Part IV. Quality Management

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Part IV Quality Management

Introduction

- What does the term *quality* mean?
- *Quality* is the ability of a product or service to consistently meet or exceed customer expectations.

Quality Assurance vs Strategic Approach

- Quality Assurance
  - Emphasis on finding and correcting defects before reaching market.
  - refers to the degree to which the product or service design specifications are met.
- Strategic Approach
  - Quality refers to the inherent value of the product in the marketplace
  - Proactive, focusing on preventing mistakes from occurring
  - Greater emphasis on customer satisfaction

Dimensions of Quality

- *Performance* – main characteristics
- *Aesthetics* - appearance, feel, smell, taste
- *Special Features* - extra characteristics
- *Conformance* - how well product/service conforms to customer's expectations
- *Reliability* - consistency of performance

- *Durability* - useful life of the product or service
- *Perceived Quality* - indirect evaluation of quality (e.g. reputation)
- *Serviceability - service after sale*

Service Quality

- Convenience-
- Reliability-dependability, consistency, accuracy
- Responsiveness-willingness to support customer in unusual situation
- Time- the speed service is provided
- Assurance-certainty, knowledge, trust, confidence of personnel
- Courtesy-
- Tangibles-physical appearance of facilities
- Serviceability

TABLE 5-1

Dimensions of Quality for Manufacturing versus Service Organizations

Manufacturing Organizations	Service Organizations
Conformance to specifications	Intangible factors
Performance	Consistency
Reliability	Responsiveness to customer needs
Features	Courtesy/friendliness
Durability	Timeliness/promptness
Serviceability	Atmosphere

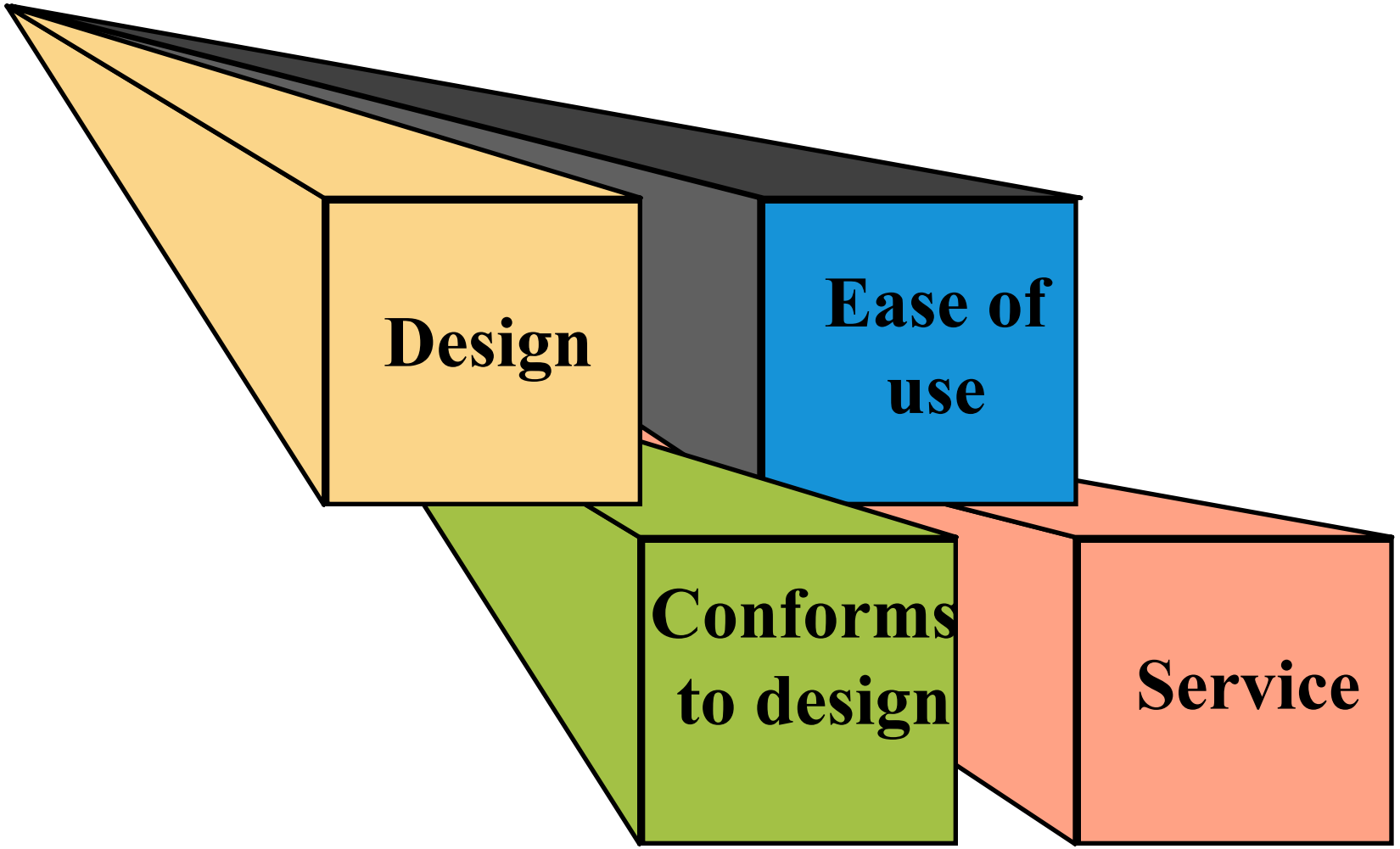
Examples of Quality Dimensions

Dimension	(Product) Automobile	(Service) Auto Repair
1. Performance	Everything works, fit & finish, Ride, handling, grade of materials used	All work done, at agreed price Friendliness, courtesy, Competency, quickness
2. Aesthetics	Interior design, soft touch	Clean work/waiting area
3. Special features	Gauge/control placement Cellular phone, CD player	Location, call when ready Computer diagnostics

Examples of Quality Dimensions (Cont'd)

Dimension	(Product) Automobile	(Service) Auto Repair
5. Reliability	Infrequency of breakdowns	Work done correctly, ready when promised
6. Durability	Useful life in miles, resistance to rust & corrosion	Work holds up over time
7. Perceived quality	Top-rated car	Award-winning service department
8. Serviceability	Handling of complaints and/or requests for information	Handling of complaints

Determinants of Quality



Challenges with Service Quality

- Customer expectations often change
- Different customers have different expectations
- Each customer contact is a “moment of truth”
- Customer participation can affect perception of quality

The Consequences of Poor Quality

- Loss of business
- Liability
- Productivity
- Costs

Costs of Quality

How significant is the cost of quality?

- Costs of quality include:

1. 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.
       - Scrap, Rework, Repair
   - External Failure Costs
     - All costs incurred to fix problems that are detected after the product/service is delivered to the customer. Warranty, loss of customer, handling complaint

2. Appraisal Costs
   - Costs of activities designed to ensure quality or uncover defects
     - Inspection, testing
3. Prevention Costs
   - All training, quality planning, customer assessment, process control, and quality improvement, redesign product, equipment modification costs to prevent defects from occurring

Prevention costs.	Costs of preparing and implementing a quality plan.
Appraisal costs.	Costs of testing, evaluating, and inspecting quality.
Internal failure costs.	Costs of scrap, rework, and material losses.
External failure costs.	Costs of failure at customer site, including returns, repairs, and recalls.

4.1.1. Evolution of Quality Management

- In the early twentieth century, quality management meant inspecting products to ensure that they met specifications.
- In the 1940s, **quality became more statistical in nature**. Statistical sampling techniques were used to evaluate quality, and quality control charts were used to monitor the production process.
- In the 1960s, with the help of so-called quality gurus, the concept took on a broader meaning.

- The term used for today's new concept of quality is *total quality management* or *TQM*.
- the old concept (inspection and statistical control) is *reactive*, designed to correct quality problems after they occur. The new concept is *proactive*, designed to build quality into the product and process design.

4.1.2. The foundations of Quality Management: Quality Gurus

- A core of quality pioneers shaped current thinking and practice.

1. **Walter A. Shewhart:** was a statistician at Bell Labs during the 1920s and 1930s.

- Shewhart **studied randomness and recognized** that variability existed in all manufacturing processes.
- He developed quality control charts that are used to identify whether the variability in the process is random or due to an assignable cause such as poor workers or miscalibrated machinery.
- **He stressed that eliminating variability improves quality**.
- He is considered as the grandfather of quality

2. **W. Edwards Deming:** is often referred to as the “father of quality control.” He was a statistics professor at New York University in the 1940s. After World War II, he assisted many Japanese companies in improving quality.

- The Japanese regarded him so highly that in 1951 they established the *Deming Prize*, an annual award given to firms that demonstrate outstanding quality.

- Historically, poor quality was blamed on workers—on their lack of productivity, laziness, or carelessness. However, Deming pointed out that only 15 percent of quality problems are actually due to worker error.
- The remaining 85 percent are caused by processes and systems, including poor management.
- Deming compiled 14 points he believed were the prescription needed to achieve quality in an organization

1. Create consistency of purpose
2. Lead to promote change, adopt new philosophies, we can't further stay with
3. Build quality into the product, stop dependence on inspection
4. Build long term relationship based on performance instead of awarding business on the basis of price. Meaningful measure of quality along with price should be the measure
5. Find problems, Continuously improve product, quality and service
6. Institute modern methods of training on the job.
7. Emphasizes leadership
8. Drive out fear
9. Breakdown barriers between departments
10. Eliminate numerical goals, slogans not backed up by methods
11. Support, help and improve
12. Remove barriers to pride in work
13. Institute a vigorous program of education and self-improvement
14. Create a structure in top management that will push every day on the above 13 points.

3. Joseph M. Juran:

- Juran viewed quality as **fitness for purpose.** He also believed that 80 percent of the quality defects are controllable; thus management has the responsibility to correct the deficiency.
- He described quality in terms of a ***trilogy*** consisting quality planning (process capability), quality control (corrective action), quality improvement (better way of doing).
- His philosophy is similar to Deming's, but while Deming stressed the need for an organizational "transformation," Juran believed that implementing quality initiatives should not require such a dramatic change and that quality management should be embedded in the organization.

4. Armand V. Feigenbaum

- Recognized that quality is not only collection of tools and techniques but also a “total filed.”
- Improvement in one process creates improvement in the whole chain of operation.
- His understanding of systems theory led him to create an environment in which people could learn from each other’s success and his leadership and open work environment led to creates cross- functional team work.
- This philosophy was adapted by the Japanese and termed “company-wide quality control.”
- He also introduced the concept “quality at the source” where by every employee should be responsible for inspecting his own work. For example a worker can stop the assembly line without any precondition if defect occurs

5. **Philip B. Crosby** is another recognized guru of TQM. He developed the phrase “Do it right the first time” and the notion of *zero defects*, arguing that no amount of defects should be considered acceptable.

6. **Kaoru Ishikawa** is best known for the development of quality tools called cause-and-effect diagrams, also called fishbone diagrams. These diagrams are used for quality problem solving.

7. **Genichi Taguchi** is a Japanese quality expert known for his work in the area of product design. He estimates that as much as 80 percent of all defective items are caused by poor product design.

- Taguchi stresses that companies should focus their quality efforts **on the design stage, as it is much cheaper and easier to make changes during the product design stage than later during the production process.**

- His idea is based on developing **robust design.**
- design a product that can perform over a wide range of environmental conditions than it is to control the environmental conditions.

