Engineering Project Management & Finance

(UESTC 3031 & UESTCHN 3012)

Design For Manufacturing
(Part 4)

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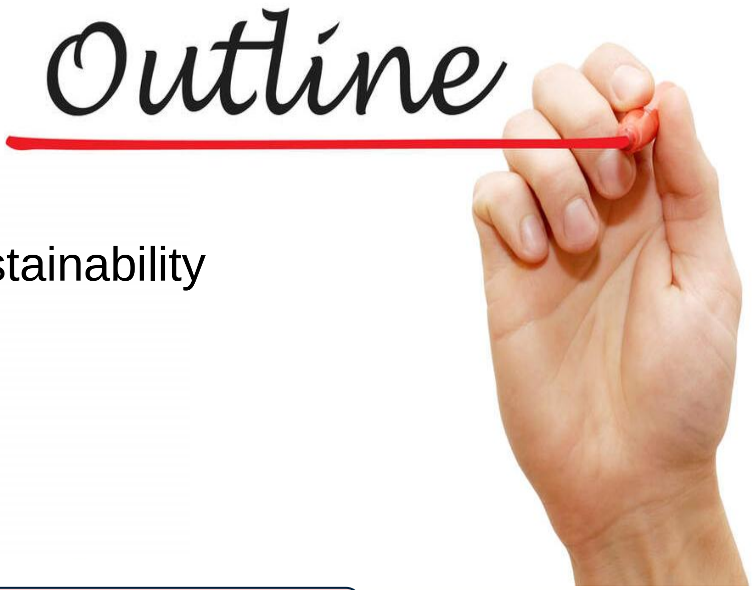


- **Part 1:** Introduction to DFM & Design for Sustainability
- **Part 2:** Quality Control & Cost of Quality
- **Part 3:** Robust Manufacturing Design
- **Part 4:** 6-Sigma & Process Capability

Six-Sigma (6σ)

Six-Sigma: Contents:

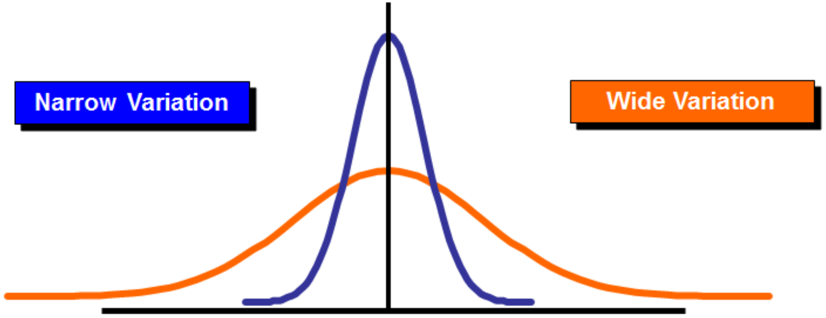
- Six Sigma : An Overview
- What is Six Sigma?
- Why Six Sigma?
- Six Sigma Phases : Define, Measure, Analyze, Improve and Control
- Tools and Key Roles for Six Sigma

What is Sigma ?

Sigma

σ

A term used in statistics to represent standard deviation, an indicator of the degree of variation in a set of a process.



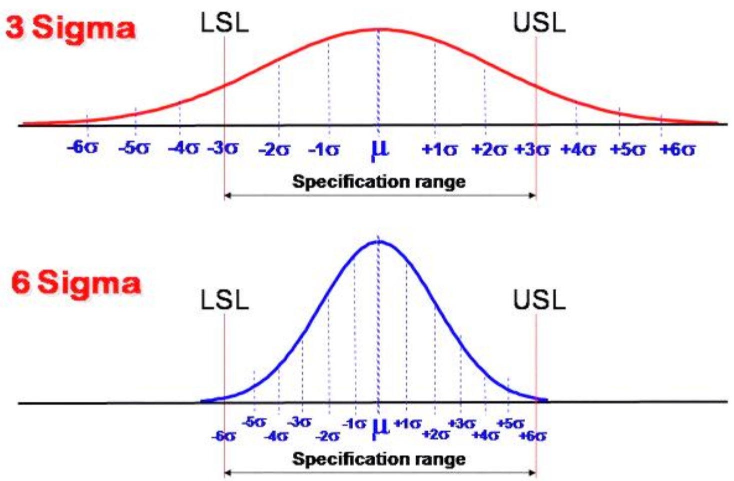
What is Six-Sigma ?

Six-Sigma

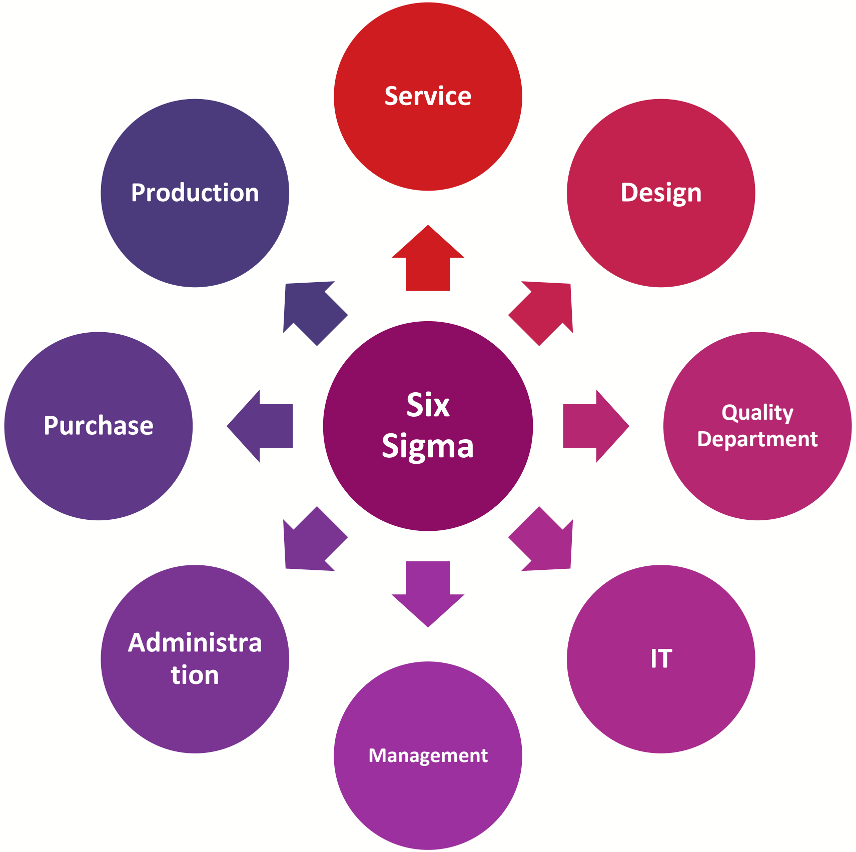
- A statistical concept that measures a process in terms of defects – at the six-sigma level, there 3.4 defects per million opportunities.
- Goal: as perfect as practically possible
- A methodology and a symbol of quality

Sigma Levels

Sigma Level (Process Capability)	Defects per Million Opportunities
2	308,537
3	66,807
4	6,210
5	233
6	3.4



Field of Application



Cost of Poor Quality

- Cost of scrap.
- Cost of rework.
- Cost of excessive cycle times and delays.
- Cost of business lost because customers are dissatisfied with your products or services.
- Cost of opportunities lost because you didn't have time or the resources to take advantage of them.

