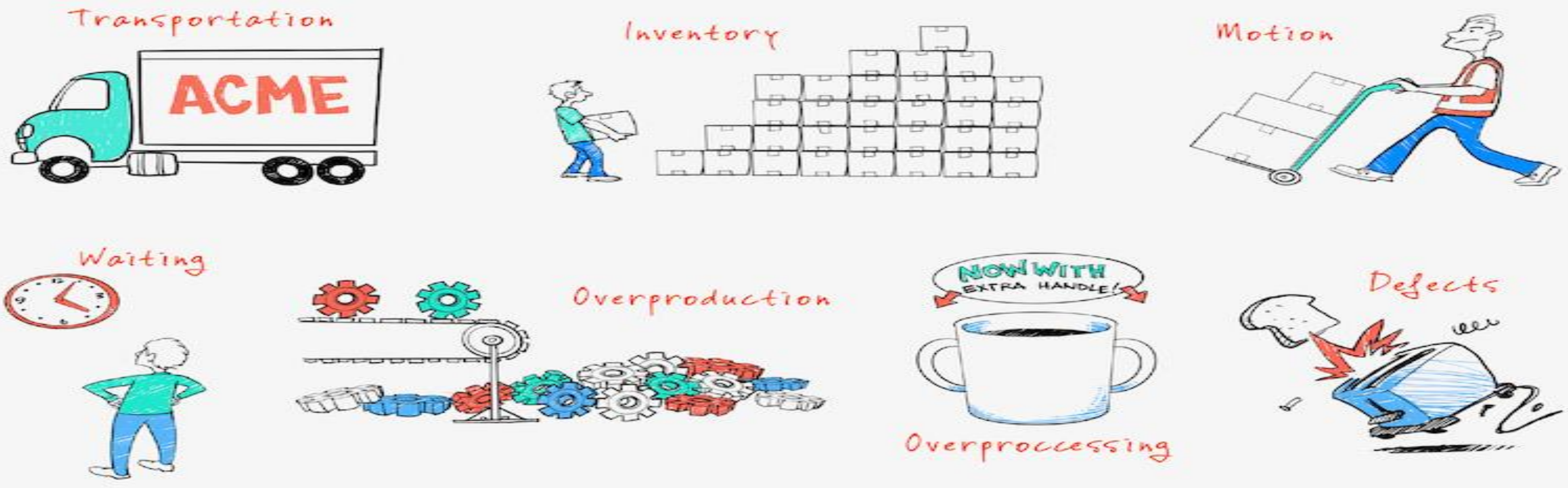


Quality and lean management

Modern definition of quality

Quality is inversely proportional to variability

Quality https://www.youtube.com/watch?v=kib6uXQsxBA

- The ability of a product or service to consistently meet or exceed customer expectations.
- Fulfill customer (market) requirement
- Fit for purpose.
- ....

Product Quality dimensions

- **Performance –** main characteristics of the product
- **Aesthetics –** appearance, feel, smell, taste
- **Special features –** extra characteristics
- **Conformance –** how well the product conforms to design specifications
- **Reliability –** consistency of performance
- **Durability –** the useful life of the product
- **Perceived quality –** indirect evaluation of quality
- **Serviceability –** handling of complaints or repairs
- **Consistency –** quality doesn't vary

TQM: A Philosophy that involves everyone in an organization in a continual effort to improve quality and achieve customer satisfaction

Dimensions of Service Quality

- **Convenience –** the availability and accessibility of the service
- **Assurance –** knowledge exhibited by personnel and their ability to convey trust and confidence
- **Reliability –** ability to perform a service dependably, consistently, and accurately
- **Time –** the speed with which the service is delivered
- **Responsiveness –** willingness to help customers in unusual situations and to deal with problems
- **Courtesy –** the way employees treat customers
- **Tangibles –** the physical appearance of facilities, equipment, personnel, and communication materials
- **Consistency –** the ability to provide the same level of good quality repeatedly
- **Expectancy –** meet (or exceed) customer expectations

The Consequences of Poor Quality

- Loss of business
- Liability
- Productivity
- Costs

Costs of Quality

Appraisal costs

Costs of activities designed to ensure quality or uncover defects

Prevention costs

All TQ training, TQ planning, customer assessment, process control, and quality improvement costs to prevent defects from occurring

Failure costs - costs incurred by defective parts/products or faulty services

Internal failure costs

Costs incurred to fix problems that are detected before the product/service is delivered to the customer

External failure costs

All costs incurred to fix problems that are detected after the product/service is delivered to the customer

Baldrige Criteria

- Leadership
- Strategic planning
- Customer focus
- Measurement, analysis, and knowledge management
- Workforce focus
- Operations focus
- Results

International Organization for Standardization

ISO 9000

Set of international standards on quality management and quality assurance, critical to international business

ISO 14000

A set of international standards for assessing a company's environmental performance

ISO 24700

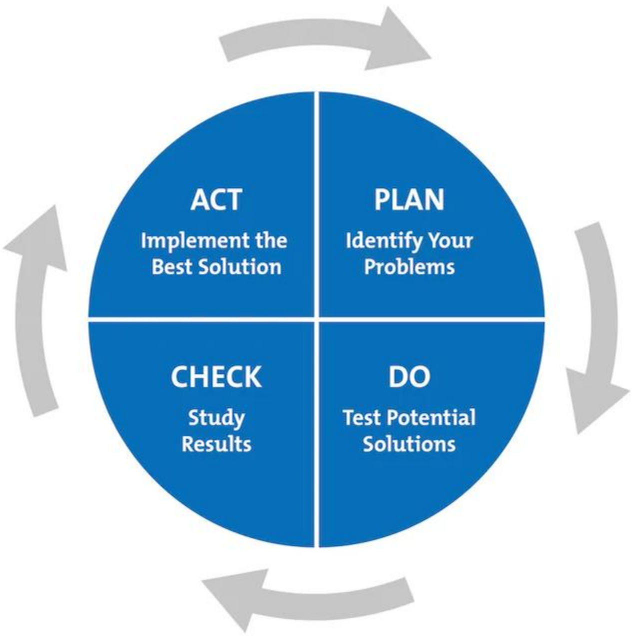
Pertains to the quality and performance of office equipment that contains reused components

