1

Introduction

Course Contents

1.1 INTRODUCTION:-

- Quality concepts are evolving continuously for more than hundred years. Organizations need to adapt these quality concepts to gain competitive advantages. In the 21st century also quality concepts will continue to evolve.
- The quality can be worked out for the enhancement of life by optimum utilization of resources in use. In recent years, Indian industries have understood this aspect of quality and have been inculcating the Quality culture in their products and services which are good sign for Indian industries.

1.2 Evolution of Quality Concepts:-

- The evolution of quality concepts have developed in the following ways according to the year in which the concept was evolved.
  - 1140- Craftsman trained apprentices to ensure the quality and standard of work.
  - 1765-1815- During the industrial revolution process of manufacturing was broken down into small jobs. The craftsman became inspector and standards emerged.
  - 1800s – 1990s- Inspection.
  - 1930s- Stastical Quality Control.
  - 1950s- Quality assurance.
  - 1980s- Strategic Quality Management.
  - Current- Continual Improvement.

The evolution has included changes in:

- Primary concerns that quality addresses.
- How quality was viewed?
- What was emphasis?
- Methods used.
- Role of quality professionals.
- Responsibility towards quality.
- Approach to quality.

Inspection era: 1800s

- Primary concern- detection of defects.
- View of quality- A problem to be solved.
- Emphasis- Product uniformity.
- Methods- gauging and measurement.
- Role of quality professionals- Inspection, counting and grading, sorting.
- Responsibility- The inspection department.
- Approach- 'Inspects in' quality.

Statistical Control: 1930s

- Primary concern- control.

- View of quality- A problem to be solved.
- Emphasis- Product uniformity with reduced uniformity.
- Methods- Statistical Tools and techniques.
- Role of quality professionals- Trouble shooting.
- Responsibility- Manufacturing and engineering.
- Approach- 'Controls in' quality.

Quality Assurance: 1950s

- Primary concern- Co-ordination.
- View of quality- A problem to be solved, but one that is attacked proactively.
- Emphasis- The entire production chain, design to market, contribution of all functional groups, especially designers, to prevent quality failures.
- Methods- Programs and systems.
- Role of quality professionals- Quality measurements, Quality Planning and Program design.
- Responsibility- All departments, although top management only periphelly involved in designing, planning and executing quality policies.
- Approach- 'Builds in' quality.

Strategic Quality Management: 1980s

- Primary concern- Strategic impact.
- View of quality- A competitive opportunity.
- Emphasis- The market and consumer needs.
- Methods- Strategic planning, goal setting, and mobilizing the organization.
- Role of quality professionals- Education and training, consultative work with other departments and program design.
- Responsibility- Everyone with top management exercising strong leadership.
- Approach- 'Manages in' quality

1.3 Definitions of Quality:-

1. Quality is dynamic state associated with the products, services, people, processes and environments that meets or exceeds the expectations of the customer. Quality is defined as the ratio of performance to expectations:

$$\text{Quality } (Q) = \frac{Performance\ (P)}{Expectations\ (E)}$$

Q=1, customer is satisfied.

Q<1, customer is not satisfied.

Q>1, customer is delighted.

2. According to W.Edward Deming, quality can be defined only in terms of an agent who is judging the quality. In the mind of production worker, he produces quality if he can take pride in his work. For a plant manager, quality means to get the numbers out and meet

the specifications. His job is also, whether he knows it or not, continual improvement of leadership.

3. According to Joseph M Juran quality means those features of products that meet customer needs and thereby provides customer satisfaction.
4. Quality is a pragmatic system of continual improvement, a way to successfully organise men and machines.
5. The meaning of excellence is called Quality.
6. Quality is unyielding and continuing effort by everyone in an organization to undestand, meet, and exceed the needs of of its customers.
7. Quality means the best product that you can produce with the materials that you have to work with.
8. Quality means continuous good product which a customer can trust.
9. Quality means producing a product or service that meets the needs or expectations of the customer.
10. Quality means not only satisfying customers, but delighting them, innovating and creating.
11. According to customers quality means fitness to purpose.
12. According to producers/providers quality means meeting requirement.
13. According to Taguchi quality means 'the minimum loss imparted by the product to society from the time product is shipped.'
14. ISO 9000 (old definition): The totality of characteristics of an entity (product or service) that bear on its ability to satisfy stated and implied needs.
15. ISO 9000 (new definition): Degree to which a set of inherent characteristics fulfill requirements.

1.4 Dimensions of Quality

– The following are the dimensions of a quality of a product.

1. Performance: Main characteristics of the products or service.
2. Aesthetics: Appearance, feel, sell and taste.
3. Special Features: extra characteristics.
4. Conformance: how will a product or service corresponds to the customer's expectations?
5. Safety: risk of injury or harm.
6. Reliability: consistency of a performance.
7. Durability: useful life of a product or service.
8. Perceived Quality: indirect evaluation of a quality (reputation).
9. Service after sales: handling of the complaints or checking for customer's satisfaction.

1.5 Quality Assurance: -

- It means ensuring conformity of quality to the required basic operation. All the planned and systematic activities implemented within the quality systems and demonstrated as needed to provide adequate confidence that an entity will fulfill for quality requirements.
- Assurance means keeping the promises. When needs and capabilities are understood, and the system is improved, we need to ensure that the process works. The modern concept of quality starts on the manufacturing line, where Quality professionals work to ensure that the products are meeting the specifications and the domain of quality assurance that masters the document systems and audit process. The quality of assurance is about meeting stated and implied promises. Quality is all about consistency.

1.6 Inspection:

- An **inspection** is, most generally, an organized examination or formal evaluation exercise. In engineering activities inspection involves the measurements, tests, and gauges applied to certain characteristics in regard to an object or activity. The results are usually compared to specified requirements and standards for determining whether the item or activity is in line with these targets. Inspections are usually non-destructive.
- The inspection can be classified into three basic kinds:

- **Centralized Inspection** which is carried out centrally in a plant in quality department of inspection room. The benefit of centralized inspection is that the process can be carried out on machines which cannot be taken to the shop floor. Also the supervisors or inspectors get a better working environment since they are away from the noises and other factors which decrease their efficiency to work on the shop floor. The results which are obtained by this kind of inspections are so accurate since the inspection is carried out in close atmosphere with machines so no chances of human errors are there.
- **Decentralized or Shop Floor or Online Inspection:** This method of inspection is carried out on shop floor while the production process is in progress, inspection is either carried out from machine to machine or from workstation to workstation so the parts or components which are manufactured can be inspected on line and if there are any defects then it can be solved out quickly and if there are any necessary steps which shall be taken in changing the process it can be done on the shop floor itself saving time and reducing the rejections.
- **Surprise Inspection:** A **surprise inspection** tends to have different results than an announced inspection. Leaders wanting to know how others in their organization perform can drop in without warning, to see directly what happens. If an inspection is made known in advance, it can give people a chance to cover up or to fix mistakes. This could lead to distorted and inaccurate findings. A surprise inspection, therefore, gives inspectors a better picture of the typical state of the inspected object or process than an announced inspection

1.7 Quality Control:

- **Quality control**, or **QC** for short, is a process by which entities review the quality of all factors involved in production. This approach places an emphasis on three aspects:

1. Elements such as controls, job management, defined and well managed processes, performance and integrity criteria, and identification of records
2. Competence, such as knowledge, skills, experience, and qualifications
3. Soft elements, such as personnel integrity, confidence, organizational culture, motivation, team spirit, and quality relationships.

- Controls include product inspection, where every product is examined visually, and often using a stereo microscope for fine detail before the product is sold into the external market. Inspectors will be provided with lists and descriptions of unacceptable product defects such as cracks or surface blemishes for example.
- The quality of the outputs is at risk if any of these three aspects is deficient in any way.
- Quality control emphasizes testing of products to uncover defects and reporting to management who make the decision to allow or deny product release, whereas quality assurance attempts to improve and stabilize production (and associated processes) to avoid, or at least minimize, issues which led to the defect(s) in the first place. For contract work, particularly work awarded by government agencies, quality control issues are among the top reasons for not renewing a contract.

1.8 Quality management:

- Quality management is a recent phenomenon. Advanced civilizations that supported the arts and crafts allowed clients to choose goods meeting higher quality standards than normal goods. In societies where arts and crafts are the responsibility of a master craftsman or artist, they would lead their studio and train and supervise others. The importance of craftsmen diminished as mass production and repetitive work practices were instituted. The aim was to produce large numbers of the same goods.
- Customers recognize that quality is an important attribute in products and services. Suppliers recognize that quality can be an important differentiator between their own offerings and those of competitors (quality differentiation is also called the quality gap). In the past two decades this quality gap has been greatly reduced between competitive products and services. This is partly due to the contracting (also called outsourcing) of manufacture to countries like India and China, as well internationalization of trade and competition. These countries amongst many others have raised their own standards of quality in order to meet International standards and customer demands. The ISO 9000 series of standards are probably the best known International standards for quality management.

Principles of Quality Management:

Quality management adopts a number of management principles that can be used by top management to guide their organizations towards improved performance. The principles include:

Customer focus

Since the organizations depend on their customers, therefore they should understand current and future customer needs, should meet customer requirements and try to exceed the expectations of customers. An organization attains customer focus when all people in the organization know both the internal and external customers and also what customer requirements must be met to ensure that both the internal and external customers are satisfied.

Leadership

Leaders of an organization establish unity of purpose and direction of it. They should go for creation and maintenance of such an internal environment, in which people can become fully involved in achieving the organization's quality objective.

Involvement of people

People at all levels of an organization are the essence of it. Their complete involvement enables their abilities to be used for the benefit of the organization.

Process approach

The desired result can be achieved when activities and related resources are managed in an organization as process.

System approach to management

An organization's effectiveness and efficiency in achieving its quality objectives are contributed by identifying, understanding and managing all interrelated processes as a system.

Continual improvement

One of the permanent quality objectives of an organization should be the continual improvement of its overall performance.

Factual approach to decision making

Effective decisions are always based on the data analysis and information.

Mutually beneficial supplier relationships

Since an organization and its suppliers are interdependent, therefore a mutually beneficial relationship between them increases the ability of both to add value.

These eight principles form the basis for the quality management system standard ISO 9001:2008.

1.9 VIEWS OF DIFFERENT QUALITY GURUS

- The following are the view of different quality gurus and their share for the quality:
- **Dr. Edward Deming:** According to him quality is dynamic and is a business strategy. He said that every activity should be aimed at customer. He then introduced the concept of activity flow, contrary to the hierarchical system. Dr. Deming defined quality as 'a product or a service possesses the quality if it helps someone to live better and enjoy a large and sustainable market.' He had given PDSA cycle (Plan, Do, Study and Act). He had also given 14 points of Quality Control.
- **Balaji Reddie- founder of the quality movement in India:** He was very much impressed by Deming's philisophy of quality and so he had founded Deming Forum (India) and got

the permission from the W. Edward Deming Institute in the United States to use their official logo, and he had started the website www.demingindia.org for the noble cause of Quality movement in India

- **Fredrick W. Taylor and specific Management:** According to Taylor, each job-time calculation finally resulted into an overall job completion time, known as standard time. Based on standard time, the production rate was decided and given to workers as targets. He is considered to be father of Scientific Management which has helped to ensure quality levels.
- **Dr. Joseph Juran:** He broadened the quality from the stastical origin to the total quality management (TQM). He added human dimension to quality. 'The Quality Trilogy: Quality Planning, Quality Control and Quality Improvement.' Published in 1986, identified a third aspect to the quality management, that is, the quality planning. Juran's triology relates the with the product deficiencies and exhibits the units of measure such as the cost of poor quality, error rate percentage, percent defective, service call rate and so on. It will also help ensure the product stability throughout the process.

[References: Quality control by V.A.Kulkarni & A.K.Bewoor-page: -5, 7, 17, 25]

2

Quality Engineering and Management Tools, Techniques & Standards

Course Contents

2.1. Introduction to Quality Engineering:-

- Quality engineering is the management, development, operation and maintenance of IT systems and enterprise architectures with a high quality standard.
- Quality objectives describe basic requirements for software quality. In Quality Engineering they often address the quality attributes of availability, security, safety, reliability and performance. With the help of quality models like ISO/IEC 25000 and methods like the Goal Question Metric approach it is possible to attribute metrics to quality objectives. This allows measuring the degree of attainment of quality objectives. This is a key component of the Quality Engineering process and, at the same time, is a prerequisite for its continuous monitoring and control.
- To ensure effective and efficient measuring of quality objectives the integration of core numbers, which were identified manually (e.g. by expert estimates or reviews), and automatically identified metrics (e.g. by statistical analysis of source codes or automated regression tests) as a basis for decision-making is favorable.

Tools and Techniques of TQM: -

- The 3 important tools of TQM are employee, product and process.
- TQM goes through the following 3 phases:-
  a. Employee development.
  b. Product development.
  c. Process development.
- **Techniques of TQM** which are used for the above mentioned developments are as follows:-

a. For employees development following is used:-

1. Communication.
2. Training.
3. Involvement.
4. Quality circle development.
5. Kaizen.

b. For product development following is used:-

1. QFD- customers' requirements.
2. Concurrent engineering.
3. Customer delight.

c. For process development following is used:-

1. 5 S practice.
2. ISO 9000.
3. TPM.
4. Six Sigma.
5. JIT and Kanban.
6. Reliability, availability and maintainability.
7. Poka-yoke and seven QC Tools.

2.2. 7 QC Tools

- In 1950, the Japanese Union of Scientists and Engineers (JUSE) invited legendary quality guru W. Edward Deming to train thousands of Japanese engineers, managers, scholars in statistical process control.
- One of the members of the JUSE was Kaoru Ishikawa, at the time an associate professor at the University of Tokyo. Ishikawa had a desire to 'democratize quality' that is to say, he wanted to make quality control comprehensible to all workers, and inspired by Deming's philosophy, he formalized the Seven Basic Tools of Quality Control.
- He believed that 90% of a company's problems could be improved using these seven tools, and that-with exception of Control charts- they could easily be taught to any member of the organization. This case-of-use combined with their graphical nature makes statistical analysis easier for all, Basic seven QC tools are as below:

  1. Histograms. 2. Pareto Charts. 3. Cause and effect diagrams (fish bone chart).
  4. Scatter Diagrams. 5. Flow Charts. 6. Run Charts. 7. Control Charts.

1. Histograms.

- Histogram is a frequency chart of measurements used to give a graphical representation of the process. The range between the largest and the smallest values is provided into classes and each measurement value is assigned to each class according to the value. Approximate average and range of dispersion of measurements are readily understandable from the graph. When the graph is a normal curve such as a bell shape, it represents the standard deviation.
- Histogram Defined as a bar graph that shows frequency data.
- Histograms provide the easiest way to evaluate the distribution of data.
- Histograms suggest the nature of and possible improvements for physical mechanisms at work in progress.

Creating a Histogram

- Collect data and sort it into categories.
- Then label the data as the independent set or the dependent set.
- The characteristic you grouped the data by would be the independent variable.
- The frequency of that set would be the dependent variable.
- Each mark on either axis should be in equal increments.
- For each category, find the related frequency and make the horizontal marks to show that frequency.

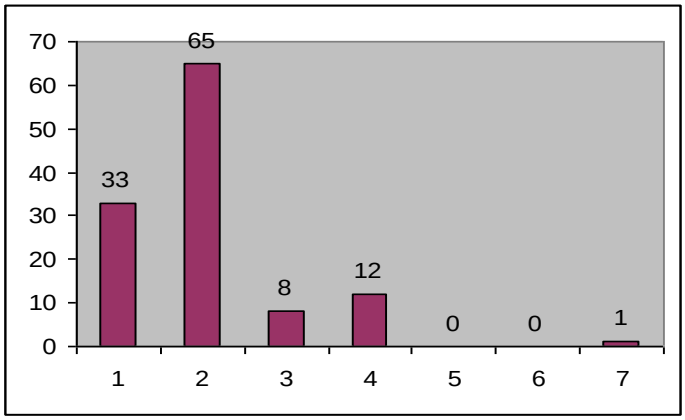


Figure 2.1: Example of Histogram

Examples of How Histograms Can Be Used

- Histograms can be used to determine distribution of sales.
- Say for instance a company wanted to measure the revenues of other companies and wanted to compare numbers.
- Perhaps the company wants to compare numbers of companies that make from 0-10000; from 10,000-20,000; from 20,000-30,000; and so on.

2. Pareto Charts.

- Pareto analysis is very helpful in studying a quality problem as it helps to breakdown the problem. It is performed by plotting the cumulative frequency of the relative frequency data or event count data, in a descending order.
- Pareto charts are extremely useful because they can be used to identify those factors that have the greatest cumulative effect on the system, and thus screen out less significant factors in analysis. This allow user to focus attention on a few important factors in a process. When this is done, the most essential factors for the analysis are graphically apparent, and in an orderly format.
- The Pareto chart can be used for the following purposes:
    1. Focusing on critical issues by ranking them in terms of importance and frequency.
    2. Prioritizing problems or causes to efficiently initiate problem-solving (what is the most frequent complaint).
    3. Analyzing problems or causes by different groupings of data (e.g. by programme, teacher, school building, machine or team.)
- They are actually histograms aided by the 80/20 rule adapted by Joseph Juran. Remember the 80/20 rule states that approximately 80% of the problems are created by approximately 20% of the causes. This is the economic concept that Juran applied to quality problems. The meaning behind that 80/20 rule is that there are vital few causes that create the problems.

Constructing a Pareto Chart

- First, information must be selected based on types or classifications of defects that occur as a result of a process.

- The data must be collected and classified into categories.
- Then a histogram or frequency chart is constructed showing the number of occurrences.
- The steps used in Pareto analysis include gathering categorical data, drawing the histogram, and concentrating on the tall bars.

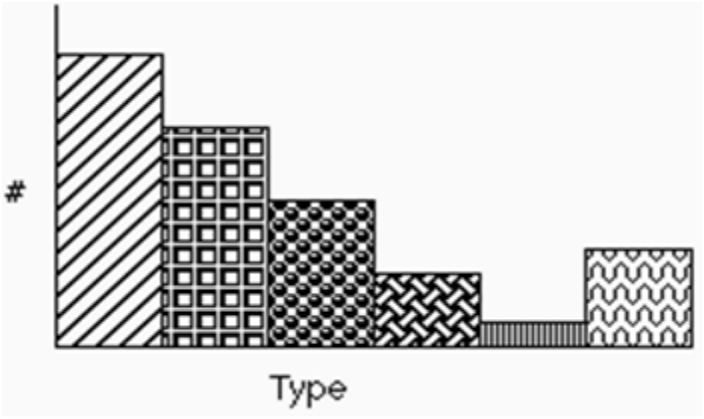


Figure 2.2: Pareto Chart

An Example of How a Pareto Chart Can Be Used

- Pareto Charts are used when products are suffering from different defects but the defects are occurring at a different frequency, or only a few accounts for most of the defects present, or different defects incur different costs. What we see from that is a product line may experience a range of defects. The manufacturer could concentrate on reducing the defects which make up a bigger percentage of all the defects or focus on eliminating the defect that causes monetary loss.
- Data should be analyzed in two cases. The manufacturer could concentrate on reducing the defects that make up a bigger percentage of all the defects or they could concentrate on the defect that is costing them the most money. As part of the analysis, look at the tallest bars when trying to solve the problem.

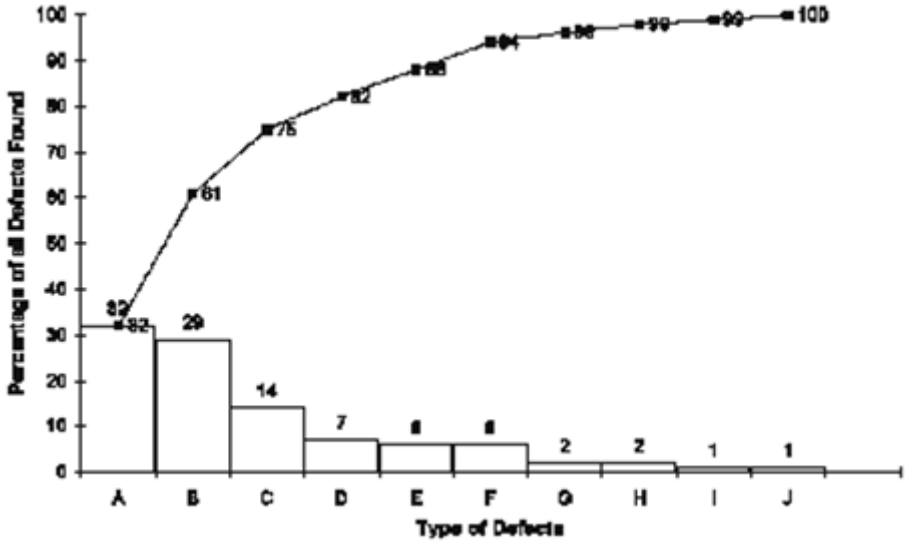


Figure 2.3: Example of Pareto Chart

- Concentrating on reducing defects A, B and C since they make up 75% of all defects. Or focus on eliminating defect E, if defect E causes 40% of monetary loss.

3. Cause and Effect Diagram (Fish bone diagram).

- Cause and effect diagram of fish bone diagram is also known as Ishikawa diagram or root cause analysis. The term cause and effect diagram also aptly describes the tool to capture the causes of a particular effect and the relationship between cause and effect. The term fishbone is used to describe the look of the diagram on paper. The basic use of the tool is to find root causes of problems; hence, it is also called root cause analysis.
- This tool helps workers spend time on concentrating on the causes of problems rather than focusing on improving the indications of problems. The basic concept in the diagram is that the name of a basic problem is entered at the right of the diagram at the end of the main bone.

