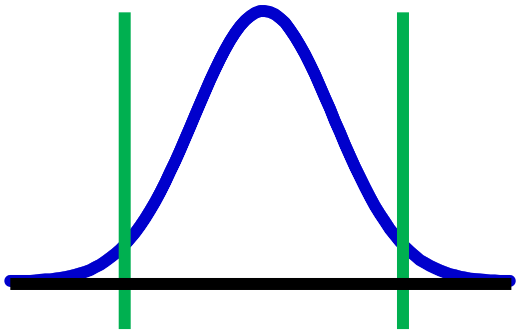
Continuous Improvement Toolkit

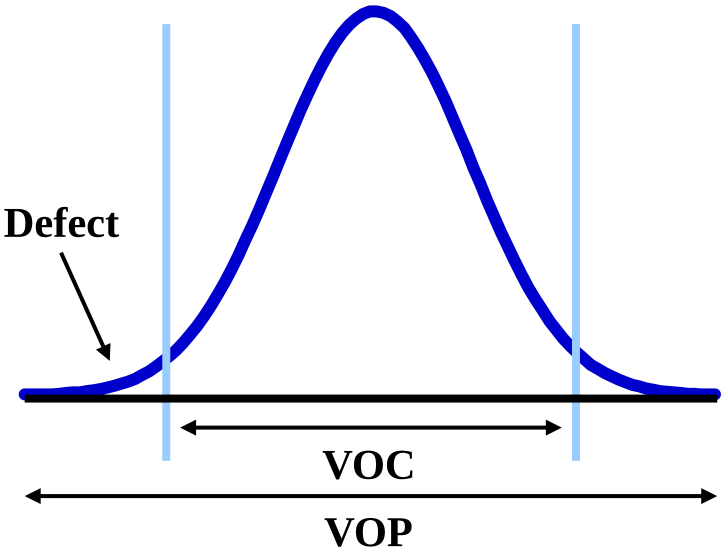
Capability Indices




Managing Risk
PDPC
FMEA
RAID Logs
Fault Tree Analysis
Risk Assessment*
Traffic Light Assessment
Deciding & Selecting
Pros and Cons
Importance-Urgency Mapping
Break-even Analysis
Cost -Benefit Analysis
Force Field Analysis
Voting
Pugh Matrix
Decision Tree
TPN Analysis
QFD
Matrix Diagram
Prioritization Matrix
Kano Analysis
Paired Comparison
Critical-to Tree
Planning & Project Management*
RACI Matrix
Stakeholders Analysis
PEST
PERT/CPM
Activity Diagram
SWOT
Roadmaps
Project Charter
Gantt Chart
PDCA
Control Planning
Gap Analysis
Hoshin Kanri
Kaizen
How-How Diagram
Tree Diagram**
Standard work
Lean Measures
KPIs
OEE
Capability Indices
Cause & Effect Matrix
Pareto Analysis
Simulation
TPM
Identifying & Implementing Solutions***
MSA
RTY
Descriptive Statistics
Confidence Intervals
Understanding Cause & Effect
Mistake Proofing
Cost of Quality
Probability Distributions
ANOVA
Pull Systems
JIT
Ergonomics
Reliability Analysis
Graphical Analysis
Hypothesis Testing
Design of Experiments
Work Balancing
Automation
Understanding Performance
Run Charts
Scatter Plot
Correlation
Regression
Bottleneck Analysis
Visual Management
Control Charts
5 Whys
Chi-Square Test
Multi-Vari Charts
Flow
Value Analysis
5S
Benchmarking
Fishbone Diagram
Relations Mapping*
Wastes Analysis
SMED
Sampling
TRIZ***
Focus groups
Interviews
Brainstorming
Analogy
SCAMPER***
Time Value Map
Process Redesign
Photography
Check Sheets
Nominal Group Technique
Mind Mapping*
IDEF0
Value Stream Mapping
SIPOC
Measles Charts
Surveys
Affinity Diagram
Attribute Analysis
Flow Process Chart
Process Mapping
Data Collection
Critical Incident Technique
Lateral Thinking
Visioning
Flowcharting
Service Blueprints
Observations
Creating Ideas**
Designing & Analyzing Processes

- Capability Indices

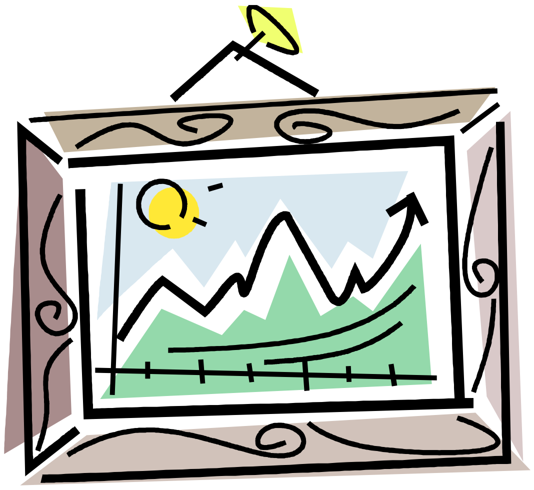
- A statistical tool that compares the actual process performance to the performance standards or design specifications.
- A measure of how well the process output (VOP) meets the customer requirements (VOC).
- Design specifications often are expressed as:
  - A target or a nominal value.
  - A tolerance or an allowance above or below the nominal value.



- Capability Indices

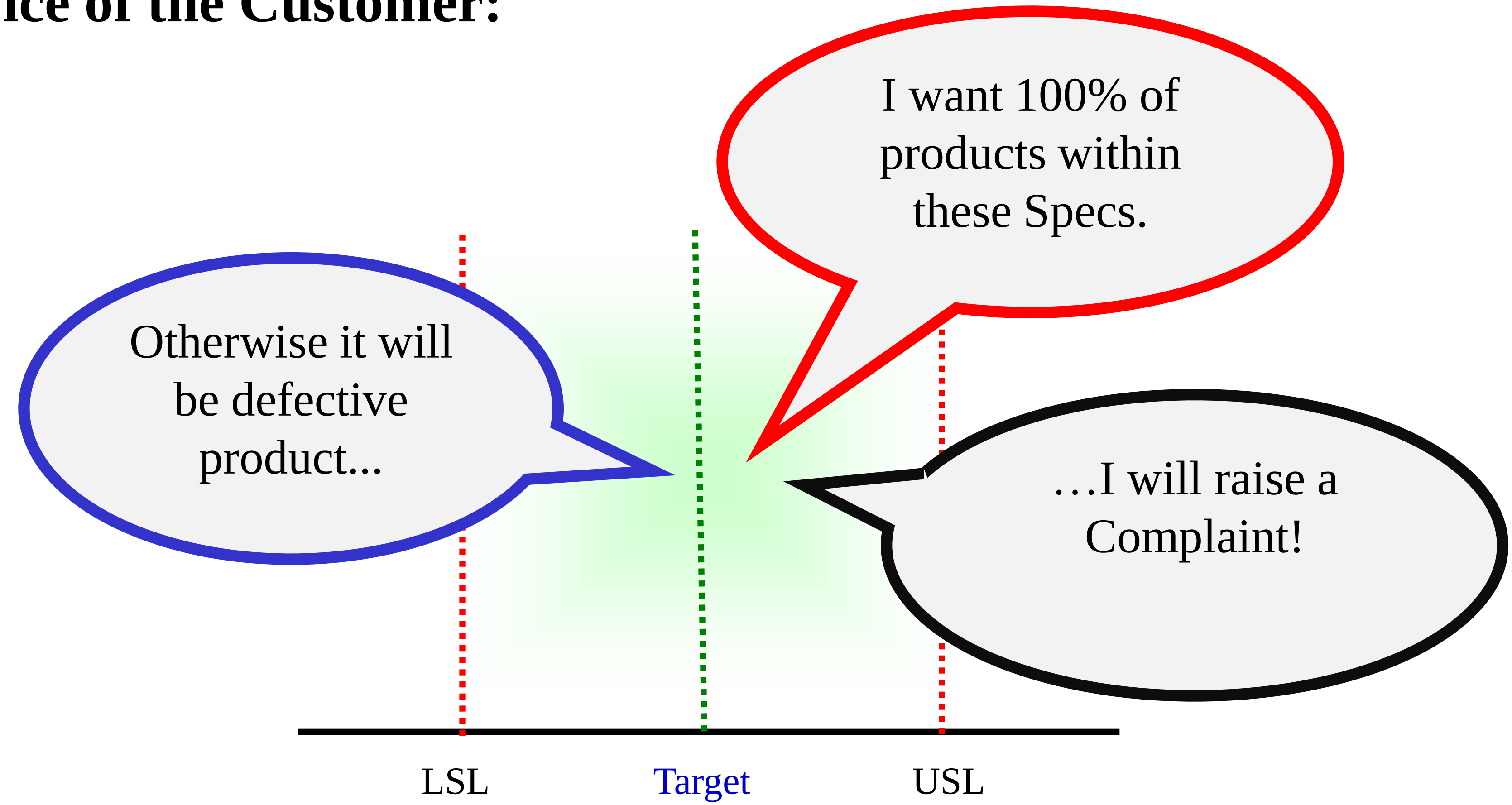
Why Process Capability?

