# Chapter 4 – Quality Assurance and Statistical Quality Control

**Fundamentals of Operations Management**

Lecturer:- Prem Gaire

Boston International College (Pokhara University)

# Learning Objectives

- Explain the meaning of Quality and **TQM**
- Identify the costs of Quality
- Describe the evolution of TQM
- Identify Quality leaders and their contributions

# Learning Objectives con’t

- Identify key features of the TQM philosophy
- Describe tools for identifying and solving quality problems
- Describe quality awards and quality certifications

# Defining Quality

- Definition of quality is dependent on the people defining it
- There is no single, universal definition of quality
- 5 common definitions include:

(See next slide)

# Defining Quality – 5 Ways

1. Conformance to specifications
   - Does product/service meet targets and tolerances defined by designers?
2. Fitness for use
   - Evaluates performance for intended use
3. Value for price paid
   - Evaluation of usefulness vs. price paid
4. Support services
   - Quality of support after sale
5. Psychological
   - Ambiance, prestige, friendly staff

# Defining Quality

- "Quality is the ability of the product to meet or exceed customer expectations" – William J Stevenson

# ISO Standards

- ISO 9000 Standards:
  - Certification developed by International Organization for Standardization
  - Set of internationally recognized quality standards
  - Companies are periodically audited & certified
  - ISO 9000:2000 QMS – Fundamentals and Standards
  - ISO 9001:2000 QMS – Requirements
  - ISO 9004:2000 QMS - Guidelines for Performance
  - More than 40,000 companies have been certified
- ISO 14000:
  - Focuses on a company's environmental responsibility

# Manufacturing Quality vs. Service Quality

- Manufacturing quality focuses on tangible product features
  - Conformance, performance, reliability, features
- Service organizations produce intangible products that must be experienced
  - Quality often defined by perceptional factors like courtesy, friendliness, promptness, waiting time, consistency

# Cost of Quality

- Quality affects all aspects of the organization
- Quality has dramatic cost implications of:
  - Quality control costs
    - Prevention costs
    - Appraisal costs
  - Quality failure costs
    - Internal failure costs
    - External failure costs

# Cost of Quality – 4 Categories

| | |
|---|---|
| **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. |

Early detection/prevention is less costly

- (Maybe by a factor of 10)

# Evolution of TQM – New Focus

| | | | | |
|---|---|---|---|---|
| **TIME:** | Early 1900s | 1940s | 1960s | 1980s and Beyond |
| **FOCUS:** | Inspection | Statistical sampling | Organizational quality focus | Customer driven quality |
| | Old Concept of Quality: Inspect for quality after production. | | | New Concept of Quality: Build quality into the process. Identify and correct causes of quality problems. |

# Quality Gurus

| Quality Guru | Main Contribution |
|---|---|
| Walter A. Shewhart | – Contributed to understanding of process variability.<br>– Developed concept of statistical control charts. |
| W. Edwards Deming | – Stressed management's responsibility for quality.<br>– Developed "14 Points" to guide companies in quality improvement. |
| Joseph M. Juran | – Defined quality as "fitness for use."<br>– Developed concept of cost of quality. |
| Armand V. Feigenbaum | – Introduced concept of total quality control. |
| Philip B. Crosby | – Coined phrase "quality is free."<br>– Introduced concept of zero defects. |
| Kaoru Ishikawa | – Developed cause-and-effect diagrams.<br>– Identified concept of "internal customer." |
| Genichi Taguchi | – Focused on product design quality.<br>– Developed Taguchi loss function. |

# Total Quality Management (TQM)

- TQM is defined as both a philosophy and a set of guiding principles that represent the foundation of a continuously improving organization. The key to an effective TQM program is to listen to the voice of the customer.

  *- Dictionary of advanced manufacturing technology*

# TQM Philosophy

- TQM Focuses on identifying quality problem root causes
- Encompasses the entire organization
- Involves the technical as well as people
- Relies on seven basic concepts of
  - Customer focus
  - Continuous improvement
  - Employee empowerment
  - Use of quality tools
  - Product design
  - Process management
  - Managing supplier quality

# TQM Philosophy - concepts

- Focus on Customer
  - Identify and meet customer needs
  - Stay tuned to changing needs, e.g. fashion styles
- Continuous Improvement
  - Continuous learning and problem solving, e.g. Kaizen, 6 sigma
  - Plan-Do-Study/Check-Act (PDSA/PDCA)
- Benchmarking
- Employee Empowerment
  - Empower all employees; external and internal customers

# TQM Philosophy– Concepts con't

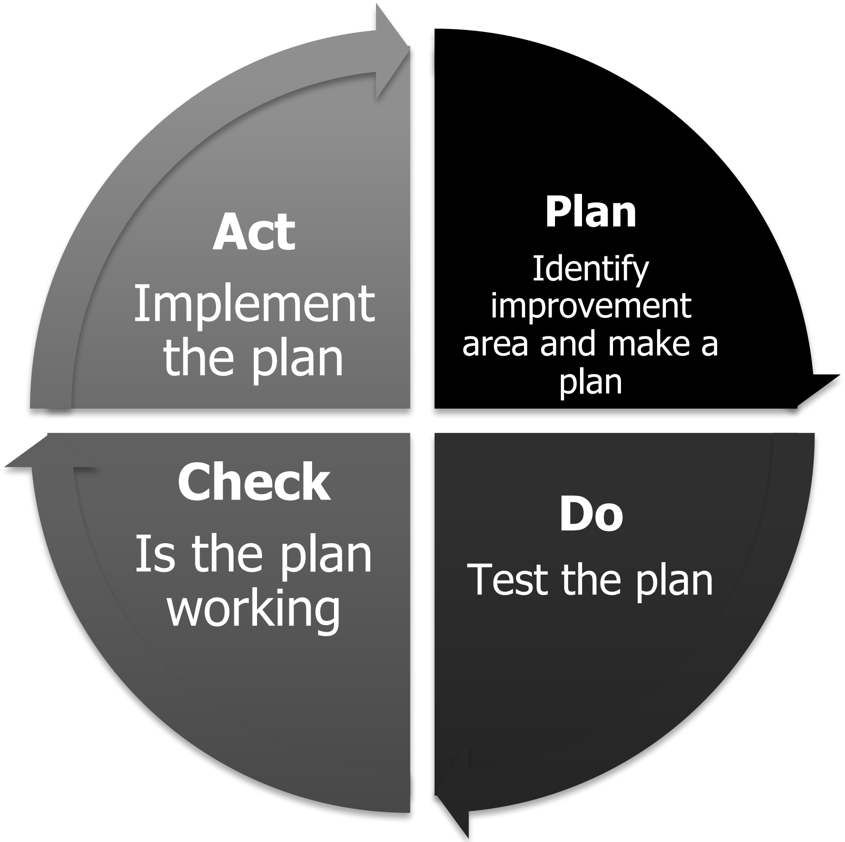
- Team Approach
  - Teams formed around processes – 8 to 10 people
  - Meet weekly to analyze and solve problems
- Use of Quality Tools
  - Ongoing training on analysis, assessment, and correction, & implementation tools
  - Studying practices at "best in class" companies

# Ways of Improving Quality

- Plan-Do-Check-Act Cycle (PDCA)
  - Also called the Deming Wheel after originator
  - Circular, never ending problem solving process
- Seven Tools of Quality Control
  - Tools typically taught to problem solving teams
- Quality Function Deployment
  - Used to translate customer preferences to design

# PDCA Details

- Plan
  - Evaluate current process
  - Collect procedures, data, identify problems
  - Develop an improvement plan, performance objectives
- Do: Implement the plan – trial basis
- Check: Collect data and evaluate against objectives
- Act
  - Communicate the results from trial
  - If successful, implement new process
- Cycle is repeated: After act phase, start planning and repeat process



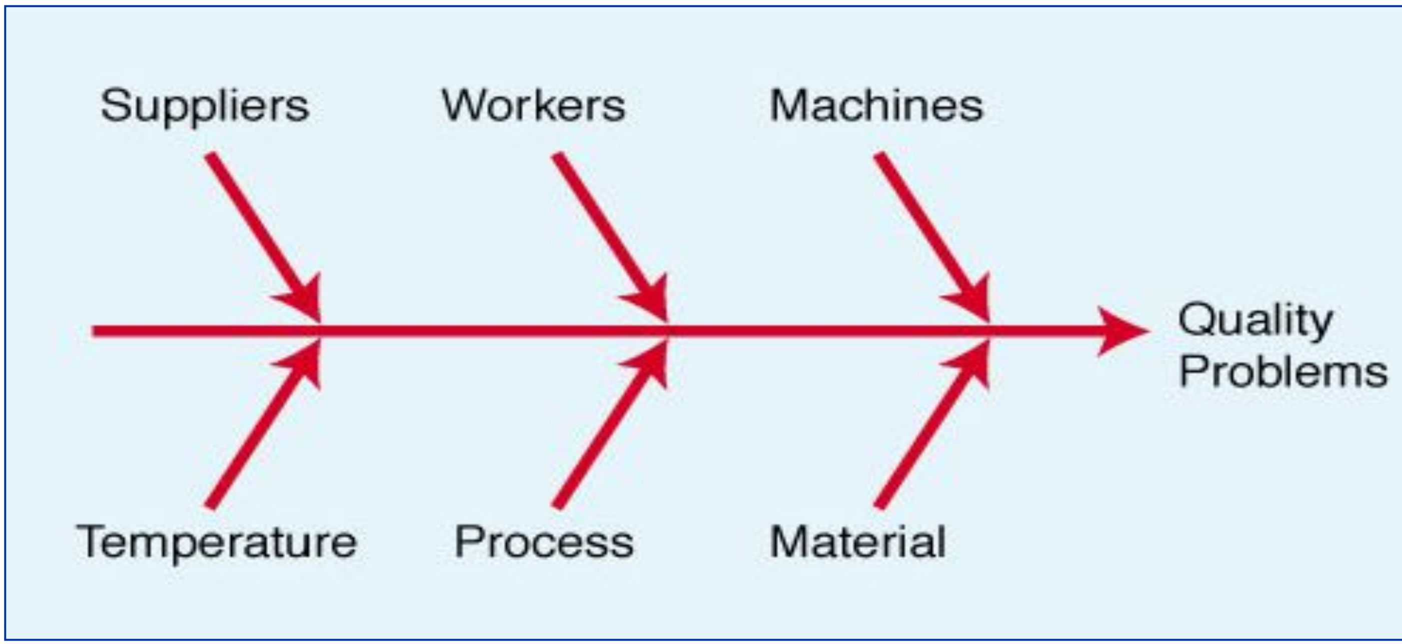

**PDCA Cycle (Deming Wheel)**

# Seven Tools of Quality Control

1. Cause-and-Effect Diagrams
2. Flowcharts
3. Checklists
4. Control Charts
5. Scatter Diagrams
6. Pareto Analysis
7. Histograms

