Six Sigma – Week 13

John Fico, Adjunct Professor
Fall 2020

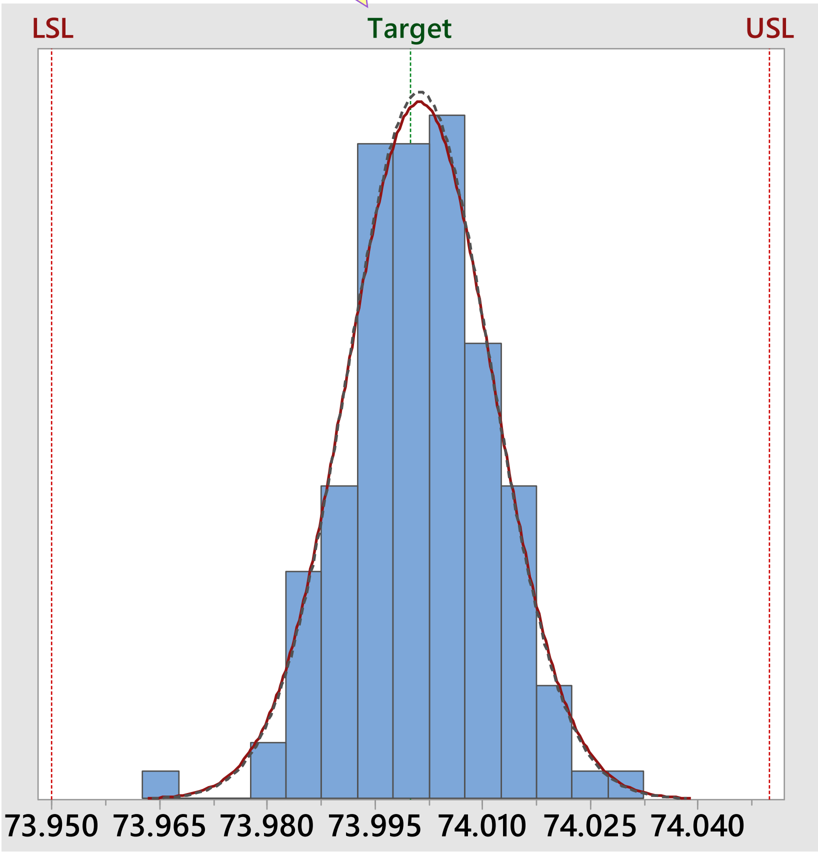
Agenda

- ✓ Week 12
  - ✓ (11/5): Multiple linear regression – work on homework in class
  - ✓ (11/7): Binary logistic regression; start process capability
- Week 13
  - (11/12): Work on Case Study 2
  - (11/14): Process capability
- Week 14
  - (11/19): Process capability and control charts
  - (11/21): Work on final team projects
- Week 15
  - (11/26): Final team project presentations
  - (11/28): No class – Happy Thanksgiving
- Week 16
  - (12/3): Topic review (last day of class)
- Final Exam Week
  - (12/10): Final exam – 6:30pm-8:30pm – IST 1065

Process Capability

- Early in any project, it is important to understand current level of performance (current state) of a process prior to making changes
- Primary purpose of establishing current performance level is to ensure that gains attained are sustained after improvements are in place
- Process capability
  - is the assessment of how well a process delivers what the customer wants
  - refers to a range of Key Process Indicators (metrics) that measure ability of a process to deliver customer requirements
  - is comparison of Voice of Customer (VOC) to Voice of Process (VOP) – LSSM text page 82
    - VOC: Range between lower and upper specification limits
    - VOP: total variation in a process (affecting width of histogram)

Example:
Piston ring diameters
(millimeters)



Process Capability

- Conducting capability studies
- Data collection – ensure data was recorded in time sequence
  - Have data reflect the long and short-term performance of the process
    - Common approach is to collect small samples (subgroups) to reflect short-term
    - Repeat this sampling at specific intervals to capture longer-term variation in process
      - Short term
        - Potential (within) capability – short term variation of process – how good the process could be
        - Overall capability – long term variation of process

Process Capability – Attribute Data

- Process capability is one of many performance metrics
  - Attribute data – measured in Defects per Unit (DPU)
    - DPU = Total Number of Defects / Total Number of Units (Examples: incomplete shipment, typographical error on an invoice)
    - DPMO = Defects per Million Opportunities
      - DPMO = (Total Number of Defects / (No. of Units) x (No. of Opportunities)) x 1,000,000
    - DPMO accounts for process complexity (Example: purchase orders – Opportunities = No. of critical fields x 2 because field can be either empty or incorrect
    - DPMO is used to calculate process Sigma Value – Six Sigma is 3.4 defects per million opportunities