Key Contributors to Quality Management

Contributor	Known for
Deming	14 points; special & common causes of variation
Juran	Quality is fitness for use
Feignbaum	Quality is a total field
Crosby	Quality is free; zero defects
Ishikawa	Cause-and effect diagrams; quality circles

4.1.3 Quality Awards and Standards

- **Malcolm Baldrige National Quality Award (MBNQA)**
- **The Deming Prize**
- European Quality Award
- **ISO 9000 Certification**
- **ISO 14000 Standards**

1. MBNQA- What Is It?

- Annual award given by the U.S government to recognize quality achievements of U.S companies
- Intended to reward and stimulate quality initiatives
- Given to no more than two companies in each of three categories; manufacturing, service, and small business

Malcolm Baldrige National Quality Award

1. Leadership (125 points)
2. Strategic Planning (85 points)
3. Customer and Market Focus (85 points)
4. Information and Analysis (85 points)
5. Human Resource Focus (85 points)
6. Process Management (85 points)
7. Business Results (450 points)

2. The Deming Prize

- **Given by the Union of Japanese Scientists and Engineers since 1951**
- **Named after W. Edwards Deming who worked to improve Japanese quality after WWII**
- Main focus on statistical quality control

3. European Quality Award

- Is Europe's most prestigious quality award for organizational excellence.
- **Award winners**: awarded to the best in each of the award strategies
- **Prizes winners**: presented to those who excel in some of the fundamental concepts of excellence like
  - Leadership and constancy of purpose
  - Customer focus
  - Corporate social responsibility
  - People development and involvement
  - Results orientation

Quality Certification

- 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

1. ISO 9000 Quality Management Principles

- Customer focus
- Leadership
- People involvement
- Process approach
- A systems approach to management
- Continual improvement
- Factual approach to decision making
- Mutually beneficial supplier relationships

2. ISO 14000

Standards in three major areas

- Management systems
  - Systems development and integration of environmental responsibilities into business planning
- Operations
  - Consumption of natural resources and energy
- Environmental systems
  - Measuring, assessing and managing emissions, effluents, and other waste

4.1.4 Total Quality Management

- TQM is a managerial philosophy that involves everyone in an organization in a continual effort to improve quality and achieve customer satisfaction.
- Ever ending push to improve quality,
- involvement of every one and
- ever increasing customer satisfaction

The TQM Approach

1. Find out what the customer wants
2. Design a product or service that meets or exceeds customer wants. Make it easy to use and produce
3. Design processes that facilitates doing the job right the first time, mistake proof process (poka yoke or “fail-safing”
4. Keep track of results, never stop trying to improve
5. Extend these concepts to suppliers

4.1.5 Elements of TQM

1. Continual improvement:
2. Competitive benchmarking
3. Employee empowerment
4. **Team approach**: for problem solving , synergy
5. **Quality at the source**: making each worker responsible for the quality of his work

Continuous improvement

Never ending improvement to the process of converting inputs into outputs

Continuous improvement model

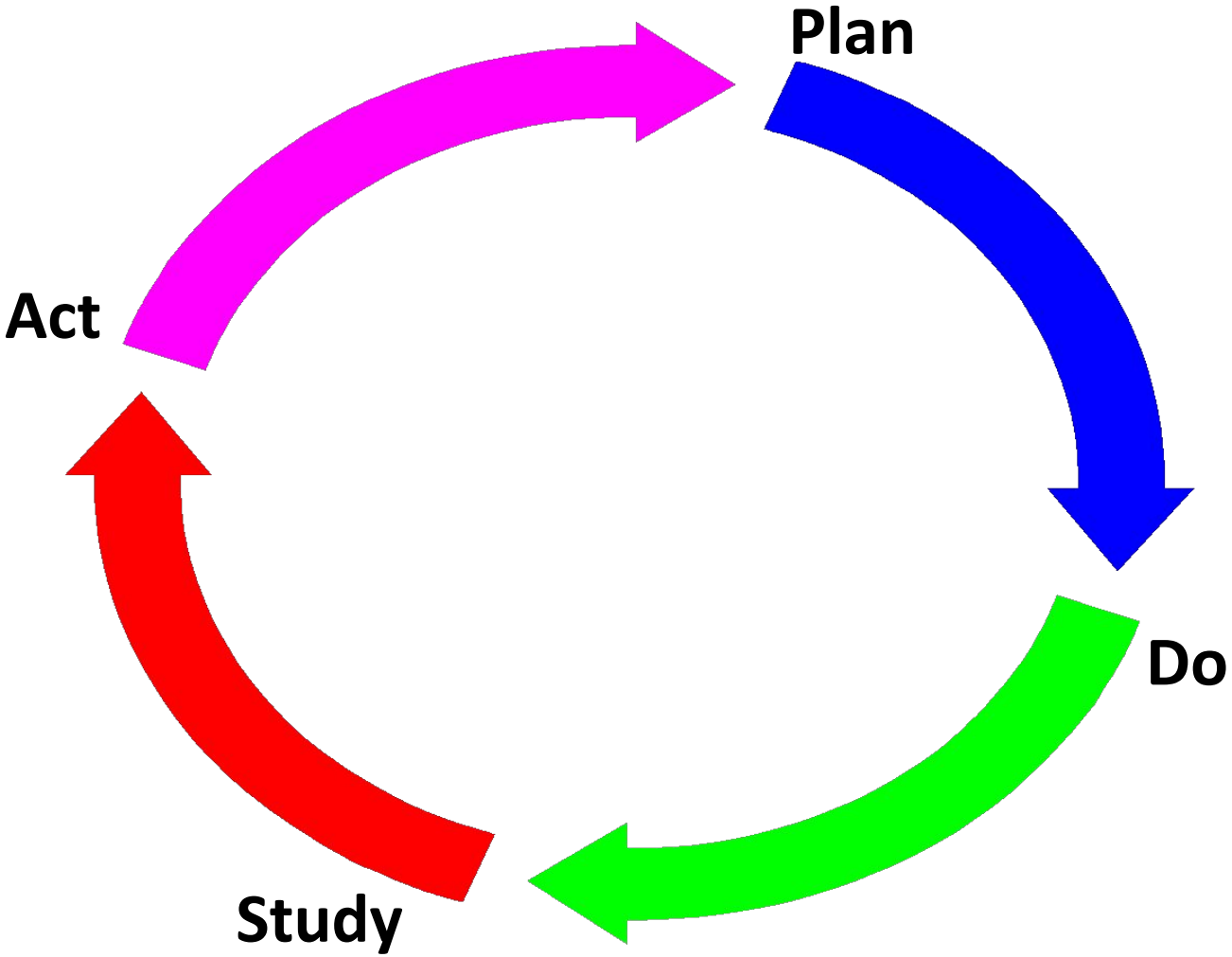
The plan-do-study- Act cycle

Plan: begin by studying the current process. Document the process then collect data on the process/problem. Then analyze the data and develop a plan for improvement. Specify measures for improvement.

Do: implement the plan on small scale if possible

Study: check how closely the results match the original goals

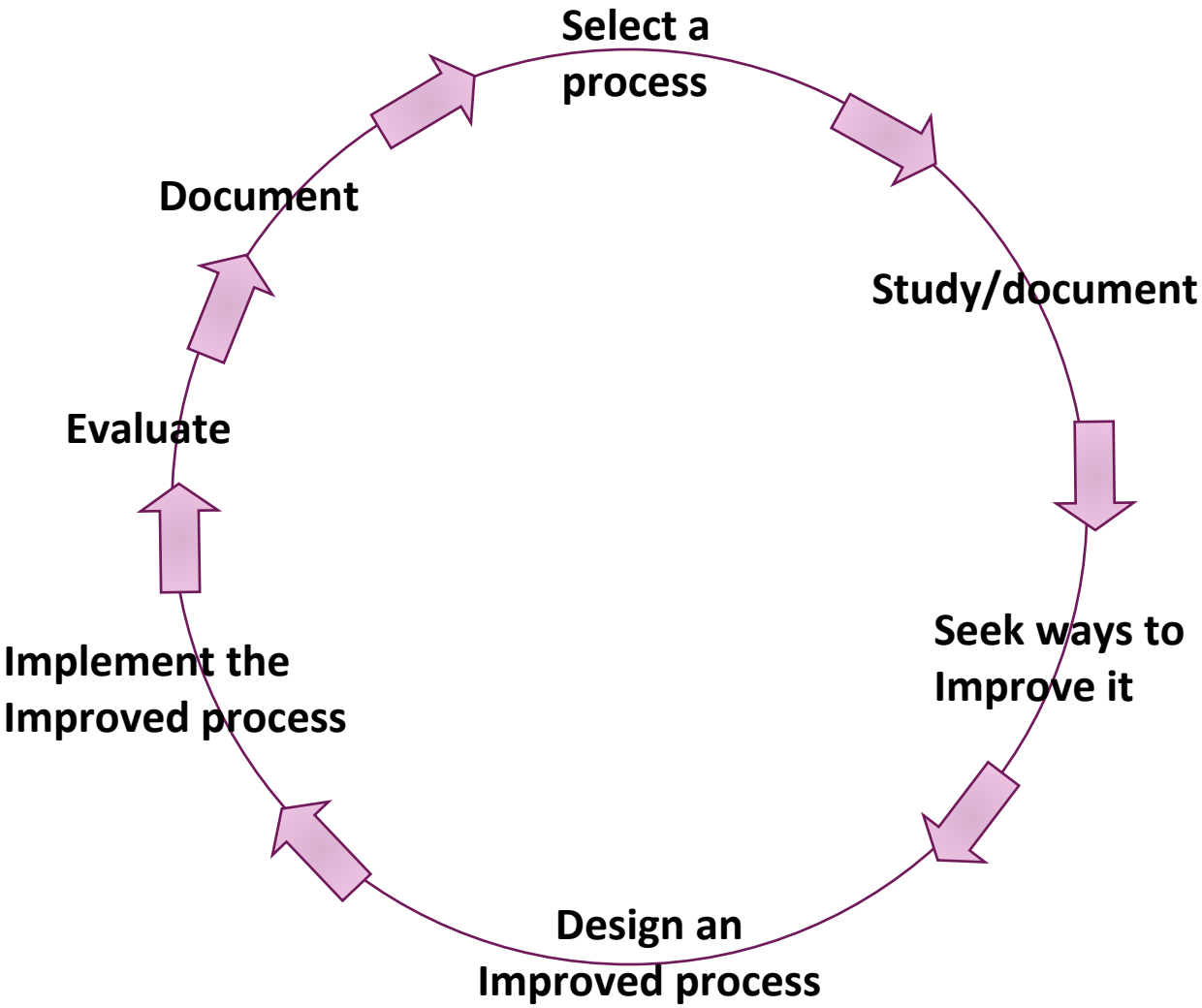
Act: if results are successful, standardize the new method and communicate it to all people


Plan
Do
Study
Act

Process Improvement

- Process Improvement: A systematic approach to improving process
- Process mapping
- Analyze the process
- Redesign the process

The Process Improvement Cycle



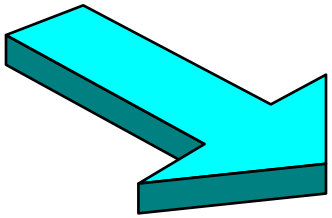
Benchmarking Process

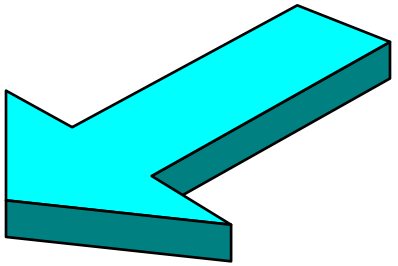
- Identify a critical process that needs improving
- Identify an organization that excels in this process
- Contact that organization
- Analyze the data
- Improve the critical process

Employee empowerments

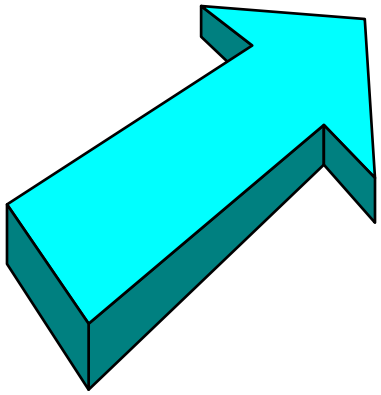
- Build communication networks
- Develop open, supportive supervisors
- Moving responsibility from managers to operating employees
- Create high morale organization, and quality circle teams

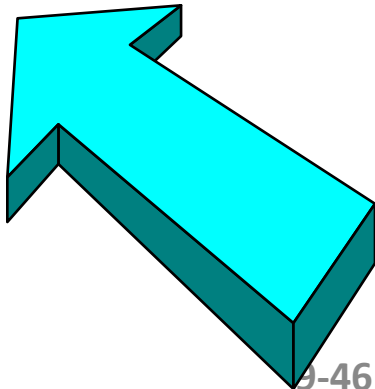
Quality at the Source





The philosophy of making each worker responsible for the quality of his or her work.





Problem solving

- Problem solving is one of the procedures of TQM. It follows a **standard approach.**
- An important aspect of problem solving in the TQM approach is eliminating the cause of so that the problem does not recur.

Obstacles to Implementing TQM

- Lack of:
  - Company-wide definition of quality
  - Strategic plan for change
  - Customer focus
  - Real employee empowerment
  - Strong motivation
  - Time to devote to quality initiatives
  - Leadership

- Poor inter-organizational communication
- View of quality as a “quick fix”
- Emphasis on short-term financial results
- Internal political and “turf” wars

4.2 Quality Control

- Every manufacturing process is a repetitive process -depending both on controllable and uncontrollable factors.
- Due to this, variation in the quality of a product is inherent in every production process

- Thus, there is always a necessity that the deviations in the quality of the product should be discovered and corrected.
- Control is the process of verification or correction in the quality of the product when the deviations in the quality are found to be more than expected.