- Provide a baseline measure of process performance.
- Monitors progress toward target.
- Gauges effectiveness of improvements.
- It is a key performance indicator (KPI) for Six Sigma projects.



- Capability Indices

Voice of the Customer:



- Capability Indices

Consequences of Defects:

- Scrap (Spoilage) is created.
- Rework is also created to correct the defect.
- Work that is required to adjust, correct, or modify the process.
- The customer wouldn’t be happy when he received the product (or service).

- Capability Indices

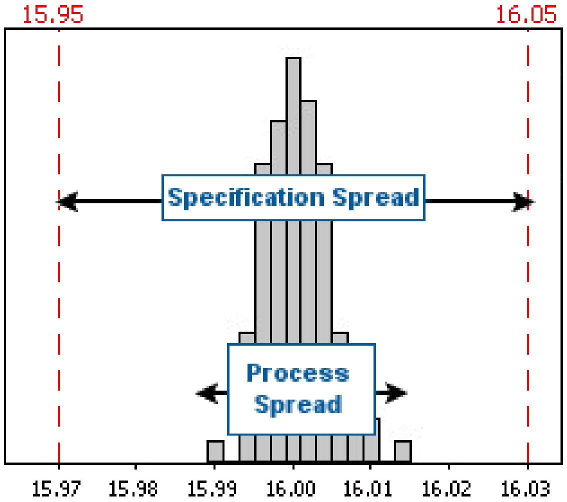
- **Question:** What causes the variation?
- **Answer:**
  - Poor understanding.
  - Poor training.
  - Poor monitoring.
  - Poor procedures.
  - Poor decision making.

The less variability, the less frequently bad output is produced

- Capability Indices

How Do We Determine if the Process is Meeting Specifications?

- **Graphical:**
  - If the process spread is smaller than or within the specification spread, the process is able to meet the specification.
- **Statistical:**
  - We use **Capability Indices** which incorporate the process spread and the specification into a single number.

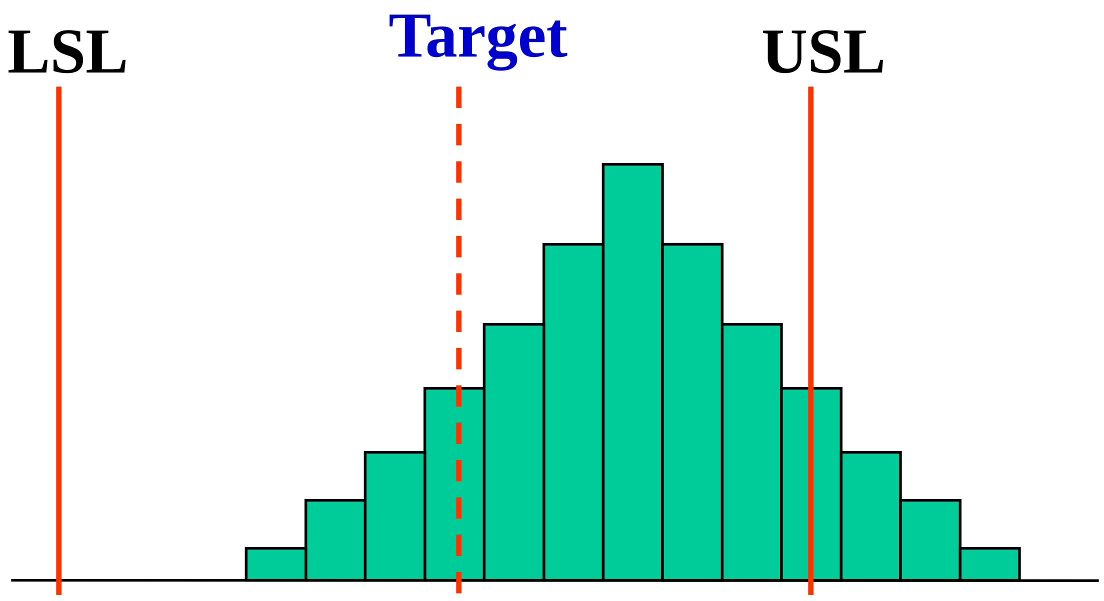


Specification spread is sometimes referred as **Tolerance**

- Capability Indices

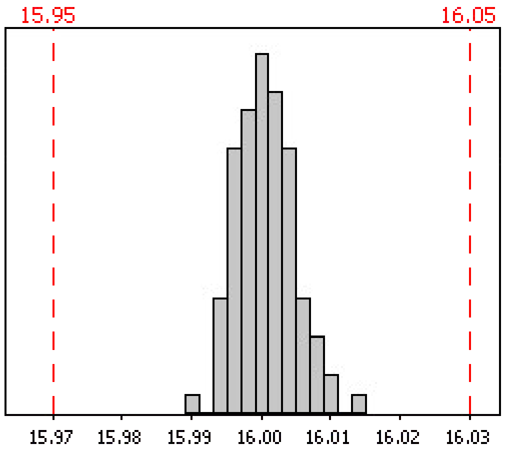
The Graphical Approach – We Use Histograms To:

- Compare process output against specification limits.
- Predict the percentage of “Out-of-Specification” production.



