Introduction to Process Capability

Indianapolis ASQ Online Speaker Meeting

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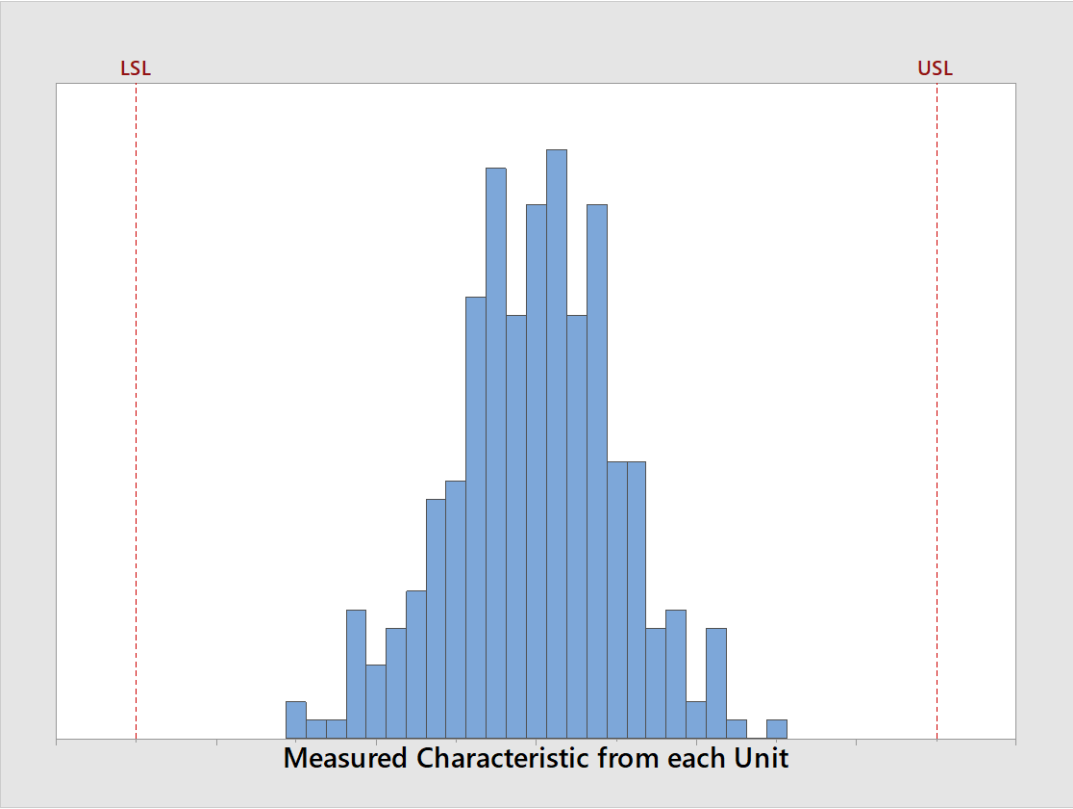
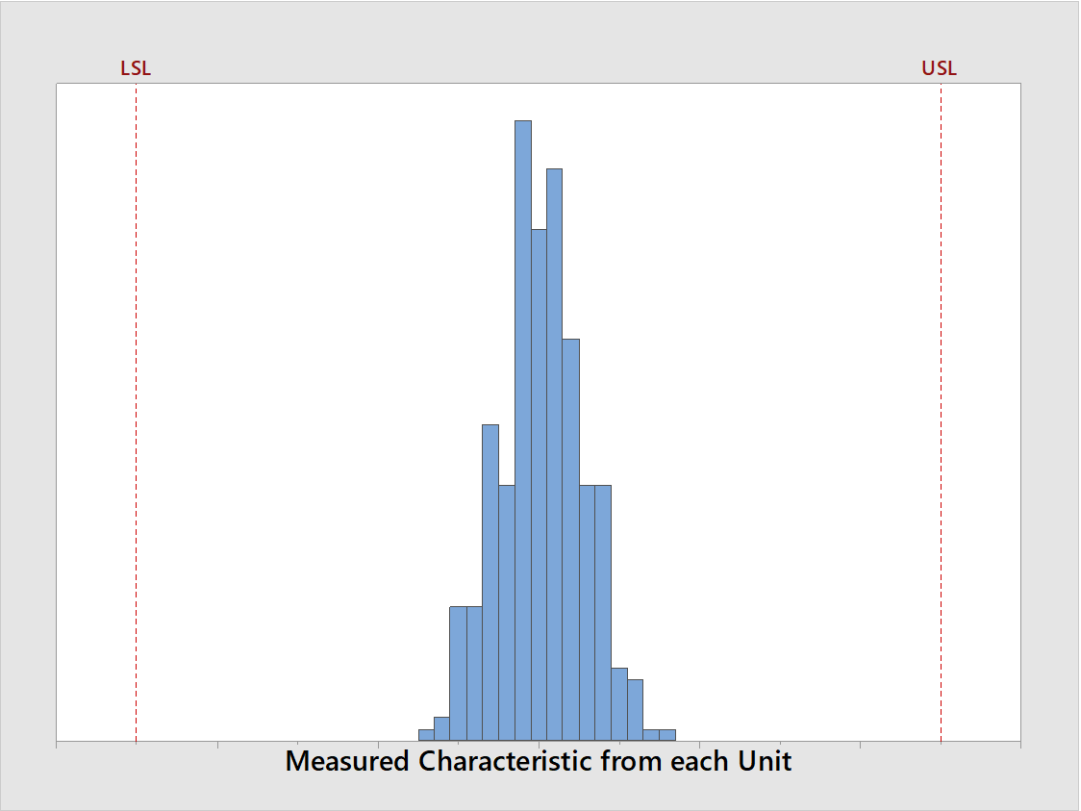
Agenda