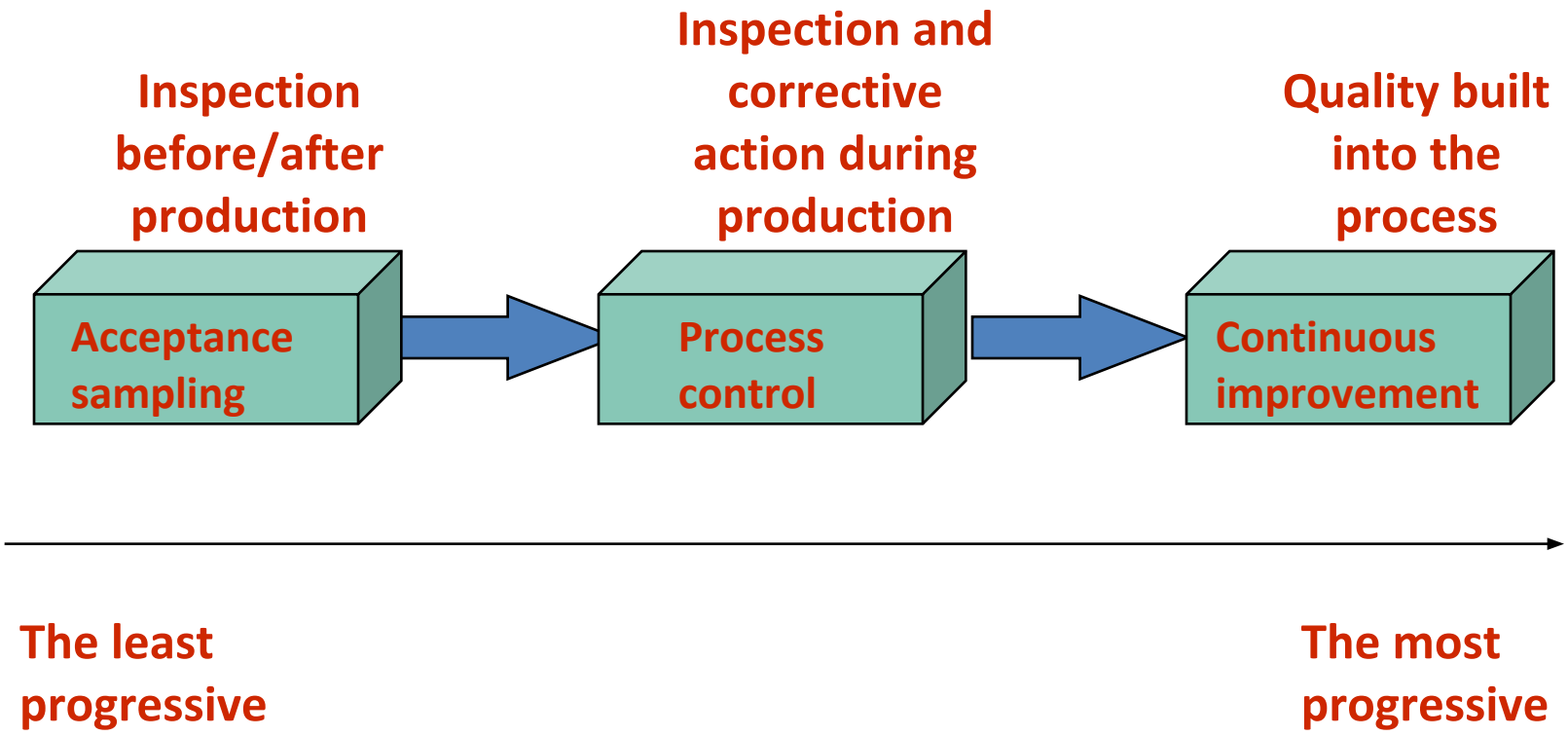
Philosophical Orientation of QC

1. Traditionally" manufacturing QC was operated as a gate keeping activity; the objective was to control product quality at the output stage through inspection. The game has changed, however.

2. The new game calls for changes from inspection toward facilitation, helping the line organization achieve its quality goals.
3. Finally, the new game calls for QC to work with all aspects of the organization in the development of a Total Quality control (TQC) system and philosophy

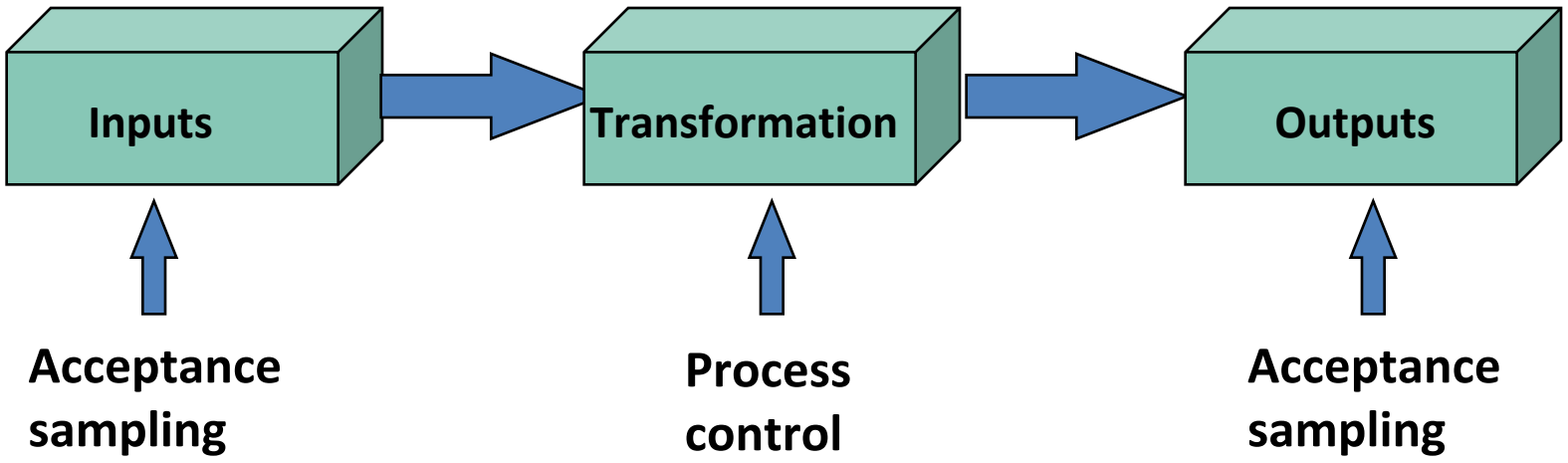
- This notion holds that quality must be approached systematically, throughout each function and activity of the firm.

Phases of Quality Assurance

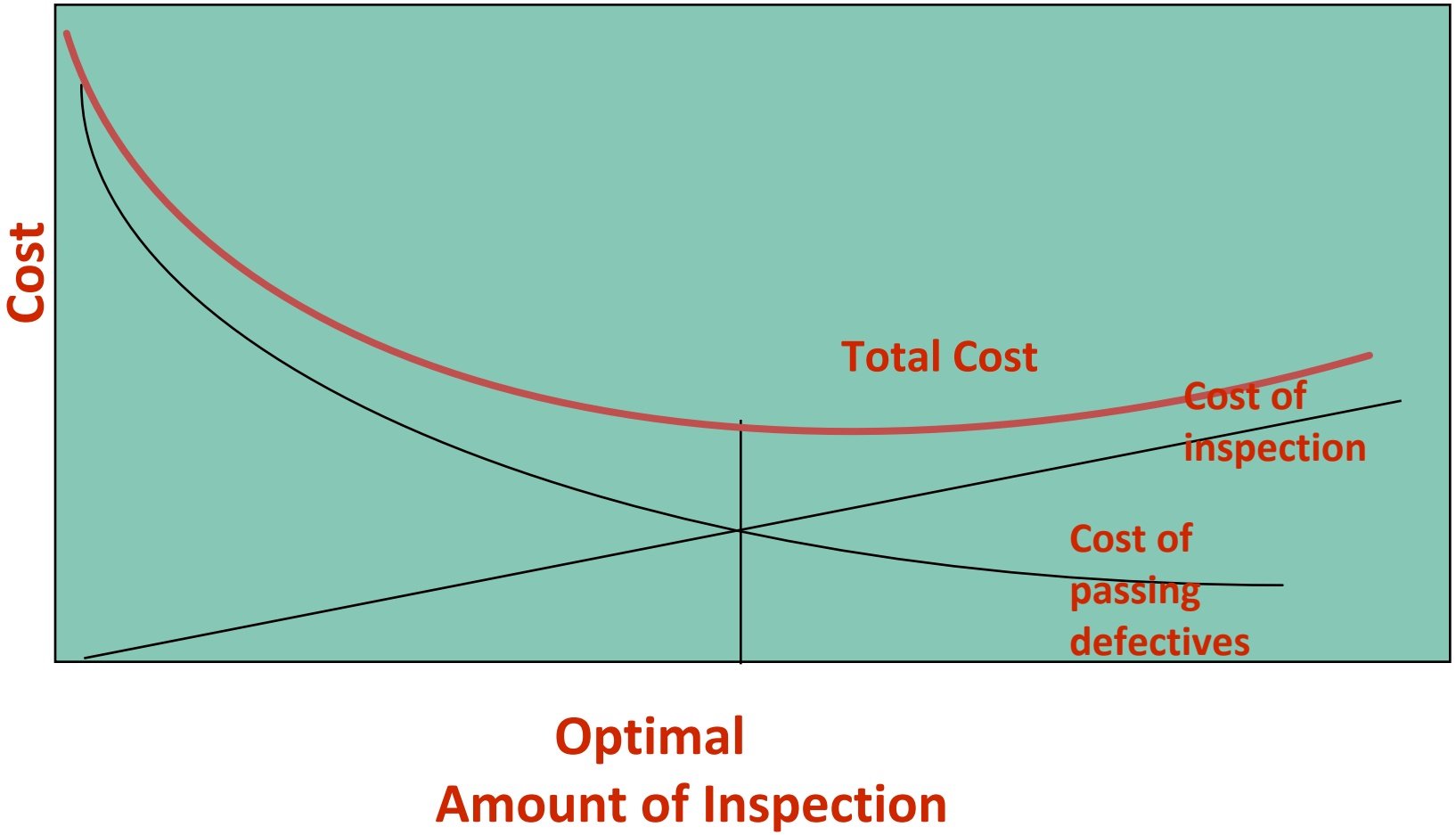


Inspection

- How Much/How Often
- Where/When
- Centralized vs. On-site



Inspection Costs



Where to Inspect in the Process

- Raw materials and purchased parts
- Finished products
- Before a costly operation
- Before an irreversible process
- Before a covering process