- Capability Indices

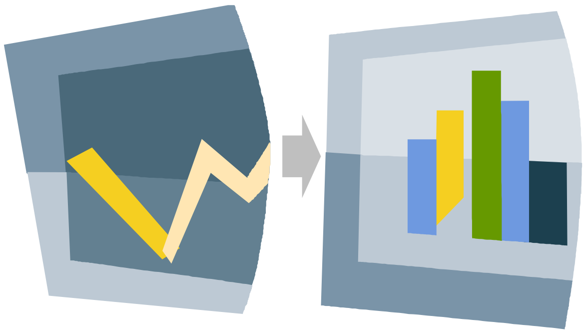
- The specification is the criteria used to decide if variability is acceptable.
- **Specification limits** are the minimum and maximum values that are acceptable.



- If the process is **stable**, this does not mean that it's meeting the specifications.
- A process is **capable** if it has a distribution whose extreme values fall within the specifications limit.

- Capability Indices

Measure of Variability:



- Where the output data shows a normal distribution, the process is described by:
  - The mean (x).
  - The standard deviation (s).
- A control chart analysis is used to determine whether the process in statistical control.
- If the process is not in statistical control then capability has no meaning.
- The more data included the more precise is the result.

- Capability Indices

Approach:

- Ensure that the process is in control (stable).
- Measure the variability of the process.
- Compare **graphically** that variability with a proposed specification (or product tolerance).
- Measure process capability using descriptive indices.
- If results are acceptable, monitor the output using the control charts, and document when necessary.
- If results are unacceptable, further explore the assignable causes to reduce the variation or centering the process distribution on the nominal value.

- Capability Indices

Assumptions:

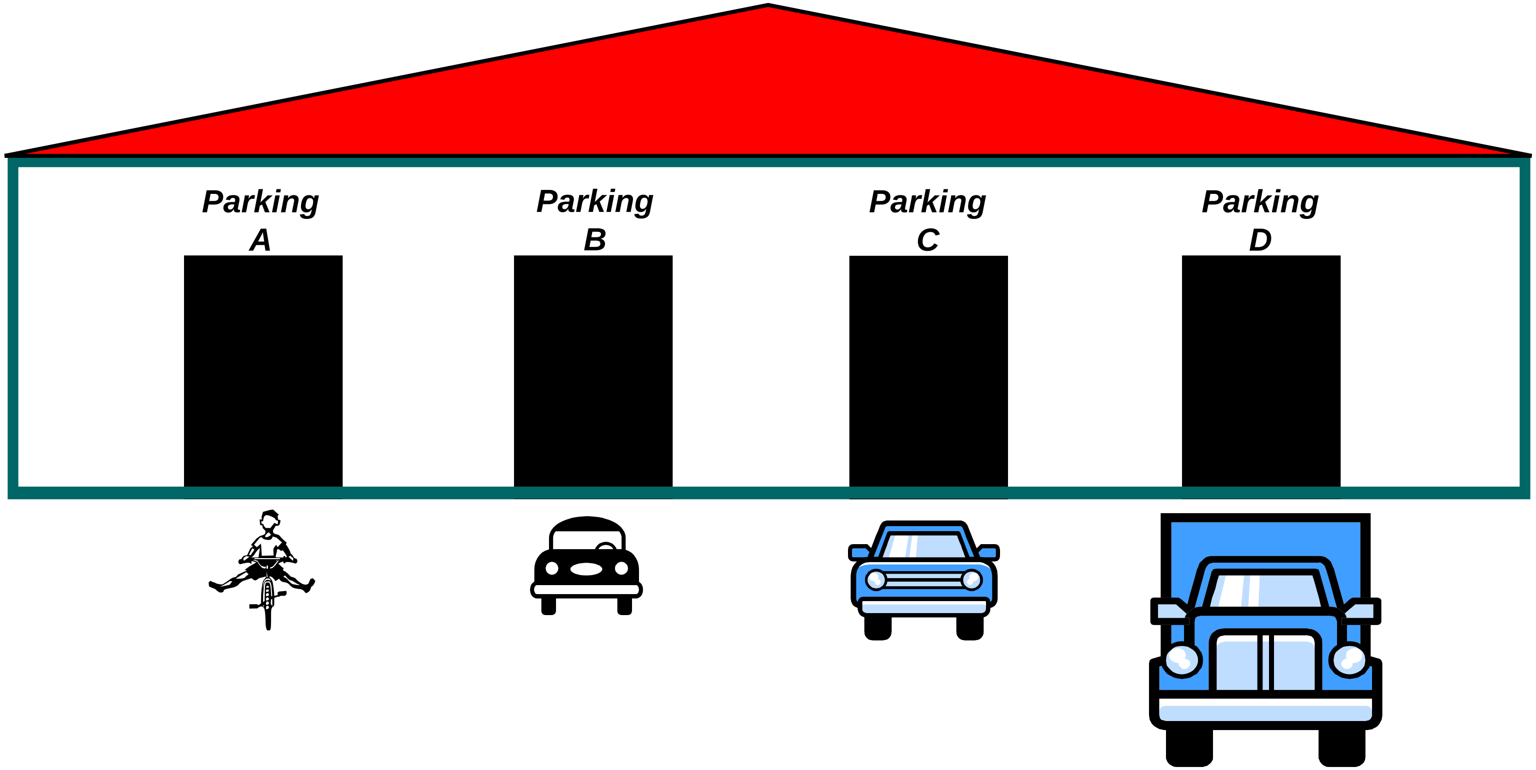
- The process is stable over time.
- The data is normally distributed.

If the data is non-normal:

- Transform the data and use normal capability tools.
- Use a different distribution that models the data.

- Capability Indices

- Can we park the vehicles with no problems?



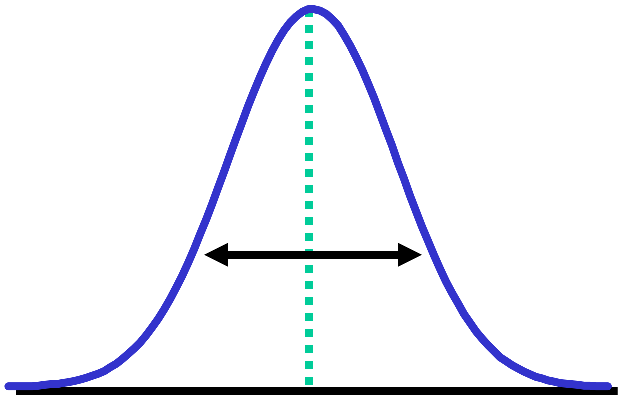
- Capability Indices

Capability Indices:

- Describe the overall effectiveness of a process in meeting specific criteria in both the short and long term.

Capability Indices includes:

- Percentage out of specification.
- Part per million out of specification (PPM).
- Potential capability (Cp and Cpk).
- Actual capability (Pp and PpK).
- Sigma value (Sigma level / Z bench).

