TOTAL QUALITY MANAGEMENT

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OUTLINE

- INTRODUCTION
- THREE QUALITY GURUS
- COMMONALITY OF THEMES OF QUALITY
- DIFINITION OF QUALITY
- FIVE APPROACHES OF DEFINING QUALITY
- SYSTEM APPROACH FOR TQM
- TRIANGLE OF WISDOM
- TQO HRM
- CUSTOMER SATISFACTION
- INDICATORS FOR CUSTOMER SATISFACTION
- BENEFITS OF TQM
- CONCLUSION

INTRODUCTION TO TQM

TQM is the integration of all functions and processes within an organization in order to achieve continuous improvement of the quality of goods and services. The goal is customer satisfaction.

THREE QUALITY GURUS

- **Deming:** the best known of the “early” pioneers, is credited with popularizing quality control in Japan in early 1950s.Today, he is regarded as a national hero in that country and is the father of the world famous Deming prize for quality.

JURAN

- Juran, like Deming was invited to Japan in 1954 by the union of Japanese Scientists and engineers.

- Juran defines quality as fitness for use in terms of design, conformance, availability, safety and field use. He focuses on top-down management and technical methods rather than worker pride and satisfaction.

Philip Crosby: author of popular book Quality is Free. His absolutes of quality are:

- Quality is **defined** as conformance to requirements, not "goodness"
- The **system** for achieving quality is prevention, not appraisal.
- The performance **standard** is zero defects, not "that's close enough"
- The **measurement** of quality is the price of non-conformance, not indexes.

COMMONALITY OF THEMES OF QUALITY

- Inspection is never the answer to quality improvement, nor is “policing”.
- Involvement of leadership and top management is essential to the necessary culture of commitment to quality.
- A program for quality requires organization-wide efforts and long term commitment, accompanied by the necessary investment in training.
- Quality is first and schedules are second.

DIFINITION OF QUALITY

- The concept and vocabulary of quality are elusive. Different people interpret quality differently. Few can define quality in measurable terms that can be proved operationalized. When asked what differentiates their product or service;

  The banker will answer" service"

  The healthcare worker will answer "quality health care"

  The hotel employee will answer "customer satisfaction"

  The manufacturer will simply answer "quality product"

FIVE APPROACHES OF DEFINING QUALITY

- Harvard professor David Garvin, in his book *Managing Quality* summarized five principal approaches to define quality.

- **Transcendent**
- **Product based**
- **User based**
- **Manufacturing based**
- **Value based**

TRANSCENDENTAL VIEW

- Those who hold the transcendental view would say “I can’t define it, but I know it when I see it”
- Advertisers are fond of promoting products in these terms.

  “ Where shopping is a pleasure” (supermarket). “We love to fly and it shows" (airline).

  Television and print media are awash with such indefinable claims and therein lies the problem:
- Quality is difficult to define or to operationalize. It thus becomes elusive when using the approach as basis for competitive advantage. Moreover, the functions of design, production and service may find it difficult to use the definition as a basis for quality management.

PRODUCT BASED

- Quality is viewed as a quantifiable or measurable characteristic or attribute. For example durability or reliability can be measured and the engineer can design to that benchmark.
- Quality is determined objectively.
- Although this approach has many benefits, it has limitation as well. Where quality is based on individual taste or preference, the benchmark for measurement may be misleading.

USER BASED

It is based on idea that quality is an individual matter and products that best satisfy their preferences are those with the highest quality. This is rational approach but leads to two problems;

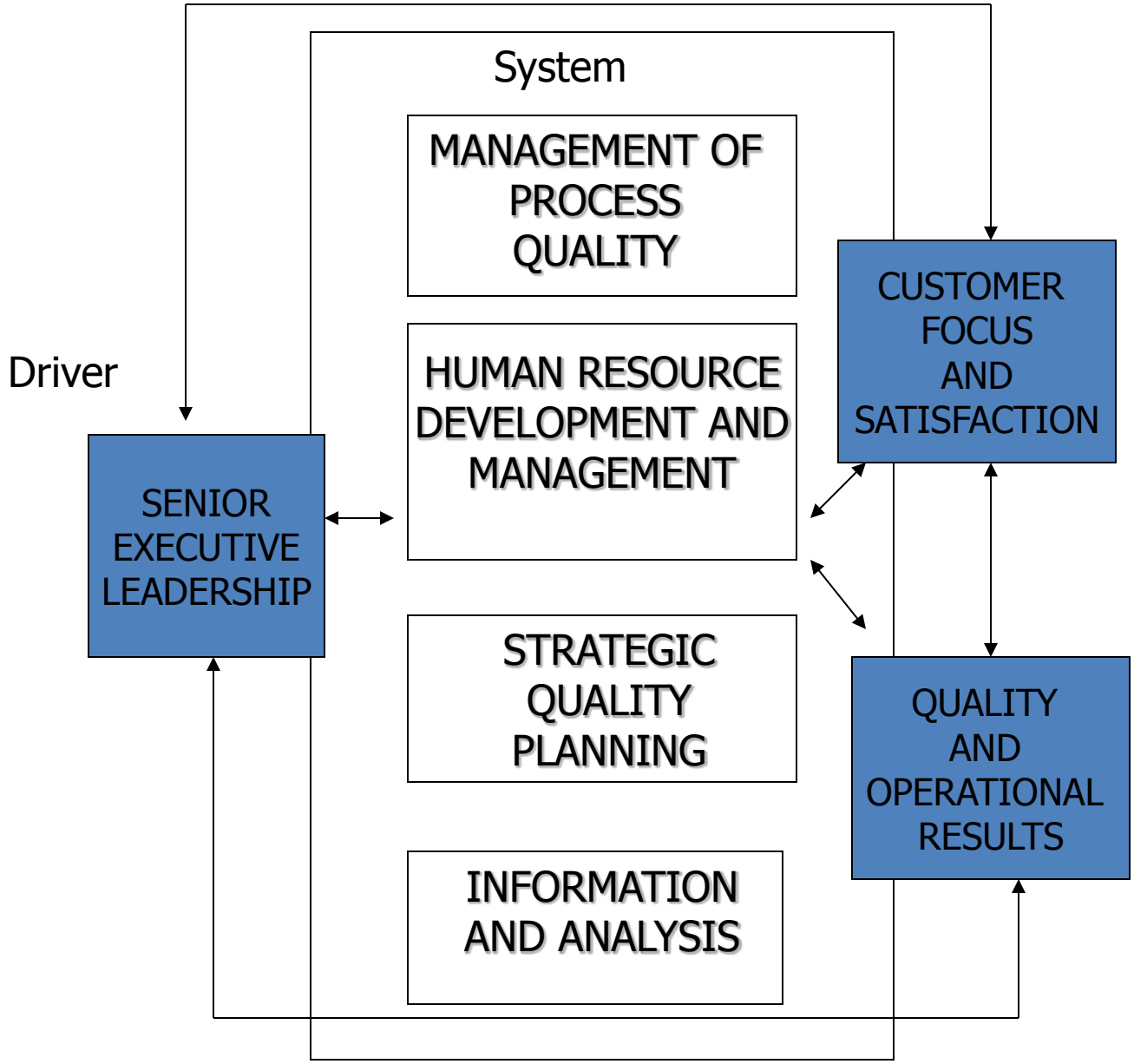
- Consumer preference vary widely and it is difficult to aggregate these preferences into products with wide appeal. This leads to the choice between a niche strategy or a market aggregation approach which tries to identify those product attributes that meet the needs of the largest number of consumers.
- Another problem concerns the answer to the question “Are quality and customer satisfaction the same?” the answer is probably not. One may admit that a Lincoln continental has many quality attribute, but satisfaction may be better achieved with an Escort.

MANUFACTURING BASED

- Manufacturing-based definitions are concerned primarily with engineering and manufacturing practices and use the universal definition of “conformance to requirements”. Requirements or specifications are established by design and any deviation implies a reduction in quality. The concept applies to services as well as product. Excellence in quality is not necessarily in the eye of the beholder but rather in the standards set by the organization.
- This approach has the serious weakness. The consumer’s perception of quality is equated with conformance and hence is internally focused.

