_{pl}
  - C_{pk}

Process Potential

The C_p index assesses whether the natural tolerance (6 σ) of a process is within the specification limits.

$$C_p = \frac{\text{Engineering Tolerance}}{\text{Natural Tolerance}} = \frac{USL - LSL}{6\sigma}$$

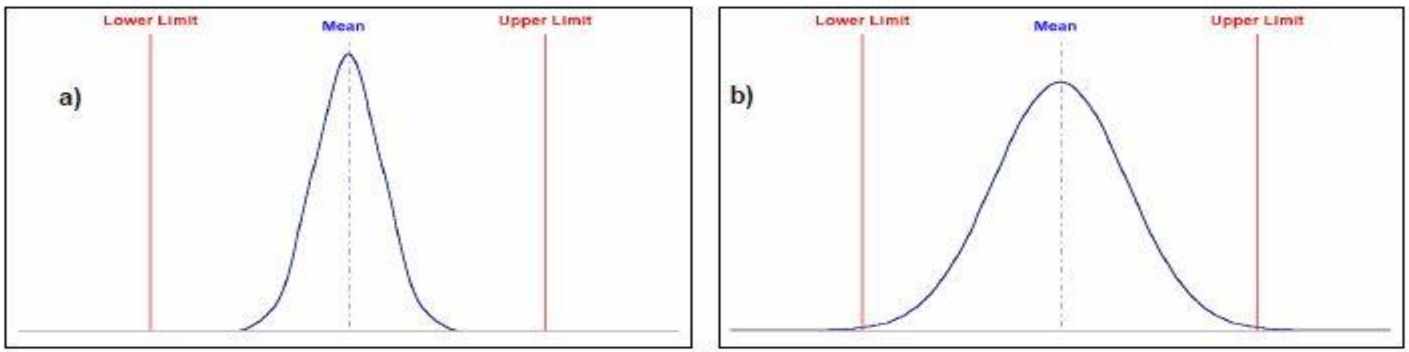


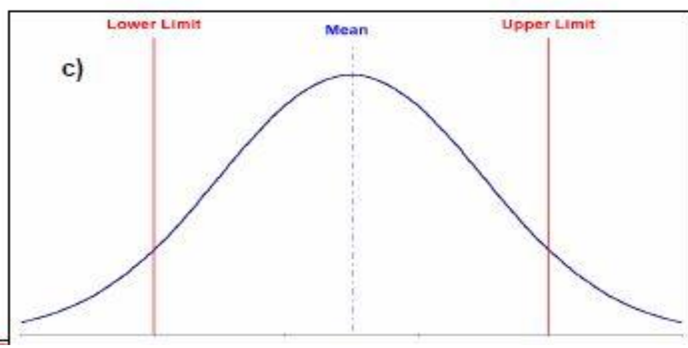
Process Potential

Historically, a C_p of 1.0 has indicated that a process is judged to be “capable”, i.e. if the process is centered within its engineering tolerance, 0.27% of parts produced will be beyond specification limits.

C_p	Reject Rate
1.00	0.270 %
1.33	0.007 %
1.50	6.8 ppm
2.00	2.0 ppb

Process Potential





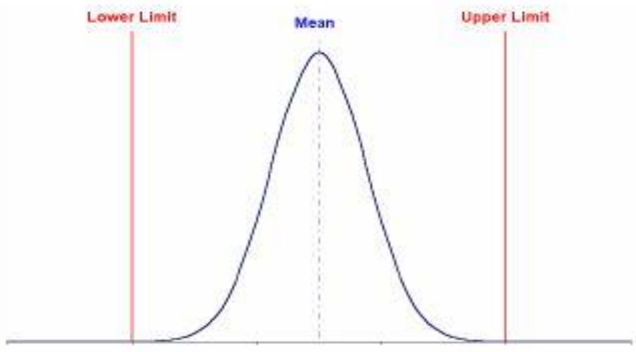
a) Process is highly capable (Cp>2)

b) Process is capable (Cp=1 to 2)

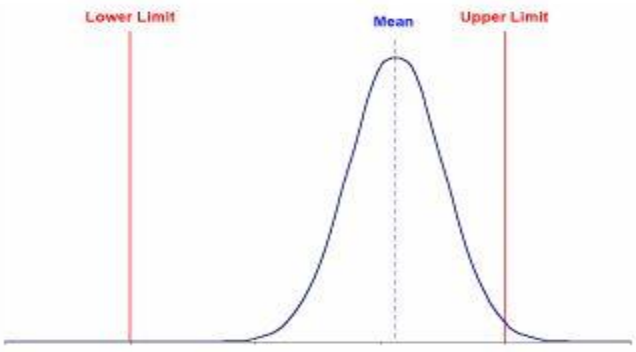
c) Process is not capable (Cp<1)

Process Potential

he C_p index compares the allowable spread (USL-LSL) against the process spread (6σ). It fails to take into account if the process is centered between the specification limits.