Critical-to-Quality (CTQ)

Elements of a process that significantly affect the output of that process. Identifying these elements is figuring out how to make improvements that can dramatically reduce costs and enhance quality.

Why Six Sigma?

Money	Quality
Customer Satisfaction	Competitive Advantage
Growth	Employee Pride

Why Six Sigma?

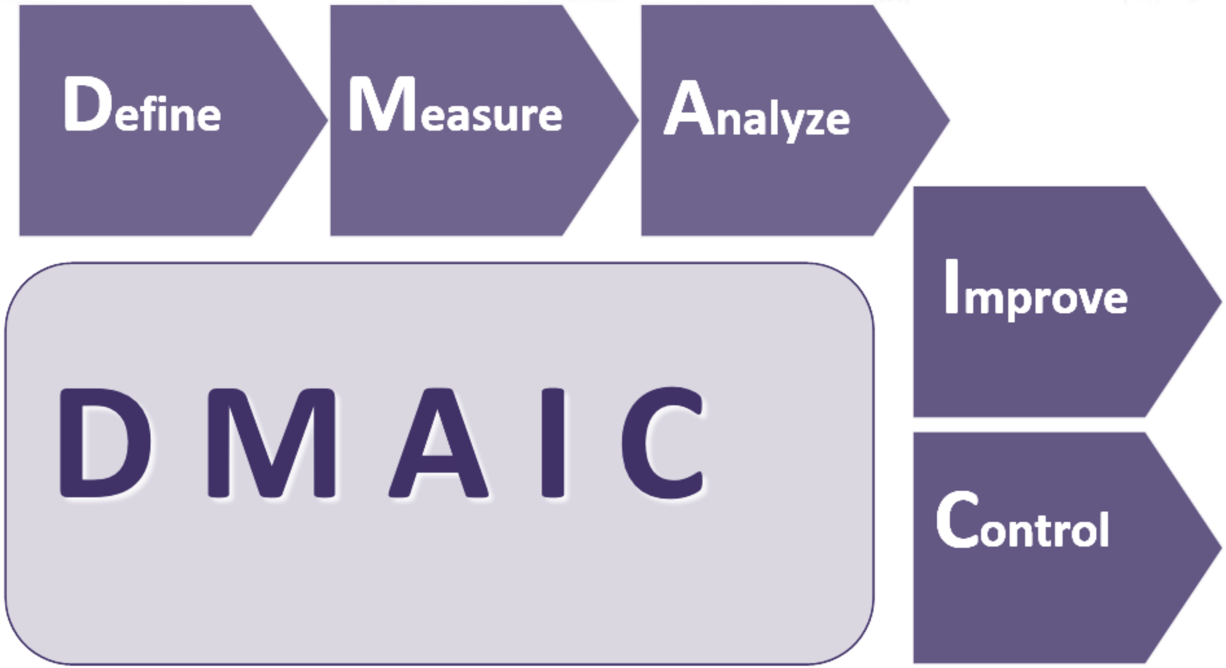
- At General Electric Company (GE), Six Sigma added more than $2 billion to a company's net income in 1999 alone.
- Motorola saved more than $15 billion in the first 10 years of its Six Sigma effort.
- AlliedSignal reports saving $1,5 billion through Six Sigma.

Six Sigma is about practices that help you eliminate defects and always deliver products and services that meet customer specifications.

Some companies that implemented Six-Sigma:

- 3M
- Air Canada
- Amazon.Com
- Bank of America
- Boeing
- Caterpillar, Inc.
- Corning
- Dell
- DHL
- Eastman Kodak Company
- Ford
- General Electric
- GlaxoSmithKline
- HSBC Group
- LG Group
- Motorola
- Samsung Group
- Siemens AG
- McGraw-Hill Companies
- US Air Force, US Navy, US Marine Corps
- Vodafone
- Whirlpool
- Xerox

Six Sigma Phases



The DMAIC model is a roadmap for Six Sigma, used to improve the quality of results that company processes produce.

DMAIC

Define

Define the project goals and customer (internal and external) deliverables.

Measure

Measure the process to determine current performance.

Analyze

Analyze and determine the root cause(s) of the defects

DMAIC

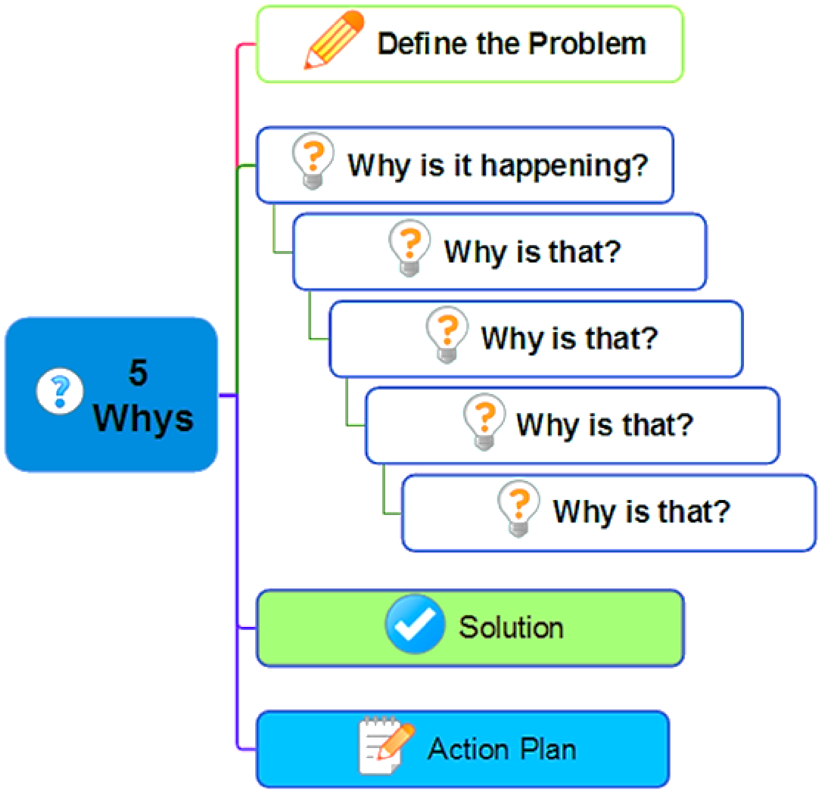
Improve

Improve the process by eliminating defects.