Constructing a Cause and Effect Diagram

- First, clearly identify and define the problem or effect for which the causes must be identified. Place the problem or effect at the right or the head of the diagram.
- Identify all the broad areas of the problem.
- Write in all the detailed possible causes in each of the broad areas.
- Each cause identified should be looked upon for further more specific causes.
- View the diagram and evaluate the main causes.
- Set goals and take action on the main causes.

An Example of When a Cause and Effect Diagram Can Be Used

- This diagram can be used to detect the problem of incorrect deliveries.
- When a production team is about to launch a new product, the factors that will affect the final product must be recognized. The fishbone diagram can depict problems before they have a chance to begin.
- The effect being examined is normally an aspect of product or service quality.

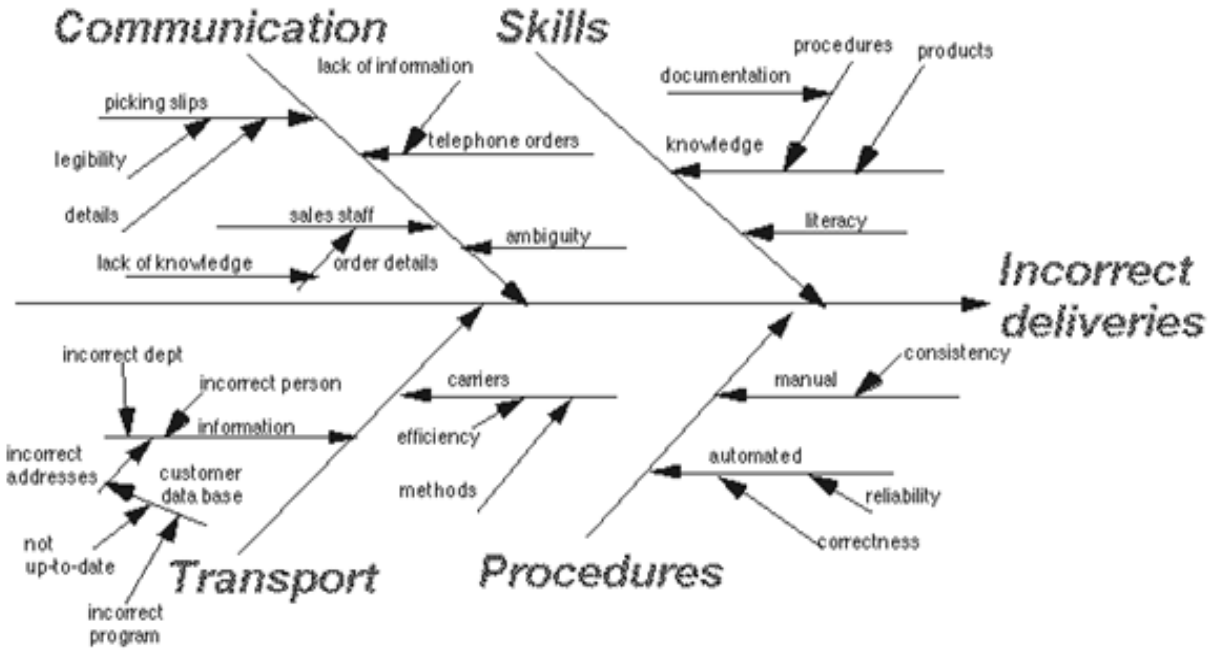


Figure 2.4: Example of Cause and effect Diagram (Fish Bone Diagram)

4. Scatter Diagrams.

- Scatter diagrams are used to study possible relationship between two variables and they do indicate the existence of a relationship, as well as the strength of that relationship. A scatter diagram is composed of a horizontal axis containing the measured values of one variable and a vertical axis representing the measurements of the other variable. Based on the theory of linear regression originated from studies performed by Sir Francis Galton (1822-1911), the scatter diagram was developed so that intuitive and qualitative conclusions could be drawn about the paired data, or variables. The concept of correlation was employed to decide whether a significant relationship existed between the paired data or not. The purpose of scatter diagram is to display what happens to one variable when another variable is changed. The type of relationship is used to test a theory to establish the relationship between two variables. The relationship that exists is indicated by the slope of the diagram. Data patterns can be positive, negative or display no relationship.

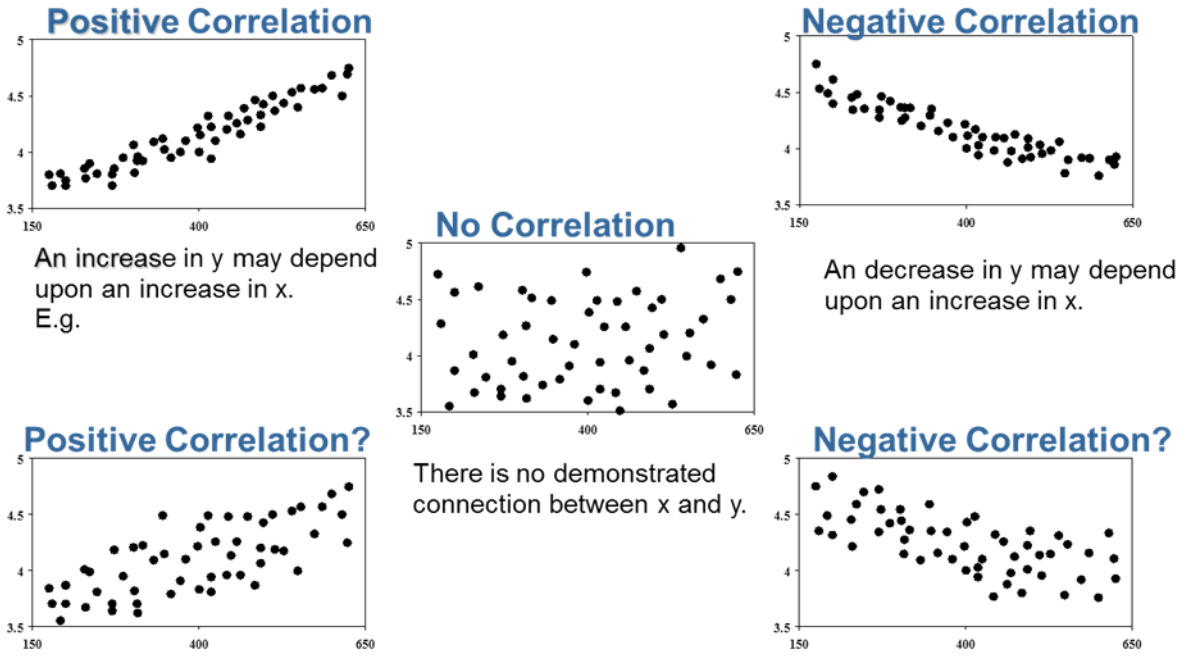


Figure 2.5: Example of Scatter Diagram

Constructing a Scatter Diagram

- First, collect two pieces of data and create a summary table of the data.
- Draw a diagram labeling the horizontal and vertical axes.
- It is common that the “cause” variable be labeled on the X axis and the “effect” variable be labeled on the Y axis.
- Plot the data pairs on the diagram.
- Interpret the scatter diagram for direction and strength.
- The X variable is independent and the Y variable is dependent.

An Example of When a Scatter Diagram Can Be Used

- A scatter diagram can be used to identify the relationship between the production speed of an operation and the number of defective parts made.
- Displaying the direction of the relationship will determine whether increasing the assembly line speed will increase or decrease the number of defective parts made.

5. Flow Chart.

- Flow chart is a pictorial representation that shows all the steps in a process. It is a graphical representation of how work is done. The first step for an improvement team is to draw a flow chart of the process under examination. The well-defined process will define all the steps during the operation and unless it is clear, the process, cannot be improved. By breaking the process down into its constituent steps, flow charts can be useful in identifying where errors are likely to be found in a system.
- Flow chart is not having any statistical basis but is an excellent visualization tool. It also shows the progress of work and flow of material through information or sequence of operation during the process. Flow chart is useful in an initial process analysis and should be complemented by process flow sheets or process flow diagrams. Everyone involved in the project should draw a flow chart of the process being studied to reveal different perceptions of how the process operates. A flow chart provides a visualization of a process by use of symbos that represents different types of actions, activities or situations.

Flowchart example

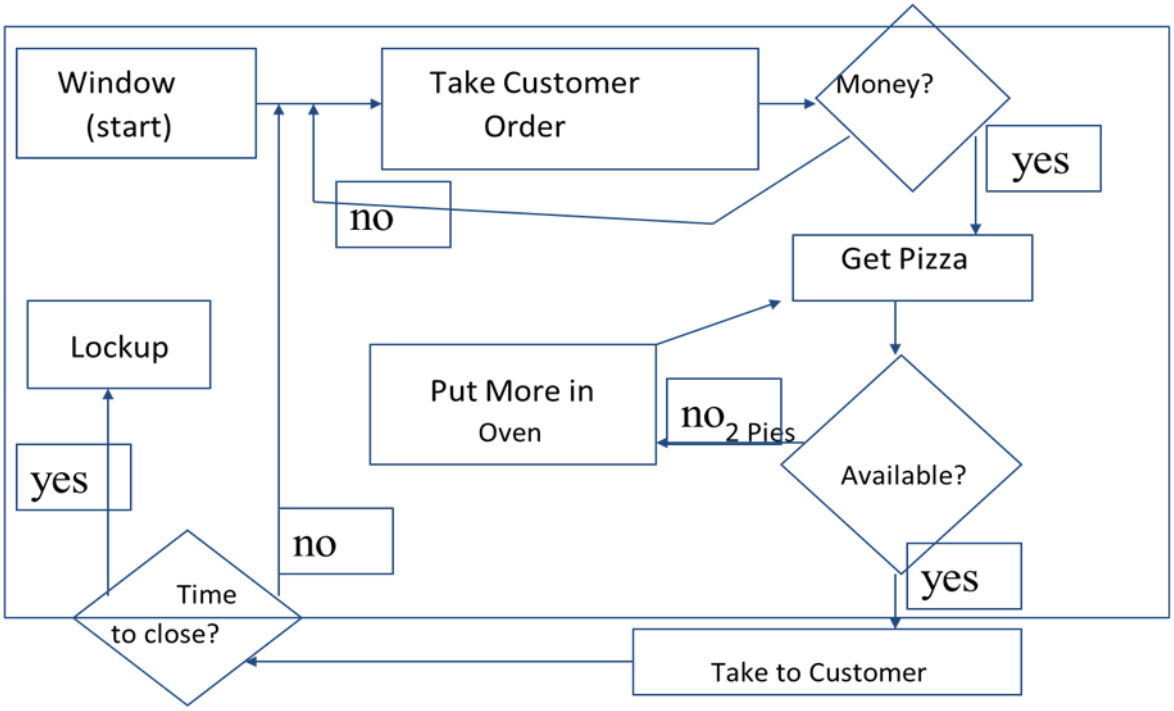


Figure 2.6: Example of Flow Diagram

6. Run Charts.

– Run charts are used to analyze processes according to time or order.
Run charts are useful in discovering patterns that occur over time.
• Creating a Run Chart
– Gathering Data
• Some type of process or operation must be available to take measurements for analysis.
– Organizing Data
• Data must be divided into two sets of values X and Y. X values represent time and values of Y represent the measurements taken from the manufacturing process or operation.
– Charting Data
• Plot the Y values versus the X values.
– Interpreting Data

Interpret the data and draw any conclusions that will be beneficial to the process or operation. When measuring data, the measurements must be taken over time and in sequential order. When plotting the values, use an appropriate scale that will make the points on the graph visible.

• Plot of some measurement/metric vs. (usually) time
– Use this when X axis is interval or ratio scale e.g. “team size”
• Shows trends over time
– Easier to spot overall upward or downward trend, or even cyclical variations
• Visually separate random from significant variation
– Major spikes / valleys triggers for explanation / investigation / action
• Value: Identification of problems, trends, unexpected good results (may learn a lot from these)

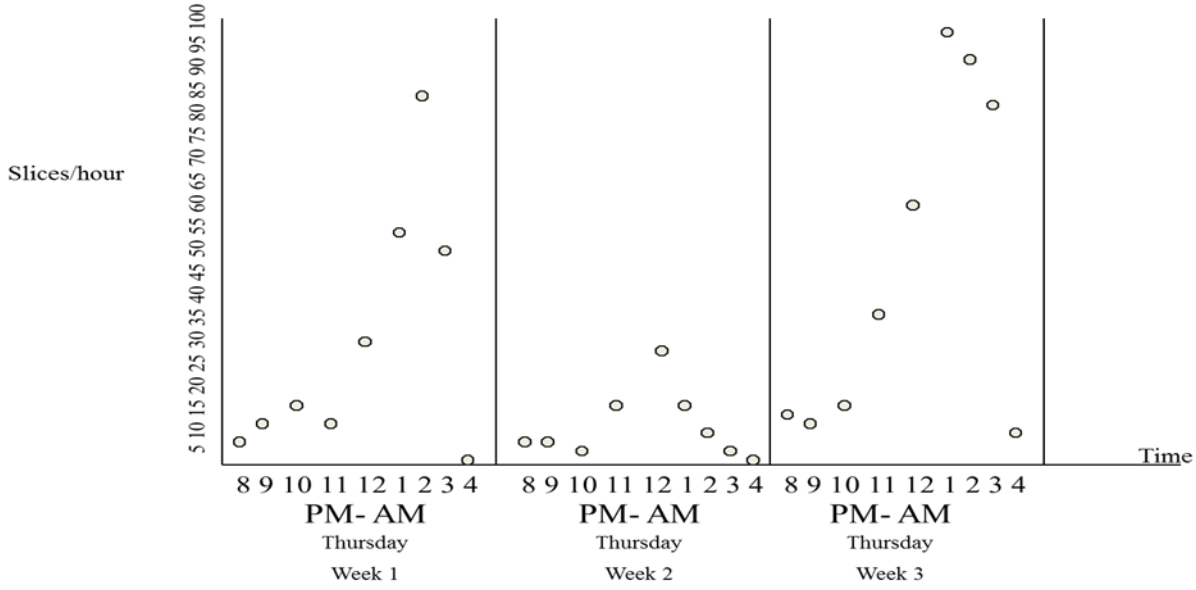


Figure 2.7: Example of Run Chart [*From http://www.freequality.org*]

7. Control Charts.

- Dating back to the work of Shewhart and Deming, there are several types of conttrol chart. They aer reasonably complex statistical tools that measures how a process changes over a time. By plotting this data against pre-defined upper and lower control limits, it can be determined whether the process is consistent and under control, or if it is unpredictable and therefore out of control.
- In control chart, data is collected and plotted over time with the upper and lower control limits set (from past performance or statistical analysis). and the average identified.
- There are two types of control charts. Control charts for continuous data and control charts for attribute data.

• Plot of a metric with control limits defined
- Upper control limit: If value of metric exceeds this, take action
- Lower control limit: If value goes below this, take action
- (maybe) Warning levels: If value outside this, check if all is well

• Control limits may be derived statistically or less formally (based on "reasonable" values / other impacts)
- Formal statistical process control has formulae for deriving limits: often 3 sigma deviation from desired outcome

• Useful to flag "outlier" values e.g. components with very high defect rates, projects that have parameters outside "normal levels" etc.

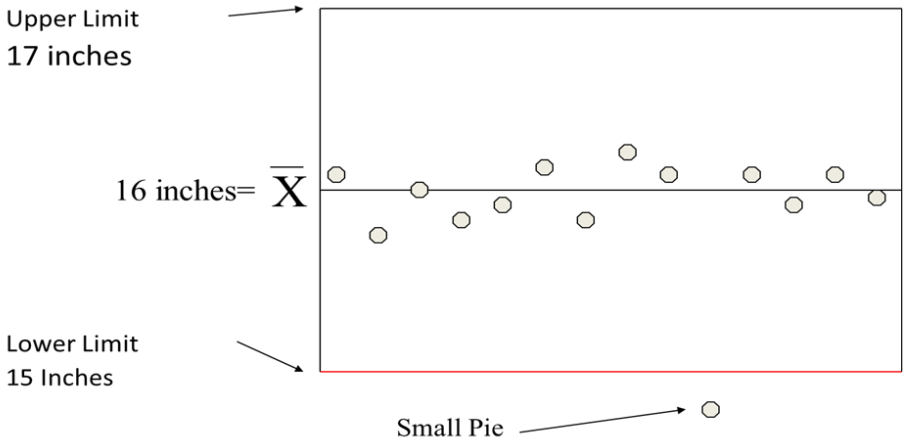


Figure 2.8: Example of Control Chart

The quality tools together form a suite:

- Histograms, run charts, control charts can identify problems
- Fishbone is used to brainstorm possible causes
- Scatterplots can be used to analyze whether relationships exist
- Pareto analysis identifies which causes are most worth addressing
- Checklists, templates, process definition and workflow automation can eliminate problems

2.3. 7 new Quality Improvement Tools

- Basic 7 Qc tools are based on numerical data, and problem is defined after collecting numerical data. It indicates analytical approach. Basic 7 QC tools are effective for data analysis, process control and quality improvement.
- New quality improvement tools are based on verbal data and it defines the problem before collecting numerical data. It helps to generate ideas and formulate plans. They are basically developed to organize verbal data diagrammatically.
- A committee for developing QC tools affiliated with JUSE was set up in April 1972. Their aim was to develop QC techniques for use by managerial level and staff. This committee was headed by Yoshinobu Nayatani and they met regularly. In January 1977 the committee announced the results of its research in the form of a new set of methods called 'The Seven New QC Tools'.

Benefits of Incorporating New Seven Q.C. Tools

- Organize verbal data
- Generate ideas
- Improve planning
- Eliminate errors and omissions
- Explain problems intelligibly
- Secure full cooperation
- Persuade powerfully
- Asses situation from varies angles.
- Clarify the desired situation.
- Prioritize tasks effectively.

The following are the new 7 QC Tools:

i. Affinity Diagrams.
ii. Relation Diagrams.
iii. Tree Diagrams.
iv. Matrix Diagrams.
v. Matrix Data Analysis.
vi. Arrow Diagrams.
vii. Process Decision Program charts (PDPC)

1. Affinity Diagram

- It is also called affinity chart of K-J diagram. The affinity diagram organizes a large number of ideas into their mutual relationships. This method taps a team's creativity and intuition. It was created in the 1960s by Japanese Anthropologist Jiro Kawakita. It is used for Pinpointing the Problem in a Chaotic Situation and Generating Solution Strategies
  - Gathers large amounts of intertwined verbal data (ideas, opinions, issues)
  - Organizes the data into groups based on natural relationship
  - Makes it feasible for further analysis and to find a solution to the problem.

Advantages of Affinity Diagrams:

- The following are the advantages of affinity diagrams
  1. Facilitates breakthrough thinking and stimulate fresh ideas
  2. Permits the problem to be pinned down accurately
  3. Ensures everyone clearly recognizes the problem
  4. Incorporates opinions of entire group
  5. Fosters team spirit
  6. Raises everyone's level of awareness
  7. Spurs to the group into action

Constructing an Affinity Diagram

1. Select a topic
2. Collect verbal data by brainstorming
3. Discuss info collected until everyone understands it thoroughly
4. Write each item on separate data card
5. Spread out all cards on table
6. Move data cards into groups of similar themes (natural affinity for each other)
7. Combine statements on data cards to new Affinity statement
8. Make new card with Affinity statement
9. Continue to combine until less than 5 groups
10. Lay the groups outs, keeping the affinity clusters together and complete the diagram

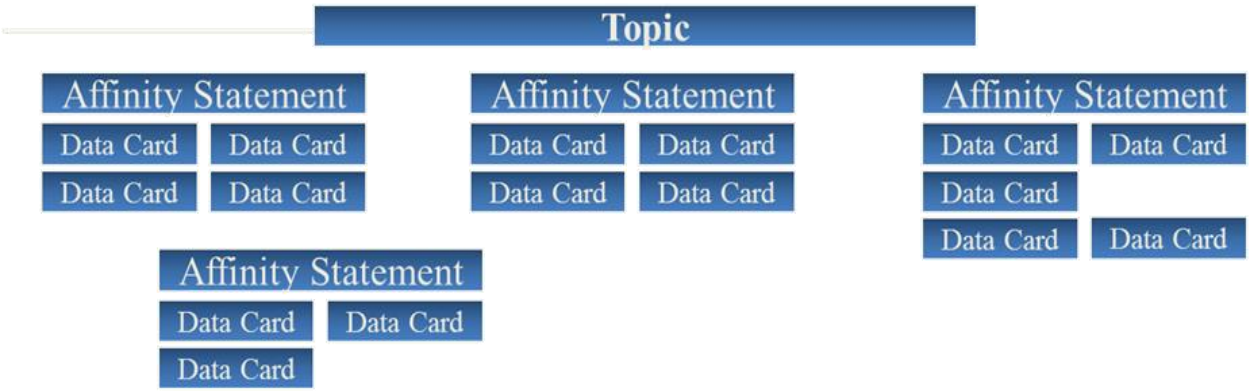


Figure 2.9: Affinity Diagram

2. Relation Diagram

- The relation diagram shows cause-and-effect relationships. Just as importantly, the process of creating a relations diagram helps a group analyze the natural links between different aspects of a complex situation. It helps for finding solutions strategies by clarifying relationships with complex interrelated causes. It resolves tangled issues by unraveling logical connections. It allows for multidirectional thinking rather than linear.

