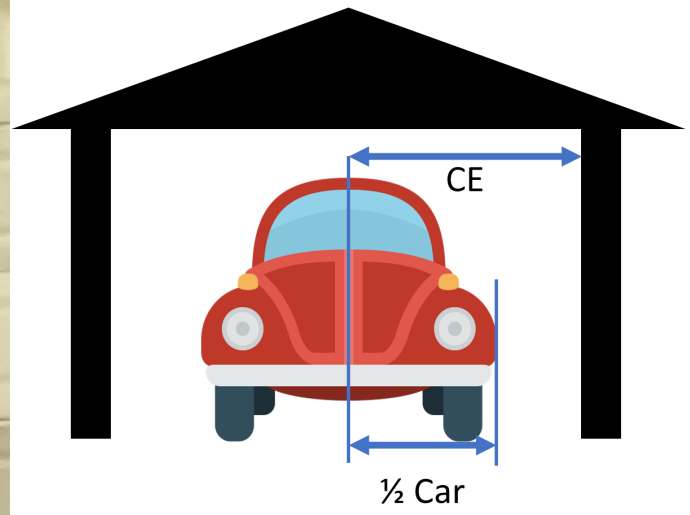
PathStone Group



$$C_{pk} = \frac{CE}{\frac{1}{2}\ Car}$$

CE = Car to Edge

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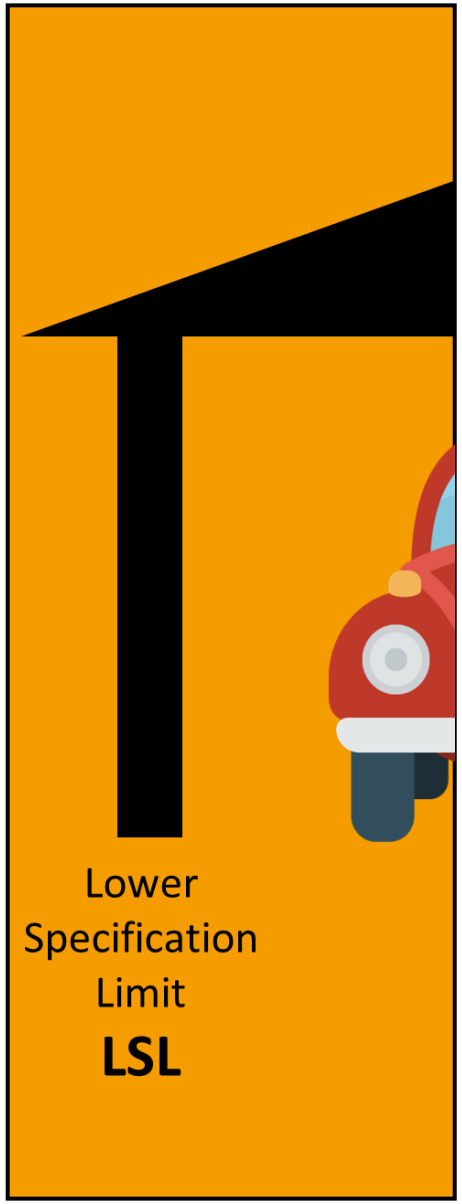
Capability and Process Performance

Agenda

1. Capability: What is it ?
2. Capability purpose and benefits
3. Cp and Cpk
4. Steps for a Capability Analysis
5. Pp and Ppk
6. Takeaways



Introduction

What is it ?

Process capability (*C*p) is a measure of the **relationship between** the voice of the process (VOP) and the voice of the customer (VOC).

It is essentially a ratio of the customer requirement (specification) and the expected process variation.

The VOC could be also interpreted as the **quality specification of the process**.

$$\text{Process Capability} = \frac{\text{Voice of the Customer}}{\text{Voice of the Process}}$$

Introduction

What is it ?

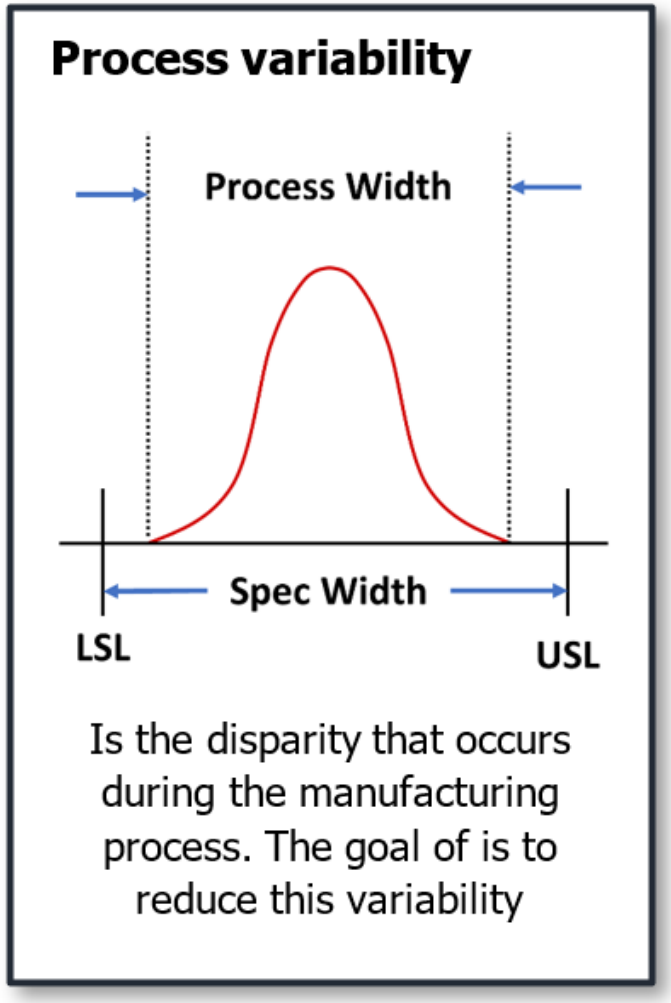
$$\text{Process Capability} = \frac{\text{Voice of the Customer}}{\text{Voice of the Process}}$$

Introduction

Purpose and Benefits

The capability index is useful for measuring:

- **Continual improvement** using trends over time, or
- For **prioritizing the order** in which process will be improved, and