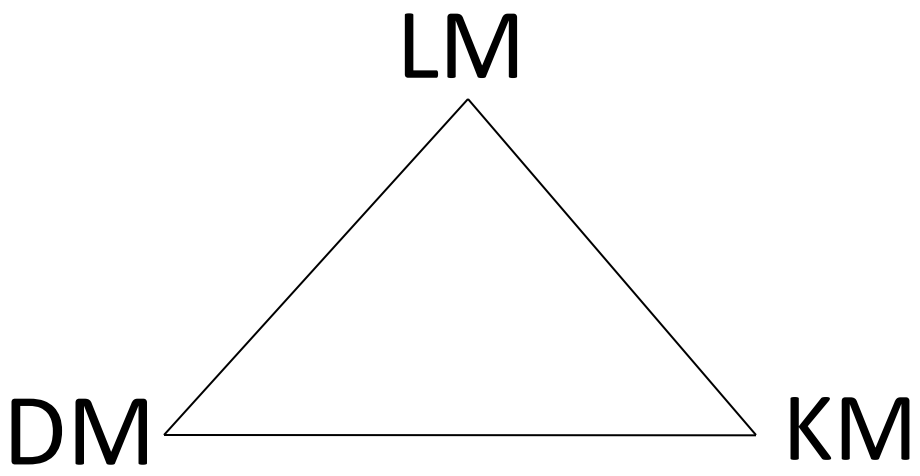
VALUE BASED

- It is defined in term of costs and prices as well as number of other attributes. Thus, the consumer's purchased decision is based on quality at an acceptable price. This approach is reflected in the popular *Consumer Reports* magazine which ranks products and services based on two criteria: Quality and Value.
- The highest quality is not usually the best value. That designation is assigned to the "best- buy" product or service.



SYSTEM APPROACH FOR TQM

TOW
Triangle of wisdom



CHARACTERISTICS OF TQM LEADER

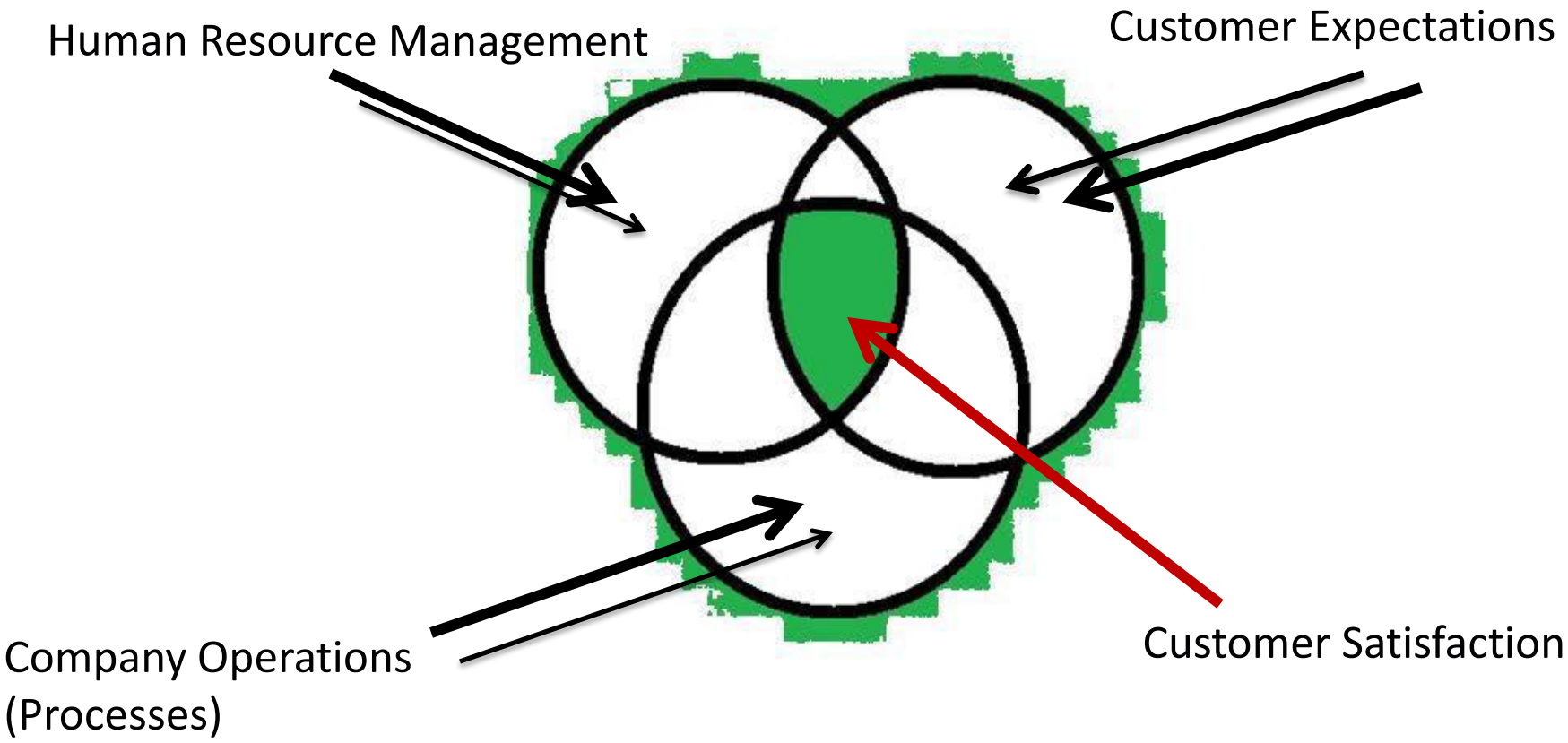
- Visible, Committed and Knowledgeable
- A Missionary Zeal
- Aggressive Targets
- Strong Drivers
- Communication of Values
- Organization
- Customers Contact

TQO HRM

Five Principles are:

- Quality Work the First Time
- Focus on the Customer
- Strategic Holistic Approach to Improvement
- CI as a Way of Life
- Mutual Respect and Teamwork

Customer Satisfaction
Three Part System



INDICATORS FOR CUSTOMER SATISFACTION

- Frontline empowerment
- Excellent hiring, training, attitude and morale for front line employees
- Proactive customer service system
- Proactive management of relationship with customers
- Use of all listening posts
- Quality requirements of market segment
- Commitment to customers
- Understanding customer requirements
- Service standards meeting customers requirements

BENEFITS OF TQM

- Greater customer loyalty
- Market share improvement
- Higher stock prices
- Reduced service calls
- Higher prices
- Greater productivity

CONCLUSION

Quality begets customers and customers beget quality. Let us all have action plans to support quality, this will make the world happy and earn us the blessing of God Almighty.

CHAPTER 8

Quality Assurance

Inside this Chapter

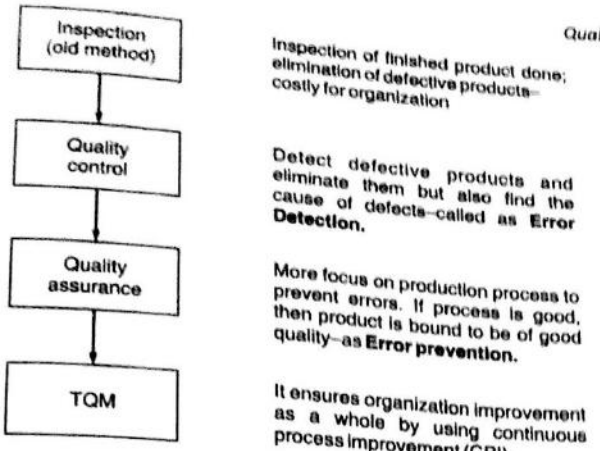


Fig. 8.1 Evolution of QA

But please keep the following points in mind:

1. Plan software assurance along with the management and engineering plan.
2. Phase assurance activities properly. **For example,** design standards must be produced will before design starts.
3. Procure or develop CASE tools before hand only.

A complete SQA plan must be now implemented. Well trained and qualified staff must be obtained. All of the management activities needs assurance staff as a resource to help complete them.

8.2 Quality Plan Objectives

The major objectives of SQA process are to ensure that the software development and software assurance processes comply with **SQA plans and standards.** To aim is to recommend, process improvements. SQA activities include **product evaluation** and **process monitoring**, which ensure the product and the process used in the development are correctly carried out and standards are followed. The quality assurance process uses the **system requirements** and **information** about the purpose and criticality of the software, to evaluate the outputs of the software development and software assurance processes.

Note

Audit is a fundamental SQA technique.

It looks at a process or product in depth, comparing then with established standards and procedures. SQA includes conduct of FTRs, using technical methods, software testings, standards enforcement, change control, metric and record keeping and reporting.

