# CHAPTER 19
# TOTAL QUALITY MANAGEMENT IN MECHANICAL DESIGN

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## 19.1 INTRODUCTION

In today's competitive environment, the age-old belief of many companies that "the customer is always right" has a new twist. In order to survive, companies are focusing their entire organization on customer satisfaction. The approach followed for ensuring customer satisfaction is known as Total Quality Management (TQM). The challenge is to "manage" so that the "total" and the "quality" are experienced in an effective manner.[1]

Though modern quality control dates back to 1916, the real beginning of TQM can be considered the late 1940s, when such figures as W. E. Deming, J. M. Juran, and A. V. Feigenbaum played an instrumental role.[2] In subsequent years, the TQM approach was more widely practiced in Japan than anywhere else. In 1951, the Japanese Union of Scientists and Engineers introduced a prize, named after W. E. Deming, for the organization that implemented the most successful quality policies. On similar lines, in 1987, the U. S. government introduced the Malcolm Baldrige Award.

Quality cannot be inspected out of a product; it must be built in. The consideration of quality in design begins during the specification-writing phase. Many factors contribute to the success of the quality consideration in engineering or mechanical design. TQM is a useful tool for application during the design phase. It should be noted that the material presented in this section does not specifically deal with mechanical design, but with the design in general. The same material is equally applicable to the design of mechanical items. This chapter presents topics such as TQM in general, Deming's approach to TQM, quality in design, quality tools and techniques, and selected references on TQM and design quality.

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## 19.2 TQM IN GENERAL

The term *quality* may simply be defined as providing customers with products and services that meet their needs in an effective manner. TQM focuses on customer satisfaction. The three words that make up this concept—"total," "quality," and "management"—are discussed separately below.[1]

### 19.2.1 Total

This calls for the involvement of all the aspects of the organization in satisfying the customer, a goal that can only be accomplished if the usefulness is recognized of having partnership environment at each stage of the business process both within and outside the organization, as applicable. With respect to the outside stage of the business process, the important critical factors for a successful supplier–customer relationship are

1. Development of a customer–supplier relationship based on mutual trust, respect, and benefit
2. Development of in-house requirements by customers
3. Customers making suppliers clearly understand their requirements
4. Customers selecting their potential suppliers with mechanisms in place to achieve zero defects
5. Regular monitoring of suppliers' processes and products by the customers

### 19.2.2 Quality

Any company or organization in pursuit of TQM must define the term *quality* clearly and precisely. It may be said that quality is deceptively simple but endlessly complicated, and numerous definitions have been proposed, such as "quality = people + attitude"; "providing error-free products and services to customers on time"; and "satisfying the requirements and expectations of customers". Another definition is offered here: "quality means providing both external and internal customers with innovative goods and services that meet their needs effectively."

This definition has three important dimensions:

1. It focuses on satisfying the needs of customers
2. Organizations using this definition provide both products and services, which jointly determine the customer's perception of the company in question
3. The concerned companies have both external and internal customers

According to a survey reported in Ref. 1, 82% of the definitions indicated that quality is defined by the customer, not by the supplier. The top five quality measures identified by the respondents were customer feedback (22.92%), customer complaints (16.67%), net profits (10.42%), returning customers (10.42%), and product defects (8.33%).

### 19.2.3 Management

The approach to management is instrumental in determining companies' ability to attain corporate goals and allocate resources effectively. TQM calls for a radical change in involving employees in company decision-making, as their contribution and participation are vital to orienting all areas of business in providing quality products to customers. It must be remembered that over the years the *Fortune* 1000 companies in the United States have reported such benefits of employee-involvement as increased employee trust in management, improved product quality, improved employee safety/health, increase in productivity, improved management decision-making, increased worker satisfaction, improvement in employee quality of work life, improved union–management relations, improved implementation of technology, improved organization processes, eliminated layers of management, and better customer service.