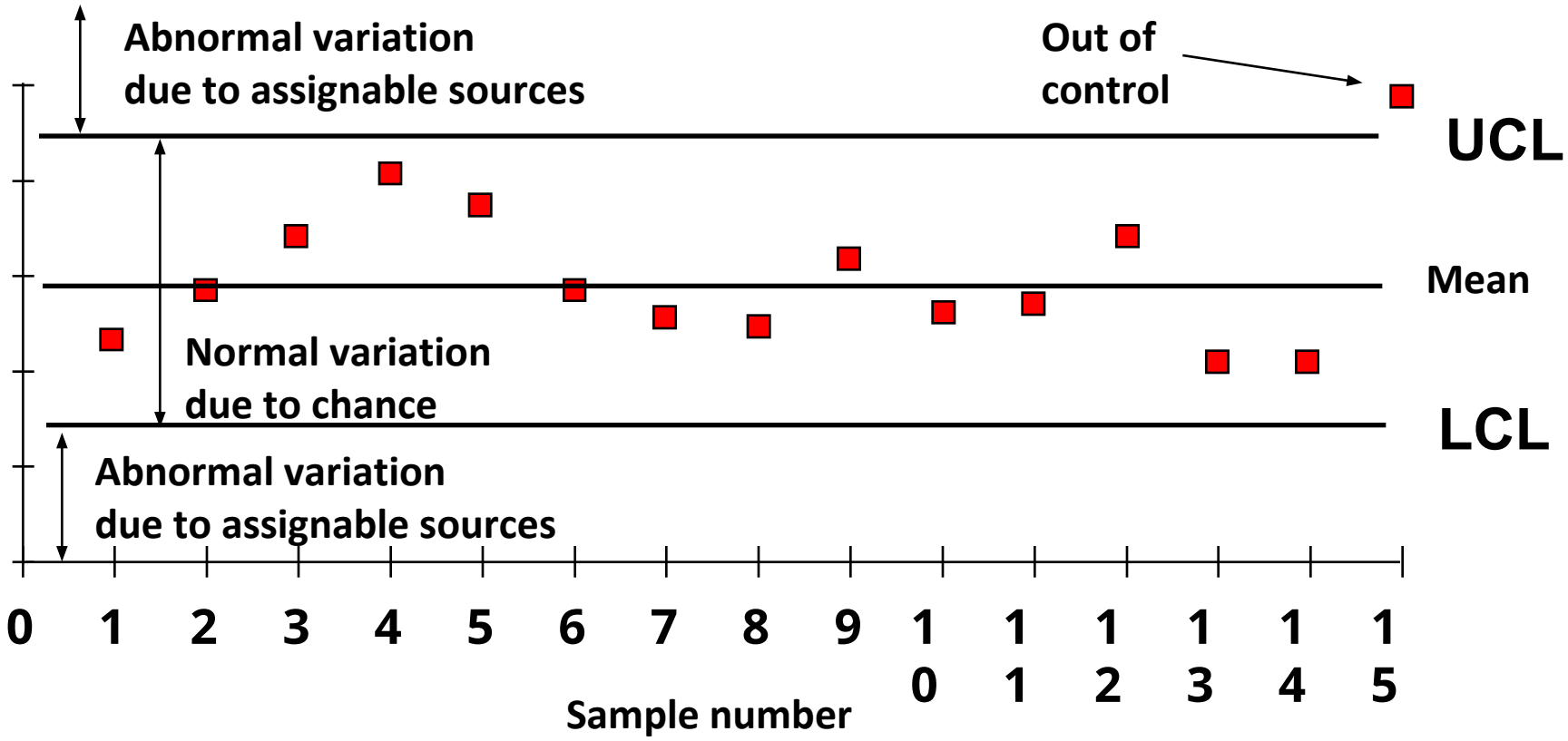
Examples of Inspection Points

Type of business	Inspection points	Characteristics
Fast Food	Cashier	Accuracy
	Counter area	Appearance, productivity
	Eating area	Cleanliness
	Building	Appearance
	Kitchen	Health regulations
Hotel/motel	Parking lot	Safe, well lighted
	Accounting	Accuracy, timeliness
	Building	Appearance, safety
	Main desk	Waiting times
Supermarket	Cashiers	Accuracy, courtesy
	Deliveries	Quality, quantity

Control Chart

- Control Chart
  - *Purpose:* to monitor process output to see if it is random
  - A time ordered plot representative sample statistics obtained from an on going process (e.g. sample means)
  - Upper and lower control limits define the range of acceptable variation

Control Chart



Statistical Process Control

- The essence of statistical process control is to assure that the output of a process is random so that *future output* will be random.

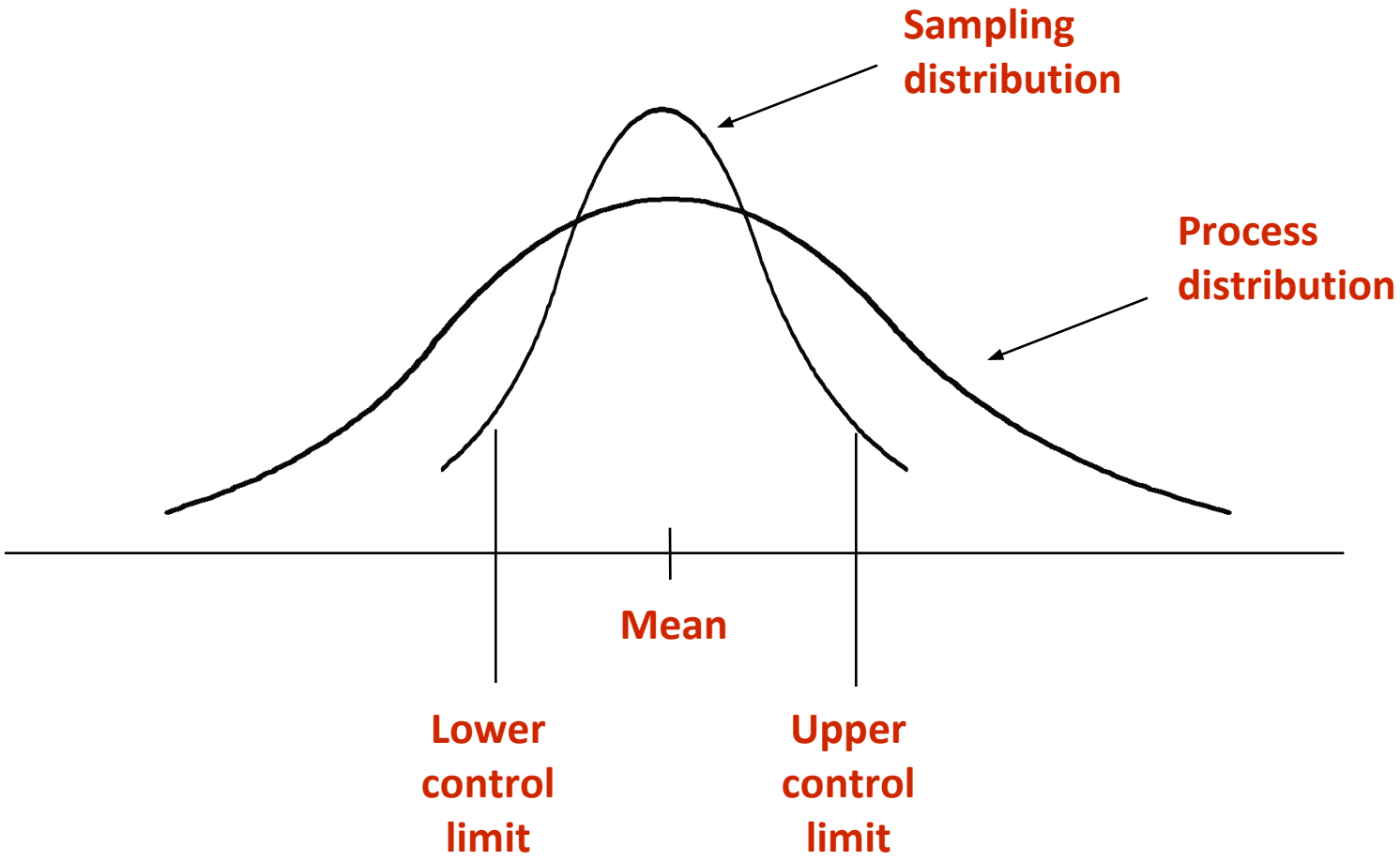
Statistical Process Control

- The Control Process
  - Define
  - Measure
  - Compare
  - Evaluate
  - Correct
  - Monitor results

Statistical Process Control

- Variations and Control
  - *Random variation*: Natural variations in the output of a process, created by countless minor factors
  - *Assignable variation*: A variation whose source can be identified

Control Limits



SPC Errors

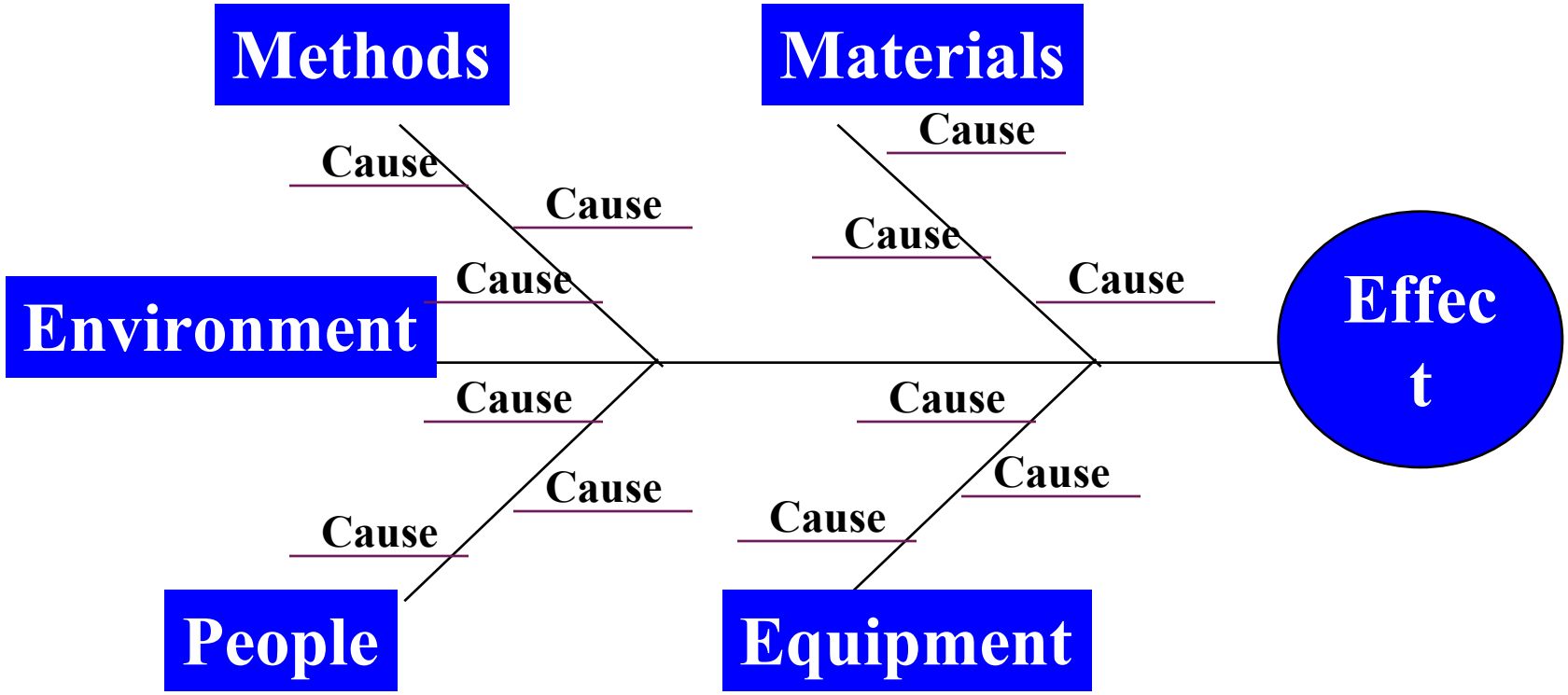
- Type I error
  - Concluding a process is not in control when it actually is.
- Type II error
  - Concluding a process is in control when it is not.

Seven Tools of Quality Control

- Cause-and-Effect Diagrams
- Flowcharts
- Checklists
- Control Charts
- Scatter Diagrams
- Pareto Analysis
- Histograms