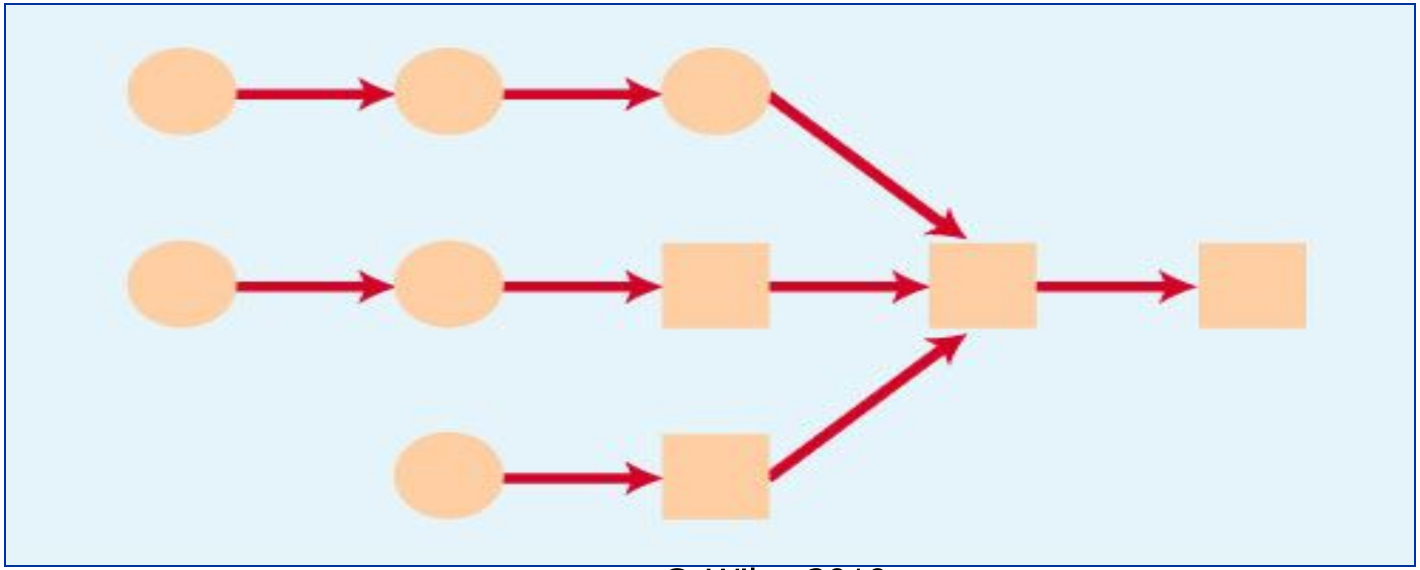
# Cause-and-Effect Diagrams

- Called **Fishbone Diagram/Ishikawa Diagram**
- Focused on solving identified quality problem



