DEPARTMENT OF AEROSPACE ENGINEERING
19MEE304 Total Quality Management

Topic: Statistical fundamentals

Statistical Fundamentals in Quality Management

Introduction to Statistics in Quality Management

- **Definition:** Statistics is the science of collecting, analyzing, interpreting, and presenting data.
- **Importance in Quality Management:**
  - ✅ Helps in monitoring and controlling processes.
  - ✅ Identifies defects and variations in production.
  - ✅ Improves decision-making through data analysis.
  - ✅ Supports predictive analytics for continuous improvement.

Types of Statistics in Quality Management

◈ Descriptive Statistics

- Summarizes and presents data in an understandable format.
- **Examples:** Mean, Median, Mode, Range, Standard Deviation.

◈ Inferential Statistics

- Draws conclusions from sample data to predict overall process performance.
- **Examples:** Hypothesis Testing, Confidence Intervals, Regression Analysis.

Data Types in Statistical Quality Control

◈ Quantitative Data (Numerical Data)

- **Continuous Data:** Measured values (e.g., weight, temperature, time).
- **Discrete Data:** Countable values (e.g., number of defects, number of customers).

◈ Qualitative Data (Categorical Data)

- **Nominal Data:** Categories without ranking (e.g., defect types, machine names).
- **Ordinal Data:** Ordered categories (e.g., customer satisfaction ratings).

Measures of Central Tendency (Averages)

- **Mean (Average):** Sum of values divided by total count.

$$\text{Mean} = \frac{\sum X}{N}$$

- **Median:** Middle value in an ordered dataset.
- **Mode:** Most frequently occurring value in a dataset.

◈ **Application in Quality Control:**

- Used to determine process consistency.
- Helps identify central process tendency in Six Sigma analysis.

Measures of Dispersion (Variability in Data)

- **Range:** Difference between maximum and minimum values.
- **Variance** (σ^2): Measure of spread in data.

$$\sigma^2 = \frac{\sum (X - \mu)^2}{N}$$

- **Standard Deviation** (σ): Square root of variance, used in control charts.

$$\sigma = \sqrt{\sigma^2}$$

◈ **Application:**

- High standard deviation indicates **process instability**.
- Low standard deviation means **consistent quality**.

Probability Concepts in Quality Control

- **Definition:** Probability measures the likelihood of an event occurring.

$$P(A) = \frac{\text{Favorable Outcomes}}{\text{Total Outcomes}}$$

- **Normal Distribution:** Bell-shaped curve used in process control.
- **Binomial & Poisson Distributions:** Used for defect prediction and failure analysis.

◈ **Example:** Probability of a defective component in a batch of 1000.

Statistical Process Control (SPC)

- **Definition:** A method of using statistical tools to monitor and improve manufacturing processes.
- **Key SPC Tools:**
  - ✅ Control Charts ($\bar{X}$ & R Charts, P Charts)
  - ✅ Process Capability Analysis (Cp, Cpk)
  - ✅ Histogram Analysis

Control Charts in Quality Control

Chart Type	Purpose	Example
$\bar{X}$ & R Charts	Monitor process mean & variation	Used in machining processes
P Chart	Monitor proportion of defective items	Used in electronic component defects
C Chart	Count defects per unit	Used in software defect tracking

🔷 **Formula for Process Capability Index (Cpk):**

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

- **Cpk > 1.33:** Process is capable.
- **Cpk < 1.00:** Process needs improvement.

Hypothesis Testing in Quality Management

- Used to compare two or more process conditions.
- **Null Hypothesis (H_0):** No significant difference.
- **Alternative Hypothesis (H_1):** Significant difference exists.
- **Common Tests:**
  - ✅ **T-Test:** Compares two sample means.
  - ✅ **Chi-Square Test:** Used for categorical data analysis.
  - ✅ **ANOVA (Analysis of Variance):** Compares multiple groups.

🔷 **Example:** Testing if a new machine improves product quality over the old machine.

Regression Analysis for Quality Prediction

- Used to model relationships between variables.
- **Simple Linear Regression Formula:**

$$Y = a + bX$$

Y: Dependent variable (e.g., defect rate).

- **X:** Independent variable (e.g., machine temperature).
- **a, b:** Regression coefficients.

🔷 **Application:** Predicting how process variables affect product quality.

Industry Applications of Statistical Fundamentals in Quality

📌 **Case Study 1: Six Sigma at General Electric (GE)**

- Used **statistical tools** to reduce defects in aircraft engines.
- Implemented **SPC & Control Charts** to monitor defects.
- **Result:** 50% defect reduction, saving millions in costs.

📌 **Case Study 2: Toyota's Statistical Quality Control**

- Uses **SPC & Cp/Cpk analysis** in the Toyota Production System (TPS).
- Continuous process improvement using **5 Whys & Pareto Analysis**.
- **Outcome:** Achieved near **zero-defect manufacturing**.

Challenges in Statistical Quality Control

🚧 **Data Collection Errors:** Inaccurate measurements lead to wrong conclusions.
🚧 **Process Variability:** Uncontrolled variations reduce reliability.
🚧 **Incorrect Statistical Interpretation:** Misuse of tools leads to poor decision-making.

🔷 **Solution:**
✔ Proper training in **SPC & Six Sigma methodologies**.
✔ Use of **Automated Quality Control Systems (AI & IoT)**.

Conclusion

- **Statistical fundamentals are the backbone of quality control.**
- **Companies use statistical tools to maintain high-quality standards and improve efficiency.**
- **Integration of AI and automation enhances statistical analysis for real-time process control.**