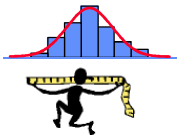
Can you Trust your Process Capability Studies

Greater Fort Worth ASQ Section 1416

Cowtown Quality Roundup

Learn Today – Apply Tomorrow

John Breckline



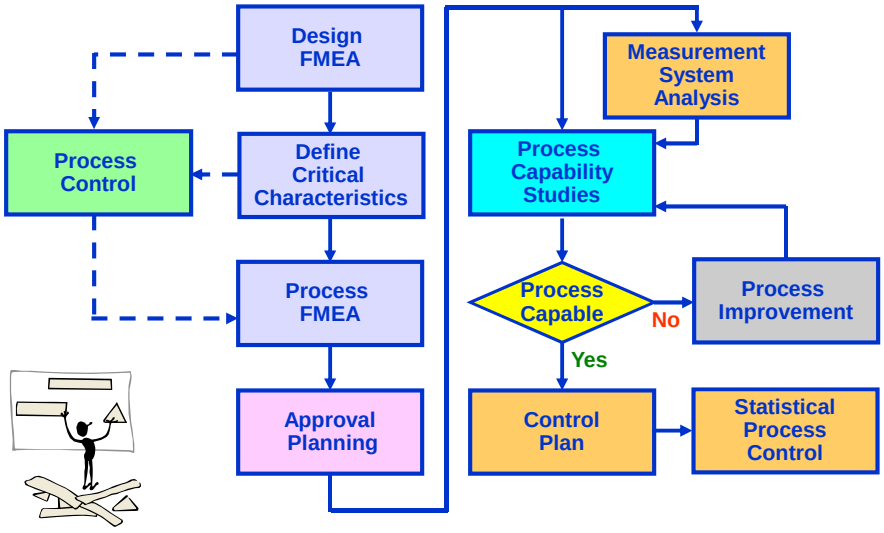
April 20, 2018

75 Minute Agenda

- Introduction to PCS
- Customer Perspective
- Capability Defined
- Short-Term v. Long-Term
- Measurement Issues
- Distribution Issues
- Conducting Studies
- Interpretation of Study
- Conclusions & Actions
- Wrap Up – Q&A

Process Capability Studies (PCS)

Statistical Thinking Map



Data Use

Why Collect and Track Data

- Data → Information → Decision
- Understand – Evaluate – Control – Predict

Objective of Capability Studies

- Predict the performance of a process to specifications
- Provide short-term capability (Cpk)
- Predict long-term performance (Ppk)
- Baseline for improving the process

Why care about Process Capability?

- Satisfy our customers
- Understand our processes
- Prioritize areas for quality improvement
  - variation reduction activities
- Verify that process improvements are successful
- Track improvements over time
- Give us information to set realistic tolerances
- Help us identify how to cost products
- Select the best qualified supplier
- Improve our company Bottom Line