# Flowcharts

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



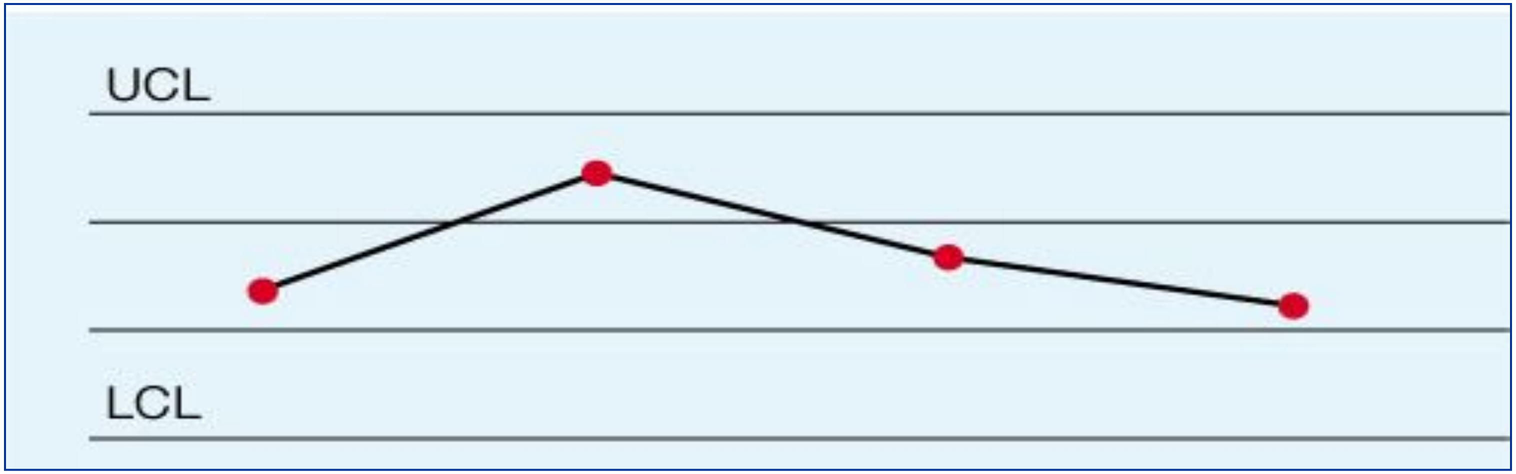
# Checklist

**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 |

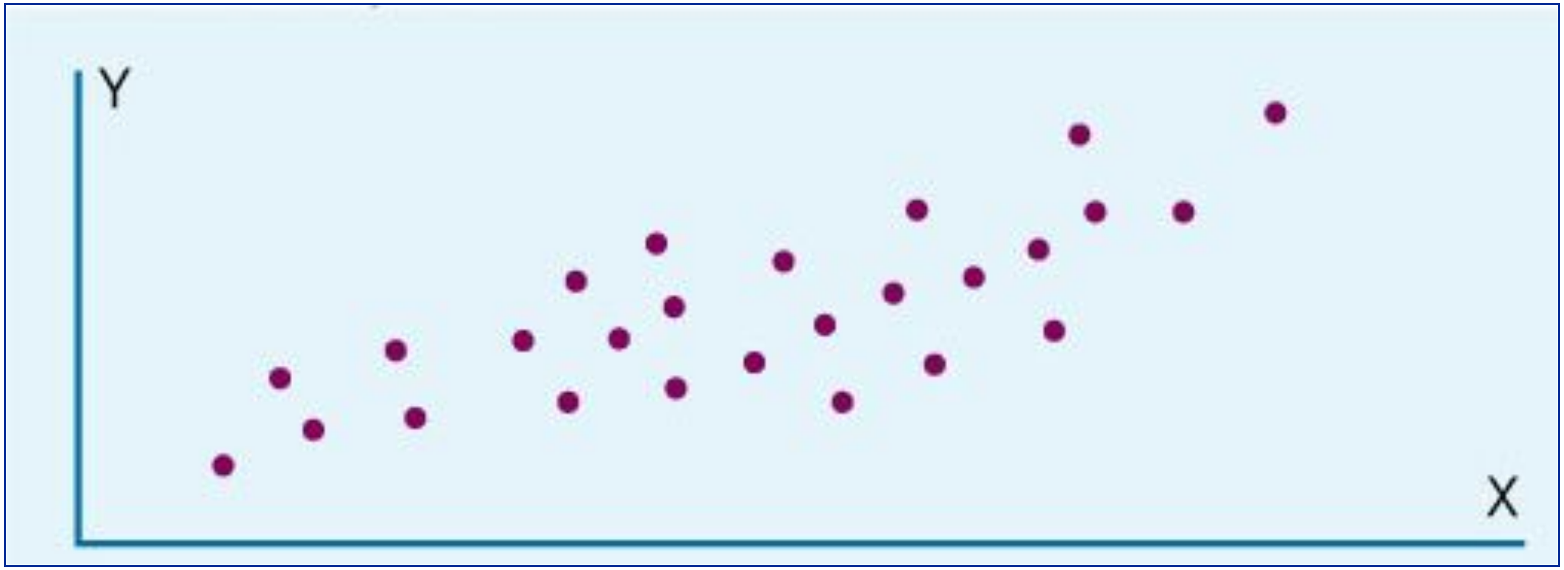
# Control Charts

- 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



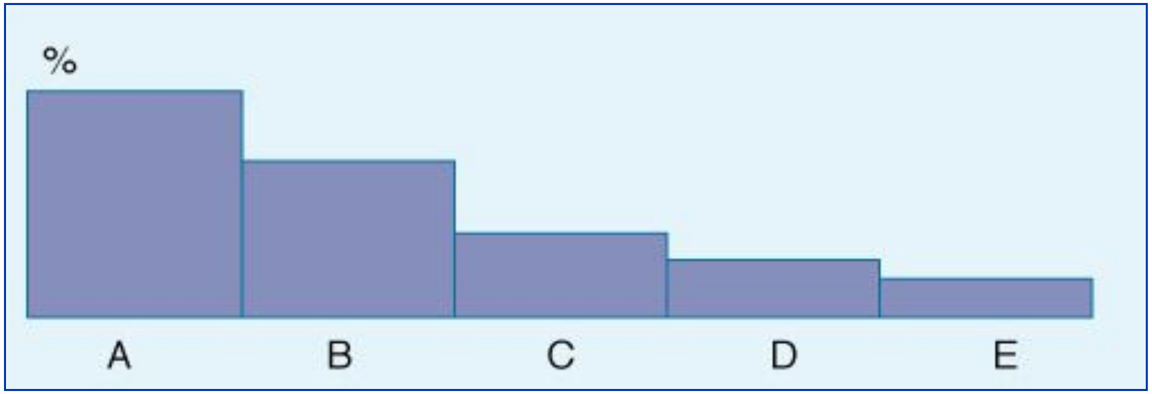
# Scatter Diagrams

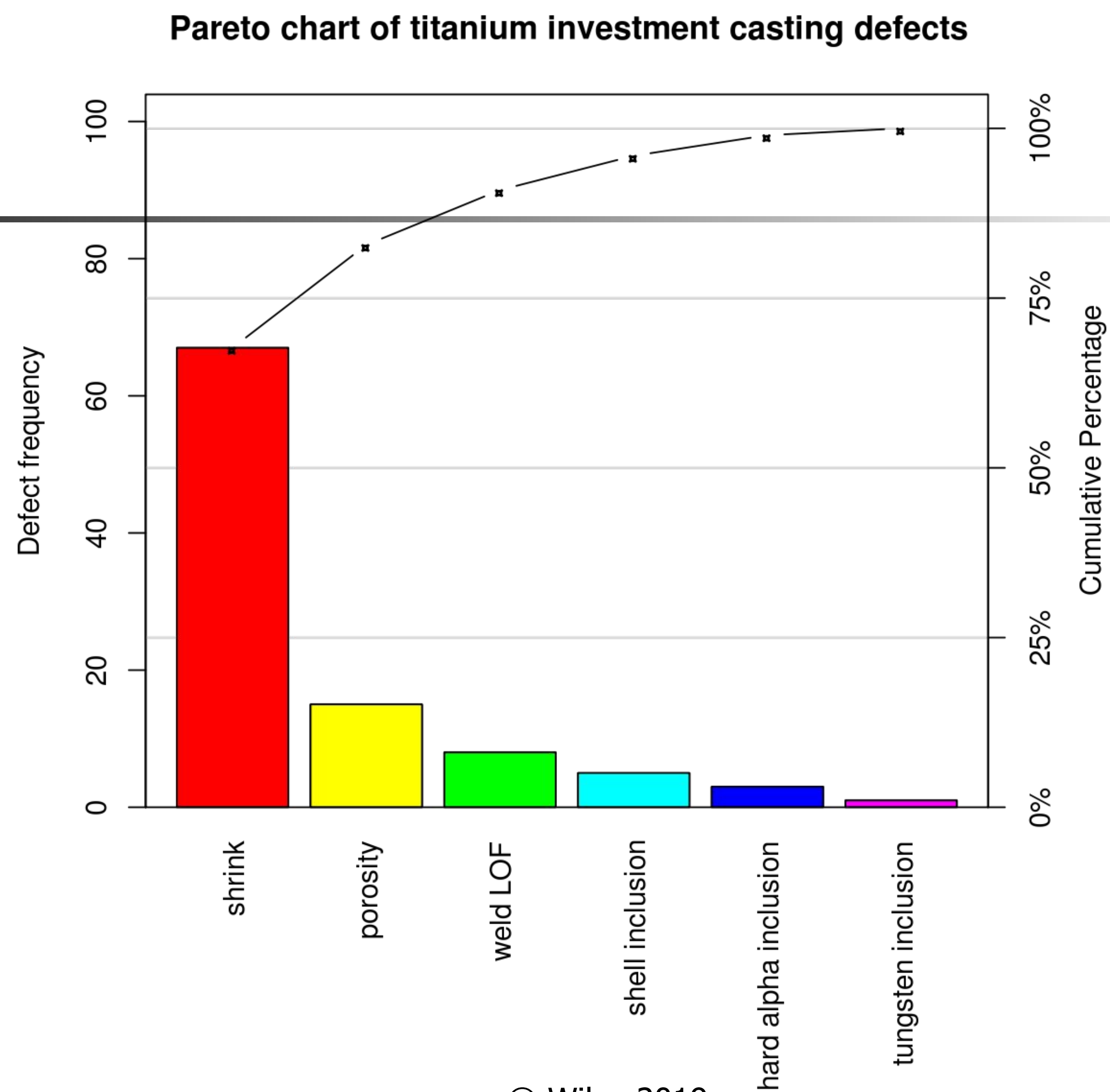
- **A graph that shows how two variables are related to one another**
- **Data can be used in a regression analysis to establish equation for the relationship**



# Pareto Analysis

- Technique that displays the degree of importance for each element
- Named after the 19th century Italian economist; often called the 80-20 Rule
- Principle is that quality problems are the result of only a few problems e.g. 80% of the problems caused by 20% of causes





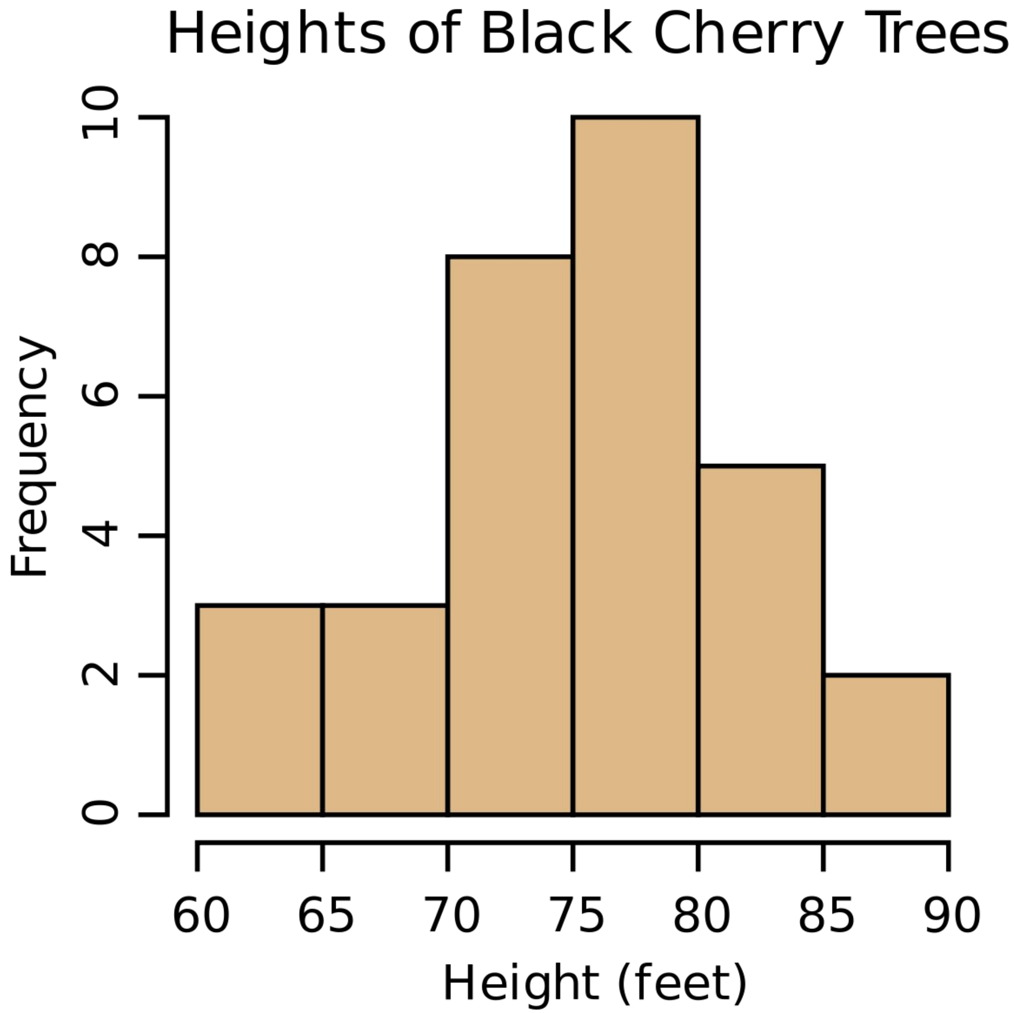
Pareto chart of titanium investment casting defects
Defect frequency
0
20
40
60
80
100
Cumulative Percentage
0%
25%
50%
75%
100%
shrink
porosity
weld LOF
shell inclusion
hard alpha inclusion
tungsten inclusion

# 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

# Histograms



Heights of Black Cherry Trees
Frequency
0
2
4
6
8
10
60
65
70
75
80
85
90
Height (feet)

# Product Design - Quality Function Deployment

- Critical to ensure product design meets customer expectations
- Useful tool for translating customer specifications into technical requirements is Quality Function Deployment (QFD)
- QFD encompasses
  - Customer requirements
  - Competitive evaluation
  - Product characteristics
  - Relationship matrix
  - Trade-off matrix
  - Setting Targets

# Quality Function Deployment (QFD) Details

Process used to ensure that the product meets customer specifications

Voice of the engineer

Product Characteristics

| Customer Requirements | Relative Importance | No. of Zippers & Compartments | Weight of Backpack | Strength of Backpack | Grade of Dye Color | Cost of Materials | Competitive Evaluation 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Durable | 25 | ✓ | ✓ | ✓⃝ | ✓ | ✓⃝ | 1 | 2 | B 3 | A 4 | US 5 |
| Lightweight | 20 | ⓧ | ⓧ | X | | ✓ | 1 | A 2 | US/B 3 | 4 | 5 |
| Roomy | 25 | ✓ | X | | | | 1 | 2 | US/A 3 | B 4 | 5 |
| Looks Nice | 20 | ✓ | | | ✓⃝ | ✓ | 1 | US 2 | B 3 | A 4 | 5 |
| Low Cost | 10 | X | X | X | X | ⓧ | 1 | US 2 | B 3 | A 4 | 5 |
| TOTAL | 100 | | | | | | | | | | |

**Relationship**

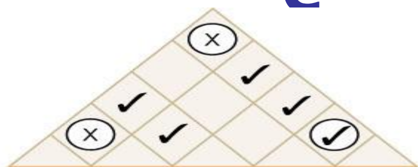
- ✓⃝ Strong Positive
- ✓ Positive
- X Negative
- ⓧ Strong Negative

US = Our Backpack
A = Competitor A
B = Competitor B

Voice of the customer

Customer-based benchmarks

# QFD - House of Quality



Trade-offs

Targets

Technical Benchmarks

| Customer Requirements | Relative Importance | No. of Zippers & Compartments | Weight of Backpack | Strength of Backpack | Grade of Dye Color | Cost of Materials | Competitive Evaluation |
|---|---|---|---|---|---|---|---|
| Durable | 25 | ✓ | ✓ | (✓) | ✓ | (✓) | 1, 2, B 3, A 4, US 5 |
| Lightweight | 20 | ⊗ | ⊗ | × | | ✓ | 1, A 2, US/B 3, 4, 5 |
| Roomy | 25 | ✓ | × | | | | 1, 2, US/A 3, B 4, 5 |
| Looks Nice | 20 | ✓ | | | (✓) | ✓ | 1, US 2, B 3, A 4, 5 |
| Low Cost | 10 | × | × | × | × | ⊗ | 1, US 2, B 3, A 4, 5 |
| TOTAL | 100 | | | | | | |
| Competitive Evaluation | A | 2 | 1.2 lbs. | 14 lbs. | Grade B | $8 | |
| | B | 3 | .8 lbs. | 10 lbs. | Grade A | $10 | |
| **OUR TARGETS** | | 4 | .5 lbs. | 16 lbs. | Grade A | $8 | |

Relationship
(✓) Strong positive
✓ Positive
× Negative
⊗ Strong Negative

US = Our Backpack
A = Competitor A
B = Competitor B

Adding trade-offs, targets & developing product specifications

# Six Sigma

- ‘Sigma’ refers to the standard deviation, a measure of variability around mean of a normal distribution.
- An approach that tries to eliminate defects to achieve, “as close to zero defects as possible”

# Six-Sigma Methodology

- **DMAIC (Define-Measure-Analyse-Improve-Control) Cycle**
- Define (D)
  - Identify customers and their priorities
  - Identify the critical-to-quality (CTQs) characteristics
- Measure (M)
  - Determine how to measure the process & performance
  - Measure the performance

# Six-Sigma Methodology

- Analyze (A)
  - Determine the most likely cause of defect
  - Understand and identify the key variable that is causing the variation
- Improve (I)
  - Identify means to remove the causes of defects
  - Identify maximum acceptable range of the key variables
- Control (C)
  - Determine how to maintain improvements
  - Put tools in place to ensure that key variables are within the maximum acceptable range

# Reliability – critical to quality

- Reliability is the probability that the product, service or part will function as expected
- No product is 100% certain to function properly
- Reliability is a probability function dependent on sub-parts or components

# Reliability – critical to quality

- Reliability of a system is the product of component reliabilities

$R_S = (R_1)\,(R_2)\,(R_3)\,.\,.\,.\,(R_n)$

$R_S$ = reliability of the product or system

$R_1$ = reliability of the components

- Increase reliability by placing components in parallel

# Reliability – critical to quality

- Increase reliability by placing components in parallel
- Parallel components allow system to operate if one or the other fails