- Basic concept of process capability and why it is important
- Generating process capability data
- Calculating and interpreting Cp and Cpk
- Process Capability (Cp, Cpk) versus Process Performance (Pp, Ppk)
- Examples

What is Process Capability?

Ability of a product or service generated by a stable, predictable process to meet a specification





Why Assess Process Capability?

Poor process capability implies …

unacceptably high nonconformance, which implies …

poor quality of product or service, which leads to …

high internal costs and

customer dissatisfaction, which leads to …

going out of business!

Business customers in supply chains demand it …

before they will become your customer

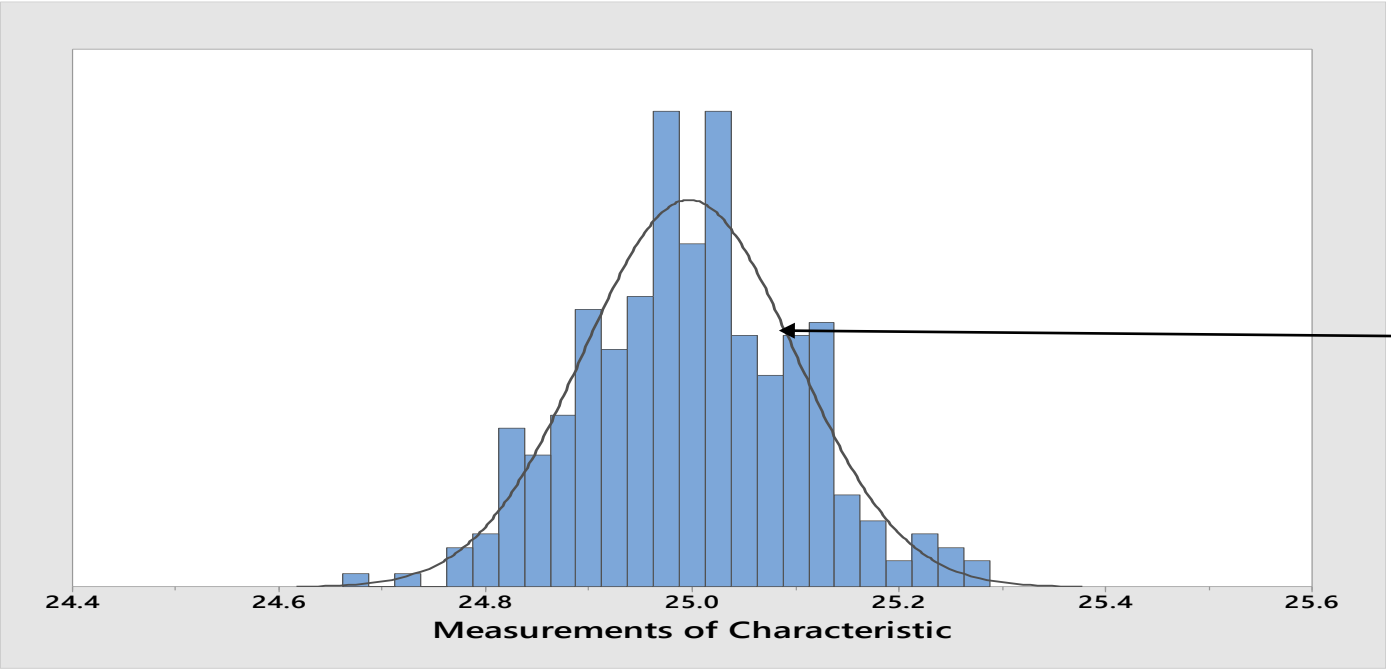
Generating Process Capability Data

Steps	Manufactured Product		Service	
Characteristic	Part diameter		Time to check out of self-scan line during store visit	
Specification	25 ± 0.5 mm		≤ 5 minutes	
Routine Sampling	N units/lot		N visits/week	
Generate Data	Go/No-go gauge (Attributes data)	Measure diameter (Variables data)	Yes/No (Attribute data)	Record check-out time (Variables data)

Capability can be assessed for:

- manufactured products or services
- 2-sided or 1-sided specifications
- attributes data or variables data