8.3 Planning Process Overview

To win top-level management's favor, software quality program (plan) is essential. It involves following steps:

1. **Preparation of SQA plan:** It specifics its goals, tasks to be performed and the standards and procedures against which the development work is to be measured.
2. **SQA monitoring and controlling:** It deals with the configuration management monitoring, V & V monitoring, formal test monitoring and FTRs.
3. The effective error detection will be ensured by the **testing phase.**
4. The appropriate standards useful to the products and process will be defined and illustrated in the phase **setting of standard and procedures.**
5. Finally, the development of relevant metrics and models will be discussed in the **development and collection of relevant metrics and model phase.**

8.4 Business Plan and Quality Plan

Quality plans define the specifics of how a project intends to implement the organization's quality management system. The purpose is to meet the quality goals and objectives of the organization and of that project. The **software quality plans** can be defined in a stand-alone software quality plan document or incorporated into the project plans. Many other quality plans exist like.

- V & V plan
- CM plan
- Risk management plan etc.

These can also be incorporated as subplans in either the project plan or software quality part or they may be documented as stand-alone planning documents. This means that the format of the plans is not significant. **Phase note that, however, quality planning takes place and is well documented.** There may also be higher-level program or **product-level quality plans** that the **project-level quality plans** are based on.

Quality planning can be done at:

(a) Organizational level.
(b) Unit level.
(c) Project level.

At organizational level, quality planning means that the company should define some policy definition and quality plans on the basis of its vision, mission and policies as set by senior management. The purpose is to understand future customers, their needs and what they expect from company. Further more, these should be measurable too.

At unit level, focus is on the operational quality plans that must be synchronized with the organizational policies and strategies. **Also understand here that the project plans and quality plan at unit level must be consistent with the strategic quality plans at the company level.**

At the project level, the projects should plan for quality at the project level. These are generally strategic-level quality plans with details of responsibilities and actions the project plan must define aspect of quality plan at the project level. **Note that the quality objectives of the project may be inherited from the organizational level objectives or may be defined separately for the project.**

Note

An organization should use good inputs as needed by quality planning so that the output of the processes match with the organization's business plans. It includes people, machines, materials and methods as inputs.

Sahi main

Fatri rahi ho ??

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Quality planning involves the following four (4) steps as follows:

S1: **Definition of processes,** procedures, standards and guidelines for developing and testing software. Reviewing of these standards is also to be done as it improves software process maturity.

S2: **Performing quality operations** like verification and validation as per process definition during entire SDLC.

S3: **Regular audits are to be done.**

S4: **Collecting metrics** and defining **action plans** for the weaker software processes is also to be done.

Note

Quality is not by accident but it is an outcome of planned activities performed during SDLC.

8.5 Total Quality Management (TQM)

Total Quality Management (TQM) means **"Quality in Totality".** We can say that — **"TQM is a systems approach to management that aims to continuously increase value to customers by designing and continuously improving the organizational process and systems. TQM involves all employees and extends backward and forwards to include the supply chain and the customers. TQM is concerned with managing the entire system and not only subsystems or functional departments."**

The need is to integrate TQM with employee involvement. TQM is the model for deciding what is important to work on while employee involvement is a model for deciding how to go about working on these objects.

Principles of TQM

General

1. Get to know the next and final customer.
2. Get to know the direct competitors.
3. Dedicate to continual, rapid improvement in quality, response time, flexibility and cost.
4. Achieve unified purpose via extensive sharing of information and involvement in planning and implementation of change.

Design and Organization

5. Cut the number of components or operation and number of suppliers to a few good ones.
6. Organize resources into chains of customers, each chain must be self-contained and focused on a customer.

Operations

7. Cut flow time, distance, inventory and space along the chain of customers.
8. Cut setup, changeover, get ready and start-up time.
9. Operate at the customer's rate of use or a smoothed representation of it.

Human Resource Development

10. Continually invest in human resources through cross training, eduction, job switching and multi-year re-assignments and improved health, safety and security
11. Develop operator of products, processes and outcomes via broadened ownership like reward and recognition

Quality and Process Improvement

12. Make it easier to produce or provide the product without mishap or process variation
13. Record and own quality, process and mishap data at the work place
14. Ensure that front-line associates get first chance at process improvement before staff experts

Accounting and Control

15. Cut transactions and reporting, control causes and measure performance at the source, not via periodic cost reports

Capacity

16. Maintain/improve present resources and human work before thinking about new equipment and automation
17. Automate incrementally when process variability cannot otherwise be reduced.
18. Seek to have workstations, machines, flow lines, cells for each product per customer family

Marketing and Sales

19. Market and sell your firm's increasing customer-oriented capabilities and competencies so that a good decision can be made. This is especially true for principle no. 4; achieve unified purpose via extensive sharing of information involvement in planning and implementation of change.

Principles 6 to 18, collectivity, are aimed at driving out costly overheads, speeding up the design and production process, improving flexibility of human and physical resonances and eliminating uncertainties caused by rework and shaky suppliers.

8.6 TQM Concepts

Total Quality Management (or TQM) is the application of quality principles to all facts and business processes of an organization. Dr. Edward Deming implemented quality management system driven by **"Total Quality Management"** and **"Continual Improvement"** in Japan. It resulted in repetitive, cost effective processes with an intention to satisfy customer requirements and achieve customers satisfaction.

The QA manager has very wide authority for setting and monitoring quality standards throughout company's functioning. The QA manager than reports directly to the chief executive. The total QA approach to reliability and quality can be very useful when applied to correct quality when it is in doubt.

The incorporation of a TQM philosophy would no doubt add to the initial costs of operation and may even result into a reduced profit situation because it takes some time to build new quality culture. However, over the preliminary step is over and people in the organization get tuned to the new system, this initial investment would generate more payback in years to come than they get otherwise. Then, on, TQM will only be gainful.

TQM is a systems approach to management that aims to continuously increase value to customers by designing and continuously improving the organizational process and systems. TQM involves all employees and extends backward and forward to include the supply chain and the customers.

Note

Good QSE (Quality System Engineering) will result in a TQM system which will provide for a set of principle activities.

KPA (Key Process Ares) of a TQM System

1. **Pre-production Quality Evaluation:** This implies that **clear procedures** are defined to analyze both the product and process design. This analysis must conclude whether or not the design will read to fulfillment of customer's need.
2. **Quality Planning–Product and Process:** This means that plans must be formalized before the start of manufacturing as to how to measure, attain and control the desired product quality and consistency of manufacturing process.
3. **Quality Planning–Purchase Activities:** This provides the produces necessary, to control the quality of purchased material. Such procedure must clearly delineate to vendors, the **quality requirements** and how they can conform to them.
4. **Quality Evaluation–Product and Process:** This means **putting into practice what was planned.** It includes:
   - Establishment of quality checks.
   - Provision of adequate measuring means
   - Proper calibrations of devices
   - Maintain proper quality records.
5. **Quality Information–System:** Quality information systems means **how this information can be analyzed** and **properly utilized to control the quality activities.**
6. **Post Production Quality Service:** It refers to **"after-sales-service".** It includes establishment of procedures to satisfy customers.

Total quality in business strategy shows our managers how to operate within a business by focusing on customer. TQ focuses first and foremost on **"customer satisfaction". Please understand that the main focus is the customer and not the competitor. Also understand that by delivering superior value to the customers, the competitors are left in dust.** We draw a flowchart to show TQM Implemntation process. (see Fig. 8.2).

8.7 Zero Defect Movement

Zero Defects (ZD) is an approach that attempts to ensure that all processes are performed without error, by providing training and motivation to all of the people concerned. It can generate improvements but it is difficult to sustain. It is not the best approach.

