

Process Capability

For Continuous and Discrete Data

Variation

- Don't worry the rope is over half an inch thick on average.



- It is not the average I'm worried about!

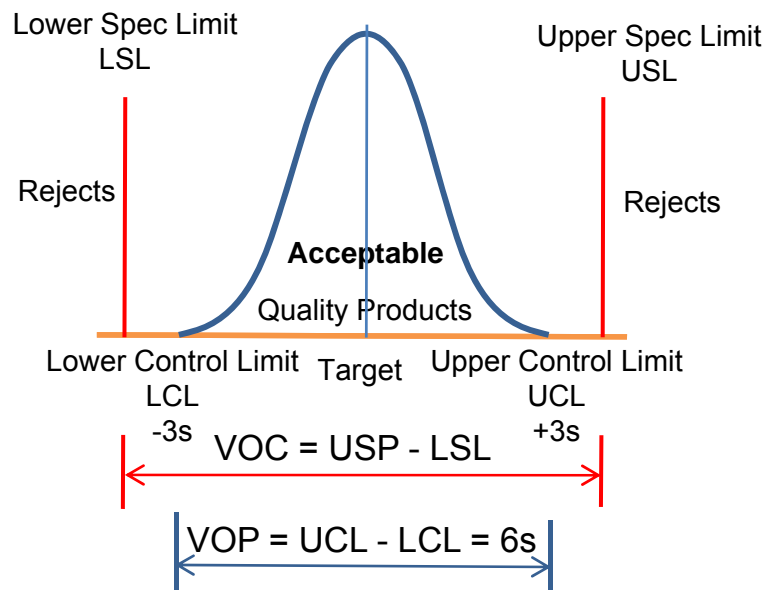
Process Capability - Definition

- Process Capability is a measurement of how the process is performing with respect to a desired outcome

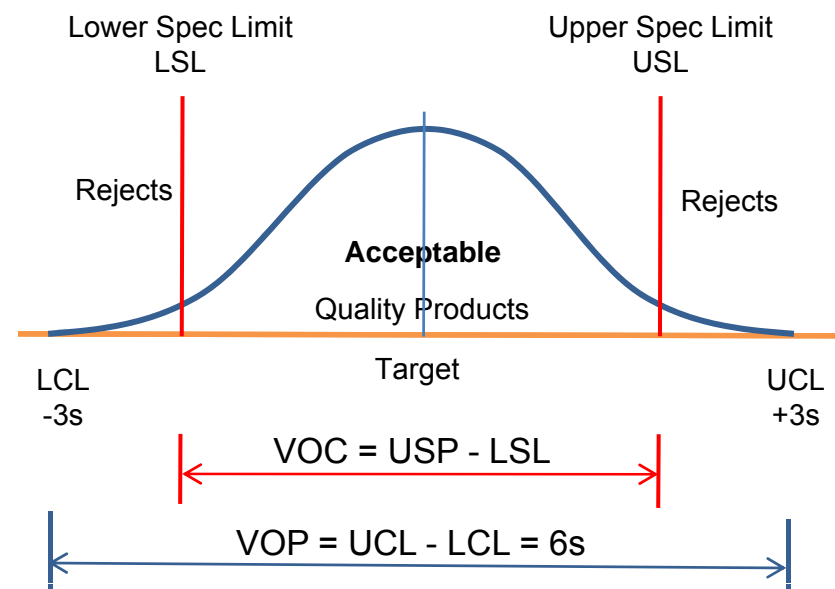
$\frac{\text{Allowed Variation}}{\text{Actual Variation}}$