Introduction

Purpose and Benefits

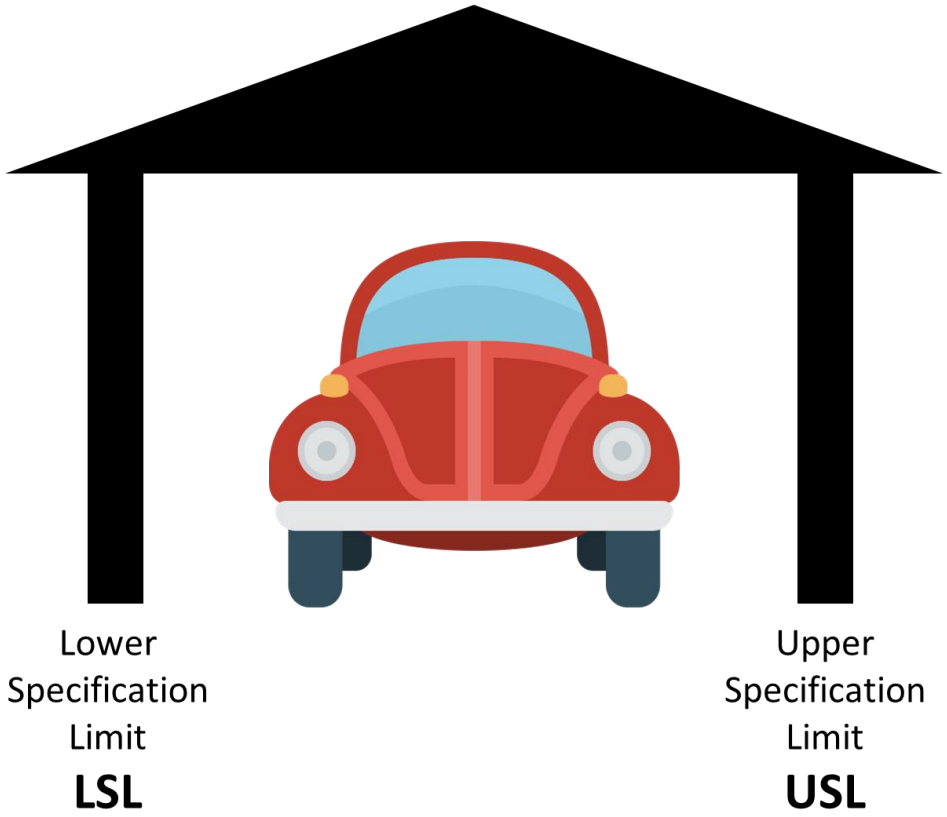
- For determining whether a process can **meet customer requirements**.
- This latter use is the original **intent of the capability index** and should not be applied to the performance index.

Capability

Cp

If the car is smaller than the garage, it means $C_p > 1$; the car will fit inside the garage.

When you find that your data (car) is smaller than the specification limits (garage), your process is capable.



Capability

Cp

$$C_p = \frac{\text{Specification width}}{\text{Process width}} = \frac{USL - LSL}{6\,\hat{\sigma}}$$

Lower Specification Limit **LSL**

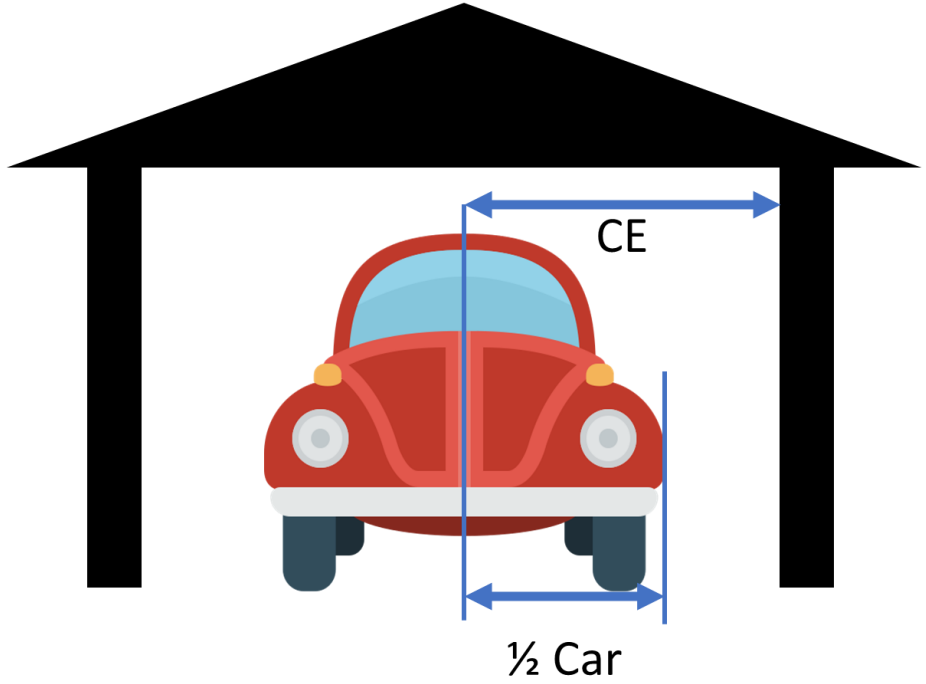
Upper Specification Limit **USL**

Capability

Cpk

The Cpk metric tells us how much **clearance we can expect from the side** of the car to the nearest edge of the garage.

Look at the distance from the center of the car to the **nearest edge of the garage**, then divide that by half of the width of the car.



$$Cpk = \frac{CE}{\frac{1}{2}\ Car}$$

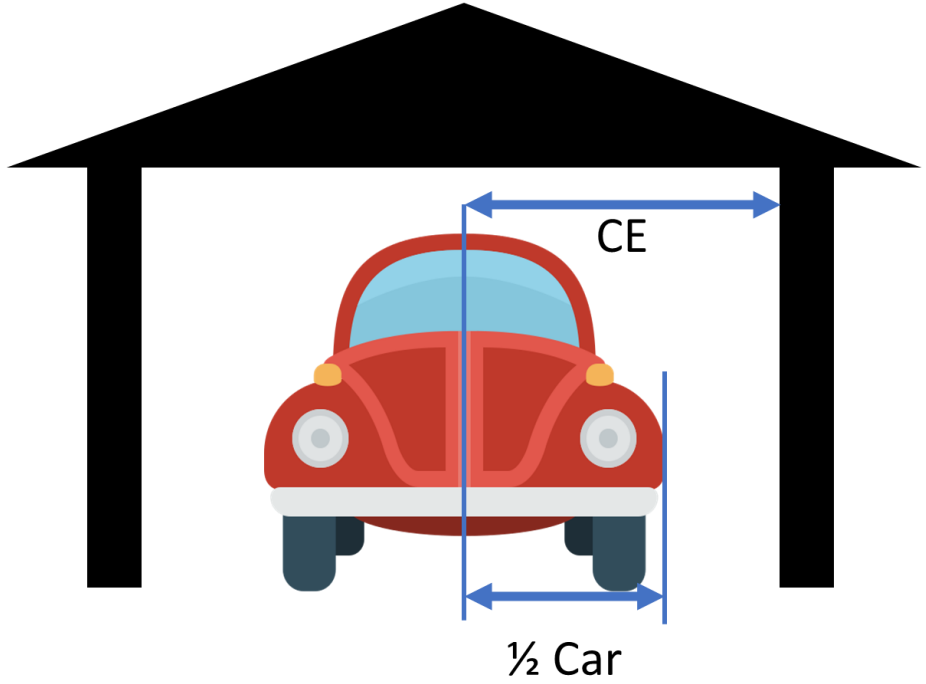
CE = Car to Edge

Capability

Cpk

$$C_{pk} = \min \left\{ \frac{\text{USL} - \text{Process mean}}{3\,\hat{\sigma}} , \frac{\text{Process mean} - \text{LSL}}{3\,\hat{\sigma}} \right\}$$

