Session 7: Quality Management

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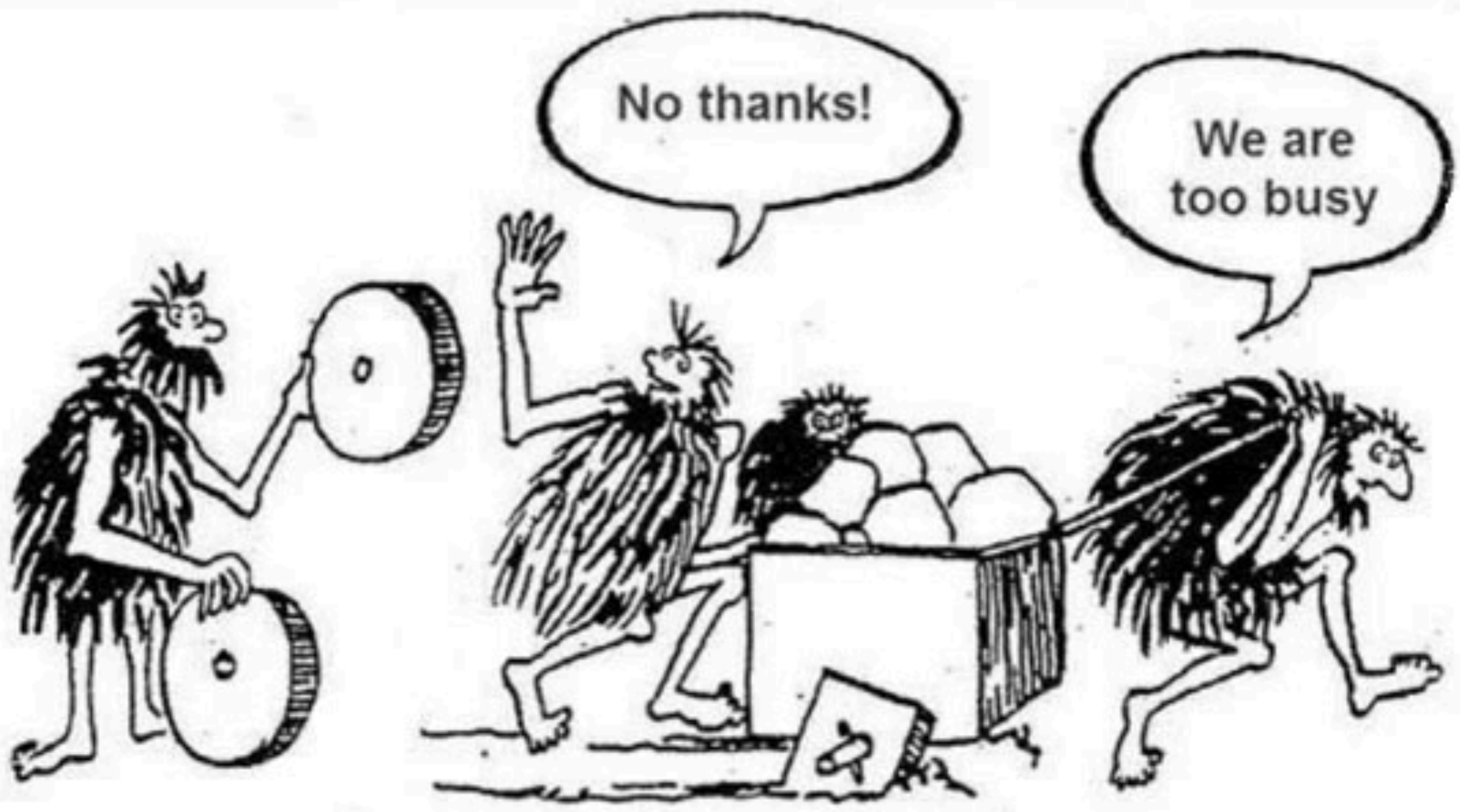

No thanks!
We are
too busy

Process Improvement

A wealth of methodologies: JIT, TPS, MRP I /II, ERP, TOC, TQM, SPC, CIM, FMS

Manufacturing techniques

- Just-in-Time (JIT), Lean Production, Lean Thinking, Toyota Production System (TPS), Theory of Constraints (TOC)

Quality movement

- Total Quality Management (TQM), Statistical Process Control (SPC), Six Sigma, Lean Six Sigma

Responsive manufacturing and supply

- Flexible Manufacturing Systems (FMS), Mass Customization

Information Technology related methodologies

- MRP/ERP, Computer Integrated Manufacturing (CIM), “Digital Factory”

Objectives for Today

- Give a brief review of the quality gurus and their approaches to quality
- Recognize the multidimensional view of product quality
- Understand the concepts of process capability and statistical process control
- Understand the role of inspection and apply sampling plans
- Recognize the DMAIC framework and the philosophy of Six Sigma

Poor Product/Service Quality

What happens when quality is poor?

- Costs increase
- Customers complain ➔ more costs
- Customers don't come back ➔ highest costs

And along with increasing costs,
you have fewer goods or services to sell.

History and Gurus

Walter Shewhart

- A statistician at Bell Laboratories in 1920s, he studied randomness in industrial processes
- Developed a system for workers to determine whether those processes were “in control”
- First defined quality as the goodness of the product
- Known as the father of Statistical Process Control (SPC)

W. Edwards Deming

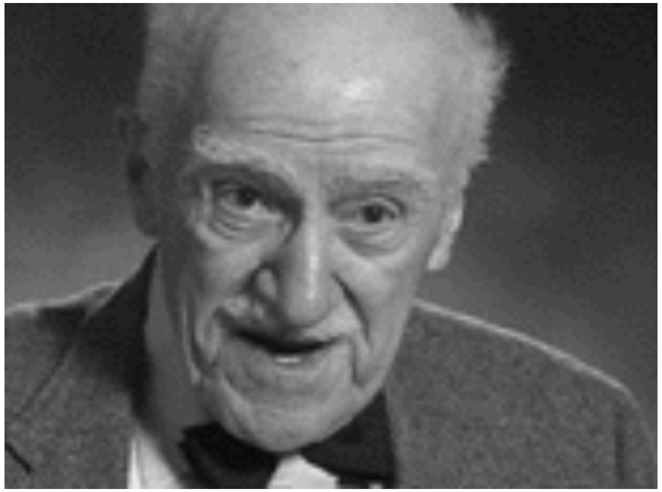
- Believed in management as a system
- Natural variation is inherent in all processes, but if reduce variation, productivity and quality both increase
- Influenced post WWII Japan's production

"Quality is not mandatory.
You can choose to go out of business."

"In God We Trust …
- all others must bring data."

Joseph Juran

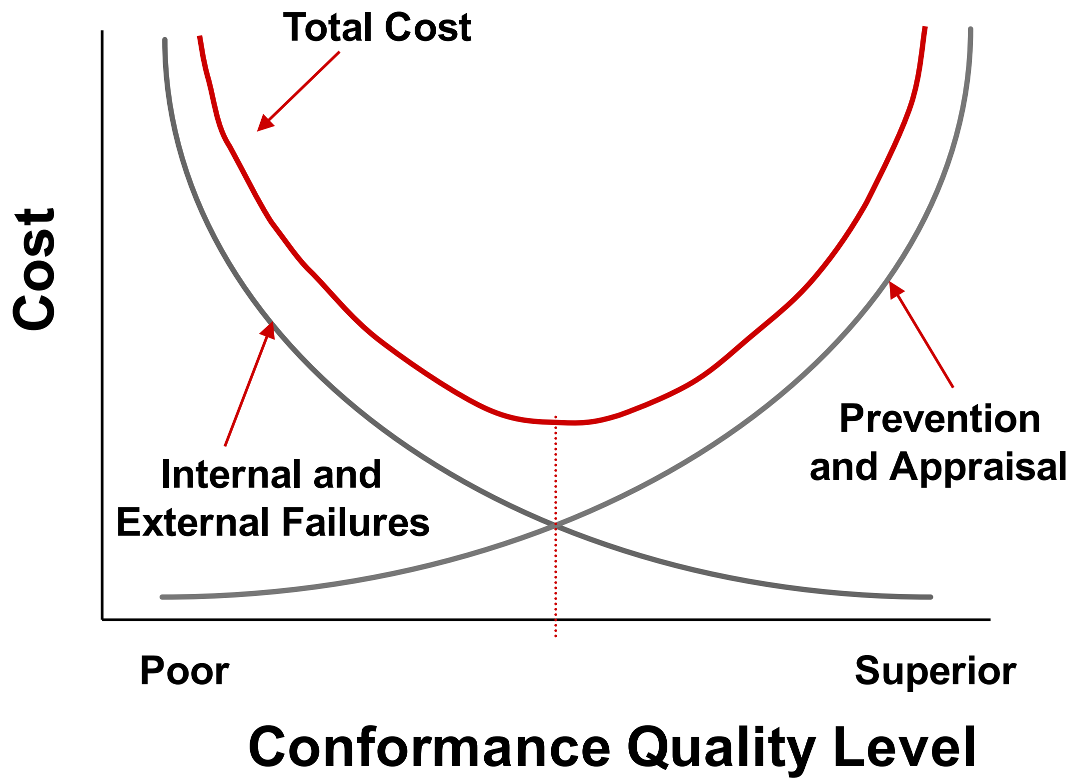
- Defined quality as fitness for use
- Focused on quality costs
- Stressed the point-in-time trade-offs of quality decisions
- In 1957 published Quality Control Handbook



Cost of Quality to the Firm

Four Categories of Cost:

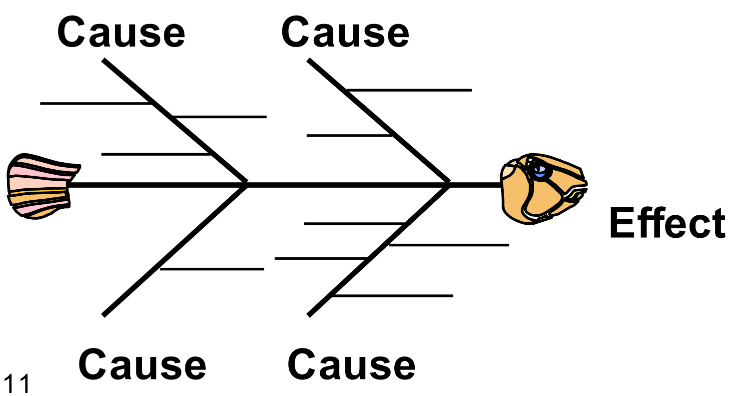
- Cost of Prevention
- Cost of Appraisal
- Cost of Internal Failure
- Cost of External Failure



Kauro Ishikawa

- Stressed basic quality tools
- Advocated quality circles
- Believed in worker involvement
- Customer satisfaction is the basis for definitions of quality

"to practice quality control is to develop, design, produce and service a quality product which is most economical, most useful and always satisfactory to the consumer"



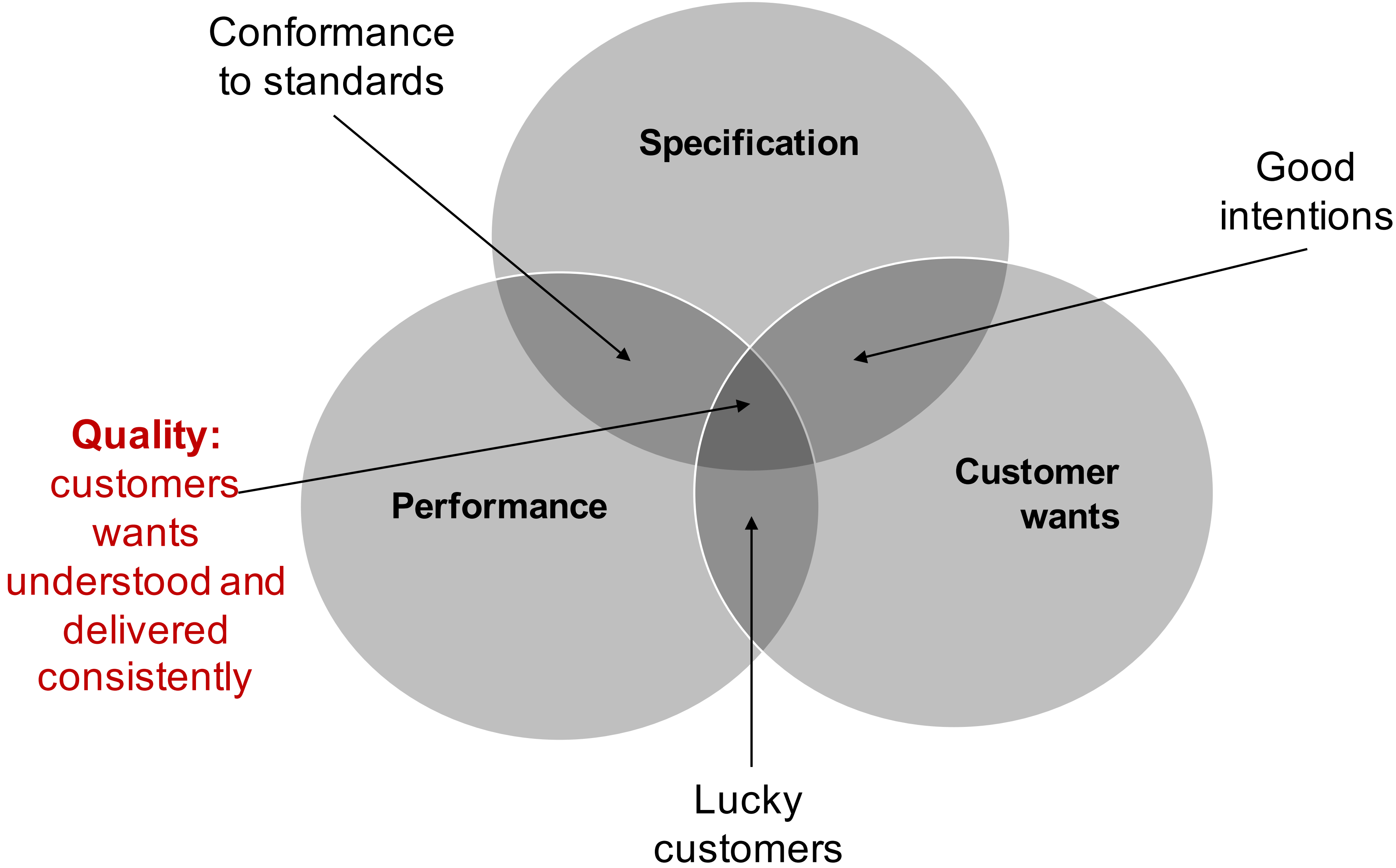
Genichi Taguchi

- Taguchi contributed to both quality philosophy and quality tools
- He said that there is a **loss to society** whenever there is a problem with the quality of a good or service
- He also developed tools to facilitate the design of experiments for building in product quality

Philip Crosby

- Defined quality as conformance to requirements
- Emphasized the importance of zero defects
- Quality is Free!

What is Quality?



Product Quality

The Dimensions of Quality

If we want to manage quality, we have to not only know what we mean by quality, but be able to measure it

Dimensions of Product Quality

Performance: Primary operating characteristics

Features: Secondary characteristics

Conformance: How well specifications are met

Reliability: Consistency of performance

Durability: Product life

Perceived Quality: Brand image/reputation

Serviceability: Ease of service/friendliness of server.

Aesthetics: Effect on senses

Source: David Garvin (1987)

Identifying Service Quality

Dimensions of Service Quality

Reliability: The ability to perform the promised service dependably and accurately

Tangibles: The appearance of physical facilities, equipment, personnel, and communications materials

Responsiveness: The willingness to help customers and to provide prompt service

Assurance: The knowledge and courtesy of employees and their ability to convey trust and confidence

Empathy: The provision of caring, individualized attention to customers

Source: Berry, Zeithaml & Parasuraman (1990)

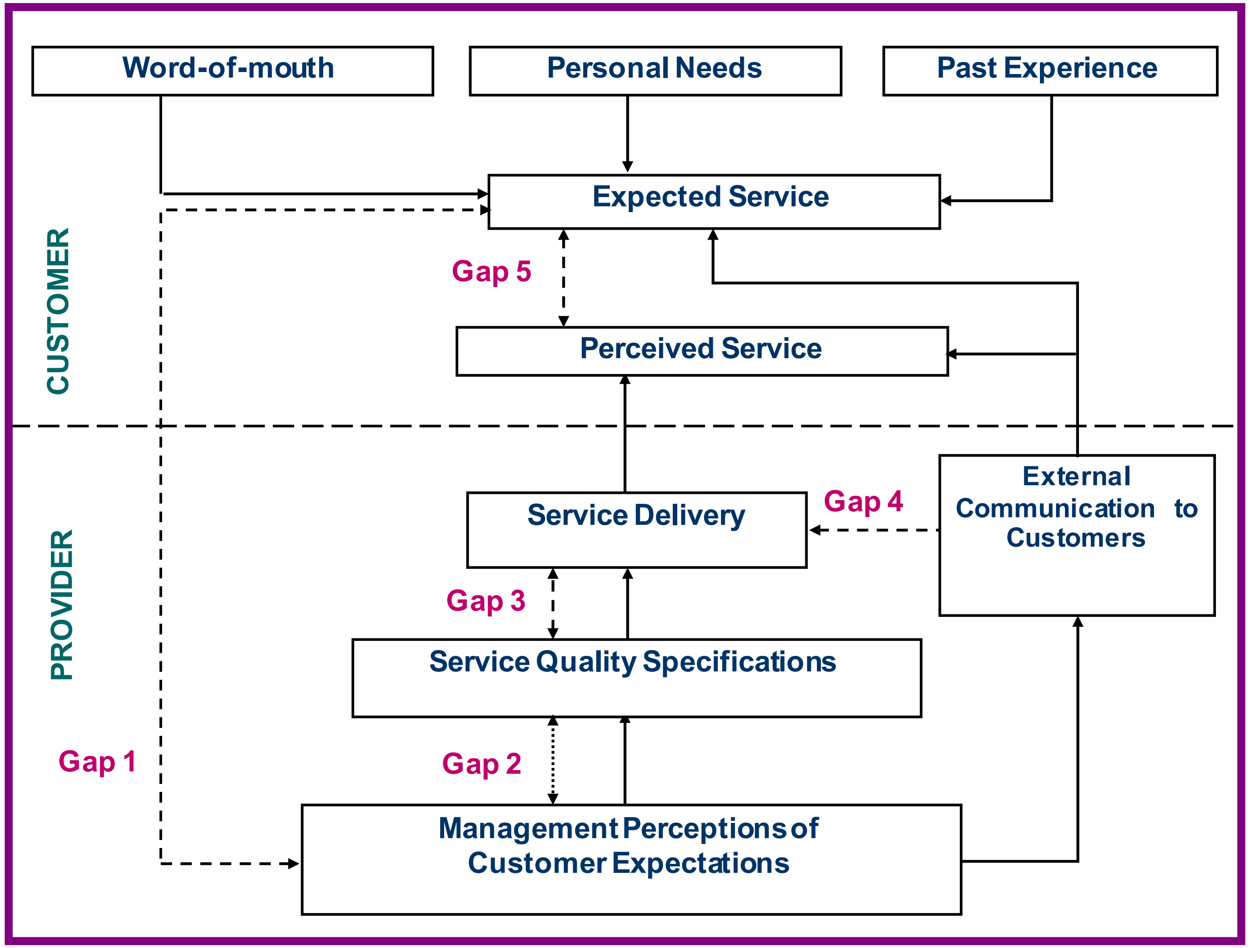
Definition of Service Quality

Quality of Service = Perceived Performance – Expectation

Relationship between what is expected and what is actually delivered

- Service quality is relative
- Determined by customer, not by provider
- Varies from one customer to another
- Quality enhanced by meeting or exceeding expectations and by controlling customer expectations

Service Quality: The Gap Model



Gap analysis identifies the differences between desired and actual performance.