Variables Data: Normal Distribution



Fitted normal distribution

μ Process Mean

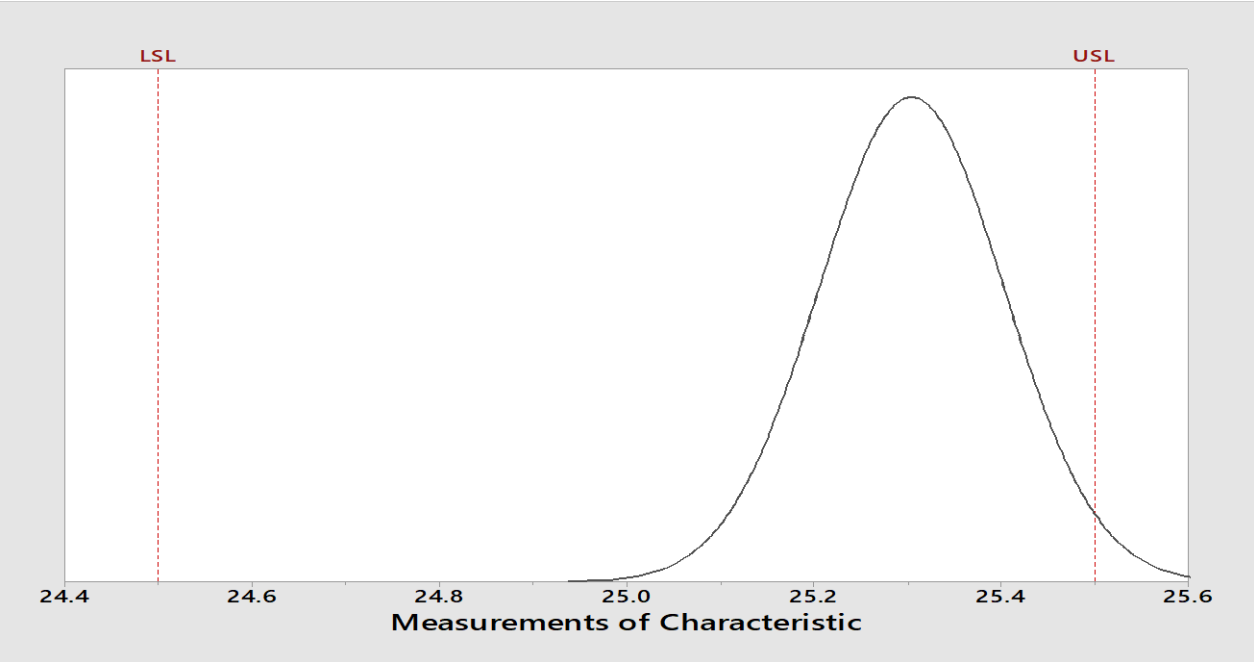
σ Process Sigma

$\mu \pm 1\sigma$ 67% of measurements

$\mu \pm 2\sigma$ 95% of measurements

$\mu \pm 3\sigma$ 99.7% of measurements (actual process spread)

Potential Process Capability: Cp