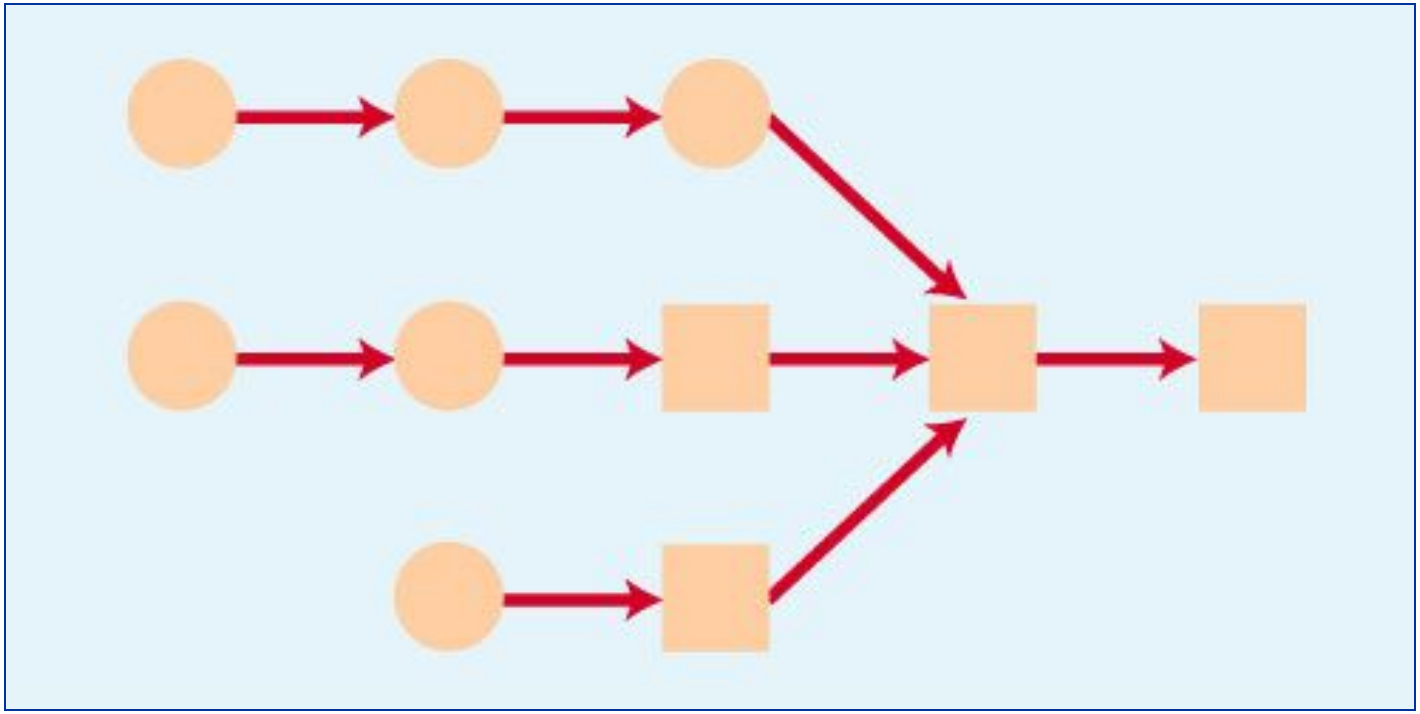
Cause-and-Effect Diagram

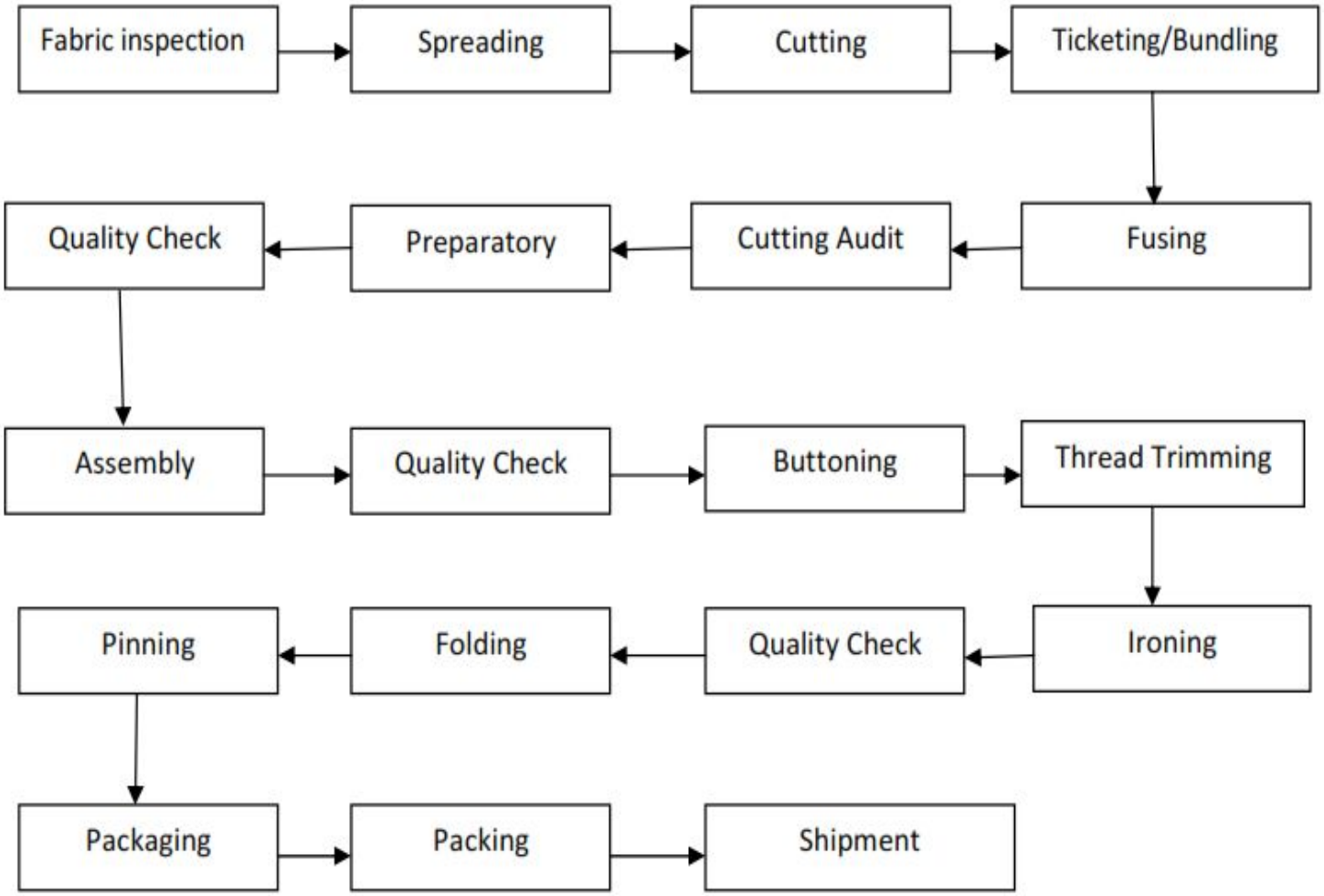
A diagram used to organize a search for the causes of a problem also known as a fishbone diagram



Flowcharts

- Used to document the detailed steps in a process
- Often the first step in Process Re-Engineering




Fabric inspection
Spreading
Cutting
Ticketing/Bundling
Fusing
Cutting Audit
Preparatory
Quality Check
Assembly
Quality Check
Buttoning
Thread Trimming
Ironing
Quality Check
Folding
Pinning
Packaging
Packing
Shipment

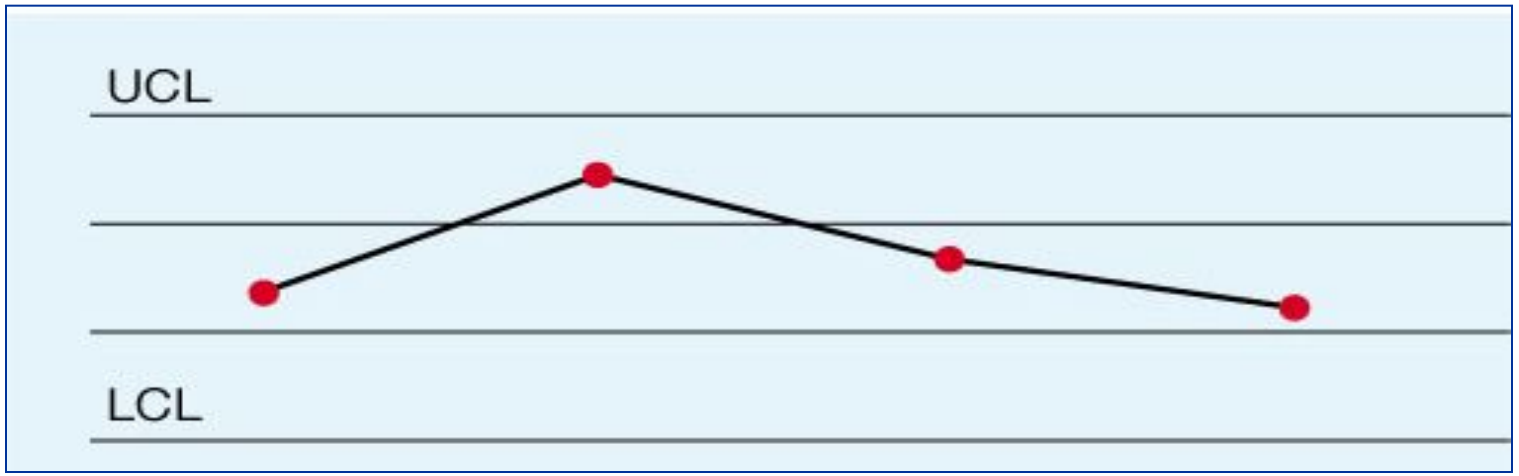
Check list

- Simple data check-off sheet designed to identify type of quality problems at each work station; per shift, per machine, per operator

Defect Type	No. of Defects	Total
Broken zipper	✓✓✓	3
Ripped material	✓✓✓✓✓✓✓	7
Missing buttons	✓✓✓	3
Faded color	✓✓	2

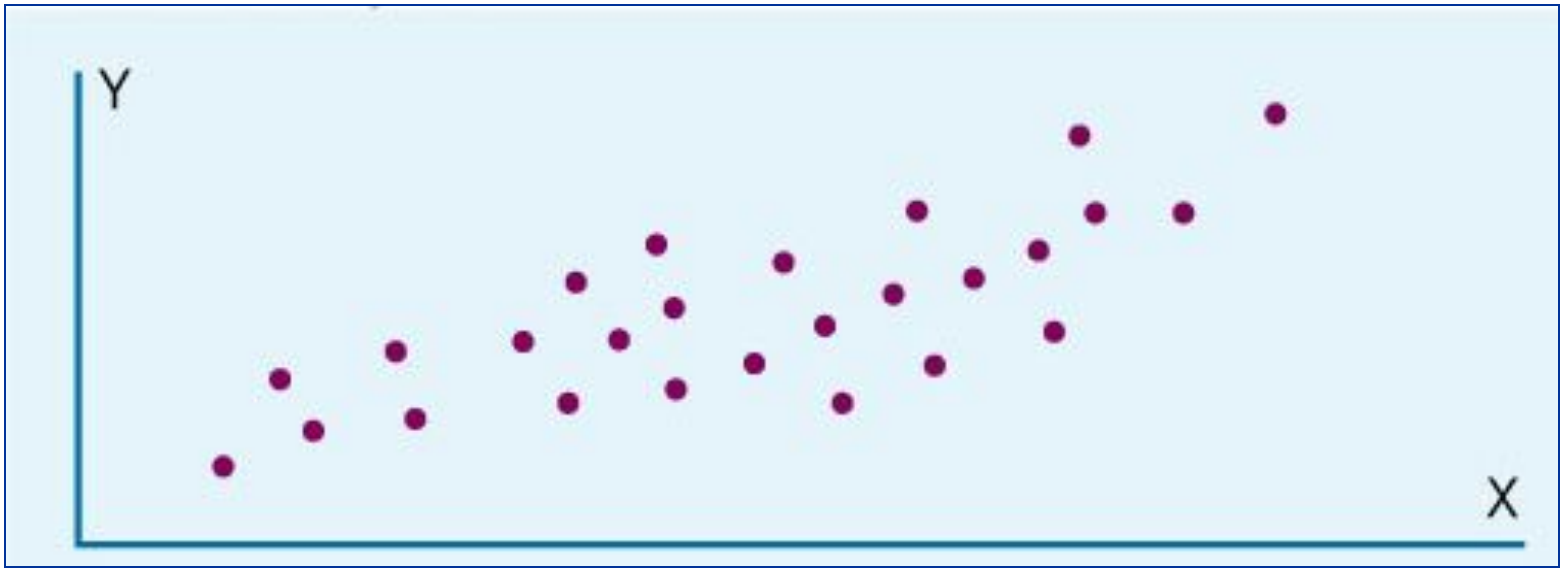
Control Charts

- Important tool used in **Statistical Process Control**
- The UCL and LCL are calculated limits used to show when process is in or out of control



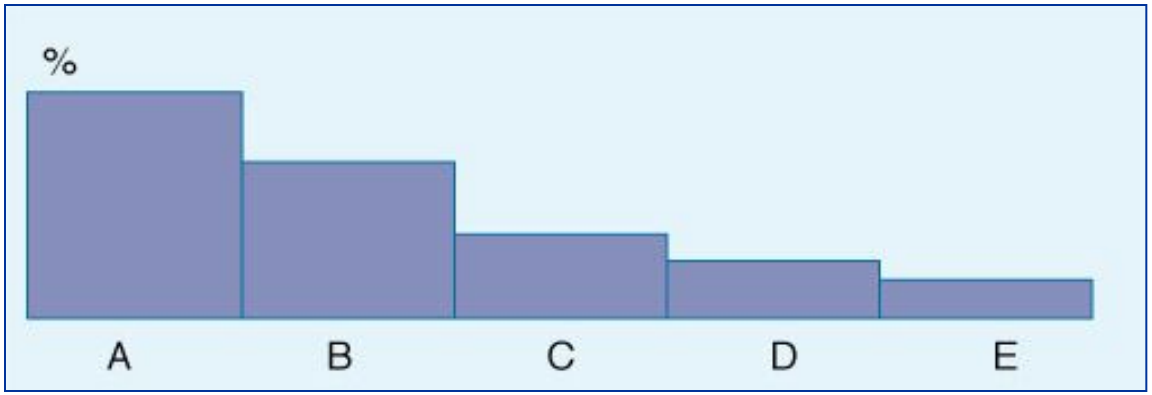
Scatter Diagrams

- A graph that shows how two variables are related to one another
- Data can be used in a regression analysis to establish equation for the relationship



Pareto Analysis

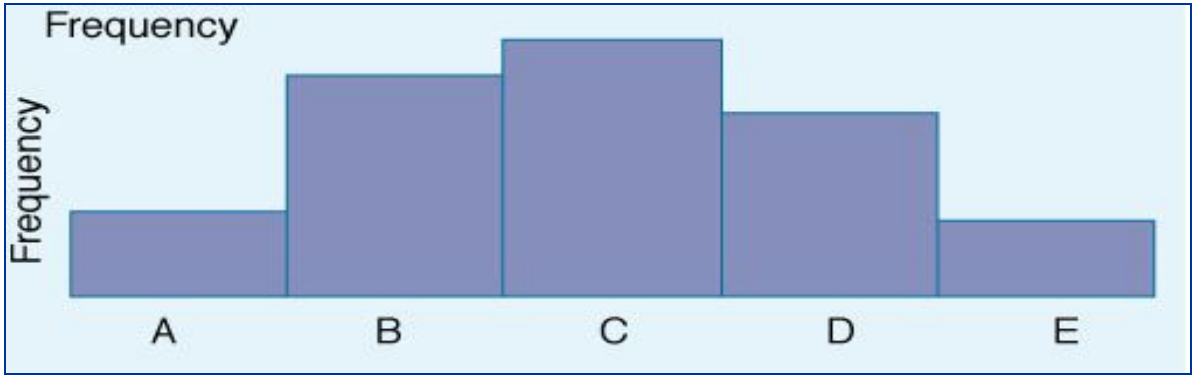
- Technique that focuses on the most important problem areas
- Principle is that quality problems are the result of only a few problems e.g. 80% of the problems are caused by 20% of causes
- Often called the 80-20 Rule
- Named after the 19th century Italian economist



Histograms

- A chart that shows the frequency distribution of observed values of a variable like service time at a bank drive-up window

- Displays whether the distribution is symmetrical (normal) or skewed



4.3 Statistical Quality Control

Meaning, Benefits and Categories of SQC

Statistical quality control (SQC)

- Describe the set of statistical tools used by quality professionals
- It is applied by taking samples and drawing conclusions by means of some mathematical analysis

Benefits of Statistical Quality Control:

- Ensures rapid and efficient inspection at a minimum cost.
- It minimizes waste by identifying the causes of excessive variability in the quality of product.
- Exerts more effective pressure for quality improvement.