From 1970 to till date, Philip Crosby is noted for his ideas relating to the cost of quality, The cost of quality is incurred as a result of producing poor-quality products and services. The essence of crosby's teaching is contained in what he calls as **"The Four Absolutes of Quality"**:

1. Quality is conformance to requirements and not goodness.
2. The system is prevention, not appraisal.
3. The performance should be **"Zero Defect".**

4. The measurement of quality is the price of non-conformance to requirements, not quality indices.

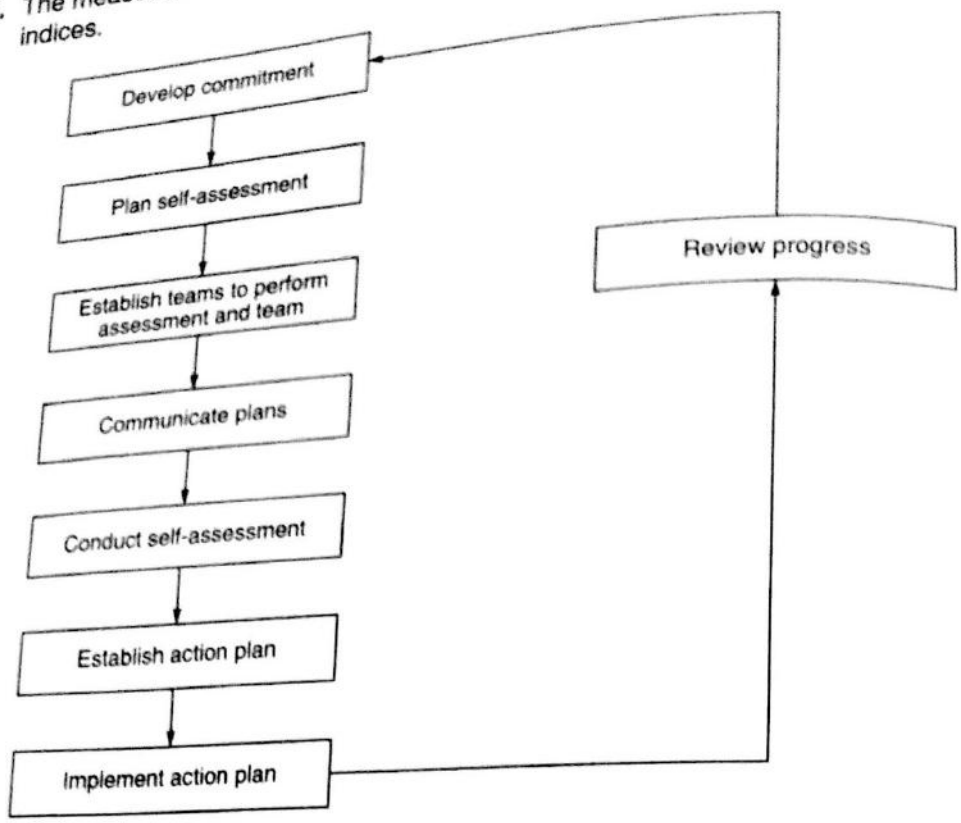


Fig. 8.2 Flowchart of TQM Model

Observe a **Zero Defect Day:** To create an event that will let all employees realize through a personal experience that there has been a change.

Management does not want to delay the launch of a product unless it is a mission-critical project, where the goal is to have a **zero-defect product.**

SUMMARY

In this chapter, we have seen what quality assurance is? How to plan quality and what are its objectives? It explains the planning process. It relates business plan with quality plan. Finally, it discusses about how total quality can be achieved and how zero-defect movement should occur.

Multiple Choice Questions

1. QA ensures that:
   (a) Software is good.
   (b) Management is good.
   (c) Software conforms to technical requirements.
   (d) None of the above
2. The fundamental SQA technique is:
   (a) Testing
   (b) Auditing
   (c) Meeting
   (d) None of the above

3. Quality is:
(a) By accident (b) Purch
(c) Planned activities during SDLC (d) None

4. Total Quality Management means:
(a) Quality in Totality (b) Quali
(c) Cost of quality (d) None

5. According to crosby:
(a) Performance should be "zero defect"
(b) Performance should have 0/1 defects.
(c) Performance should not be on the basis
(d) None of the above

6. Two commonly used metrics of quality are:
(a) Defect count and rework cost (b) LOC
(c) FP count and project cost (d) None

7. A quality factor that reduces the project's dev
(a) Reliability (b) Reus
(c) Re-engineering (d) None

8. The goal is to have a:
(a) Zero-defect product (b) Zero
(c) Defect product (d) None

9. Quality is NOT manufactured, it is:
(a) Engineered (b) Purc
(c) Hired (d) None

10. The average time for a system to perform wi
(a) MTBF (b) MTT
(c) MTS (d) Non

ANSWER

1. (c) 2. (b) 3. (c)
6. (a) 7. (b) 8. (a)

Conceptual Short Quest

Q.1. Differentiate between Tools and Techniques?

Ans.

Tools
1. Tools are useful only if technique is available to use.
2. Different techniques may use the same tool to achieve different results.
3. Tool improvement needs technological change.
4. Contribution of tolls in improvement is limited.

Q. 2. Distinguish between Guidelines and standards?

Ans.

Guidelines	Standards
1. They are suggested ways of doing things by some experts.	1. Standards improve quality.
2. Guidelines may not be followed.	2. Standards are a must.
3. Guidelines may or may not be written.	3. Standards must be written to avoid any misunderstanding or loss of communication.

Q. 3. Differentiate between internal and external customer?

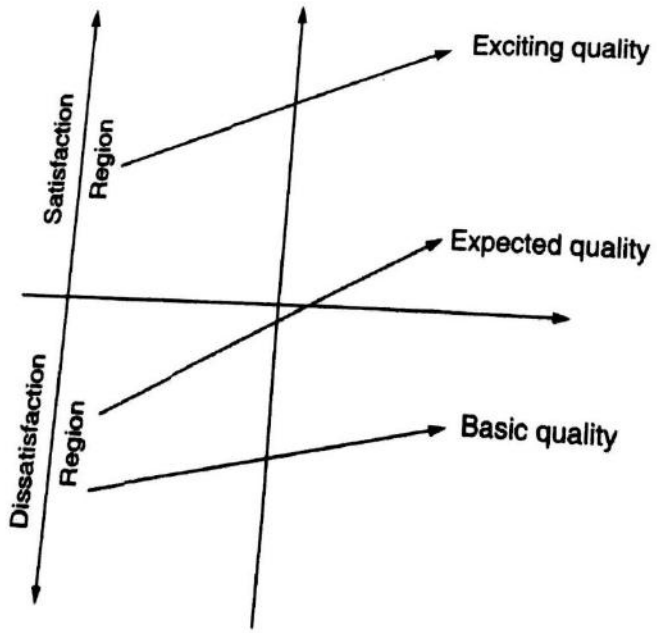
Ans. Internal Customer: Internal customer satisfaction philosophy is guided by the principles of **'Total Quality Management'**. There are different departments in a company. Thus, one department acts as a supplier or customer of another department. So, every department must identify its customer and supplies and try to filfill their requirements. Thus, external requirements of customer are satisfied.

External Customer: The are their final users like those who buy you software. SRS is prepared. Customers are paying us. Customer is the king !

Q. 4. Explain Kano's model of quality.

Ans. According to Noritaki model, quality can be of 3 types:

(a) **Basic Quality:** There is a basic level of quality that a customer expects the product to have. These are quality requirements that are assumed by the customer and are typically not explicitly stated or requested. **For example,** customers expect the software vendor to provide a manual also when they are purchasing software(s). They will not ask for these items but will expect then to be there. This level of quality does not satisfy the customer. This is shown in graph also.



(b) **Expected Quality:** These are these quality requirements that the customer explicitly requests, For example, they will state their preferences for the software versions when they buy. The customer will be dissatisfied if this level of quality is NOT met and increasingly satisfied as this quality level increases.

(c) **Exciting Quality:** Say, we wish to develop a word processor software. It has all features but if we also include features like keep sounds, music etc. The features customer need but he may not state them. These are exciting features.

Q. 5. What is Benchmarking?

Ans. It is the process used by an organization to identify, understand, adapt, adopt outstanding practices and processes from others.

Q. 6. What are the advantages and disadvantages of formal meetings?

Ans.

Advantages	Disadvantages
1. Allows multiple people to express opinions and issues. 2. Creates team synergy. 3. Can discuss wide range of topics and issues in detail. 4. Two-way communications.	1. Can degrade into time-wasters. 2. Some people may feet uncomfortable. 3. All topics may not be relevant to all people. 4. Difficult when people are at remote (far) locations.

REVIEW QUESTIONS

1. The company maintains information system for the purpose of meeting customers needs. How are these needs determined for external customers? For internal customers?
2. 'Software quality is not by accident'. Justify the statement.
3. How can we plan quality?
4. What is TQM? Explain TQM concepts.
5. What is 'Zero Defect' Movement?
6. Explain different types of quality requirements?
7. How testing and SQA are related?
8. Assume that you are responsible for developing a web-based application and in application you need to prepare the Quality Control (QC) check list for conducting a base testing. In this require mention the specific items, responses and comments that n to be incorporated in the checklist.