Advantages of Relations Diagram:

- The following are the advantages of relations diagram.
  1. Useful at planning stage for obtaining perspective on overall situation
  2. Facilitates consensus among team
  3. Assists to develop and change people's thinking
  4. Enables priorities to be identified accurately
  5. Makes the problem recognizable by clarifying the relationships among causes

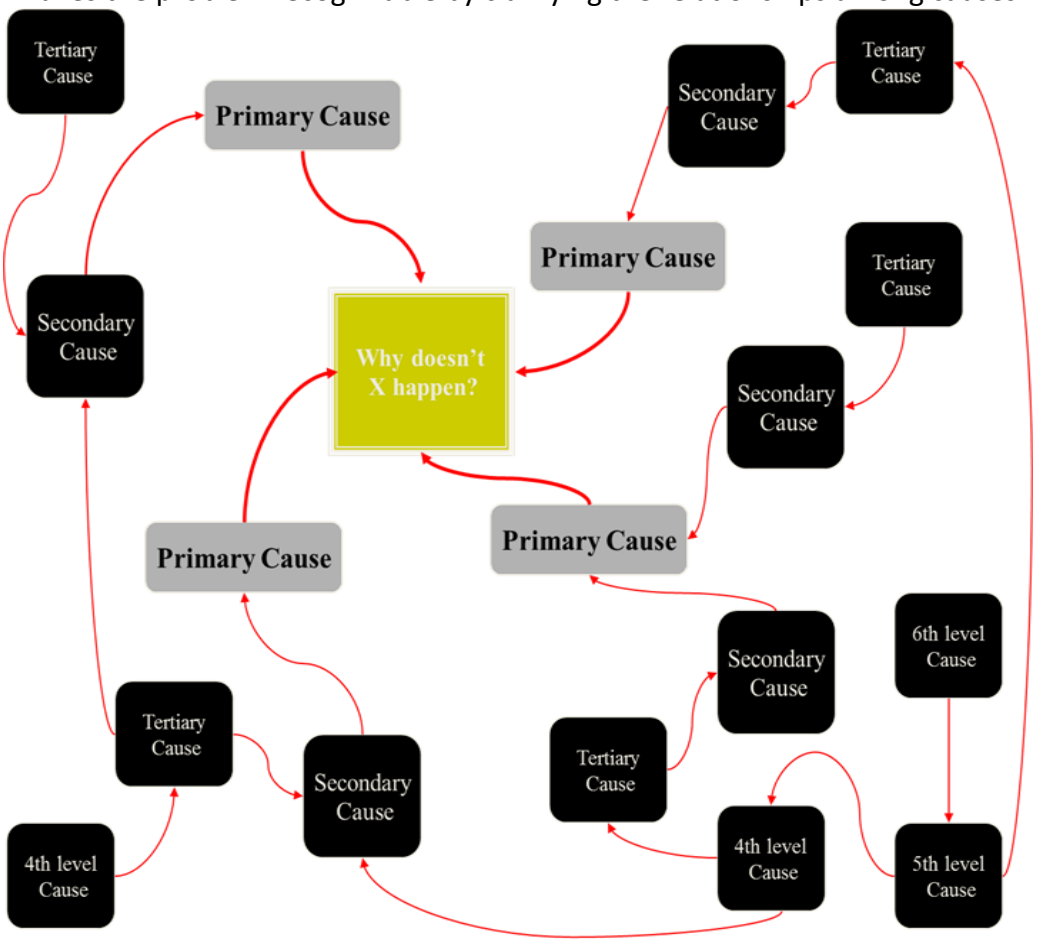


Figure 2.10: Relation Diagram

Constructing a Relations Diagram:

1. Express the problem in form of "Why isn't something happening?"
2. Each member lists 5 causes affecting problem
3. Write each item on a card
4. Discuss info collected until everyone understands it thoroughly
5. Move cards into similar groups
6. Asking why, explore the cause-effect relationships, and divide the cards into primary, secondary and tertiary causes

7. Connect all cards by these relationships
8. Further discuss until all possible causes have been identified
9. Review whole diagram looking for relationships among causes
10. Connect all related groups
11. Next, complete the diagram

3. Tree Diagram

- Tree diagram is used for systematically pursuing the best strategies for attaining an objective. It develops succession of strategies for achieving objectives. It reveals methods to achieve the results.
- The tree diagram starts with one item that branches into two or more, each of which branch into two or more, and so on. It looks like a tree, with trunk and multiple branches. It is used to break down broad categories into finer and finer levels of details. Developing the tree diagram helps more thinking step by step from generalities to specifics.

Advantages of Tree Diagram:

- The following are the advantages of tree diagram
  1. Systematic and logical approach is less likely that items are omitted
  2. Facilitates agreement among team
  3. Are extremely convincing with strategies

Constructing a Tree Diagram:

1. Write Relations Diagram topic (Objective card)
2. Identify constraints on how objective can be achieved
3. Discuss means of achieving objective (primary means, first level strategy)
4. Take each primary mean, write objective for achieving it (secondary means)
5. Continue to expand to the fourth level
6. Review each system of means in both directions (from objective to means and means to objective)
7. Add more cards if needed
8. Connect all levels
9. Complete the diagram

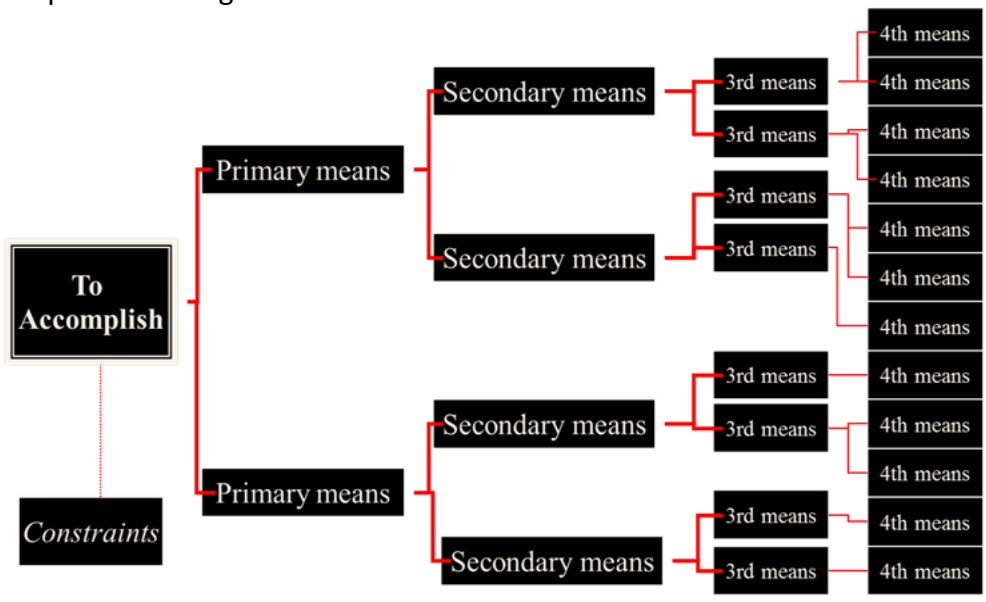


Figure 2.11: Tree Diagram

4. Matrix Diagram

- It helps for clarifying problems by thinking multi dimensionally. The matrix diagram shows the relationship between two, three or four groups of information. It also can give information about the relationship, such as its strength, the roles played by various individuals or measurements.
- Six differently shaped matrices are possible, L, T, Y, X, C and roof shaped, depending on how many groups must be compared.

Advantages of Matrix Diagram:

- The following are the advantages of matrix diagram:
  1. Enable data on ideas based on extensive experience
  2. Clarifies relationships among different elements
  3. Makes overall structure of problem immediately obvious
  4. Combined from two to four types of diagrams, location of problem is clearer.
  5. 5 types: L-shaped, T-shaped, Y-shaped, X-shaped, and C-shaped

	O	O	=1	△	O	=4	◎	Principal
	O	△	=2	O	X	=5	O	Subsidiary
	△	△	=3	△	X	=6		

	Evaluation			Responsibilities					
	Efficacy	Practicability	Rank	Site QCcircle	SectionPlant QCcircle supporter	SectionPlant Manager	Leader	Member	Remarks
4th level means from Tree diagram	O	O	1	O	◎				
4th level means from Tree diagram	O	O	1				◎	O	Hold 4 times/month
4th level means from Tree diagram	△	O	3				◎	O	At every meeting
4th level means from Tree diagram	O	△	2				O	◎	
4th level means from Tree diagram	O	X	5		O	◎			At least 3 times/year/person
4th level means from Tree diagram	O	O	1	O	◎	O			
4th level means from Tree diagram	△	△	4			O	◎		
4th level means from Tree diagram	O	△	2				◎	O	
4th level means from Tree diagram	O	O	1				◎	O	
4th level means from Tree diagram	O	O	1				◎	O	

Figure 2.12: Matrix Diagram

Constructing a Matrix Diagram:

1. Write final-level means from Tree diagram forming vertical axis
2. Write in Evaluation categories (efficacy, practicability, and rank) on horizontal axis.
3. Examine final-level means to identify whom will implement them
4. Write names along horizontal axis
5. Label group of columns as “Responsibilities”
6. Label right-hand end of horizontal axis as “Remarks”
7. Examine each cell and insert the appropriate symbol

8. Efficancy: O=good, ▲=satisfactory, X=none Practicability: O=good, ▲=satisfactory, X=none
9. Determine score for each combination of symbols, record in rank column
10. Examine cells under Responsibility Columns, insert double-circle for Principal and single-circle for Subsidiary
11. Fill out remarks column and record meanings of symbol and complete diagram.

5. Matrix Data Analysis.

- It is very much similar to matrix diagram with a difference that numerical data is used instead of symbols indicating the existence and strength of relationship. It uses numerical data to produce numerical results.

Advantages of Matrix Data Analysis:

- The following are the advantages of matrix data analysis:
  1. Can be used in various fields (market surveys, new product planning, process analysis)
  2. Can be when used when Matrix diagram does not give sufficient information
  3. Useful as Prioritization Grid

Steps for matrix data analysis:

1. Determine your goal, your alternatives, and criteria for decision
2. Place selection in order of importance
3. Apply percentage weight to each option (all weights should add up to 1)
4. Sum individual ratings to establish overall ranking (Divide by number of options for average ranking)
5. Rank order each option with respect to criterion (Average the rankings and apply a completed ranking)
6. Multiply weight by associated rank in Matrix (in example, 4 is best, 1 is worst)
7. Result is Importance Score
8. Add up Importance Scores for each option

Rank orders the alternatives according to importance and completes the diagram.

Criteria	Customer Acceptance (most important)	Cost	Reliability	Strength (least important)	Importance Sum Score	Option Ranking
Options						
Design A						
Percentage weight	.40	.30	.20	.10		
Rank	4	3	3	1		
Importance score	1.6	.90	.60	.10	3.2	1 (tie)
Design B						
Percentage weight	.30	.40	.10	.20		
Rank	3	4	1	2		
Importance score	.90	1.6	.10	.40	3.0	2
Design C						
Percentage weight	.25	.25	.25	.25		
Rank	1	2	4	3		
Importance score	.25	.50	1	.75	2.5	3
Design D						
Percentage weight	0.3	.10	.20	.40		
Rank	3	1	3	4		
Importance score	.90	.10	.60	1.6	3.2	1 (tie)
Sum of weights	1.25	1.05	.75	.95		
Average weight	.31	.26	.19	.24		
Criterion Ranking	1	2	4	3		

Figure 2.13: Matrix Data Analysis

6. Arrow Diagram.

- The arrow diagram shows the required order of tasks in a project or process, the best schedule for the entire project, and potential scheduling and resource problems and their soulitons. The arrow diagram lets you calculate the 'critical path' of the project. This is the flow of critical steps where delays will affect the timing of the entire project and where addition of resources can speed up the project.

Advantages of Arrow Diagram:

- The following are the advantages of arrow diagram:
  1. Allows overall task to viewed and potential snags to be identified before work starts
  2. Leads to discovery of possible improvements
  3. Makes it easy to monitor progress of work
  4. Deals promptly with changes to plan
  5. Improves communication among team
  6. Promotes understanding and agreement among group

Constructing a Arrow Diagram:

1. From strategies on Tree diagram, select one (Objective of Arrow Diagram)
2. Identify constraints to Objective
3. List all activities necessary to achieving Objective
4. Write all essential activities on separate cards
5. Organize cards in sequential order of activities
6. Remove any duplicate activities
7. Review order of activities, find sequence with greatest amount of activities
8. Arrange parallel activities
9. Examine path, number nodes in sequence from left to right
10. Record names and other necessary information and complete the diagram.

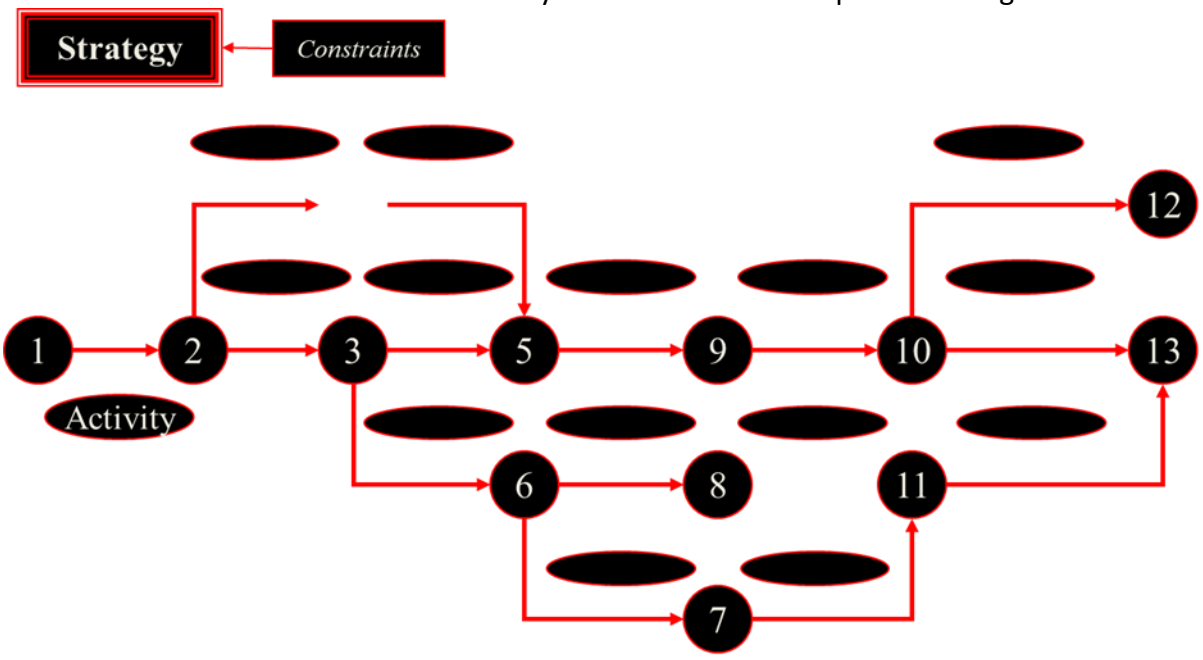


Figure 2.14: Arrow Diagram

7. Process Decision Program Charts (PDPC).

- The process decision program chart systematically identifies what might go wrong in a plan under development. Countermeasures are developed to prevent or offset those problems. By using PDPC, it can either revise the plan to avoid the problems or be ready with the best response when a problem occurs.

Advantages of PDPC:

- The following are the advantages of process decision program charts:
  1. Facilitates forecasting
  2. Uses past to anticipate contingencies
  3. Enables problems to pinpointed
  4. Illustrates how events will be directed to successful conclusion
  5. Enables those involved to understand decision-makers intentions
  6. Fosters cooperation and communication in group
  7. Easily modified and easily understood

Constructing a PDPC:

1. Select a highly effective, but difficult strategy from the Tree diagram
2. Decide on a goal (most desirable outcome)
3. Identify existing situation (Starting point)
4. Identify constraints of objective
5. List activities to reach goal and potential problems with each activity
6. Review list. Add extra activities or problems not thought of previously
7. Prepare contingency plan for each step and review what action is needed if step is not achieved
8. Examine carefully to check for inconsistencies and all important factors are included
9. Examine to make sure all contingency plans are adequate and complete the chart.

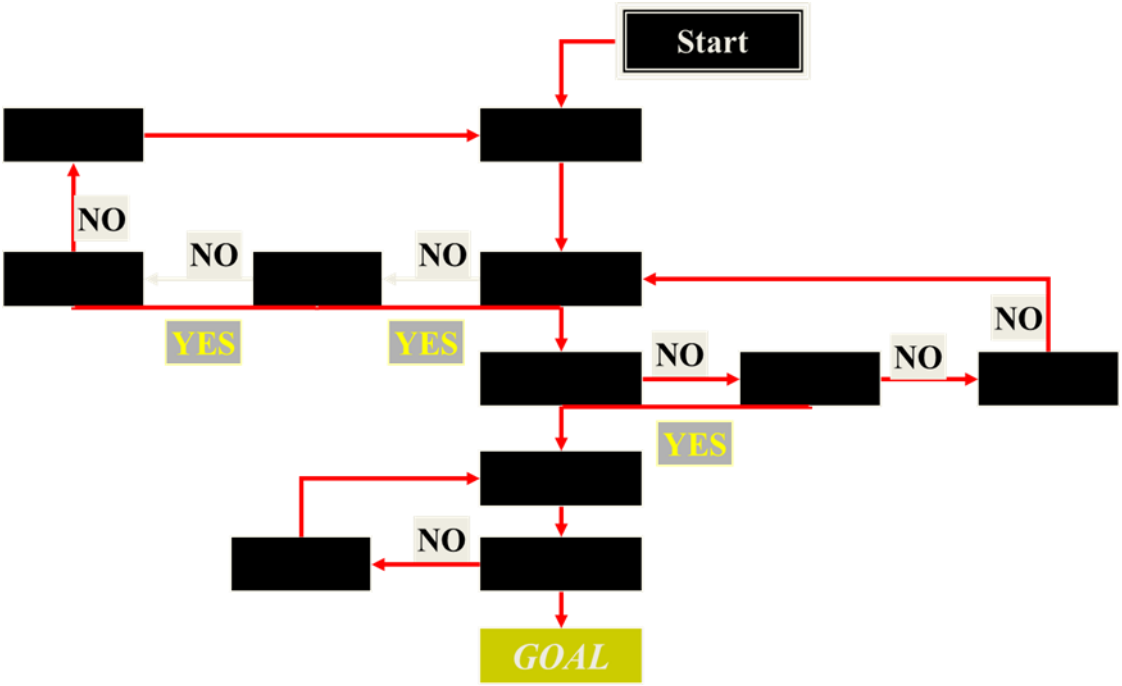


Figure 2.15: PDPC Diagram

2.4. 5 S Practice

- The 5 S practices or 5 S process is a structured program to systematically achieve the total organization and maintain cleanliness and standardization in the workplace. A well-organized workplace results in a safer, more efficient, more productive and customer-focused operation. It boosts the morale of the workers, promoting a sense of pride in their work and ownership of their responsibilities. The workers will enjoy working rather than completing it's for enjoyment. The 5 S is one of these techniques, a step for the systematic workplace organization and standardization. The 5 S was invented in Japan and it stands for the five Japanese words that start with the letter 'S': seiri, seiton, seiso, seiketsu, and shitsuke. An equivalent set of five 'S' words in English has been adopted to preserve the 5 S acronym- sort, set(in place), shine, standardize and sustain- in the English usage.

1. Seiri (Sort)

- The first step of the 5 S processes, seiri, refers to the act of throwing away all the unwanted, unnecessary and unrelated materials in the workplace. The people involved in seiri must not feel sorry about having to throw away things. The idea is to ensure that everything left in the workplace related to the work. Even the number of necessary items in the workplace must be kept to its absolute minimum. Because of seiri, the simplification of tasks, an effective use of space and the careful purchase of the items follow.
- The most effective method to implement Seiri is to place/ attach a red tag to all unneeded items and move them to a location outside the work area for storage until disposed off.
- Sorting is an excellent way to free up valuable space and eliminate such things as obsolete stock, used and broken tools, irreparable jigs and fixtures, non-renewable jobs, surplus stocks etc.

Red Tagging:

- A method to identify items that will eventually be removed from an area.
- Contains Data describing:
  - Red Tag No.
  - Name/Description of item
  - Reason for Tagging
  - Date Tagged
  - Current Location
  - **Create a log** maintained by the Red Tag Area Manager.

Benefits expected from Seiri (sort):

1. Seiri (sorts) saves productive work.
2. It prevents incidents of unnecessary things.
3. It provides clarity as to what is in stock.
4. It reduces unnecessary handling, as there are less number of items to handle.
5. It reduces number of lockers/cabinets for storage (as numbers of filed papers/items stored are reduced)

Red Tag Log.