Source: Parasuraman et al. (1985) The Gap Model of Service Quality

Technical/Functional Service Quality

Technical: the what of service

Functional: the how of service

Challenges Delivering Service Quality

"Managers do not control the quality of the product when the product is a service .... the quality of the service is in a precarious state – it is in the hands of the service workers who 'produce' and deliver it."

- Karl Albrecht

However, Metrics Drive Behaviour

You cannot manage what you do not measure.

What you get is what you measure.

The White Bead Company

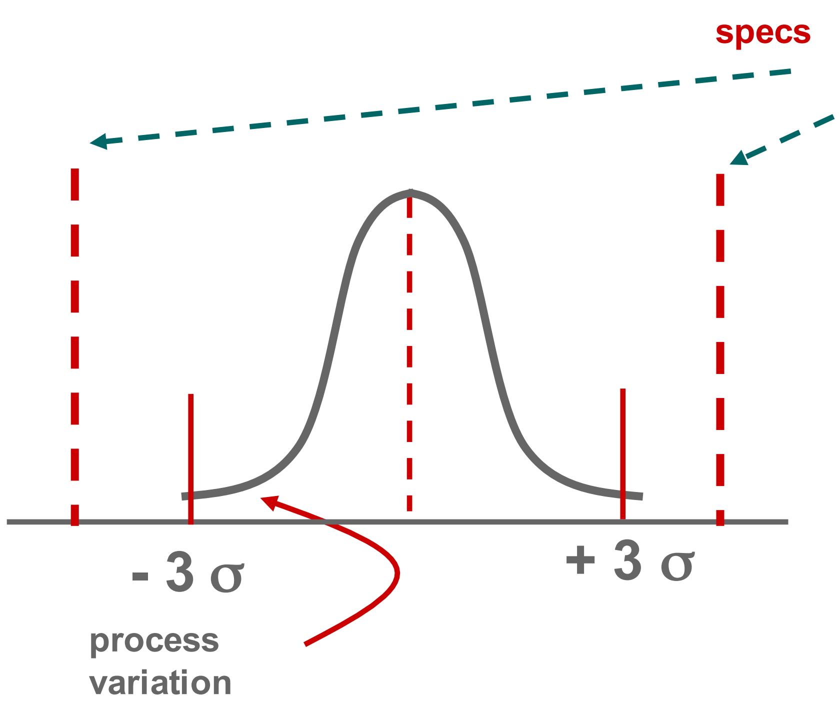
Deming's 14 Points

1. Create constancy of purpose for continuous improvement
2. Adopt the new philosophy (mistakes and negativism are unacceptable)
3. Cease dependence upon mass inspection
4. End the practice of awarding business on price tag alone
5. Improve constantly and forever the system of production and service
6. Institute training
7. Institute leadership
8. Drive out fear
9. Break down barriers between staff areas
10. Eliminate slogans, exhortations, and targets for the workforce
11. Eliminate numerical quotas
12. Remove barriers to pride of workmanship
13. Institute a vigorous program of education and training
14. Take action to accomplish the transformation

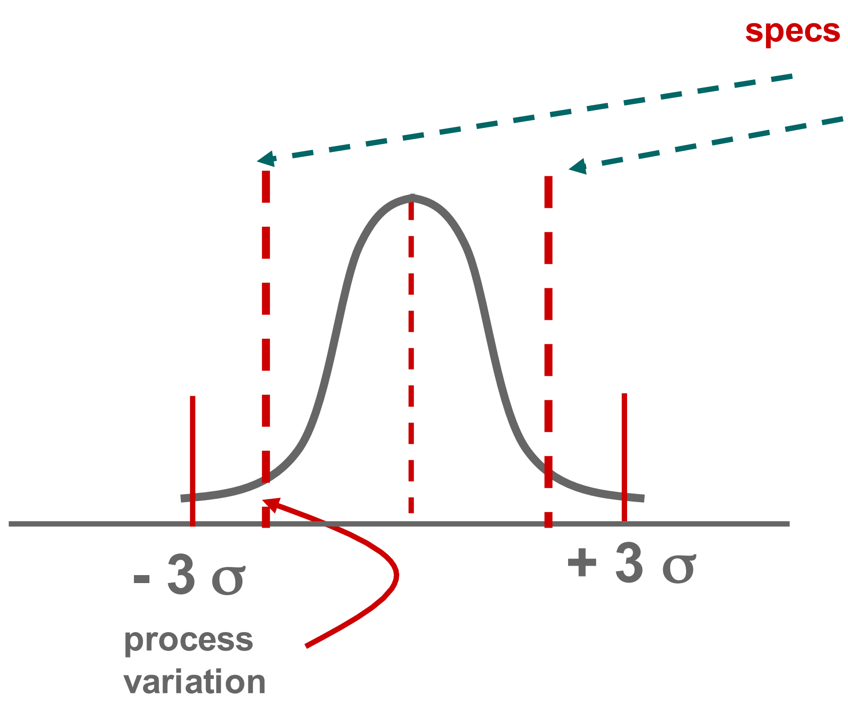
Capability & Control

Capability Study

If specifications (specs) are outside at least 3 standard deviations, the process is capable



If specs are within 3 sigma, process is not capable of consistently producing within customer requirements



Capability Study

Steps:

1. Determine process requirements
2. Collect baseline data on process output when process is not exhibiting “unusual” behavior; calculate process mean and standard deviation (σ)
3. Compare specs to process mean $\pm$ 3 σ
4. If specs are outside $\pm$ 3 σ, process is capable

C_P

- Compares the "natural tolerance" of the process (its natural variation) to the specs

$$C_P = \frac{\textit{engineering tolerance}}{\textit{natural tolerance}} = \frac{\textit{customer specification range}}{6\sigma}$$

- A C_P of 1 denotes a capable process – but to allow for drift, 1.33 is often used as the acceptable minimum

- Disadvantage: C_P does not account for process centering

C_{PK}

- Compares the “natural tolerance” of the process (its natural variation) to the specs for process centering

$$C_{PK} = \frac{\min(Z_L, Z_U)}{3}$$

where

$$Z_U = \frac{\text{Upper specification} - \bar{X}}{\sigma}$$

$$Z_L = \frac{\bar{X} - \text{Lower specification}}{\sigma}$$

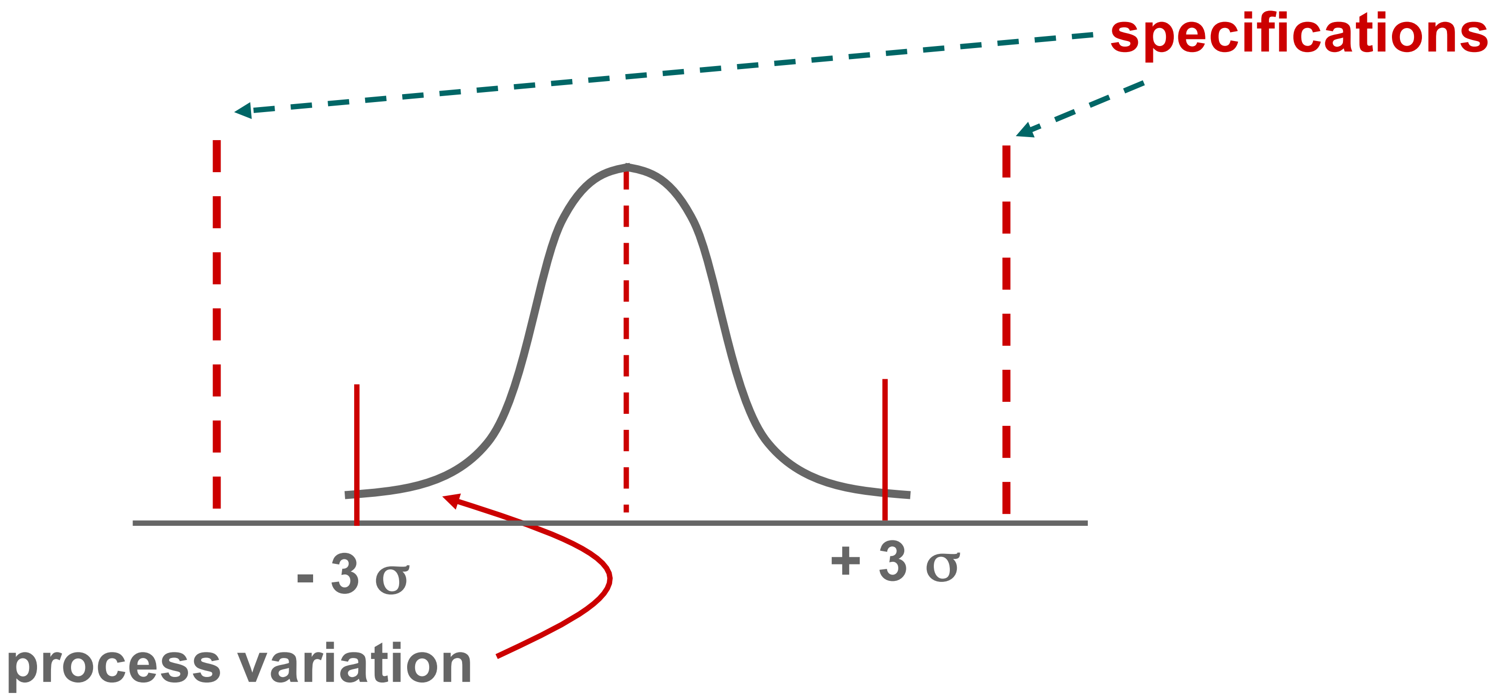
C_{PK}

- We are looking at the difference between the mean and the upper and lower specs
  - In a centered process, we would expect these to be equal
  - When a process is not centered around the mean, one Z will be smaller than the other