determined by the customer
determined by the process

$\frac{\text{Voice of Customer}}{\text{Voice of Process}}$



GOOD CAPABILITY

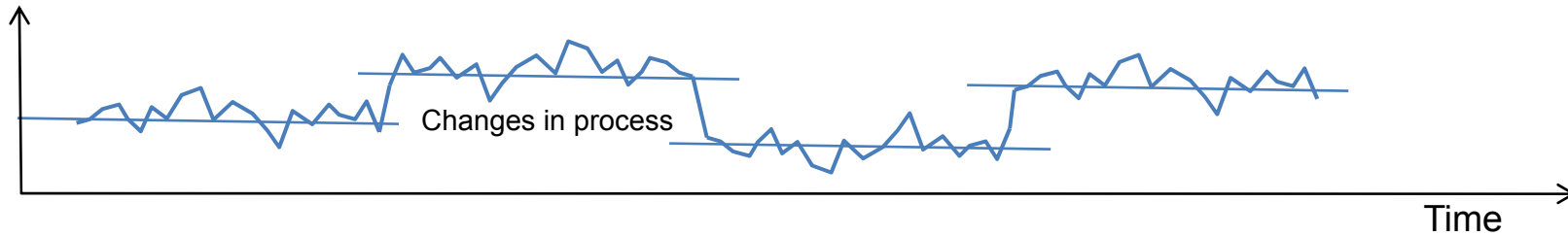


POOR CAPABILITY

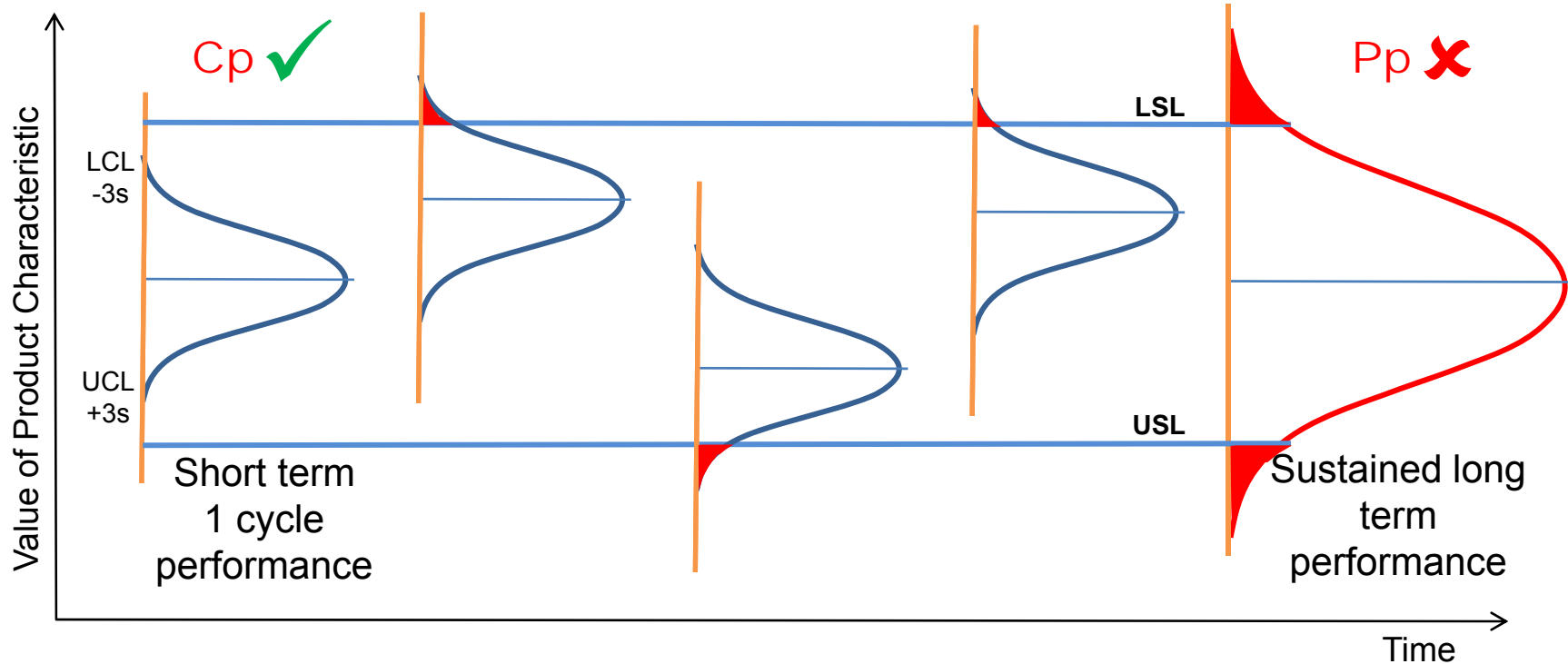
Short Term (Cp) vs Long Term (Pp) Capability