Process Capability Studies

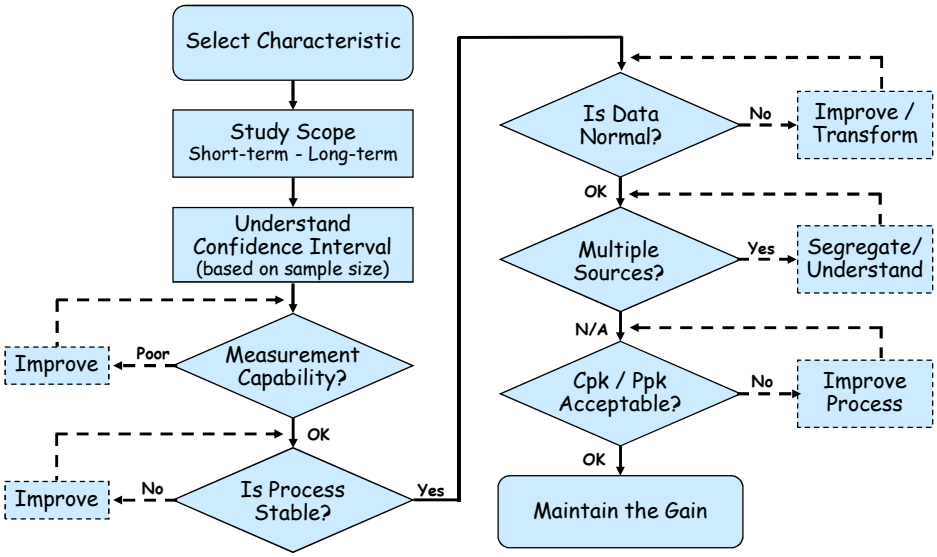
Definition

– Process Capability refers to the capability of a process to consistently make a product (outputs) that meets customer specifications.

– Capability Indices are used to predict performance of a process by comparing the width of process variation to the width of specification tolerances.

– Higher level indices include a ‘centering’ calculation

Process Capability Roadmap



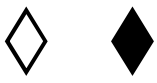
Key Characteristics

What is Important

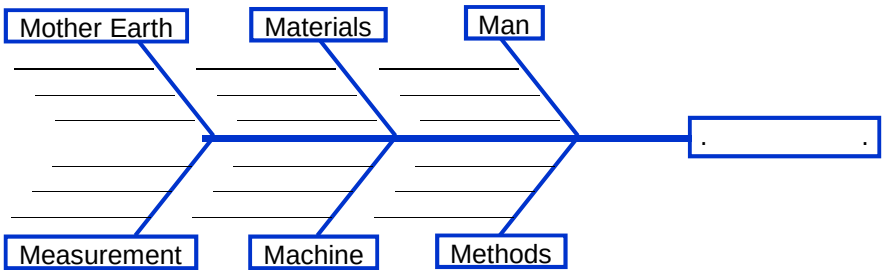
- to End Customer
- to Manufacturers
- to Company Operations
- to Supplier Operations

Identifying Characteristics

- Design FMEA
- Early Supplier Involvement
- Process FMEA
- White / Black Diamond Designation



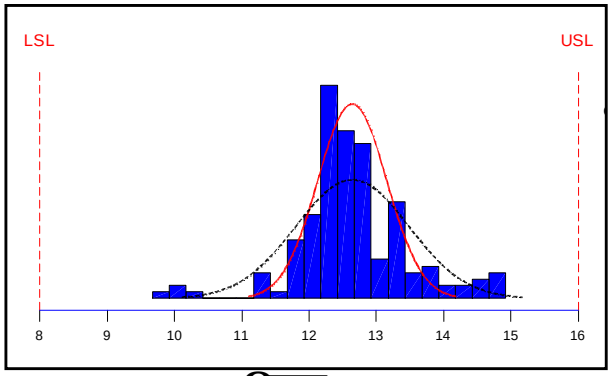
Key Process Characteristics



Performance vs. Requirements

Requirements

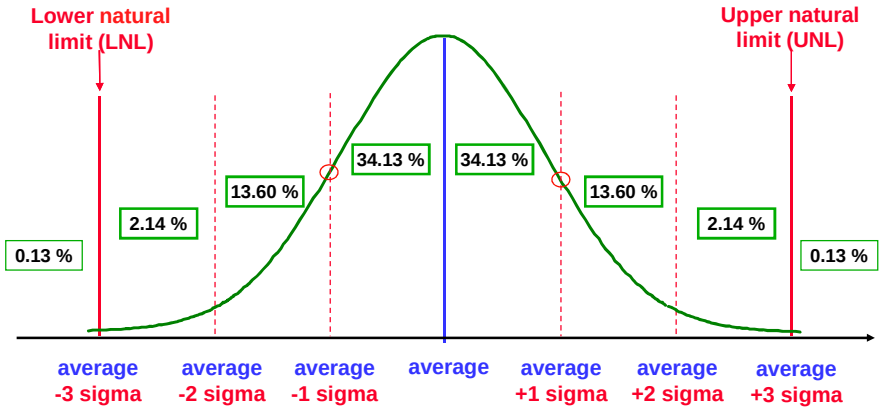
- Customer Specifications
- Internal Operating Control Levels
- Compare Performance to Requirements