- If that Z divided by 3 is at least 1 (preferably 1.33, then the process is capable)

C_{PK} and the Comparison Method

- Basically, C_P and C_{PK} are computing a single value to determine whether a process is capable
- We did this visually, ensuring that the process specs are outside *at least* ± 3 sigma on each side



Capability Study

- When a process is not capable, we have to inspect to find the output that does not meet the requirements, which adds cost
- If we need to rework or scrap bad output, that adds even more cost!

Capable Processes in Control

- When a process is capable, it can produce output that meets customer specifications
- However, a process is only in control when it haves as expected, that is it exhibits only random variation
- When a process is capable and in control, the process is producing output that meets customer specifications consistently

Statistical Analysis of Processes

Statistical Analysis

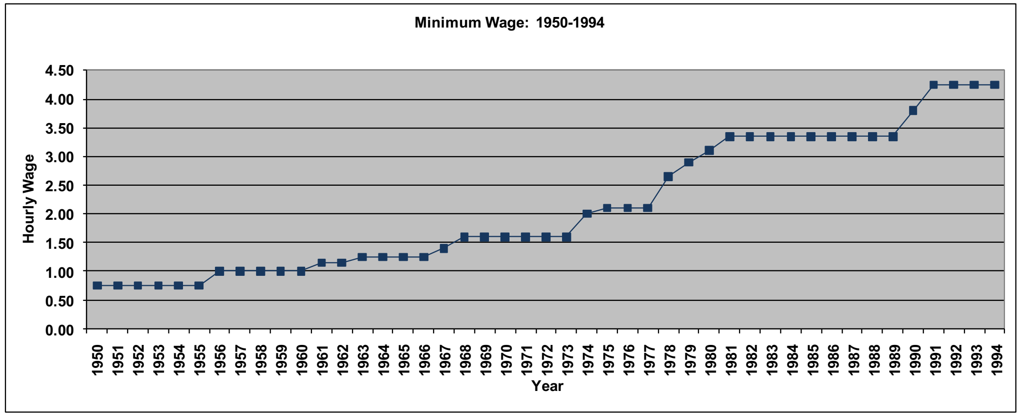
- Requires less labor (reduces costs)
- Useful when testing destroys products

Categories of Statistical Tools

- Acceptance sampling
  - ➢ Assesses the quality of parts or products after they have been produced
- Statistical process control
  - ➢ Assesses whether or not an ongoing process is performing within established limits

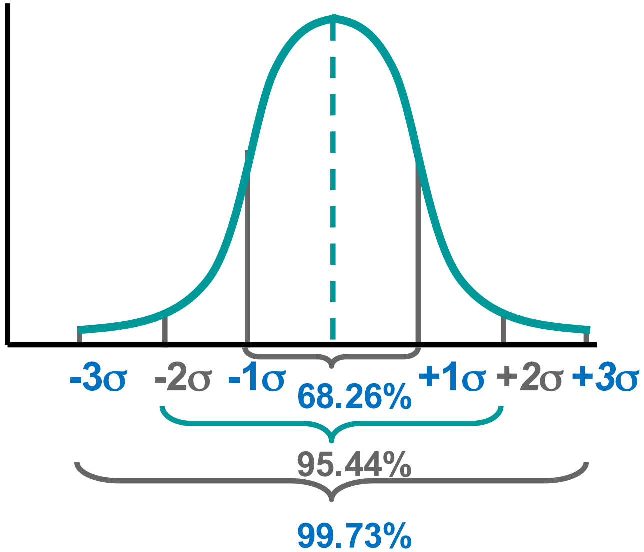
Statistical Process Control (SPC)

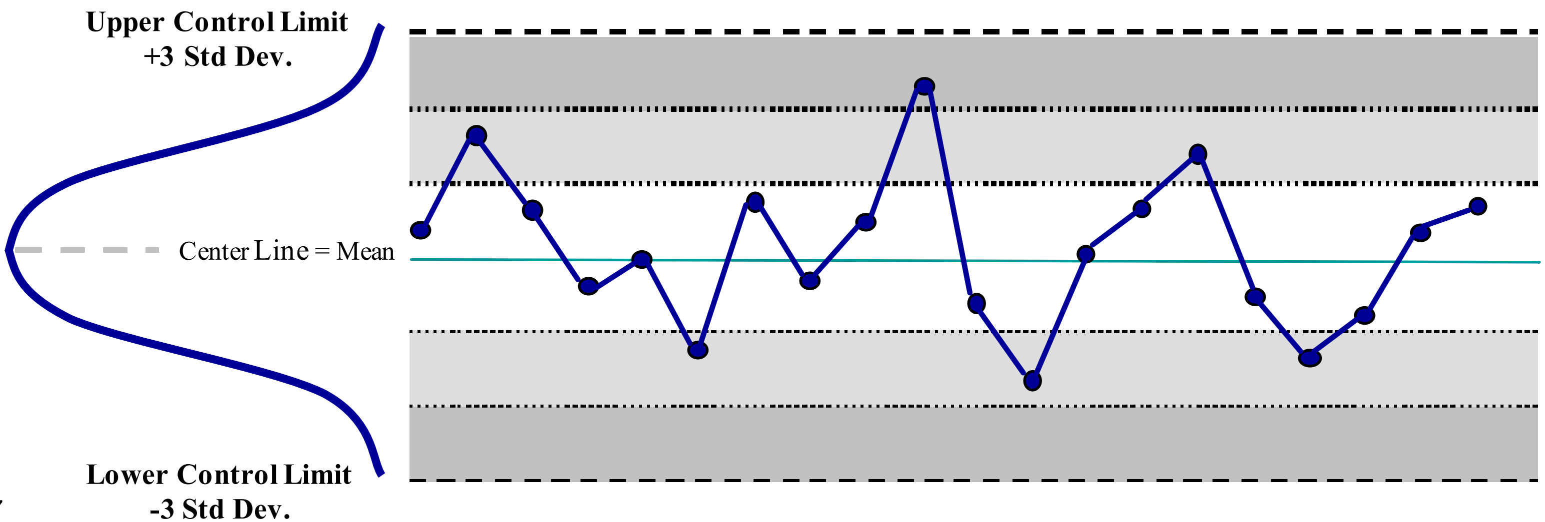
Run chart



+

Normal curve





Attributes and Variables

Attribute data

- Data that count items, such as the number of defective items in a sample

Variable data

- Data that measure of a particular product characteristic such as length or width

Control Charts

- There are a number of types of control charts
- What type of control chart should be used depends on
  - The type of data
  - The size of the sample
- With variable data the key is sample size
- With attribute data, we must determine whether
  - We are counting defectives (whether a unit of output is good or bad within a sample of units) or
  - Defects (number of occurrences of a flaw on a single unit) and

Two Basic Types of Control Charts

Counted Data ("Attribute Data"):

- Nominal data
  - ➢ Need just one chart, because mean determines standard deviation
  - ➢ p chart

Measured Data ("Variables Data"):

- Ratio and interval data
  - ➢ Need two charts, because mean and standard deviation are independent
  - ➢ X-bar and R charts