$$C_p = \frac{Allowable\ process\ spread}{Actual\ process\ spread} = \frac{USL - LSL}{6\,\sigma}$$

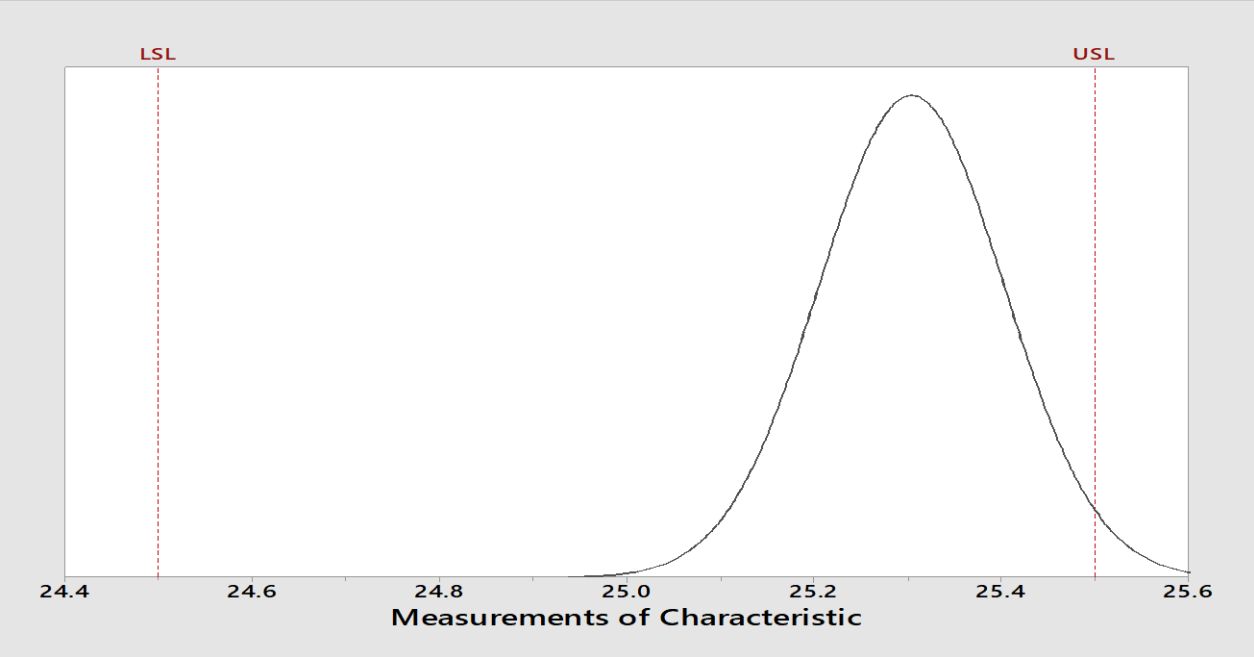
Allowable process spread

Actual process spread

C_p

- Higher is better
- Does not depend on the location of the distribution
- Measures potential capability
- Cannot be calculated for 1-sided specification

