Green Belt Training
Process Capabilities

(Green Belt)

Why Measure Capability?

- Enables allocation of resources based on **DATA!** (This is not common!)
- Quantifies the defect rate
- Identifies opportunities for improvement
- Assessing capability allows the organization to predict its true quality levels for all its goods and services
- Identifies the nature of the process problem – centering or spread

Capability studies are a Lean Six Sigma deliverable.

Capability : Some common Metric

- ❑ Sigma Level/ Z-Score
- ❑ IPY/ RTY
- ❑ Cp / Cpk etc…

Capability studies are a Six Sigma deliverable.

Introducing the "Z Score"

- Scenario:
  - You are asked to evaluate a customer complaint about the time it took to be serviced on a telephone customer help line
  - The session took 9 minutes
- Question: Comment on this event?
- Approach:
  - First, consider how different this is from a typical time: mean
    - Assume the process μ = 4.0 minutes
    - Calculate **(x- μ)** = (9-4) = 5 minutes…….is this a big difference???
  - Second, consider whether 5 minutes is a typical difference
    - Assume the process σ = 4.5 minutes
    - Calculate **(x- μ)/ σ** = (9-4)/4.5= 5/4.5 = 1.11 standard deviations
- The number of STANDARD DEVIATIONS from the MEAN is called the:

Z Score

Combining μ and σ with the Z -score

- Given a value "x" drawn from a population with μ and σ
  - The Z score for x = $\boxed{\dfrac{(x-\mu)}{\sigma}}$

How far from the average?

How typical is the distance?

- Z-Score: the number of standard deviations between a value and the mean
- Has many purposes:
  - General "normalizing" for comparisons
  - Used to look up probabilities for the NORMAL distribution
  - Used to generate a Capability metric

A Simple Definition

- Capability metrics report how well process output features meet customer specifications

Specification Range

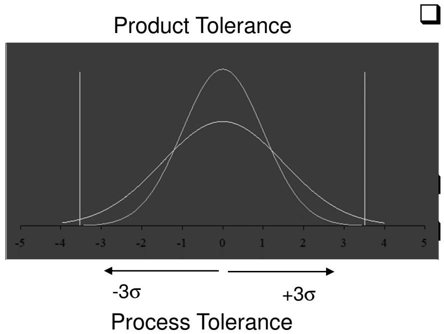
Process Range

- EXAMPLE:
  - **PPM** (Parts Per Million) reports the number of defective parts expected in a group of 1,000,000, and thus the defective and compliance rate.
    - Example: 100,000 PPM reflects 90% compliance to specifications
  - **Cp** reports the ratio of the specification range to the natural range of process output
    - Example:
      - Temperature Spec range: 68 to 72 ^{0}F
      - Process Temperature Range: 69 to 71 ^{0}F
      - Cp = (72-68)/(71-69) = 4/2 = 2.0

Compute C_p

Process Potential Capability(Cp):

$$Cp = \frac{\text{Product Tolerance}}{\text{Process Tolerance}} = \frac{USL - LSL}{6\sigma_{st}}$$

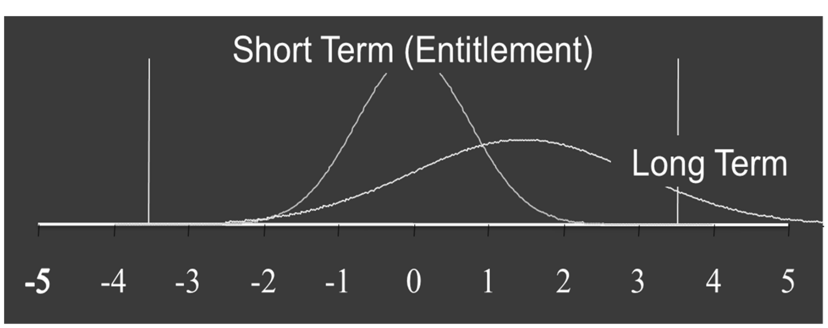


- Example:
  - A process mean is 325, standard deviation is 15, an upper spec. limit is 380 and lower spec. limit is 270
- What is Cp?
- What is Cp if the mean is 355 but the standard deviation does not change?

What are the issues if Cp = 1.0?

Cp & Entitlement

- Cp is a good indicator of entitlement.
- *Entitlement* – the best, observed, short-term performance of a process.
- *Opportunity* – the difference between the observed long-term performance of the process and the entitlement.
- *Six Sigma projects* – designed to reduce the opportunity by driving the long-term performance toward the short-term entitlement.

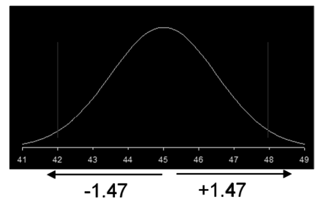


Cp for Soaking Cycles

- LSL = 1235 USL = 1265
- μ = 1246.1 σ = 4.86

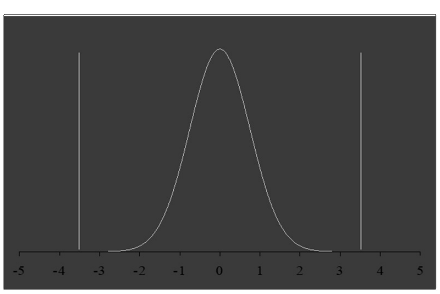
$$Cp = \frac{\text{Product Tolerance}}{\text{Process Tolerance}} = \frac{USL - LSL}{6\sigma_{st}}$$