Seriously? :P

Quality Standards

Inside this Chapter

9.0 Introduction

Literature says that unlike standardization in the communications field, in software development, standardization is viewed with mixed-type of reactions. Opponents (not in favor) say that standardization curtails individual drive to be innovative. **Proponents** (in favor) say that standards reduce the activity of reinventing the same or similar processes for development and QA. **Please note that the repeatability of processes is the key benefit of this standardization. Also note that repeatability reduces the cost of software development and produces a base quality level of software products.**

9.1 Quality Models/Standards/Guidelines

Standards have always been associated with quality measures. They are the benchmarks against which the quality of the software application is measured.

One of the most vital attribute of standards is **consistency.** Standards must be **flexible** too, in order to adapt to changing technology. Standards should be **usable** and **understandable.** Standards can **steam line transitions** when developers leave projects. In nutshell, standards are **key components** to successful software development.

As per Kramm and Graziano, using standards:

(a) Provides **consistency** a cross projects.
(b) Eliminates conjecturing (i.e., guess works).
(c) Improves model's maintainability.
(d) Reduces long-term costs
(e) Promote reusability.

The ISO (International Standard Organization) has developed a series of standards, collectively known as **ISO 9000**. ISO was founded in 1946 in Geneva, Switzerland. It develops and promotes international standards in the field of **quality assurance** and **quality management** ISO 9000 standards are generally applicable to all tangible products manufactured-from fans and light to software. ISO standards are reviewed and updated from time to time (once every 5–8 years). The latest ISO 9000 standards released in 2000 are named as ISO 9000: 2000. It has 3 components:

ISO 9000 : Fundamentals and Vocabulary
ISO 9001 : Requirements
ISO 9004 : Guidelines for performance improvements.

Note

ISO 9002 — Deals with quality system model for QA in production
ISO 9003 — Deals with quality system model for QA in testing product.

9.2 Types of Models

To quantitatively and qualitatively evaluate the software quality, metrics users need to establish a quality metrics models. Most of the quality models are hierarchical models. Models may be:

(a) **Theoretical models:** Based on hypothesis relations among variables.
(b) **Data-driven models:** Based on statistical analysis.
(c) **Combined models:** Here, intuition is used to find the basic type of model and data analysis is used to find model's constants.

There are 2 terms used here:

(a) Quality Factor
(b) Quality Criterion.

A **quality factor** represents a behavioral characteristic of a system. Some high-level quality factors are correctness, reliability, efficiency, testability, portability and reusability (as per McCall's quality factors). On the other hand, **quality criterion is an attribute of a quality factor that is related to software system. Please note that a highly modular software allows designers to add cohesive components in one module so as to increase the system's maintainability.** Similarly, traceability of a user requirement allows developers to accurately map the requirement to a subset of the modules, thus increasing the system's correctness. Some quality criteria relate to products and some to personnel. For e.g., **modularity** is a **product-level quality criterion** whereas **training** relates to **development** and SQA people.

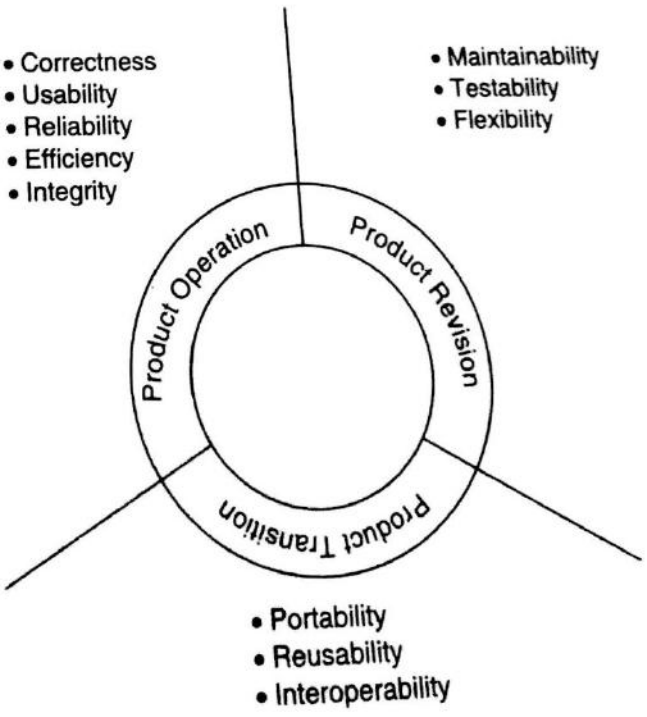


Fig. 9.1 McCall's Quality Factors.

According to McCall et at., there are 23 quality criteria (three quality categories) as follows:

The relationship between quality factors and quality criteria is also shown in Fig. 9.1. **It is clear from the figure that an arrow from a quality**

criterion to a quality factor means that the quality criterion has a positive impact on the qu
factor. For example, traceability has a positive impact on correctness.

In general, quality factors are NOT completely independent. **Please note the following:**

1. These quality factors are inversely proportional i.e., if we try to improve one quality factor another one may be degraded. **For example,** if a software is made more testable then its efficiency will go down. Similarly, an effort to make code portable will reduce its efficiency
2. Some quality factors have a positive impact on others. **For example,** an effort to enhance the correctness of a system will increase its reliability. Similarly, if we enhance system testability, we will improve its maintainability too.

The relationship diagram is shown below:

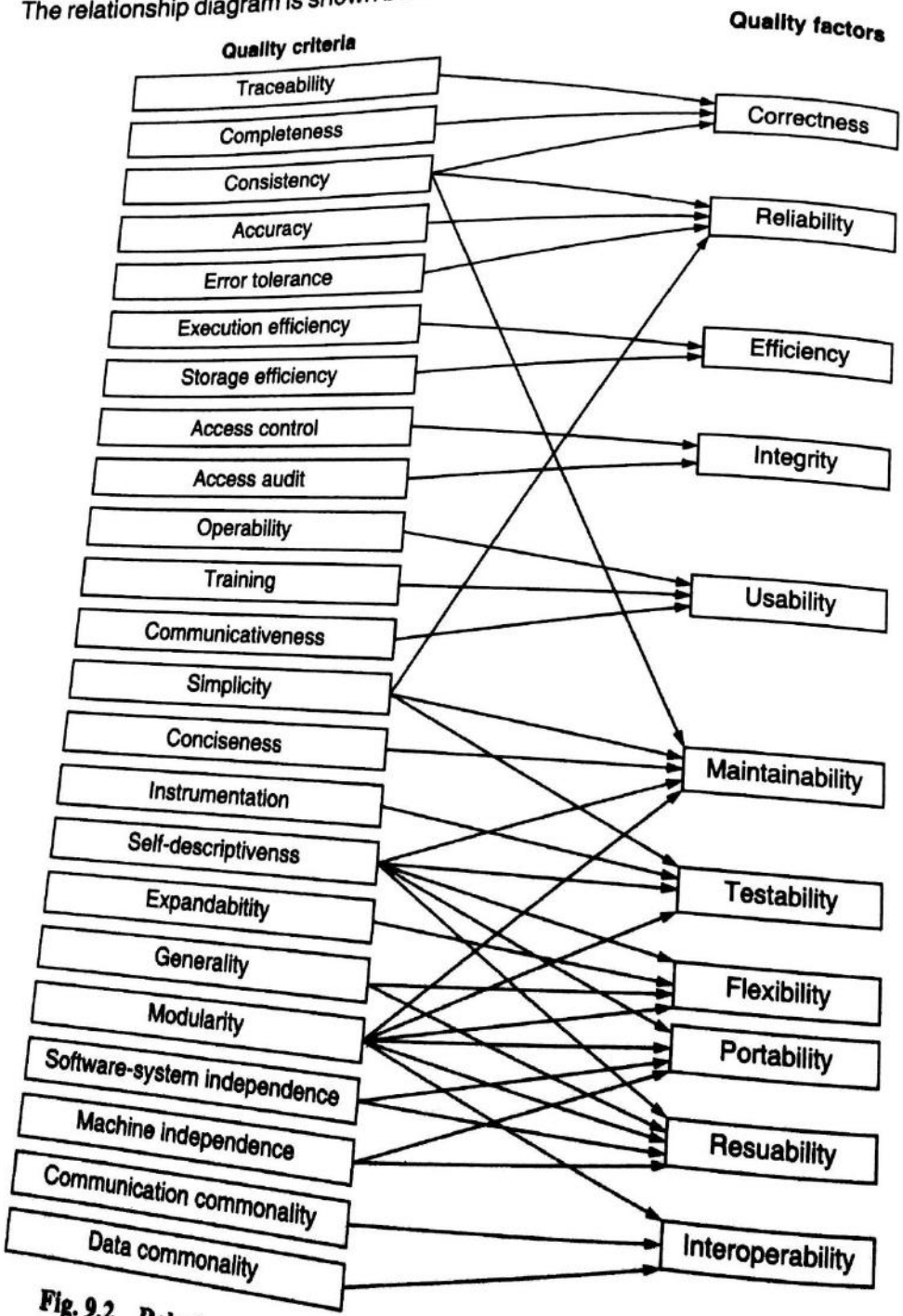


Fig. 9.2 Relationships between quality factors and qualit

Another quality model, very recent one is ISO 9126.