Control

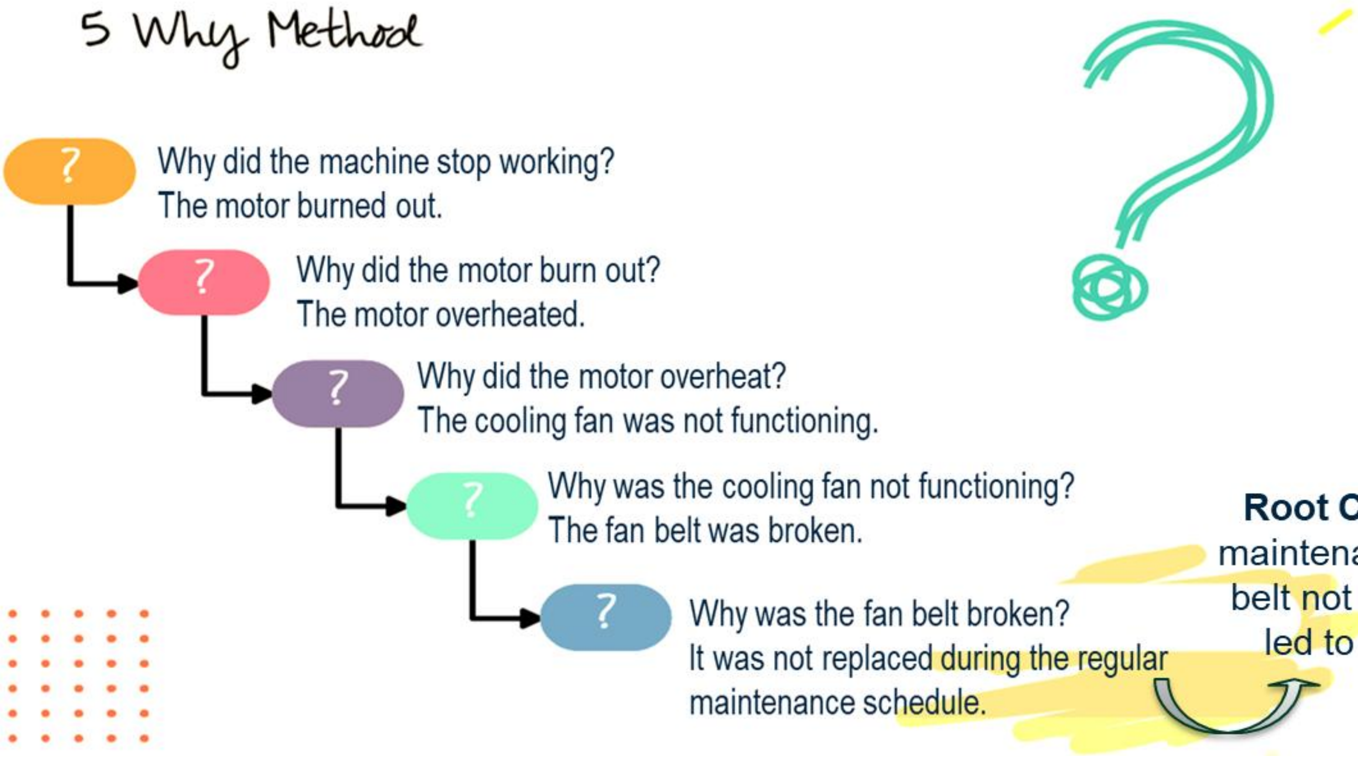
Monitor all improvements made to ensure sustainable changes and long-lasting results.

Tools for Six Sigma



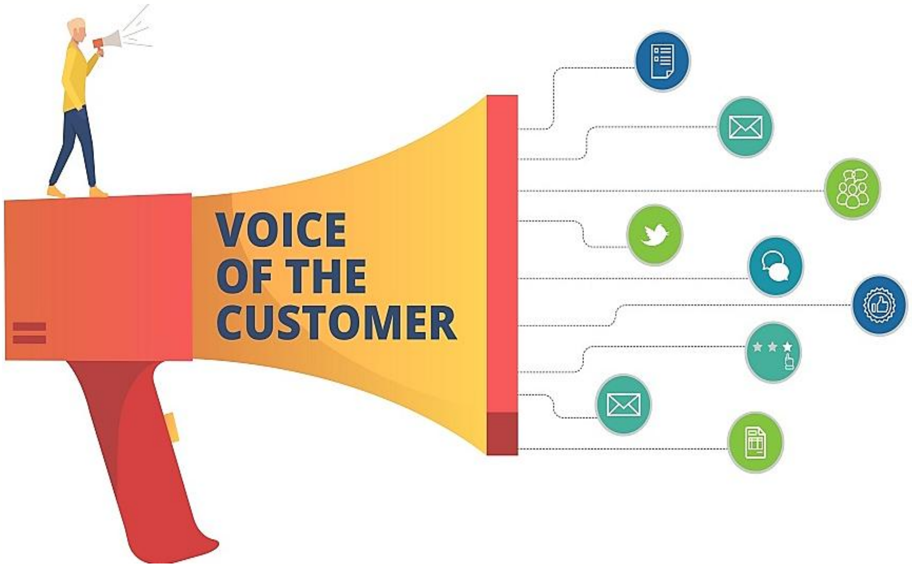
Tools for Six Sigma

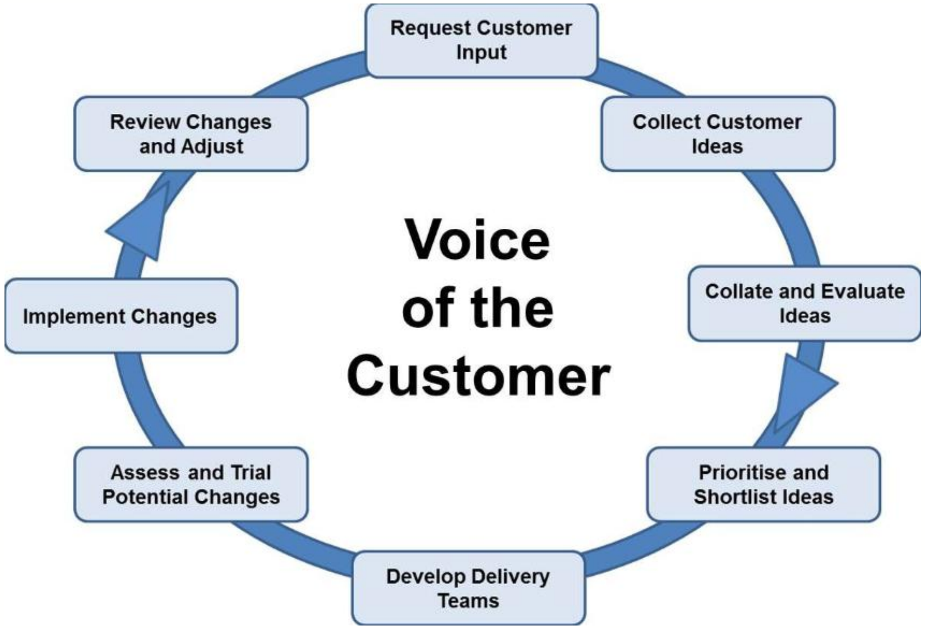
Example: (5 Whys in problem solving)



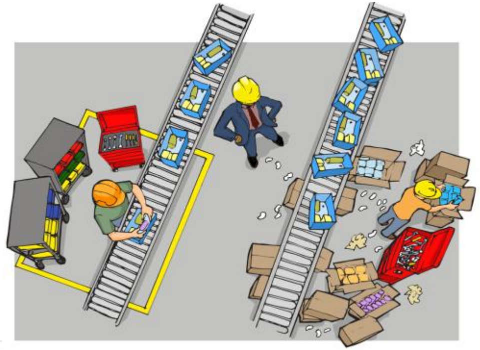
Root Cause: Lack of proper maintenance resulted in the fan belt not being replaced, which led to the machine failure.