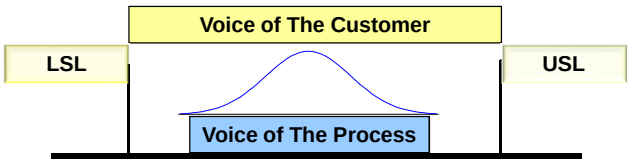
Normal Curve – Area Under the Curve

Normal Curve

- Accounts for Common Cause variation – 99.97%



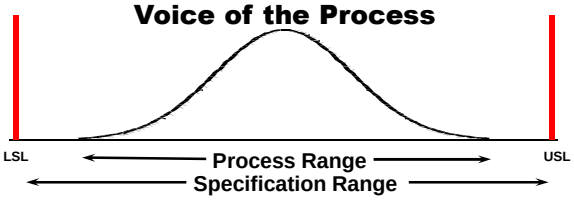
Process Capability Ratios



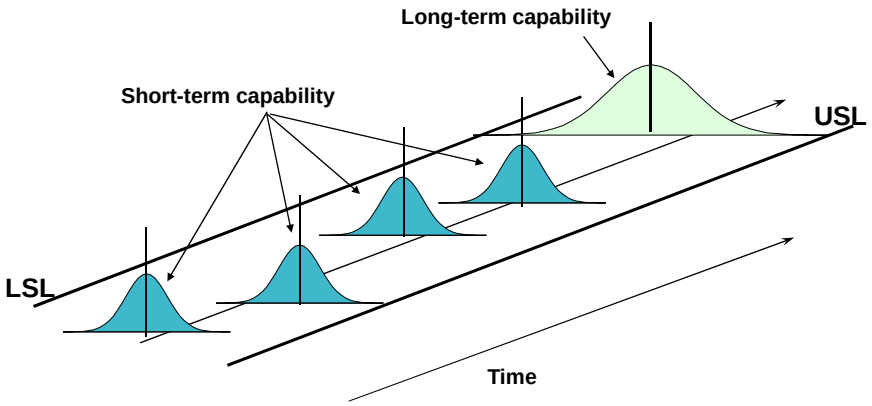
Capability Ratio:

comparison of the capability of a process to the specification limits

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



Short-Term / Long-Term



Process Capability

How it's measured

- Cp – capability index
- Pp – performance index
- Cpk – ratio to the smallest value (USL/LSL)
- Ppk – ratio to the smallest value (USL/LSL)