Red Tag Log					
Area of Review:					
Team Leader:				Page: _____ of _____	
Name/Description of Item	Reason Tagged	Date Tagged	From Location	Person Responsible	Disposition and Date

Figure 2.16: Red Tag Log Sample

2. Seiton (Set in order)

- Seiton means systematic, orderly, efficient and effective arrangement of items in use. For effective storage, answers to the following questions are required.
  - What items are to be stored?
  - Where should the items be stored?
  - What quantity of the items is generally required to be stored?
  - Are there any special storage requirements?
  - How often the items are to be stored or retrieved?
- Therefore, section means, “to arrange correctly in accordance with the correct method of doing activities and making through preparation so that the activities can be performed even if they occur abruptly.”
- Since arranging correctly is a natural follow up activity after segregation, seiri and seiton are often used and practiced together. Some areas which often needs attention are unlabeled tool cribs, cluttered shelves./ lockers, office files and things lying on the shop floor.
- Thus this step of 5 S process can be carried out in the following manner step by step:-

Set in Order:

- **Review the process flow in the area.**
- Flow Process Chart.
- 30 second storage and retrieval.
- **Motion Study Analysis**.
- Position things to promote good posture and safe lifting/retrieval.
- Minimize body motions and travel

- **Establish a layout proposal to optimize a safe work space**:

– Safety concerns all addressed
– Material flows
– Tools accessible
– Safety covers in place
– Anti-fatigue mats
– Defined and straight aisles

- **Create the Visual Workplace**

– Tools labeled and/or outlined &Visual indicators
– Material placement markers or outlines on the floor

Benefits of Seiton:

1. Easy retrieval of materials.
2. Time taken to search is minimized.
3. Unnecessary purchase is avoided.
4. Categorize files, mails, papers, etc. based on specific criterion viz. subject/title; project; customer/supplier/department/usage.
5. Compartmentalize cabinets/drawers/shelves/desks.
6. Determine quantity of each item and plan storage according to pre-fixed quantity.
7. Plan storage to ensure easy retrievability (within pre-set target time).
8. Color code items for easy identification.
9. Keep files/binders vertically and not laid out.
10. Plan storage of compact disks to prevent them from getting scratched.
11. Install visual control for replenishment of stocks and checking missing items.
12. Observe a ‘Paper destruction day’ once a every quarter of the year.

3. Seiso (shine)

– Seiso is cleaning the workplace completely so that there is no dust on floor, machines and equipment. The objective of seiso is to return items, jigs/fixtures, moulds, equipments and other utilities and work places used during work to their original clean and polished condition by removing scrap and leftovers and wiping all surfaces to make dust/dirt free. The presence of dust can cause abrasions, scratches, blockages, leakages, bad connection (electrical defects), quality defects (e.g. painting on dusty surfaces), variability (e.g. wrong measurements and lack of process control). Since while cleaning, the surfaces are seen and touched, Seiso prevents potential problems by discovering abnormalities, which are still in the initial stages.People generally take pride in working in clean and clutter free area and sparkling/shining helps to create ownership of the equipment and facility.
– Cleaning is not a one-time activity. Some sort of standards of cleaning needs to be developed and regular follow up is necessary to sustain this improvement. This can be done with the help of making checklists the example is shown in below.

Shine Checklist

– A finalized checklist should be posted at the area in the specified location.
– The list should include the “target areas” that were identified as trouble spots.

- An inventory of materials necessary for the cleaning should be listed.

The activities necessary to implement Seiso in the organization

1. Keep own machines and work place clean through sweeping floor and surroundings, dusting to make dirt free, cobweb free wiping to make oil/grease, free polishing and painting.
2. Clean machines/worktable before start of the daily routine. Eliminate leagkage/spilage.
3. Brainstorm for creative ideas to make cleaning and inspection easier.
4. Clean even places most people don't notice. Remove scrap to avoid scratching.
5. Clean elements to remove dirt that cause sub-standard performance.
6. Clean electrical contacts to avoid bad connections (e.g. electrical contacts, push buttons, switches, etc.)
7. Dust off dirt inside computer to avoid play up.
8. Remove oil and dust before painting to ensure better finish.
9. Prepare schedule for cleaning and assign clear-cut responsiblities.
10. Conduct inspection to unearth problems, identify root causes and establish corrective action.
11. Carryout daily follow-up cleaning to sustain this improvement.
12. Clean up machine, jigs/fixtures, tools/gauges, etc. after use.
13. Place trash bins at strategic places and empty them at the end of the shift/day.
14. Clean up supply lines and coolant tanks; spray point booth, water storage tank, material handling trolleys.
15. Dust off parts, components, items lying in shelves in store.

Benefits of Seiso:

1. Early identification of problems like cracks/oil leakage.
2. Greater confidence of customers.
3. Improved product quality.
4. Pride for the employees.

4. Seiketsu (Standardize)

- Seiketshu is repeatedly following of "Seiri", "Seiton" and "Seiso", developing and implementing standard operating procedures and maintaining safe and hygienic conditions at work leading to serene atmosphere. Seiketshu embraces both personal cleanliness and that of the work environment.
- It emphasis on 5-S standardization and visual management. Standardization ensures that all assignments are absolutely clear and there is no undefined area. Visual maangemetn ensures that communication is simple and effective. Together, they (i.e. standardization and visual management) provide an effective way of continuous improvements.

Guidelines

- *Make standards obvious from a distance.*
- *Necessary information is located on or near the process it relates to…*
- *Everyone can understand the standards.*
- *Visuals created:*
  - Checklists
  - Labels

- Material placements
- Safety Equipment labelled and accessible
- Gauge limits are labelled

- *Establish and implement areas of standardization*

- Documents, instructions, labels, signage
- Material handling, colour codes
- Review cycles
- Also, standardize the work itself
- How is the work process done properly in this area?
- Create / revise Standard Work
- Post it prominently in the work area

The activities necessary to implement Seiketsu in the organization are:

1. Mark aisles of sufficient width and ensure that they are free from obstruction.
2. Standardize best practices in your work areas and implement them as effective work standards.
3. Create as many visual control system as possible such as:

- OK/Rejection.
- Reworks stickers/labels.
- "Danger zones" marks on meters and switches.
- Warning signs and marks (e.g. no smoking warning sign in paint area)
- Fire extinguishers and exit signs.

4. Display department/office labels and nameplates. Ensure proper ventilation and exhaust.
5. Introduce color for easy and faster identification (color codes as shown in above).
6. Place first aid boxes and fire extinguishers at suitable locations and display location map for fire extinguishers at strategic places.

5. Shitsuke (Sustain)

- Shitsuke means self discipline. It denotes commitment to maintain orderliness and to practice the first 4S as a way of life. The emphasis of shitsuke is elimination of the bad habits and constant practice of the good ones. Once a true shitsuke is achieved, the personnel voluntarily observe cleanliness and orderliness at all times, without having to be reminded by the management. One must train oneself to keep the 4S principles and realize that by following the 5S, ultimately the work will become easier.
- Shitsuke is the most difficult 'S' to implement and achieve. Since human nature is to resist change, many organization returns to status quo (i.e. end up with a dirty cluttered shop) a few weeks following implementation of 5S.

Methodology of Shitsuke (Sustain)

1. Monitor the refined methods consistently.
2. Maintain the defined methods for continuous improvement.
3. Establish norms and follow them.
4. Keep repeating the 1 to 4 'S'.

Benefits of Shitsuke (Sustain)

1. Discipline in the system.
2. Waste reduction.
3. High morale.
4. Neat and cleanliness.
5. Easier to work.
6. Lesser stress at work.

Therefore, in order to ensure 5S gets into the blood of the organization, the following action list needs to be put into place.

a. Arrange employees training in 5S technique and provide pamphlets / easy to read booklets on 5S practices to all employee.
b. Practice pick up components / papers /rubbish and promote friendly competition & competitive benchmarking among the departments for 5S.
c. Observe paper destruction day (say 15^{th}/16^{th} day of the month following each quarter.
d. Conduct fire drills and practice dealing with emergencies.
e. Replace equipment after its economic retentive period.
f. Work together on specific 5S projects.
g. Insist that employees attend works in uniform and wear safety shoes.
h. Set aside a short period (say 10 minutes) when everyone must concentrate on 5S (e.g. one day to ensure everything in place, another day to ensure there is no oil or air leaks.
i. Mark 5 minutes in the beginning or end of the day to practice 5S.
j. Use visuals to draw attention to 5-S non-conformances and achievements over the period and to create competitive point.
k. Audit 5-S housekeeping and follow-up on non-conformances.
l. Display correct work instructions in the shop and offices and ensure employees perform work according to the laid down standard operation procedures.

Benefits of 5-S system

1. Reduction in errors/defects due to standardized procedures.
2. Consistent and improved quality.
3. Higher productivity.
4. Lesser accidents.
5. Higher morale of employees.
6. Gets to work in a clean, organized and clutter free workplace.
7. Lesser time to retrieve things when required.
8. More useable space.
9. Reduction in machine down time.

2.5. Kaizen

- Kaizen, Japanese for "improvement", or "change for the better" refers to philosophy or practices that focus upon continuous improvement of processes in manufacturing, engineering, and business management.
- Kaizen is a daily process, the purpose of which goes beyond simple productivity improvement. It is also a process that, when done correctly, humanizes the workplace, eliminates overly hard work ("muri"), and teaches people how to perform experiments on their work using the scientific method and how to learn to spot and eliminate waste in business processes. In all, the process suggests a humanized approach to workers and to increasing productivity: "The idea is to nurture the company's human resources as much as it is to praise and encourage participation in kaizen activities." Successful implementation requires "the participation of workers in the improvement." People at all levels of an organization participate in kaizen, from the CEO down to janitorial staff, as well as external stakeholders when applicable. The format for kaizen can be individual, suggestion system, small group, or large group. At Toyota, it is usually a local improvement within a workstation or local area and involves a small group in improving their own work environment and productivity. This group is often guided through the kaizen process by a line supervisor; sometimes this is the line supervisor's key role. Kaizen on a broad, cross-departmental scale in companies, generates total quality management, and frees human efforts through improving productivity using machines and computing power.
- While kaizen (at Toyota) usually delivers small improvements, the culture of continual aligned small improvements and standardization yields large results in the form of compound productivity improvement. This philosophy differs from the "command and control" improvement programs of the mid-twentieth century. Kaizen methodology includes making changes and monitoring results, then adjusting. Large-scale pre-planning and extensive project scheduling are replaced by smaller experiments, which can be rapidly adapted as new improvements are suggested.
- In modern usage, it is designed to address a particular issue over the course of a week and is referred to as a "kaizen blitz" or "kaizen event". These are limited in scope, and issues that arise from them are typically used in later blitzes.

1. Implementation

- The Toyota Production System is known for kaizen, where all line personnel are expected to stop their moving production line in case of any abnormality and, along with their supervisor, suggest an improvement to resolve the abnormality which may initiate a kaizen.
- The cycle of kaizen activity can be defined as:

- Standardize an operation and activities.
- Measure the standardized operation (find cycle time and amount of in-process inventory)
- Gauge measurements against requirements
- Innovate to meet requirements and increase productivity
- Standardize the new, improved operations
- Continue cycle ad infinitum

- This is also known as the Shewhart cycle, Deming cycle, or PDCA. Other techniques used in conjunction with PDCA include 5 Whys, which is a form of root cause analysis in which the user asks "why" to a problem and its answer five successive times. There are normally

a series of root causes stemming from one problem, and they can be visualized using fishbone diagrams or tables.

- Apart from business applications of the method, both Anthony Robbinsand Robert Maurer have popularized the kaizen principles into personal development principles. In the book One Small Step Can Change Your life: The Kaizen Way, and CD set The Kaizen Way to Success, Maurer looks at how individuals can take a kaizen approach in both their personal and professional lives.
- In the Toyota Way Field book, Liker and Meier discuss the kaizen blitz and kaizen burst (or kaizen event) approaches to continuous improvement. A kaizen blitz, or rapid improvement, is a focused activity on a particular process or activity. The basic concept is to identify and quickly remove waste. Another approach is that of the kaizen burst, a specific kaizen activity on a particular process in the value stream.

2.6. Poka-yoke

- Poka yoke is a quality management concept developed by a Matsushita manufacturing engineer, Shigeo Shingo, to prevent the human errors from occurring in the production line. Poka yoke comes from two Japanese words- yokeru that means 'to avoid' and poka that means 'inadvertent errors'. Poka yoke more or less translates to 'avoiding inadvertent errors'.It is also referred as fool-proofing. However, this is not correct if applied to the employees, and therefore the English equivalent used by Shingo was the error avoidance. Other meaning such as 'mistake-proofing' or 'fail-safe operation' convey similar meanings. The main objective of poka-yoke is to achieve zero defects.
- It is very simple concept and can be widely used, in operations. For example, if one part fits into hole and it must fit in only one orientation, then fool-proofing the assembly of the parts requires that the part fit in only one orientation, and then fool-proofing the assembly of the parts requires that the part fit in the hole in only the correct orientation. This assembly constraint can be implemented, for example, by placing a small extrusion on the side of the inserted part that matches with a key on the part in which the first part is inserted, like the printer cord attachment to the central processing unit (CPU) of a computer. There are many examples of this type that can be found in processing, assembly, measurement and other tasks. Workers will make mistakes if it is possible. Poka-yoke simply removes the possibility of making mistakes. Poka-yoke is more of a concept that a procedure. Thus, its implementation is governed by what people think they can do to prevent the errors in their workplace, and not by a set of the step-by-step instructions on how they should do their job.
- Poka-yoke is implemented by using simple objects such as fixtures, jigs, gadgets, warning devices, paper systems and the like to prevent people from committing mistakes, even if they try to. These objects, known as poka-yoke devices, are usually used to stop the machine and alert the operator if something is about to go wrong. A poka-yoke device should have the following characteristics : (a) useable by all workers, (b) simple to install, (c) does not require continuous attention from the operator (ideally, it should work even if the operator is not aware of it), (d) low cost and (e) provides instantaneous feedback, prevention or correction.
- Poka-yoke is at its best when it prevents mistakes, not when it merely catches them. Since the human errors usually stem from the people who get distracted, tired, confused or demotivated, a good poka-yoke solution is one that requires no attention from the

operator. Such a poka-yoke device will prevent the occurrence of mistake even if the operator loses focus on what he or she is doing.

- The examples of 'attention-free' poka-yoke are:
  1. A jig that prevents a part from being disoriented during location.
  2. Non-symmetrical screw hole locations that would prevent a plate from being screwed down incorrectly. Electrical plugs that can only be inserted into the correct outlets.
  3. Notches on board that only allow correct insertion into edge connectors.
  4. A flip-type cover over a button that will prevent the button from being accidently pressed.
  5. Filing cabinets that only allow one drawer to be opened at a time to prevent them falling over.Dead-man's handles on power tools that cut power when released.

2.7. Quality Circles

- Quality circle is a people-building philosophy, providing self discipline and happiness to improving the environment without any compulsion or monetary benefits. It refers to a small group of employees (7-15) in the same work area (in same shop) or doing similar type of work, who voluntarily meet regularly for about an hour every week to identify, analyze and resolve work-related problems, leading to improvement in their total performance and enrichment of their work-life.
- Quality circle is a homogenous group and not an interdepartmental or interdisciplinary one. The members participating must be of the same wavelength. Each one of the members should actively participate in the discussions. This is possible only when the cirlce employees are working in the same area or are engaged in similar type of work. The designations of members need not be necessarily equal but the work on which they all are engaged should be common. For example, in any assembly area, turners, drillers, electricians, unskilled workers, etc., would decide to form a circle. The membership of circles in such work should be thrown open to all the employees at grass-root areas from the level of foreman downwards.
- The success of Quality circles in Japan is striking. The quality circles can be effective here or elsewhere also, if the management commitment to the basic philosophy underlying the concept of Quality circles is there. BHEL started its first Quality Circle at its Hyderabad unit in 1980-81. The idea caught on in the entire corporation and in two years there were more than 200 circles with about 1800 members. Other companies also immediately followed suit. But quality circles cannot immediately be imposed on any unit and expect to yield results. It should be implemented gradually with building appropriate work culture.

Organization for Quality Circle

1. Steering Committee

- It generally consists of various functional heads as well as Head of the manufacturing plant. They generally prepare a list of problems with priorities. The steering committee is also responsible for accepting or rejecting the recommendations made by the Quality circle leader during their group presentations.

2. Facilitators

- The main role of facilitators is to guide the Quality circle leaders and providing them support by taking up relevant issues with other functional heads as appropriate. Facilitator is responsible for handling three to four quality circle at a time. Many managers working

at a middle level in various departments having facilitation skills are generally selected as facilitators.

3. Leader

- For every quality circle there is a leader. Person working at lower level, say worker can be also become a leader. Quality circle leader is responsible for ensuring meeting at regular intervals with active involvement of all participants. Generally each Quality Circle gives two presentations i.e. interim and final to the members of the steering committee. The responsibility for these presentations is with Quality circle leader.

4. Members

- Generally there are 7 to 15 members in each quality circle who are participating voluntarily. Members on an average spend one hour per week for regular meeting. It provides excellent opportunity for the members to show their talent. Members are trained in various quality control tools and techniques so that they can use the same as appropriate.

Benefits of Quality Circle

1. It helps management to nurture and bring out the human potential.
2. It improves the morale and motivation of level of workers.
3. It provides opportunity especially to the workers to show their innovativeness and creativity.
4. Quality improvements done within the various Quality circles lead to productivity improvements and cost reductions which benefits the organization the most.
5. Workers and lower level employees get more job satisfaction due to recognition given to their performance by the management.

2.8. Cost of quality

- The reason quality has gained such prominence is that organizations have gained an understanding of the high cost of poor quality. Quality affects all aspects of the organization and has dramatic cost implications. The most obvious consequence occurs when poor quality creates dissatisfied customers and eventually leads to loss of business. However, quality has many other costs, which can be divided into two categories. The first category consists of costs necessary for achieving high quality, which are called quality control costs.
- These are of two types: prevention costs and appraisal costs. The second category consists of the cost consequences of poor quality, which are called quality failure costs. These include external failure costs and internal failure costs. These costs of quality are shown in Figure. The first two costs are incurred in the hope of preventing the second two.

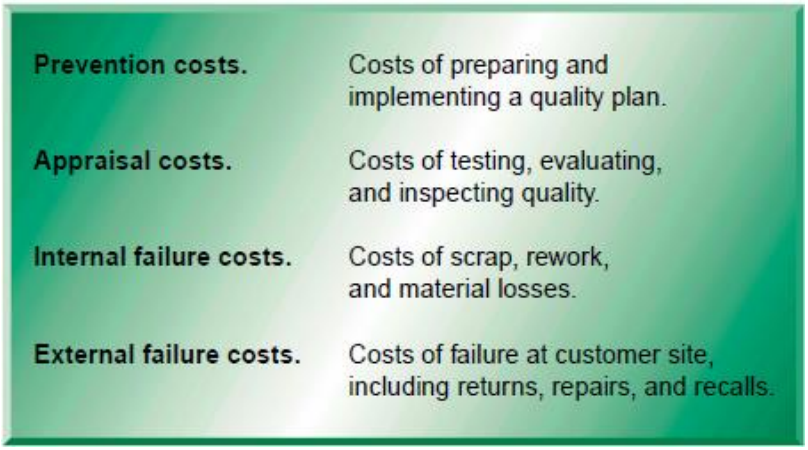


Figure 2.17 Costs of Quality

- Prevention costs are all costs incurred in the process of preventing poor quality from occurring. They include quality planning costs, such as the costs of developing and implementing a quality plan. Also included are the costs of product and process design, from collecting customer information to designing processes that achieve conformance to specifications. Employee training in quality measurement is included as part of this cost, as well as the costs of maintaining records of information and data related to quality. Appraisal costs are incurred in the process of uncovering defects. They include the cost of quality inspections, product testing, and performing audits to make sure that quality standards are being met. Also included in this category are the costs of worker time spent measuring quality and the cost of equipment used for quality appraisal.
- Internal failure costs are associated with discovering poor product quality before the product reaches the customer site. One type of internal failure cost is rework, which is the cost of correcting the defective item. Sometimes the item is so defective that it cannot be corrected and must be thrown away. This is called scrap, and its costs include all the material, labor, and machine cost spent in producing the defective product. Other types of internal failure costs include the cost of machine downtime due to failures in the process and the costs of discounting defective items for salvage value.
- External failure costs are associated with quality problems that occur at the customer site. These costs can be particularly damaging because customer faith and loyalty can be difficult to regain. They include everything from customer complaints, product returns, and repairs, to warranty claims, recalls, and even litigation costs resulting from product liability issues. A final component of this cost is lost sales and lost customers. For example, manufacturers of lunch meats and hot dogs whose products have been recalled due to bacterial contamination have had to struggle to regain consumer confidence. Other examples include auto manufacturers whose products have been recalled due to major malfunctions such as problematic braking systems and airlines that have experienced a crash with many fatalities. External failure can sometimes put a company out of business almost overnight. Companies that consider quality important invest heavily in prevention and appraisal costs in order to prevent internal and external failure costs. The earlier defects are found, the less costly they are to correct. For example, detecting and correcting defects during product design and product production is considerably less expensive than when the defects are found at the customer site. This is shown in Figure.