Companies considering the introduction of TQM will have to see their employees in a new way, for the change in management philosophy needed to truly manage total quality is nothing short of dramatic. Furthermore, it is important that the managment infrastructure lay the foundation for involving the entire workforce in the pursuit of customer satisfaction.

#### The Senior Management Role

Senior management must show enthusiasm for improving product quality if employees are to seriously consider its importance. The following steps by management are useful in gaining commitment to total quality:[3]

- Announce absolutely clear quality policies and goals and ensure that these are explained to everyone involved.
- Regularly show management support through action.

- Ensure that everyone in the organization understands his or her necessary input in making quality happen.
- Eradicate any opportunity for compromising conformance.
- Make it clearly known to everyone concerned, including suppliers, that they are an important element in contributing to the quality of the end product.

## 19.3 DEMING'S APPROACH TO TQM

One of the pioneers of the TQM concept has expressed his views on improving quality. His fourteen-point approach is as follows:[4]

1. Establish consistency of purpose for improving services.
2. Adopt the new philosophy for making the accepted levels of defects, delays, or mistakes unwanted.
3. Stop reliance on mass inspection as it neither improves nor guarantees quality. Remember that teamwork between the firm and its suppliers is the way for the process of improvement.
4. Stop awarding business with respect to the price.
5. Discover problems. Management must work continually to improve the system.
6. Take advantage of modern methods used for training. In developing a training program, take into consideration such items as
    - Identification of company objectives
    - Identification of the training goals
    - Understanding of goals by everyone involved
    - Orientation of new employees
    - Training of supervisors in statistical thinking
    - Team-building
    - Analysis of the teaching need
7. Institute modern supervision approaches.
8. Eradicate fear so that everyone involved may work to his or her full capacity.
9. Tear down department barriers so that everyone can work as a team member.
10. Eliminate items such as goals, posters, and slogans that call for new productivity levels without the improvement of methods.
11. Make your organization free of work standards prescribing numeric quotas.
12. Eliminate factors that inhibit employee workmanship pride.
13. Establish an effective education and training program.
14. Develop a program that will push the above 13 points every day for never-ending improvement.

## 19.4 QUALITY IN THE DESIGN PHASE

Although TQM will help generally to improve design quality, specific quality-related steps are also necessary during the design phase. These additional steps will further enhance the product design.

An informal review during specification writing may be regarded as the beginning of quality assurance in the design phase. As soon as the first draft of the specification is complete, the detailed analysis begins.

Some of the important areas assocated with quality in design are discussed separately below.[5]

### 19.4.1 Product Design Review

Various types of design reviews are conducted during the product-design phase. One reason for performing these reviews is to improve quality. Design reviews conducted during the design phase include preliminary design review, detailed design reviews (the number of which may vary from one project to another), critical design review (the purpose of this review is to approve the final design), preproduction design review (this review is performed after the prototype tests), postproduction design review, and operations and support design review.

The consideration of quality begins at the preliminary design review and becomes stronger as the design develops. The role of quality assurance in preliminary design review is to ensure that the new design is free of quality problems of similar existing designs. This requires a good knowledge of the strengths and weaknesses of the competing products. The following approaches are quite useful in ensuring quality during the design phase.

#### Quality Function Deployment (QFD), Quality Loss Function, and Benchmarking

Quality function deployment is a value-analysis tool used during product and process development. It is an extremely useful concept for developing test strategies and translating needs to specification.

QFD was developed in Japan. In the case of new product development, it is simply a matrix of consumer/customer requirements versus design requirements. Some of the sources for the input are market surveys, interviews, and brainstorming. To use the example of an automobile, customer needs include price, expectations at delivery (safety, perceived quality, service ability, performance, workmanship, etc.), and expectations over time (including customer support, durability, reliability, performance, repair part availability, low preventive maintenance and maintenance cost, mean time between failures within prediction, etc.).

Finally, QFD helps to turn needs into design engineering requirements.

The basis for the quality loss function is that if all parts are produced close to their specified values, then it is fair to expect best product performance and lower cost to society. According to Taguchi,[6] quality cost goes up not only when the finished product is outside given specifications, but also when it deviates from the set target value within the specifications.