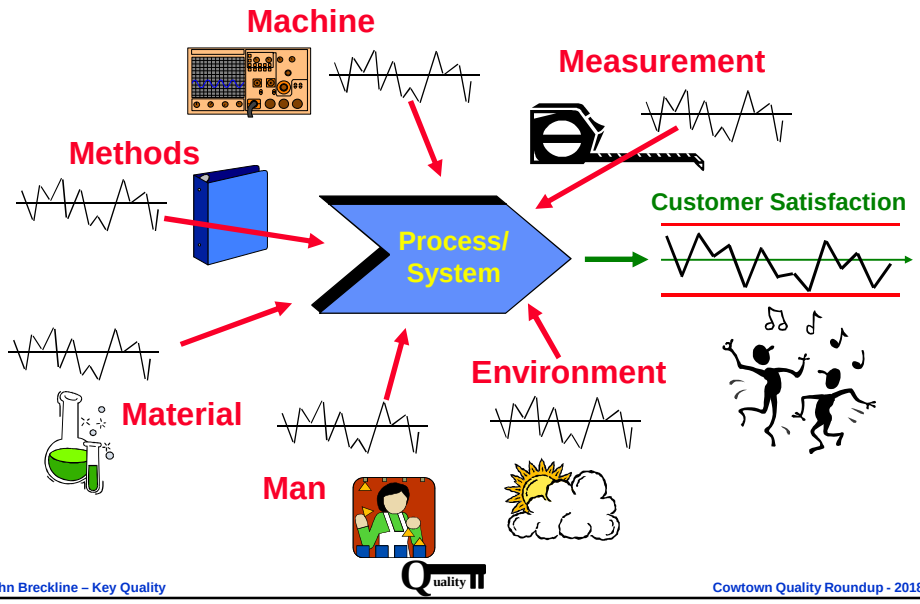
$$C_p = \frac{USL - LSL}{6\,s}$$

$$C_p = \frac{\text{Total Tolerance}}{\text{Process Spread}}$$

$$C_{pk} = \text{Min}\left(\frac{\bar{X} - LSL}{3\,s}, \frac{USL - \bar{X}}{3\,s} \right)$$

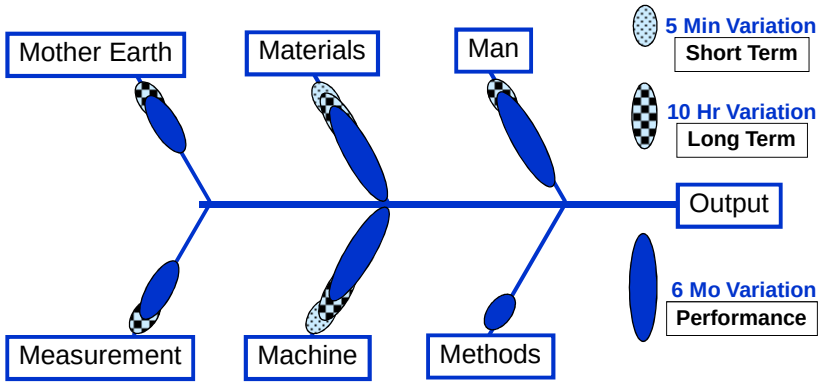
$$C_{pL} = \frac{\bar{X} - LSL}{3\,s} \quad \textbf{or} \quad C_{pU} = \frac{USL - \bar{X}}{3\,s}$$

The Sources of Variation



Process Capability

Long Term vs. Short Term Variation



Measurement

Measurement Systems Analysis (MSA)

- Gage Repeatability & Reproducibility (GR&R)

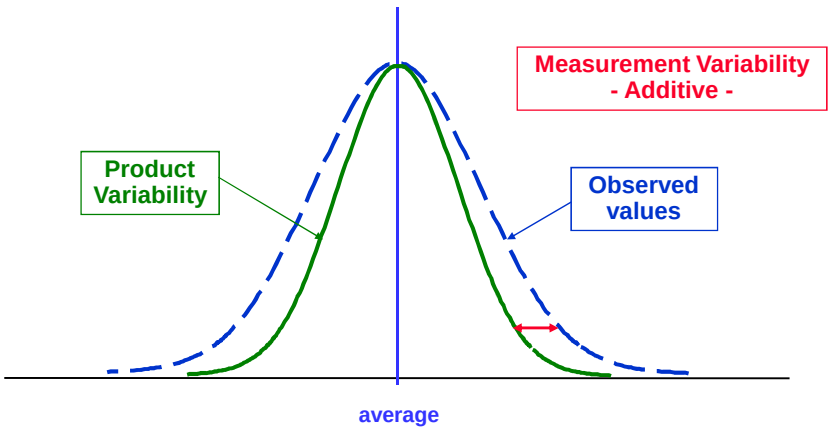
Variable GR&R

- Understand capability of measurement
  - Percent of Contribution – Variance
  - Percent of Study – Std Dev
  - Percent of Tolerance (P/T Ratio) ****
  - Effect of sample selection
  - <10% acceptable
  - 10-30% marginal
  - >30% high risk