USL = upper specification limit
LSL = lower specification limit
$\hat{\sigma}$ = estimate of the process's standard deviation



$$C_{pk} = \frac{\text{CE}}{\text{½ Car}}$$

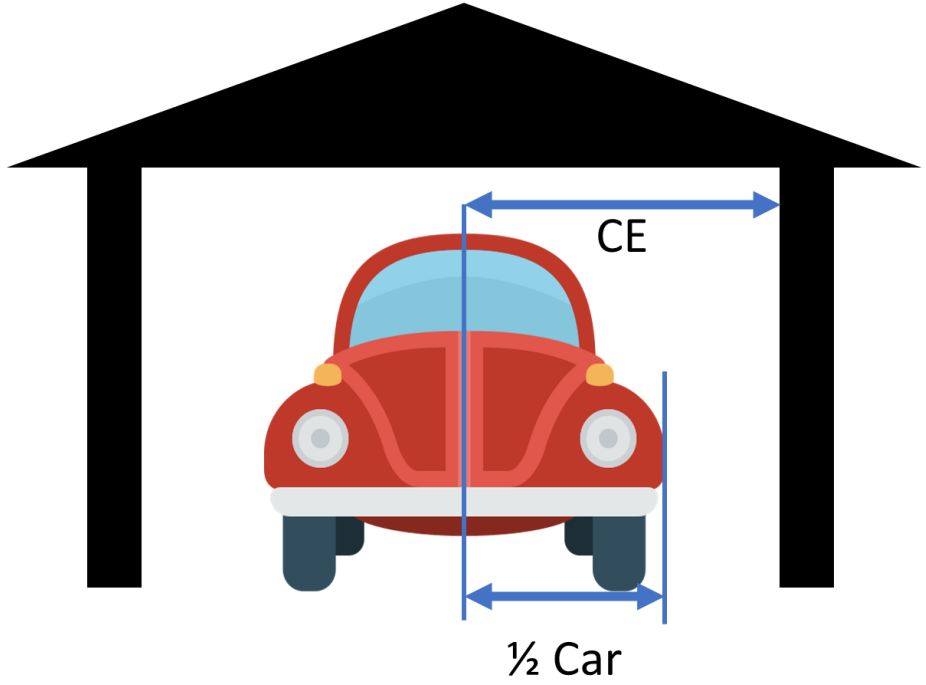
CE = Car to Edge

Capability

Cpk

When the car is not centered, we are at risk of damaging the car and the garage or, in process terms, falling outside of the specification limits and not meeting customer requirements.

We need another process measure to address the centering of the car in the garage.



$$C_{pk} = \frac{CE}{\frac{1}{2}\ Car}$$

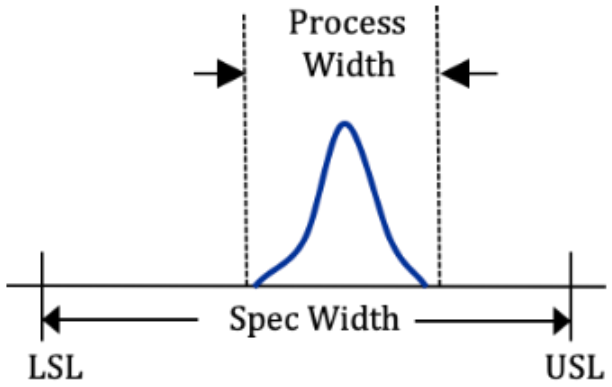
CE = Car to Edge

Capability

Relationship Between C_p and C_{pk}.

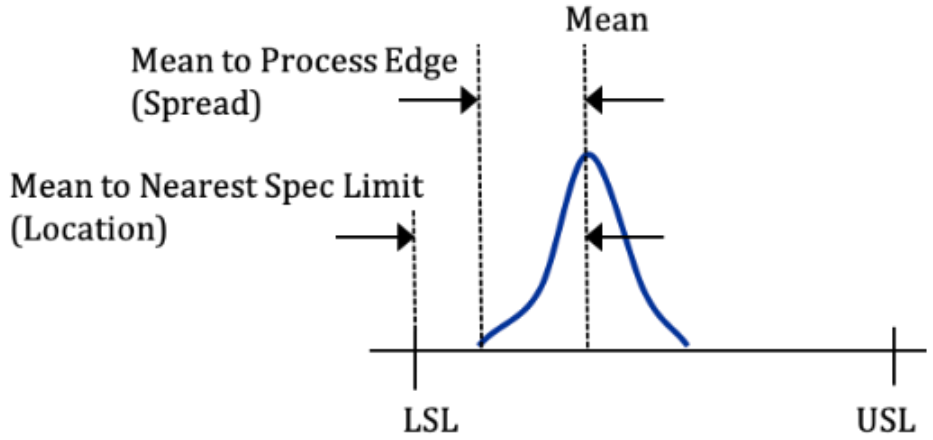
Cp and Cpk

$$\mathbf{Cp} = \frac{\text{Specification Width}}{\text{Process Width}}$$



Cp accounts for only the spread (or variation) of the process.

$$\mathbf{Cpk} = \frac{\text{Distance from Mean to Nearest Spec Limit}}{\text{Distance from Mean to Process Edge}}$$



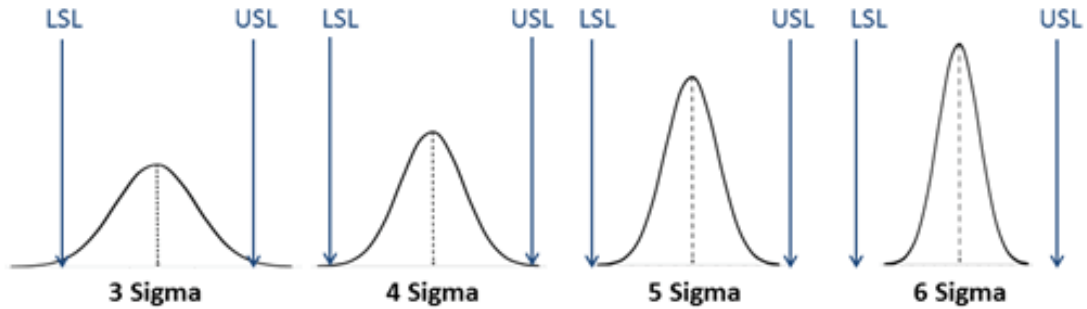
Cpk accounts for both the spread and location of the process.

Capability

How do Cp and Cpk relate to Sigma.