Process is centered



Process is not centered

Process Potential

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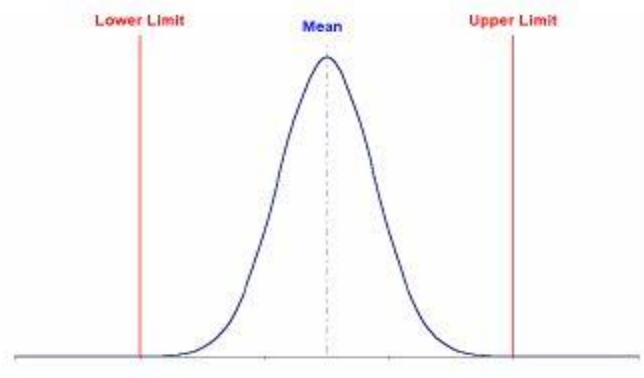
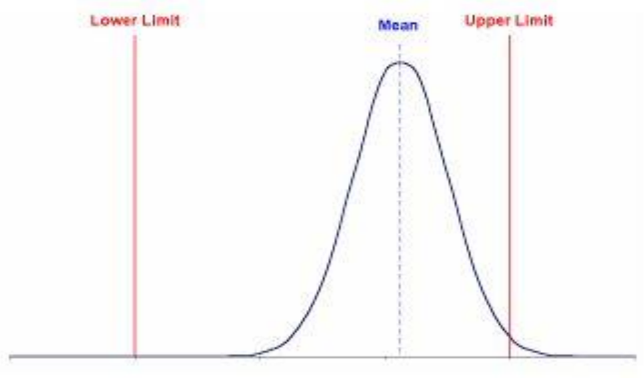


Process is centered



Process is not centered

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Process Performance

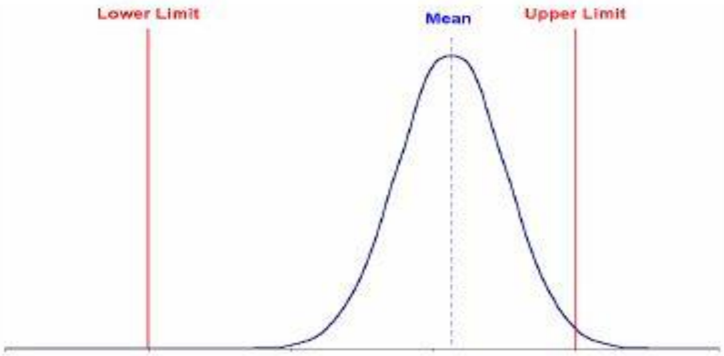
C_{pk}	Reject Rate
1.0	0.13 – 0.27 %
1.1	0.05 – 0.10 %
1.2	0.02 – 0.03 %
1.3	48.1 – 96.2 ppm
1.4	13.4 – 26.7 ppm
1.5	3.4 – 6.8 ppm
1.6	794 – 1589 ppb
1.7	170 – 340 ppb
1.8	33 – 67 ppb
1.9	6 – 12 ppb
2.0	1 – 2 ppb

Process Performance

The C_{pk} index relates the scaled distance between the process mean and the nearest specification limit.

$$C_{pu} = \frac{USL - \mu}{3\sigma}$$

$$C_{pl} = \frac{\mu - LSL}{3\sigma}$$



$$C_{pk} = \text{Minimum}\{C_{pu}, C_{pl}\}$$

Improve dev 6 sigma case

Example 1

Specification Limits : 4 to 16 g

Machine	Mean	Std Dev
(a)	10	4
(b)	10	2
(c)	7	2
(d)	13	1

Determine the corresponding C_p and C_{pk} for each machine.