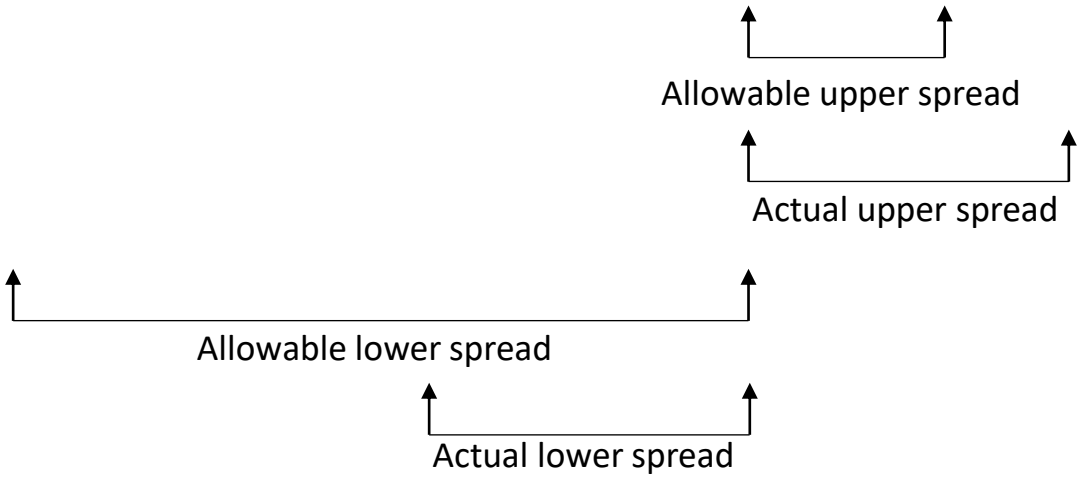
Realized Process Capability: Cpk



$$C_{pu} = \frac{Allowable\ upper\ process\ spread}{Actual\ upper\ process\ spread} = \frac{USL - \mu}{3\,\sigma}$$

$$C_{pl} = \frac{Allowable\ lower\ process\ spread}{Actual\ lower\ process\ spread} = \frac{\mu - LSL}{3\,\sigma}$$