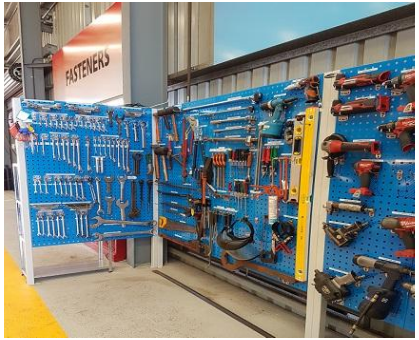
Tools for Six Sigma



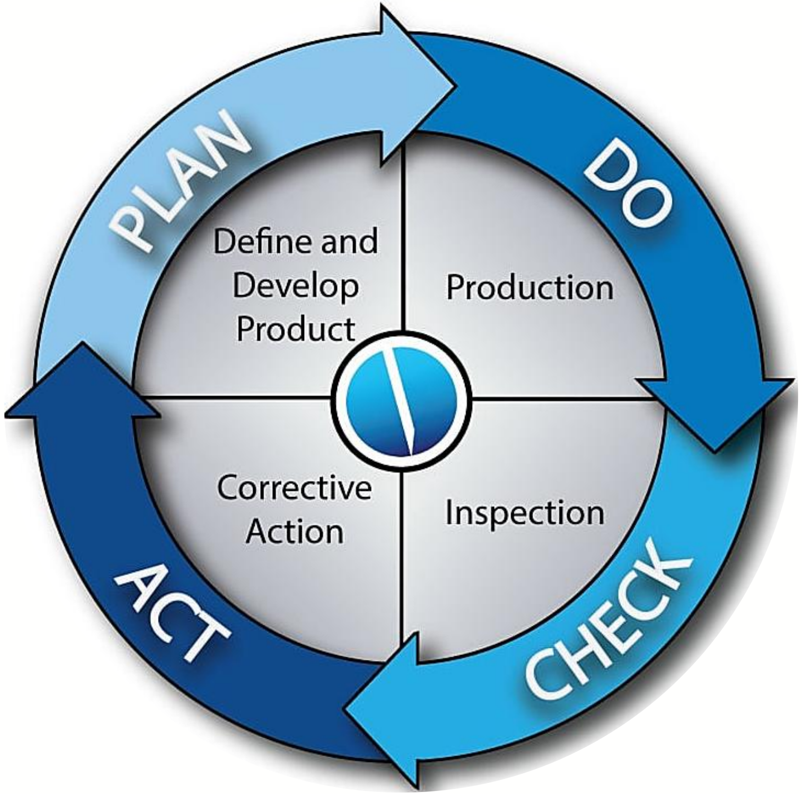


Tools for Six Sigma





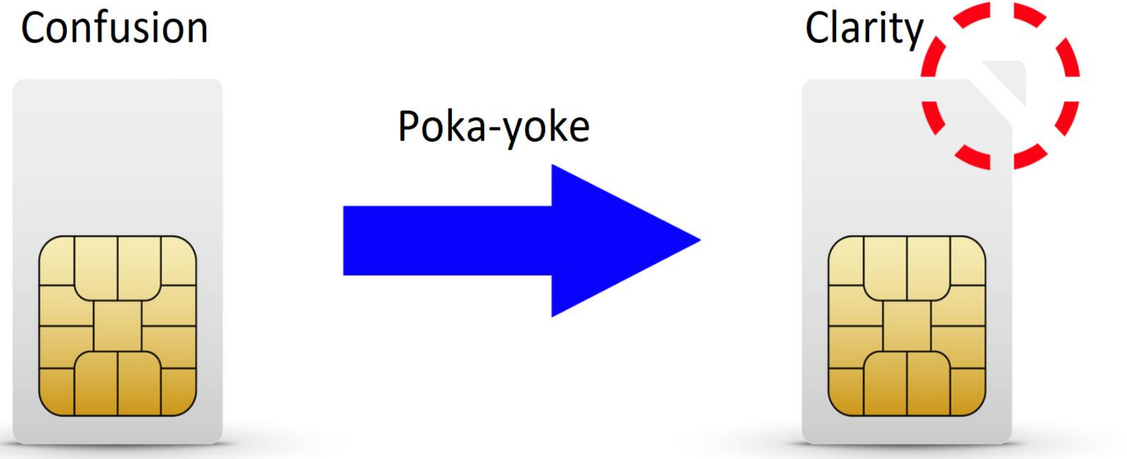
Tools for Six Sigma

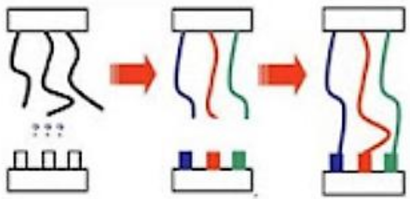


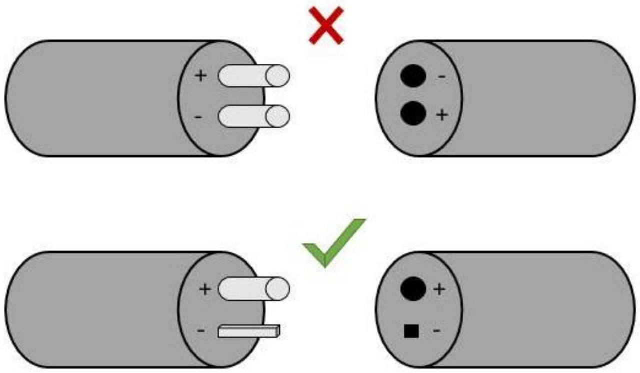
Continuous Improvement with PDCA

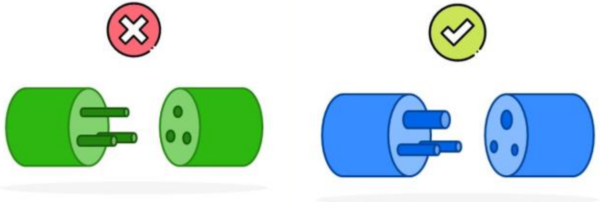
Tools for Six Sigma

Mistake Proofing



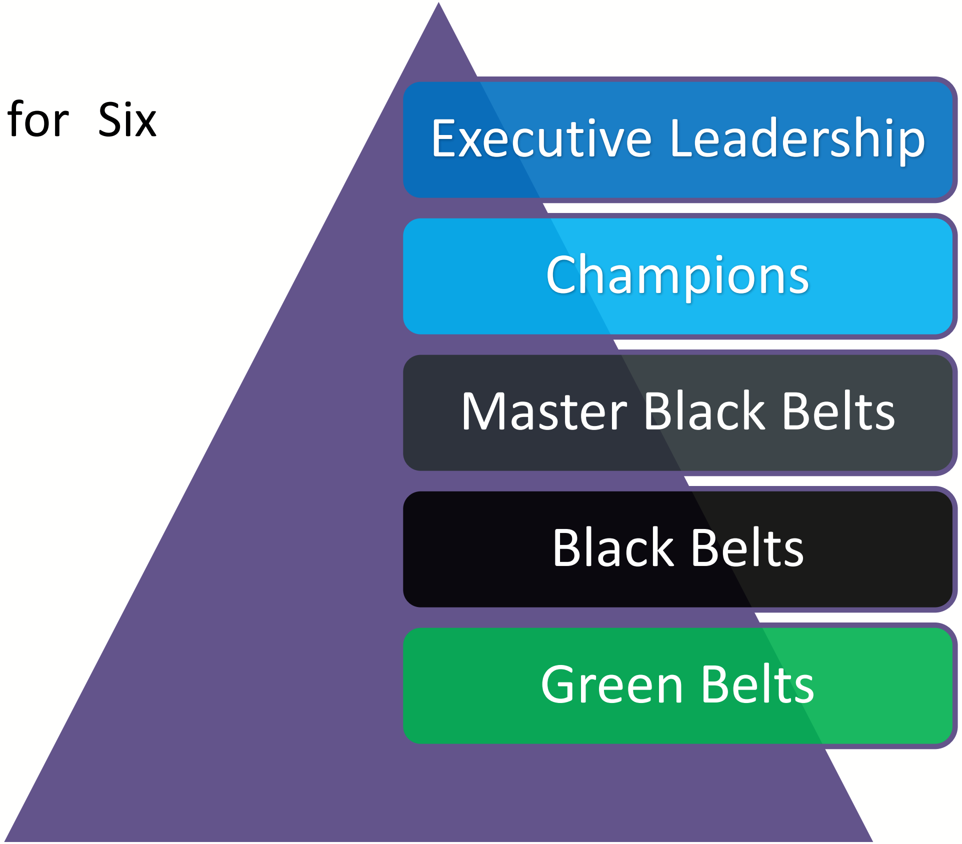






Key Roles for Six Sigma

There are five key roles for Six Sigma in manufacturing:



Key Roles for Six Sigma

Executive Leadership

Includes CEO and other key top management team members. They are responsible for setting up a vision for Six Sigma implementation.

Champions

Are responsible for the Six Sigma implementation across the organization in an integrated manner. Champions also act as a mentor to Black Belts.

Master Black Belts