- Irrespective of all possible precautions and quality measures there are always a large number disturbances responsible for deviations in the quality of the product from the set standards.
- The variation might be caused by several factors, which can be classified in to two categories.

1. Usual or chance variations, which are likely to occur in a random manner and about which the firm can do little.

– they occur randomly and can be described by the normal probability distribution.

– Quality controllers define limits within which variations are acceptable and beyond which they are unacceptable or necessitate some examination. Such limits are called control limits.

2. Unusual or assignable variations which occur less frequently and can normally be traced to some external causes

- The sources of these disturbances are known as chance causes, e.g. movement of the machine due to passing traffic, sudden changes in temperature etc.

- The subject of statistical quality control can be divided into process control and acceptance sampling
  1. **Statistical process control (SPC):** Process control involves **testing a random sample of output** from a process to determine whether the process is producing items within a pre-selected range.
     - provide timely information on whether currently produced items arc meeting design specifications,
     - Helpful in identifying in-process variations

- It uses process control charts

Process Control Charts

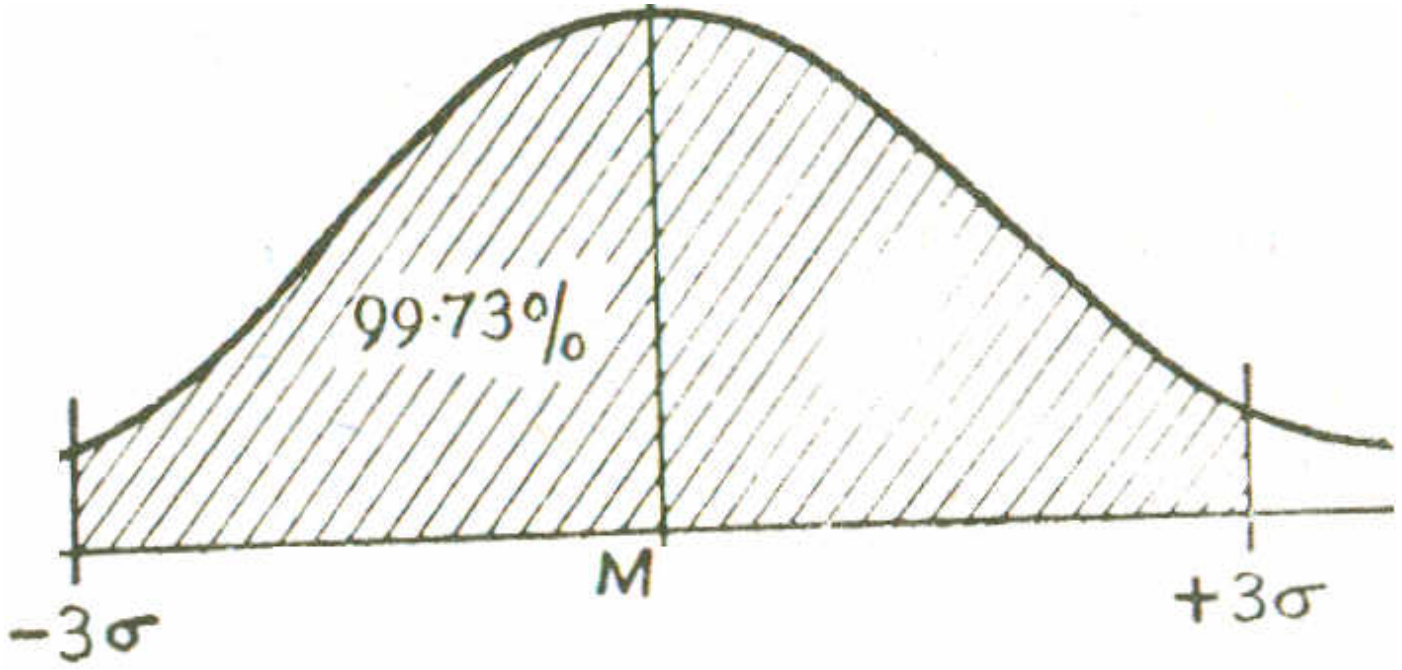
- Process control concepts, especially statistically based control charts, have seen wide use outside factories.
- In statistics it is assumed that various characteristics observed in different areas of study are found to follow any of the Normal, Poisson or Binomial distributions.

- In a normal distribution $M \pm 3\sigma$ limits contains approximately 99.73% of the observations, 99% of the area under the curve is included in the $M \pm 2.58\sigma$, Similarly $M \pm 1.96\sigma$ limits contains 95% observations.
- This fundamental concept of normal distribution becomes the basis of control charts i.e.
- If all the values of Q lie within $M \pm 3\sigma$ limits then this is an indication that assignable causes are absent and the process is said ,to be in control otherwise the process is said to be out of control and some remedial action is planned.

– **The Mean-** measure of central tendency and **Standard Deviation** measures the amount of data dispersion around mean

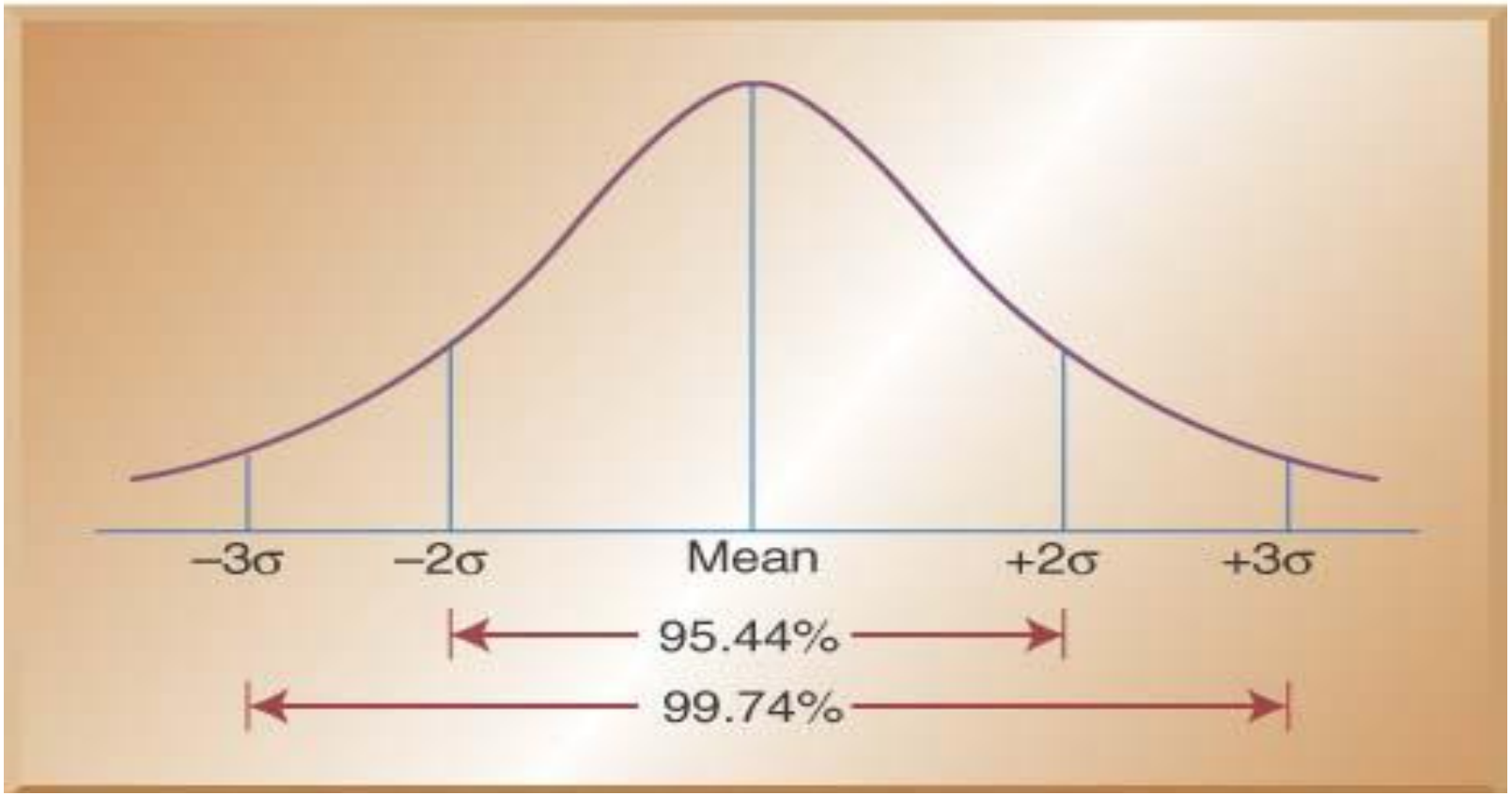
$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} \left(x_i - \bar{X}\right)^2}{n-1}}$$


99·73%
M
-3σ
+3σ

Setting Control Limits

- **Percentage of values under normal curve**



A typical control chart do have the following main characteristics

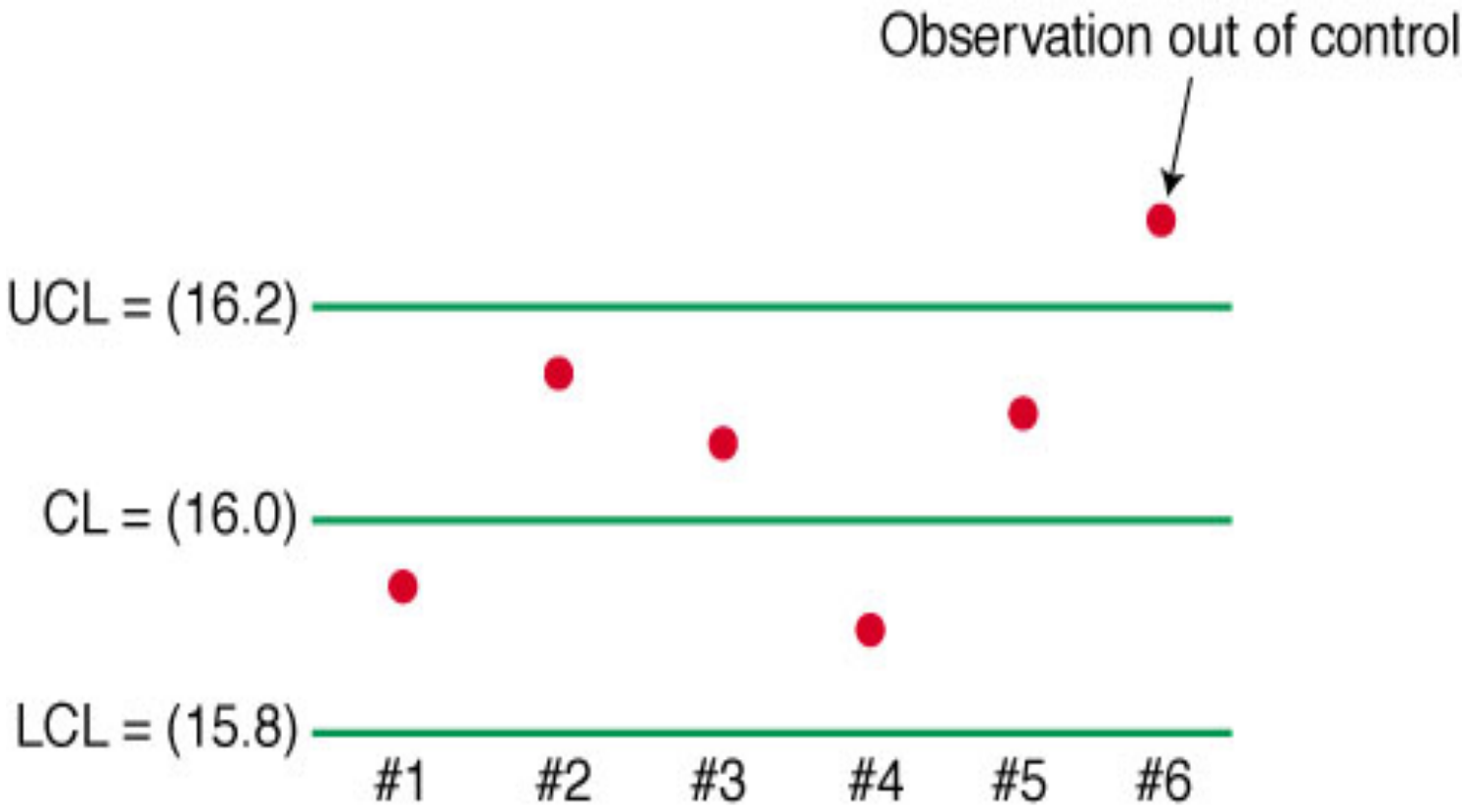
(i) Rational-subgroup which can be taken in order of time or sample number are taken on horizontal axis.