$R_S = R_1 + (R_2$ * Probability of needing 2$^{nd}$ component)

# Process Management & Managing Supplier Quality

- Quality products come from quality sources
- Quality must be built into the process
- Quality at the source is belief that it is better to uncover source of quality problems and correct it
- TQM extends to quality of product from company’s suppliers

# Quality Awards and Standards

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

# MBNQA- What Is It?

- Award named after the former Secretary of Commerce – Reagan Administration
- Intended to reward and stimulate quality initiatives
- Given to no more than two companies in each of three categories; manufacturing, service, and small business
- Past winners; Motorola Corp., Xerox, FedEx, 3M, IBM, Ritz-Carlton

# 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
- Not open to foreign companies until 1984
- Florida P & L was first US company winner

# Why TQM Efforts Fail

- Lack of a genuine quality culture
- Lack of top management support and commitment
- Over- and under-reliance on SPC methods

# TQM Within OM

- TQM is broad sweeping organizational change
- TQM impacts
  - Marketing – providing key inputs of customer information
  - Finance – evaluating and monitoring financial impact
  - Accounting – provides exact costing
  - Engineering – translate customer requirements into specific engineering terms
  - Purchasing – acquiring materials to support product development
  - Human Resources – hire employees with skills necessary
  - Information systems – increased need for accessible information

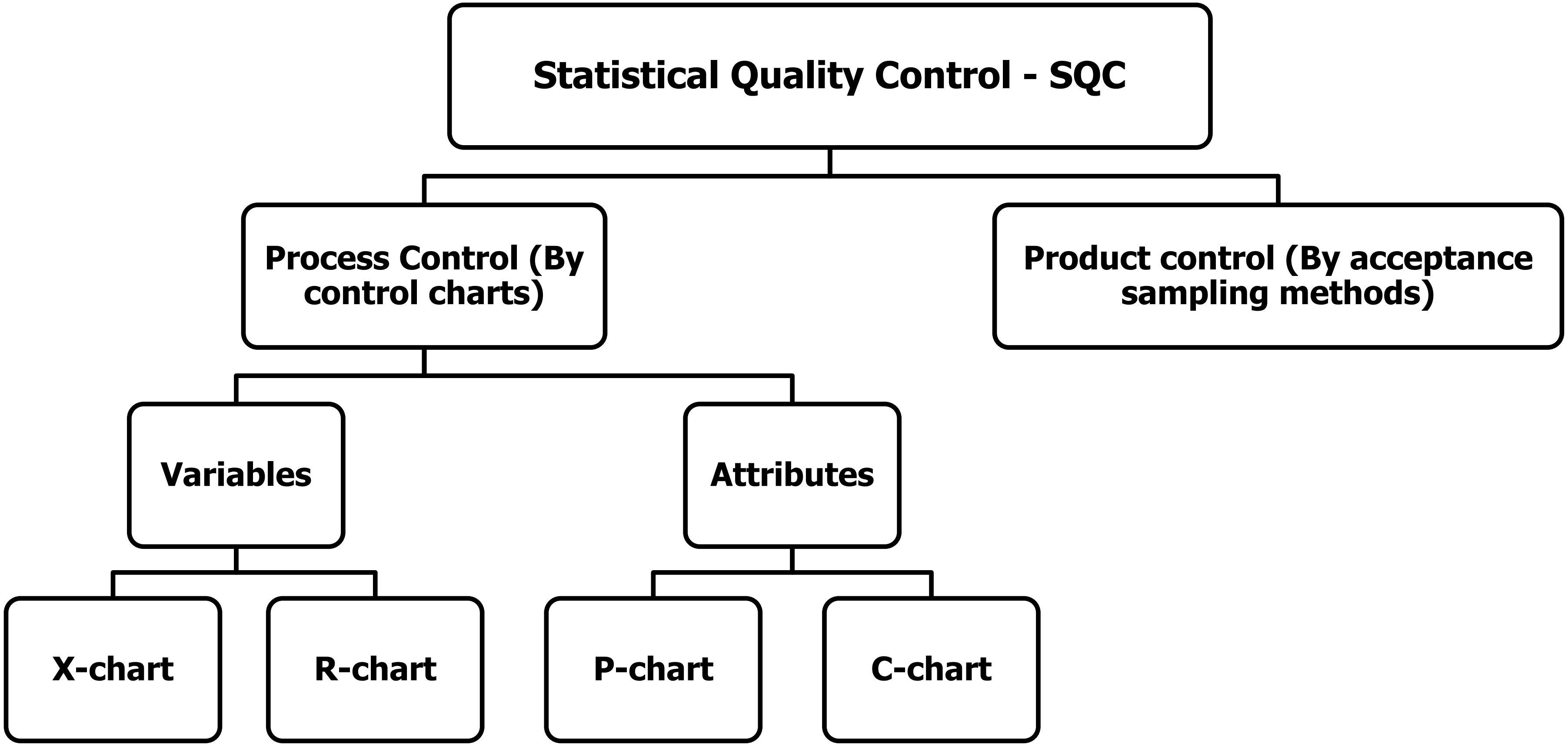
# Statistical Process Control

- SQC is the application of statistical techniques to determine whether the output of a process conforms to the product or service design.
  - Prevention rather than detection
  - If process is good, the product will automatically be good
- Objectives
  - To maintain product quality of outputs
  - To better use raw materials
  - To locate and identify process faults
  - To achieve better quality and consistency

# Three SQC Categories

- **Statistical quality control (SQC) is the term used to describe the set of statistical tools used by quality professionals**
- **SQC encompasses three broad categories of;**
  - **Descriptive statistics**
    - e.g. the mean, standard deviation, and range
  - **Statistical process control (SPC)**
    - Involves inspecting the output from a process
    - Quality characteristics are measured and charted
    - Helpful in identifying in-process variations
  - **Acceptance sampling** used to randomly inspect a batch of goods to determine acceptance/rejection
    - Does not help to catch in-process problems

# Three SQC Categories



# Sources of Variation

- **Variation exists in all processes.**
- **Variation can be categorized as either;**
  - **<u>Common or Random causes</u> of variation, or**
    - Random causes that we cannot identify
    - Unavoidable or elimination not economically feasible
    - e.g. slight differences in process variables like diameter, weight, service time, temperature; slight variations of machines
  - **<u>Assignable causes</u> of variation**
    - Causes can be identified and eliminated
    - Any one cause might result in large amount of variation
    - e.g. poor employee training, worn tool, machine needing repair (faulty equipment), negligence of employees/operators, defective raw material

# Traditional Statistical Tools

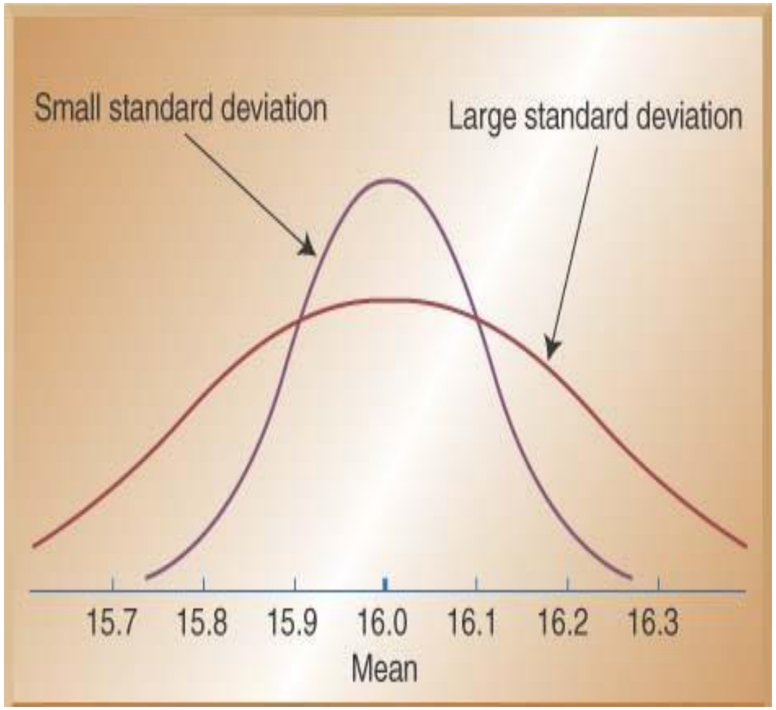
- **Descriptive Statistics include**
  - **The Mean-** measure of central tendency
  - **The Range-** difference between largest/smallest observations in a set of data
  - **Standard Deviation** measures the amount of data dispersion around mean
  - **Distribution of Data shape**
    - Normal or bell shaped or
    - Skewed

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

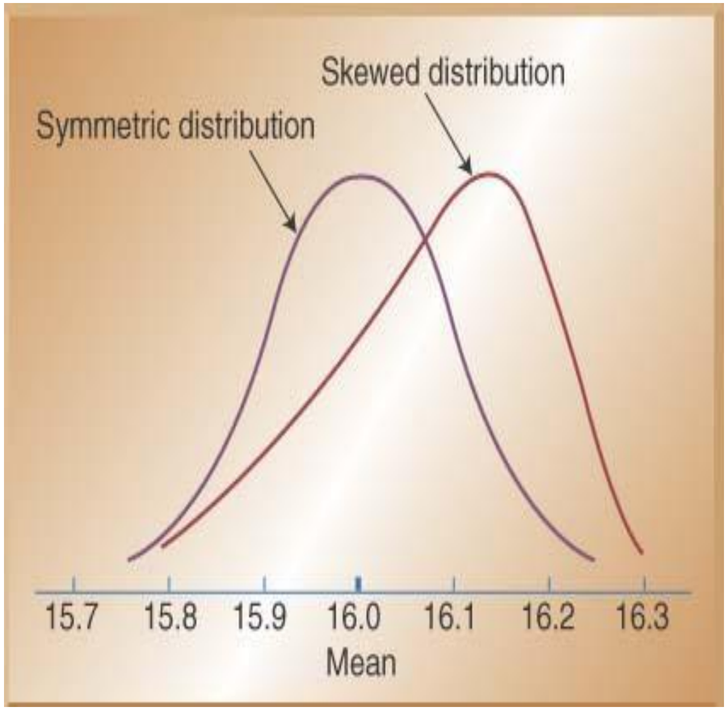
$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}}$$