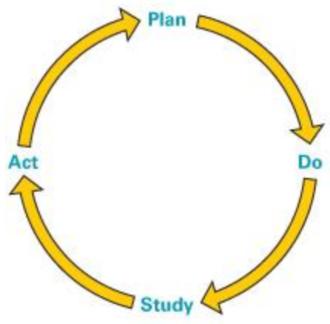
TQM Approach

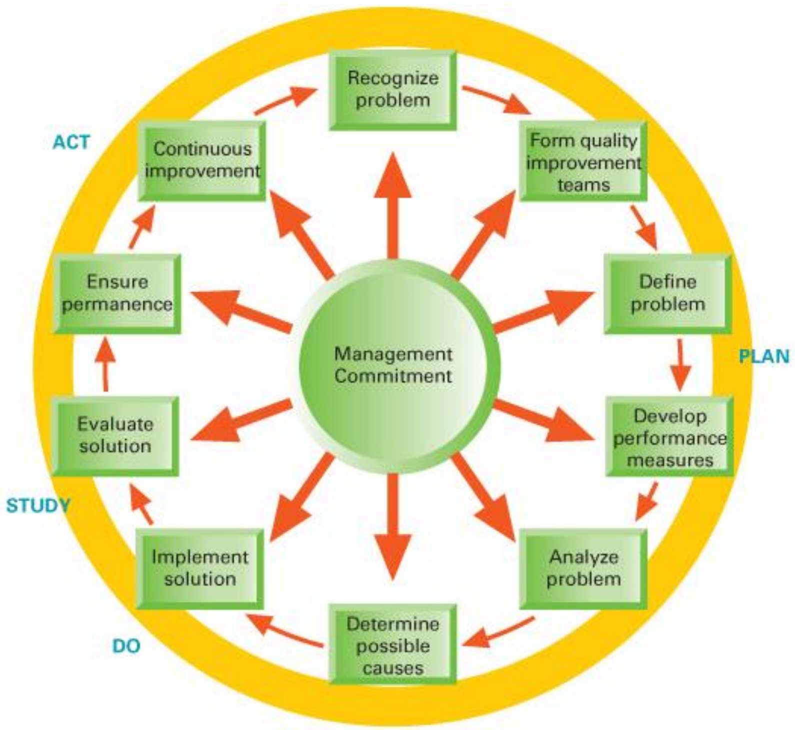
1. Find out what the customer wants
2. Design a product or service that meets or exceeds customer wants
3. Design processes that facilitate doing the job right the first time
4. Keep track of results
5. Extend these concepts throughout the supply chain
6. Top management must be involved and committed

Continuous Improvement

- **Continuous improvement**
  - Philosophy that seeks to make never-ending improvements to the process of converting inputs into outputs
  - **Kaizen**
    - Japanese word for continuous improvement







Six Sigma

- **Six Sigma**
  - A business process for improving quality, reducing costs, and increasing customer satisfaction
  - **Statistically**
    - Having no more than 3.4 defects per million
  - **Conceptually**
    - Program designed to reduce defects
    - Requires the use of certain tools and techniques
- **Principles**
  - Reduction in variation is an important goal
  - The methodology is data driven; it requires data validation
  - Outputs are determined by inputs
  - Only a critical few inputs have a significant impact on outputs

DMAIC

Define: Set the context and objectives for improvement

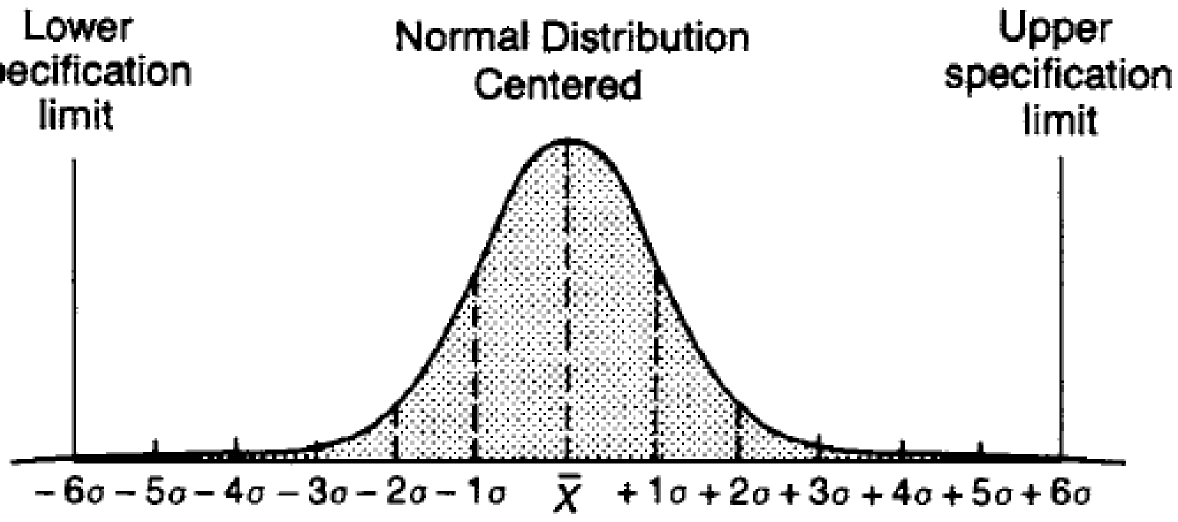
Measure: Determine the baseline performance and capability of the process