- Over an extended period we expect to see more variation



This process is short term Capable but not long term Capable



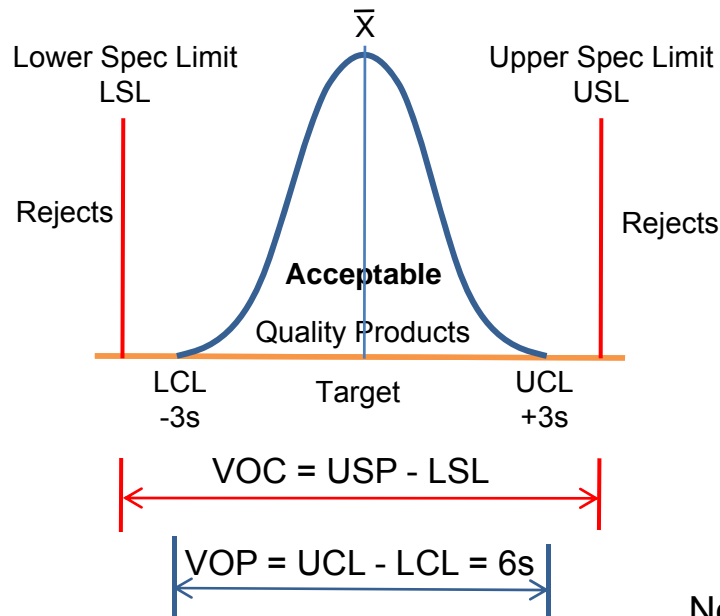
Process Capability Ratios (Cp, Pp) & Index (Cpk, Ppk)



A centred process

$$C_p = \frac{USL - LSL}{6s_{\text{short term}}}$$

$$P_p = \frac{USL - LSL}{6s_{\text{long term}}}$$



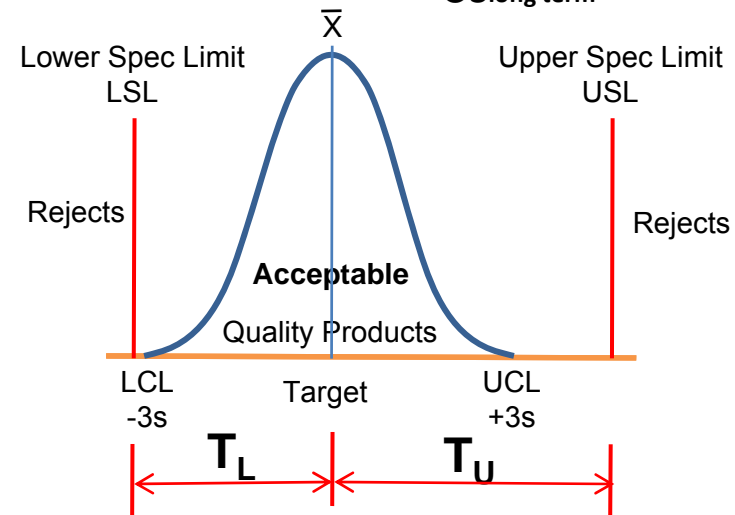
An off-centred process

$$T_L = \frac{\bar{X} - LSL}{3s}$$

$$T_U = \frac{USL - \bar{X}}{3s}$$

$$C_{pk} = \frac{\text{Min}(T_L, T_U)_{\text{short term}}}{3s_{\text{short term}}}$$

$$P_{pk} = \frac{\text{Min}(T_L, T_U)_{\text{long term}}}{3s_{\text{long term}}}$$