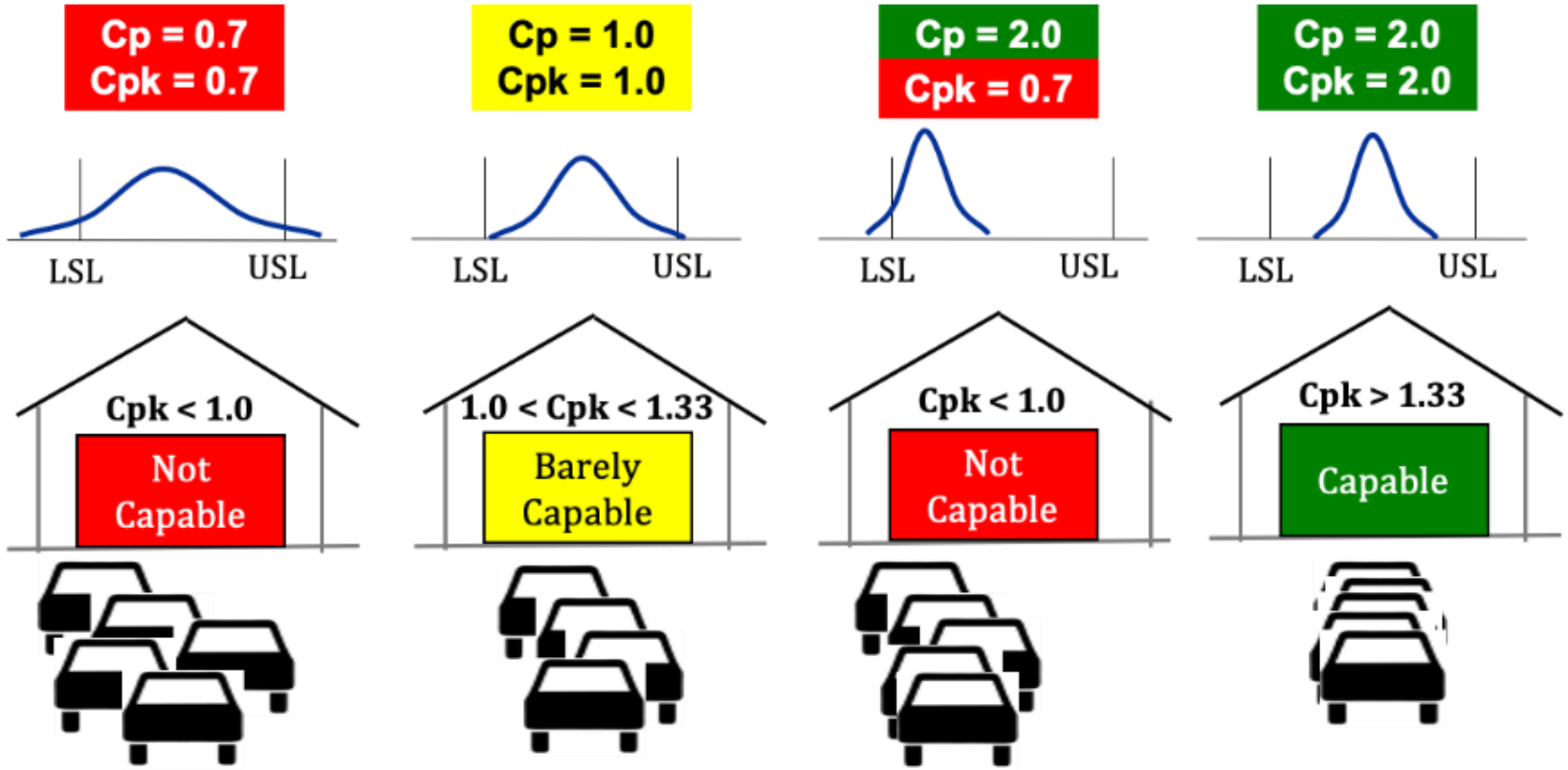
Cp and Cpk

Cp Cpk	1.0	1.33	1.66	2.0
Sigma	3 Sigma	4 Sigma	5 Sigma	6 Sigma
% of Spec Tolerance Used	100%	75%	60%	50%



Capability

Cp and Cpk



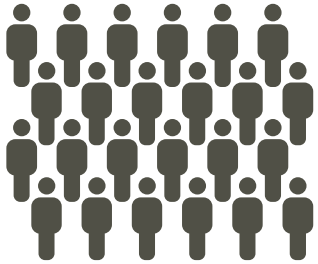
Capability

Cp and Cpk

When calculating process capability *C*p or *C*pk, there are three key assumptions:

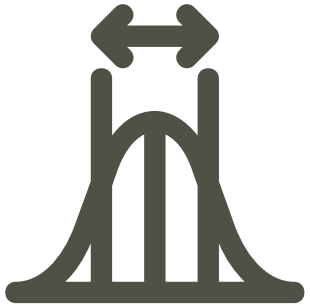
- **Large** sample size
- **Stable** process
- **Normal** distribution

When these assumptions are not met, the **values are not valid**. Most capability index estimates are valid only if the sample size used is "large enough," which is thought to be **about 30 or more independent data values.**



Sample Size

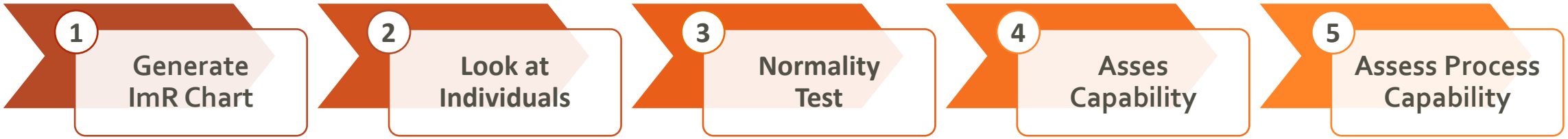
Stable Process



Normal Distribution

Capability

Steps for a Capability Analysis



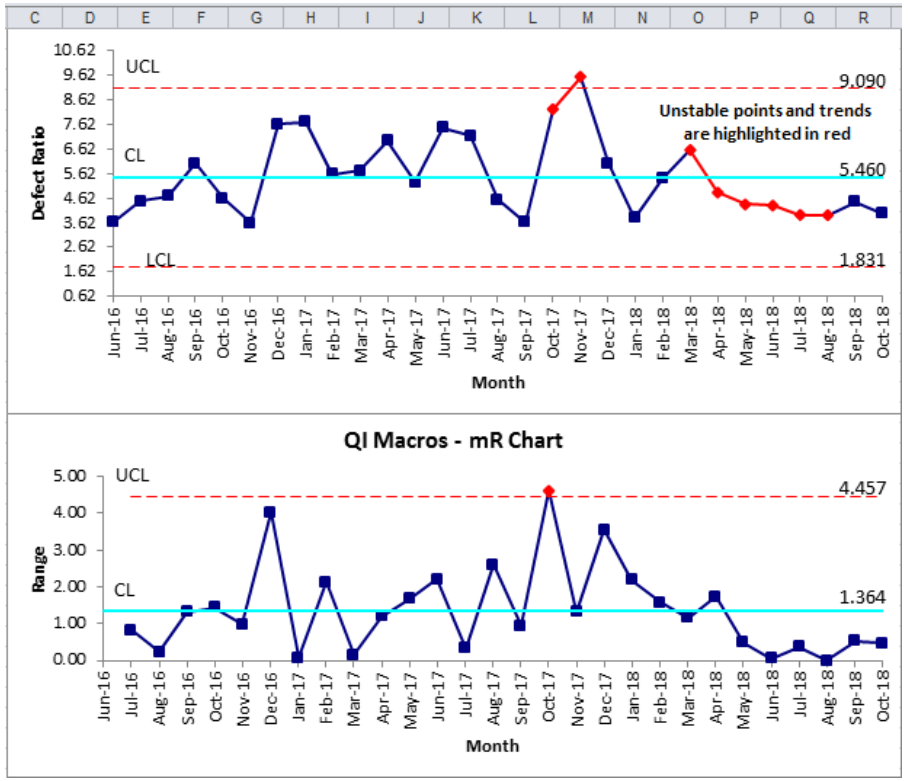
Capability

Steps for a Capability Analysis

1 Generate ImR Chart

Start with the **range chart** and determine stability. Are all points inside of the control limits? If yes, the process is stable, and the analysis can move forward.