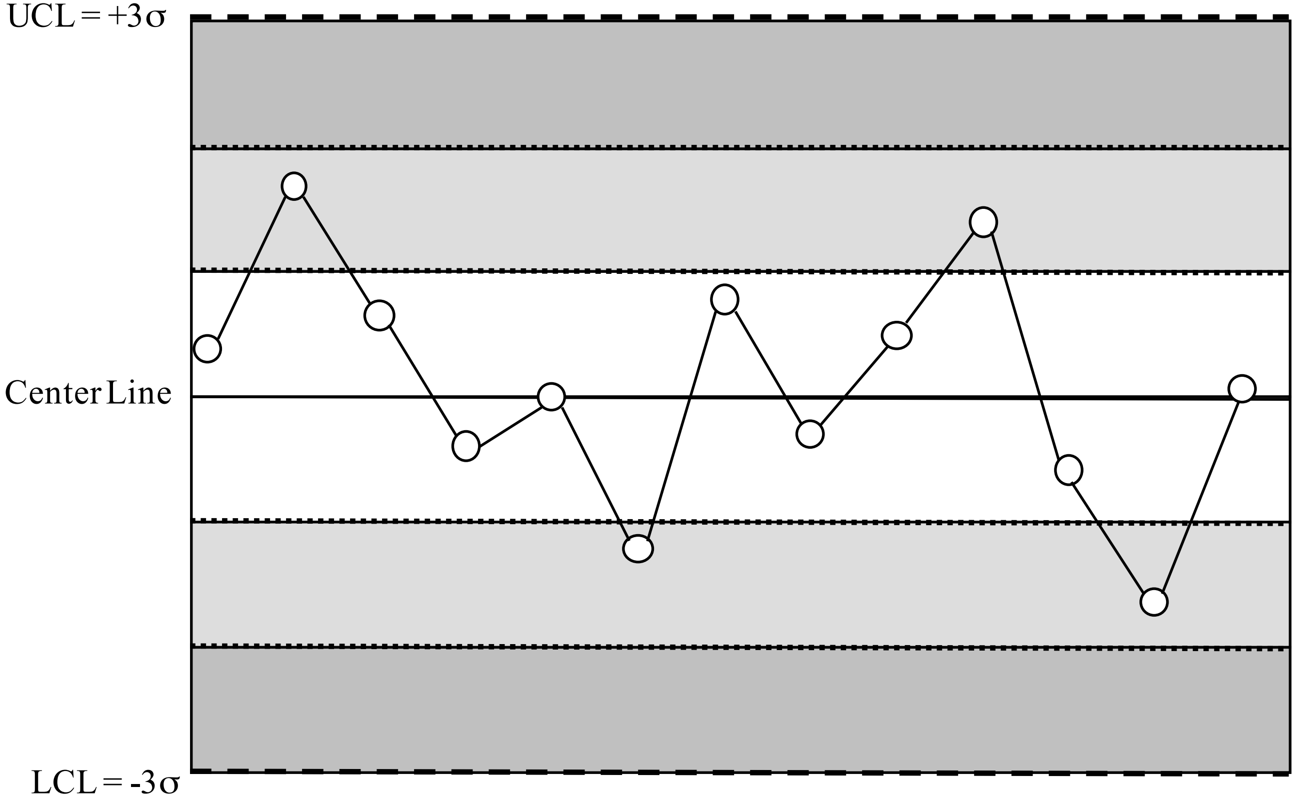
Variation Occurs Because Of …

- Worker - Operator error, e.g., lack of training
- Machine - Worn parts, e.g., improper maintenance
- Materials - Variation in raw materials, e.g., wood grain
- Methods - Differences in procedures or setups

Only when a process is in control can you know its true capability

How do we identify whether a process is in or out of control?

Control Chart Interpretation: In Control - Random Pattern

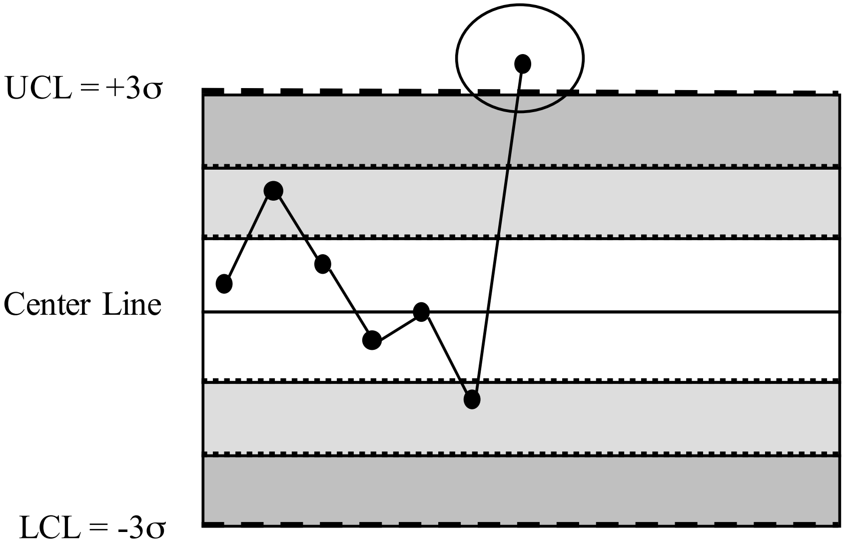


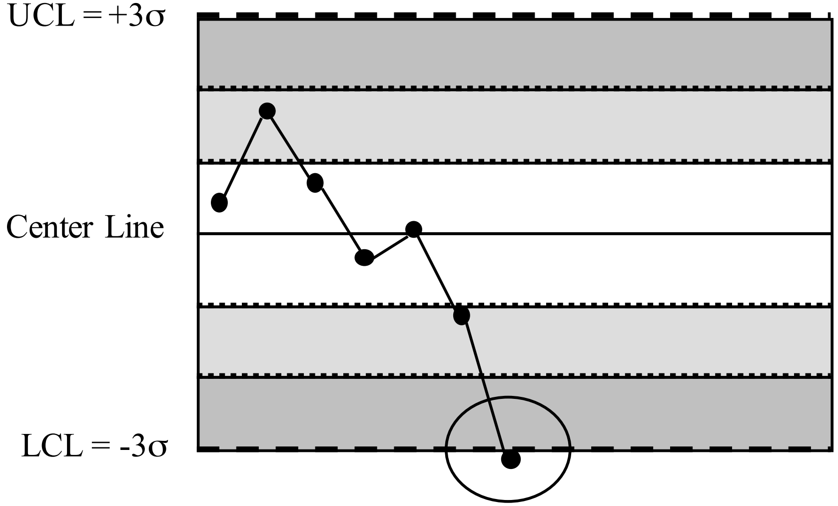
Typical Out-of-Control Patterns

- Point outside control limits
- Sudden shift in process average
- Cycles
- Trends
- Hugging the center line
- Hugging the control limits
- Instability

Control Chart Interpretation: Points Outside Limits

One sample mean above UCL;
investigate for assignable cause.

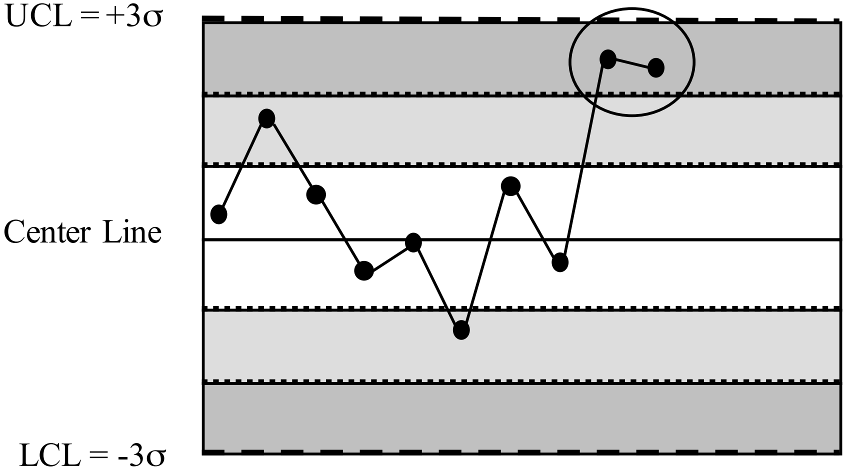


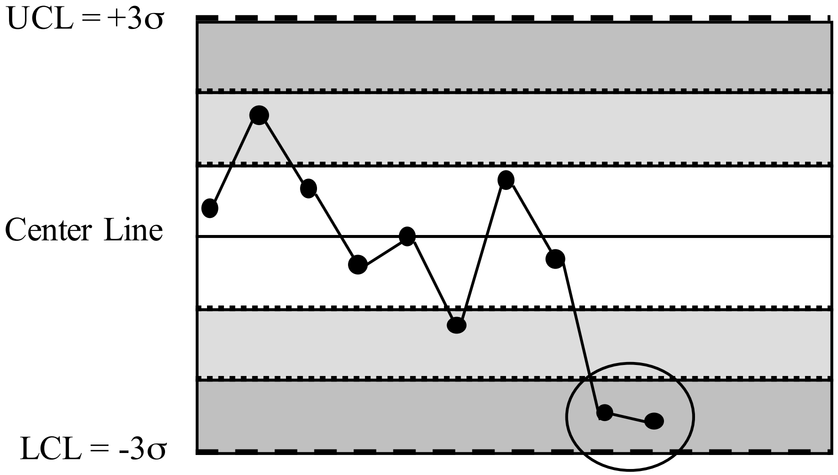


One sample mean below LCL;
investigate for assignable cause.

Control Chart Interpretation: Two-in-a-Row Between 2&3σ

Two consecutive sample means between
+2 and +3 σ; investigate for assignable cause.