Variable Gage R&R

$$\sigma^2_{total} = \sigma^2_{product} + \sigma^2_{measurement\ system}$$

Observed Variability = **Product Variability** + **Measurement Variability**

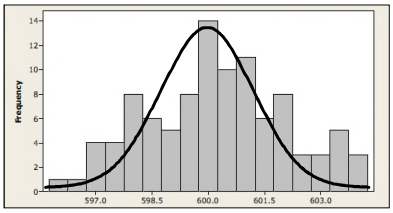


Basic Statistics… Distributions

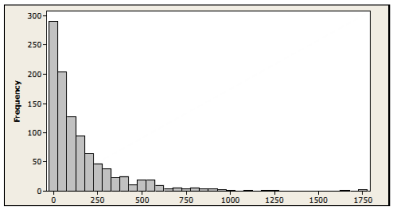
Distributions:

- Not all distributions are Normal
- Exponential Distribution is common for one-sided specs
  - Flatness – PPB – many other
- Predictive statistics require Normal Distributions

Normal Distribution – not perfect



Exponential Distribution



Central Limit Theorem

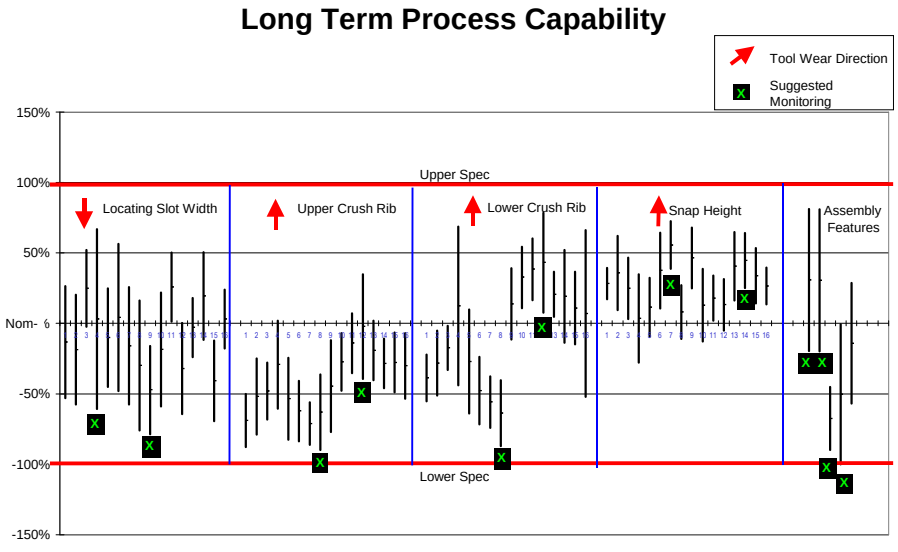
Concept

- The sample mean become normally distributed as sample size increases
- The spread of the sample means are less than the spread of the individuals of the sample