If not, the process is unstable, and **we must address this before moving on.**



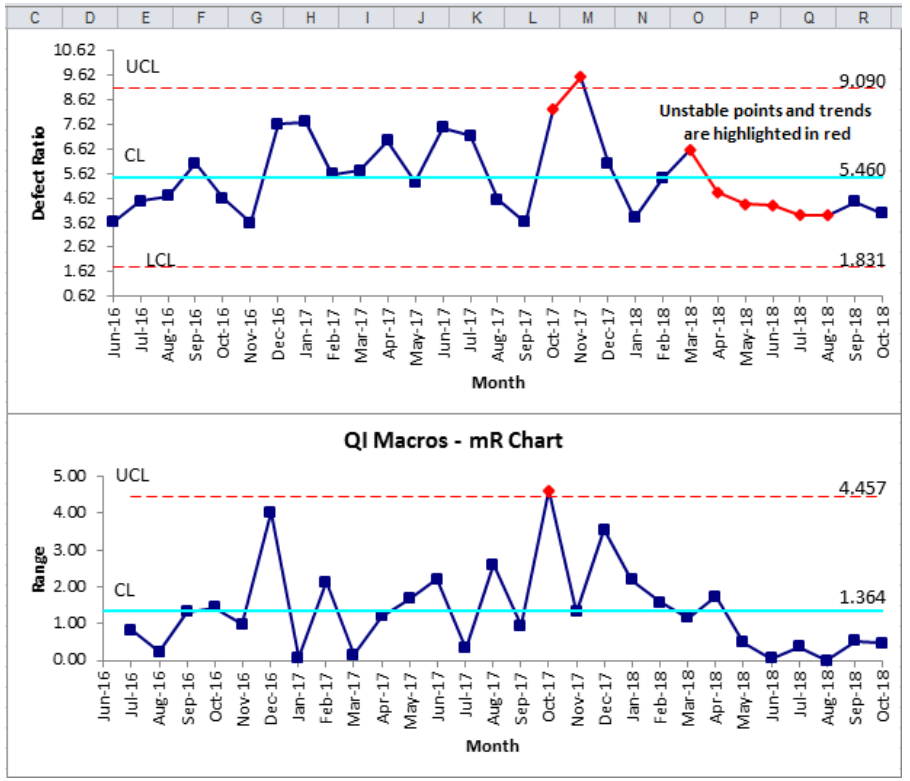
Capability

Steps for a Capability Analysis

2 Look at Individuals

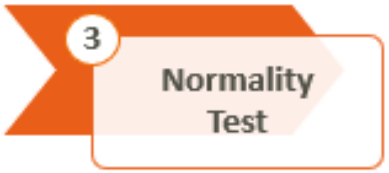
Are there any indications of **out-of-control** data per the rules of process control? If yes, the process is out of control, and we **must address this before** advancing in the capability analysis.

If no, then the process is in control and analysis may proceed.



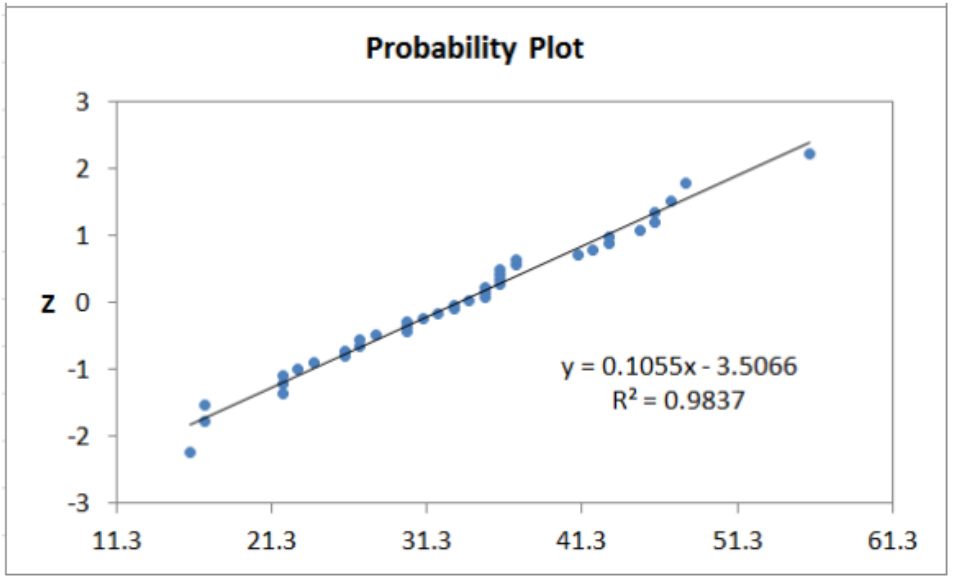
Capability

Steps for a Capability Analysis



If a distribution is close to normal, the normal probability plot will be **close to a straight line**.

The null hypothesis for this test is that the distribution is normal; thus, to conclude that **the data is normal**, the p-value **must be greater than 0.05** (typically).



Capability

Steps for a Capability Analysis

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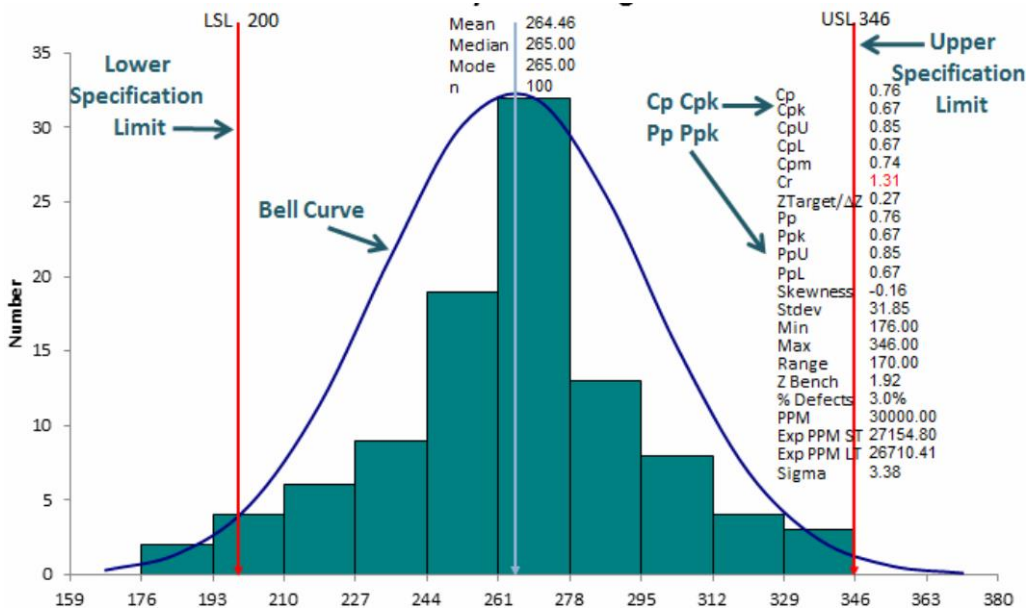
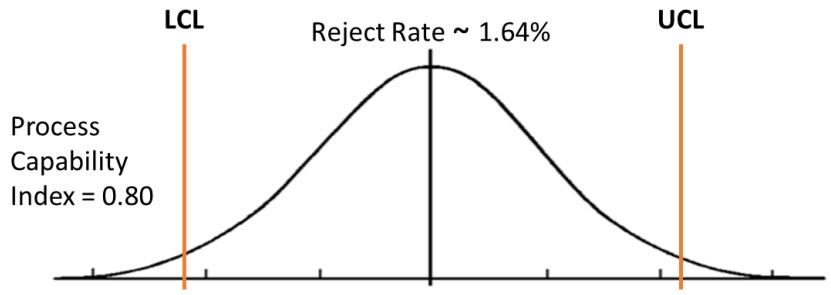