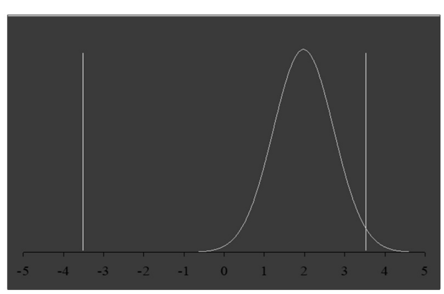
$$= \frac{1265\text{-}1235}{6 \times 4.86} = \frac{3}{2.94} = 1.02$$



A Problem With Cp

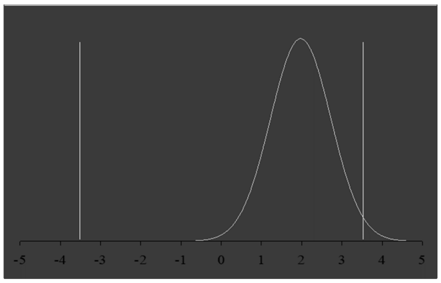
- Which is the better process?
- What is the difference in Cp between the two processes?
- What can be done to make Cp more effective as a process capability statistic?





Meet Cpk – Process Performance

$$Cpk = \min\{Cpl, Cpu\}$$
$$\text{Cpl} = \frac{\mu - LSL}{3\sigma_{st}}$$
$$\text{Cpu} = \frac{USL - \mu}{3\sigma_{st}}$$



- Example:
  - A process mean is 355, standard deviation is 15, an upper spec. limit is 380 and lower spec. limit is 270
- What is the Cpk?
- What is the Cp?

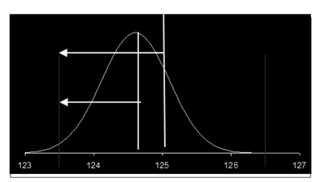
C_{pk} for Soaking Temperature

$$Cp = \frac{USL - LSL}{6 \times S_{st}} = \frac{1265 - 1235}{6 \times 4.86} = 1.01$$

$$Cpk = \min\left[\frac{\overline{X} - LSL}{3 \times s_{st}}, \frac{USL - \overline{X}}{3 \times s_{st}}\right]$$

$$= \min\left[\frac{1246.1 - 1235}{3 \times 4.86}, \frac{1265 - 1246.1}{3 \times 4.86}\right]$$

$$= 0.74$$



Estimate Long Term Capability P_{pk}

- Ppk = Cpk using long term variation instead of short term variation

$$C_{pk} = \min\left[\frac{\mathrm{USL}-\mu}{3 \times \sigma_{\mathrm{st}}}, \frac{\mu - \mathrm{LSL}}{3 \times \sigma_{\mathrm{st}}}\right]$$

$$P_{pk} = \min\left[\frac{\mathrm{USL}-\mu}{3 \times \sigma_{\mathrm{lt}}}, \frac{\mu - \mathrm{LSL}}{3 \times \sigma_{\mathrm{lt}}}\right]$$

Estimate Long Term Capability Ppk

$$z_{LT} \approx z_{ST} - 1.5$$
$$z_{LT} \approx 2.28 - 1.5 = 0.78$$

$$z_{LT} = \frac{Specification - \mu}{\sigma_{lt}}$$
$$= 3 \times Ppk$$
$$Ppk = \frac{z_{LT}}{3}$$

$$\mathrm{Ppk} = \frac{\mathrm{Z_{LT}}}{3} = \frac{.78}{3} = 0.26$$

Capability Formulae – Summary

Short -Term Capability Indices

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

$$C_{pk} = \min \ (C_{pk(USL)}, C_{pk(LSL)})$$

$$C_{pk(USL)} = \frac{(USL - \bar{X})}{3 * s_{short-term}}$$

$$C_{pk(LSL)} = \frac{(\bar{X} - LSL)}{3 * s_{short-term}}$$

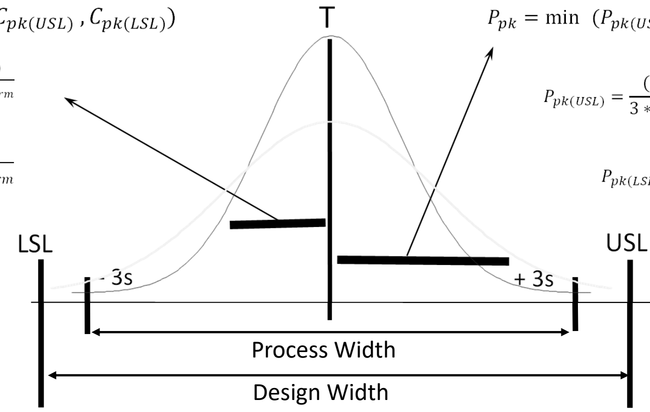
Long -Term Capability Indices

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

$$P_{pk} = \min \ (P_{pk(USL)}, P_{pk(LSL)})$$

$$P_{pk(USL)} = \frac{(USL - \bar{X})}{3 * s_{long-term}}$$

$$P_{pk(LSL)} = \frac{(\bar{X} - LSL)}{3 * s_{long-term}}$$



Capability Compares Design & Process Widths