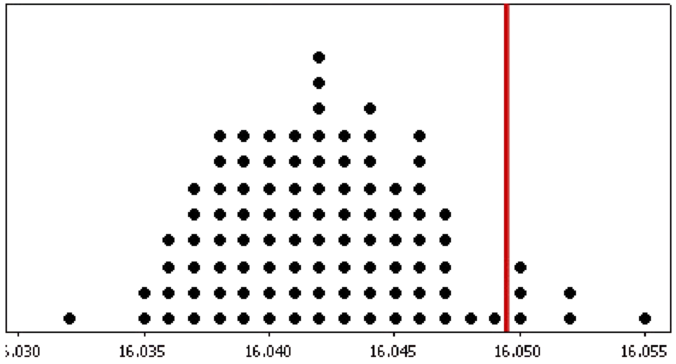


- Capability Indices

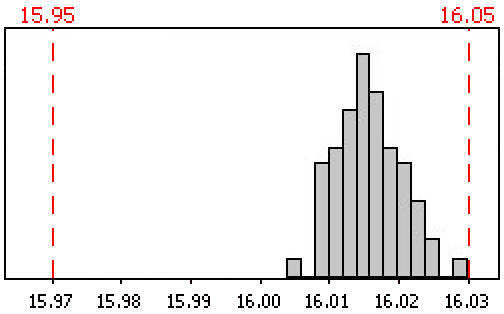
Part per Million:

- **Example:** What is the percentage out of specification in terms of part per million assuming that n = 100?

- **Answer:** 60,000 part per million are out of specification.



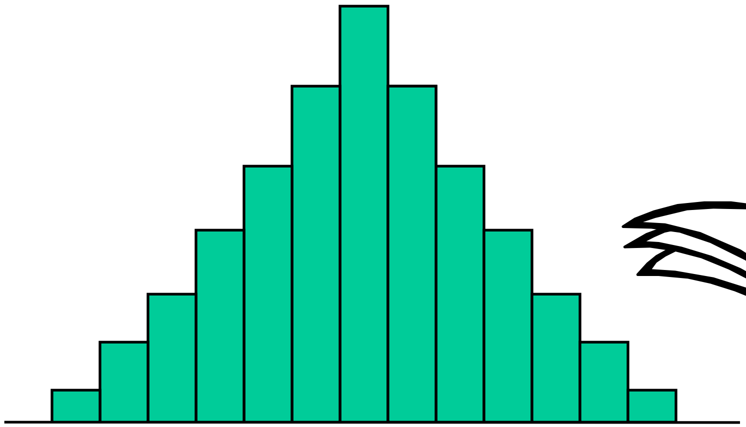
But what if the process looks like this?



- Capability Indices

Potential Capability (Cp & Cpk):

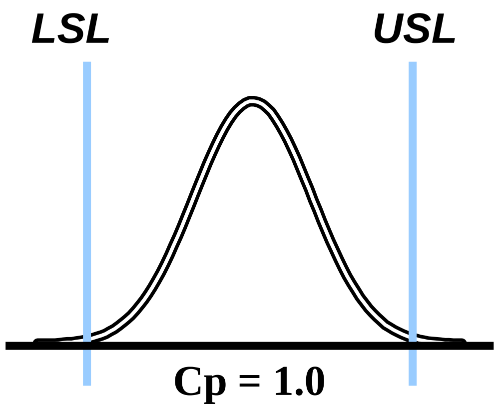
- Represent what the process would be capable of if it did not have shifts and drifts.
- Also known as "within" or "short-term" capability.



- Capability Indices

Cp:

- An index used to assess the width of the process spread in comparison to the width of the specification.
- The Cp states how many times the process can fit inside the specification.
- A Cp of 1 indicates that the width of the process and the width of the specification are the same.

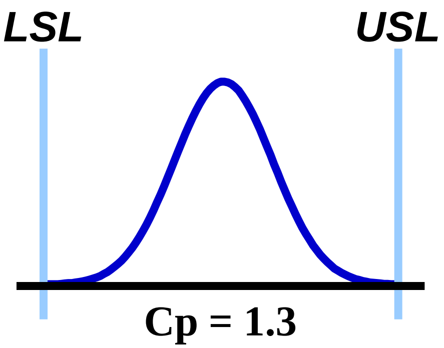


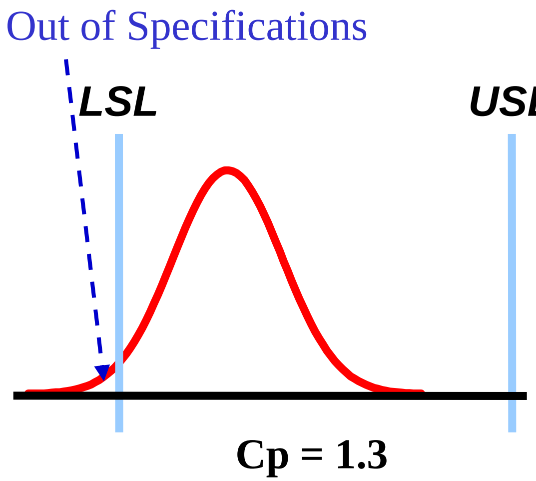
Cp = Allowed variation (spec.) / Normal variation of the process