Note: Standard Deviation long term is usually referred to as Sigma or σ

Summary of Capability Metrics



Short Term
Performance

Long Term
Performance

Considers
Centring

Cpk

Ppk

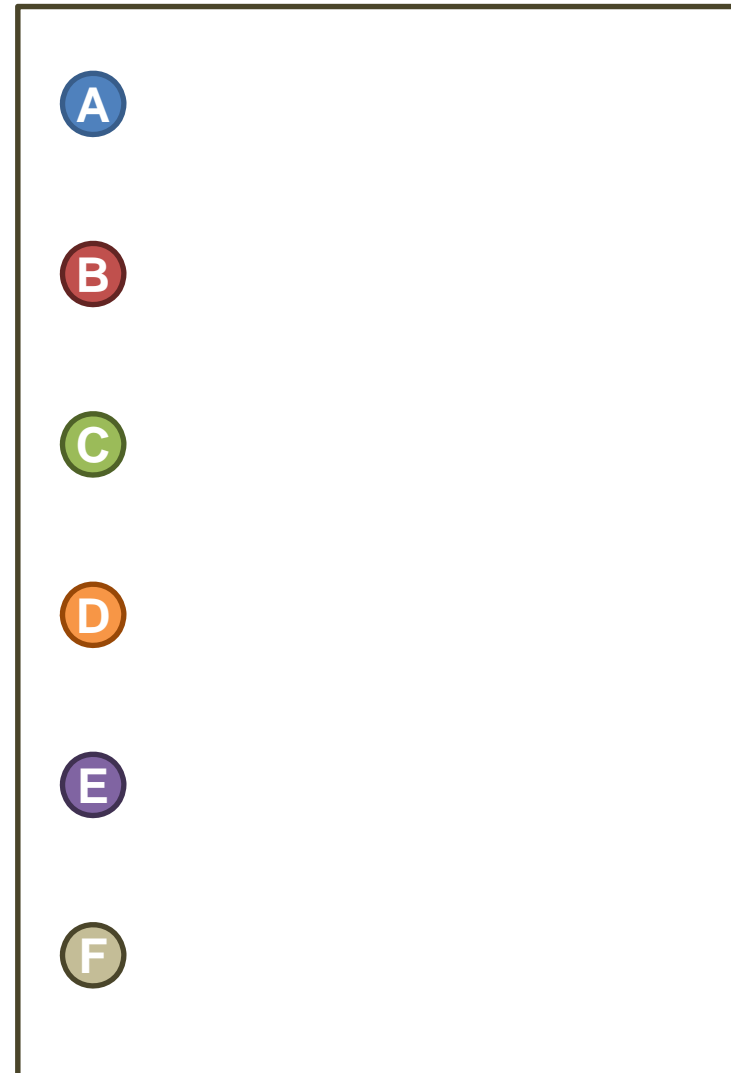
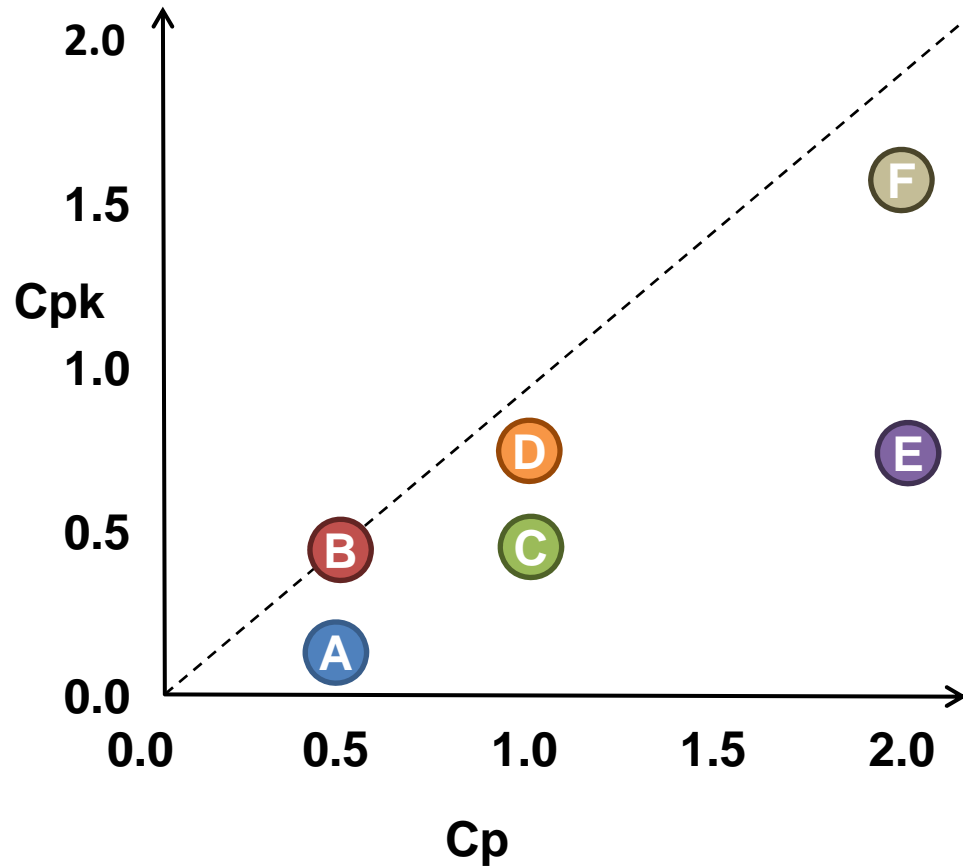
Does Not
Consider
Centring