Identified by champions, act as an in-house expert coach for the organization on Six Sigma. They devote 100% of their time to Six Sigma.

Key Roles for Six Sigma

Black Belts

Operate under Master Black Belts to apply Six Sigma methodology to specific projects. They primarily focus on Six Sigma project execution.

Green Belts

They are the employees who take up Six Sigma implementation along with their other job responsibilities. They operate under the guidance of Black Belts and support them in achieving overall results.

Process Capability

What is Process Capability?

You will take some historical data, and extrapolate out to the future to answer the question:

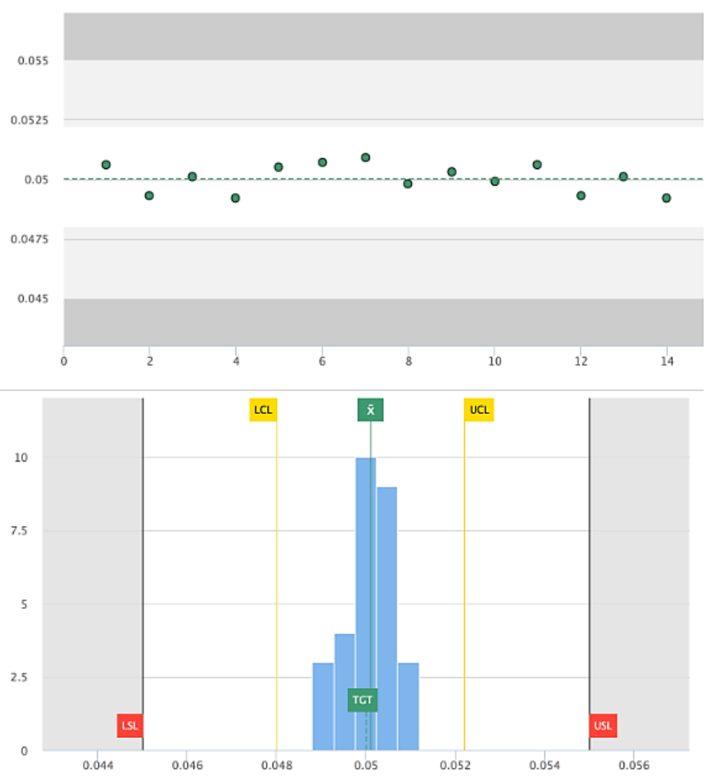
Can I rely on this process to deliver good parts?

Definition:

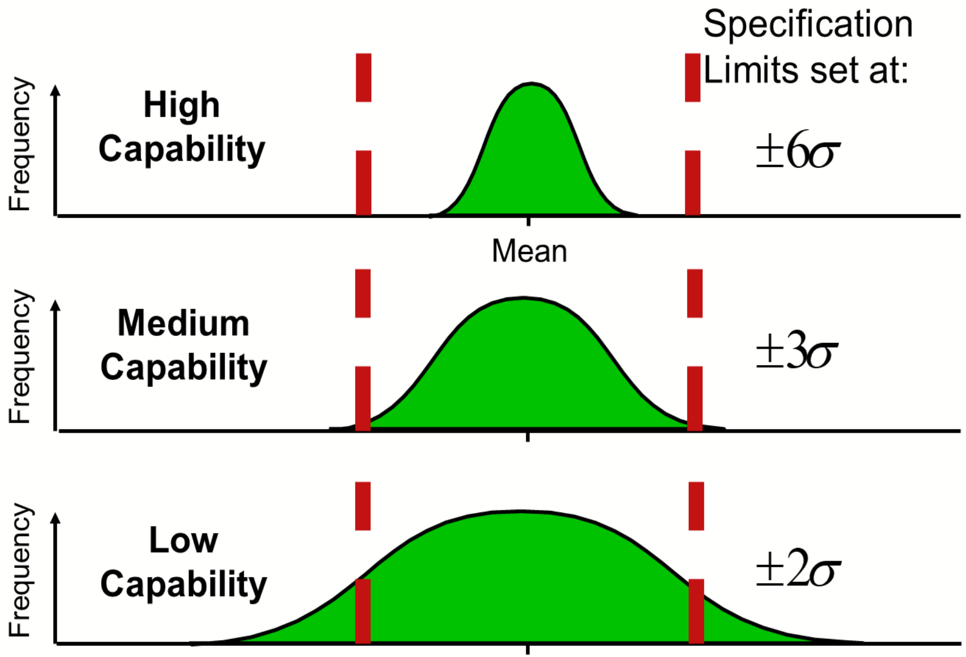
Process capability refers to the measure/degree to which a process can consistently produce output that meets process specifications.