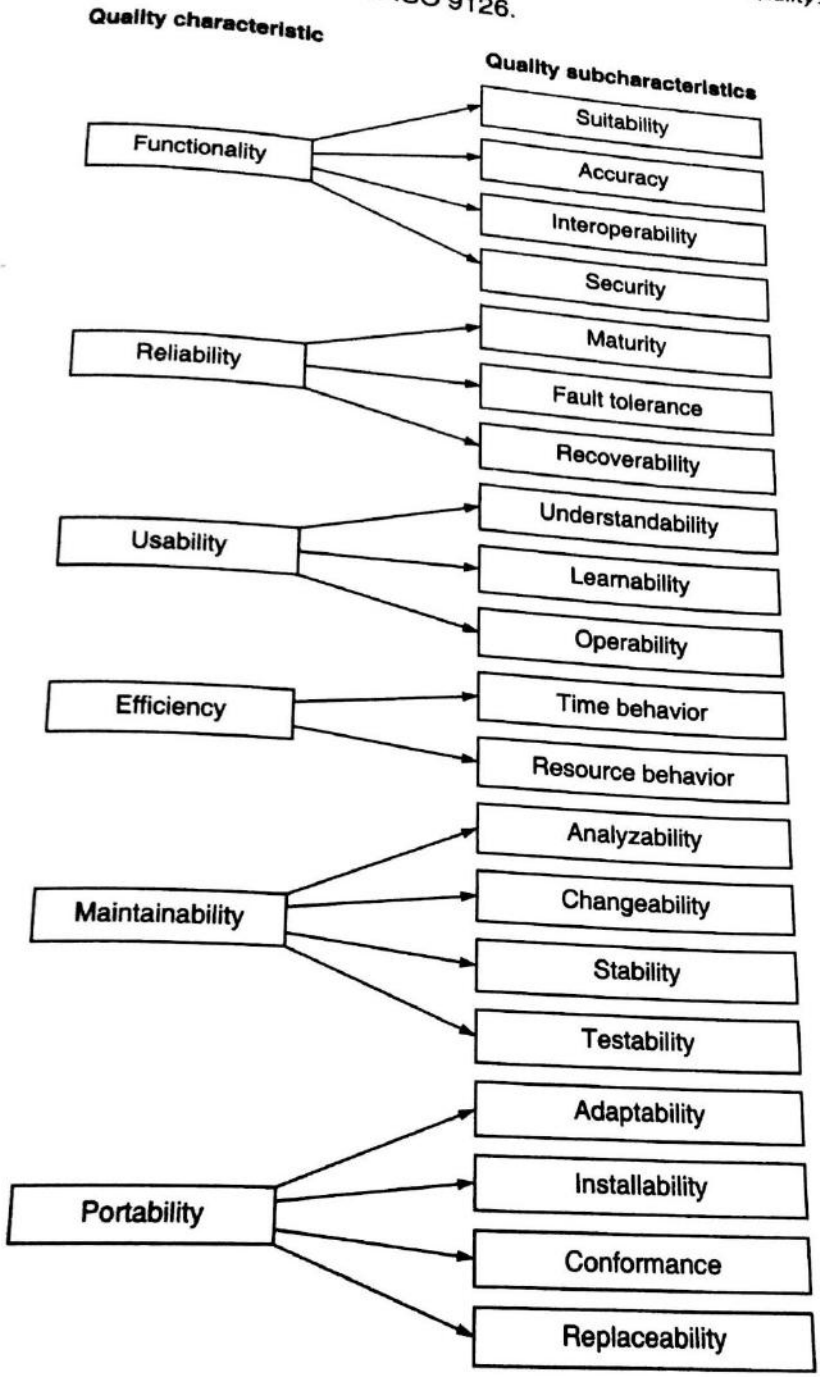


Fig. 9.3 ISO 9126 Model

ISO 9126 defines 6 categories of quality characteristics as follows:

1. **Functionality:** The ability of a system to perform required functions that satisfy user's need.
2. **Reliability:** A set of attributes that give the ability of a software to do failure-free operation under stated conditions for a stated period of time.

3. **Usability:** The ease with which a software can be used by its end users.
4. **Efficiency:** A set of attributes showing relationship between the software's performance and the amount of resource used under stated conditions.
5. **Maintainability:** The ease with which a software can be changed like corrections, improvements of adaptations of software to environmental changes etc.
6. **Portability:** The ability of a software system to run on different platforms both hardware and software platforms.

Actually, ISO 9126 standard includes a quality model that further decomposes the quality characteristics into more correct subcharacteristics. Like, probability characteristic has been decomposed into 4 subcharacteristics — adaptability, insatiability, conformance and replaceability. There are broad and independent quality characteristic and totally 20 subcharacteristics. We define each of them.

Quality Characteristics (6):

1. **Functionality:** The extent to which the software performs intended functions that satisfy customer's need.
2. **Reliability:** The ability of a software to perform (run) without fasting under stated conditions for a stated period of time.
3. **Usability:** The ease with which the users can use and understand the system.
4. **Efficiency:** A set of attributes that bear on the relationship between the software's performance and the amount of resource used under stated conditions.
5. **Maintainability:** The ease with which the software can be changed, improved and corrected.
6. **Portability:** The ability of software to run on any platform (hardware or software environments).

Let us now define 20 subcharacteristics under these 6 quality characteristic, as given by ISO 9126 software quality model:

1. **Suitability:** The capability of the software to provide an adequate set of functions for specified tasks and user objectives.
2. **Accuracy:** The capability of the software to provide the right or agreed upon results (as agreed in SRS).
3. **Interoperability:** The capability of the software to interact with one or more other systems (softwares). Like, Java with Oracle 8i (RDBMS).
4. **Security:** The ability of software to prevent or deny unintended access.
5. **Maturity:** The ability of the software to avoid failure as a result of faults in the software.
6. **Fault Tolerance:** The ability of the software to maintain a specified level of performance in case of faults.
7. **Recoverability:** The ability of the software to reestablish its level of performance and recover data directly in case of a failure.
8. **Understandability:** The ability of the software product to enable the user to understand whether the software is suitable or not.
9. **Learnability:** The ability of the software to enable the user to learn its applications.
10. **Operability:** The capability of the software to enable a user to operate it.
11. **Attractiveness:** The capability of the software to be liked by the user.
12. **Time Behavior:** The ability of software to provide suitable response, processing times and through put rates when performing its functi

13. **Resource Utilization:** The ability of software to use appropriate resources in an appropriate time when the software performs its function under stated condition.
14. **Analyzability:** The capability of the software to be diagnosed for deficiences or causes of failures in software.
15. **Changeability:** The ability of a software to implement change.
16. **Stability:** The ability of software to optimize unexpected effects from modifications of the software.
17. **Testability:** The ability of the software to enable the changed software to be validated.
18. **Adaptability:** The capability of the software to get changed/modified for different specified environments.
19. **Installability:** The ability of the software to be installed in a specified environment.
20. **Coexistence:** The ability of the software to co-exist with other independent software in a common environment sharing common resources.
21. **Replaceability:** The ability of the software to be used in place of other specified software. Organizations take time to reach best quality level from the present level. It is a slow process.

Comparisons of McCall's and ISO 9126 Models

I. Similarities

Both models focus on one word only i.e., **quality.** In McCall's model, what we call as **quality factor** is called as **quality characteristic** in ISO 9126 model. Both models have some quality factors in common like reliability, usability, efficiency, maintainability and portability.