Analyze: Use data and tools to understand the cause-and-effect relationships of the process

Improve: Develop the modifications that lead to a validated improvement of the process

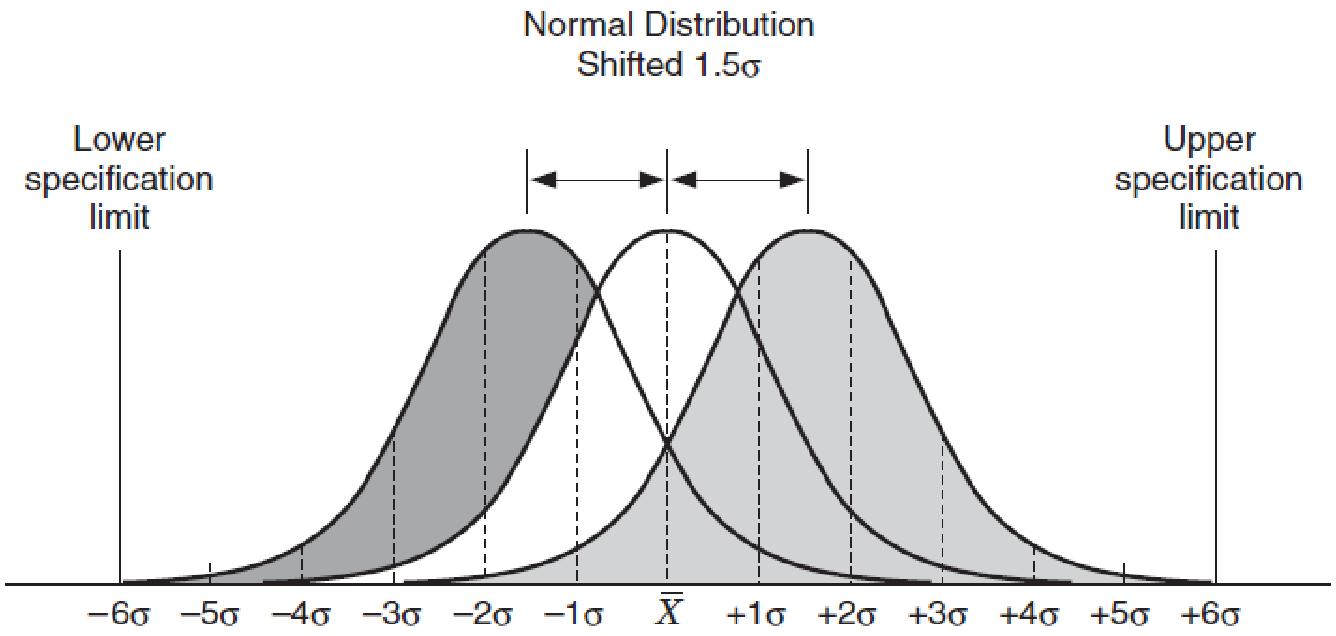
Control: Establish plans and procedures to ensure that improvements are sustained

Centered normal distribution between Six Sigma limits



Spec. limit	Percent	Defective ppm
±1 sigma	68.27	317300
±2 sigma	95.45	45500
±3 sigma	99.73	2700
±4 sigma	99.9937	63
±5 sigma	99.999943	0.57
±6 sigma	99.9999998	.002

Effects of a 1.5 shift



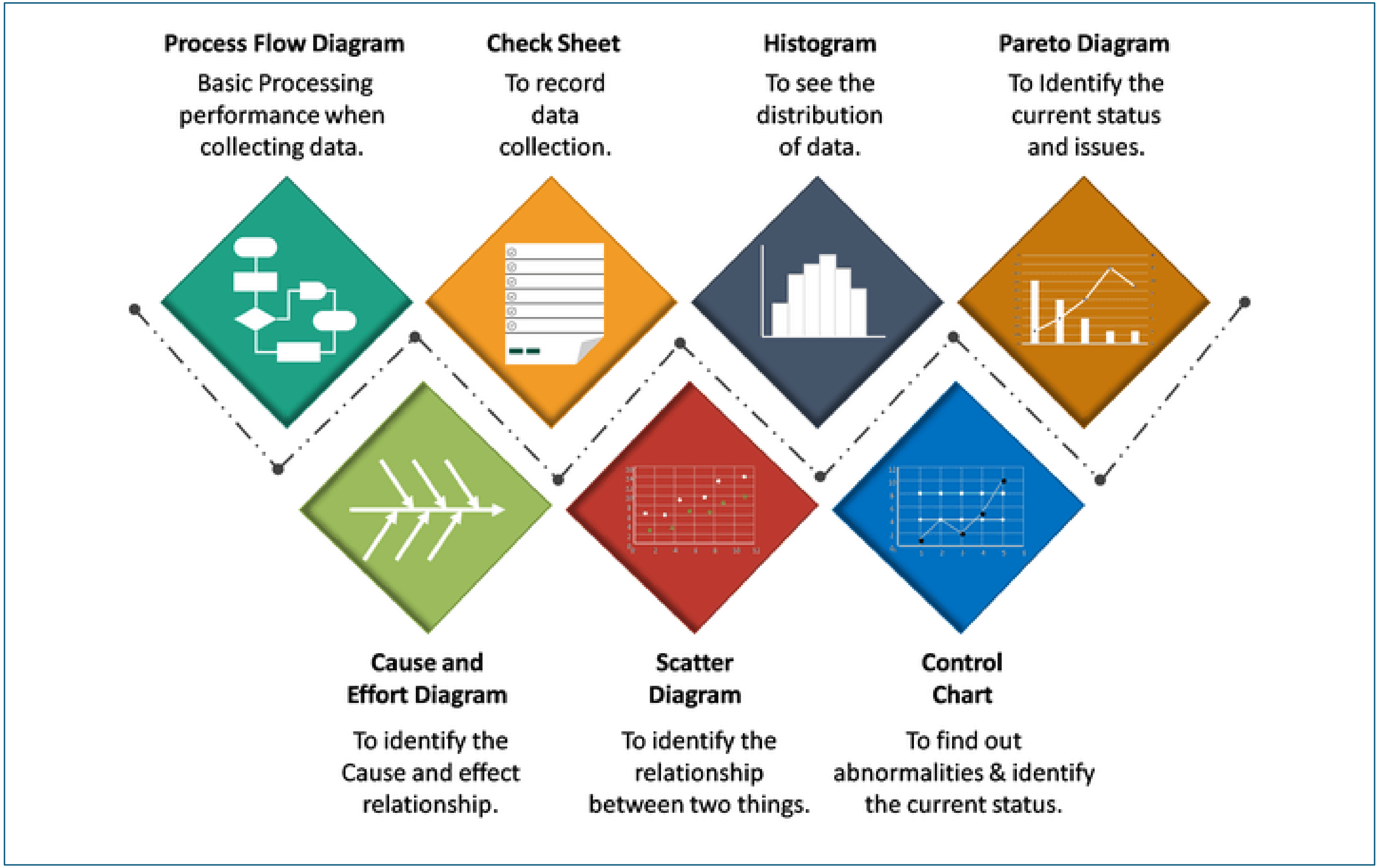
Spec. limit	Percent	Defective ppm
±1 σ	30.23	697700
±2 σ	69.13	308700
±3 σ	93.32	66810
±4 σ	99.3790	6210
±5 σ	99.97670	233
±6 σ	99.999660	3.4