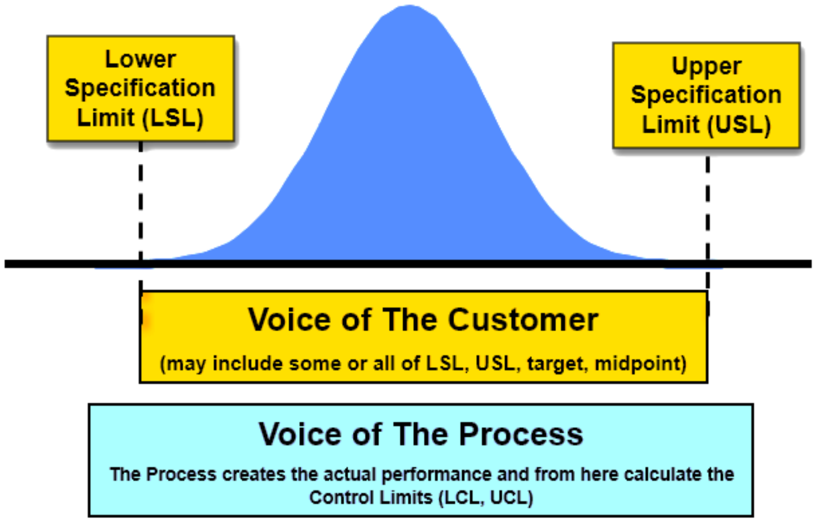
SPEC	Spec no.	Place no.	Spec type	Spec
	19	1 of 2	NUM	0.050 ± 0.005 in

	Measurement
1	0.0506 ✓
2	0.0493 ✓
3	0.0501 ✓
4	0.0492 ✓
5	0.0505 ✓
6	0.0507 ✓
7	0.0509 ✓
8	0.0498 ✓
9	0.0503 ✓
10	0.0499 ✓
11	0.0506 ✓
12	0.0493 ✓
13	0.0501 ✓
14	0.0492 ✓
15	0.0501 ✓
16	0.0510 ✓
17	0.0505 ✓
18	0.0507 ✓
19	0.0501 ✓
20	0.0506 ✓
21	0.0493 ✓
22	0.0499 ✓
23	0.0492 ✓
24	0.0501 ✓



Process Capability Overview

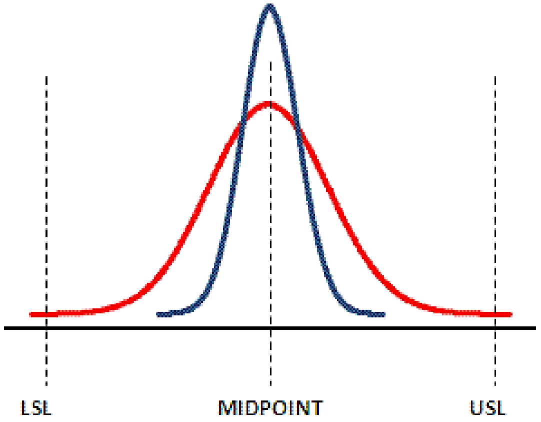


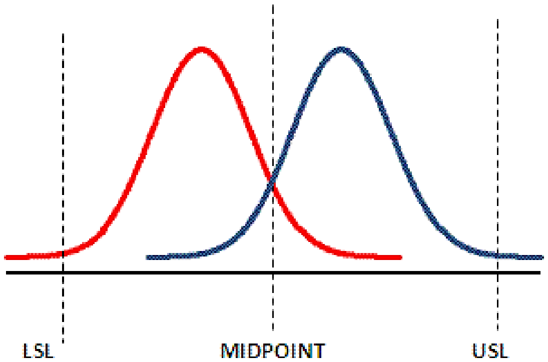


Goal is to shift the process to a target (which may not be a midpoint) and reduce the spread (variation) to meet the customer specifications. Accuracy + Precision

Process Capability Indices

- ✓ There are two main statistics that can be used to measure the capability of a process (C_p and C_{pk}).
- ✓ Most capability indices estimates are valid only if the sample size used is "large enough". Large enough is generally thought to be about 50 independent data values.
- ✓ The C_p and C_{pk} statistics assume that the population of data values is normally distributed.
- ✓ μ and σ are the mean and standard deviation, respectively, of the normal data and USL and LSL are the upper and lower specification limits, respectively.

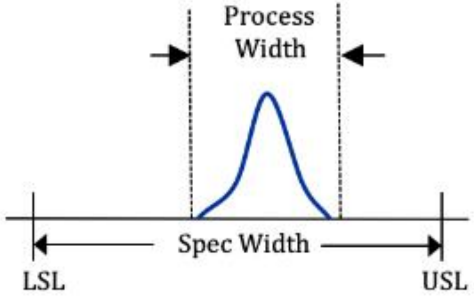




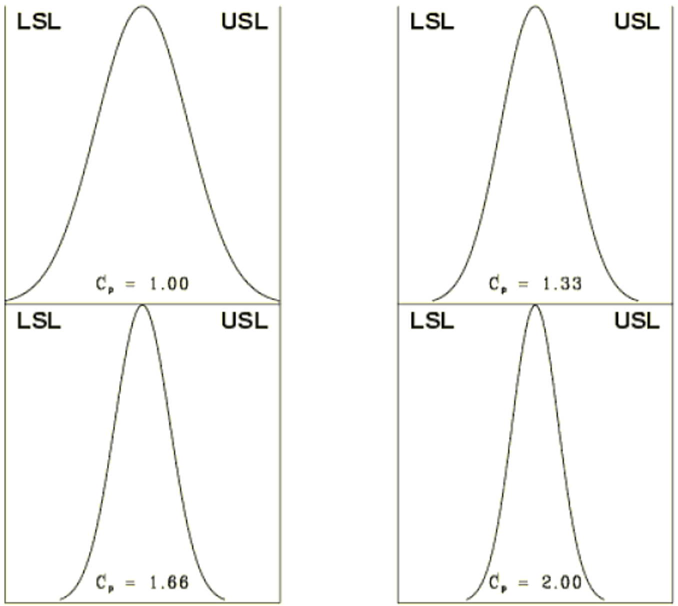
Process Capability Indices

$$C_p = \frac{USL - LSL}{6\sigma}$$

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



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

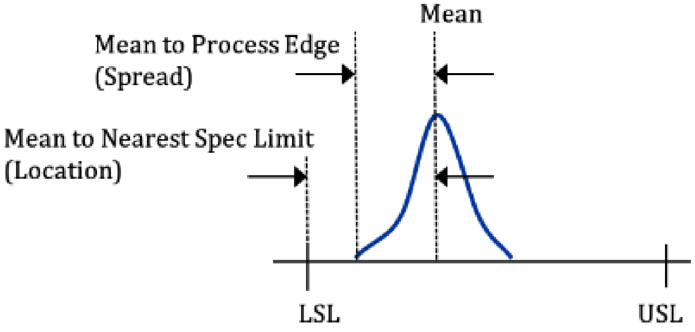


USL – LSL	6σ	8σ	10σ	12σ
C_p	1.00	1.33	1.66	2.00
Rejects	0.27 %	64 ppm	0.6 ppm	2 ppb
% of spec used	100	75	60	50