# Distribution of Data

- **Normal distributions**

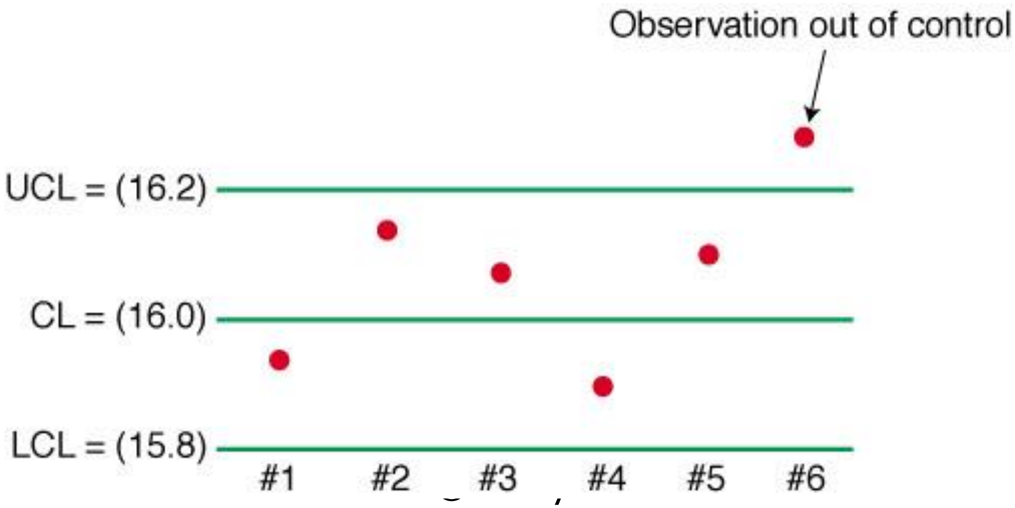



- **Skewed distribution**



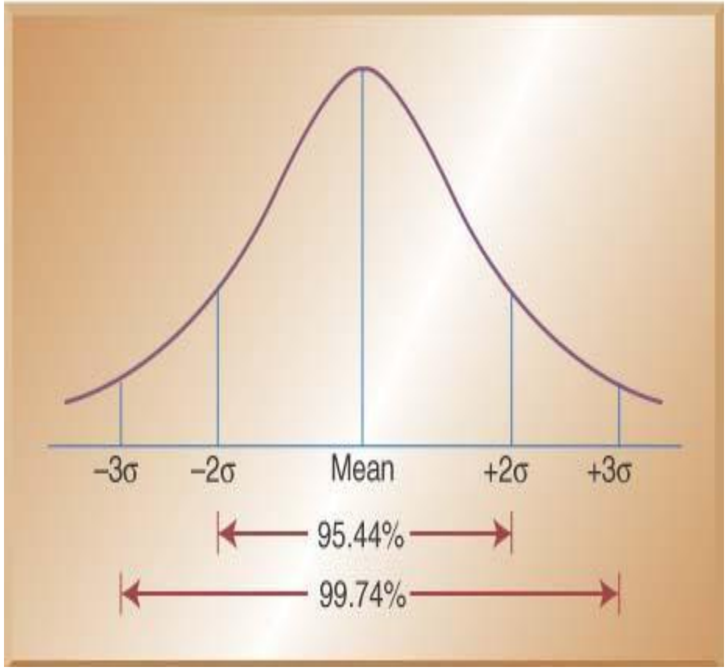
# SPC Methods-Control Charts

- **Control Charts** show sample data plotted on a graph with CL, UCL, and LCL
- **Control chart for <u>variables</u>** are used to monitor characteristics that can be measured, e.g. length, weight, diameter, time
- **Control charts for <u>attributes</u>** are used to monitor characteristics that have discrete values and can be counted, e.g. % defective, number of flaws in a shirt, number of broken eggs in a box

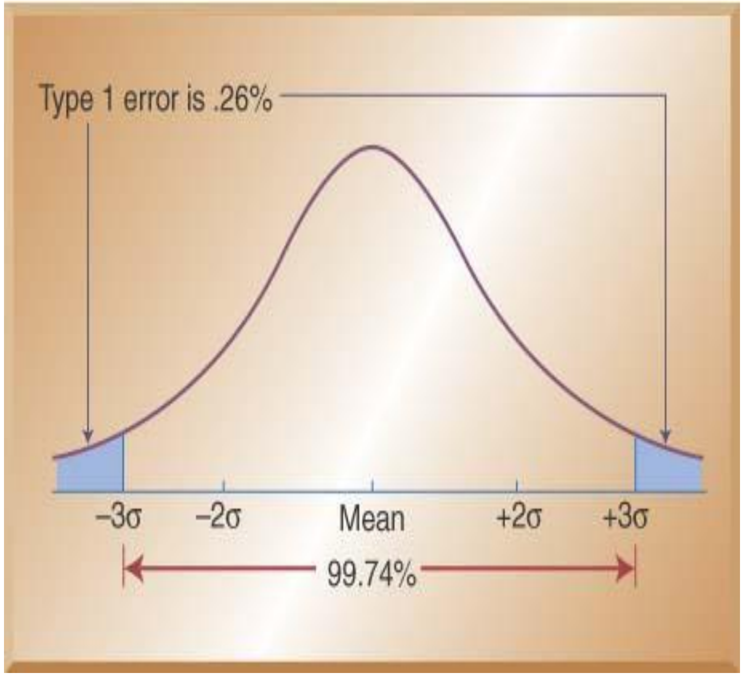


# Setting Control Limits

- **Percentage of values under normal curve**

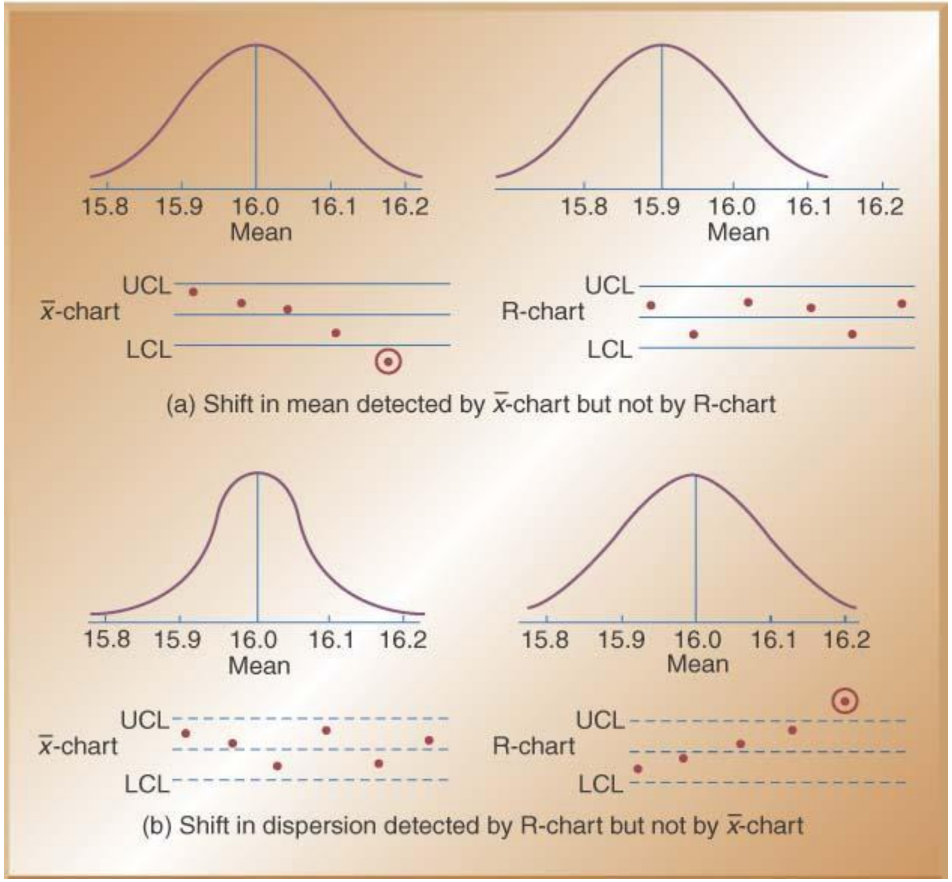



- **Control limits balance risks like Type I error**



# Control Charts for Variables

- Use x-bar and R-bar charts together
- Used to monitor different variables
- X-bar & R-bar Charts reveal different problems
- In statistical control on one chart, out of control on the other chart? OK?



# Control Charts for Variables

- 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
- System can show acceptable variability but unacceptable central tendencies

**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**, use the below data to develop control charts with limits of **3** standard deviations for the 16 oz. bottling operation.

| | observ 1 | observ 2 | observ 3 | observ 4 | mean | range |
|---|---|---|---|---|---|---|
| samp 1 | 15.8 | 16 | 15.8 | 15.9 | 15.88 | 0.2 |
| samp 2 | 16.1 | 16 | 15.8 | 15.9 | 15.95 | 0.3 |
| samp 3 | 16 | 15.9 | 15.9 | 15.8 | 15.90 | 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 and Control Chart (x-bar)

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

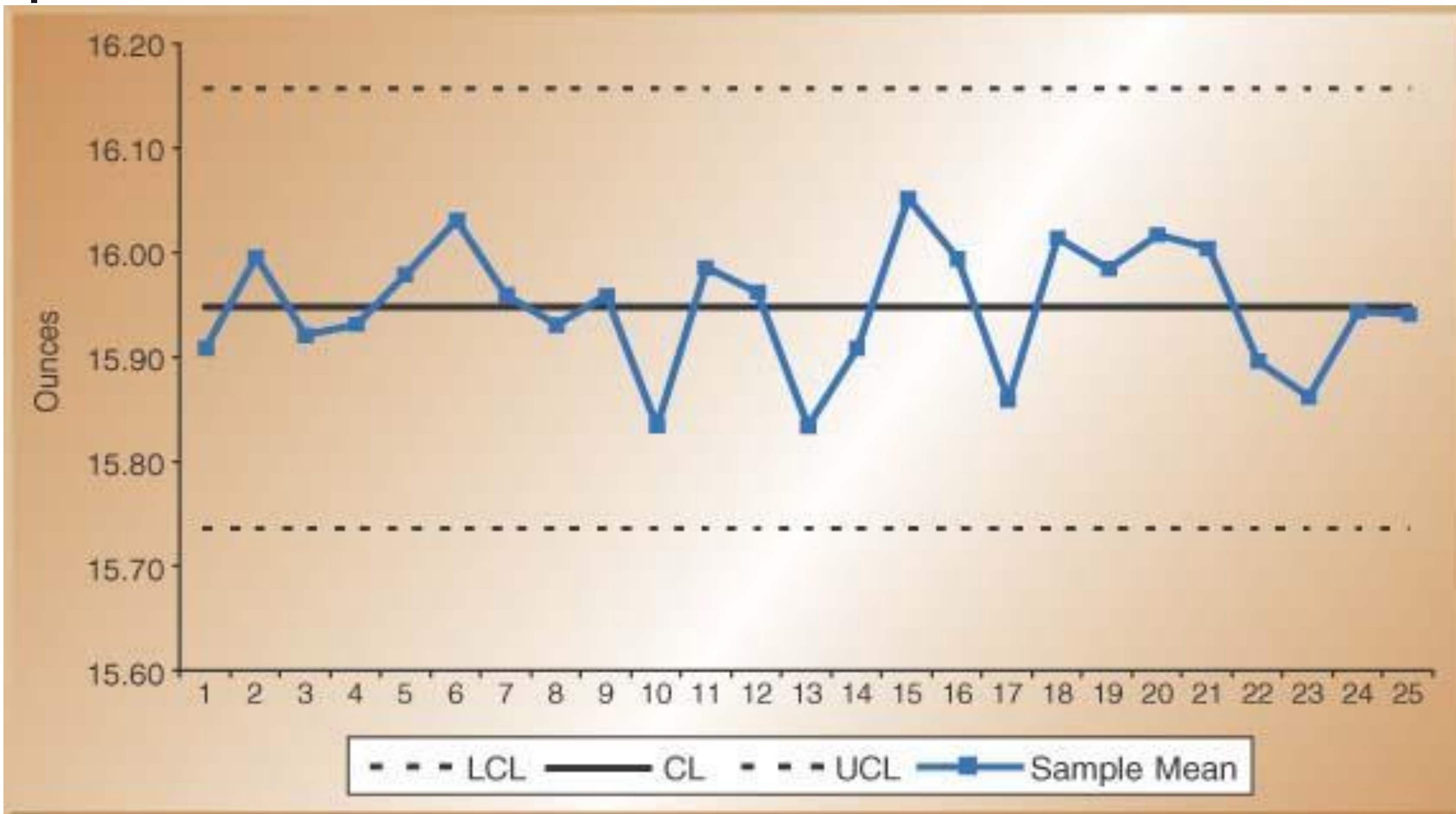
$$\bar{\bar{x}} = \frac{15.875 + 15.975 + 15.9}{3} = 15.92$$