Expertise rank of 6 sigma

1. **White Belt**: Basic understanding of Six Sigma concepts.
2. **Yellow Belt**: Contributes to projects as a team member.
3. **Green Belt**: Leads small-scale improvement projects.
4. **Black Belt**: Expert in Six Sigma tools and methodologies; leads larger projects.
5. **Master Black Belt**: Oversees Six Sigma strategy, training, and mentoring.
6. **Champion**: Senior executive responsible for driving Six Sigma initiatives.

Basic Quality Tools (7QC)

https://www.viddler.com/embed/ee24445d



Statistical Process Control (SPC)

- **Quality control seeks**
  - **Quality of conformance**
    - A product or service conforms to specifications
- **A tool used to help in this process**
- **SPC**
    - Statistical evaluation of the output of a process
    - Helps us to decide if a process is “in control” or if corrective action is needed

Process Variability

- **Two basic questions: concerning variability:**
  1. Issue of process control
     - Are the variations random? If nonrandom variation is present, the process is said to be unstable.
  2. Issue of process capability
     - Given a stable process, is the inherent variability of the process within a range that conforms to performance criteria?

Variation

- **Variation**
  - *Random (common cause) variation*:
    - Natural variation in the output of a process, created by countless minor factors
  - *Assignable (special cause) variation*:
    - A variation whose cause can be identified
    - A nonrandom variation