$Cp = |USL - LSL| / 6\sigma$

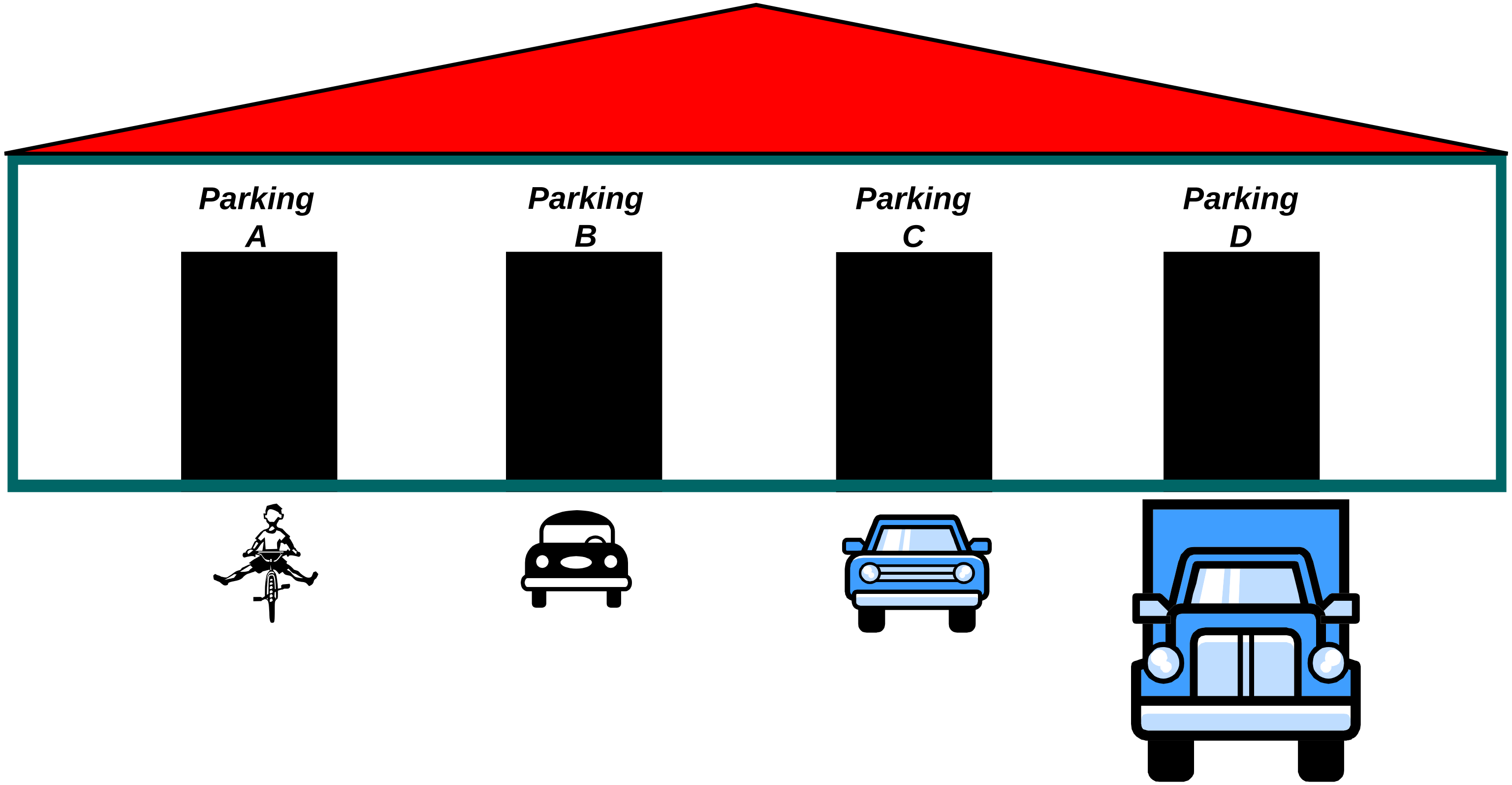
- Capability Indices

- A Cp of 1.3 means the process can fit inside the specification 1.3 times.
- Sometimes a Cp can be greater than one and yet still has data outside the specification.
- Cp takes no account of process settings.
- Use Cpk to overcome this problem.



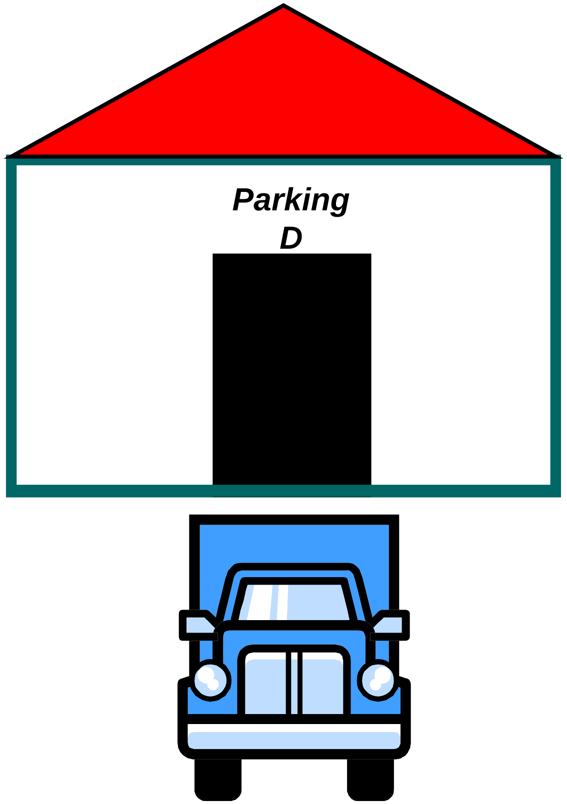


- Capability Indices



Cp = 2	**Cp = 1.33**	**Cp = 1**	**Cp = 0.67**
Very good	**Good**	**Regular**	**Bad**
Parking space double than vehicle	Parking space bigger than vehicle	Parking space same size of vehicle	Parking space smaller than vehicle

- Capability Indices



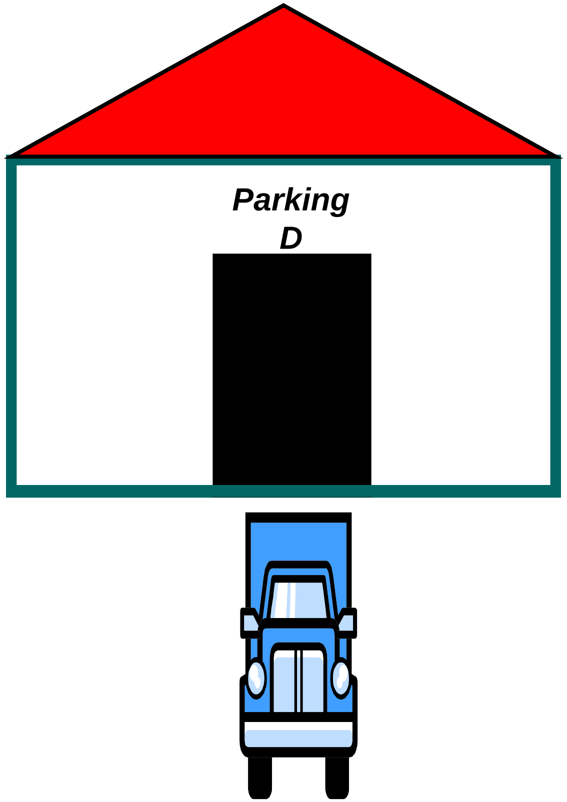
Cp = 0.67

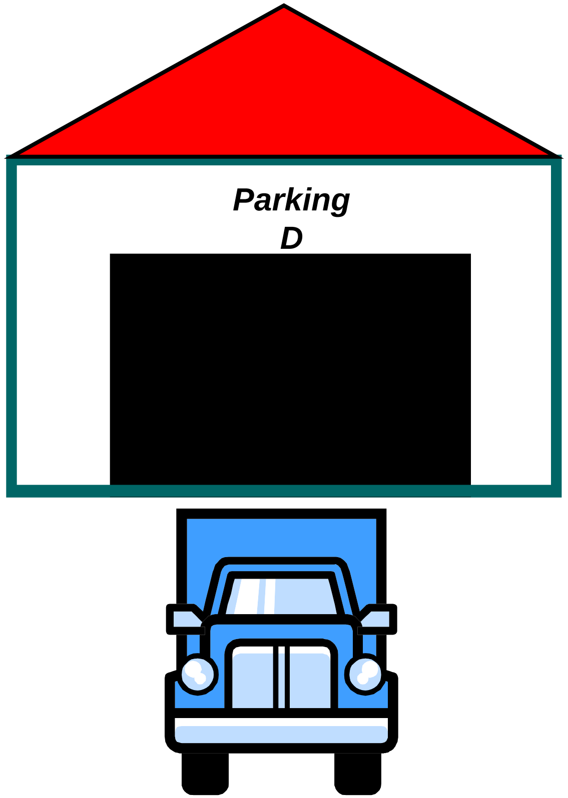
Bad

Parking space smaller than vehicle

What can we do to solve the problem?

- Capability Indices





Reduce the variability of the process **Or** Change the specifications

- Capability Indices

Cpk:

- Takes into account the center of the data relative to the specifications (as well as the process variation).
- A Cpk of less than one means that some of the data is beyond the specification limit.
- The larger the Cpk, the more central and within specification the data.
- Cpk is always smaller or equal to Cp.