Cp

Pp

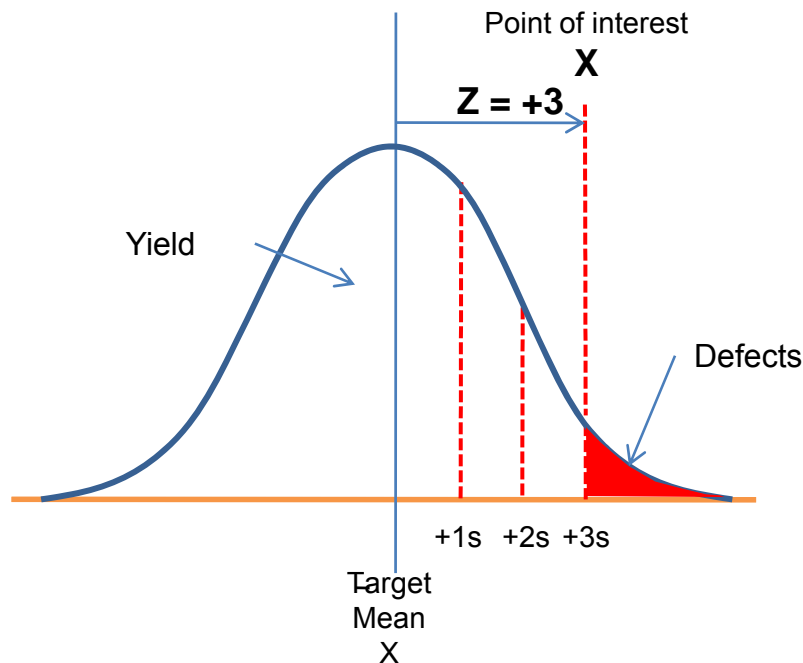
Test Your Understanding

Sketch the histogram and specification limits for the data sets below



A vertical list of six colored circles, each containing a letter from A to F. The circles are arranged vertically and are colored as follows: A (blue), B (red), C (green), D (orange), E (purple), and F (tan).