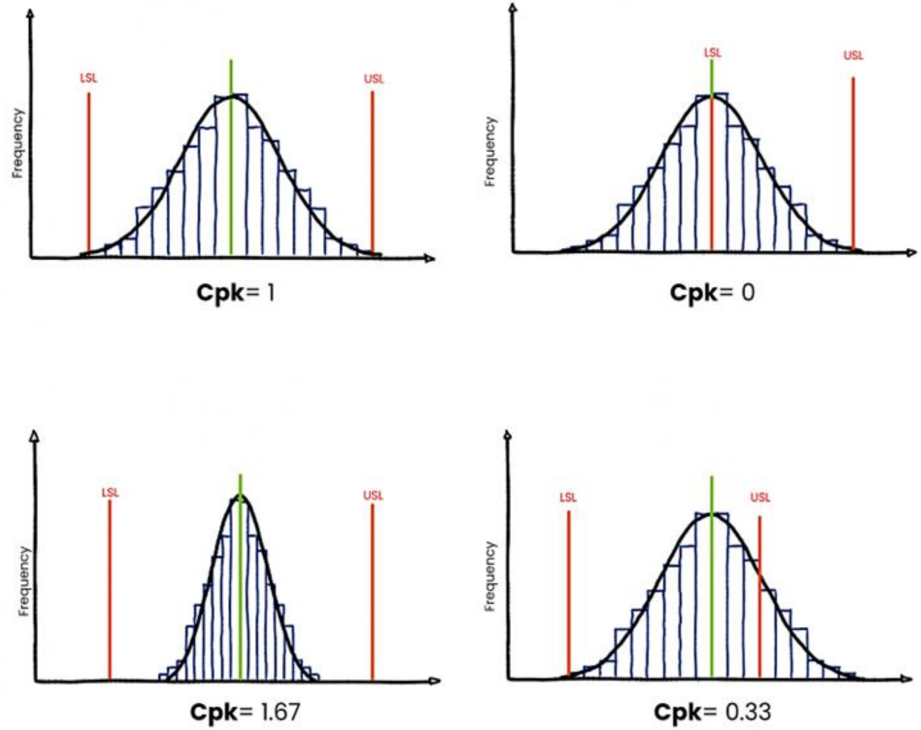
Process Capability Indices

$$C_{pk} = \min\left[\frac{USL-\mu}{3\sigma}, \frac{\mu-LSL}{3\sigma}\right]$$

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

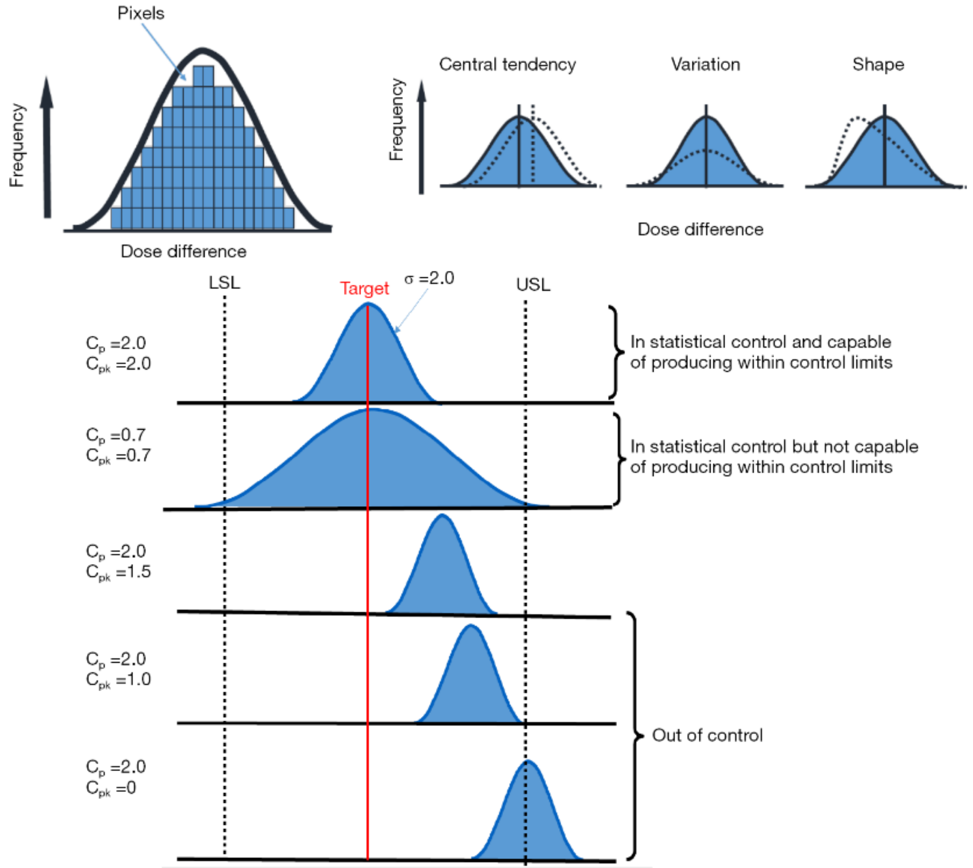


Cpk accounts for both the spread and location of the process.



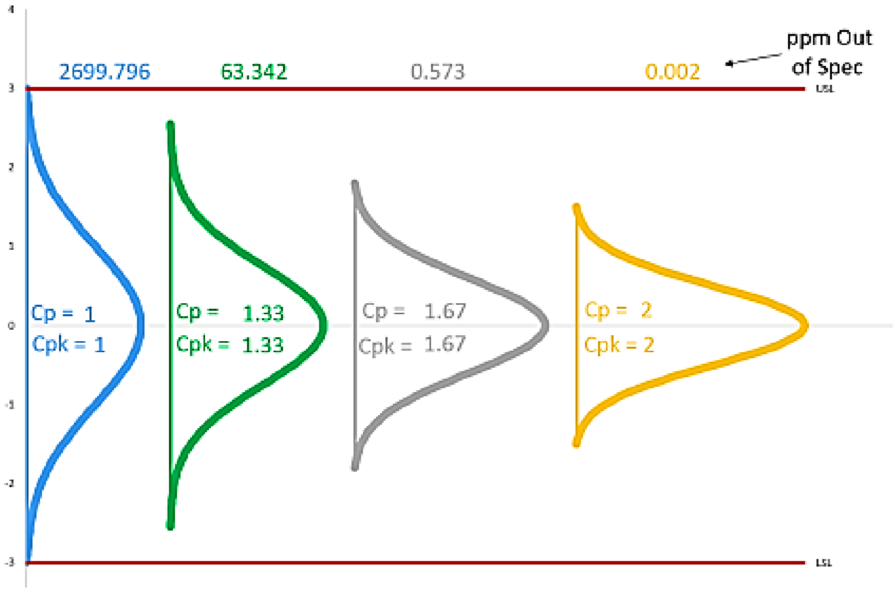
Process Capability Indices

Example:



Process Capability Indices

Example:



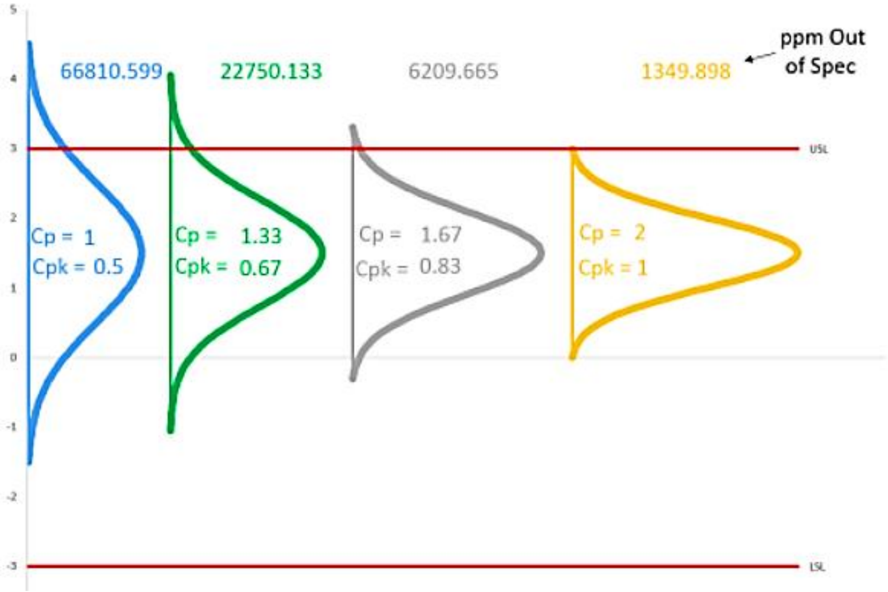
Average = 0, USL = 3, LSL = -3

Sigma	1	0.75	0.6	0.5
Cp	1	1.33	1.67	2
Cpk	1	1.33	1.67	2
Out of Spec LSL (ppm)	1350	32	0.29	0.001
Out of Spec USL (ppm)	1350	32	0.29	0.001
Total Out of Spec (ppm)	2700	63	0.57	0.002

Impact of Decreasing Variation for Centered Process

Process Capability Indices

Example:



Results from 1.5 Shift in Average

Sigma	1	0.75	0.6	0.5
Cp	1	1.33	1.67	2
Cpk	0.5	0.67	0.83	1
Out of Spec LSL (ppm)	3	0	0.00	0.000
Out of Spec USL (ppm)	66807	22750	6210	1350
Total Out of Spec (ppm)	66811	22750	6210	1350

Process Shift from 0 to 1.5

Process Capability Indices

Example:

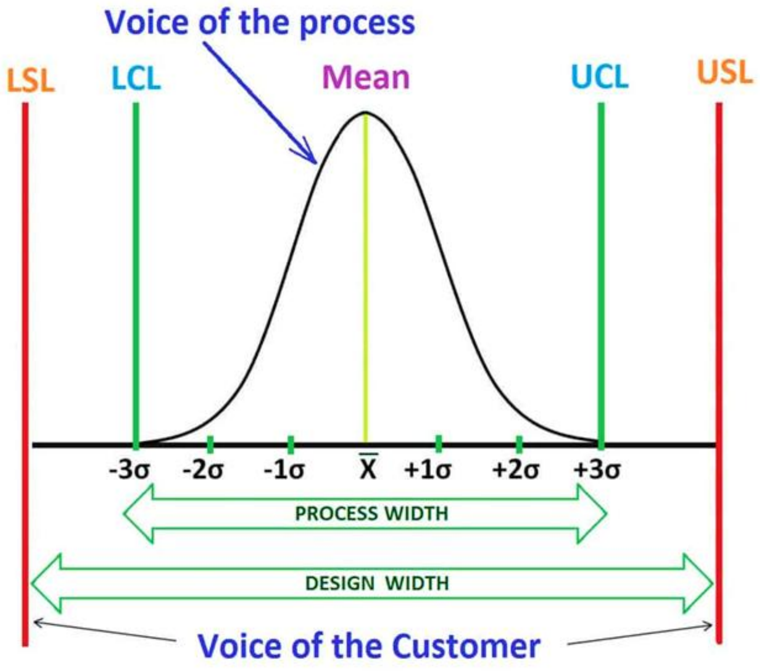
A manufacturer produces a type of resistor that should have a resistance of 10 ohms, with a tolerance of ±1 ohm. To ensure that the manufacturing process is capable of producing resistors within specifications, the manufacturer measures the resistance of a sample of resistors and calculates the Cp and Cpk indices. Assume that the sample of resistors has a mean resistance of 10.1 ohms and a standard deviation of 0.3 ohms.

Process Capability Indices

Risk Assessment for Cpk Value:

- Cpk < 1.00: High risk of defects, the process is not capable.
- 1.00 ≤ Cpk < 1.33: Moderate risk of defects, improvement needed for better capability.
- 1.33 ≤ Cpk < 1.67: Low risk of defects, the process is capable but has some room for improvement.
- Cpk ≥ 1.67: Minimal risk of defects, the process is highly capable.

Aim for a Cpk value of 2.00 or higher where possible. A Cpk of 2.00 implies that the process uses only 50% of the spec width, significantly reducing the risk of defect.




Q
A

Which of the following statements is true regarding process capability?

A. Process capability is a measure of how efficient a process is in terms of time and resources.

✓ B. Process capability refers to the degree to which a process can consistently produce output that meets process specifications.

C. Process capability is determined solely by the skill level of the workers involved in the process.

D. Process capability is not relevant for service industries.

E. None of the above statements is true regarding process capability.

Six-sigma is a statistical concept that measures a process in terms of defects – at the six-sigma level, there are 3.4 defects per million opportunities. What is Critical-to-Quality (CTQ)?

Elements of a process that significantly affect the output of that process. Identifying these elements is figuring out how to make improvements that can dramatically reduce costs and enhance quality

A manufacturing process produces a new product with an upper and lower specified length of 20±1 mm. The process has a mean diameter of 19.8 mm and a standard deviation of 0.2 mm. Calculate the process capability index Cpk.

To calculate Cpk, we first need to determine the upper and lower specification limits. The upper specification limit (USL) is 20+1=21 mm and the lower specification limit (LSL) is 20-1=19 mm.

Next, we can calculate the process capability index using the following formula:

Cpk = min[(USL - mean)/ (3 x standard deviation), (mean - LSL)/ (3 x standard deviation)]

Plugging in the given values, we get:

Cpk = min[(21 - 19.8)/ (3 * 0.2), (19.8 - 19)/ (3 * 0.2)]

Cpk = min[2, 1.33]

Cpk = 1.33

List any of the two main phases in 6-Sigma

Accept any 2 of the below:

- Define
- Measure
- Analyze
- Improve
- Control

There are five key roles for Six Sigma in manufacturing including Executive Leadership, Champions, Master Black Belts, Black Belts, and Green Belts. Explain briefly any two of these roles.

- Executive Leadership: Includes CEO and other key top management team members. They are responsible for setting up a vision for Six Sigma implementation.
- Champions: Are responsible for the Six Sigma implementation across the organization in an integrated manner. Champions also act as a mentor to Black Belts.
- Master Black Belts: Identified by champions, act as an in-house expert coach for the organization on Six Sigma. They devote 100% of their time to Six Sigma.
- Black Belts: Operate under Master Black Belts to apply Six Sigma methodology to specific projects. They primarily focus on Six Sigma project execution.
- Green Belts: They are the employees who take up Six Sigma implementation along with their other job responsibilities. They operate under the guidance of Black Belts and support them in achieving overall results.


thank
you