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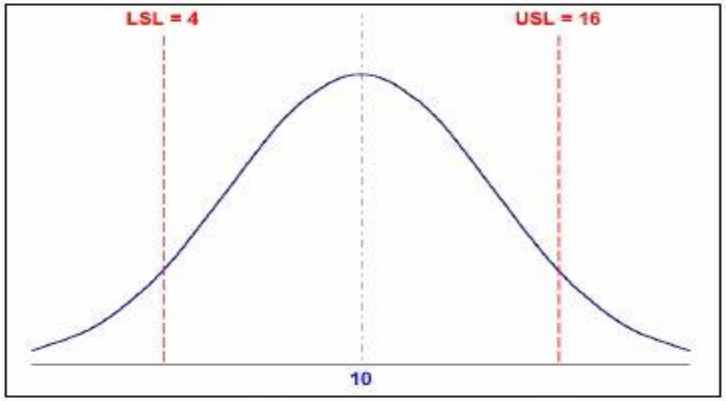
Example 1A

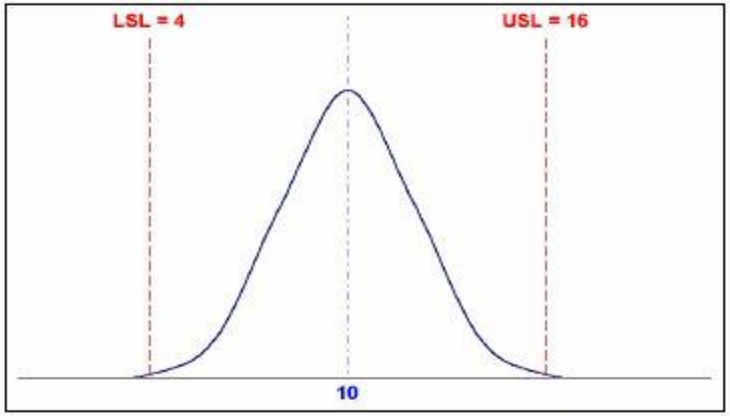
$$C_p = \frac{USL - LSL}{6\sigma} = \frac{16-4}{6(4)} = 0.5$$



$$C_{pk} = \text{Min}\left\{\frac{USL-\mu}{3\sigma}; \frac{\mu - LSL}{3\sigma}\right\} = \text{Min}\left\{\frac{16-10}{3(4)}; \frac{10-4}{3(4)}\right\} = 0.5$$

Example 1B

$$C_p = \frac{USL - LSL}{6\sigma} = \frac{16-4}{6(2)} = 1.0$$



$$C_{pk} = Min\left\{\frac{USL-\mu}{3\sigma};\frac{\mu - LSL}{3\sigma}\right\} = Min\left\{\frac{16-10}{3(2)};\frac{10-4}{3(2)}\right\} = 1.0$$

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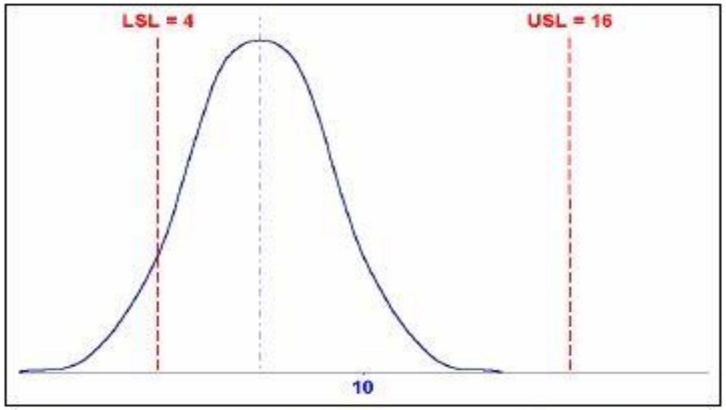
Example 1C