II. Dissimilarities

(a) ISO 9126 model focuses on the characteristics **visible to customers** whereas McCall model focuses on **internal qualities** also. **For e.g. Reusability** is an **internal characteristic** of a product. Software developers try hard to produce **remissible components** whereas its impact is not perceived by customers.

(b) In McCall's model, one quality criteria can impact several quality factors whereas in ISO 9126 model, one subcharacteristics impacts exactly one quality characteristic.

(c) A high-level quality factor like testability in McCall method is a low-level subcharacteristic of manageability in ISO 9126 model.

(d) McCall suggests 11 high-quality factors whereas ISO 9126 standard defines only 6 quality characteristics.

Note

Quality factors like reusability and interoperability are significant for software developers.

ISO 9126 model just considers the product.

(d) There is no clear cut demarcation between top-level quality factor/characteristic and concrete quality. **For e.g.** Interoperability is a dependent quality characteristic. It is a part of functionality attribute. It is not clear as to why is it so?

9.3 ISO STANDARDS

Standards are the benchmark against which software quality is measured. Consistency is one of the most important attributes of standards. They must be **flexible** too in order to adapt to the changing technology. Standards should be usable and understandable. Standards can smoothen the transitions when developers leave projects.

According to Kramm, standards:

(a) Provides **consistency** across all projects
(b) Eliminates **guesswork**
(c) **Improves** model's maintainability
(d) **Reduces** long-term costs
(e) Promotes **reusability**

ISO 9000 Standards

ISO or International Organization for standardization is a worldwide federation of National Standards bodies. ISO 9000 series is one of the quality system standards that is widely accepted all over the world.

ISO 9000 improves the cost structure of any company by 5–20%. **Please understand that ISO 9000 standards define minimum requirements for business quality assurance systems.** These are **consensus standards** by ISO in Europe and ANSI in U.S.

ISO 9000 series is emerging as the quality system standards for industry with ISO 900–3 providing guideline for applying ISO 9001 to software development, supply and maintenance. First of all ISO 9000 quality standards were published in 1987. Then they were revised in 1994 and in 2000. They are reviewed constantly to retain their efficiency.

ISO 9000 is a series of documents dealing with quality systems. The following documents exists here:

1. **ISO 9000 (Q90):** It is a guideline for selection and use of quality system standards.
2. **ISO 9001 (Q91):** It defines minimum quality system requirements for design, production, installation and service. It applies to manufacturing and service businesses.
3. **ISO 9002 (Q92):** It is a subset of 9001. It applies to production and installation activities only.
4. **ISO 9003 (Q93):** It is applicable to final inspection and test.
5. **ISO 9004 (Q94):** It is a guideline for quality system elements. It is like a helpbook that describes, explains and recommends.

ISO 9000 is designed to provide a flexible structure that ensures the identification and enforcement of QA principles. For R and D organizations, ISO 9000 QA principles are as follows:

1. Precise goals/objectives related to specific requirements.
2. Clearly identified responsibilities.
3. Preventive and corrective actions.
4. Process control-flow of requirements.
5. Constant evaluation and feedbacks.
6. Plan-do-check-act (PDCA) cycle.

ISO 9000 QA approach to management is a documented system approach. It adds the following features:

1. A method system monitoring
2. A method for correcting mistakes
3. A method for changing the system if it has become old (obsolete)

These aspects are very much practically useful. ISO 900 prepares for it. Three types of failures are recognized:

(a) Human error
(b) Failure of inputs
(c) Obsolescence of existing method

ISO 9000 quality system distinguishes between these causes. In first case, the error or omission is corrected. In other cases, the method is amended. Thus, we can say that **ISO 9000 is both self-correcting and a learning system.** It changes to reflect changing needs. **Also note that it is known as QA rather than a traditional quality control-type system.**

The final management note is the **quality review.** This is possible because of the self-adjusting nature of the R and D QA system. The **management review** is the engine for that process. Review should find out:

(a) What information is needed to be sure that the quality policy is being implemented?
(b) What information is needed to decide whether the policy needs amendment?
(c) How frequently these data need to be collected?

Please note that it is vital to decide what is critical and genuinely indicative of the health of the organization. The more data, management asks for, the less it will be able to make sense of. Also note that the cost of data collection need to be considered. The more management asks or data that are not automatically collected as plot of day-to-day work, the more the cost of quality system will rise. The **efficient** and **economic** way to resolve this is to **scan the procedures** once they have been written in order to identify data that exists in the system.

9.4 CMM AND CMMI

CMM or Capability Maturity Model is developed by the Software Engineering Institute (SEI) at Carnegie Mellon University. Actually, in order to improve a defined process, organizations need to evaluate its capabilities and limitations. So, CMM allows an organization to evaluate its software development processes. CMM is not a process model but supports incremental process improvement.

Immature Organizations may not have a defined process. Even if it is there, it may not follow it. Developers and managers must realize that 'prevention is better than cure' i.e., they must not react to problems when they occur but instead should take preventive measures to eliminate them or to reduce the frequency of their occurrences. So, immature organizations work in adhoc manner. That is, both product and process problems are resolved in an adhoc-manner. Also, in these organizations the cost, time and quality estimates are highly inaccurate as there are no measurement programs to collect process data. That is why, there are cost overruns and time slippages. No quality metrics exist in these immature organizations.

Mature Organizations are those perform its activities in a well-planned manner. These organizations will measure both process and product characteristics. The aim is to keep track of progress and quality of products. As **proper metrics** exist in these organizations, so estimates of cost, time, manpower and quality are much **more accurate.** Proper **employee trainings** are done. **Constant effort** is made to improve quality. **Define processes** are regularly updated in order to introduce newer techniques, tools and experience from past projects. **Please note that as**

organizations grow old (mature) then standards and organizational policies play key role in software development. Also note that organization's processes become mature in a step-wise fashion i.e., in an evolutionary manner, processes are improved.

Note

As organizations move from one level to next, its process maturity improves to produce better quality software at a lower cost.

CMM Model

Capability Maturity Model (CMM)

The Capability Maturity Model (CMM) is a methodology used to develop and refine an organization's software development process.

The core principles of CMM include:

- well-defined steps for performing each task;
- proper training for each person to perform his or her job;
- existence of management support for all efforts performed;
- measurement of all steps performed.

Overview of CMM

The Capability Maturity Model (CMM) is not a software life cycle model. Instead, it is a strategy for **improving the software process,** irrespective of the actual life cycle model used. The CMM was developed by Software Engineering Institute (SEI) in 1986. CMM is used to judge the maturity of the software processes of an organization. Term maturity is a measure of the goodness of the process itself.

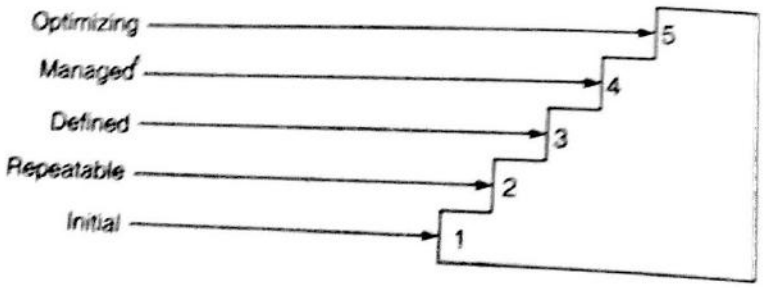


Fig. 9.4

Level 1: Initial—The software process is characterized as **adhoc** i.e., most activities are responses to crisis. It depends totally on current staff; as the staff changes, so does the process. Few processes are defined and success depends on individual effort. It is unfortunate fact that majority of software organizations all over world are level-1 organizations.

Level 2: Repeatable—Basic Project Management Processes are established to track cost, schedule and functionality. The necessary process discipline is in place to repeat earlier successes on projects with similar applications.

Level 3: Defined—The software process for both management and engineering activities is documented, standardized and integrated into an organization wide software process. All projects use a documented and approved version of the organization's process for developing and supporting software. This level includes all characteristics defined for level 2.

Level 4: Managed—Detailed *measures* of the software process and product quality are collected. Both the software process and products are quantitatively understood and controlled using detailed measures. This level includes all characteristics defined for level 3.

Level 5: Optimizing—Continues process improvement is enabled by quantitative feedback from the process and from testing innovative ideas and technology. This level includes all characteristics defined for level 4.

Key Process Area (KPA) determines a group of related activities, which are performed collectively to achieve goals for establishing process at that maturity level.