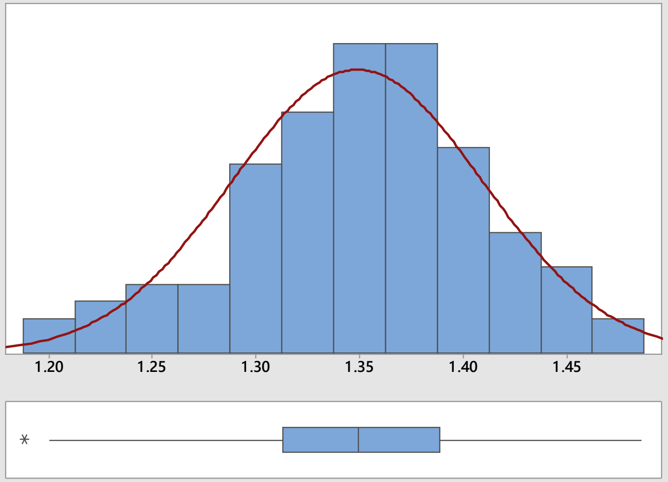
Process Capability – Continuous Data

- Process capability is one of many performance metrics
  - Continuous data – Sigma Value is primary common metric (There are other measures such as Cp, Cpk, Pp and Ppk)
  - Fundamental equation for process capability for continuous data
    - Cp = Upper Specification Limit (USL) – Lower Specification Limit (LSL) / 6s
      - s is short-term process standard deviation
- With so many different process capability metrics available, Six Sigma aimed to create one common metric applies to all data worlds and environments – the Sigma Level (LSSM text page 93)
- For our class objectives, we will focus on calculating ***Sigma Level***
- Two key advantages of using *Sigma Level*
  - Common capability measure that allows processes to be benchmarked against each other across different industries, technologies and data worlds (***Z.Bench*** in Minitab)
  - Scale is not linear – Sigma values have increasing resolution at low defect levels
    - Example: the difference between 99.8% and 99.9% can be reflected more easily and resulting impact

LSSM Text: Process Capability (Normal Data)

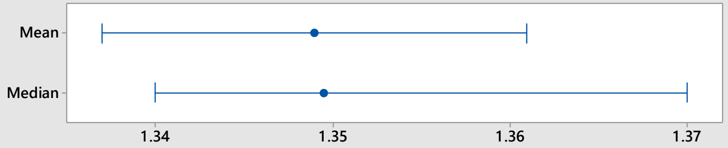
Example: A CD manufacturer has had problems producing CDs within the maximum thickness specification of 1.5mm. They are testing a new production machine that they hope will produce better CD products.

Summary Report for CD Thickness (mm)



Anderson-Darling Normality Test	
A-Squared	0.30
P-Value	0.572
Mean	1.3489
StDev	0.0604
Variance	0.0037
Skewness	-0.280859
Kurtosis	0.078033
N	100
Minimum	1.1880
1st Quartile	1.3130
Median	1.3495
3rd Quartile	1.3890
Maximum	1.4860
95% Confidence Interval for Mean	
1.3370	1.3609
95% Confidence Interval for Median	
1.3400	1.3700
95% Confidence Interval for StDev	
0.0531	0.0702

95% Confidence Intervals

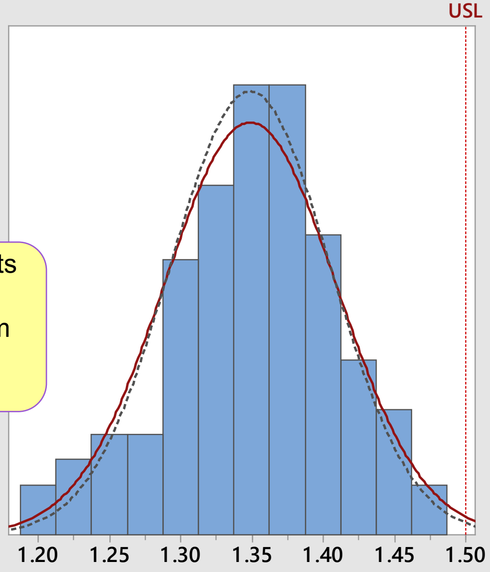


Process Capability Report for CD Thickness (mm)

Process Data	
LSL	*
Target	*
USL	1.5
Sample Mean	1.34895
Sample N	100
StDev(Overall)	0.0604359
StDev(Within)	0.0562182

Z Bench of 2.50 predicts 0.6% of CDs will fall outside spec limit (from Z table – back cover Text 2)

Overall capability = long term
Within capability = short term



Overall
Within

Overall Capability	
Z.Bench	2.50
Z.LSL	*
Z.USL	2.50
Ppk	0.83
Cpm	*
Potential (Within) Capability	
Z.Bench	2.69
Z.LSL	*
Z.USL	2.69
Cpk	0.90

Refer to LSSM text pages 93-94 for coverage of Sigma levels.