- **Control limits for±3σ limits:**

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

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

# X-Bar Control Chart



# Control Chart for Range (R)

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

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

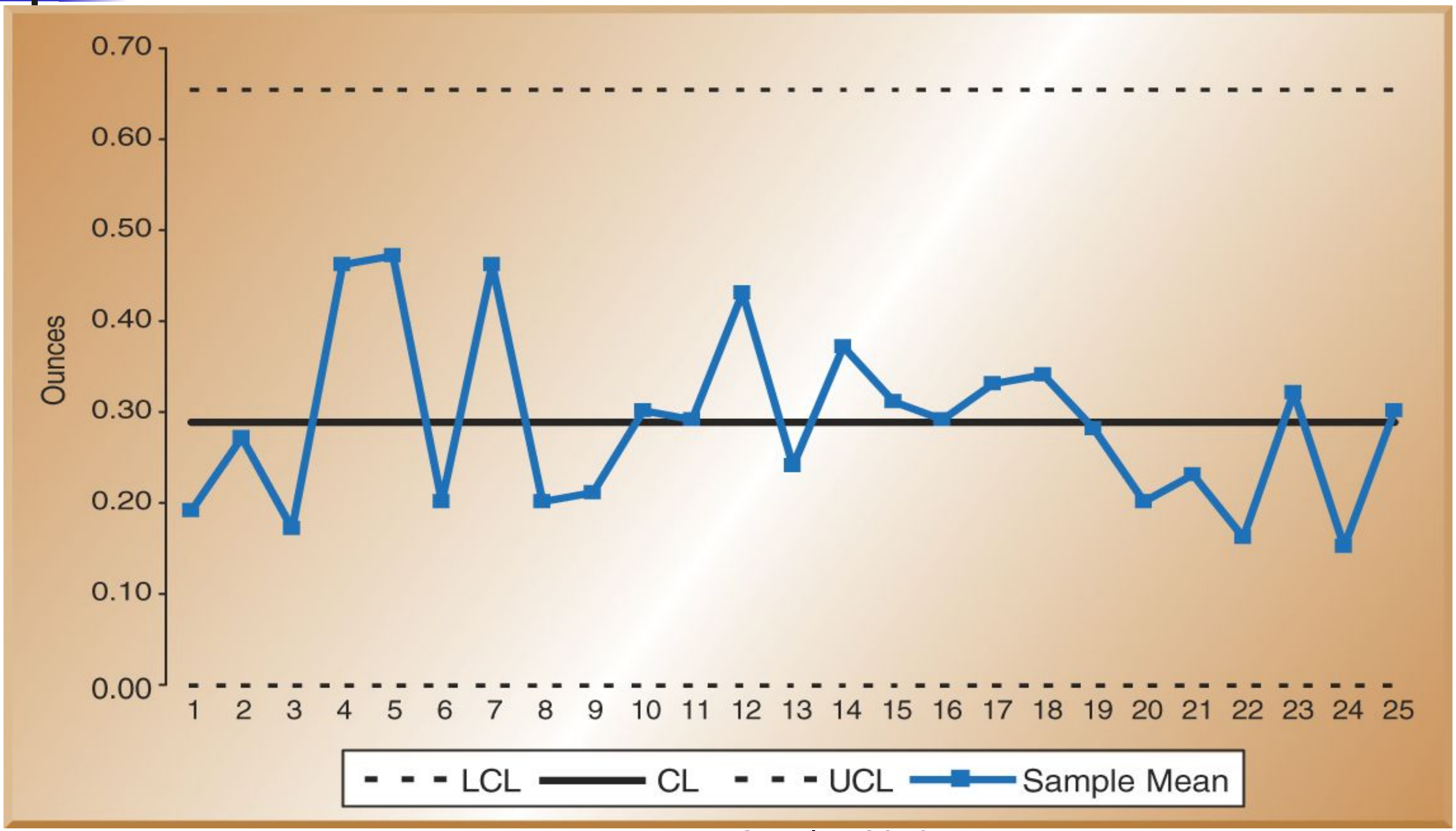
$$UCL_R = D_4\overline{R} = 2.28(.233) = .53$$

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

- Factors for three sigma control limits

| Sample Size (n) | A2 | D3 | D4 |
|---|---|---|---|
| | 1. | 0. | 3. |
| | 88 | 00 | 27 |
| | 02 | 00 | 57 |
| | 73 | 00 | 28 |
| | 58 | 00 | 11 |
| | 48 | 00 | 00 |
| | 42 | 08 | 92 |
| | 37 | 04 | 86 |
| 10 | 34 | 18 | 82 |
| 11 | 31 | 22 | 78 |
| 12 | 29 | 26 | 74 |
| 13 | 27 | 28 | 72 |
| 14 | 25 | 31 | 69 |
| 15 | 24 | 33 | 67 |
| | 22 | 35 | 65 |

# R-Bar Control Chart



# Second Method for the X-bar Chart Using R-bar and the $A_2$ Factor (table 6-1)

- **Use this method when sigma for the process distribution is not know**
- **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 Charts for Attributes i.e. discrete events

- **Use a P-Chart for yes/no or good/bad decisions in which defective items are clearly identified**
- **Use a C-Chart for more general counting when there can be more than one defect per unit**
  - Number of flaws or stains in a carpet sample cut from a production run
  - Number of complaints per customer at a hotel

**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 control limits.

| 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 | 1 | 20 | **.05** |
| Total | 9 | 100 | **.09** |

- **Solution:**

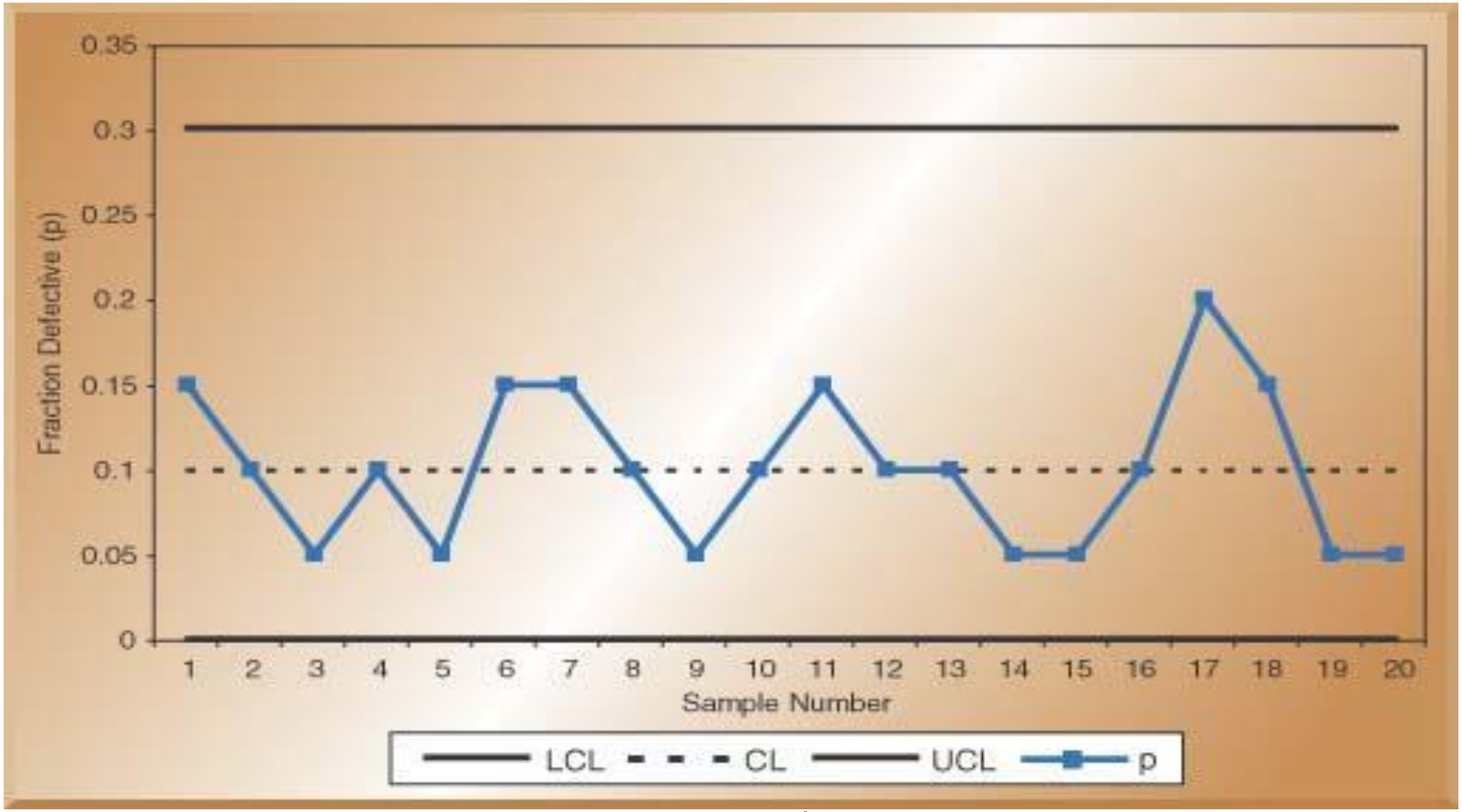
$$CL = \bar{p} = \frac{\#\,\text{Defectives}}{\text{Total Inspected}} = \frac{9}{100} = .09$$

$$\sigma_p = \sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = \sqrt{\frac{(.09)(.91)}{20}} = 0.64$$