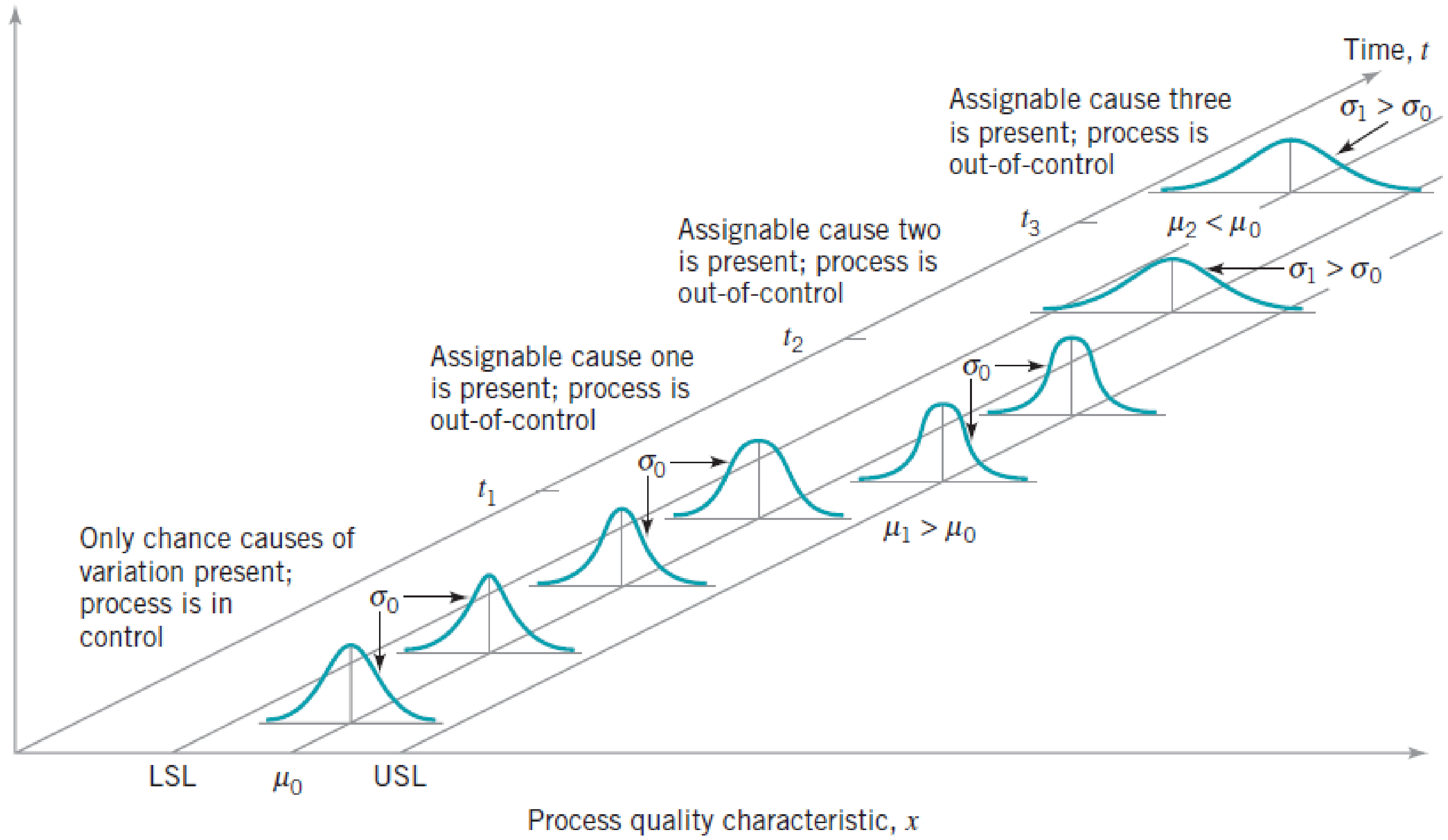
Control Process

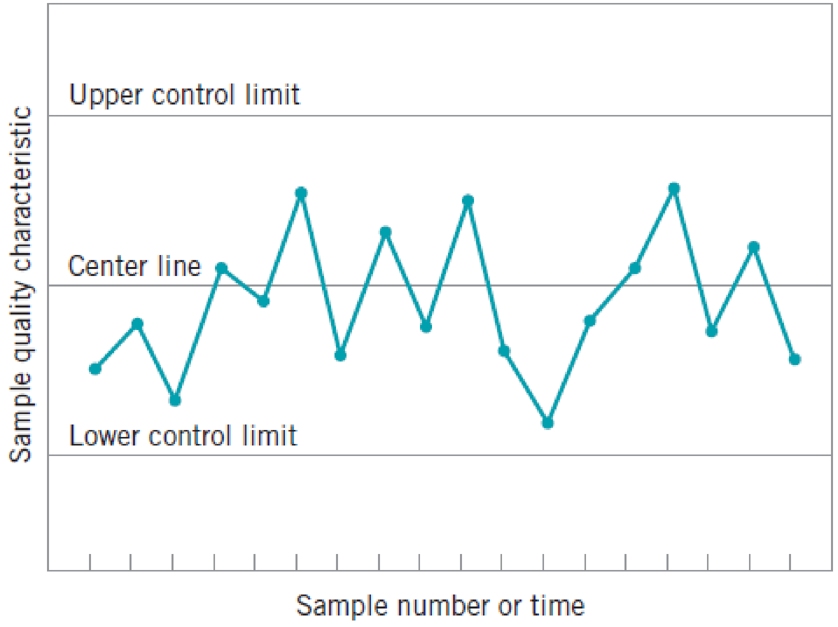
- Sampling and corrective action are only a part of the control process
- Steps required for <u>effective</u> control:
  - **Define:** What is to be controlled?
  - **Measure:** How will measurement be accomplished?
  - **Compare:** There must be a standard of comparison
  - **Evaluate:** Establish a definition of *out of control*
  - **Correct:** Uncover the cause of nonrandom variability and fix it
  - **Monitor:** Verify that the problem has been eliminated

Control Charts: The Voice of the Process

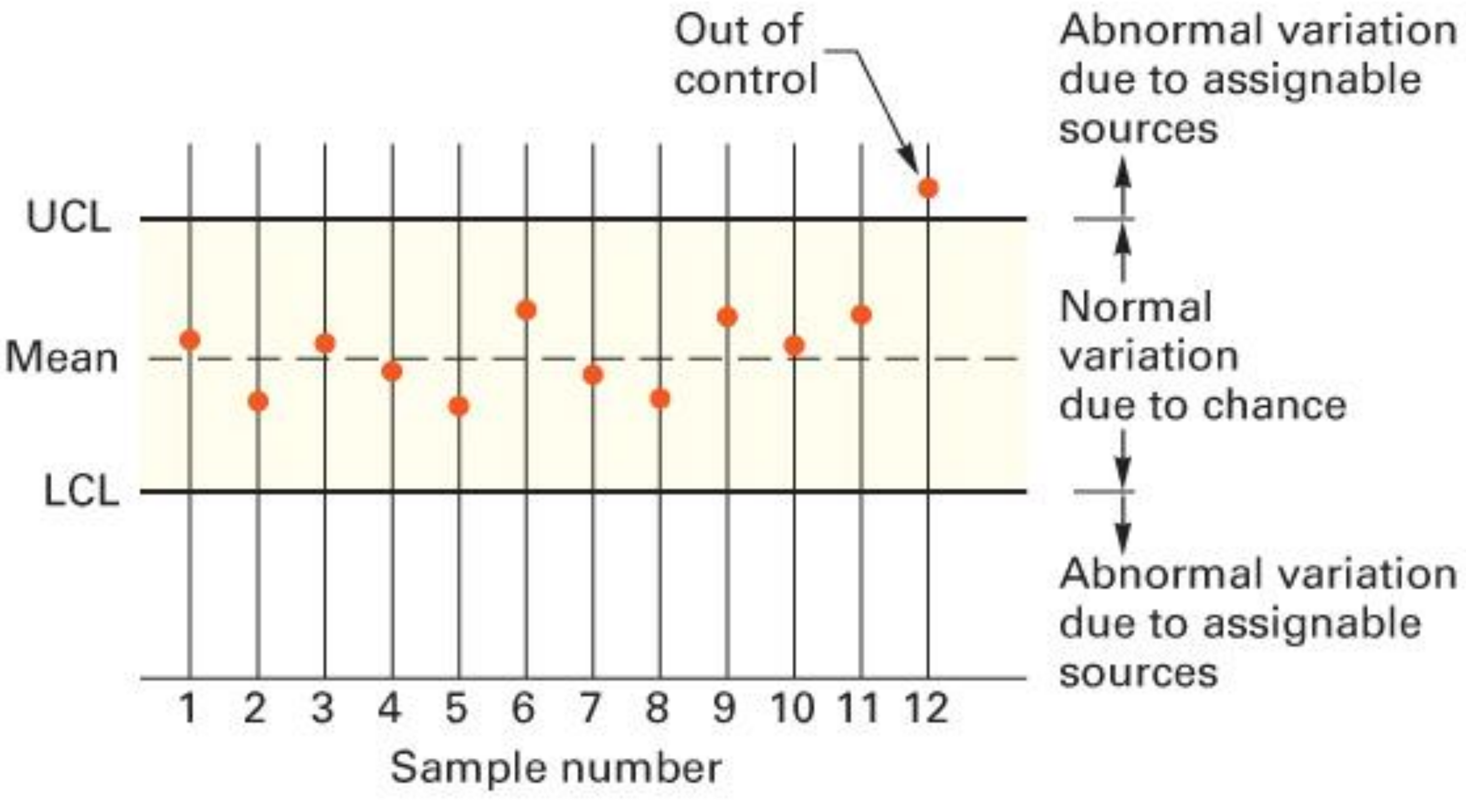
- **Control chart**
  - A time ordered plot of representative sample statistics obtained from an ongoing process (e.g., sample means), used to distinguish between random and nonrandom variability
  - **Control limits**
    - The dividing lines between random and nonrandom deviations from the mean of the distribution
    - Upper and lower control limits define the range of acceptable variation