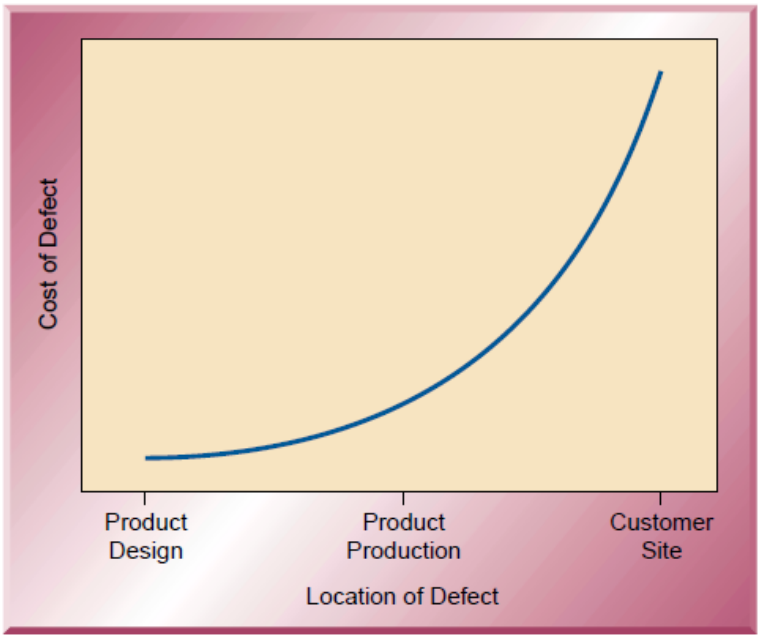


Figure 2.18 Costs of Defect

- External failure costs tend to be particularly high for service organizations. The reason is that with a service the customer spends much time in the service delivery system, and there are fewer opportunities to correct defects than there are in manufacturing. Examples of external failure in services include an airline that has overbooked flights, long delays in airline service, and lost luggage.

BENEFITS OF minimizing COQ…

Increases	Decreases
• Sales • Profit • Capacity • Customer Satisfaction • Market Share • Competitive Edge • Employee Satisfaction	• Defects • Overall Costs • Returned Goods • Customer Complaints • Owner & Mgmt. Stress • Decrease Legal Costs

2.9. Introduction to Management Standards

- System exists in any organization but the top management must make an effort to ensure that all the interrelated elements must impact thus making the system effective in its approach. Systems must clarify to all the organization what to do, who will do it, how the work will be done, when to do it, etc. Systems in an organization must be focused towards a direction, i.e. there must exist a management system, without which an organization would virtually collapse.
- ISO is an acronym for international organization for standardization. It is a voluntary body and has representation from more than 100 countries. Bureau of Indian Standards (BIS) represents India of ISO, whose headquarter is based in Geneva.

2.10. ISO 9000

- The **ISO 9000** family of standards is related to quality management systems and designed to help organizations ensure that they meet the needs of customers and other

stakeholders while meeting statutory and regulatory requirements related to the product. The standards are published by ISO, the International Organization for Standardization, and available through National standards bodies. ISO 9000 deals with the fundamentals of quality management systems, including the eight management principles on which the family of standards is based. ISO 9001 deals with the requirements that organizations wishing to meet the standard have to fulfill.

- Third party certification bodies provide independent confirmation that organizations meet the requirements of ISO 9001. Over a million organizations worldwide are independently certified, making ISO 9001 one of the most widely used management tools in the world today. Despite widespread use, however, the ISO certification process has been criticized as being wasteful and not being useful for all organizations.
- The global adoption of ISO 9001 may be attributable to a number of factors. A number of major purchasers require their suppliers to hold ISO 9001 certification. In addition to several stakeholders' benefits, a number of studies have identified significant financial benefits for organizations certified to ISO 9001, with a 2011 survey from the British Assessment Bureau showing 44% of their certified clients had won new business. Corbett *et al.* showed that certified organizations achieved superior return on assets compared to otherwise similar organizations without certification. Here as *et al.* found similarly superior performance and demonstrated that this was statistically significant and not a function of organization size. Naveha and Marcus claimed that implementing ISO 9001 led to superior operational performance in the US motor carrier industry. Sharma identified similar improvements in operating performance and linked this to superior financial performance. Chow-Chua *et al.* showed better overall financial performance was achieved for companies in Denmark. Rajan and Tamimi (2003) showed that ISO 9001 certification resulted in superior stock market performance and suggested that shareholders were richly rewarded for the investment in an ISO 9001 system.
- While the connection between superior financial performance and ISO 9001 may be seen from the examples cited, there remains no proof of direct causation, though longitudinal studies, such as those of Corbett et al. (2005) may suggest it. Other writers, such as Here as et al. (2002), have suggested that while there is some evidence of this, the improvement is partly driven by the fact that there is a tendency for better performing companies to seek ISO 9001 certification.
- The mechanism for improving results has also been the subject of much research. Lo et al. (2007) identified operational improvements (cycle time reduction, inventory reductions, etc.) as following from certification. Internal process improvements in organizations lead to externally observable improvements. The benefit of increased international trade and domestic market share, in addition to the internal benefits such as customer satisfaction, interdepartmental communications, work processes, and customer/supplier partnerships derived, far exceeds any and all initial investment.

Summary of ISO 9001:2008 in informal language

- The quality policy is a formal statement from management, closely linked to the business and marketing plan and to customer needs.
- The quality policy is understood and followed at all levels and by all employees. Each employee works towards measurable objectives.
- The business makes decisions about the quality system based on recorded data.
- The quality system is regularly audited and evaluated for conformance and effectiveness.

- Records show how and where raw materials and products were processed to allow products and problems to be traced to the source.
- The business determines customer requirements.
- The business has created systems for communicating with customers about product information, inquiries, contracts, orders, feedback, and complaints.
- When developing new products, the business plans the stages of development, with appropriate testing at each stage. It tests and documents whether the product meets design requirements, regulatory requirements, and user needs.
- The business regularly reviews performance through internal audits and meetings. The business determines whether the quality system is working and what improvements can be made. It has a documented procedure for internal audits.
- The business deals with past problems and potential problems. It keeps records of these activities and the resulting decisions, and monitors their effectiveness.
- The business has documented procedures for dealing with actual and potential non-conformances (problems involving suppliers, customers, or internal problems).
- The business:
  1. makes sure no one uses a bad product,
  2. determines what to do with a bad product,
  3. deals with the root cause of problems, and
  4. Keeps records to use as a tool to improve the system.

Certification

- ISO does not itself certify organizations. Numerous certification bodies exist, which audit organizations and, upon success, issue ISO 9001 compliance certificates. Although commonly referred to as 'ISO 9000' certification, the actual standard to which an organization's quality management system can be certified is ISO 9001:2008. Many countries have formed accreditation bodies to authorize ("accredit") the certification bodies. Both the accreditation bodies and the certification bodies charge fees for their services. The various accreditation bodies have mutual agreements with each other to ensure that certificates issued by one of the Accredited Certification Bodies (CB) are accepted worldwide. Certification bodies themselves operate under another quality standard, ISO/IEC 17021, while accreditation bodies operate under ISO/IEC 17011.
- An organization applying for ISO 9001 certification is audited based on an extensive sample of its sites, functions, products, services and processes. The auditor presents a list of problems (defined as "nonconformities", "observations" or "opportunities for improvement") to management. If there are no major nonconformities, the certification body will issue a certificate. Where major nonconformities are identified, the organization will present an improvement plan to the certification body (e.g. corrective action reports showing how the problems will be resolved); once the certification body is satisfied that the organization has carried out sufficient corrective action, it will issue a certificate. The certificate is limited by a certain scope (e.g. production of golf balls) and will display the addresses to which the certificate refers.
- An ISO 9001 certificate is not a once-and-for-all award, but must be renewed at regular intervals recommended by the certification body, usually once every three years. There are no grades of competence within ISO 9001: either a company is certified (meaning that it is committed to the method and model of quality management described in the

standard) or it is not. In this respect, ISO 9001 certification contrasts with measurement-based quality systems such as the Capability Maturity Model.

Auditing

- Two types of auditing are required to become registered to the standard: auditing by an external certification body (external audit) and audits by internal staff trained for this process (internal audits). The aim is a continual process of review and assessment to verify that the system is working as it is supposed to; to find out where it can improve; and to correct or prevent problems identified. It is considered healthier for internal auditors to audit outside their usual management line, so as to bring a degree of independence to their judgments.
- Under the 1994 standard, the auditing process could be adequately addressed by performing "compliance auditing":
  - Tell me what you do (describe the business process)
  - Show me where it says that (reference the procedure manuals)
  - Prove that this is what happened (exhibit evidence in documented records)
- The 2000 standard uses a different approach. Auditors are expected to go beyond mere auditing for rote compliance by focusing on risk, status, and importance. This means they are expected to make more judgments on what is effective, rather than merely adhering to what is formally prescribed. The difference from the previous standard can be explained thus:
- Under the 1994 version, the question was broad: "Are you doing what the manual says you should be doing?", whereas under the 2000 version, the questions are more specific: "Will this process help you achieve your stated objectives? Is it a good process or is there a way to do it better?"

Effectiveness

- Effectiveness of the ISO system being implemented depends on a number of factors, the most significant of which are:

1. Commitment of senior management to monitor, controls, and improve quality. Organizations that implement an ISO system without this desire and commitment often take the cheapest road to get a certificate on the wall and ignore problem areas uncovered in the audits.
2. How well the ISO system integrates into current business practices. Many organizations that implement ISO try to make their system fit into a cookie-cutter quality manual instead of creating a manual that documents existing practices and only adds new processes to meet the ISO standard when necessary.
3. How well the ISO system focuses on improving the customer experience. The broadest definition of quality is "Whatever the customer perceives good quality to be." This means that a company doesn't necessarily have to make a product that never fails; some customers will have a higher tolerance for product failures if they always receive shipments on-time or have a positive experience in some other dimension of customer service. An ISO system should take into account all areas of the customer experience and the industry expectations, and seek to improve them on a continual basis. This means taking into account all processes that deal with the three stakeholders (customers, suppliers, and organization); only then will a company be able to sustain improvements in the customer's experience.

4. How well the auditor finds and communicates areas of improvement. While ISO auditors may not provide consulting to the clients they audit, there is the potential for auditors to point out areas of improvement. Many auditors simply rely on submitting reports that indicate compliance or non-compliance with the appropriate section of the standard; however, to most executives, this is like speaking a foreign language. Auditors that can clearly identify and communicate areas of improvement in language and terms executive management understands facilitate action on improvement initiatives by the companies they audit. When management doesn't understand why they were non-compliant and the business implications associated with non-compliance, they simply ignore the reports and focus on what they do understand.

Advantages

- It is widely acknowledged that Implementing ISO often gives the following advantages:
  1. Creates a more efficient, effective operation
  2. Increases customer satisfaction and retention
  3. Reduces audits
  4. Enhances marketing
  5. Improves employee motivation, awareness, and morale
  6. Promotes international trade
  7. Increases profit
  8. Reduces waste and increases productivity
  9. Common tool for standardization.

2.11. ISO 14000

- ISO 14000 is a family of standards related to environmental management that exists to help organizations (a) minimize how their operations (processes etc.) negatively affect the environment (i.e. cause adverse changes to air, water, or land); (b) comply with applicable laws, regulations, and other environmentally oriented requirements, and (c) continually improve in the above.
- ISO 14000 is similar to ISO 9000 quality management in that both pertain to the process of how a product is produced, rather than to the product itself. As with ISO 9000, certification is performed by third-party organizations rather than being awarded by ISO directly. The ISO 19011 audit standard applies when auditing for both 9000 and 14000 compliance at once.
- The requirements of ISO 14000 are an integral part of the European Union‘s Eco-Management and Audit Scheme (EMAS). EMAS‘s structure and material requirements are more demanding, foremost concerning performance improvement, legal compliance and reporting duties.

Development of the ISO 14000 series

- The ISO 14000 family includes most notably the ISO 14001 standard, which represents the core set of standards used by organizations for designing and implementing an effective environmental management system. Other standards included in this series are ISO 14004, which gives additional guidelines for a good environmental management system, and more specialized standards dealing with specific aspects of environmental management. The major objective of the ISO 14000 series of norms is "to promote more effective and efficient environmental management in organizations and to provide useful and usable tools - ones that are cost effective, system-based, flexible and reflect the best

organizations and the best organizational practices available for gathering, interpreting and communicating environmentally relevant information"

- Prior to the development of the ISO 14000 series, organizations voluntarily constructed their own EMS systems, but this made comparisons of environmental effects between companies difficult and therefore the universal ISO 14000 series was developed. An EMS is defined by ISO as: "part of the overall management system, that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving and maintaining the environmental policy' (ISO 1996 cited in Federal Facilities Council Report 1999).

ISO 14001 standard

- The standard is not an environmental management system as such and therefore does not dictate absolute environmental performance requirements (National Academy Press 1999), but serves instead as a framework to assist organizations in developing their own environmental management system (RMIT University). ISO 14001 can be integrated with other management functions and assists companies in meeting their environmental and economic goals.
- ISO 14001, as with other ISO 14000 standards, is voluntary (IISD 2010), with its main aim to assist companies in continually improving their environmental performance, whilst complying with any applicable legislation. Organizations are responsible for setting their own targets and performance measures, with the standard serving to assist them in meeting objectives and goals and the subsequent monitoring and measurement of these (IISD 2010). This means that two organizations that have completely different measures and standards of environmental performance, can both comply with ISO 14001 requirements (Federal Facilities Council Report 1999).

Basic principles and methodology

- Plan – establish objectives and processes required
- Do – implement the processes
- Check – measure and monitor the processes and report results
- Act – take action to improve performance of EMS based on results

Benefits

- ISO 14001 was developed primarily to assist companies in reducing their environmental impact, but in addition to an improvement in environmental standards and performance, organizations can reap a number of economic benefits including higher conformance with legislative and regulatory requirements (Sheldon 1997) by utilizing the ISO standard. Firstly by minimizing the risk of regulatory and environmental liability fines and improving an organization's efficiency (Delmas 2001), leading to a reduction in waste and consumption of resources, operating costs can be reduced (ISO14001.com.au 2010). Secondly, as an internationally recognized standard, businesses operating in multiple locations across the globe can register as ISO 14001 compliant, eliminating the need for multiple registrations or certifications (Hutchens 2010). Thirdly there has been a push in the last decade by consumers, for companies to adopt stricter environmental regulations, making the incorporation of ISO 14001 a greater necessity for the long term viability of businesses (Delmas & Montiel 2009) and providing them with a competitive advantage against companies that do not adopt the standard (Potoki & Prakash, 2005). This in turn can have a positive impact on a company's asset value (Van der Deldt, 1997) and can lead

to improved public perceptions of the business, placing them in a better position to operate in the international marketplace (Potoki & Prakash 1997; Sheldon 1997). Finally it can serve to reduce trade barriers between registered businesses (Van der Deldt, 1997).

- Organizations can significantly benefit from EMS implementation through the identification of large cleaner production projects (e.g. which can drastically cut electricity costs in manufacturing industries). ISO 14001 can be a very effective tool to identify these cost savings opportunities for some organizations. Some other organizations can falter in its planning, lack of senior management commitment and poor understanding of how it should be implemented and find themselves managing an ineffective EMS. Improvements that organizations can make include adequately planning their structure and allocating adequate resources, providing training, creating forums for discussion, setting measurable targets and working according to the philosophy of continuous improvement (Burden, 2010).

2.12. QS 9000

- QS-9000 is a set of Quality System requirements recently adopted by members of the automotive industry. In September 1994 Ford Chrysler and General Motors announced that QS-9000 would immediately replace all previous supplier quality programs. Several heavy truck manufacturers's also adopted the QS-9000 standard.
- Each of "The Big Three" US automobile manufacturer's requirements for QS-9000 requires that: "Suppliers registered to an ISO 9000 standard without consideration of QS-9000 requirements shall contact their registrar and indicate that their customer(s) require(s) inclusion of QS-9000 in the registration process. The supplier shall update the quality system... to meet QS-9000. When conformance with QS-9000 has been verified, the registrar will issue a certificate citing conformance with QS-9000. Only registration certificates citing conformance to QS-9000 will be acceptable to the companies using this [QS-9000] document."
- The minimum seven documents one will need for the QS-9000 program are:
  1. QS-9000 Quality System Requirements
  2. Advanced Product Quality Planning and Control Plan (APQP)
  3. Failure Mode and Effects Analysis (FMEA)
  4. Measurement Systems Analysis
  5. Fundamental SPC
  6. Production Part Approval Process (PPAP) manual, and
  7. The Quality System Assessment (QSA) manual.
  8. QS-9000 – Obsolete

The QS-9000 Standard is Now Obsolete

- QS-9000 phased out at the end of 2006. It has been replaced by ISO/TS 16949:2002 and ISO 9001:2008 for suppliers in the automotive supply chain. Please refer to the ISO/TS information in the "Standards" tab. The information below is an outline of what the QS-9000 standard was.

QS-9000: A Brief Overview

- QS-9000 was a set of quality system requirements developed specifically for the automotive sector. In 1994, the requirements were initiated by Ford, General Motors, and

DaimlerChrysler (Big Three) for their suppliers to improve quality, efficiency, delivery, and communications.

- Since then, QS-9000 went through three major revisions or "editions" all based on ISO 9001:1994 -- the last revision was QS-9000:1998 Third Edition. The International Automotive Sector Group (IASG) had provided "Sanctioned Interpretations" on an as needed basis to clarify the QS-9000 requirements. The IASG issued "Sanctioned Interpretations" that became effective on July 1, 2001. You can still download QS-9000 Sanctions Interpretations at www.qs-9000.org.SRI's Founder and EO Peter Lake, as an Independent Association of Accredited Registrars (IAAR) officer, had chaired the IASG for seven years.

History:-

- DaimlerChrysler, Ford, and General Motors Harmonize Their Supplier Quality System Requirements. Late in 1992, Purchasing and Quality executives of the Big Three automakers met in Detroit and agreed to help themselves and their suppliers by replacing their individual quality system standards with a single set of Quality System Requirements, later named QS-9000.After two years of development involving the Big Three and their suppliers and representatives of third-party certification organizations, the automotive industry's needs and expectations of its parts suppliers were developed.

QS-9000: The Process for Third-Party Registration

- Certification to QS-9000:1998 was very similar to the registration process for ISO 9000. Both processes involved an application, documentation review, pre-assessment (optional), and registration/certification audit. Once certification was achieved, periodic surveillance audits were conducted to ensure compliance. The certification process was made more efficient through the use of appropriate forms, registration checklists, and supporting documents available from SRI.

QS-9000: Qualified Auditors

- SRI's team of QS-9000 qualified auditors had experience working in the automotive industry; many worked for Tier-1 supplier organizations. SRI's scope of accreditation is broad, such that SRI could register many different automotive suppliers, whether their focus was material, parts, tooling, or equipment.

QS-9000: SRI is there!

- SRI began working with the Big Three Supplier Quality Task Force in 1992, developing and refining the QS-9000 criteria and the audit/registration process for third-party registrars. SRI helped form the IASG, and has been an active member since its first meeting early in 1994.
- SRI was among the first registrars to be accredited by Raad voor de Certificatie (RvC) and American National Standards Institute Registrar Accreditation Board National Accreditation Program (ANSI-RAB NAP) to implement QS-9000 and registered its first QS-9000 company in January 1995.

QS-9000: Third-Party Registration

- QS-9000 was a contractually-mandated quality system requirement designed to be confirmed by independent third-parties. As a result, specially-qualified ISO 9000 registrar

auditors were trained to apply the internationally recognized automotive-focused registration system.

QS-9000: the First Set of Common Requirements

- Initially issued in late 1994 and updated in February 1995, the first set of requirements applied to parts suppliers only. More than 100 accredited registrars in North America and around the world had met the special automotive sector requirements established by the Big Three and the world's accreditation bodies. Initial registrations to QS-9000 occurred in January 1995.

QS-9000: An Ongoing Worldwide System

- In early 1994, the IASG was established to develop interpretations and answers relative to QS-9000 criteria, processes and registration. The IASG consisted of SRI and four other registrars, three accreditation bodies, Big Three Supplier Quality Task Force representatives and several automotive suppliers. The IASG had expanded to include numerous registrars. The IASG functioned to develop a consensus of all parties, balancing interests and limitations in order to assure the successful interpretation of the QS-9000 requirements.

2.13. Malcolm Baldrige Criteria for Business Performance Excellence

- Malcolm Baldrige Awards are given by the US President every year in the fields of business, education and healthcare.
- These awards are given to the organizations which fulfil the award criteria published every year by National Institute of Standards and Technology, US Department of Commerce.
- Fig. shows the various clauses and sub-clauses of Malcolm Baldrige Criteria for Business Performance Excellence.
- It also shows the break-up of a maximum score of 1000 points.

Organizational profile

- The organization must give details about the products and services it provides, its mission, vision and values, and its employee profile.
- The organization must state the kind of technology, equipment etc. used by it in the production/service process.
- The organization would have well-established communication mechanisms between various levels of its organization structure.
- The organization must identify its major competitors and its relative ranking in the market place.

Leadership (Clause 1)

- The senior leaders of the organization must create its vision and values through sound, well documented practices.
- They must ensure that these are communicated properly up to the lowest level of the organization and to the external suppliers.