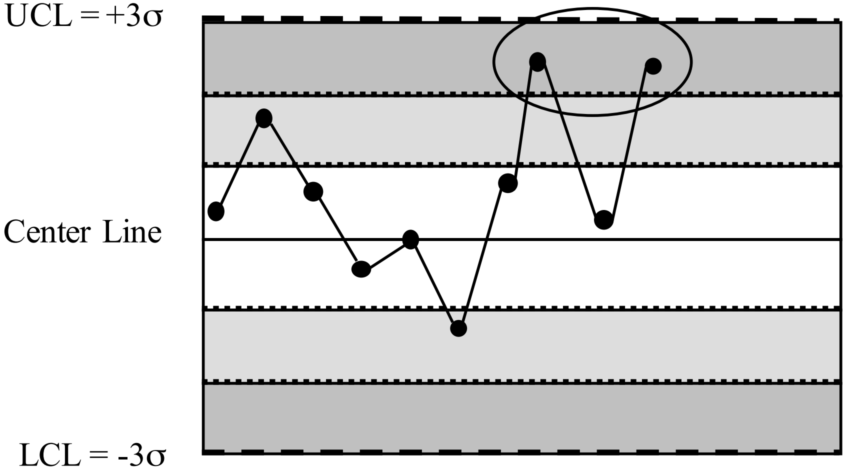


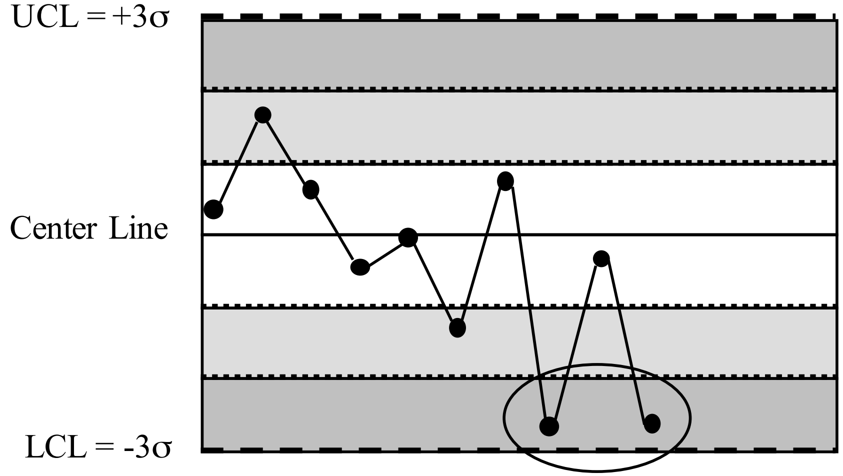


Two consecutive sample means between
-2 and -3 σ. Investigate for assignable cause.

Control Chart Interpretation: Two-out-of-Three Between 2&3σ

Two out of 3 sample means between
+2 and +3 σ; investigate for assignable cause.

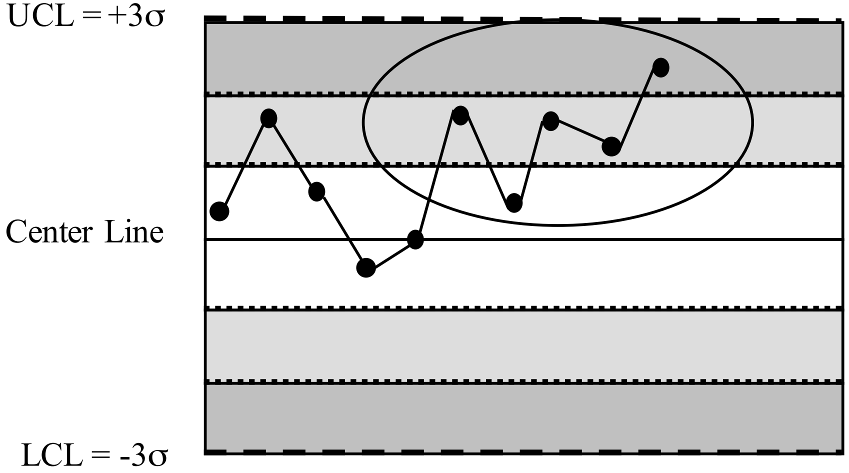


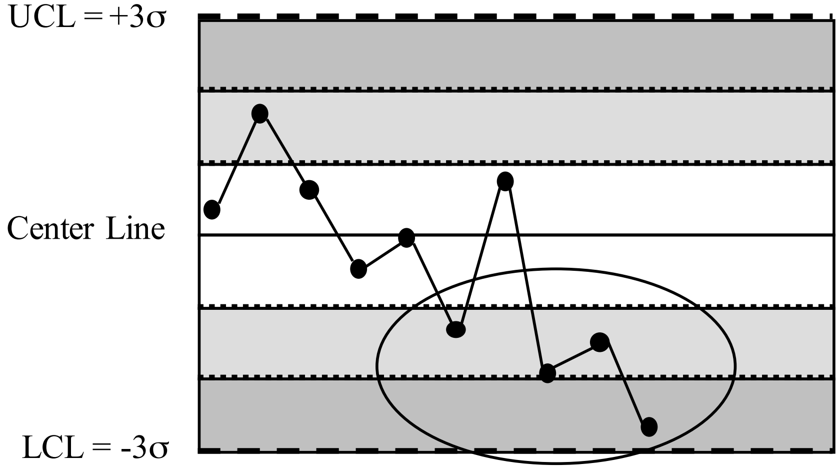


Two out of 3 sample means between
-2 and -3 σ. Investigate for assignable cause.

Control Chart Interpretation: Four-out-of-Five Between 1&3σ

Four out of five sample means between
+1 and +3 σ; investigate for assignable cause.

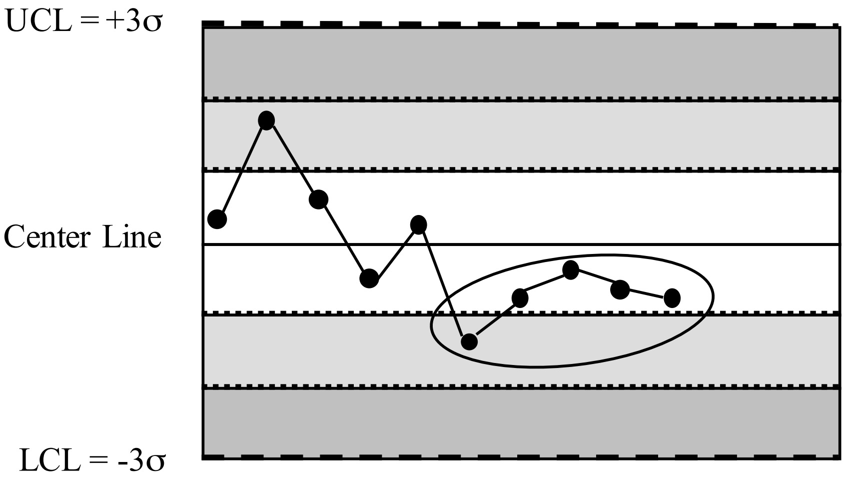


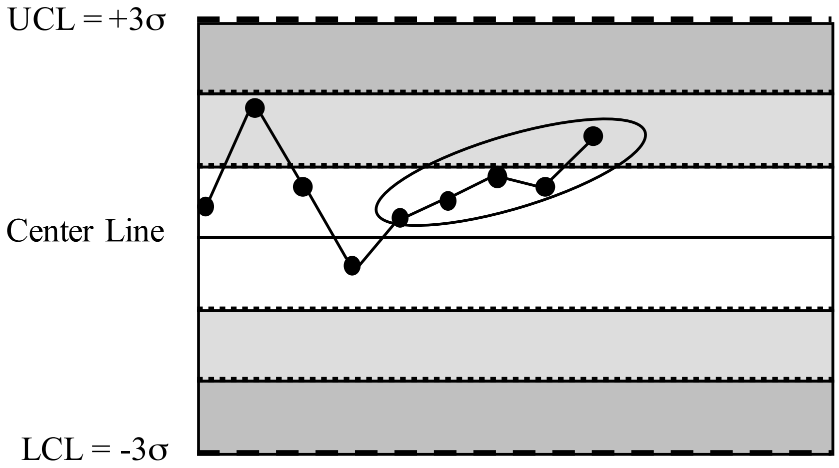


Four out of five sample means between
-1 and -3 σ. Investigate for assignable cause.

Control Chart Interpretation: Five-in-a-Row on One Side of CL

Run of five sample means below Center Line; investigate for assignable cause.

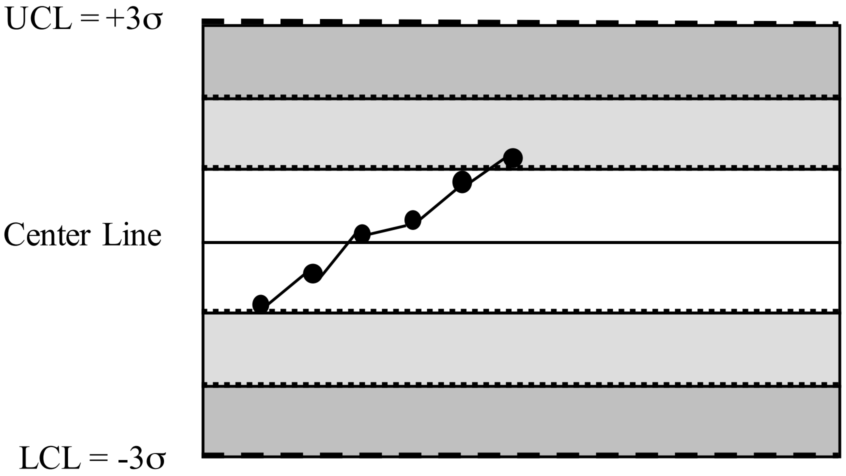


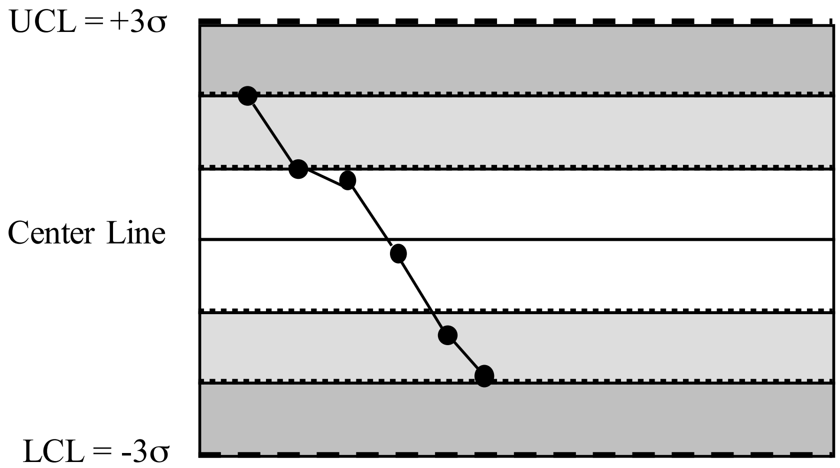


Run of five sample means above Center Line; investigate for assignable cause.