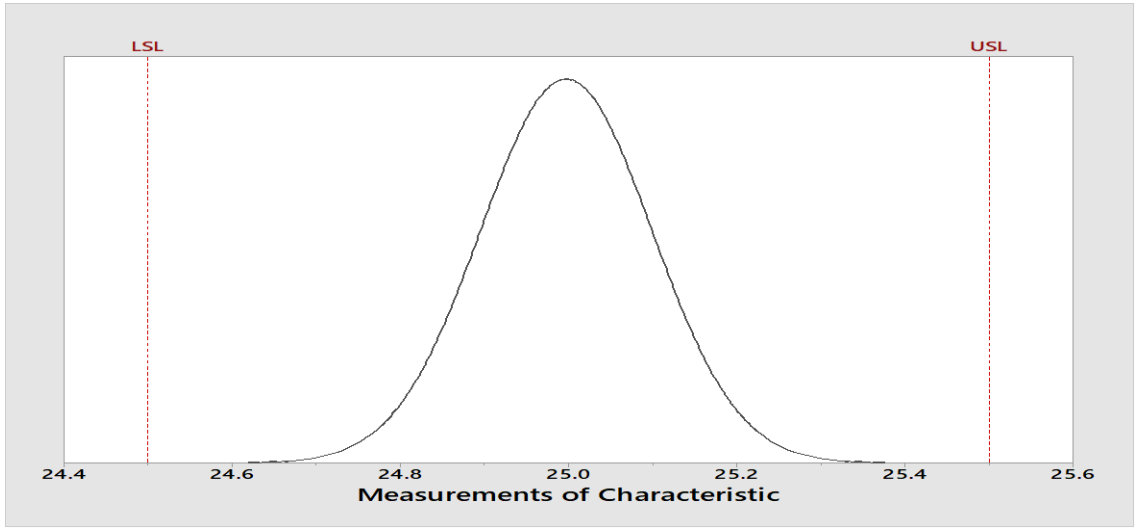
$$C_{pk} = Min\,(C_{pu}\,,\,C_{pl})$$



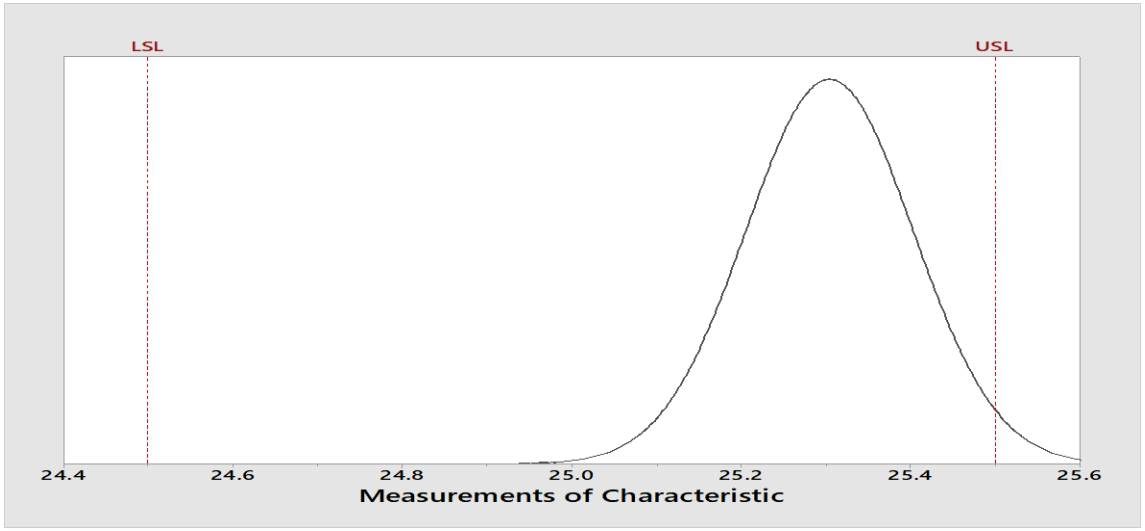
C_{pk}

- Higher is better
- 1-sided or 2-sided specifications
- Does depend on the location of the distribution
- Measures realized capability
- Tied to nonconformance rate (% OOS or PPM) relative to the nearest specification

Interpreting Cp and Cpk



Cp = 1.64
Cpk = 1.63



Cp = 1.69
Cpk = 0.66

Cp measures potential capability
Cpk measures realized capability

Cpk	% OOS (nearest spec)	PPM (nearest spec)
0.67	2.2%	22,216
1.00	0.13%	1350
1.33	0.0033%	33
1.50	0.00034%	3.4
1.67	0.000027%	0.27
2.00	0.0000001%	0.001

min

Process Capability vs. Process Performance

Process Capability

- Routine process monitoring
- Requires a stable and predictable process
- Good predictor of future capability
- Cp, Cpk based on within-subgroup estimate of "process σ" from control charts