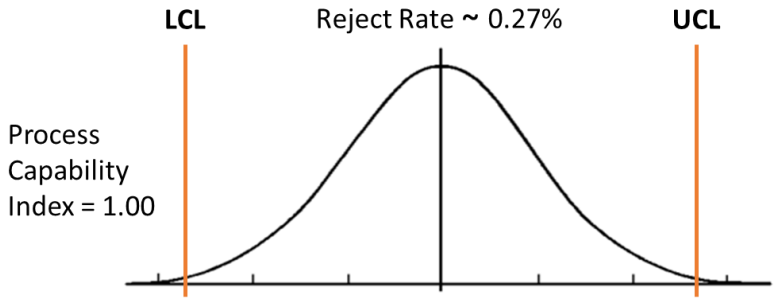
Capability

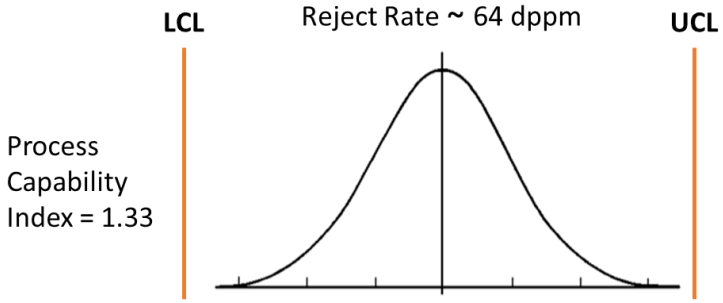
Interpretation of Values in Process Capability.

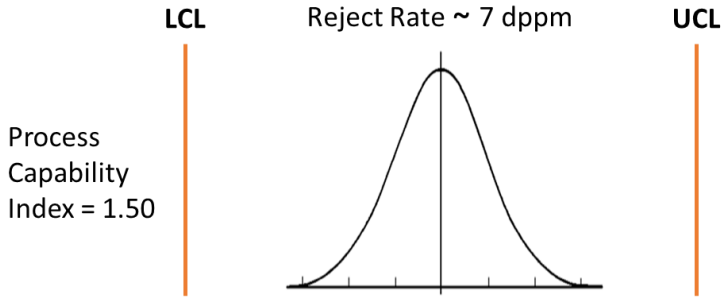
Steps for a Capability Analysis

5 Asses Process Capability









Capability

Interpretation of Values in Process Capability.

Steps for a Capability Analysis

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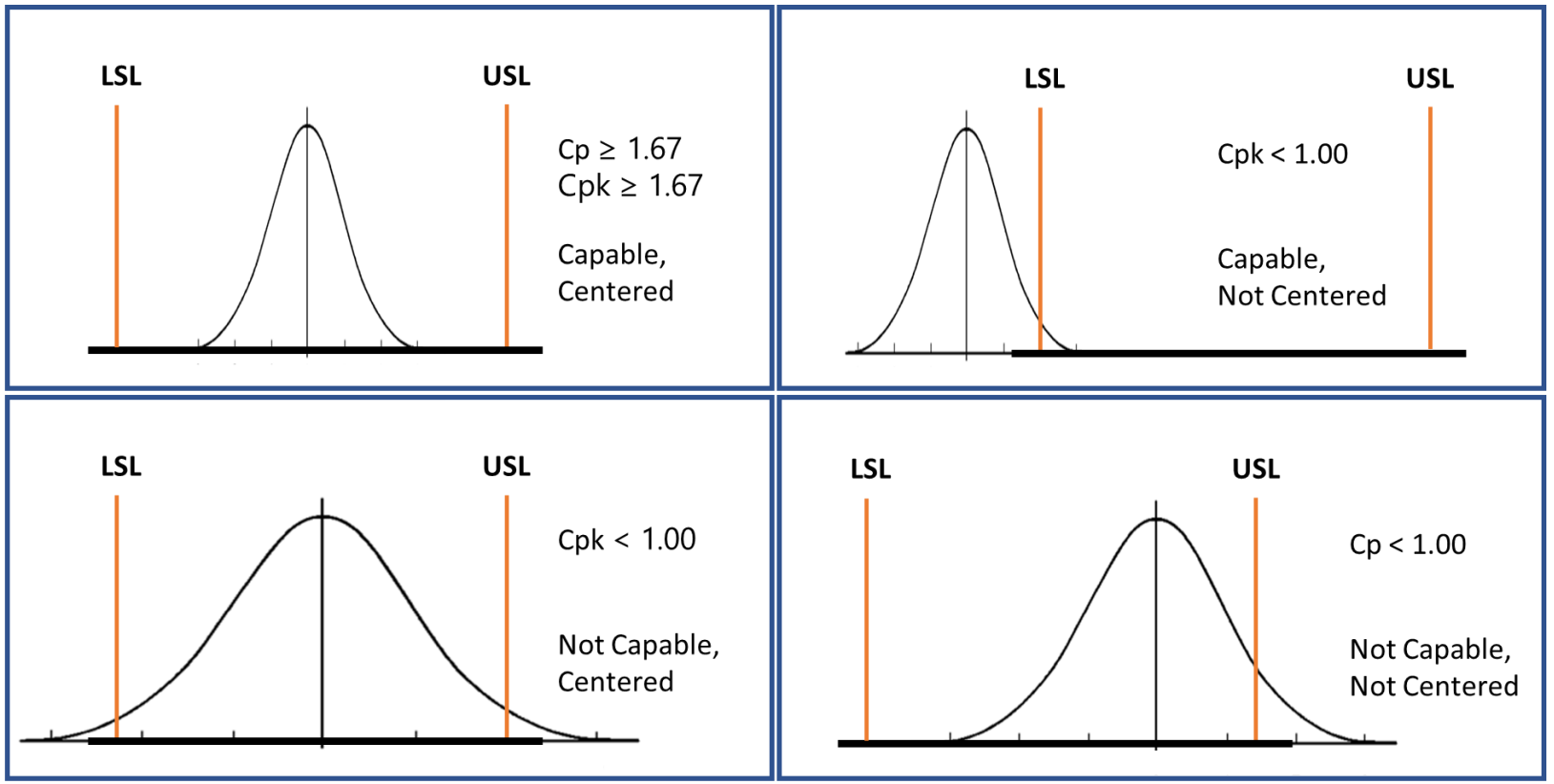


Capability

Pp

Like the C_p calculation, we find the performance Pp rate as follows:

$$P_p = \frac{USL - LSL}{6S}$$

Where S is the standard deviation of all data.