Calculating Sigma Score (Z)

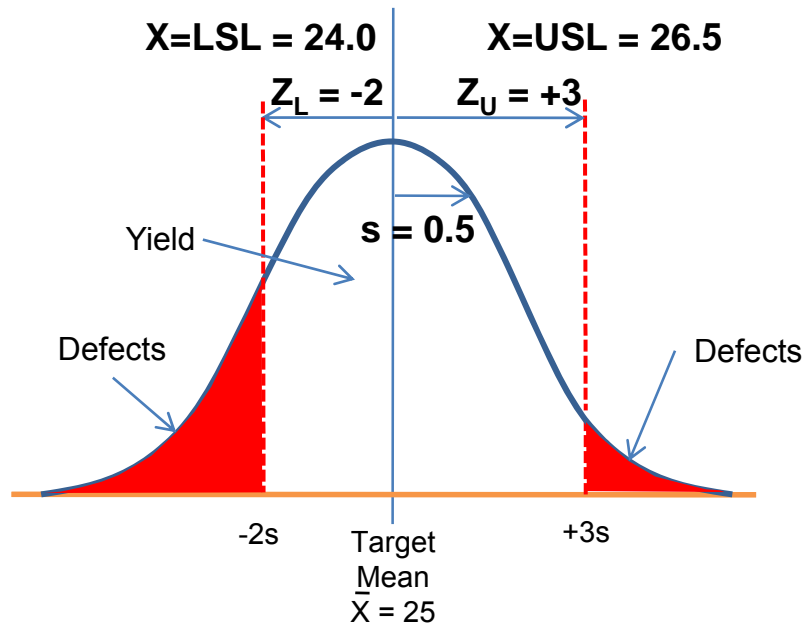


$$Z = \frac{(X - \bar{X})}{s}$$

(Z = the number of standard deviations from the mean. Z = 3Cp if using USL and LSL)

- For normally distributed data the standard deviation (s) and mean (Xbar) can be used to estimate the probability of defects
- Point of interest X can be an USL or LSL
- Example with X = 25, s = 0.5, X=USL=26.5 then $Z = (26.5-25)/0.5 = 3$.
- Z scores can be converted to probabilities in Minitab or Excel *fx* NORMSDIST(Z). Note Excel returns the “left tail” or yield of the distribution. If you enter Z=3 you get 0.99865. The defects are $1-0.99865 = 0.00135$ or 0.135% (defects = 1-yield).

Calculating the Total Defect Rate (Z_{bench})



$$Z = \frac{(X - \bar{X})}{s}$$

(Z = the number of standard deviations from the mean. $Z = 3Cp$ if using USL and LSL)

- The total defect rate expected from a process can be estimated by converting both upper and lower Z scores to probabilities and adding them :-
 $NORMSDIST(3)=0.99865 \rightarrow P=1-0.99865 = 0.00135$. $NORMSDIST(-2)=0.02275$ (left tail).
 Total probability $P_T = 0.00135+0.02275 = 0.0241$ or 2.41%.
- The total sigma score called Z_{bench} can be found from the total yield of the process $Y_T = 1 - P_T$. This represents the overall process capability:-
 If total probability $P_T = 0.0241$ then $Y_T = 0.9759$. Using Excel *fx* $NORMSINV(0.9759) = 1.9756$.
- We say the SIGMA of this process is ~2!

Cp/Pp Relationships



Sigma	Cp/Pp	Yield (2 sided)*	PPM (2 sided)*
1	0.33	68.27%	317,310.5
1.5	0.50	86.64%	133,614.4
2	0.67	95.45%	45,500.3
2.5	0.83	98.7581%	12,419.3
3	1.0	99.7300%	2,699.8
3.5	1.17	99.9535%	465.3
4	1.33	99.9937%	63.3
4.5	1.5	99.99932%	6.8
5	1.67	99.999943%	0.57
5.5	1.83	99.999996%	0.038
6	2.0	99.9999998%	0.00197