Process Performance

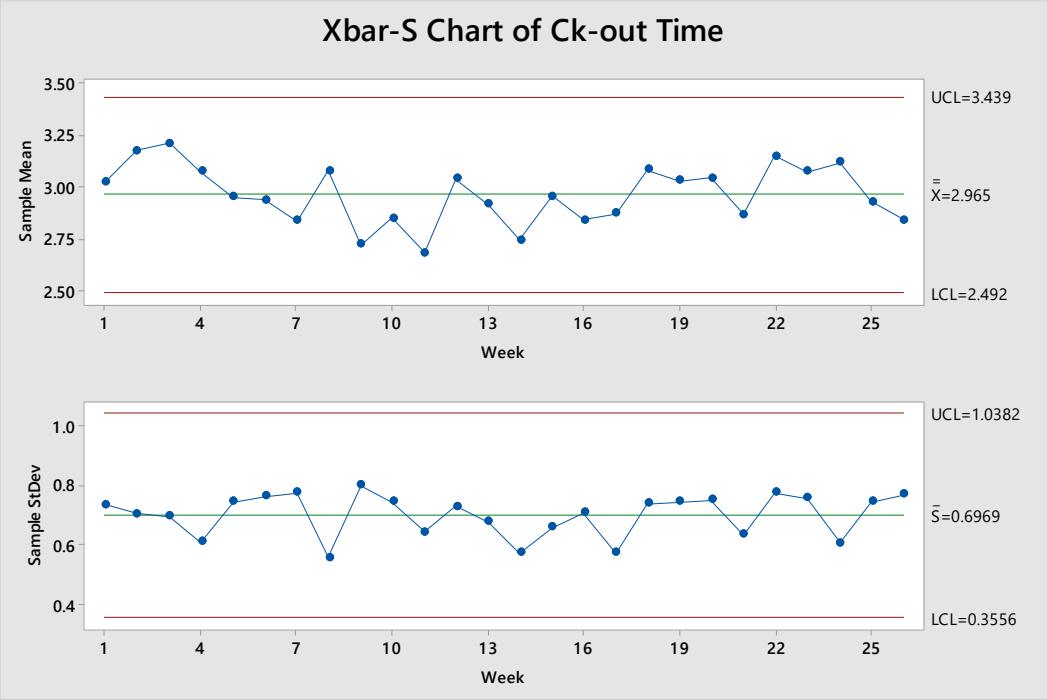
- Preliminary capability studies and sometimes routine process monitoring
- Does not require a stable predictable process
- Not necessarily a good predictor of future capability
- Pp, Ppk based on overall standard deviation as an estimate of "process σ"

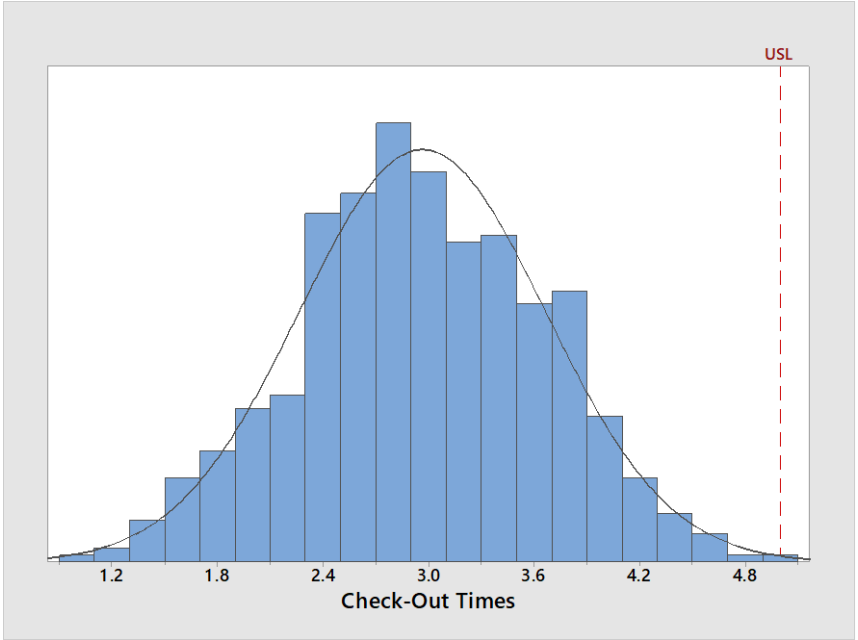
If stable predictable process, Cp, Cpk $\cong$ Pp, Ppk

Example: Check-Out Time for Self-Scan Line

Routine monitoring: Measure check-out times (minutes) for 20 visits/week for 26 weeks