(ii) Quality characteristic measure for each subgroup is taken on vertical axis

(iii) UC.L. (M+3σ) and L.C.L. (M-3σ) are drawn as horizontal lines.

(iv) C.L. at a distance M on Y-axis is drawn between UC.L. and L.C.L.

(v) Points are plotted on the graph for each group and its corresponding quality characteristic.


Observation out of control
UCL = (16.2)
CL = (16.0)
LCL = (15.8)
#1
#2
#3
#4
#5
#6

Types of Control Charts

Control charts can be classified as control charts for variables and attributes :

A. Control charts for variables.

- When the quality characteristic is capable of direct quantitative measurement, e.g. life of some item, diameter of a screw etc.
- Such characteristics usually follow normal distribution.
- The charts for variables are known as X and R charts

- Use **x-bar** charts to monitor the changes in the mean of a process (central tendencies)

- **Use R-bar** charts to monitor the dispersion or variability of the process

- System can show acceptable central tendencies but unacceptable variability or vice versa

Constructing a X-bar Chart: A quality control inspector at the Cocoa Fizz soft drink company has taken **three samples with four** observations each of the volume of bottles filled. If the **standard deviation** of the bottling operation is **.2 ounces (0.028 lit)**, use the below data to develop control charts with limits of **3** standard deviations for the 16 oz. bottling operation.

	Time 1	Time 2	Time 3
Observation 1	15.8	16.1	16.0
Observation 2	16.0	16.0	15.9
Observation 3	15.8	15.8	15.9
Observation 4	15.9	15.9	15.8
Sample means (X-bar)	**15.875**	**15.975**	**15.9**
Sample ranges (R)	**0.2**	**0.3**	**0.2**

- **Center line and control limit formulas**

$$\bar{\bar{x}} = \frac{x_1 + x_2 + \ldots x_n}{k}, \quad \sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

where (k) is the # of sample means and (n) is the # of observations w/in each sample

$$UCL_{\bar{x}} = \bar{\bar{x}} + z\sigma_{\bar{x}}$$

$$LCL_{\bar{x}} = \bar{\bar{x}} - z\sigma_{\bar{x}}$$

Solution

Control Chart (x-bar)

- **Center line (x-double bar):**

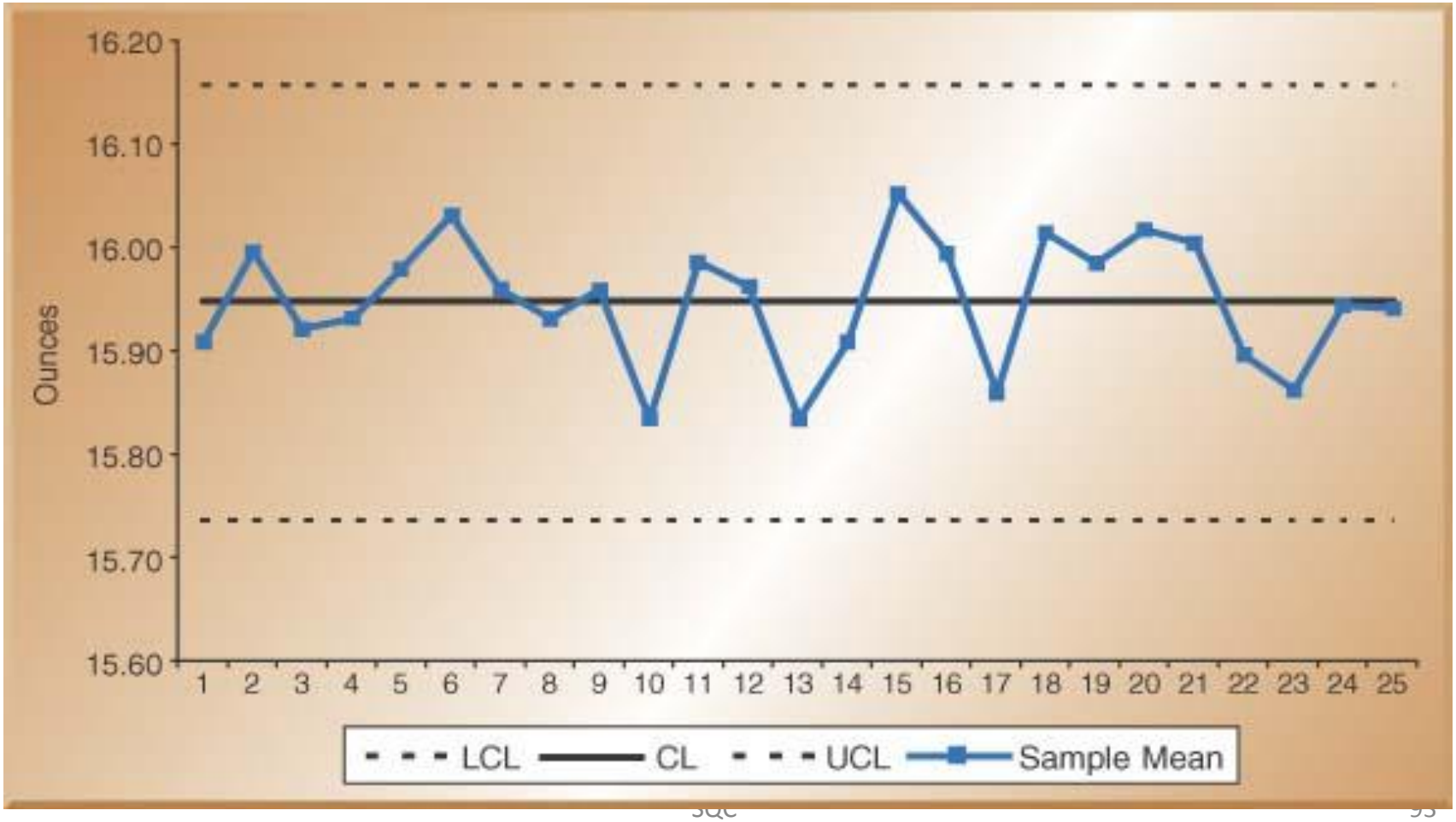
$$\overline{\overline{x}} = \frac{15.875 + 15.975 + 15.9}{3} = 15.92$$

- **Control limits for±3σ limits:**

$$UCL_{\bar{x}} = \overline{\overline{x}} + z\sigma_{\bar{x}} = 15.92 + 3\left(\frac{.2}{\sqrt{4}}\right) = 16.22$$

$$LCL_{\bar{x}} = \overline{\overline{x}} - z\sigma_{\bar{x}} = 15.92 - 3\left(\frac{.2}{\sqrt{4}}\right) = 15.62$$

X-Bar Control Chart



Second Method for the X-bar Chart Using R-bar and the A_2 Factor (Table 4.3)

- Use this method when **sigma for the process distribution** is not known. This is another way to construct the control limits. It **uses the sample range** as an estimate of the variability of the process.
- Control limits solution:

$$\overline{R} = \frac{0.2 + 0.3 + 0.2}{3} = .233$$

$$UCL_{\bar{x}} = \overline{\overline{x}} + A_2\overline{R} = 15.92 + (0.73).233 = 16.09$$

$$LCL_{\bar{x}} = \overline{\overline{x}} - A_2\overline{R} = 15.92 - (0.73).233 = 15.75$$

Control Chart for Range (R)

- R-charts monitor the range or dispersion of the values of a product characteristic.

- Range is the difference between the highest and lowest value in the sample.

- **Center Line and Control Limit formulas:**

$$\overline{R} = \frac{0.2 + 0.3 + 0.2}{3} = .233$$

$$UCL_R = D_4\overline{R} = 2.28(.233) = 0.53$$

$$LCL_R = D_3\overline{R} = 0.0(.233) = 0.0$$

- Table 4.3: Factors for three sigma control limits

Sample Size (n)	Factor for x-Chart	Factors for R-Chart	
	A2	D3	D4
2	1.88	0.0	3.267
3	1.023	0.0	2.575
4	0.729	0.0	2.282
5	0.577	0.0	2.115
6	0.483	0.0	2.004
7	0.419	0.076	1.924
8	0.373	0.136	1.864
9	0.337	0.184	1.816
10	0.308	0.223	1.777
11	0.285	0.256	1.744
12	0.266	0.283	1.717
13	0.249	0.307	1.693
14	0.235	0.328	1.672
15	0.223	0.347	1.653

Factors for 3-sigma control limits and *R-charts Source: Factors adapted from* the *ASTM Manual on Quality control of materials*

B. Control charts for attributes.

- used for quality characteristics that are counted rather than measured.
- the items can be classified only as:
  - "good' or 'bad';
  - right or wrong
  - acceptable or not acceptable
  - defective or non-defective
- Two of the most common types of control charts for attributes are *p-charts and c-charts.*

- They are used to monitor characteristics that have discrete values and can be counted, e.g. % defective,

- The quality characteristic is assumed to follow Binomial or Poisson distributions. The charts are known as p, and c charts.

Control Charts for Attributes –P-Charts & C-Charts

P-charts: used to monitor the proportion of defective items

appropriate when **observations are placed in either of two groups** and when the two occurrence can be counted. Examples:

- Defective or not defective
- Good or bad
- Broken or not broken

C-charts: *used to*

control the number of occurrences (e.g defects)

when only number of occurrence but not non occurrence is countable

- *bacteria/pollutants per unit of volume*
- *Number of complaints per unit of time (e.g., hour, month, year)*

P-Chart Example:

A Production manager for a tire company has inspected the number of defective tires in five random samples with 20 tires in each sample. The table below shows the number of defective tires in each sample of 20 tires. Calculate the 3 sigma control limits .