Process Control and Capability Analysis





Control Chart

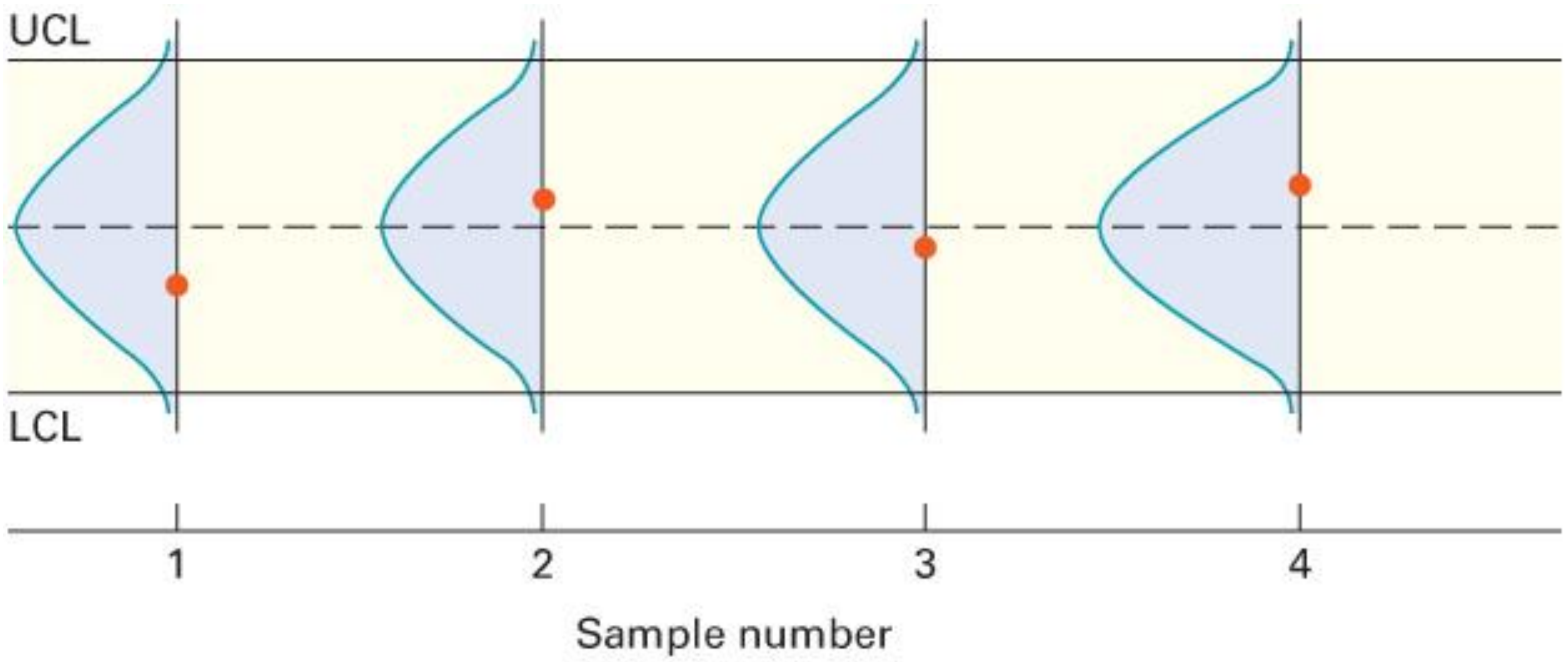


Each point on the control chart represents a sample of *n* observations

Process Errors

- **Type I error**
  - Concluding a process is not in control when it actually is.
    - The probability of rejecting the null hypothesis when the null hypothesis is true.
    - Manufacturer’s risk
- **Type II error**
  - Concluding a process is in control when it is not.
    - The probability of failing to reject the null hypothesis when the null hypothesis is false.
    - Consumer’s risk