Specification: ≤ 5 minutes





C_p

$$C_{pk} = Min(Cpu, Cpl)$$

$$= \frac{USL - \mu}{3\,\sigma}$$

$$C_{pk} = 0.97$$

Process stable and predictable (i.e. in statistical control)? Yes

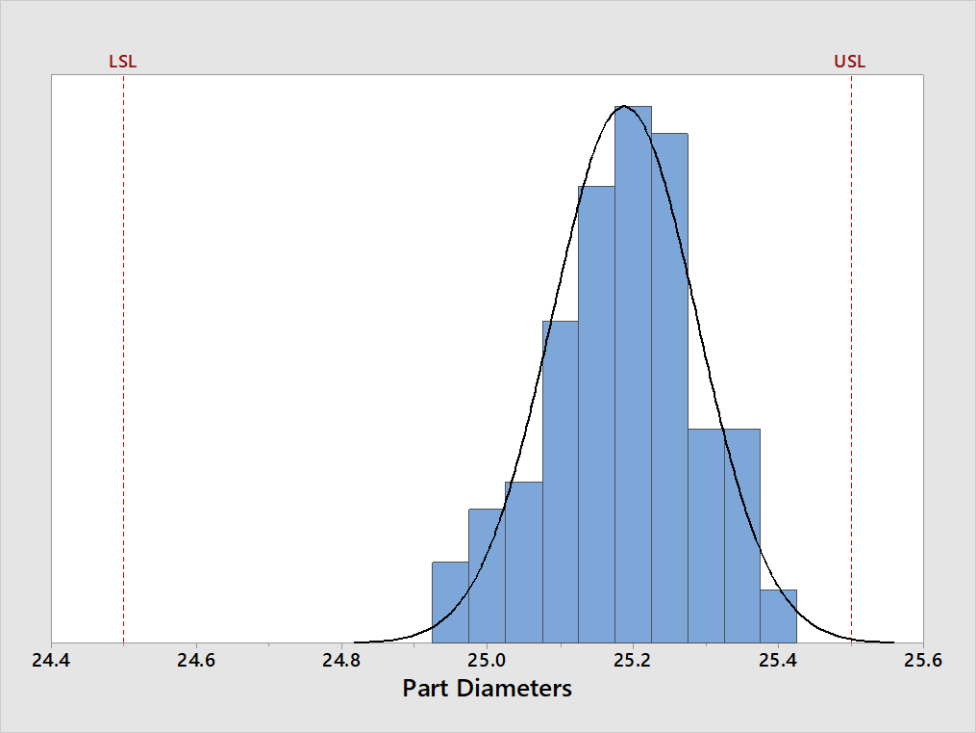
Estimated process μ 2.9653 minutes = $\bar{\bar{X}}$

Estimated process σ 0.700706 minutes = $\frac{\bar{S}}{c_4}$

% OOS = 0.18% or 1843 PPM

Example: Preliminary Capability Study for Part Diameter

Preliminary Capability Study: Measure diameter of 100 parts
Specification: 25 ± 0.5 mm



$$P_p = \frac{USL - LSL}{6\,\sigma} = 1.67$$

$$P_{pk} = Min\left(\frac{USL - \mu}{3\,\sigma}, \frac{\mu - LSL}{3\,\sigma}\right) = 1.04$$

P_p and $P_{pk} \geq 1.67$ considered acceptable

Conclusion: Center distribution before starting production

Estimated process μ	25.1882 mm = sample mean of all 100 results
Estimated process σ	0.0997664 mm = sample standard deviation of all 100 results

Summary

- Process capability is the ability of a product or service generated by a stable, predictable process to meet a specification
- Important quality tool
- Process capability data can be generated in a variety of situations
- Normal distribution
- Cp, Cpk are for stable, predictable processes monitored via control charts
- Pp, Ppk are primarily for preliminary capability studies

Additional Topics on Process Capability

- Confidence intervals for capability indices
- Handling non-normal variables data
- Capability indices that incorporate a target
- Capability indices for processes that are not stable and predictable