It Uses binomial distribution

- **Solution:**

Sample	Number of Defective Tires	Number of Tires in each Sample	Proportion Defective
1	3	20	.15
2	2	20	.10
3	1	20	.05
4	2	20	.10
5	2	20	.05
Total	9	100	.09

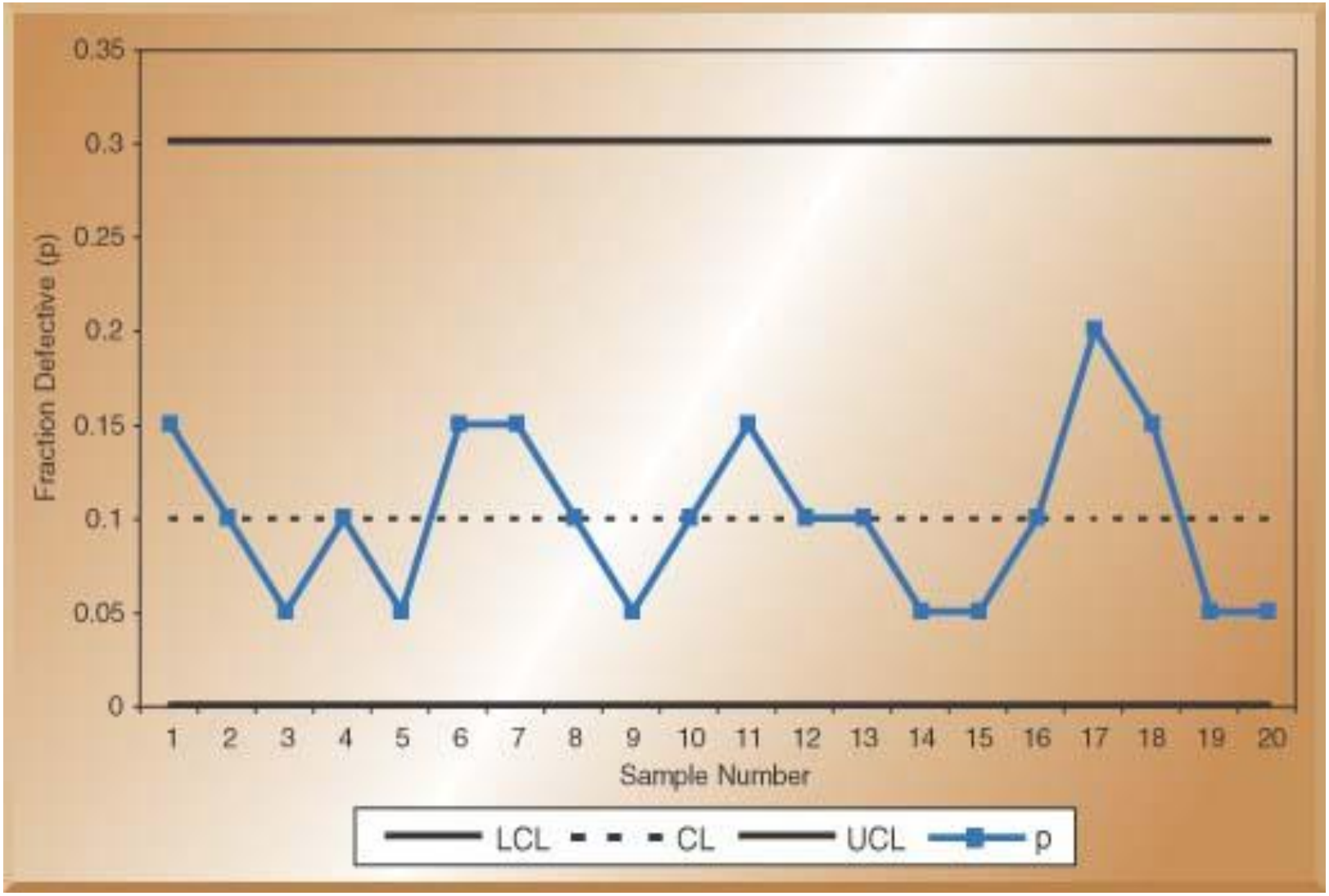
$$CL = \bar{p} = \frac{\#\,\text{Defectives}}{\text{Total Inspected}} = \frac{9}{100} = .09$$

$$\sigma_p = \sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = \sqrt{\frac{(.09)(.91)}{20}} = 0.064$$

$$UCL_p = \bar{p} + z(\sigma) = .09 + 3(.064) = .282$$

$$LCL_p = \bar{p} - z(\sigma) = .09 - 3(.064) = -.102 = 0$$

P- Control Chart



C-Chart Example:

The number of weekly **customer complaints** are monitored in a large hotel using a c-chart. Develop **three sigma control limits** using the data table below.

Week	Number of Complaints
1	3
2	2
3	3
4	1
5	3
6	3
7	2
8	1
9	3
10	1
Total	**22**

It uses poison distribution

NB. In poison distribution, the mean and the variance are same ($\mu = \delta^2$)

solution:

$$CL = \frac{\#\text{complaints}}{\#\text{ of samples}} = \frac{22}{10} = 2.2$$

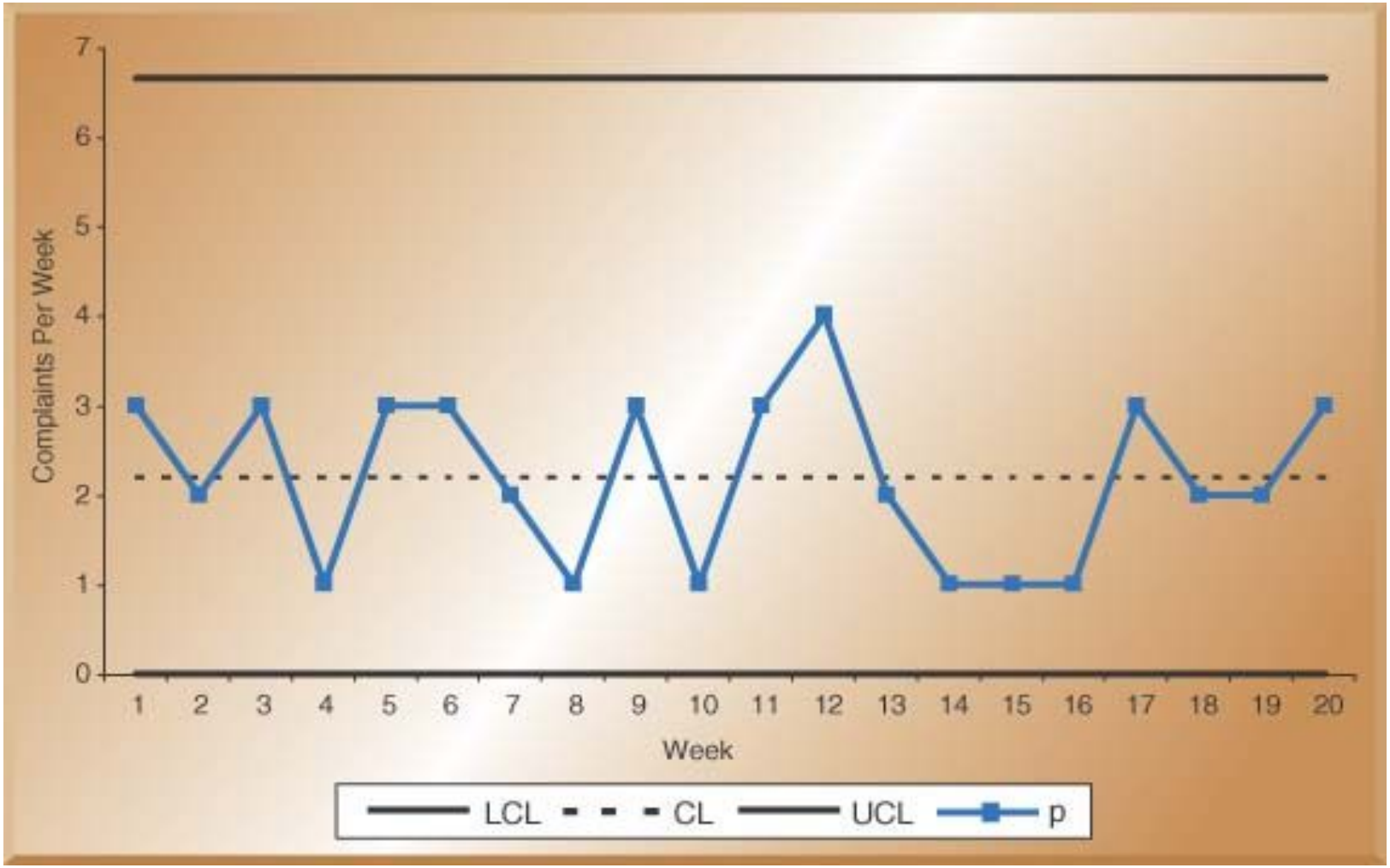
$$UCL_c = \bar{c} + z\sqrt{\bar{c}} = 2.2 + 3\sqrt{2.2} = 6.65$$

$$LCL_c = \bar{c} - z\sqrt{\bar{c}} = 2.2 - 3\sqrt{2.2} = -2.25 = 0$$

C-chart…cont.

- Use of poison distribution assumes that defects occur over some continuous region and that the probability of more than one defect at any particular point is negligible.
- The mean number of defects per unit is C and the standard deviation is square root of C.

C- Control Chart



2. Acceptance sampling

2. Acceptance sampling

- Acceptance sampling involves testing a random sample of existing goods and deciding whether to accept an entire lot based on the quality of the random sample.
- Thus the sample items are considered to be the representatives of the whole lot.

  - Acceptance sampling is frequently used in a purchasing or before shipment
  - Different from SPC because acceptance sampling is performed either *before* or *after* the process rather than *during*
  - Does not help to catch in-process problems

- Used where 100% inspection is expensive, volume is high, or inspection is destructive.

- Moreover due to boredom and fatigue involved in the repetitive, inspection process there is always a possibility to overlook some defective item even by most competent and efficient inspectors.

The advantages of sampling inspection can be listed as follows

(i) items of destructive nature during inspection can be inspected by sampling only.

(ii) economy of time and money in comparison to 100% inspection

(iii) Problem of inspection fatigue occurring in 100% inspection is eliminated.

(iv) Small inspection staff required

(v) Due to quick inspection, scheduling and delivery times are improved.

(vi) Can exert more effective pressure on quality improvement than the rejection of individual items,

Limitations of Acceptance Sampling:

- There is always some likelihood (risk) of making wrong inference about the quality of the lot.

- The success of the scheme depends on, randomness of samples, quality characteristic to be tested, lot size, acceptance Criteria etc.

4.4. Process Capability

(reading assignment)

Process capability….

- So far, we have discussed ways of monitoring the production process to ensure that it is in a *state of control and that there are no assignable causes of variation.*
- *A critical aspect* of statistical quality control is evaluating the ability of a production process to meet or exceed preset specifications. This is called **process capability.**
- ***Product specifications,*** often called *tolerances*, *are preset ranges of acceptable quality characteristics, such as* product dimensions.

Measurement of process capability

- Process capability is measured by the **process capability index, *Cp, which is computed*** as the ratio of the specification width to the width of the process variability:

$$Cp = \frac{\text{specification width}}{\text{process width}} = \frac{USL - LSL}{6\delta}$$

- where the specification width is the difference between the upper specification limit(USL) and the lower specification limit (LSL) of the process.
- The process width is computed as 6 standard deviations (6δ) of the process being monitored.

cont.

- The reason we use 6δ is that most of the process measurement (99.74 percent) falls within 3 standard deviations, which is a total of 6 standard deviations.
- There are three possible ranges of values for *Cp that also help us interpret its value:*

1. *Cp≥ 1: A value of Cp above 1 means that the process variability is tighter than specifications* and the process exceeds minimal capability.
2. *Cp = 1: A value of Cp equal to 1 means that the process variability just meets specifications*. We would then say that the process is minimally capable.
3. *Cp≤ 1: A value of Cp below 1 means that the process variability is outside the range* of specification. This means that the process is not capable of producing within specification and must be improved.

- A *Cp value of 1 means that 99.74 percent of the products produced will fall within* the specification limits. This also means that 0.26 % (100% - 99.74%) of the products will not be acceptable.
- Although this percentage sounds very small, when we think of it in terms of parts per million (ppm), we can see that it can still result in a lot of defects.
- The number 0.26 percent corresponds to 2600 parts per million (ppm) defective (0.0026 x 1,000,000). That number can seem very high if we think of it in terms of 2600 wrong prescriptions out of a million, or 2600 incorrect medical procedures out of a million, or even 2600 malfunctioning aircraft out of a million.
- You can see that this number of defects is still high. The way to reduce the ppm defective is to increase process capability.

Example

- Three bottling machines at Cocoa Fizz are being evaluated for their capability

Bottling machine	standard deviation
A	0.05
B	0.1
C	0.2

- If specifications are set between 15.8 and 16.2 ounces, determine which of the machines are capable of producing within specifications.

Solution

- To determine the capability of each machine, we need to divide the specification width

(USL- LSL = 16.2 - 15.8= 0.4) by 6δ For each machine:

Bottling machine	δ	USL-LSL	6δ	Cp= $\frac{\text{USL-LSL}}{6\delta}$
A	0.05	0.4	0.3	1.33
B	0.1	0.4	0.6	0.67
C	0.2	0.4	1.2	0.33

- Looking at the *Cp values, only machine A is capable of filling bottles within specifications because* it is the only machine that has a *Cp value at or above 1.qa*

- Let’s look at the examples of process variation relative to design specifications for the Cocoa Fizz soft-drink company.
- Let’s say that the specification for the acceptable volume of liquid is preset at 16 ounces ±0.2 ounces, which is 15.8 and 16.2 ounces. In part (a) of Figure 4-8 the process produces 99.74 percent (3 sigma) of the product with volumes between 15.8 and 16.2 ounces.
- You can see that the process variability closely matches the preset specifications. Almost all the output falls within the preset specification range.