One important point to note, using Taguchi's philosophy, is that a product's final quality and cost are determined to a large extent by its design and manufacturing processes. It may be said that the loss function concept is simply the application of a life cycle cost model to quality assurance. Taguchi expresses the loss function as follows:

$$L(x) = c(x - T_v)^2 \qquad (19.1)$$

where $x$ = the variable
$L(x)$ = the loss at $x$
$T_v$ = the targeted value of the variable at which the product is expected to show its best performance
$c$ = the proportionality constant
$(x - T_v)$ = the deviation from the target value

In the formulation of the loss function, assumptions are made, such as zero loss at the target value and that the dissatisfaction of customer is proportional only to the deviation from the target value. The value of the proportionality constant, $c$, can be determined by estimating the loss value for an unacceptable deviation, such as the tolerance limit. Thus, the following relationship can be used to estimate the value of $c$:

$$c = \frac{L_a}{\Delta^2} \qquad (19.2)$$

where $L_a$ = the amount of loss expressed in dollars
$\Delta$ = the deviation amount from the target value $T_v$

**Example 19.1**

Assume that the estimated loss for Rockwell hardness number beyond 56 is \$150 and the targeted value of the hardness number is 52. Estimate the value of the proportionality constant. Substituting the given data into Eq. (19.2), we get

$$c = \frac{150}{(56 - 52)^2} = 9.375$$

Thus, the value of the proportionality constant is 9.375.

Benchmarking is a process of comparing in-house products and processes with the most effective in the field and setting objectives for gaining a competitive advantage. The following steps are associated with benchmarking:[7]

- Identify items and their associated key features to benchmark during product planning.
- Select companies, industries, or technologies to benchmark against. Determine existing strengths of the items to benchmark against.
- Determine the best-in-class target from each selected benchmark item.
- Evaluate, as appropriate, in-house processes and technologies with respect to benchmarks.
- Set improvement targets remembering that the best-in-class target is always a moving target.

### 19.4.2 Process Design Review

Soon after the approval of a preliminary design, a process flowchart is prepared. In order to assume the proper consideration being given to quality, the quality engineer works along with process and reliability engineers.

For the correct functioning of the process, the quality engineer's expertise in variation control provides important input.

Lack of integration between quality assurance and manufacturing is one of the main reasons for the failure of the team effort. The performance of process failure mode and effect analysis (FMEA) helps this integration to take place early. The consideration of the total manufacturing process performance by the FMEA concept, rather than that of the mere equipment, is also a useful step in this regard. For FMEA to produce promising results, the quality and manufacturing engineers have to work as a team. Nervertheless, FMEA is a useful tool for performing analysis of a new process, including analysis of receiving, handling, and storing materials and tools. Also, the participation of suppliers in FMEA studies enhances FMEA's value. The following steps are associated with the process of FMEA:[8,9]

- Develop process flowchart that includes all process inputs: materials, storage and handling, transportation, etc.
- List all components/elements of the process.
- Write down each component/element description and identify all possible failure modes.
- Assign failure rate/probability to each component/element failure mode.
- Describe each failure mode cause and effect.
- Enter remarks for each failure mode.
- Review each critical failure mode and take corrective measures.

### 19.4.3 Plans for Acquisition and Process Control

The development of quality assurance plans for procurement and process control during the design phase is useful for improving product quality. One immediate advantage is the smooth transition from design to production. The equipment-procurement plan should include such items as equipment-performance verification, statistical tolerance analysis, testing for part interchangeability, and pilot runs. Similarly, the component-procurement quality plans should address concerns and cooperation on areas including component qualification, closed-loop failure managment, process control implementation throughout the production lines, and standard and special screening tests.