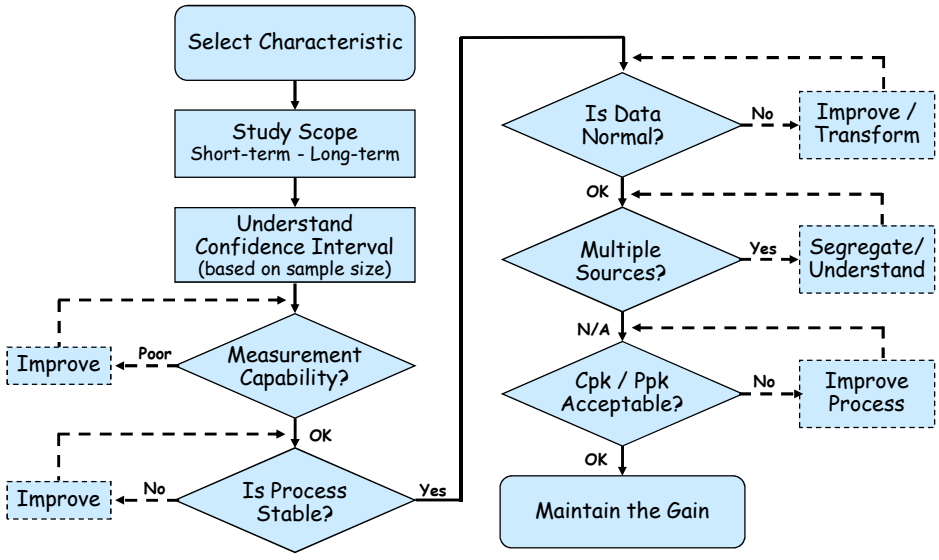
Value

- Non-normal distributions can be assessed using normal distribution statistics and tools (Cpk, SPC, etc.)
- Most inferential statistical tools assume normality of data
  - Confidence Intervals
  - SPC / Control Charts

Understand Your Process



Process Capability Roadmap



Conducting Capability Studies

Preparation:

- Select 'critical to customer' characteristics
- Assure validity of specifications
- Assure capability of measurement system (GR&R & P/T)
- Assure process stability at time of study – document ?
- Study Run / Data Collection (sampling plan)
  - Process Potential – 30+ Consecutive Pieces
    - Cannot truly calculate Ppk or predict long term performance
  - Short Term Study – n=5 for a day (20 groups of n)
    - Ppk statistics used to predict long term performance
  - Long Term Study – extract data from ongoing SPC
    - Cpk and Ppk values will effectively be the same – actual long-term

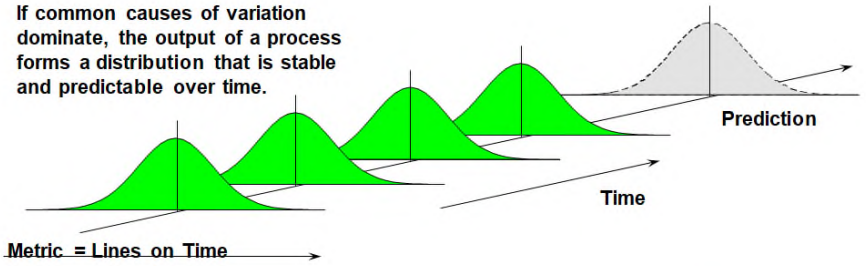
Conducting Capability Studies

Analysis / Action:

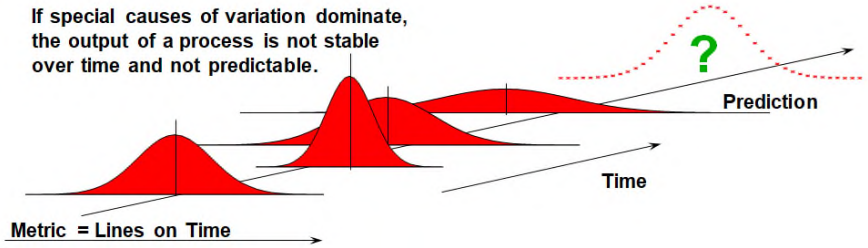
- Process data – include specification
- Check stability – run chart analysis
- Check normality – visual, probability plot, statistic
- **THEN**
- Determine Cpk & Ppk as appropriate
  - Must understand process conditions and limitations
  - Ppk is an estimate
- Determine actions to improve or maintain

Stability

If common causes of variation dominate, the output of a process forms a distribution that is stable and predictable over time.



If special causes of variation dominate, the output of a process is not stable over time and not predictable.