Control Chart Interpretation: Trends

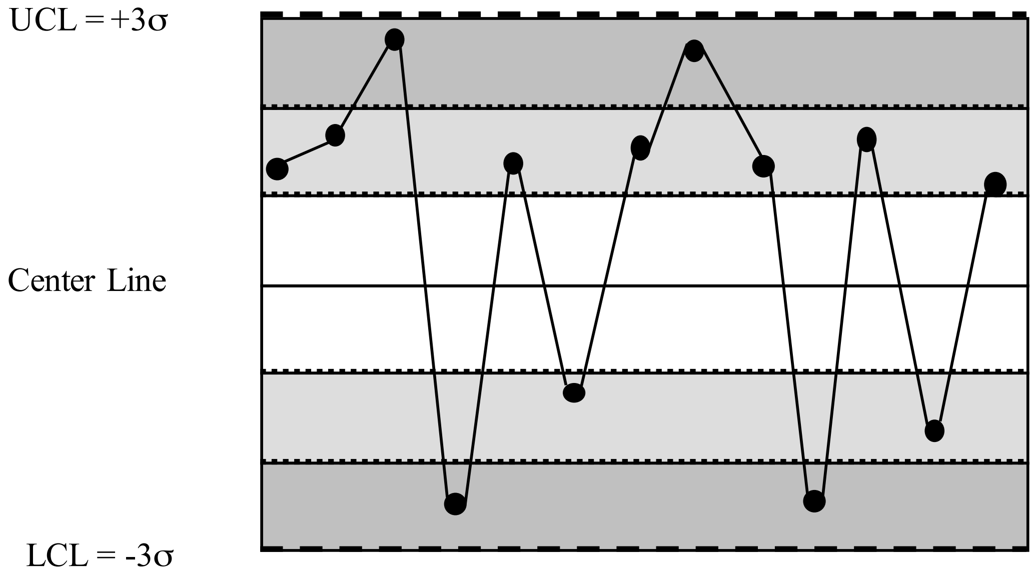
6 in a row steadily increasing;
investigate for assignable cause.



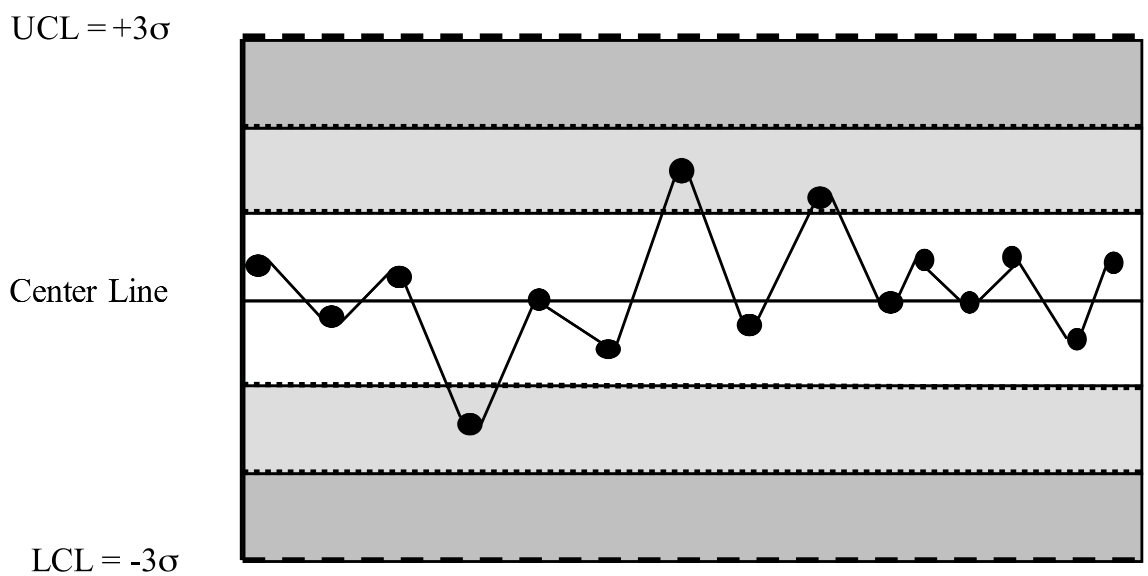


6 in a row steadily decreasing;
investigate for assignable cause.

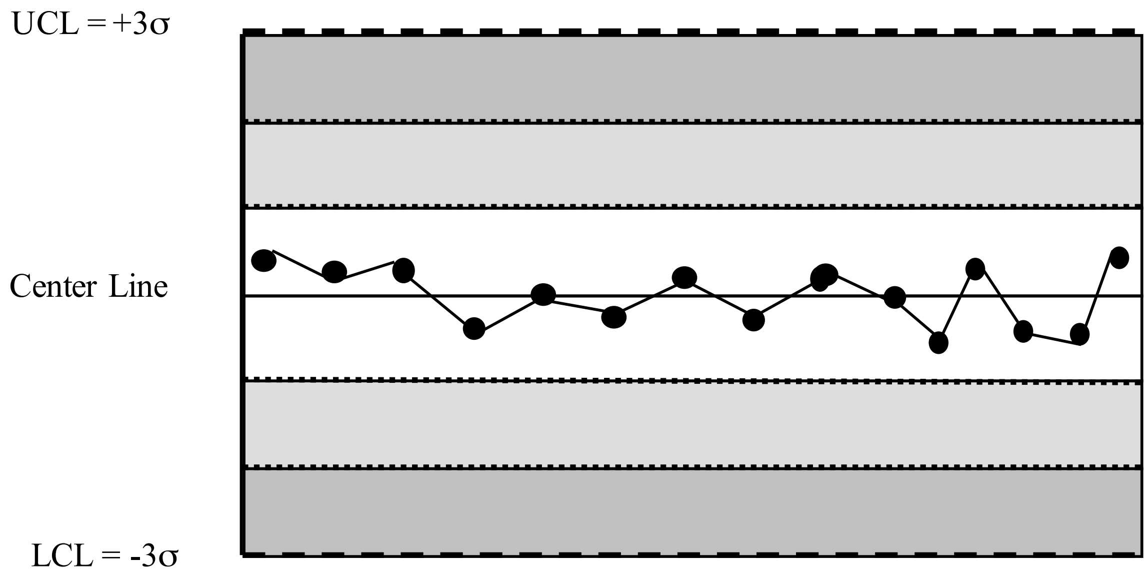
Control Chart Interpretation: Eight-in-a-Row on Between 2&3σ



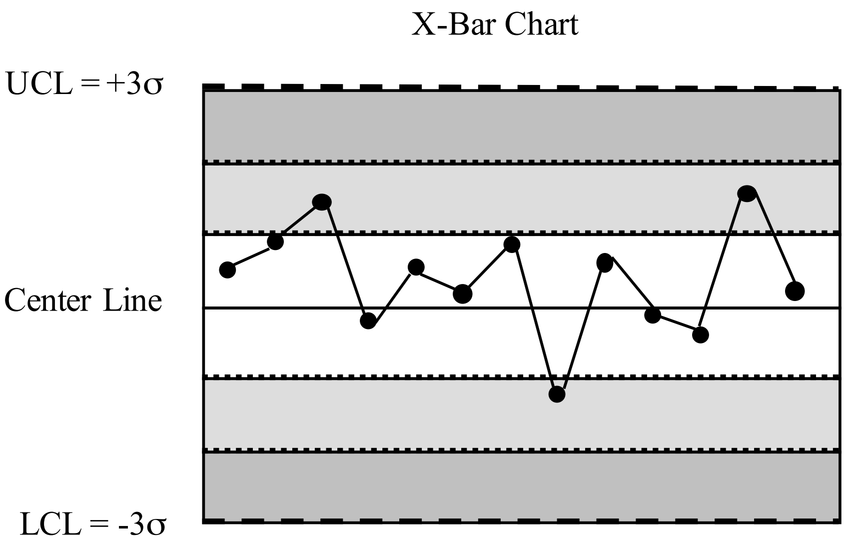
Control Chart Interpretation: Fourteen-in-a-Row Alternating

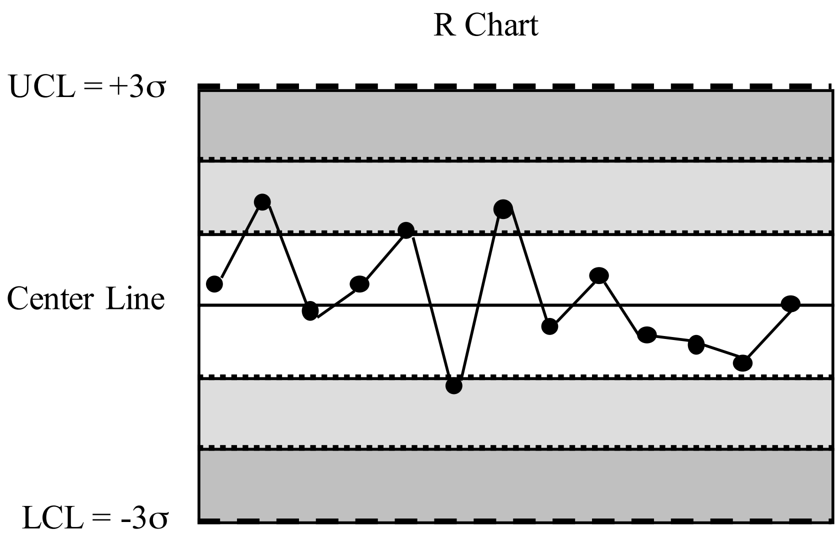


Control Chart Interpretation: Fifteen-in-a-Row within ± 1 σ



Control Chart Interpretation: In or Out of Control?