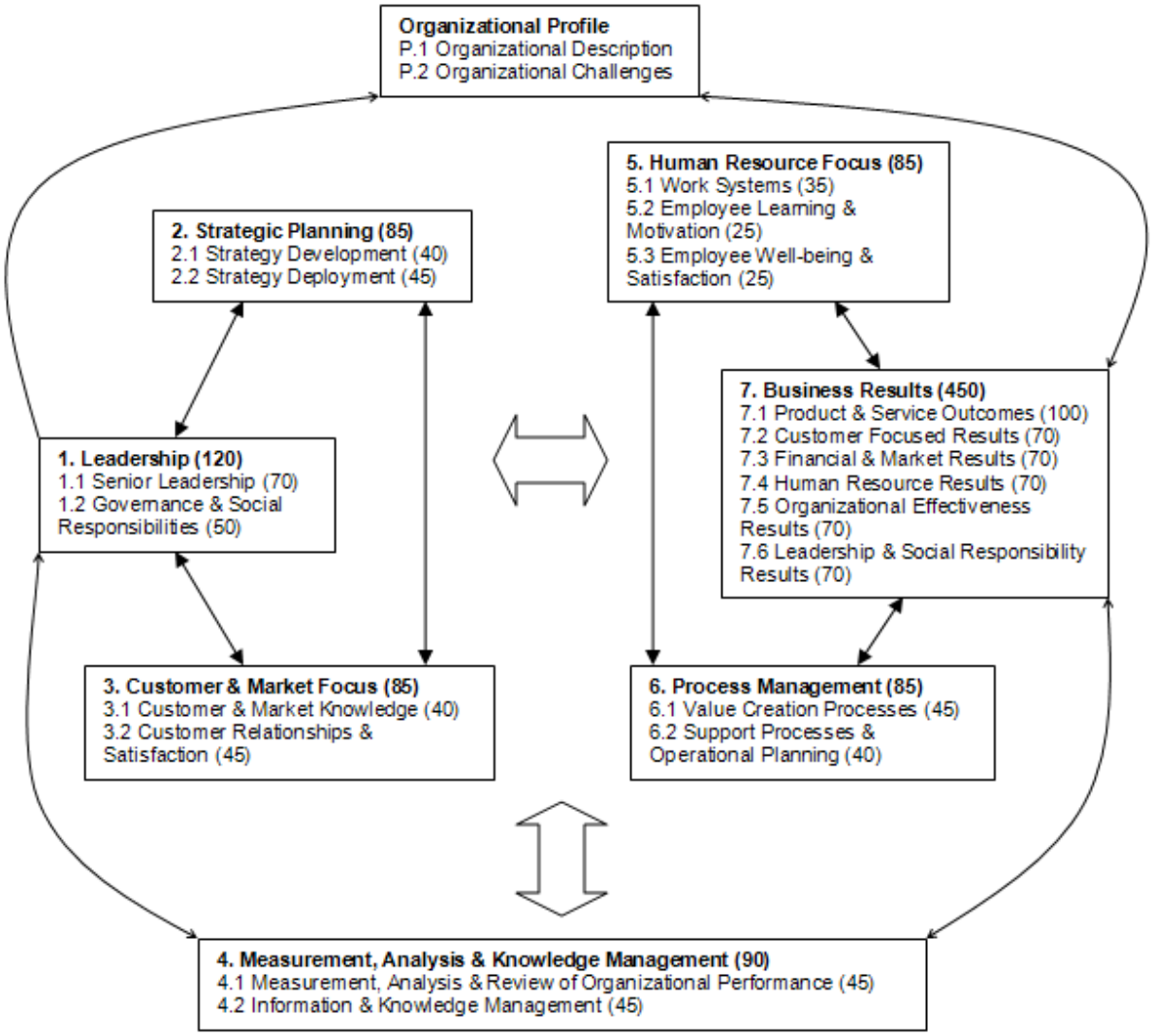


Figure 2.19 Clauses and Sub-Clauses of Malcolm Baldrige Criteria

Strategic planning (Clause 2)

- The organization must clearly explain the steps followed by it in its strategic planning, the key personnel involved, and the time frame considered for these plans.
- The organization must perform strength, weakness, opportunity and threat (SWOT) analysis in this planning process.
- The organization must evolve an action plan to attain key strategic objectives.

Customer and Market focus (Clause 3)

- The organization must identify its various customers, customer groups, and market segments.
- The organization must have established ways of determining the customer expectations, perceptions and requirements.

Measurement, Analysis and Knowledge Management (Clause 4)

- The organization must have formal systems of collection of data for tracking daily operations and overall business performance with respect to strategic and action plans.

- The organization must create information systems to ensure that relevant information is easily accessible to its employees, suppliers, partners etc.

Human Resource Focus (Clause 5)

- This clause focuses upon ensuring that the organization must organize and manage work and jobs to promote creatively and better organizational culture.
- The employees must be trained on a regular basis for the achievement of the action plans.
- Employee well-being, motivation and satisfaction levels should be measured by using formal and informal assessment methods.

Process Management (Clause 6)

- The key processes that add value to the products and services being produced should be identified.
- These processes should be designed so as to fulfil the requirements of the customers, suppliers and partners.

Business Results (Clause 7)

- The organization must summarize the key performance results of its products and services according to product/service categories and market segments.
- The comparison of these results must be done with competitor's performance.
- The current levels and trends in customer satisfaction and dissatisfaction must be compared with that of competitors.
- The current levels and trends in key measures of work system performance, employee learning and development, and employee well-being satisfaction and dissatisfaction must be tracked.

2.14. Deming Award Criteria

- Dr. William Edwards Deming is one of the foremost experts of quality control in the United States. The Deming Prize is given to companies, has exerted an immeasurable influence directly or indirectly on the development of quality control/management in Japan. The Japanese Union of Scientists and Engineers (JUSE) started the Deming prize in 1951. Initially, this prize was open only to the Japanese industry, but in 1985 it was thrown open for rest of the world. Deming Grand Prize with laurel tree bearing fruit of Quality.

The prize has three categories:

1. The first category is the Deming Application prize, which is given to companies or divisions of companies that have enhanced performance through TQM in given year.
2. The second category is the Deming Prize for Individuals, that is, TQM scholars and practitioners.
3. The third category of the prize is Quality Control Award for Operations Business Units given out for exceptional implementation of TQM.

What is the Deming Application Prize?

- The Deming Application Prize is an annual award presented to a company that has achieved distinctive performance improvements through the application of TQM. All organizations that score the passing points or higher upon examination will be awarded the Deming Application Prize.

Eligibility for the Prize

- Following viewpoints are used for the examination to determine whether or not the applicant should be awarded the Prize. Reflecting its management principles, type of industry, business scope, and business environment, the applicant has established challenging and customer-oriented business objectives and strategies under its clear management leadership. TQM has been implemented properly to achieve business objectives and strategies as mentioned Item 1 above. As an outcome of Item 2, the outstanding results have been obtained for business objectives and strategies as stated in Item 1.
- The five winners of this prestigious honor in 2003 include
    1. Rane Brake Linings,
    2. Mahindra & Mahindra – farm equipment & tractor division
    3. Brakes India – foundry division
    4. Sona Koyo steering systems and
    5. Grasim Industries – birla cellulosic kharach unit
- While the first four companies got the Deming Application prize, Grasim Industries unit got the Quality Control Award. Mahindra's tractor unit is the first tractor unit in the world to win the Deming. Rane Brake Lining became world's second brake lining manufacturer to became a Deming Company. The First one was TVS group's Sundaram Brake Lining in 2001. Apart from Deming, TVS group outfits have been wining other quality medals. It may not be wrong to call TVS group as the Deming group.

2.15. Rajiv Gandhi National Quality Award

- This Instituted by BIS in 1991
- It's an annual feature
- Designed similar to Malcolm Baldrige National Quality Award in USA, Deming Prize in Japan and European Quality Award.

RGNQA help's Industry

- Encouraging improvements, consumer satisfaction
- Recognize improved quality
- Guideline to evaluate own quality
- Providing specific guidance

It comprises

- Large scale manufacturing
- Small scale manufacturing
- Large scale service sector
- Small scale service sector
- BEST of ALL

Rajiv Gandhi National Quality Award Commendation Certificates As Per Industry Sector

1. chemical industry
2. electrical and electronic industry
3. food and drug industry

4. gems, jewellery and allied industry
5. metallurgical industry
6. textile industry
7. engineering industry and others
8. Finance
9. Healthcare
10. Information Technology
11. Utilities
12. Others

Rajiv Gandhi NQA Assessment Criteria

Large scale Org

1. Leadership
2. Policies
3. Objectives
4. HRM
5. Resources
6. Process
7. Employee satisfaction
8. Business results

Small scale Org

1. Leadership
2. HRM
3. Processes
4. Customer focused results
5. Impact On society
6. Business results

3

Total Quality Management

Course Contents

3.1 Introduction:-

- Total quality management is defined as management approach of an organization centered on quality, based on the participation of all its members and aiming at long term success through customer satisfaction and benefits to all members of the organization and to society.
- The expression “all its members”, means personnel in all departments and at all levels of the organizational structure.
- In total quality management, the concept of quality relates to the achievement of all managerial objectives.
- The concept “benefits to society”, implies, as applicable, fulfillment of the requirements of society. The strong and persistent leadership of top management and the education and training of all members of the organization are essential for the success of this approach.

3.2 Definitions of TQM

- TQM can be defined as, “ The act or manner of handling, controlling made up by the whole system to achieve degree of excellence that a product or service provides for the th whole
- Total: - made up by the whole for the whole.
- Quality: - The degree of excellence a product or a service provides.
- Management: - Act, art or manner of handling and controlling.

- As per Indian Statistical Institute: TQM is an integrated organizational approach in delighting customers by meeting their expectations on a continuous basis through everyone involved with the organization working on continuous improvement in all products, services, and processes with proper problem solving methodology
- As per Quality Forum of USA: - TQM is a people focused management system that aims at continual increasing customer satisfaction at continually lower cost. TQM is total system approach and an integral part of high level strategy; it works horizontally across functions and departments involving all employees top to bottom and exceeds backwards and forwards to include the supply chain and the customer chain.
- TQM as Philosophy and ISO-9000 quality system model: - TQM is a concept that goes beyond ISO 9000. It must be immediately made clear that TQM and ISO 9000 are not two different choices to be made. There is no contradiction between the two.
- According to CII (Confederation of Indian Industries) : - TQM is an approach for effective management of business enterprise through the focus on its people and the process by a company wide customer driven relationship.

3.3 Principles of TQM: -

- TQM is based on the following principles:

1. The employees are not just the resources, they are for purpose.
2. A company hires a total man with the body, mind and intellect and not just the hands.
3. The problems are with the system not with the people.
4. The variance analysis focuses on what, how, why and not who.
5. The aim is to utilize the full potential of all the employees.
6. The total employee's involvement is essential for the customers' satisfaction.
7. TQM is led by the top management.
8. The system is focused on satisfying customers.
9. Process approach to management.
10. Based on error/ failure prevention strategy.
11. Aimed at continual improvement.
12. Built on cooperative, trustful relationship to have win-win situation.
13. Team working to ensure functioning as effective groups.
14. Fact based management.
15. Largely aimed at long term goals.
16. Systematic and methodical.
17. Geared towards public responsibility.
18. A holistic approach.

3.4 Characteristics of TQM: -

- The essential characteristics of an effective TQM system are: -

1. Every company member, from the CEO to the lowest level employee is focused on product or service quality. If management is not behind TQM, then it will fail.
2. Everyone must have the required training and be familiar with the necessary TQM techniques.
3. Anyone can suggest areas for improvement- as general operatives will be more familiar with their workstation than anyone else is, valuable ideas for improvement at a production line level can, in many cases, come from line workers.
4. All departments are expected to focus on quality and productivity improvement and implement changes for their area.
5. In addition, all departments interact with each other to fix common problems in the product or process.
6. Collaboration on external issues (end-users defects for example) is expected from all departments.
7. Decisions made are based on the best solutions, not on hidden agendas for favoritism.
8. Quality becomes a governing part of operations, with decisions that impact on quality, rejected immediately, despite perceived cost-savings involved.

3.5 Benefits of TQM: -

- The benefits of TQM can classify in to three separate areas: -

A. The major benefits of TQM in terms of cost savings include: -

1. Elimination of non-confirmation and repetitive work.
2. Elimination of waste of costs and reject products.
3. Elimination of repairs and reworks.
4. Reduced warranty and customer support costs.
5. Process efficiency leading to improved profit per product or service.
6. Fiscal discipline through elimination of unnecessary steps and wasteful expenditure.

B. TQM free up management time from redressing problems and directs management time and effort to: -

1. Increase production.
2. Extend the range of products.
3. Improve existing products.

C. TQM and customer satisfaction: -

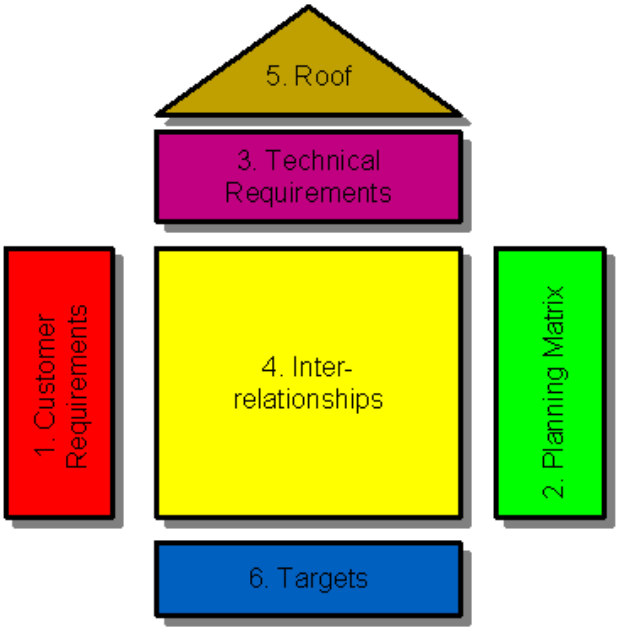
1. Reduction of waiting time by changing the method of appointment scheduling or client handling.
2. Making changes to the delivery process so that the product reaches the customer faster.
3. Better quality products requiring no repairs improving customer loyalty.

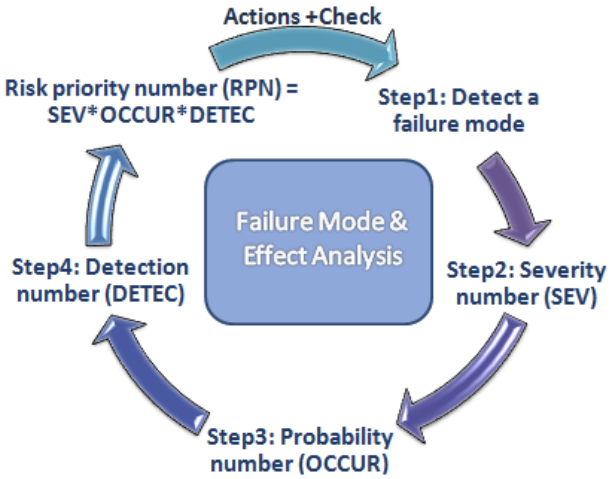
Key elements of TQM: -

1. **Foundation: -** includes ethics, integrity and trust.
2. **Building bricks: -** includes training, team work and leadership.
3. **Binding mortar: -** includes communication.
4. **Roof: -** includes recognition.

4

Designing for Quality





Course Contents

4.1. Concurrent Engineering

- Concurrent engineering is a design and project management philosophy aimed at developing the product and its related manufacturing and support process concurrently that is to say that the product design engineering and process engg. Functions are performed at the same time.
- Concurrent Engineering (CE) is a systematic approach to integrated product development that emphasizes the response to customer expectations. It embodies team values of co-operation, trust and sharing in such a manner that decision making is by consensus, involving all perspectives in parallel, from the beginning of the product life cycle.
- Design process adopted to evolve into a concurrent process for following reasons:
  1) Rapid pace of technology
  2) Forces design cycle compression
  3) Emerging information technology & methodologies

Basic Principle in CE

- Start all tasks as early as possible
- Utilize all relevant information as early as possible
- Work structuring: systematically structure the work or work environment so that each task can be performed independently of each other either by a machine, human or computer
- Everyone participates in defining the objectives of their work
- Operational understanding is achieved for all relevant information as team will work better if they know what other members are doing e.g. what constraints a team member could encounter when certain parameters will be changed.
- A strong commitment is made to adhere to the decisions taken earlier.
- Decisions are made in a single trade off space.
- Decisions are robust, overcoming a natural tendency to resort to quick, novel decisions.
- Trust among team mates Trusting members, if they agree to accept responsibility for a task, prefer to work together rather in isolation. This will also lead to better teamwork affinity.
- The team strives for consensus.
- Team should be empowered to make decisions in product development and should be given the “ownership” of what they produce. The team uses a visible concurrent process.
- **Constancy of purpose:** This requires a change in thinking beyond the goals of one/s individual department or team to the company’s goals. Aiming towards the constancy of the purpose results in everyone contributing his/her best working towards a common set of consistent goals.

Need of Concurrent Engineering

- Need to reduce product development lead time.
- Increased competition.
- New manufacturing processes developed.
- More demanding customers.

CE tools & Techniques:

- Design for manufacturing(DFM)
- Design for assemblability(DFA)
- Failure effects and modes analysis(FEMA)
- Cost driven design or target costing.
- Quality function deployment(QFD)
- Robust design through Taguchi method.
- Pugh's theorem.
- Experimental design techniques
- Design stress analysis
- Benchmarking and competitive analysis
- Rapid prototyping
- Customer focused design
- Computer & it based tools like CAD tools (mechanical), CAD tools (electronic), CAM/CAE tools and electronic information or data network.

Advantages of CE :

- Faster time to market which results in increased market share
- Lower manufacturing and production costs.
- Improved quality of resulting end products.
- Increased positioning in a highly competitive world market.
- Increased accuracy in predicting and meeting project plans, schedules, timelines and budgets.
- Increased efficiency and performance.
- Higher reliability in the product development process.
- Reduced defect rates.
- Increased effectiveness in transferring technology
- Increased customer satisfaction
- Ability to execute high and complex level of projects whilw minimizing the difficulties.
- Shorter design and development process with accelerated project execution
- Higher return on investments
- Reduced labor and resource requirements
- Overlapping capabilities and the ability to work in parallel

- Increased cohesiveness within the firm
- Lower implementation risks
- Faster reaction time in responding to the rapidly changing market
- Lower product and process design and development costs
- Improved inventory control, scheduling and customer relations.

4.2. QFD (Quality Function Deployment)

- Definition: A quality assurance tool for profit and non-profit organizations aimed at locating customer needs and transcending those needs into product/service production stages, ensuring that customer needs are delivered in the end.
- Dr. Mizuno, professor Emeritus of Tokyo Institute of Technology is credited for initiating the QFD System. The QFD can be applied practically to any manufacturing or service industry. It is an approach to the continual improvement that brings the customers into the design of processes. It translates customer's wants into what the organization produces.
- Purpose of QFD: - The following is the purpose of QFD
  1. Translate consumer's voice into technical design requirements
  2. Determine & prioritize customer needs
  3. Translate customer needs to product design parameters
  4. Coordinate efforts and skills of an organization from a project's inception to its completion
  5. Ensure customer expectations
  6. Avoid manufacturing catastrophe

QFD can be used for:-

1. Reduce product development time by 50%
2. Cut start-up & engineering costs by 30%
3. Reduce time to market.
4. Reduce # of design changes.
5. Lower rework.
6. Reduce facility's maintenance/operation costs.
7. Improve quality.

House of Quality

- QFD is also known as House of Quality. It translates the voice of customers into the design requirements that meet the specific target values and ways of matching them against how an organization will meet those requirements. It is the 1st matrix that a product development team uses to initiate the QFD processes.