Stability & Normality

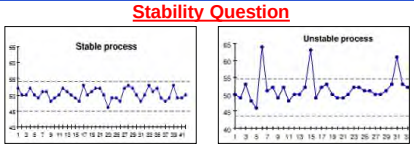
Stability

- Without stability, cannot use data as a predictor of future
- Special Causes create instability – removal for study?

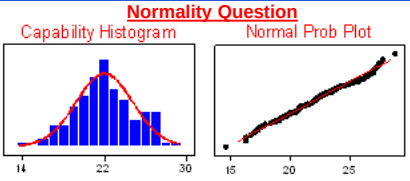
Normality:

- Calculations are based on Normal Distribution
- Further from 'normal' less accurate → totally invalid
- Calculation Tests (p-value) & Probability Plotting

Stability Question



Normality Question

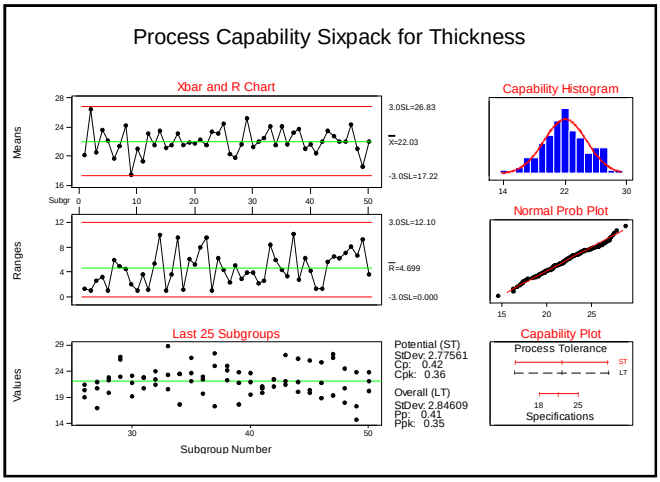


Minitab Capability Sixpack

Is it in control? (stable)

Is it in control? (stable)

What do the last 25 groups look like?

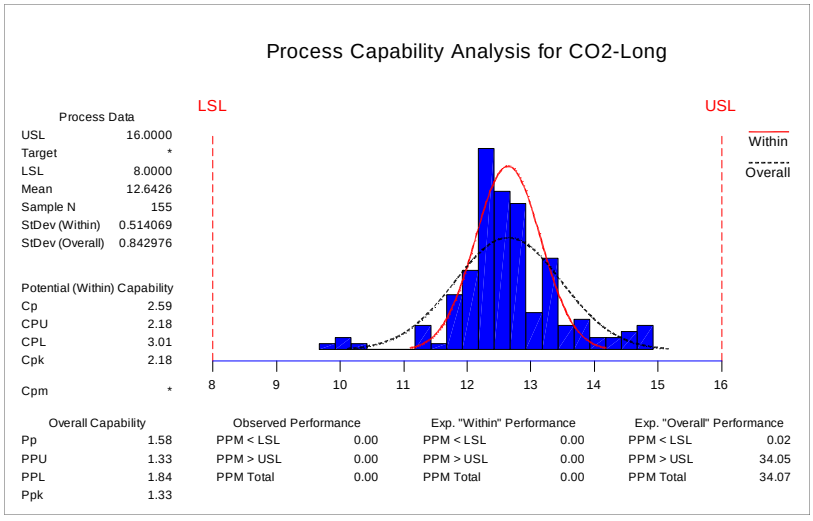


Is it Normal?

Is It Normal?

How does the process variation compare to the spec limits?