For Attribute Data - p Chart

$$UCL = \overline{p} + 3\sqrt{\frac{\overline{p}(1-\overline{p})}{n}}$$

$$CL = \overline{p}$$

$$LCL = \overline{p} - 3\sqrt{\frac{\overline{p}(1-\overline{p})}{n}}$$

where $\overline{p}$ is the observed value of the average fraction defective/defects

For Variable Data - X-bar & R Charts

$\overline{X}$ **chart**

$$UCL = \overline{\overline{x}} + A_2\overline{r}$$

$$CL = \overline{\overline{x}}$$

$$LCL = \overline{\overline{x}} - A_2\overline{r}$$

R **chart**

$$UCL = D_4\overline{r}$$

$$CL = \overline{r}$$

$$LCL = D_3\overline{r}$$

Determining SPC Sample Size

For attributes (data you count):

- Want to collect a large enough sample that you find, on average, two of the attribute you are looking for
- For example, in a p chart if you have a baseline percent defective of 10%, what should sample size be?
  - There would be one defect every 10 units, on average, so you'd need a sample of size 20

For variables (data you measure):

- Sample size is typically 4 or 5 – because measured data is continuous and is therefore more "powerful" for finding changes

When to Sample?

Frequency depends on two factors:

- How often a process is likely to change.
- How much the sampling process costs.

SPC Summary

- SPC does not stop the production of defects
(but it does minimize them!)
- SPC does not measure the quality of a worker
- SPC tests whether the system is operating as intended
- SPC lies at the core of continuous improvement

Six Sigma

What is Six Sigma?

- Is a philosophy of doing business
- Focuses on eliminating defects through reducing variation
- Uses teams for maximum effectiveness
- Focuses on results

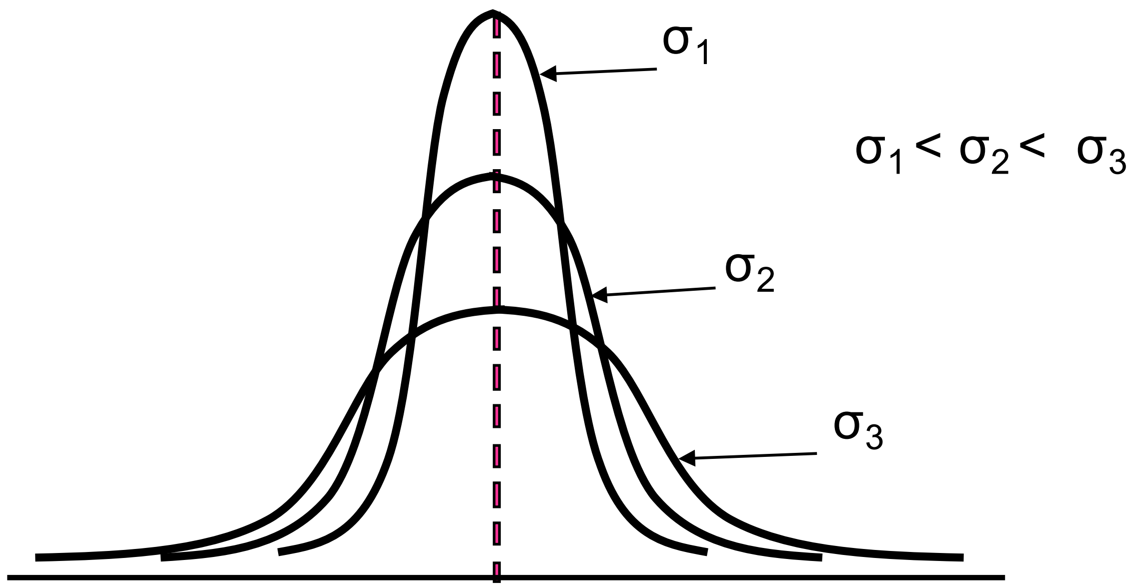
A rigorous, focused, and highly effective implementation of proven quality principles and techniques … that aims for error-free business performance.

The Six Sigma Handbook,
Thomas Pyzdek

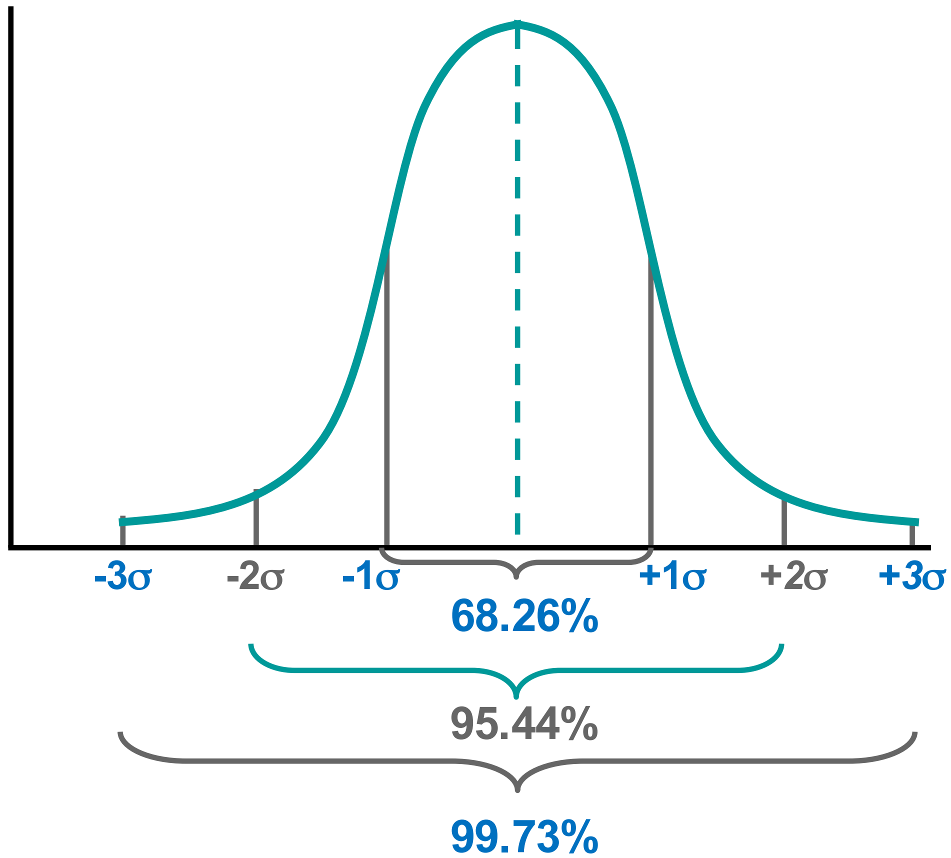
M&M Game

Variation

The output of all processes will exhibit variation



The Normal Distribution



Defect Rates for Different Levels of Sigma (σ)

Sigma Level of Quality	Defects per Million
1.5σ	500,000
2.0σ	308,300
2.5σ	158,650
3.0σ	67,000
3.5σ	22,700
4.0σ	6,220
4.5σ	1,350
5.0σ	233
5.5σ	32
6.0σ	3.4

Six Sigma Results

At 3 Sigma:

- 20,000 wrong drug prescriptions a year.
- More than 25,000 newborn babies dropped by nurses or doctors each year.
- No electricity, water, or heat for 8.6 hours each .
- 730 short or long landings at O'Hare Airport each year.
- Almost 500 incorrect surgical operations each week.

At 6 Sigma:

- 25 wrong drug prescriptions a year.
- Thirty newborn babies dropped each year.
- No electricity, water, or heat for 0.6 minutes each year.
- One short or long landing in a year
- One incorrect surgical operation every two weeks.

Source: Don Desfosse
Raytheon Six Sigma Black Belt

Magnitude of Difference Between σ Levels

- Phone-in tax advise - 2.2σ
- Restaurant bills, doctors prescription writing, and payroll processing - 2.9σ
- Average company - 3.0σ
- Airline baggage handling - 3.2σ
- Best in class companies - 5.7σ
- U.S. Navy aircraft accidents - 5.7σ
- Watch off by 2 seconds in 31 years - 6σ
- Airline industry fatality rate - 6.2σ

Source: Don Desfosse
Raytheon Six Sigma Black Belt

The Six Sigma DMAIC Framework

Define: the goals of the improvement activity

Measure: the existing system

Analyze: the system to eliminate the gap between the current performance of the system or process and the desired goal

Improve: the system

Control: the new system

The Six Sigma DMADV Framework

Define: the goals of the development/change activity

Measure: the customer requirements and specifications

Analyze: the system options to meet the customer need or the desired goal

Design: the system

Verify: the new system

Benefits from Six Sigma

- Motorola reduced manufacturing costs by $1.4 billion from 1987-1994
- Six Sigma reportedly saved Motorola $15 billion over the last 11 years
- GE produces annual benefits of over $2.5 billion across the organization from Six Sigma
- GE saved $12 billion over five years and added $1 to its earnings per share
- Honeywell (AlliedSignal) recorded more than $800 million in savings

Operations Management

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