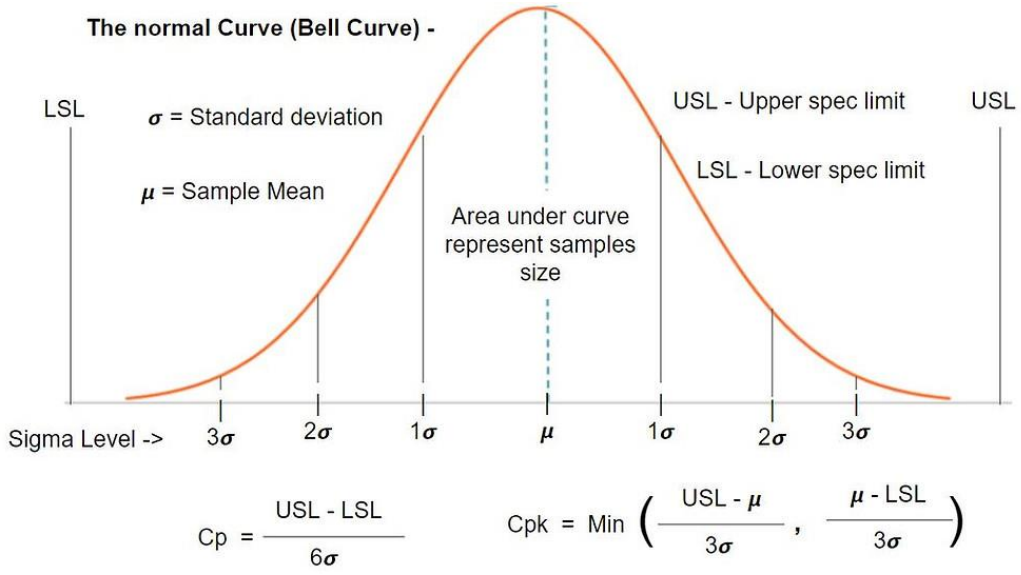
Capability

Pp

The major difference between the P_p and C_p studies is that within a rational subgroup where samples are produced, practically the standard deviation is lower.

In the P_p study, variation between subgroups enhances the S value along the time continuum, a process which normally creates more conservative P_p estimates.

Including between-group variation in the calculation of P_p makes the result more conservative than the estimate of C_p.



Capability

Ppk

The difference between *C*p and *P*p lies in the method for calculating s, and whether the existence of rational subgroups is considered.

Calculating *P*pk presents similarities with the calculation of *C*pk. We calculate the capability rate for Ppk using the formula:

$$P_{pk} = \min \left\{ \frac{USL - \mu}{3S}, \frac{\mu - LSL}{3S} \right\}$$

Capability

Ppk

The difference between *C*p and *P*p, as well as between *C*pk and *P*pk, results from the method of calculating standard deviation.

*C*p and *C*pk consider the deviation mean within rational subgroups, while *P*p and *P*pk set the deviation based on studied data.

It is worth working with more conservative *P*p and *P*pk data in case it is unclear if the sample criteria follow all the prerequisites necessary to create a rational subgroup.

- Population
- Sample

$$\sigma^2 = \frac{\sum (X-\mu)^2}{N} \qquad S^2 = \frac{\sum (X-\overline{X})^2}{n-1}$$

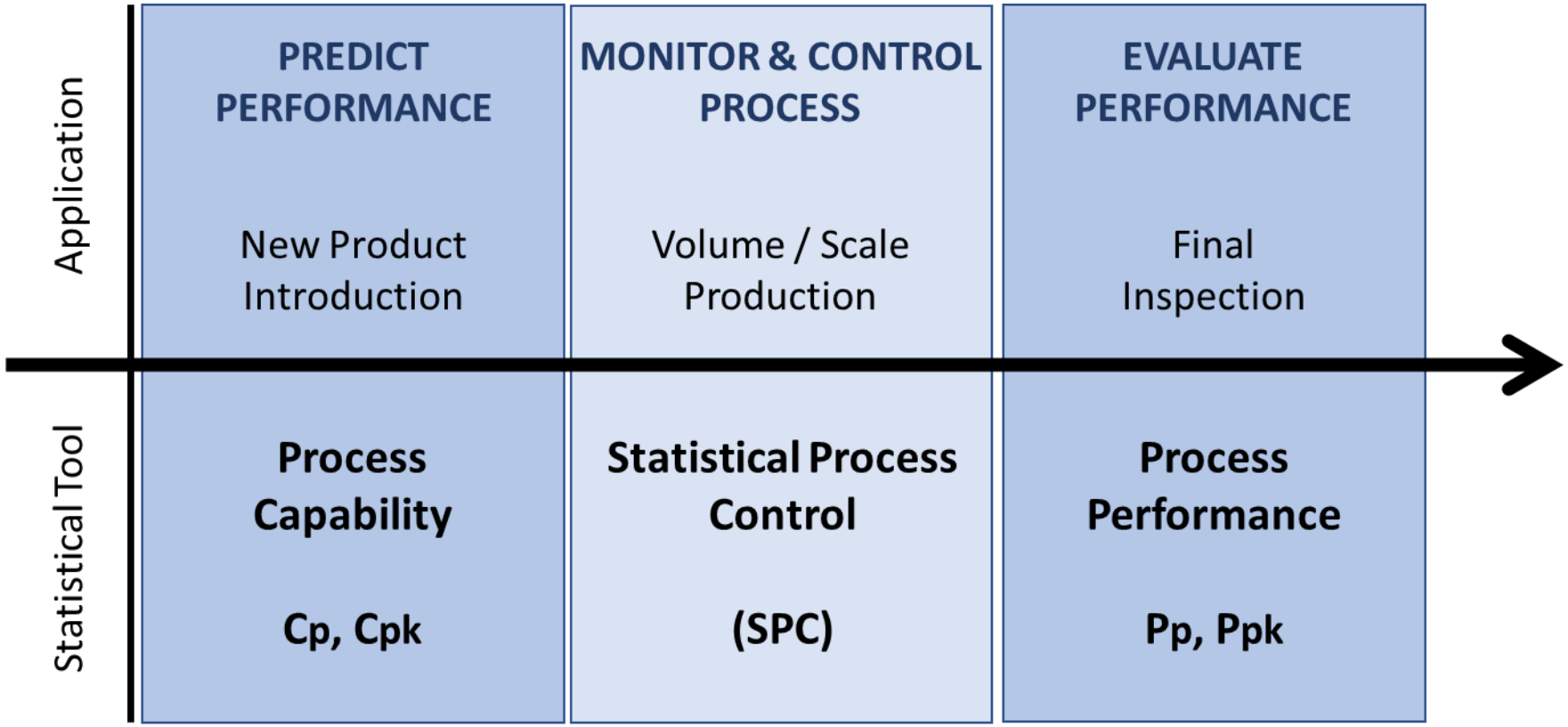
"sigma"

*Note the "n-1" in the sample formula!

Capability

Cp and Cpk Process Capability Metrics	Pp and Ppk Process Performance Metrics
Cp is the capability index. It measures how well the data **might fit between** the spec limits (USL, LSL). It doesn't care if the process is centered within the limits only if it would fit if it was centered.	**Pp is the performance index.** It measures how well the data **might fit between** the spec limits (USL, LSL). It doesn't care if the process is centered within the limits only if it would fit if it was centered.
Cpk is the centering capability index. It measures how well the data is centered between the spec limits.	**Ppk is the performance centering index.** It measures how well the data is centered between the spec limits.
Use **Cp Cpk** when you have a **sample**, not the population, and are testing the potential capability of a process to meet customer needs.	Use **Pp Ppk** when you have the **total population** and are testing the performance of a system to meet customer needs.
Cp and Cpk use *Sigma estimator*.	**Pp, Ppk use *standard deviation*.**

Capability

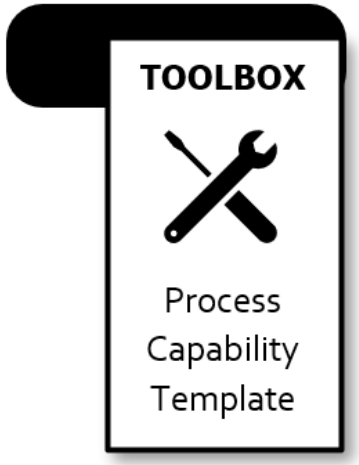

Application
Statistical Tool
PREDICT PERFORMANCE
New Product Introduction
Process Capability
Cp, Cpk
MONITOR & CONTROL PROCESS
Volume / Scale Production
Statistical Process Control
(SPC)
EVALUATE PERFORMANCE
Final Inspection
Process Performance
Pp, Ppk