$$UCL_p = \bar{p} + z(\sigma_p) = .09 + 3(0.64) = .282$$

$$LCL_p = \bar{p} - z(\sigma_p) = .09 - 3(0.64) = -.102 = 0$$

# 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** |

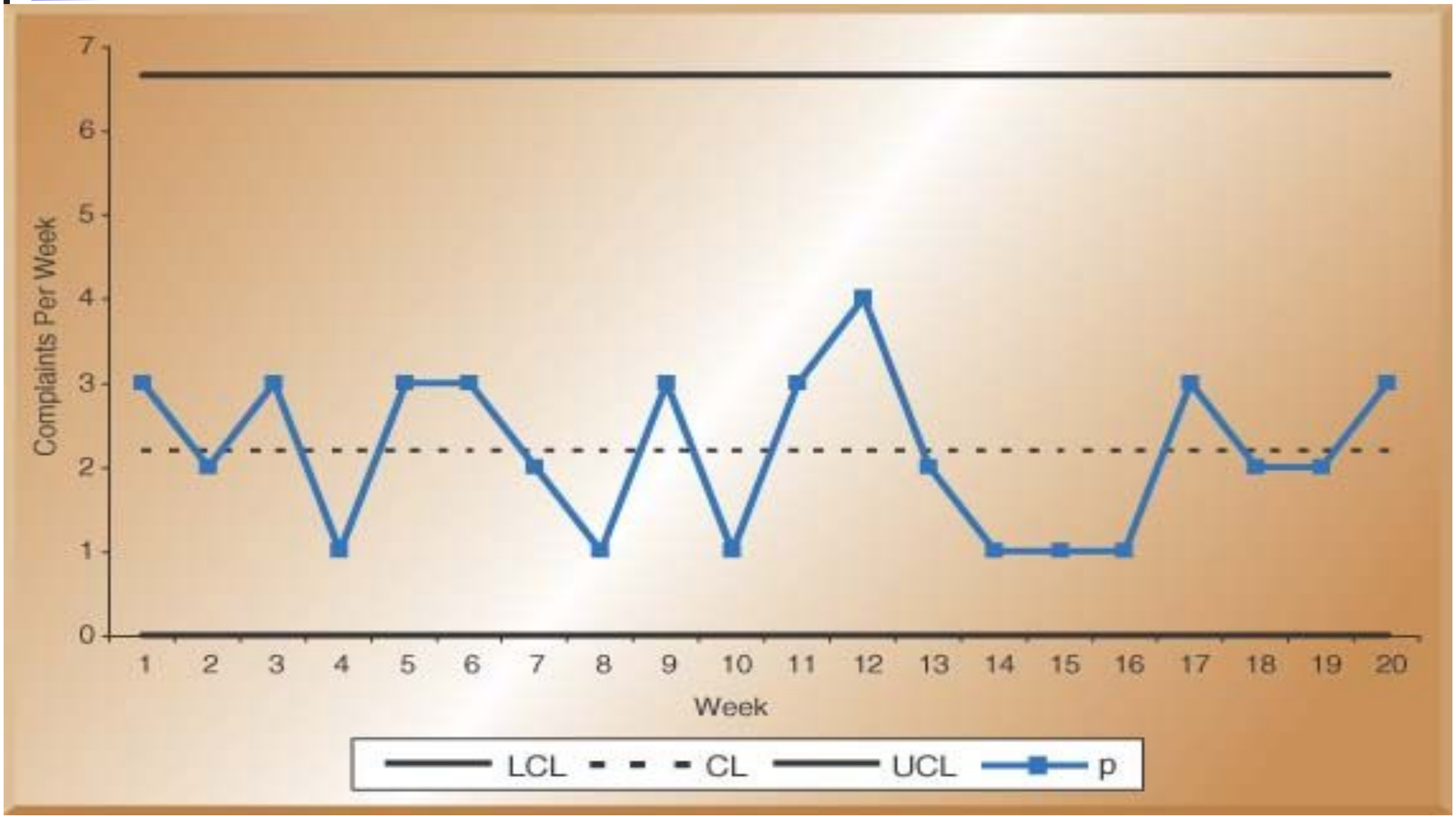
- **Solution:**

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

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

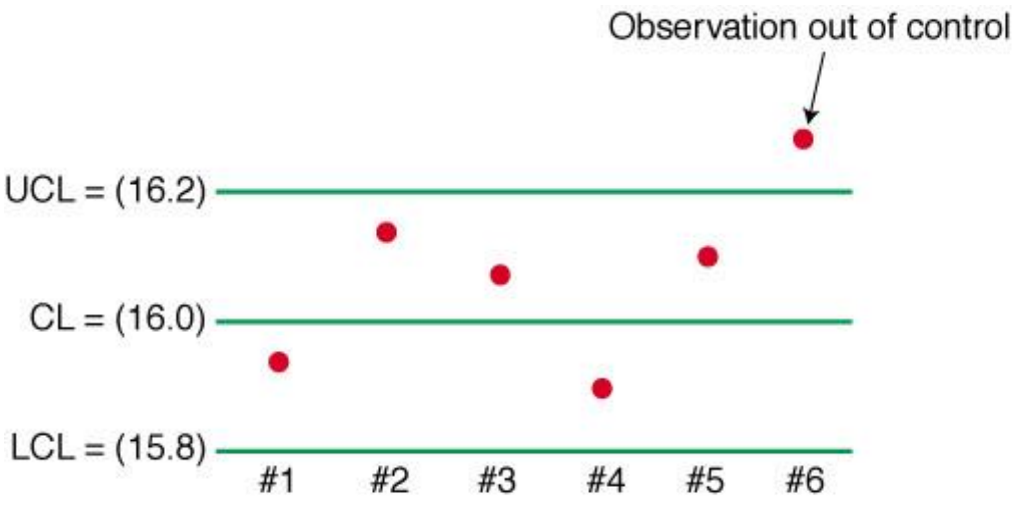
$$LCL_c = \bar{c} - z\sqrt{\bar{c}} = 2.2 - 3\sqrt{2.2} = -2.25 = 0$$

# C- Control Chart

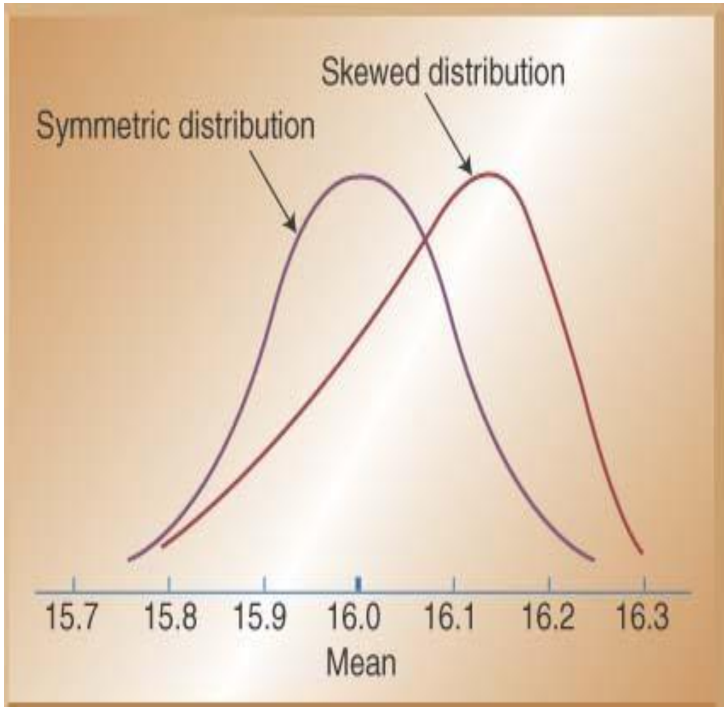


# Out of control conditions indicated by:

## Data Point out of limits




## Skewed distribution



# Process Capability

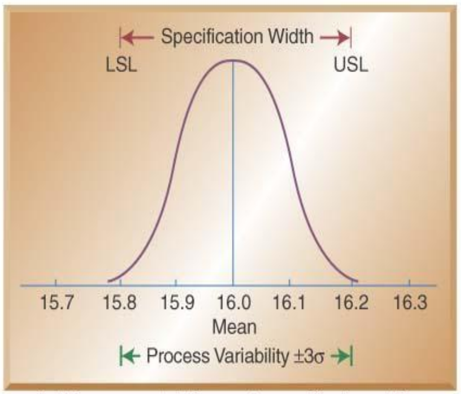
- **Product Specifications**
  - Preset product or service dimensions, tolerances
  - e.g. bottle fill might be 16 oz. ±.2 oz. (15.8oz.-16.2oz.)
  - Based on how product is to be used or what the customer expects
- **Process Capability – Cp and Cpk**
  - Assessing capability involves evaluating process variability relative to preset product or service specifications
  - **Cp** assumes that the process is centered in the specification range

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

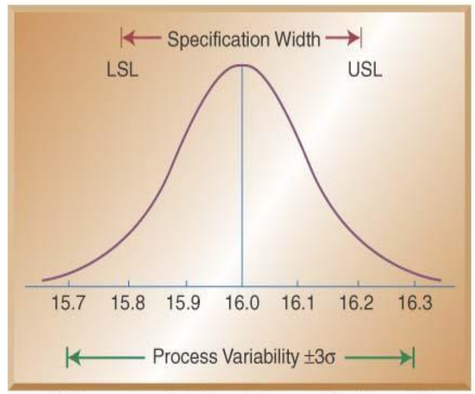
  - **Cpk** helps to address a possible lack of centering of the process

$$\mathrm{Cpk} = \min\left(\frac{\mathrm{USL} - \mu}{3\sigma}, \frac{\mu - \mathrm{LSL}}{3\sigma}\right)$$

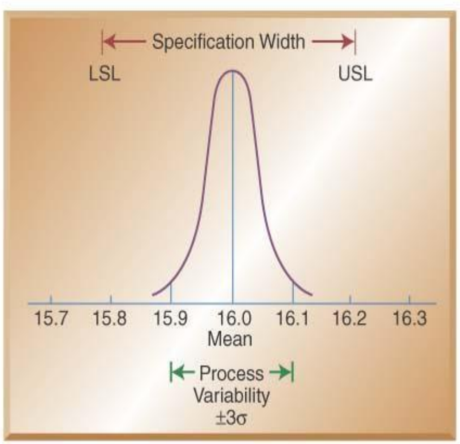
# Relationship between Process Variability and Specification Width




(a) Process variability meets specification width




(b) Process variability outside specification width




(c) Process variability within specification width

**Possible ranges** for **Cp**

- **Cp < 1, as in Fig. (b), process not capable of producing within specifications**
- **Cp ≥ 1, as in Fig. (c), process exceeds minimal specifications**

**One shortcoming, Cp assumes that the process is centered on the specification range**

**Cp=Cpk when process is centered**

**Computing the Cp Value at Cocoa Fizz: three bottling machines** are being evaluated for possible use at the Fizz plant. The machines **must be capable of meeting the design specification of 15.8-16.2 oz**. with at least a **process capability index of 1.0 ($C_p \geq 1$)**

- The table below shows the information gathered from production runs on each machine. **Are they all acceptable?**

| Machine | σ | USL-LSL | 6σ |
|---|---|---|---|
| A | .05 | .4 | .3 |
| B | .1 | .4 | .6 |
| C | .2 | .4 | 1.2 |