N.B. Yields and PPM's are calculated using defects at both tails of the Distribution assuming a Centred Process

Capability for Discrete/Attribute Data

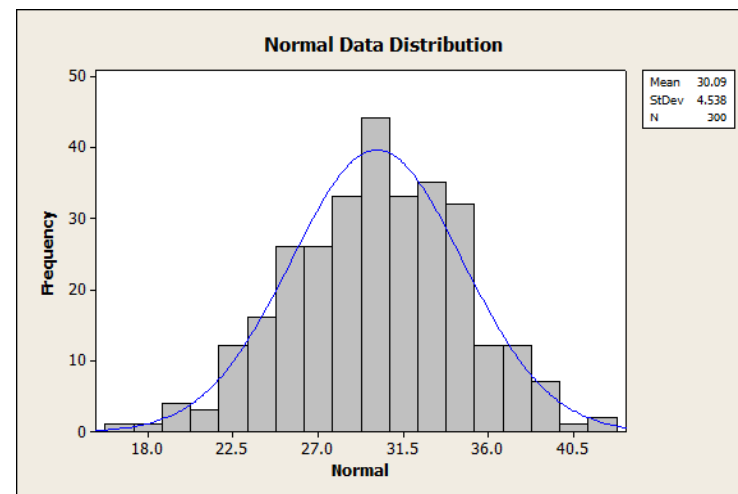
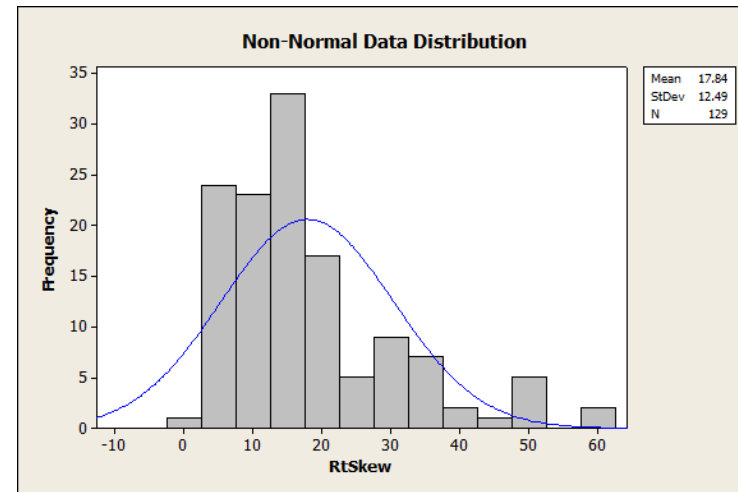


- Discrete data has clear boundaries between adjoining values includes names, categories, counts and rank orders e.g. dates, colours, defects, defectives
- The data will either be Defectives (e.g. pass/fail or on time or late) = 'Binomial' (0 or 1) or the data will be Defects (e.g. scratches or number of omissions) = 'Poisson'.
- Capability can be calculated directly from Binomial or Poisson distributions using Minitab or other statistical software packages, however you can convert the data to continuous and then use the previous method. e.g. convert defects to probabilities (%ages / 100).

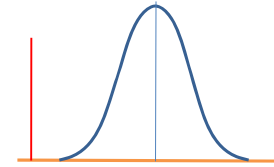
Capability for Non-Normal Data



- Normal capability analysis with non-normal data would give misleading results
- Non-normal capability can be found from software packages like Minitab or by transforming the data to a distribution which is Normal.
- Try taking logs (either Log_{10} or Ln) or by raising the data to a power (called a Box-Cox transformation) e.g. data^2 .



Process Capability Summary



- All processes have variation
- Process Capability is a measurement of how the process is performing with respect to a desired outcome
- Capability is defined as the voice of the customer over the voice of the process
- Long term capability is not the same as short term capability
- Covert discrete to continuous and non-normal data to normal before analysing capability or use specialist software
- The overall capability of a process can be defined by it's Sigma value.