Observations from Sample Distribution



Control Charts for Variables

- **Variables generate data that are *measured***
  - Mean control charts
    - Used to monitor the central tendency of a process
      - "*x*-bar" charts
  - Range control charts
    - Used to monitor the process dispersion
      - R charts

$$\bar{R} = \frac{\sum_{i=1}^{k} R_i}{k}$$

where

$\bar{R}$ = Average of sample ranges

R_i = Range of sample i

$$\bar{\bar{x}} = \frac{\sum_{i=1}^{k} \bar{x}_i}{k}$$

where

$\bar{\bar{x}}$ = Average of sample means

$\bar{x}_i$ = mean of sample i

k = number of samples

X-Bar/ range Chart: Control Limits

Used to monitor the central tendency of a process

$\bar{x}$ – chart Control Limits

$$UCL_{\bar{x}} = \bar{\bar{x}} + A_2 \bar{R}$$

$$LCL_{\bar{x}} = \bar{\bar{x}} + A_2 \bar{R}$$

where

A_2 = a control factor based on sample size, n

When sd known
UCL=x double bar+z(sigma/sqrt(n))

R Chart Control Limits

$$ULR_R = D_4 \bar{R}$$

$$LCL_R = D_3 \bar{R}$$

where

D_3 = a control chart factor based on sample size, n

D_4 = a control chart factor based on sample size, n

Factors for Three Sigma Control Charts

Factors for three-sigma control limits for

$\bar{x}$ and R charts

Number of Observations in Subgroup, n	Factor for $\bar{x}$ Chart, A_2	FACTORS FOR R CHARTS Lower Control Limit, D_3	FACTORS FOR R CHARTS Upper Control Limit, D_4
2.........	1.88	0	3.27
3.........	1.02	0	2.57
4.........	0.73	0	2.28
5.........	0.58	0	2.11
6.........	0.48	0	2.00
7.........	0.42	0.08	1.92
8.........	0.37	0.14	1.86
9.........	0.34	0.18	1.82
10.........	0.31	0.22	1.78
11.........	0.29	0.26	1.74
12.........	0.27	0.28	1.72
13.........	0.25	0.31	1.69
14.........	0.24	0.33	1.67
15.........	0.22	0.35	1.65
16.........	0.21	0.36	1.64
17.........	0.20	0.38	1.62
18.........	0.19	0.39	1.61
19.........	0.19	0.40	1.60
20.........	0.18	0.41	1.59

Problem 1

A quality inspector took five samples, each with four observations ($n = 4$), of the length of time for glue to dry. The analyst computed the mean of each sample and then computed the grand mean. All values are in minutes. Use this information to obtain three-sigma (i.e., $z = 3$) control limits for means of future times. It is known from previous experience that the standard deviation of the process is .02 minute.

		SAMPLE				
		1	2	3	4	5
Observation	1	12.11	12.15	12.09	12.12	12.09
	2	12.10	12.12	12.09	12.10	12.14
	3	12.11	12.10	12.11	12.08	12.13
	4	12.08	12.11	12.15	12.10	12.12
	$\bar{X}$	12.10	12.12	12.11	12.10	12.12

$$\bar{\bar{x}} = \frac{12.10 + 12.12 + 12.11 + 12.10 + 12.12}{5} = 12.11$$

$$\text{UCL:} \quad 12.11 + 3\left(\frac{.02}{\sqrt{4}}\right) = 12.14$$

$$\text{LCL:} \quad 12.11 - 3\left(\frac{.02}{\sqrt{4}}\right) = 12.08$$

When sigma is unknown

- Compute R bar= (0.03+0.05+0.06+.04+0.05)/5=0.46

$\bar{x}$ – chart Control Limits

$$UCL_{\bar{x}} = \bar{\bar{x}} + A_2\bar{R}$$

$$LCL_{\bar{x}} = \bar{\bar{x}} + A_2\bar{R}$$

where

A_2 = a control factor based on sample size, n

UCL=12.11+ 0.73(0.046)= 12.14
LCL= 12.11-0.73(0.046)=12.08

R Chart Control Limits

$$ULR_R = D_4\bar{R}$$

$$LCL_R = D_3\bar{R}$$

where

D_3 = a control chart factor based on sample size, n

D_4 = a control chart factor based on sample size, n

LCL=0
UCL 2.28*0.046=0.105

Control Charts for Attributes

- **Attributes generate data that are *counted*.**
  - **p-chart**
    - Control chart used to monitor the proportion of defectives in a process
  - **c-chart**
    - Control chart used to monitor the number of defects per unit

When observations can be placed into two categories

Good or bad

Pass or fail

Operate or don't operate

When the data consists of multiple samples of several observations each

$$\bar{p} = \frac{\text{Total number of defectives}}{\text{Total number of observations}}$$

$$\hat{\sigma}_p = \sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

$$UCL_p = \bar{p} + z\left(\hat{\sigma}_p\right)$$

$$LCL_p = \bar{p} - z\left(\hat{\sigma}_p\right)$$

Problem

An inspector counted the number of defective monthly billing statements of a telephone company in each of 20 samples. Using the following information, construct a control chart that will describe 99.74 percent of the chance variation in the process when the process is in control. Each sample contained 100 statements.