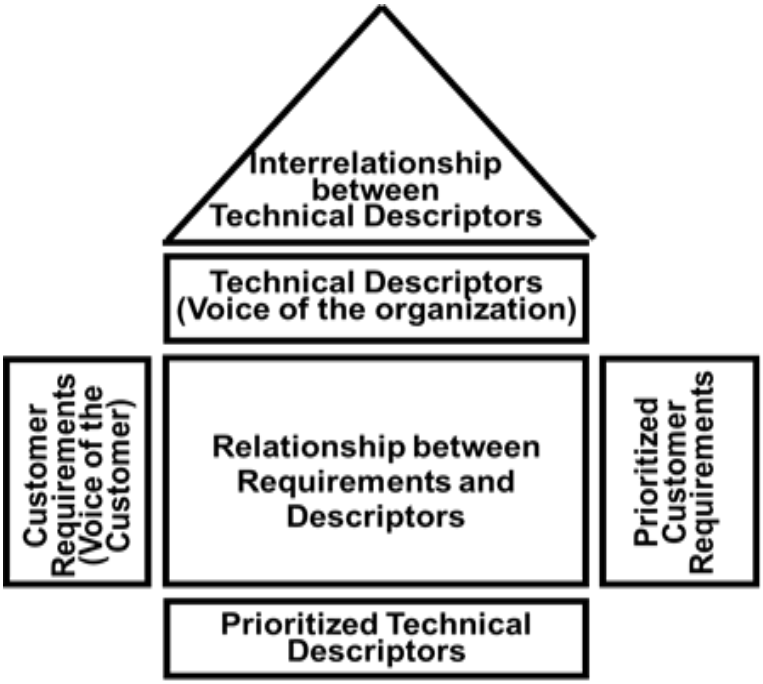


Figure 2.1: Structure of House of Quality

Building a House of Quality:

- List Customer Requirements (What's)
- List Technical Descriptors (How's)
- Develop Relationship (What's & How's)
- Develop Interrelationship (How's)
- Competitive Assessments
- Prioritize Customer Requirements
- Prioritize Technical Descriptors

QFD Matrix

Prioritized Customer Requirements

- Importance Rating
- Target Value
- Scale-Up Factor
- Sales Point
- Absolute Weight & Percent

– (Importance Rating)
– (Scale-Up Factor)
– (Sales Point)

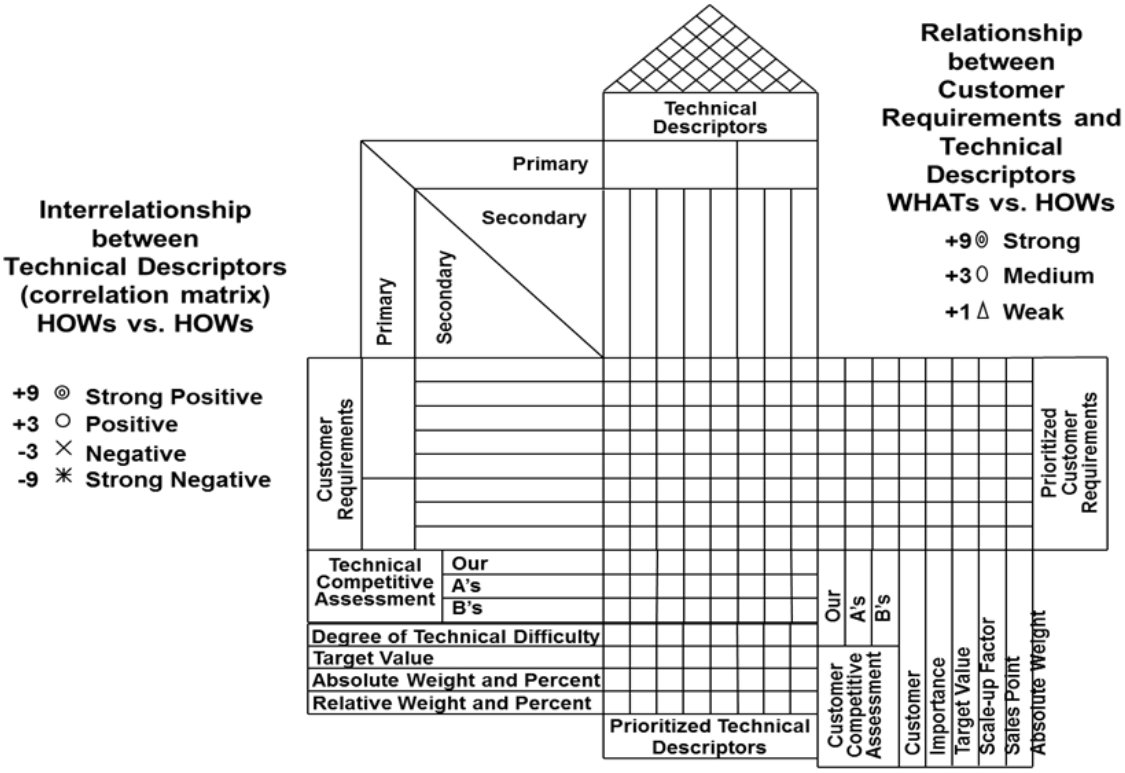


Figure 2.2: QFD Matrix

Prioritized Technical Descriptors

- Degree Of Difficulty
- Target Value
- Absolute Weight & Percent

$$a_j = \sum_{i=1}^{n} R_{ij} c_i$$

R is Relationship Matrix
c is Customer Importance

- **Relative Weight & Percent**

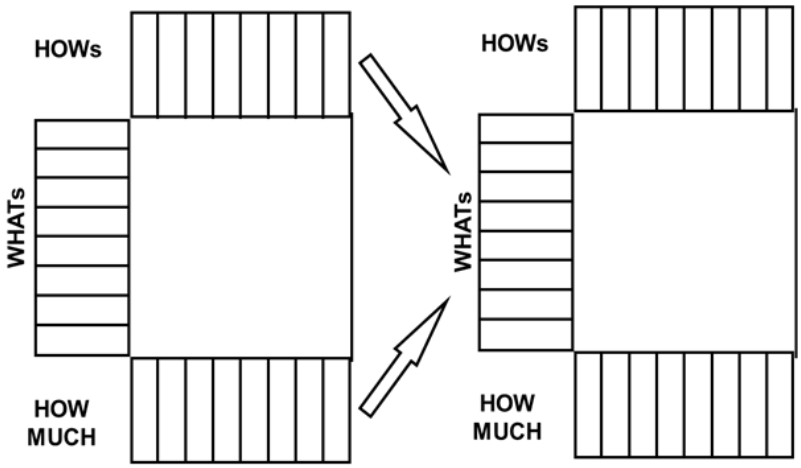
$$b_j = \sum_{i=1}^{n} R_{ij} d_i$$

R is Relationship Matrix
c is Customer Absolute Weights

QFD Process

Step 1: Identify Customer(s)

- Repair Department
- Automobile Owner
- Manufacturing Plant
- Sales Force



Step 2: Determine Customer Requirements/Constraints

- I want something that looks nice (basic)
- It must hold my license plate (performance)
- I want it strong enough not to dent (excitement)
- It must protect my tail-lights and head-lights (performance)
- I don't want to pay too much (basic)

Step 3: Prioritize Customer Requirements

Step 4: Put prioritized Customer Requirements into a House of Quality chart

Steps 5 and 6: Translate Customer Requirements into Measurable Engineering Specifications and define target values

- Specify how license plate will be held
- Specify how to resist dents through material yield strength, young's modulus, etc. and specify with a dollar amount the term 'inexpensive'

Benefits of QFD

- The following are the benefits of QFD:-
  1. Better understanding of customer's demands.
  2. Better understanding of design interactions.
  3. Early manufacturing involvement during the design process reducing design alterations and focusing the design while fostering teamwork.

Limitations of QFD

- The following are the limitations of QFD:-
  1. Data needed to be accurate.
  2. Customer expectations need to be aligned with technical capabilities.
  3. Customer expectations change rapidly.

4.3. Failure Mode and Effect Analysis (FMEA)

- A failure mode effect analysis is an extremely powerful tool that all people can and will benefit from no matter your occupation and status in life.
- The FMEA is not new tool. Begun in the 1940s by the US Military, FMEA was further developed by the aerospace and automotive industries. Several industries maintain formal FMEA standards. The aerospace industry used the FMEA during the Apollo mission in the 1960s. Later in 1974 the US Navy developed MIL-STD-1629 which discussed the proper use of the tool. And around this time the automotive folks latched onto the tool and never let go. Today the FMEA is universally used by many different industries.

Failure Mode:-

- Failure modes mean the ways, or modes, in which something might fail. Failures are any errors or defects, especially once that affect the customer, and can be potential or actual. The manner in which the product/part/service does not meet the customers' expectations.

Effect Analysis:

- Effect analysis refers to studying the consequences of those failures. A study of the effect of failure on the function or purpose of the product/part/service.

Failure modes and Effect Analysis is:

- A structured approach to:
- Identifying the ways in which a product or process can fail
- Estimating risk associated with specific causes
- Prioritizing the actions that should be taken to reduce risk
  Evaluating design validation plan (product) or current control plan (process)
- The way in which the component, subassembly, product, input, or process could fail to perform its intended function.
- Failure modes may be the result of upstream operations or may cause downstream operations to fail.
- Things that could go wrong.
- Failure Modes & Effects Analysis is a methodology to evaluate failure modes and their effects in designs and in processes

The following are the reasons for using FMEA:

- Methodology that facilitates process improvement
- Identifies and eliminates concerns early in the development of a process or design
- Improve internal and external customer satisfaction
- Focuses on prevention
- FMEA may be a customer requirement. FMEA may be required by an applicable Quality System Standard

How FMEA is implemented?

- Team identifies potential failure modes for design functions or process requirements
- They assign severity to the effect of this failure mode
- They assign frequency of occurrence to the potential cause of failure and likelihood of detection
- Team calculates a Risk Priority Number by multiplying severity times frequency of occurrence times likelihood of detection
- Team uses ranking to focus process improvement efforts.

When to conduct FMEA?

- Early in the process improvement investigation
- When new systems, products, and processes are being designed
- When existing designs or processes are being changed
- When carry-over designs are used in new applications
- After system, product, or process functions are defined, but before specific hardware is selected or released to manufacturing

Types of FMEAs

- Design
  - Analyzes product design before release to production, with a focus on product function
  - Analyzes systems and subsystems in early concept and design stages
- Process
  - Used to analyze manufacturing and assembly processes

FMEA Procedure

1. For each process input (start with high value inputs), determine the ways in which the input can go wrong (failure mode)
2. For each failure mode, determine effects
   - Select a severity level for each effect
3. Identify potential causes of each failure mode
   - Select an occurrence level for each cause
4. List current controls for each cause
   - Select a detection level for each cause
5. Calculate the Risk Priority Number (RPN)
6. Develop recommended actions, assign responsible persons, and take actions
   - Give priority to high RPNs
   - MUST look at severities rated a 10
7. Assign the predicted severity, occurrence, and detection levels and compare RPNs

The FMEA Form

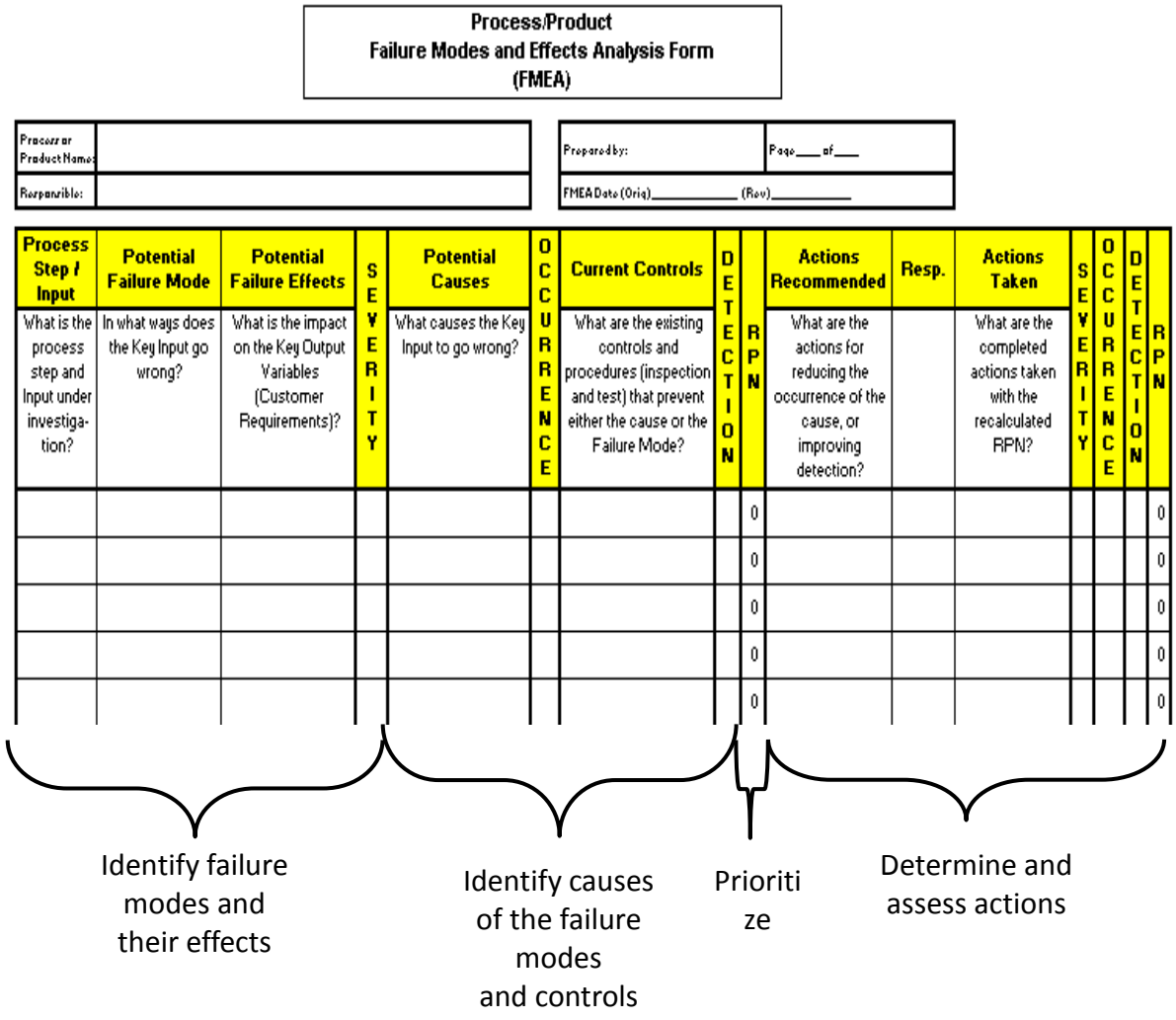


Figure 2.5: FMEA form

FMEA Inputs and Outputs

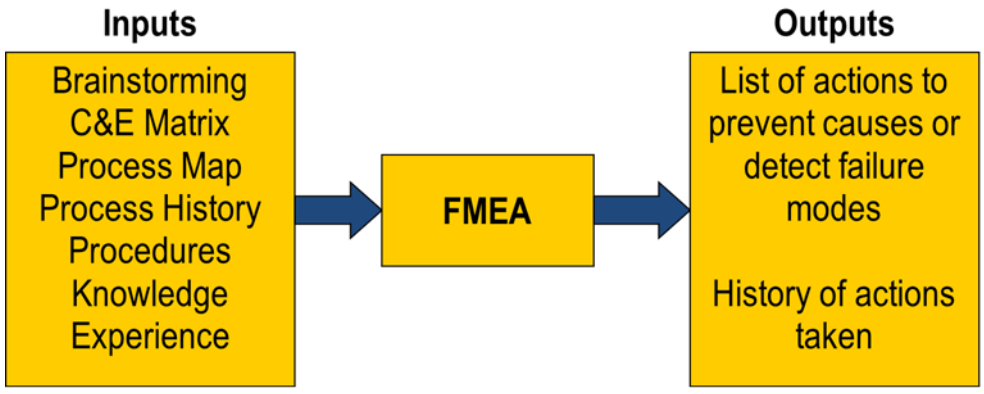


Figure 2.6: FMEA inputs and outputs

Severity, Occurrence, and Detection

- Severity
  - Importance of the effect on customer requirements
    Often can't do anything about this

- Occurrence
  - Frequency with which a given cause occurs and creates failure modes
- Detection
  - The ability of the current control scheme to detect or prevent a given cause

Rating Scales

- There are a wide variety of scoring “anchors”, both quantitative or qualitative
- Two types of scales are 1-5 or 1-10
- The 1-5 scale makes it easier for the teams to decide on scores
- The 1-10 scale allows for better precision in estimates and a wide variation in scores (most common)
- Severity

  1 = Not Severe, 10 = Very Severe
- Occurrence

  1 = Not Likely, 10 = Very Likely
- Detection

  1 = Likely to Detect, 10 = Not Likely to Detect

Benefits of FMEA

1. Prevention Planning.
2. Identifies changes requirements.
3. Cost Reduction.
4. Increased output.
5. Decreased waste.
6. Decreased warranty costs.
7. Reduce non-value added operations.
8. It increases the likelihood that potential failures, and their effects and causes, will be considered prior to the final design and/or release to production.
9. To plan preventive actions.
10. It can be used as the starting point for later control plans, trouble-shooting guides, preventive maintenance plans, etc.

5

INTRODUCTION TO DESIGN OF EXPERIMENT

Course Contents

5.1.INTRODUCTION TO DESIGN OF EXPERIMENT

In general usage, design of experiments (DOE) or experimental design is the design of any information-gathering exercises where variation is present, whether under the full control of the experimenter or not. However, in statistics, these terms are usually used for controlled experiments. Other types of study, and their design, are discussed in the articles on opinion polls and statistical surveys (which are types of observational study), natural experiments and quasi-experiments (for example, quasi-experimental design).

In the design of experiments, the experimenter is often interested in the effect of some process or intervention (the "treatment") on some objects (the "experimental units"), which may be people, parts of people, groups of people, plants, animals, materials, etc. Design of experiments is thus a discipline that has very broad application across all the natural and social sciences.

5.1.1 Benefits of Design of Experiments:

1. Comparing alternatives
2. Significant inputs-separating the vital few from the trivial many.
3. Optimal process output.
4. Reducing variability
5. Minimizing, maximizing or targeting an output.
6. Robustness.
7. Balancing tradeoffs.

5.1.2 Types of Design of Experiments:

There are two main types of design of experiments:
1. One factor experiment.
2. Multifactor experiment.

1. One factor Experiment (Test of Means): -

One of the most common types of experiment is the comparison of two process methods, or two methods of treatment. There are several ways to analyze such an experiment depending upon the information available from the population as well as the sample. One f the most straight-forward method to evaluate a new process method is to plot the results on an SPC chart that also includes historical data from the baseline process, with established control limits. Then apply the standard rules to evaluate out-of-control conditions to see if the process has been shifted.

An alternative to the control chart approach is to use the F-test to compare the means of alternate treatments. This is done automatically by the ANOVA functions of statistical software.

2. Multifactor Experiments: -

Multi-factor experiments are designed to evaluate multiple factors set at multiple levels. One approach is called Full Factorial experiments, in which each factor is tested at each level in every possible combination with the other factors and their levels. Full factorial experiments that study all paired interactions can be economic and practical if there are few factors and only 2 or 3 levels per factor. The advantage is that all paired interactions can be studied. However, the number of runs goes up exponentially as additional factors are added. Experiments with many factors can quickly become unwieldy and costly to execute.

5.2.Taguchi Methods:

Professor Genichi Taguchi was the director of the Japanese Academy of quality and four times receipt of the Deming Prize. He starts where SPC (temporarily) finishes. He can help with the identification of common cause of variation, the most difficult to determine and eliminate in process. He attempts to go even further: he tries to make the process and the product robust against their effect (eliminate of the effect rather than the cause) at the design stage. Even if the removal of the effect is impossible, he provides a systematic procedure for controlling the noise (through tolerance design) at the minimum cost. When Dr. Taguchi was first brought his ideas to America in 1980, he was already well known in Japan for his contribution to quality engineering.

5.2.1 Traditional and Taguchi's Definition of Quality

Traditional

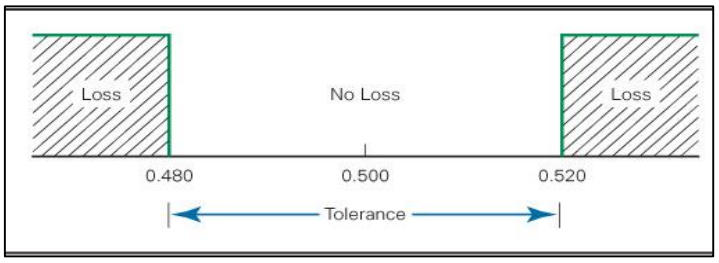


Figure 5.1: Traditional Approach of Quality

Taguchi's

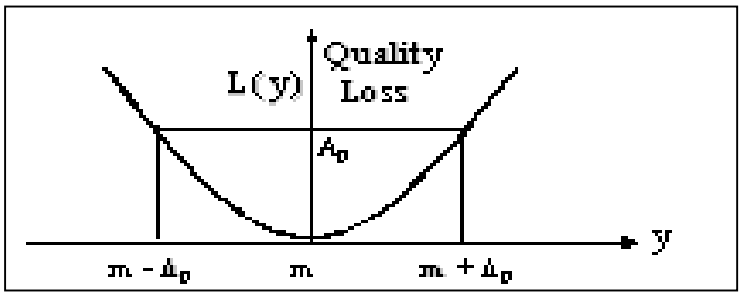


Figure 5.2: Taguchi's Approach of Quality

5.2.2 Objective of Taguchi Methods

1. Minimize the variation in product response while keeping the mean response on target.
2. The product can be made robust to changes in operating and environmental conditions.
3. Since the method is applied in a systematic way at a pre-production stage (off-line), it can greatly reduce the number of time-consuming tests, thus saving in costs and wasted products.

5.2.3 Loss functions

Loss functions in statistical theory

Traditionally, statistical methods have relied on mean-unbiased estimators of treatment effects: Under the conditions of the Gauss-Markov theorem, least squares estimators have minimum variance among all mean-unbiased estimators. The emphasis on comparisons of means also draws (limiting) comfort from the law of large numbers, according to which the sample means converge to the true mean. Fisher's textbook on the design of experiments emphasized comparisons of treatment means.

Gauss proved that the sample-mean minimizes the expected squared-error loss-function (while Laplace proved that a median-unbiased estimator minimizes the absolute-error loss function). In statistical theory, the central role of the loss function was renewed by the statistical decision theory of Abraham Wald.

However, loss functions were avoided by Ronald A. Fisher.

Taguchi's use of loss functions

Definition: "Quality is the loss a product causes to society after being shipped, other then any losses caused by its intrinsic functions."

By "loss" Taguchi refers to the following two categories:

1. Loss caused by variability of function.
2. Loss caused by harmful side effects.
3. **An example** of loss caused by variability if function would be an automobile that does not start in cold weather. The car's owner would suffer a loss if he or she had to pay some to start a car. The car owner's employer losses the services of the employee who is now late for work.

Taguchi's Quadratic Quality Loss Function

1. Quality Loss Occurs when a product's deviates from target or nominal value.
2. Deviation Grows, then Loss increases.
3. Taguchi's U-shaped loss Function Curve

Taguchi's U-shaped loss Function Curve

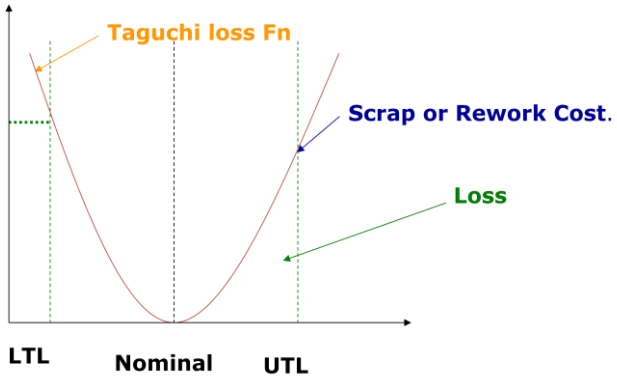


Figure 5.3: Taguchi's U shaped Loss Function Curve

Taguchi's method: Loss function

Loss = $L(y) = L(m + (y-m))$

$= L(m) + (y-m) L'(m)/1! + (y-m)^2 L''(m)/2! + \ldots$

Ideally:

(a) $L(m) = 0$ [if actual size = target size, Loss = 0], and

(b) When $y = m$, the loss is at its minimum, therefore $L'(m) = 0$

Example of loss function

Suppose that the specification on a part is 0.500 ± 0.020 cm. A detailed analysis of product returns and repairs has discovered that many failures occur when the actual dimension is near the extreme of the tolerance range (that is, when the dimensions are approximately 0.48 or 0.52) and costs $50 for repair.