Prior to embarking on product manufacturing, there is a definite need for the identification of the critical points where the probability of occurrence of a serious defect is quite high. Thus, the process control plans should be developed by applying the quality function deployment and process FMEA. These plans should include items such as

- Acceptance of standard definitions
- Procedures to monitor defects
- Approaches for controlling critical process points

### 19.4.4 Guidelines for Improving Design Quality

During the product design phase, there are various measures concerned professionals should take to improve quality. These include[10,11] designing for effective testing, simplifying assembly and making it foolproof, designing for robustness, minimizing the number of parts, reducing the number of different parts, using well-understood and repeatable processes, minimizing engineering changes to released products, eliminating adjustments, selecting components that can withstand process operations, and laying out components for reliable process completion. These factors may be taken into consideration during designing and/or during design reviews.

Past experience has shown that guidelines such as those listed above lead to many benefits, including

- Increase in part yield
- Decrease in degradation of performance with time
- Improvement in product reliability
- Reduction in part damage
- Better serviceability
- Improvement in consistency in part quality
- Reduction in the volume of drawings and instructions to control
- Lower assembly error rate

Today, many engineering systems use computer technology, to varying degrees. This means that it is important not only to have good-quality hardware, but also good-quality software. The software-development environment possesses certain characteristics that may adversely affect its quality, including outdated support tools, cost and time constraints, complex hardware, variations in programmer skill, poorly defined customer objectives, a small project staff, high programmer turnover, and software-naive customers.

Directly or indirectly, from the TQM perspective, some basic rules must be followed:[12]

- Do not leave management to managers alone. Remember that everyone in an organization is a manager of tasks or processes and, in fact, those closest to the task or process should play a leading role in its management.
- Quality through inspection is no longer a competitive option today. A sensible approach for companies to increase their market share is to design quality into products and processes.
- Random variability exists in all processes. Failure to take this into account by engineering design and control methods will lead to high production costs and out-of-specification products.
- Today's customers want reliable, safe, and low-cost products to satisfy their needs. Remember that use of the latest technology will not alone hold the market share; the manufacturer must also champion its customers' concerns.
- Remember that experimentation belongs on the manufacturing floor, not just in the research laboratory. It is impossible to reproduce the exact production environment in the laboratory. Further, do not overlook teaching the methods of experimentation to production people.

Additional information on improving design quality may be found in Refs. 13–15.

### 19.4.5 Taguchi's Quality Philosophy Summary and Kume's Approach for Process Improvement

Taguchi's approach was discussed earlier, but because of its importance, this section summarizes his quality philosophy again, in seven basic steps:[12,16]

1. A critical element of a manufactured item's quality is the total loss generated by that item to society as whole.
2. In today's market, continuous cost reduction and quality improvement are critical for companies to stay in business.
3. Design and its associated manufacturing processes determine, to a large extent, the ultimate quality and cost of a manufactured product.
4. Unceasing reduction in a product-performance characteristic's variation from its target value is part of a continuous quality-improvement effort.
5. The loss of customers due to variation in an item's performance is frequently almost proportional to the square of the performance characteristic's deviation from its target value.
6. The identification of the product and process parameter settings that reduce performance variation can be accomplished through statistically designed experiments.
7. Reduction in the performance variation of a product of process can be achieved by exploiting the product or process parameter nonlinear effects on performance characteristics.

To improve process, Kume[17] outlined a seven-step approach:

1. Select project.
2. Observe the process under consideration.
3. Perform process analysis.
4. Take corrective measures.
5. Evaluate effectiveness of corrective measures.
6. Standardize the change.
7. Review and make appropriate modifications, if applicable, in future plans.