Sample	Number of Defectives	Sample	Number of Defectives	Sample	Number of Defectives	Sample	Number of Defectives
1	7	6	11	11	8	16	10
2	10	7	10	12	12	17	8
3	12	8	18	13	9	18	12
4	4	9	13	14	10	19	10
5	9	10	10	15	16	20	21
							220

$$\bar{p} = \frac{\text{Total number of defectives}}{\text{Total number of observations}} = \frac{220}{20(100)} = .11$$

$$\hat{\sigma}_p = \sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = \sqrt{\frac{.11(1-.11)}{100}} = .0313$$

Control limits are

$$\text{UCL}_p = \bar{p} + z(\hat{\sigma}_p) = .11 + 3.00(.0313) = .2039$$

$$\text{LCL}_p = \bar{p} - z(\hat{\sigma}_p) = .11 - 3.00(.0313) = .0161$$

c-chart

- **Use only when the number of occurrences per unit of measure can be counted; non-occurrences cannot be counted.**
  - Scratches, chips, dents, or errors per item
  - Cracks or faults per unit of distance
  - Breaks or tears per unit of area
  - Bacteria or pollutants per unit of volume
  - Calls, complaints, failures per unit of time

$$\text{UCL}_c = C + Z\sqrt{C}$$

$$\text{LCL}_c = C - Z\sqrt{C}$$

Sample	Number of Defects	Sample	Number of Defects	Sample	Number of Defects
1	3	7	4	13	2
2	2	8	1	14	4
3	4	9	2	15	2
4	5	10	1	16	1
5	1	11	3	17	3
6	2	12	4	18	1
					45

$$\bar{c} = 45/18 = 2.5 = \text{Average number of defects per coil}$$

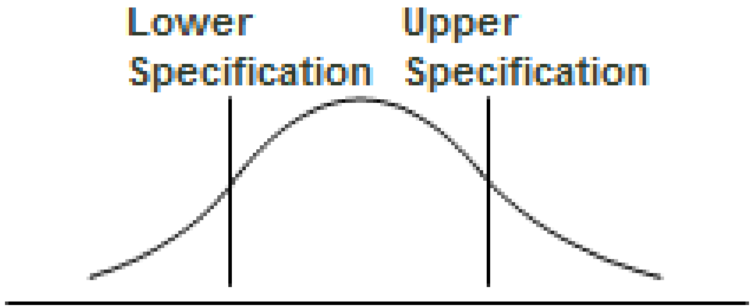
$$UCL_c = \bar{c} + 3\sqrt{\bar{c}} = 2.5 + 3\sqrt{2.5} = 7.24$$

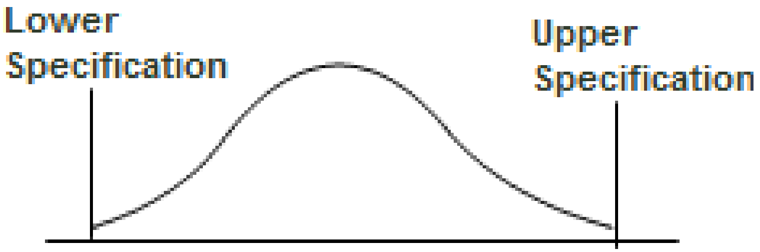
$$LCL_c = \bar{c} - 3\sqrt{\bar{c}} = 2.5 - 3\sqrt{2.5} = -2.24 \rightarrow 0$$

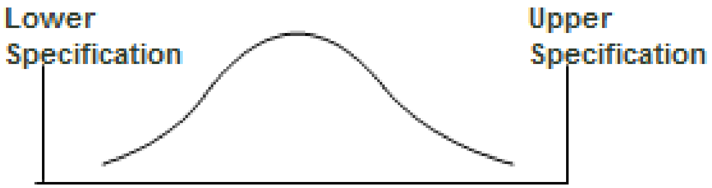
Process Capability

Once a process has been determined to be stable, it is necessary to determine if the process is capable of producing output that is within an acceptable range

- Tolerances or specifications
  - Range of acceptable values established by engineering design or customer requirements
- Process variability
  - Natural or inherent variability in a process







$$C_p = \frac{\text{UTL} - \text{LTL}}{6\sigma}$$

UTL = upper tolerance (specification) limit
LTL = lower tolerance (specification) limit

Process Capability

C_{pk}

- Used when a process is not centered at its target, or nominal, value

$$C_{pk} = \min\{C_{pu}, C_{pl}\}$$

$$= \min\left\{\frac{UTL - \bar{x}}{3\sigma}, \frac{\bar{x} - LTL}{3\sigma}\right\}$$

Problem

- A manager has option of using any one of the three machines for a job. The processes and their standard deviations are listed below. Determine which m/cs are capable if the specifications are 10.00 mm and 10.80 mm.

Process	Sd	Process width	Cp
A	0.13	0.13*6=0.78	0.8/0.78=1.03
B	0.08	0.48	0.8/0.48=1.67
C	0.16	0.96	0.8/0.96=0.83

Cp is not a true measure for process capability; therefore, measuring Cpk is necessary to collude process capability.

Min [(USL-mean)/3sd, (mean-LSL)/3sd]
A process has a mean of 9.2 grams and the sd of 0.3 grams. The LSL is 7.5 grams and USL is 10.50 grams. Compute Cpk.

Lower index= (9.2-7.5)/3 *0.3=1.89; upper index= (10.50-9.20/3*0.3)=1.44
Min is 1.44 hence process is capable

Class practice

Process	Mean	Sd	LSL	USL
1	7.5	0.1	7	8
2	4.5	0.12	4.5	4.9
3	6.5	0.14	5.5	6.7

Determine process control nature.

As part of an insurance company's training program, participants learn how to conduct an analysis of a client's insurability. The goal is to have participants achieve a time range of 30 to 45 minutes. The test results of three managers as Ashok, a mean of 38 min. and sd 2 min; Pooja, a mean of 37 minutes and sd 0f 2.5 min; and Jaya with mean of 37.5 and sd of 1.8 min. Compute

- Which of the participants would you judge to be capable? Explain
- Can the value of Cpk exceed the value of for given participant? Explain

A quality manager found an average of 3.9 defects in a car engine start while doing a quality check. Managers attempt to start before delivery to the dealer, but the engine is not started in the first go. The lot size of car is 100 and an average of 4 did not start (4%). Use a suitable control chart for modelling quality issue.