Thus, in Equation, the deviation from the target, x – T, is 0.02 and L(x) = $50. Substituting these values, we have:

$$50 = k\,(0.02)2$$

Or

$$k = 50/0.0004 = 125{,}000$$

Therefore, the loss function for a single part is $L(x) = 125000(x - T)\,2$.

This means when the deviation is 0.10, the firm can still expect an average loss per unit of:

$L(0.10) = 125{,}000(0.10)2 = \$12.50$ per part

Knowing the Taguchi loss function helps designers to determine appropriate tolerances economically. For example, suppose that a simple adjustment can be made at the factory for only $2 to get this dimension very close to the target.

If we set L(x) = $2 and solve for x – T, we get:

$$2 = 125000(x - T)\,2$$

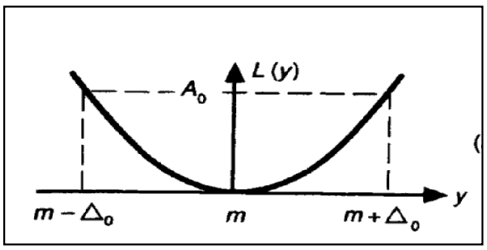
$$x - T = 0.004$$

Therefore, if the dimension is more than 0.004 away from the target, it is more economical to adjust it at the factory and the specifications should be set as 0.500 ± 0.004.

Variation of the Quadratic Loss Function

1. *Nominal the best type*: Whenever the quality characteristic y has a finite target value, usually nonzero, and the quality loss is symmetric on the either side of the target, such quality characteristic called *nominal-the-best type*. This is given by equation

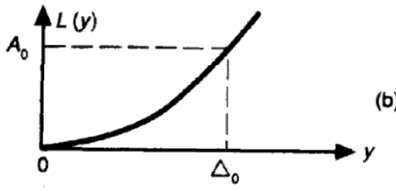
$$L(y) = k(y-m)^2$$



2. ***Smaller-the-better type*:** Some characteristic, such as radiation leakage from a microwave oven, can never take negative values. Also, their ideal value is equal to zero, and as their value increases, the performance becomes progressively worse. Such characteristic are called smaller-the-better type quality characteristics.

Examples: The response time of a computer, leakage current in electronic circuits, and pollution from an automobile.

In this case m = 0; $L(y) = ky^2$. This is one side loss function because y cannot take negative values.

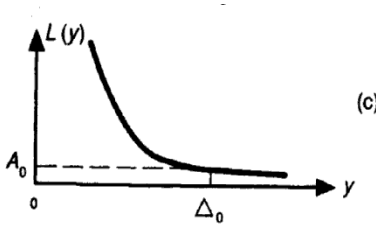


(b) Smaller-the-better

3. *Larger-the-better type*: Some characteristics do not take negative values. But, zero is there worst value, and as their value becomes larger, the performance becomes progressively better-that is, the quality loss becomes progressively smaller, also Their ideal value is infinity and at that point the loss is zero. Such characteristics are called larger-the-better type characteristics**.**

Example: Such as the bond strength of adhesives. Thus we approximate the loss function for a larger-the-better type characteristic by substituting 1/y for y in

$$L(y) = k\,[1/y^2]$$

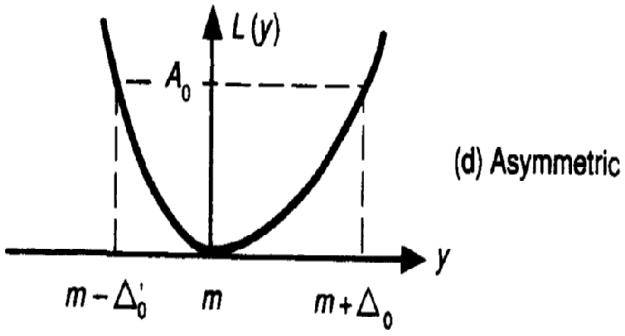


(c) Larger-the-better

4. ***Asymmetric loss function***: In certain situations, deviation of the quality characteristic in one direction is much more harmful than in the other direction. In such cases, one can use a

different coefficient k for the two directions. Thus, the quality loss would be approximated by the following asymmetric loss function:

$$L(y) = \begin{cases} k(y-m)^2, & y > m \\ k(y-m)^2, & y \leq m \end{cases}$$



(d) Asymmetric

[Reference: ppt from www.slideshare.com]

6

CONTEMPORARY TRENDS IN QUALITY ENGINEERING & MANAGEMENT

Course Contents

6.1 Just-In-Time Production System

Just in Time or JIT is a management philosophy that strives to eliminate the sources of manufacturing waste by producing the right part in the right place at the right time. It is system that aims at successful completion of a product or service at each stage of the production activity from the vendor to the customer just in time for its use and at a minimum cost. JIT is a strategy or guiding philosophy whose goal is to seek manufacturing excellence.

Waste is the result of any activity that adds cost without adding value, such as moving and storing. JIT improves the profit and the return on investment by reducing the inventory levels, increasing the inventory turnover rate, reducing the variability, improving the product quality, reducing the production and delivery lead times and reducing the other costs associated with the machine set-up and equipment breakdown. JIT system, an underutilised or an excess capacity is used instead of the buffer inventories compensate against the probable problems that may arise. Application of JIT is focused on identifying a production flow and product quality-related problems. As the production flow increases, the productivity improves and the cost decreases while if the quality improves, the scrap and customer complaints will decrease. This will help in reducing the cost of product and increased market share by the organization, making the logical result of JIT to dominate the market possible.

The basic element of JIT was developed by Toyoto in the 1950s and became known as the Toyoto Production system (TPS). JIT was firmly in place in numerous Japanese plants by the early 1970s. It began to be adopted in the United States in the 1980s and thereafter. It was developed and perfected by Taiichi Ohno of Toyoto, who is now referred as the father of JIT.

6.2.1 Principles of JIT (how to implement JIT):

1. Set up production flow process.
2. Solve problems concurrently.
3. Reduce inventory more.
4. Improve product and process.
5. Apply scrap/quality control.
6. Apply kanban pull system.
7. Stabilize master production schedule
8. Work with suppliers.

6.2Concurrent Engineering

Concurrent engineering is a design and project management philosophy aimed at developing the product and its related manufacturing and support process concurrently that is to say that the product design engineering and process engg. Functions are performed at the same time.
Concurrent Engineering (CE) is a systematic approach to integrated product development that emphasizes the response to customer expectations. It embodies team values of co-operation, trust and

sharing in such a manner that decision making is by consensus, involving all perspectives in parallel, from the beginning of the product life cycle.
Design process adopted to evolve into a concurrent process for following reasons:

1) Rapid pace of technology
2) Forces design cycle compression
3) Emerging information technology & methodologies

6.2.1 Basic Principle in CE

- Start all tasks as early as possible
- Utilize all relevant information as early as possible
- Work structuring: systematically structure the work or work environment so that each task can be performed independently of each other either by a machine, human or computer
- Everyone participates in defining the objectives of their work
- Operational understanding is achieved for all relevant information as team will work better if they know what other members are doing e.g. what constraints a team member could encounter when certain parameters will be changed.
- A strong commitment is made to adhere to the decisions taken earlier.
- Decisions are made in a single trade off space.
- Decisions are robust, overcoming a natural tendency to resort to quick, novel decisions.
- Trust among team mates Trusting members, if they agree to accept responsibility for a task, prefer to work together rather in isolation. This will also lead to better teamwork affinity.
- The team strives for consensus.
- Team should be empowered to make decisions in product development and should be given the "ownership" of what they produce. The team uses a visible concurrent process.
- **Constancy of purpose:** This requires a change in thinking beyond the goals of one/s individual department or team to the company's goals. Aiming towards the constancy of the purpose results in everyone contributing his/her best working towards a common set of consistent goals.

6.2.2 Need of Concurrent Engineering

- Need to reduce product development lead time.
- Increased competition.
- New manufacturing processes developed.
- More demanding customers.

6.2.3 CE tools & Techniques:

- Design for manufacturing(DFM)
- Design for assemblability(DFA)
- Failure effects and modes analysis(FEMA)
- Cost driven design or target costing.
- Quality function deployment(QFD)
- Robust design through Taguchi method.

- Pugh's theorem.
- Experimental design techniques
- Design stress analysis
- Benchmarking and competitive analysis
- Rapid prototyping
- Customer focused design
- Computer & it based tools like CAD tools (mechanical), CAD tools (electronic), CAM/CAE tools and electronic information or data network.

6.2.4 Advantages of CE :

- Faster time to market which results in increased market share
- Lower manufacturing and production costs.
- Improved quality of resulting end products.
- Increased positioning in a highly competitive world market.
- Increased accuracy in predicting and meeting project plans, schedules, timelines and budgets.
- Increased efficiency and performance.
- Higher reliability in the product development process.
- Reduced defect rates.
- Increased effectiveness in transferring technology
- Increased customer satisfaction
- Ability to execute high and complex level of projects whilw minimizing the difficulties.
- Shorter design and development process with accelerated project execution
- Higher return on investments
- Reduced labor and resource requirements
- Overlapping capabilities and the ability to work in parallel
- Increased cohesiveness within the firm
- Lower implementation risks
- Faster reaction time in responding to the rapidly changing market
- Lower product and process design and development costs
- Improved inventory control, scheduling and customer relations.

6.3Lean manufacturing (1980)

- Lean means speed .goal of lean is to quickly make to order a profession of different products within the low cost & eliminate wait time.
- Lean manufacturing, lean enterprise or lean production, often simply, "Lean " is a production practice that considers the expenditure of resources for nay goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination of such unwanted expenditure. Working from the perspective of the customer who consumes a product or service, "value" is defined as any action or process that a customer would be willing to pay for.

6.3.1 Fundamental of Lean manufacturing

- Production of smaller lots of different parts
- Manufacturing as per possible correct customer demand, produce in small lots.
- Made to order. You have much more accepted information about when the customer really wants.
- You are making to actual demand
- Lean ensures that each stage process is exactly what and as much as the next stage want and exactly what and as much as the next stage want and exactly when it wants it.

6.3.2 Advantage of Lean manufacturing

- Better Quality
- Low cost
- Less number of people
- Low inventory, inventory turn increase
- Less waste. Optimize men and materials
- Customer delivery performance better, reducing order to shipment time
- Enormous variety in products without the kind of change over costs that customized involves, flexible manufacturing.

Toyota's view is that the main method of lean is not the tools ,but the reduction of three types of waste:

1) **Muda**(" non-value adding work")
2) **Muri** (" overburden")
3) **Mura** ("unevenness")

Muda (7 wastes)

- Transportation
  Each time a product is moved it stands the risk of being damaged, lost, delayed, etc. as well as being a cost for no added value. Transportation does not make any transformation to the product that the consumer is willing to pay for.
- Inventory
  Inventory, be it in the form of raw materials, work-in-progress (WIP), or finished goods, represents a capital outlay that has not yet produced an income either by the producer or for the consumer. Any of these three items not being actively processed to add value is waste.
- **Motion**
  In contrast to transportation, which refers to damage to products and transaction costs associated with moving them, motion refers to the damage that the production process inflicts on the entity that creates the product, either over time (wear and tear for equipment and repetitive for workers) or during discrete events (accidents that damage equipment and/or injure workers).
- Waiting
  Whenever goods are not in transport or being processed, they are waiting. In traditional processes, a large part of an individual product's life is spent waiting to be worked on.

- Over-processing
  Over-processing occurs any time more work is done on a piece than what is required by the customer. This also includes using tools that are more precise, complex, or expensive than absolutely required.
- Over-production
  Overproduction occurs when more product is produced than is required at that time by your customers. One common practice that leads to this muda is the production of large batches, as often consumer needs change over the long times large batches require. Overproduction is considered the worst muda because it hides and/or generates all the others. Overproduction leads to excess inventory, which then requires the expenditure of resources on storage space and preservation, activities that do not benefit the customer.
- Defects
  Whenever defects occur, extra costs are incurred reworking the part, rescheduling production, etc.
  An easy way to remember the 7 wastes is **TIMWOOD.**

6.3.3 Objectives of lean manufacturing:

- **Improve quality:** to stay competitive in today's marketplace, a company must understand its customers' wants and needs and design processes to meet their expectations and requirements.
- **Eliminate waste:** waste is any activity that consumes time, resources, or space but does not add any value to the product or service.
- **Reduce time:** reducing the time it takes to finish an activity from start to finish is one of the most effective ways to eliminate waste and lower costs.
- **Reduce total costs:** to minimize cost, a company may produce only to customer demand. Overproduction increases a company's inventory costs because of storage needs.

6.3.4 Tools for lean manufacturing

- Focus on core competencies
- Establish flexibility and low inertia
- Speed
- Integration
- People

6.3.5 Implementation of lean manufacturing

- Removing waste
- Kaizen vs breakthrough
- Discrete improvements
- Reengineering the process
- Time to market
- Concurrent ways

- Time in the supply chain
- JIT
- Flexibility

6.4World class manufacturing (WCM)

- WCM has place great emphasis on being close to the customer. Customer prosperity goes much further and examine how much value is added to the customer by the use of your company's products & services.

7 steps:

1) Focus on competitive quality
2) Implement lean manufacturing
3) Achieve cost efficiency
4) Reduce time to market
5) Exceed customer expectations
6) Stream line outsourcing process
7) Have a global prospective

6.4.1 Eight dimension of WCM

1) Waste(Muda) elimination
2) Work environment(5's)
3) JIT/supply chain management
4) Equipment effectiveness/TPM
5) Customer driven
6) Quality first.six sigma/SQM and best practices
7) Liason team force and skill development
8) Information system/BPR, technology and cash flow

6.5Agile manufacturing (AM)

- Agile manufacturing is the science of a business system that integrates management, technology and workforce, making the system to flexible and engages for a manufacturer to switch over from one product to another product in cost effective manner within the framework of the system.
- Agile manufacturing includes planning, finance, and process design, tooling, machines and machinery. Layout, materials and inventory cost. Specification, prime constraint, marketing and sales service support.
- To approach agile manufacturing requires that the company already be world class and using lean manufacturing methods. Agile manufacturing deals with the things we can control.

6.5.1 Characteristics of AM:

- Fast new product development
- Modular design

- Modular assembly
- Short/fast order processing
- ConFigureure to order
- Make-to-Order
- Low volumes
- Low quantities
- High product mix
- ConFigureurable components
- Fast supplier deliveries
- Short lead times
- Short cycle times
- Highly flexible and responsive processes
- Highly flexible machines and equipment
- Deployment of Group Technology principles
- Use of Solids Modeling
- Use of advanced CAD/CAM
- Quick changeover
- Collocated machines, equipment, tools and people
- Compressed space
- Multi-skilled employees
- Empowered employees
- High first-pass yields with major reductions in defects

6.5.2 Attributes of Agility:

1) Delivering value to the customer
2) Being ready for change
3) Valuing human knowledge and skills
4) Forming virtual partnerships.

The first three of these are also attributes of lean manufacturing

6.5.3 Advantages of AM:

1) Lead time reduction upto 38 per cent
2) Inventory reduction upto 40 per cent
3) Production floor space utilization increased by 27 per cent
4) Reduction of management layers upto 70 per cent
5) Capacity to make variety products increases.

6.5.4 Comparing Agile manufacturing with lean manufacturing

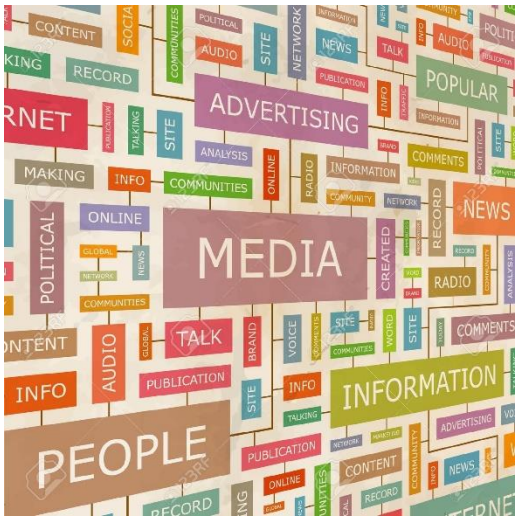
- Agile manufacturing is seen as the next step after lean in the evolution of production methodology. The key difference between the two is like between a thin and athletic person, agile being the latter. One can be neither, one or both. In manufacturing theory being both is

often referred to as agile. When companies have to decide what to be, they have to look at the customer order cycle (COC-The time the customers are willing to wait) and lead time for getting supplies. If the supplier has a short lead time, lean production is possible. If the customer order cycle is short, agile production is beneficial.

- This concept is closely related to lean manufacturing, in which the goal is to reduce waste as much as possible. In lean manufacturing, the company aims to cut all costs which are not directly related to the production of a product for the consumer. Agile manufacturing can include this this concept, but it also adds an additional dimension, the idea that customer demand need to be met rapidly and effectively. In situations where companies integrate both approaches , they are sometimes said to be using " lean and agile manufacturing"
- Companies which utilize an agile manufacturing approach tend to have very strong networks with suppliers and related companies, along with numerous cooperative teams which work within the company to deliver products effectively. They can retool facilities quickly, negotiate, new agreements with suppliers and other partners in response to changing market forces, and take other steps to meet customer demands. This means that the company can increase production on products with a high consumer demand, as well as redesign products to respond to issues which have emerged on the open market.

7

Quality in Service Sector



Course Contents

7.1 Introduction

- All institutions, whether for manufacture, service or other purposes, face problems of attaining quality. In the case of the manufacturing industries, extensive work has been done in the last three decades to identify the quality problems which are common to all manufacture, and to discover common solutions to these problems. This search for commonality has led to identification and successful application of various universals of quality control. Some of these universals (e.g., process capability, the Pareto Principle, quality cost analysis, statistical methodology) have been of great aid to practitioners.
- The present article examines the problems of commonality as it applies to quality control in service industries.

7.2 What is Service?

- Service, as used here, is work performed for someone else. The recipient of the service (often called the client) may be:

A: an individual user, e.g., the housewife (often called a consumer)
B: an institution, e.g., a company occupying office space under a lease
C: both, e.g., users of electrical energy from a central source.
Service Work exists for a variety of reasons, principally to:
1. Enable the client to meet needs which he would otherwise be unable to meet, e.g., distant voice communication.
2. Offer the client alternatives which are superior in cost, time, convenience, etc., e.g., public transportation.
3. Meet a wide variety of human psychological and physiological needs, e.g., amusement, freedom from disagreeable tasks, opportunity for learning and creativity.
Service work may include sale of a product, e.g., food in restaurants, spare parts used during automobile repair. However, such sale of a product is normally incidental to the work performed for
Definitions for 'service industries' usually exclude manufacture, agriculture, mining and construction.

- The definitions usually include:

- Public transportation.
- Public utilities (telephone communication, energy services, and sanitation services).
- Restaurants, hotels and motels.
- Marketing (retail food, apparel, automotive, wholesale trade, department stores).
- Finance (commercial banks, insurance, sales finance, investment).
- News media.
- Personal services (amusements, laundry and cleaning, barber and beauty shops).
- Professional services (physicians, lawyers).
- Government (defense, health, education, welfare, municipal services).

7.3 Characteristics of a Service Company

- A service company is a system of special facilities and skills, organized to provide services to clients. It sells the benefits of this system to its clients in a variety of ways, for example:

• Lease of facilities, e.g., apartments, office space
• Use of facilities, e.g., bus rides, telephone calls

- Professional advice, e.g., medical, legal
- Health maintenance, e.g., hospital service
- Product maintenance, e.g., automobile repairs
- Relief from self-service, e.g., restaurant service.

- In carrying out its mission the service company usually sells direct to the user. This is true not only as to large industrial users but for numerous small users as well. In this latter respect, the service company differs sharply from the manufacturing company.
- These direct sales bring the service company into multiple contact with large numbers of consumers, giving rise to huge numbers of individual transactions. All of these transactions have their impact on human beings, many of whom are articulate.
- A favorable aspect of these direct contacts with the consumer is the opportunity for good feedback as to fitness for use. In this respect. The service company has an easier job than the manufacturing company, which is comparatively insulated from the consumer, and must resort to special studies to secure adequate feedback.
- The extensive personal contact also sets up some relationships which are inherently uncomfortable for the consumer. To secure some services he surrenders his property into the custody of the service company, e.g., baggage for transport. The service company holds this property in captivity, and a failure or a delay in returning it can greatly inconvenience the consumer. In other cases it is the consumer himself who feels he is held captive. The most usual form of this is waiting in line in a queue, or waiting for service when there are no effective alternatives.
- For some service failures the consumer can make a direct complaint and claim. He may be compensated for loss of property, but he is seldom compensated for loss of time or for his annoyance. What he can do is to turn to competing service, if they exist. He can also do damage to the company by publicizing the trouble he has had. If the service is a monopoly, he can join other disgruntled consumers in collective efforts to force improvements through publicity or political action.