Cpk = Min [(USL – Xbar) / 3σ] OR [(Xbar – LSL) / 3σ]

- Capability Indices

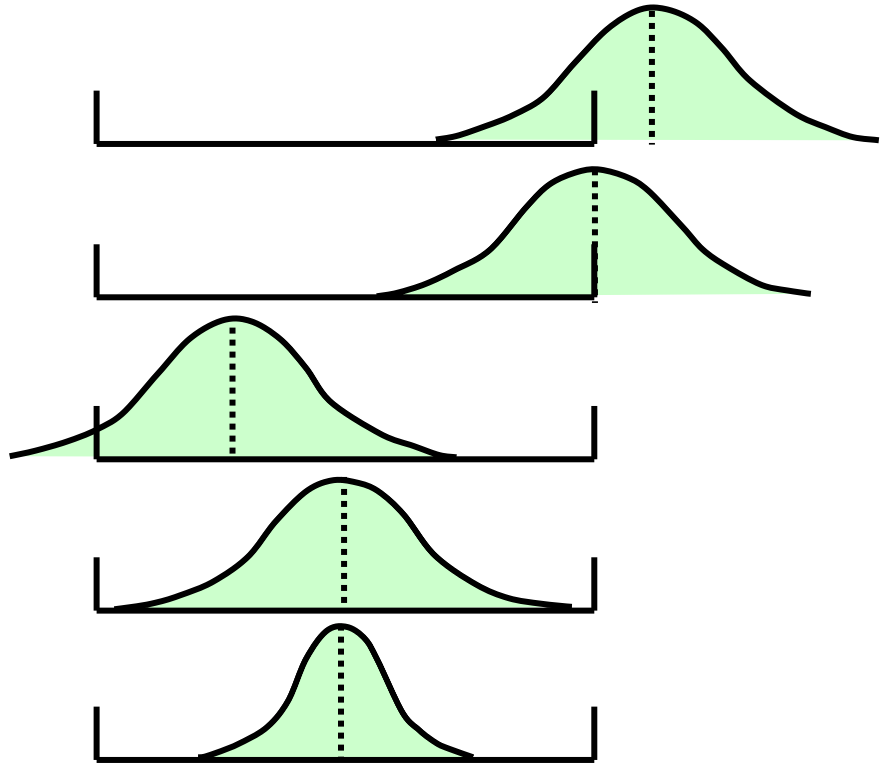
C_{pk} = Negative number

C_{pk} = Zero

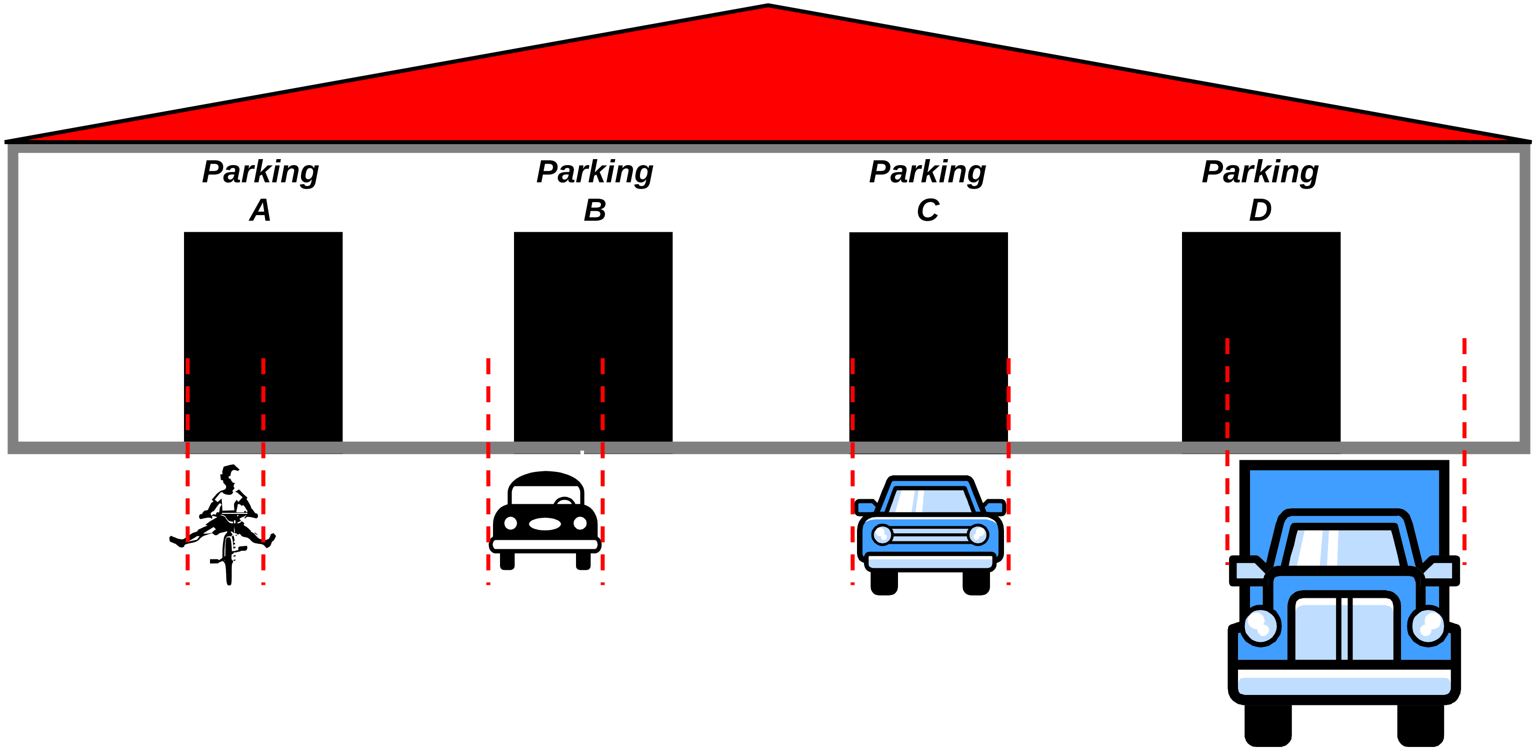
C_{pk} = Between 0 and 1

C_{pk} = 1

C_{pk} > 1



- Capability Indices



Cp = 2 **Cpk = 1** **Regular** Space enough but vehicle not centered	**Cp = 1.33** **Cpk = 0.67** **Bad** Parking space bigger than vehicle, but vehicle not centered	**Cp = 1** **Cpk = 1** **Regular** Parking space same size than vehicle. Vehicle centered	**Cp = 0.67** **Cpk = 0.45** **Very Bad** Parking space smaller than vehicle and vehicle not centered

- Capability Indices

- When Cp and Cpk are over 1.0, the process is capable.
- The goal is to reduce variation so that all of the points fit within the specification limits.

Cp / Cpk	Sigma
1.0	3
1.33	4
1.67	5
2.0	6

A company targeting five-sigma level will aim for Cpk = 1.67

Example – Benchmarked Capability Indices of a Company:

	Cp	Cpk	Pp	Ppk
Unacceptable	< 1.6	< 1.3	< 1.3	< 1.0
Borderline	1.6 – 1.8	1.3 – 1.6	1.3 – 1.6	1.0 – 1.3
Acceptable	1.8 – 2.0	1.6 – 1.8	1.6 – 1.8	1.3 – 1.6
World Class	> 2.0	> 1.8	> 1.8	> 1.6

- Capability Indices

Actual Capability (Pp & Ppk):

- Represent the actual performance of the process incorporating all observed variation.
- They estimate total variability from all sources.
- Also known as “overall” or “long-term” capability.
- Reflects more truthfully the current performance of the process.