## 19.5 QUALITY TOOLS AND METHODS

Over the years, many quality-improvement tools and methods have been developed by researchers and others. Effective application of these tools and techniques becomes a vital element in the success of the TQM concept during product design. Examples of these tools and techniques are control charts, fishbone or cause-and-effect diagram, Pareto diagram, Poka-yoke, force field analysis, benchmarking, Kaizen, customer needs mapping, Hoshin planning technique, and gap analysis.[4] These approaches are described below.[4]

### 19.5.1 Fishbone Diagram

This approach, also known as the cause-and-effect or Ishikawa diagram, was originally developed by K. Ishikawa in Japan. The diagram serves as a useful tool in quality-related studies to perform cause-and-effect analysis for generating ideas and finding the root cause of a problem for investigation. The diagram somewhat resembles a fishbone; thus the name. A typical fishbone diagram is shown in Fig. 19.1. The diagram depicts the "effect" on the right hand (i.e., in the "fish head"). The boxes in the main area are for writing in possible causes. All of these boxes (i.e., in the main area) are connected to the central "fish spine" or the main line. For example, in the case of total quality management, the "fish head" or "effect" box will become "customer satisfaction" and the boxes in the main area will represent people, methods, machines, materials, and so on.

Major steps for developing a fishbone diagram are as follows:[4]

- Establish problem statement.
- Brainstorm to highlight possible causes.
- Categorize major causes into natural grouping and stratify by steps or the process.
- Insert the problem or effect in the "fish head" box on the right-hand side. Develop the diagram by unifying the causes through following the necessary process steps.
- Refine categories by asking questions such as "What causes this?" and "Why does this condition exist?"

### 19.5.2 Pareto Diagram

An Italian economist, Vilfredo Pareto (1848–1923) developed a formula in 1897 to show that the distribution of income is uneven.[14,15] In 1907, a similar theory was put forward in a diagram by M. C. Lorenz, a U.S. economist. In later years, J. M. Juran[19] applied Lorenz's diagram to quality problems and called it *Pareto analysis*.

In quality-control work, Pareto analysis simply means, for example, that there are always a few kinds of defects in the hardware manufacture that loom large in occurrence frequency and severity. Economically, these defects are costly, and thus of great significance. Alternatively, it may simply be stated that on the average about 80% of the costs occur due to 20% of the defects.

The Pareto diagram, derived from the above reasoning, is helpful in identifying the spot for concerted effort. The Pareto diagram is a type of frequency chart with bars arranged in descending order from left to right, visually highlighting the major problem areas. The Pareto principle can be quite instrumental in TQM effort, particularly in improving quality of product designs.

### 19.5.3 Kaizen Method

"Kaizen"[4] means improvement in Japanese, and the Kaizen philosophy maintains that the current way of life deserves to be improved on a continuous basis. This philosophy is broader than TQM because it calls for ongoing improvement as workers, leaders, managers, and so on. Thus, Kaizen includes TQM, quality circles, zero defects, new product design, continuous quality improvement, customer service agreements, and so on.

Kaizen is often referred to as "the improvement movement" because it encompasses constant improvement in social life, working life, and the home life of everyone.

### 19.5.4 Force Field Analysis

This method was developed by Kurk Lewin[4] to identify forces existing in a situation. It calls first for clear understanding of the driving and restraining forces and then for developing plans to implement change.

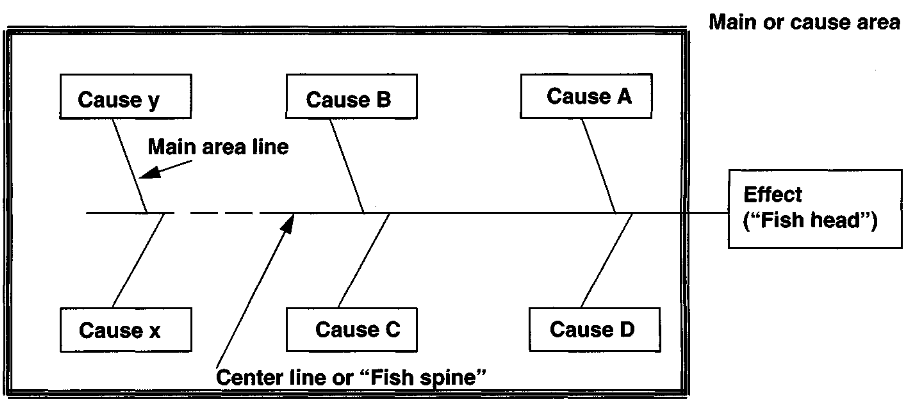


**Fig. 19.1** Fishbone diagram layout.

The change is considered as a dynamic process and as the result of a struggle between driving forces (i.e., those forces seeking to upset the status quo) and restraining forces (i.e., those forces attempting to maintain the status quo). A change occurs only when the driving forces are stronger than the restraining forces.