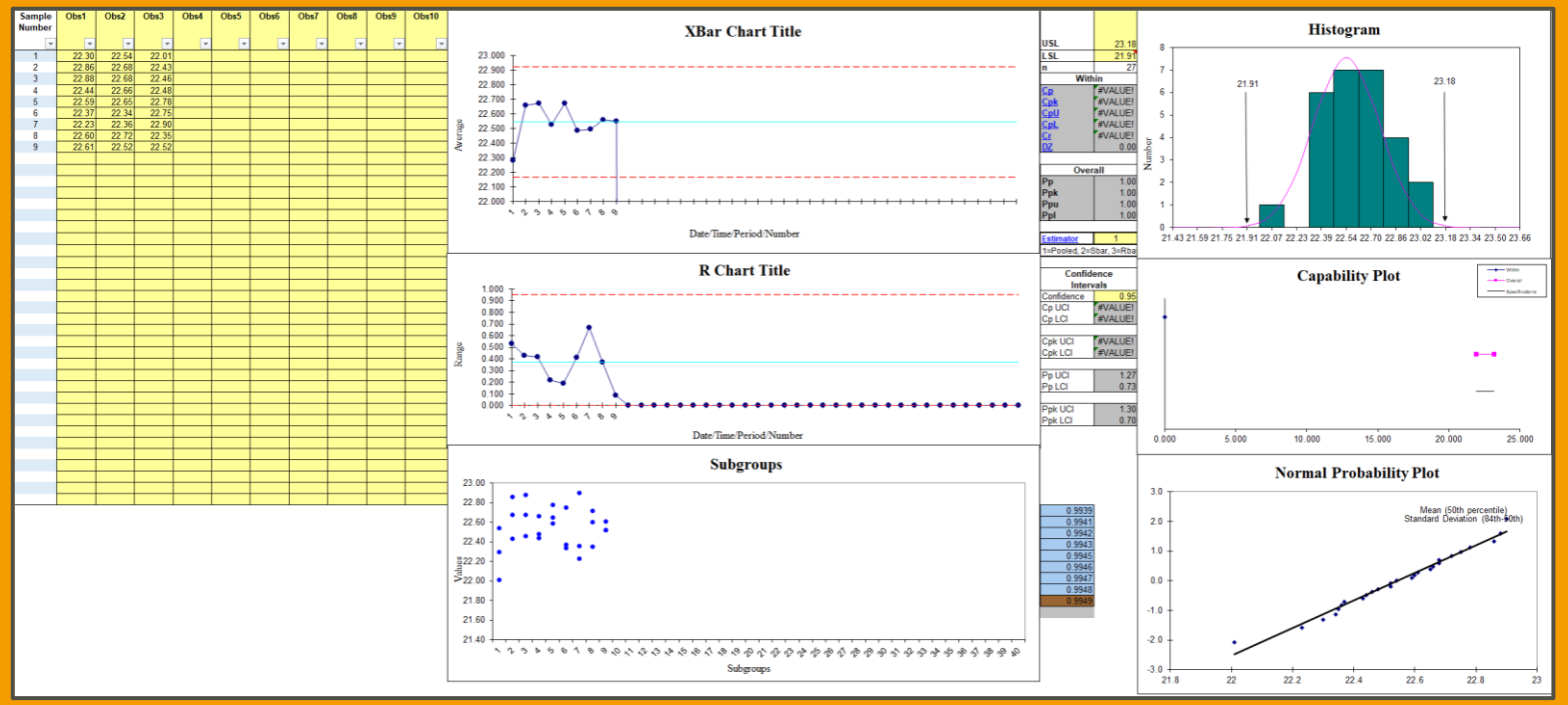
LEARNING HUB

Understanding Process Capability

Understanding Process Capability

Process Capability Template





Takeaways

- Once the process is **under statistical control** and showing only normal causes, **it is predictable**.
- This is when it becomes interesting for companies to predict the **current process's probability** of meeting customer specifications or requirements.
- When working with **continuous variables**, the traditional statistical measures are quite useful, especially in manufacturing.
- The difference between capability rates (*C*p and *C*pk) and performance rates (*P*p and *P*pk) is the method of estimating the **statistical population standard deviation**.

Thank You

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Capability and Process Performance

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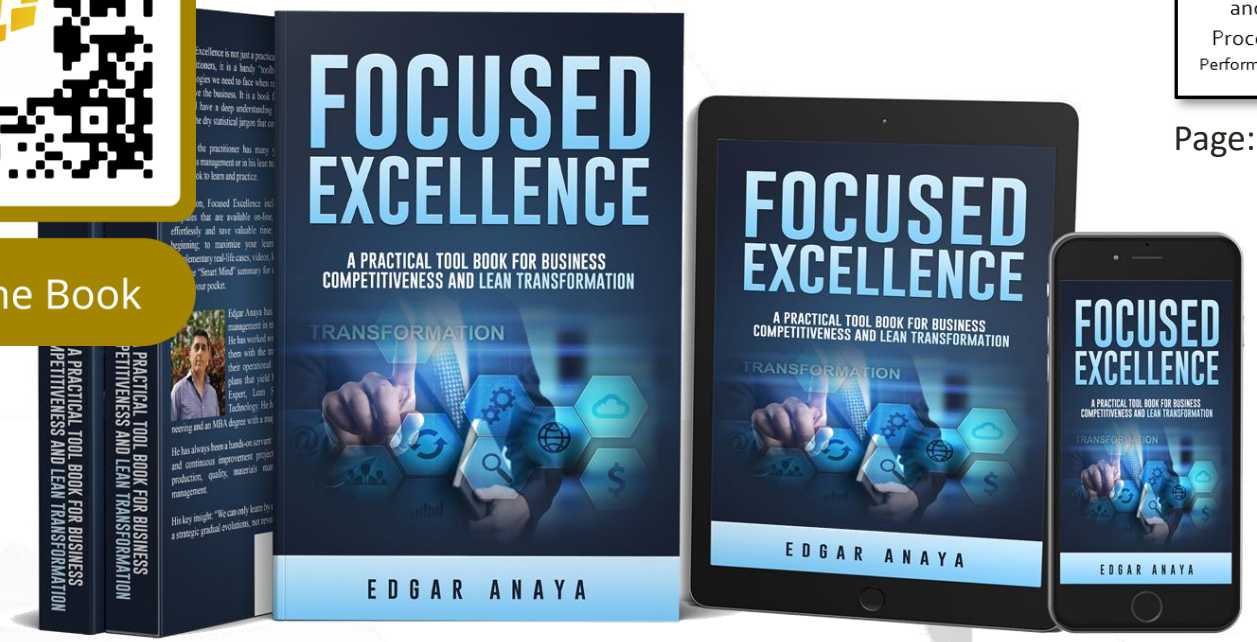

TOPIC

Capability and Process Performance

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Reference: Focused Excellence by Edgar Anaya

A Practical Tool Book for **Business Competitiveness** and **Lean Transformation**