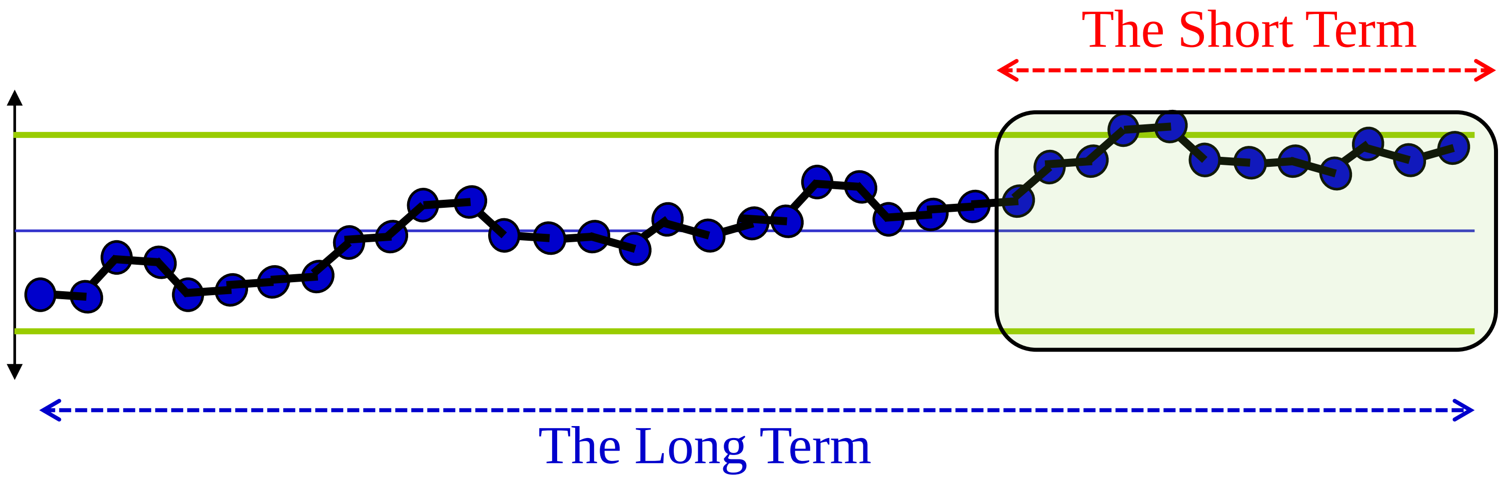
$$Pp = |USL – LSL| / 6\sigma$$

$$Ppk = Min [(USL – Xbar) / 3\sigma] \text{ OR } [(Xbar – LSL) / 3\sigma]$$

- Capability Indices

Actual capability (Pp & Ppk):

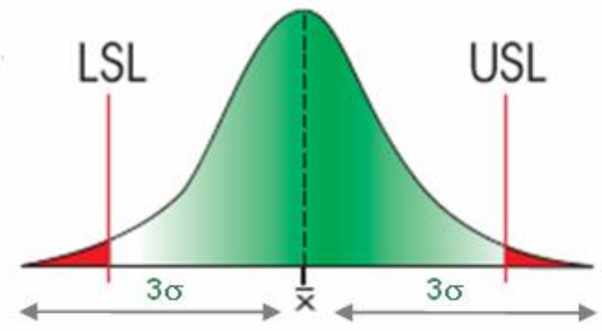
- Based on total process variation, including:
  - The effects of sampling variation.
  - The variation due to special causes and common causes.



- Capability Indices

Sigma Level:

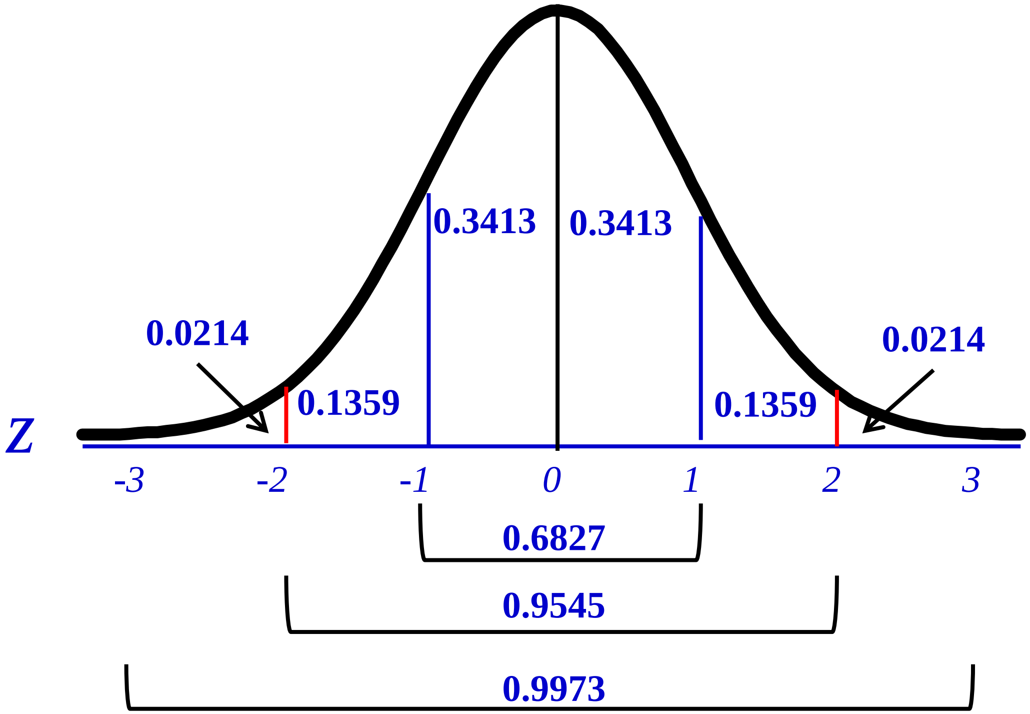
- A metric that measures the level of performance of a process based on the number of Defects per Million Opportunities (DPMO).
- Helps to determine how close (or far) the process is from Six Sigma.
- Calculated using Z Value (Z Score) from the Z Table.



- A high Sigma Level indicates a high level of customer satisfaction.

- Capability Indices

- Z Value is a measurement of a data sample's distance from the population mean, calculated in standard deviations.



- Capability Indices

Z Table:

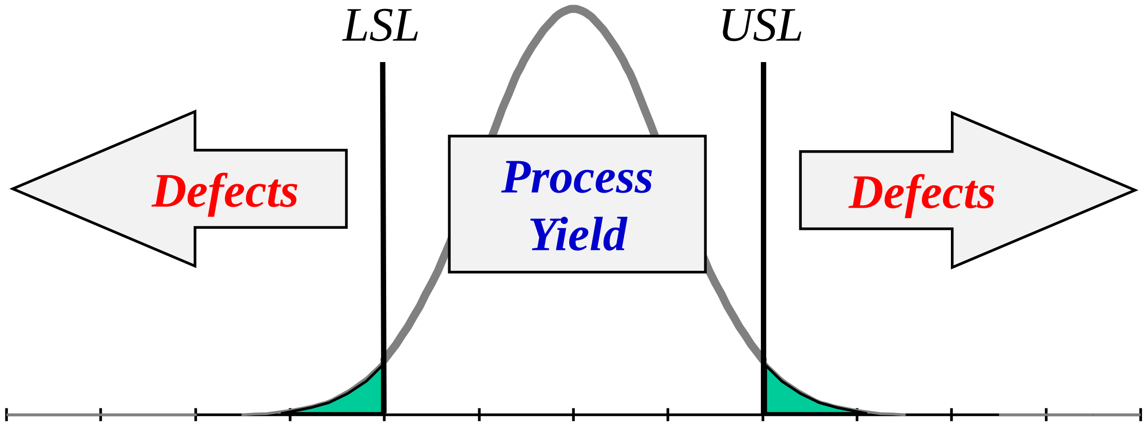
Process Sigma Level	Process PPM	Process Sigma Level	Process PPM
6.27	1	4.66	800
6.12	2	4.62	900
6.00	3.4	4.59	1,000
5.97	4	4.38	2,000
5.91	5	4.25	3,000
5.88	6	4.15	4,000
5.84	7	4.08	5,000
5.82	8	4.01	6,000
5.78	9	3.96	7,000
5.77	10	3.91	8,000
5.61	20	3.87	9,000
5.51	30	3.83	10,000
5.44	40	3.55	20,000
5.39	50	3.38	30,000
5.35	60	3.25	40,000
5.31	70	3.14	50,000
5.27	80	3.05	60,000
5.25	90	2.98	70,000
5.22	100	2.91	80,000
5.04	200	2.84	90,000
4.93	300	2.78	100,000
4.85	400	2.34	200,000
4.79	500	2.02	300,000
4.74	600	1.75	400,000
4.69	700	1.50	500,000

*Assumes that in the long term the process could drift by ± 1.5σ

- Capability Indices

Sigma Level (approach):

- Determine the proportions related to the upper & lower specifications.
- Calculate the proportion (defect rate).
- Calculate the DPMO.
- Use the Z Table to determine the equivalent Z Value to the DPMO.



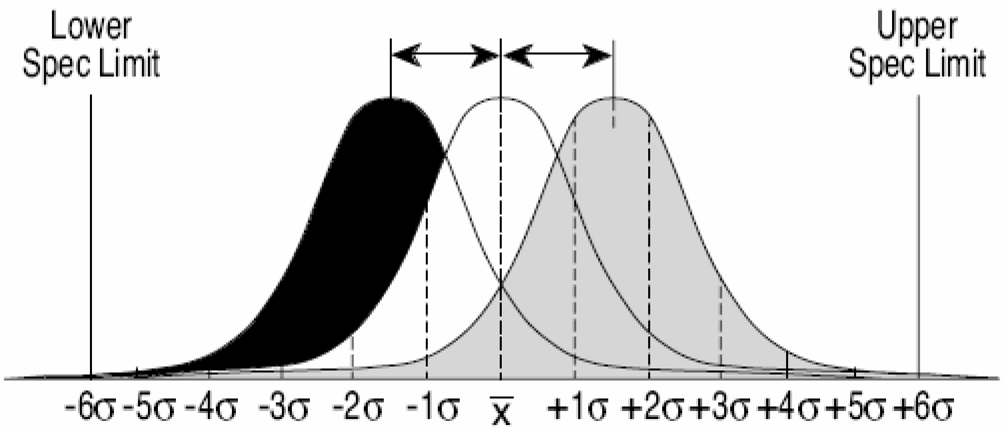
- Capability Indices

Example:

- 400 units were shipped, and 10 were returned as defective. Find out process Sigma Level:
  - Defect % = 10/400 * 100% = 2.5%
  - Defect rate = 10/400 = 0.025
  - DPMO = 1,000,000 * 0.025 = 25,000
  - Sigma Level = 3.46σ (from the Z Table)

Determining the Sigma Level allows process performance to be compared

- Capability Indices



Normal distribution shifted 1.5σ

SPEC LIMIT	PERCENT	DEFECTIVE PPM
±1 sigma	30.23	697,700
±2 sigma	69.13	308,700
±3 sigma	93.32	66,810
±4 sigma	99.379	6,210
±5 sigma	99.9767	233
±6 sigma	99.99966	3.4

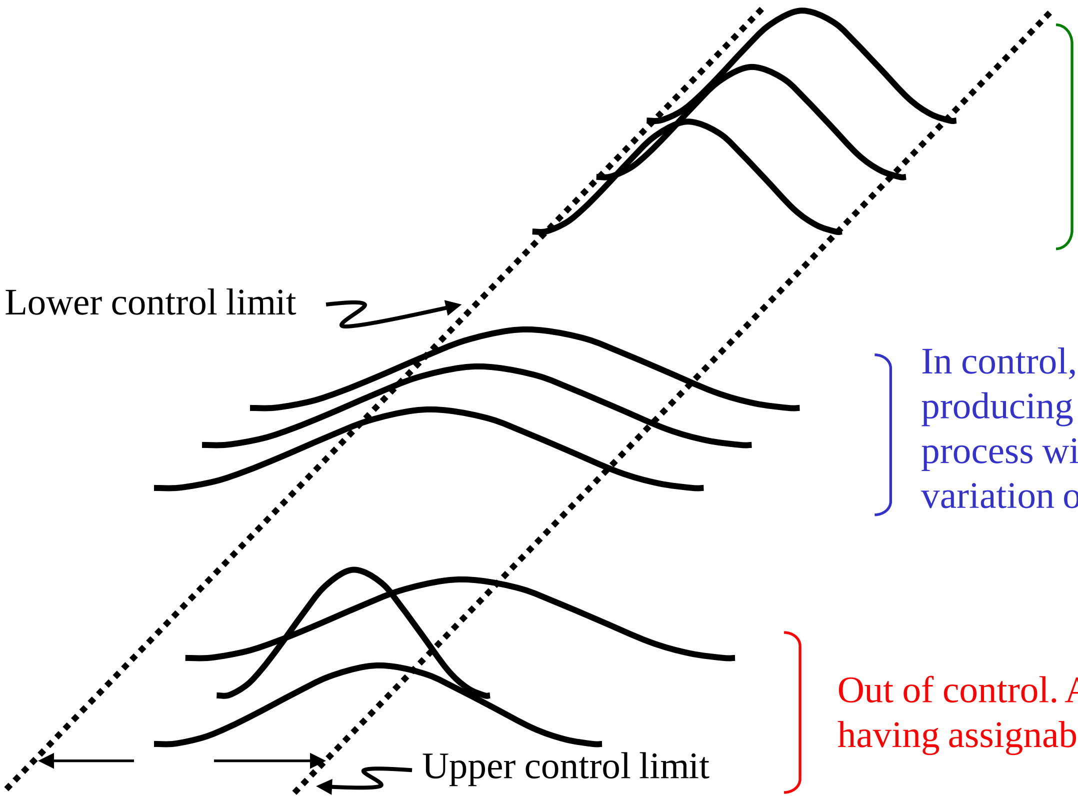
Actual / Long-term

Normal distribution centred

SPEC LIMIT	PERCENT	DEFECTIVE PPM
±1 sigma	68.27	317,300
±2 sigma	95.45	45,500
±3 sigma	99.73	2,700
±4 sigma	99.9937	63
±5 sigma	99.999943	0.57
±6 sigma	99.9999998	0.002

Potential / Short-term

- Capability Indices



In control & capable of producing within control limits. A process with only natural causes of variation.

In control, but not capable of producing within control limits. A process with only natural causes of variation of variation.

Out of control. A process out of control having assignable causes of variation.

- Capability Indices

Further Information:

- The 1.5 standards deviation value is a factor used to account for the shift and drift in the mean of a process output due to assignable causes over the long term.