The group brainstorming method[20] serves as a useful tool to identify the driving forces and restraining forces in a given situation.

With respect to improving engineering design quality, the force field analysis facilitates changes in the following way:

- It forces the concerned personnel to identify and to think through the certain facets of an acquired change.
- It highlights the priority order of the involved driving and restraining forces.
- It leads to the establishment of a priorty action plan.

An example of using the force field analysis technique is given in Ref. 4.

### 19.5.5 Customer Needs Mapping Method

This approach is used to identify consumer requirements and then to identify in-house processes' ability to meet those requirements statisfactorily. A process's two major customers are the external customer (the purchaser of the product or service) and the internal customer (the next step in the process of receiving the output). Past experience has shown that the internal customer is often overlooked by groups such as inventory control, accounting, facilities, and computer.

Both the external and internal customer's wants or requirements can be identified through brainstorming, customer interviews, and so on.

Some of the advantages of customer needs mapping are as follows:

- It enhances the understanding of the customer background.
- It highlights customer wants.
- It translates customer needs into design features.
- It focuses attention on process steps important to customers.
- It highlights overlooked customer needs.

### 19.5.6 Control Charts

Control charts were developed by Walter A. Shewhart[21] of Bell Telephone Laboratories in 1924 for analyzing discrete or continuous data collected over a period of time. A control chart is a graphical tool used for assessing the states of control of a given process. The variations or changes are inherent in all processes, but their magnitude may be large or very small. Minimizing or eliminating such variations will help to improve quality of a product or service.

Physically, a control chart is composed of a center line (CL), upper control limit (UCL), and lower control limit (LCL). In most cases, a control chart uses control limits of plus or minus three standard deviations from the mean of the quality or other characteristic under study.

Following are some of the reasons for using control charts for improving product design quality:[20]

- To provide a visual display of a process
- To determine if a process is in statistical control
- To stop unnecessary process-related adjustments
- To provide information on trends over time
- To take appropriate corrective measures

Prior to developing a control chart, the following factors must be considered:

- Sample size, frequency, and the approach to be followed for selecting them
- Objective of the control chart under consideration
- Characteristics to be examined
- Required gauges or testing devices

### 19.5.7 Poka-Yoke Method

This is a mistake-proofing approach. It calls for designing a process or product so that the occurrence of any anticipated defect is eliminated. This is accomplished through the use of automatic test equipment that "inspects" the operations performed in manufacturing a product and then allows the product to proceed only when everything is correct. Poka-Yoke makes it possible to achieve the goal of zero defects in production process.

### 19.5.8 Benchmarking*

This may be described as a strategy of duplicating the best practice of an organization excelling in a specified business function. The benchmarking may be grouped into the following five categories:

1. *Competitive benchmarking* is concerned with identifying the important competitive characteristics of a competitive product or service and then comparing them to your own.
2. *Internal benchmarking* is concerned with identifying and comparing internal repetitive operational functions among divisions and/or branches.
3. *Industrial or functional benchmarking* is concerned with comparing functions within the same industry.
4. *Shadow benchmarking* is concerned with monitoring important product and service attributes of a dominant competitor in the field as well as meeting changes as they happen.
5. *World-class benchmarking* is concerned with comparing processes across diverse industries.