- **Solution:**
  - **Machine A**

$$\mathbf{Cp \frac{USL - LSL}{6\sigma} = \frac{.4}{6(.05)} = 1.33}$$

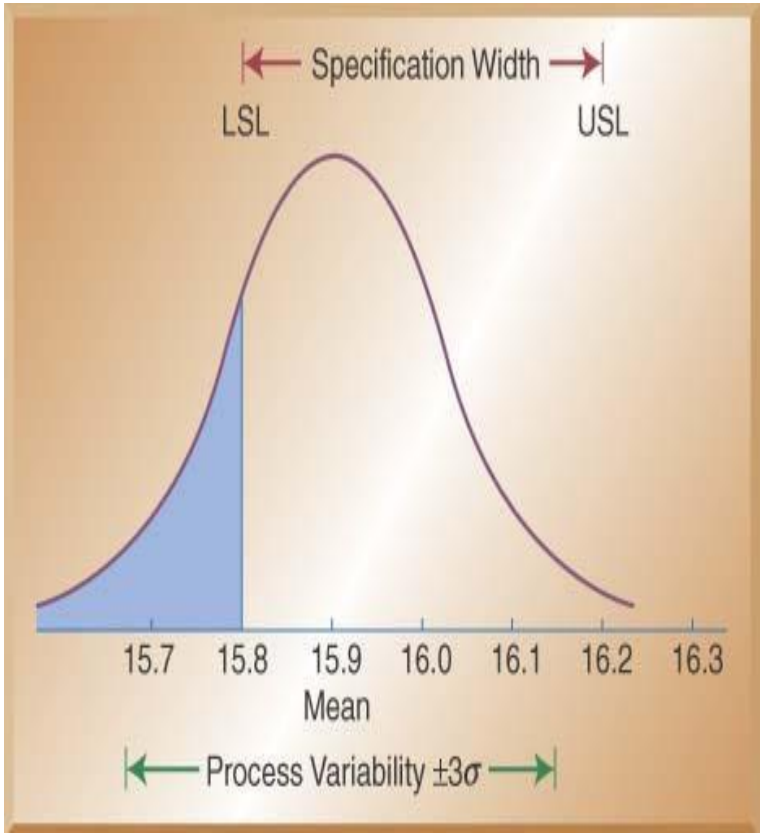
  - **Machine B**

$$Cp \frac{USL - LSL}{6\sigma} = \frac{.4}{6(.1)} = 0.67$$

  - **Machine C**

$$Cp \frac{USL - LSL}{6\sigma} = \frac{.4}{6(.2)} = 0.33$$

# Computing the $C_{pk}$ Value at Cocoa Fizz




- Design specifications call for a target value of **16.0 ±0.2 OZ.** **(USL = 16.2 & LSL = 15.8)**
- Observed process output has now shifted and has a **μ of 15.9** and a **σ of 0.1 oz.**

$$\text{Cpk} = \min\left(\frac{16.2 - 15.9}{3(.1)}, \frac{15.9 - 15.8}{3(.1)}\right)$$

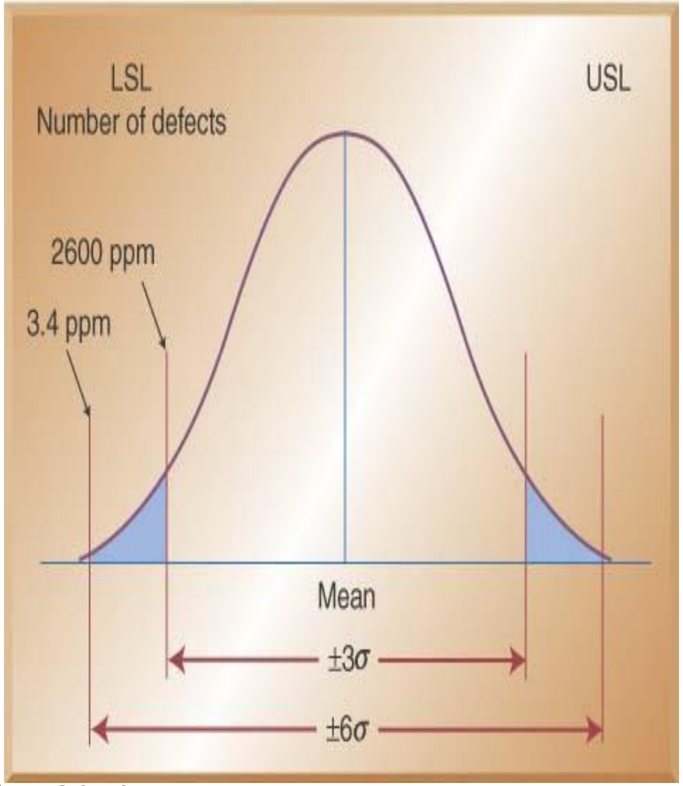
$$\text{Cpk} = \frac{.1}{.3} = .33$$

- **Cpk is less than 1**, revealing that the process **is not capable**

# ±6 Sigma versus ± 3 Sigma

- **Motorola coined "six-sigma" to describe their higher quality efforts back in 1980's**
  - **Ordinary quality standard requiring mean±3σ to be within tolerances implies that 99.74% of production is between LSL and USL**
  - **Six sigma is much stricter: mean ±6σ must be within tolerances implying that 99.99966% production between LSL and USL**
  - **same proportions apply to control limits in control charts**
- **Six-sigma quality standard is now a benchmark in many industries**

- **PPM Defective for ±3σ versus ±6σ quality**



# Six Sigma

Six Sigma Still Pays Off At Motorola

**It may surprise those who have come to know Motorola (MOT ) for its cool cell phones, but the company's more lasting contribution to the world is something decidedly more wonkish: the quality-improvement process called Six Sigma. In 1986 an engineer named Bill Smith, who has since died, sold then-Chief Executive Robert Galvin on a plan to strive for error-free products 99.9997% of the time. By Six Sigma's 20th anniversary, the exacting, metrics-driven process has become corporate gospel, infiltrating functions from human resources to marketing, and industries from manufacturing to financial services.**

**Others agree that Six Sigma and innovation don't have to be a cultural mismatch. At Nortel Networks (NT ), CEO Mike S. Zafirovski, a veteran of both Motorola and Six Sigma stalwart General Electric (GE ) Co., has installed his own version of the program, one that marries concepts from Toyota Motor (TM )'s lean production system. The point, says Joel Hackney, Nortel's Six Sigma guru, is to use Six Sigma thinking to take superfluous steps out of operations. Running a more efficient shop, he argues, will free up workers to innovate.**

http://www.businessweek.com/magazine/content/06_49/b4012069.htm?chan=search

# Acceptance Sampling

- **Definition**: **the third branch of SQC refers to the process of *randomly inspecting* a certain number of items from a lot or batch in order to *decide* whether to *accept* or *reject* the entire batch**
- **Different from SPC because acceptance sampling is performed either *before* or *after* the process rather than *during***
  - Sampling before typically is done to supplier material
  - Sampling after involves sampling finished items before shipment or finished components prior to assembly
- **Used where inspection is expensive, volume is high, or inspection is destructive**

# Acceptance Sampling Plans

- **Goal of Acceptance Sampling plans is to determine the criteria for acceptance or rejection based on:**
  - Size of the lot (N)
  - Size of the sample (n)
  - Number of defects above which a lot will be rejected (c)
  - Level of confidence we wish to attain
- **There are single, double, and multiple sampling plans**
  - Which one to use is based on cost involved, time consumed, and cost of passing on a defective item
- **Can be used on either variable or attribute measures, but more commonly used for attributes**

# Implications for Managers

- **How much and how often to inspect?**
  - Consider product cost and product volume
  - Consider process stability
  - Consider lot size
- **Where to inspect?**
  - Inbound materials
  - Finished products
  - Prior to costly processing
- **Which tools to use?**
  - Control charts are best used for in-process production
  - Acceptance sampling is best used for inbound/outbound

# SQC in Services

- **Service Organizations have lagged behind manufacturers in the use of statistical quality control**
- **Statistical measurements are required and it is more difficult to measure the quality of a service**
  - Services produce more intangible products
  - Perceptions of quality are highly subjective
- **A way to deal with service quality is to devise quantifiable measurements of the service element**
  - Check-in time at a hotel
  - Number of complaints received per month at a restaurant
  - Number of telephone rings before a call is answered
  - Acceptable control limits can be developed and charted

**Service at a bank**: The Dollars Bank competes on customer service and is concerned about **service time** at their drive-by windows. They recently installed new system software which they hope will meet **service specification limits of 5±2** minutes and have a Capability Index ($C_{pk}$) of at least **1.2**. They want to also design a control chart for bank teller use.

- **They have done some sampling recently (sample size of 4 customers) and determined that the process mean has shifted to 5.2 with a Sigma of 1.0 minutes.**

$$\mathrm{Cp}\,\frac{\mathrm{USL}-\mathrm{LSL}}{6\sigma}=\frac{7-3}{6\left(\frac{1.0}{\sqrt{4}}\right)}=1.33$$

$$\mathbf{Cpk}=\min\left(\frac{5.2-3.0}{3(1/2)},\frac{7.0-5.2}{3(1/2)}\right)$$

$$\mathbf{Cpk}=\frac{1.8}{1.5}=1.2$$

- **Control Chart limits for ±3 sigma limits**

$$\mathrm{UCL}_{\bar{x}}=\overline{\overline{X}}+z\sigma_{\bar{x}}=5.0+3\left(\frac{1}{\sqrt{4}}\right)=5.0+1.5=6.5\ \text{minutes}$$

$$\mathrm{LCL}_{\bar{x}}=\overline{\overline{X}}-z\sigma_{\bar{x}}=5.0-3\left(\frac{1}{\sqrt{4}}\right)=5.0-1.5=3.5\ \text{minutes}$$

# SQC Across the Organization

- SQC requires input from other organizational functions, influences their success, and are actually used in designing and evaluating their tasks
  - Marketing – provides information on current and future quality standards
  - Finance – responsible for placing financial values on SQC efforts
  - Human resources – the role of workers change with SQC implementation. Requires workers with right skills
  - Information systems – makes SQC information accessible for all.

# Chapter 5 Highlights

- TQM is different from the old concept of quality as it focus is on serving customers, identifying the causes of quality problems, and building quality into the production process
- Four categories of quality cost of prevention, appraisal, internal and external costs
- Seven TQM notable individuals include Walter A. Shewhart, W. Edwards Demings, Joseph M. Juran, Armand V. Feigenbaum, Philip B. Crosby, Kaoru Ishikawa, and Genichi Taguchi

# Chapter 5 Highlights – con't

- Seven features of TQM combine to create TQM philosophy; customer focus, continuous improvement, employee empowerment, use of quality tools, product design, process management, and managing supplier quality
- QFD is a tool used to translate customer needs into specific engineering requirements
- Reliability is the probability that the product will functions as expected
- The Malcom Baldridge Award is given to companies to recognize excellence in quality management.

# Chapter 4 Homework Hints

- This is not required, but for extra credit!
- Research on TQM:
  - Internet probably best, but library OK.
  - Link on my website: http://www.csus.edu/mgmt/blakeh/www.html
- Find an article that tells how a firm uses one (or more) of the quality concepts in Chapter 4.
- Write a summary of the article:
  - One page—single space paragraphs, double space between paragraphs.
  - Give the source, like in a bibliography.