Minitab Capability Summary



Process Data	
USL	16.0000
Target	*
LSL	8.0000
Mean	12.6426
Sample N	155
StDev (Within)	0.514069
StDev (Overall)	0.842976

Potential (Within) Capability	
Cp	2.59
CPU	2.18
CPL	3.01
Cpk	2.18
Cpm	*

Overall Capability		Observed Performance		Exp. "Within" Performance		Exp. "Overall" Performance	
Pp	1.58	PPM < LSL	0.00	PPM < LSL	0.00	PPM < LSL	0.02
PPU	1.33	PPM > USL	0.00	PPM > USL	0.00	PPM > USL	34.05
PPL	1.84	PPM Total	0.00	PPM Total	0.00	PPM Total	34.07
Ppk	1.33						

Process Capability

Process Capability rule of thumb:

- Cpk > 1.50 Process is Six Sigma
- Cpk > 1.00 All Product Meets Requirements
- Cpk = 1.00 Most Product Meets Requirements
- Cpk < 1.00 Some Product Does Not Meet Requirements
- Ppk typically 0.33 less than Cpk

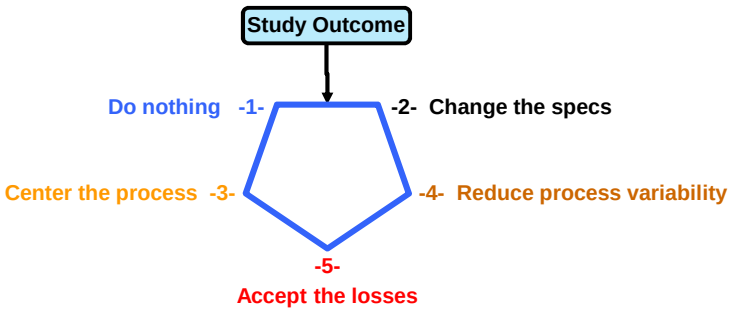
What are YOUR standards for Cpk ?
What is difference between Cpk & Ppk in YOUR PROCESSES?

Note: Above calculates take in 1.5 σ shift of mean over time

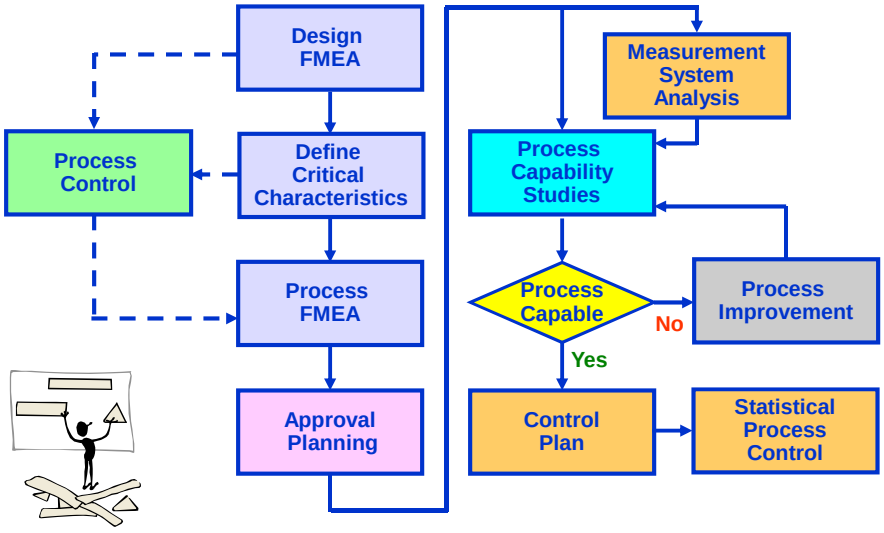
Process Capability

Objective of Process Capability Analysis

- Determine how the natural process limits compare with the specification range
- Depending on the comparison to standard:



Statistical Thinking Map



John Breckline

Retired but…
Motorola: Auto Electronics, Commercial, Telecom (pagers)
Nokia: MBB / Continuous Improvement Manager
AT&T: MBB – Transactional / Lean Projects
ASQ Certifications: CQE (87), CBB (03), CSQP (17)
Certification Preparation Instructor since 1997
30+ years in Quality Disciplines

- Inspection, Sampling, Data Systems
- SPC, Measurement, Supplier Quality
- Quality Systems Management
- Six Sigma Master Black Belt

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