In order to perform benchmarking, two teams are formed: one for need assessment and one for actual benchmarking. The following factors should be identified for the need assessment:

- Key strategically important success factors for the organization
- The firm's differentiating factors from the point of view of the customer
- Factors that significantly impact quality, costs, or cycle times
- The most important area for improvement
- The data requirement for determining the critical success factor's effectiveness

The benchmarking team conducts its mission in six steps:

1. Developing operational definitions for the key success factors identified
2. Baselining operations by making use of the operational definitions developed
3. Identifying the best-in-class ideas through brainstorming
4. Collecting data through appropriate means
5. Performing analysis and communicating findings
6. Developing strategies by implementing procedures to lower the cycle time

In conducting benchmarking studies, it must be remembered that some of the common benchmarking characteristics are data-collection difficulty, cost and speed of performing benchmarking, risk of adoption, expected benefits, and difficulty in convincing management to adopt improvement ideas.

The following index could be used to measure the gap between the company performance and the benchmark performance:

$$G = \left(\frac{BP}{CP} - 1\right)(100) \tag{19.3}$$

where $G$ = the gap factor expressed in percentage
$CP$ = the (your) company performance
BP = the benchmark performance

**Example 19.2**
Assume that the benchmark response time to process a customer is 6 minutes and your firm's response time for the same process is 10 minutes. Calculate the value of the gap factor.

Substituting the given data into Eq. (19.3), we get

$$G = \left(\frac{6}{10} - 1\right)(100) = -40\%$$

There is a 40% gap in performance.

*This approach was briefly discussed earlier and is described again here because of its importance.

### 19.5.9 Hoshin Planning Method

This method,[22] also known as the "seven management tools," helps to tie quality-improvement activities to the long-term plans of the organization. Hoshin planning focuses on policy-development issues: planning objective identification, management and employee action identification, and so on. The following are the three basic Hoshin planning processes:

1. *General planning* begins with the study of consumers for the purpose of focusing the organization's attention on satisfying their needs.
2. *Intermediate planning* begins after the general planning is over. It breaks down the general planning premises into various segments for the purpose of addressing them individually.
3. *Detailed planning* begins after the completion of the intermediate planning and is assisted by the arrow diagram and by the process decision program chart.

The seven management tools related to or used in each of the above three areas are as follows:

***General***

1. Interrelationship diagram
2. Affinity chart

***Intermediate***

3. Matrix data analysis
4. Tree diagram
5. Matrix diagram

***Detailed***

6. Arrow diagram
7. Process decision program chart

Each of the above management tools is discussed below.

The *interrelationship diagram* is used to identify cause-and-effect links among ideas produced. It is particularly useful in situations where there is a requirement to identify root causes. One important limitation of the interrelationship diagram is the overwhelming attempts to identify linkages between all generated ideas.

The *affinity chart* is used to sort related ideas into groups and then label each similar group. The affinity chart is extremely useful in handling large volumes of ideas, including the requirement to identify broad issues.

The *matrix data analysis* is used to show linkages between two variables, particularly when there is a requirement to show visually the strength of their relationships. The main drawback of this approach is that only two relationships can be compared at a time.

The *tree diagram* is used to map out required tasks into detailed groupings. This method is extremely useful when there is a need to divide broad tasks or general objectives into subtasks.

The *matrix diagram* is used to show relationships between activities, such as tasks and people. It is an extremely useful tool for showing relationships clearly.

The *arrow diagram* is used as a detailed planning and scheduling tool and helps to identify time requirements and relationships among activities. The arrow diagram is an extremely powerful tool in situations requiring detailed planning and control of complex tasks with many interrelationships.

The *process decision program chart* is used to map out contingencies along with countermeasures. The process decision program chart is an advantage in implementing a new plan with potential problems so that the countermeasures can be thought through.

### 19.5.10 Gap Analysis Method

This method is used to understand services offered from different perspectives. The method considers five major gaps that are evaluated so that when differences are highlighted between perceptions, corrective measures can be initiated to narrow the gap or difference.

1. *Consumer expectation and management perception gap*
2. *Management perception of consumer expectation and service quality specification gap*
3. *Service quality specifications and service delivery gap*
4. *External communication and service delivery gap*
5. *Consumer expectation concerning the service and the actual service received gap*

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