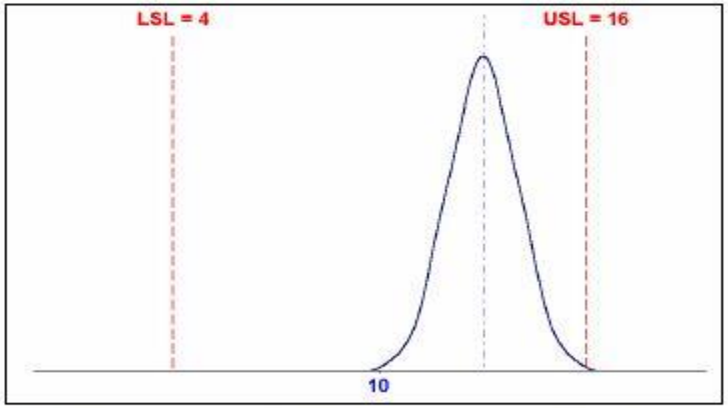
$$C_p = \frac{USL - LSL}{6\sigma} = \frac{16-4}{6(2)} = 1.0$$



$$C_{pk} = \text{Min}\left\{\frac{USL-\mu}{3\sigma};\frac{\mu-LSL}{3\sigma}\right\} = \text{Min}\left\{\frac{16-7}{3(2)};\frac{7-4}{3(2)}\right\} = 0.5$$

Example 1D

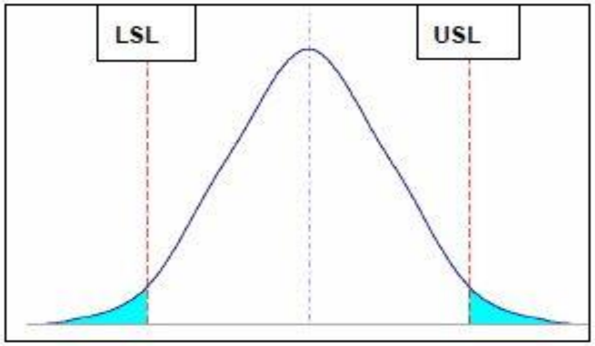
$$C_p = \frac{USL - LSL}{6\sigma} = \frac{16-4}{6(1)} = 2.0$$



$$C_{pk} = Min\left\{\frac{USL-\mu}{3\sigma}; \frac{\mu - LSL}{3\sigma}\right\} = Min\left\{\frac{16-13}{3(1)}; \frac{13-4}{3(1)}\right\} = 1.0$$

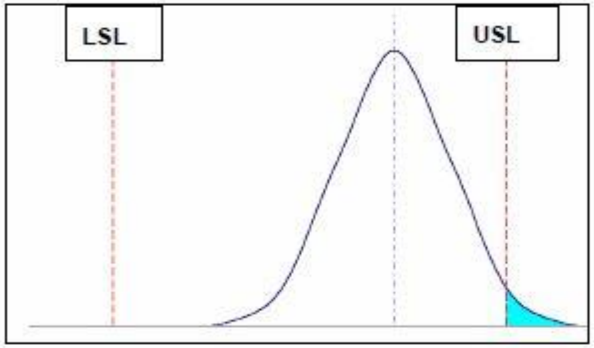
Process Potential vs Process Performance

(a) Poor Process Potential



Experimental Design
- to reduce variation

(b) Poor Process Performance



Experimental Design
- to center mean
- to reduce variation

Which Control Chart Should Be Used?

Individuals and Moving Range (XmR or ImR) Charts

Use the short term variation between adjacent observed values to estimate the natural (inherent) variation of the process. This leads to a pair of charts, one for the individual values (X or sometimes reffered to as I) and another for the successive two point moving ranges (mR)

Note: XmR charts are sometimes referred to as ImR charts with the “I” representing Individual data points

mR = moving Range = the absolute difference between successive individual values

X-Bar and R Charts

- When the measurements of product or process characteristics are collected under basically the same conditions, the data may be grouped into self-consistent sets (subgroups of size = n)

- The results of the groupings are used to calculate process control limits, which, in turn, are used to examine stability and process capability

Detecting Process Instabilities -1

- To test for instabilities in processes, examine all control charts for instances and patterns that signal process anomalies

- Look for values that
  - Fall outside the control limits
  - Have unusual (non random) patterns within the running record
  - Suggest that assignable causes exist

Detecting Process Instabilities -2

•The following four tests are used to detect instabilities:

Test 1: A single point falls outside the 3-sigma control limits
Test 2: At least two of three successive values fall on the same side of, and more than two sigma units away from, the center line.
Test 3: At least four out of five successive values fall on the same side of, and more than one sigma unit away from, the center line.
Test 4: At least eight successive values fall on the same side of the center line

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धन्यवाद (dhanyavād)

Dank u wel

Thank you