Performance	Observed	Expected Overall	Expected Within
% < LSL	*	*	*
% > USL	0.00	0.62	0.36
% Total	0.00	0.62	0.36

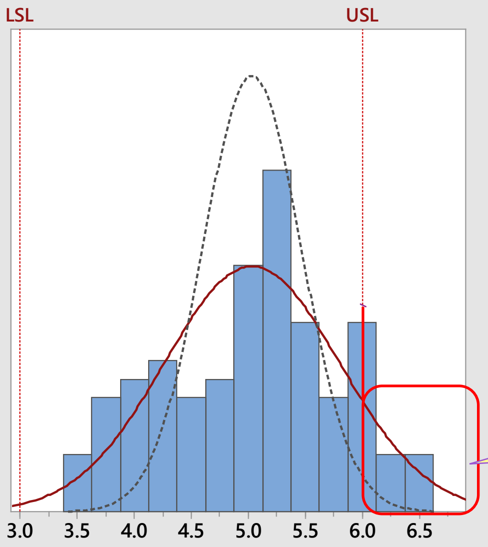
In this example:
Z Bench = Sigma Level =
(USL – Mean) / Standard Deviation
(1.5 – 1.35) / 0.06 = 2.5

LSSM Text: Process Capability (Normal Data)

Example: A project is looking at the time required for field teams to repair faults in air conditioning systems at customer sites. (5) consecutive repair tasks were sampled randomly every day for 20 days (so the data has natural subgroups within it)

Process Capability Report for Time to fix fault (decimal hrs)

Process Data	
LSL	3
Target	*
USL	6
Sample Mean	5.0333
Sample N	100
StDev(Overall)	0.770317
StDev(Within)	0.433805



Overall Capability	
Z.Bench	1.23
Z.LSL	2.64
Z.USL	1.25
Ppk	0.42
Cpm	*

Potential (Within) Capability	
Z.Bench	2.23
Z.LSL	4.69
Z.USL	2.23
Cpk	0.74

Performance

	Observed	Expected Overall	Expected Within
% < LSL	0.00	0.42	0.00
% > USL	11.00	10.48	1.29
% Total	11.00	10.89	1.29

No repairs were <3 hrs.
11/100 were >6 hrs., or 11%

Z bench values are used to describe the capability of the process, also known as the sigma capability of the process.

Z Bench = Sigma Level =
Distance (in std dev) between process average & USL

As the process moves farther away from the specification limit (to the left for USL), the Sigma Level (Z bench) will increase, and the proportion of products falling outside the control limits (the % defective) will decrease.

Higher Sigma Level = higher performance
See LSSM text Pages 93 & 94.

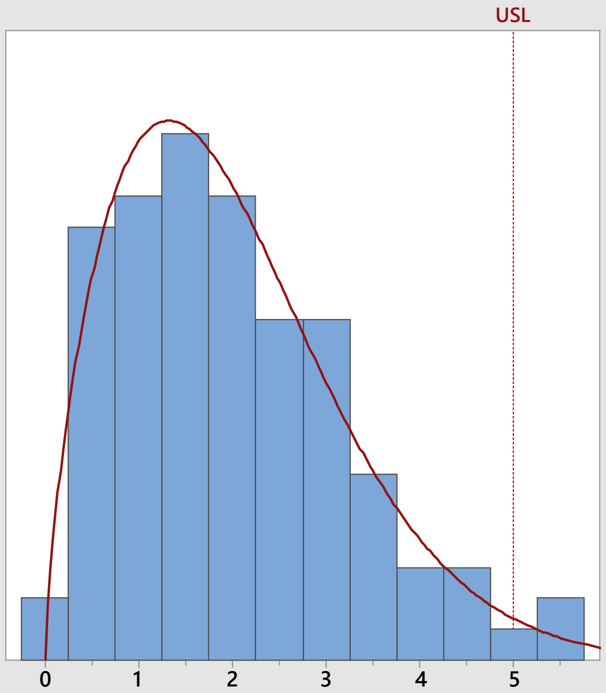
LSSM Text: Process Capability (Non-Normal Data)

Example: A project is looking at the amount of time that mortgage applications spend queuing between two critical steps in application process. Queue times of 100 mortgage applications are sampled from process over two month period (to represent short & long term data). Max acceptable queue time is 5 working hours. Project leader wants to understand process capability.

Process Capability Report for Queue Times
Calculations Based on Weibull Distribution Model

Process Data	
LSL	*
Target	*
USL	5
Sample Mean	1.99499
Sample N	100
Shape	1.69368
Scale	2.23732

Observed Performance	
% < LSL	*
% > USL	2.00
% Total	2.00



Overall Capability	
Z.Bench	2.05
Z.LSL	*
Z.USL	1.91
Ppk	0.64

Exp. Overall Performance	
% < LSL	*
% > USL	2.02
% Total	2.02

2 of 100 mortgage applications queue time >5 hrs. 2% exceeded USL

Z Bench = Sigma Level = Distance (in std dev) between process average & USL

Refer to pages 87 & 88 of LSSM text

Refer to LSSM text pages 191-192 to see how to select distribution for non-normal distributions (i.e. Weibull)