Each maturity level comprises KPAs to identify the area that need improvements in the organization. The maturity levels and their KPAs are given below:

Tabulated summary of above levels is given below:

Maturity level	Characterization	Key Process Areas (KPA)
1. Initial	Adhoc Process	—
2. Repeatable	Basic Project Management Process	Project Planning, SCM
3. Defined	Process Definition	Training Program
4. Managed	Process Measurement	Quality Management
5. Optimizing	Process Control	Defect Prevention

Experience shows that advancing a complete maturity level usually takes from 18 months to 3 years, but moving from level 2 sometimes takes 3 or even 5 years.

Overview of Quality Standard (ISO 9001)

Quality assurance systems are created to help organizations ensure their products and services and to satisfy customer expectations. It is a different attempt to improve software quality. This standard is a **set of documents** dealing with quality systems that can be used for quality assurance purposes. ISO 9000 describes the elements of quality assurance system in general terms. These elements include the organizational structure, procedures, processes and resources needed to implement quality planning, quality control, quality assurance and quality improvement.

ISO-9000 is a series of five related standards, within this series, ISO 9001 standard for quality system is the standard applicable to software development.

ISO 9001 is the quality assurance standard that applies to Software Engineering. This standard contains 20 requirements that must be present for an effective quality assurance system. The requirements delineated by ISO-9001 address topics such as management responsibility, quality system, contract review, design control, document and data control, product identification, process control, inspection and testing, corrective and preventive action, control of quality records, training, servicing and statistical techniques.

Comparison of ISO 9001 and CMM

Differences

1. CMM emphasizes on continuous process improvement whereas ISO 9001 addresses the minimum criteria for an acceptable quality system.
2. CMM focuses strictly on software while ISO-9001 focuses on hardware, software, processed materials and services.

external assessments.

Capability Maturity Model Integration

oftware area is known as CMM–SW i.e., **software CMM** that was first released in 1991 a
Ver 1.0. Then, CMM-SW Ver 1.1 was released in 1993. The concept of CMM is not only
pecific.

many CMMs, an organization used to have many problems because these different
ve different structures, no commonality of goals, integration of different CMMs also become
c. So, there was a need to have a **unified view of process improvement** throughout an
n. Thus, came into existence CMMI. Thus, CMMI inputs are received from the following

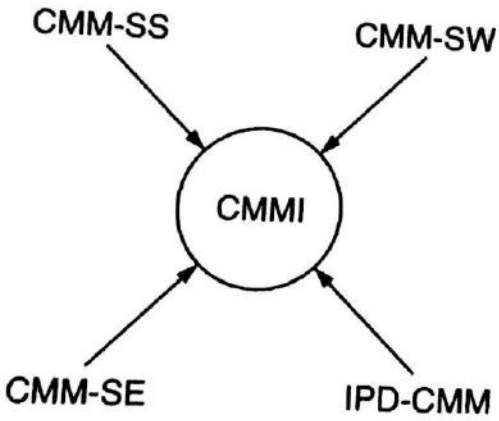


Fig. 9.5 CMMI

SW is CMM for software,
MM is Integrated product development CMM,
SE is CMM for Systems Engineering
SS is CMM for supplier sourcing.

del

t is clear that each process area of the staged representation of the CMMI for
ludes ***one or more specific goals.*** Also, the CMMI for development has **generic**

consider the process area satisfied. Each goal includes one or more practices. A **practice** is an expected component where each practice or an equivalent alternative must be achieved to consider the process are satisfied. This is shown below:

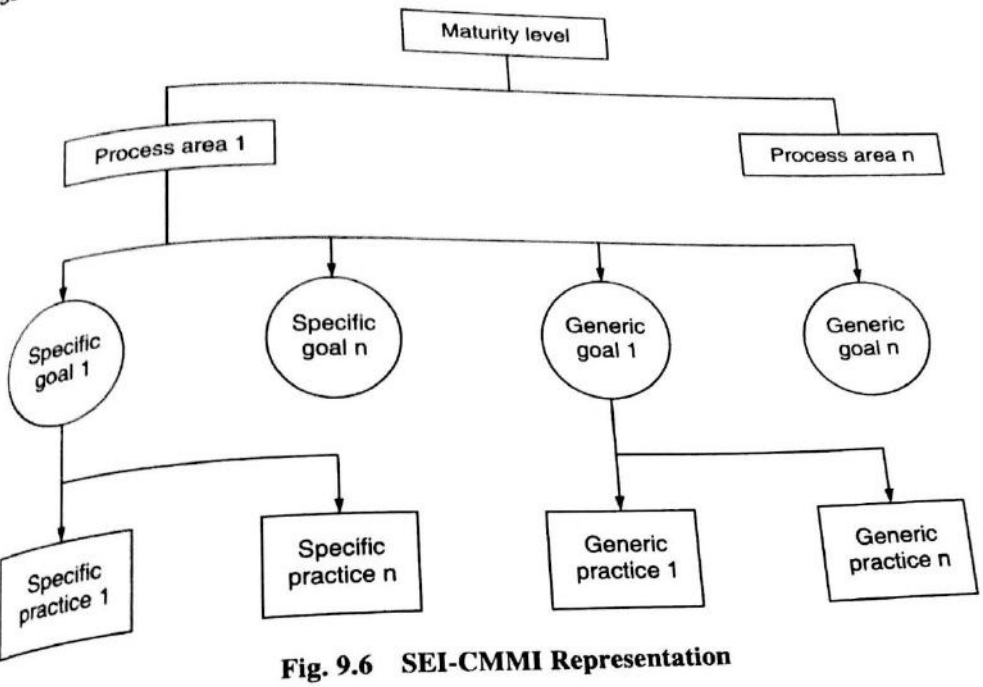


Fig. 9.6 SEI-CMMI Representation

Level	CMMI—Process Areas
1.	Initial (Adhoc)
2.	Repeatable: Project planning, SCM, project monitoring, requirements management, process and product quality assurance
3.	Defined: Requirements development, trainings, Technical Solution, Risk Management, V and V
4.	Quantitatively Managed: Organizational process performance, SPM
5.	Optimizing: Organizational innovation and causal analysis

Need of CMMI

1. Present day web applications are very complex. So, they use some subsystems (3rd party components) also. For e.g., a communication module may be purchased from some 3rd party vender.
2. Many other components like RDBMS, messaging, security and real-time processing are part of bigger softwares.

   Now, please understand that the coexistence and interoperability of these different components developed by different venders is very important for project's success. Thus, there is a need to find out the maturity level of an integrated product development process.
3. Complex software systems usually run on a specialized hardware and a specialized OS. These need to be evaluated.

9.5 Six Sigma Concepts

Six Sigma is a business management strategy, initially implemented by Motorola that today enjoys widespread application in many sectors of industry.

Six Sigma seeks to improve the quality of process outputs by identifying and removing the causes of defects (errors) and variability in manufacturing and business processes. It uses a set of quality management methods, including statistical methods, and creates a special infrastructure of people within the organization ("Black Belts", "Green Belts", etc.) who are experts in these methods. Each Six Sigma project carried out within an organization follows a defined sequence of steps and has quantified financial targets (cost reduction or profit increase).

The term "Six Sigma" is derived from a field of statistics known as process capability studies. Originally, it referred to the ability of manufacturing processes to produce a very high proportion of output within specification. Processes that operate with "six sigma quality" over the short term are assumed to produce long-term defect levels below 3.4 defects per million opportunities (DPMO). Six Sigma's implicit goal is to improve all processes to that level of quality or better.

Why Six Sigma is so Important?

Six sigma refers to 99.997% perfection rate i.e. 3.4 parts per million. If a company is producing only 3.4 defective products per million units of the product then it is considered to have achieved six sigma level. Top notch companies around the world generally are considered to be operating at around 99% perfection, which suggests that there can be further improvement and reduction in defects hence helping company increase profitability. This improvement can save millions of dollars for the companies which are wasted in various un-necessary processing and defects those lead to customer dissatisfaction.

Six sigma uses process data and analytical techniques in order to find out various process variables. Once the process variables are obtained, they help in developing the exact understanding of various processes. This understanding/data is then used to improve the processes and help in reducing defects/losses in other areas of the organization.

Six Sigma stands for **Six Standard Deviations** (Sigma is the Greek letter used to represent standard deviation in statistics) from mean. Six Sigma methodologies provide the techniques and tools to improve the capability and reduce the defects in any process. Six Sigma is a registered service mark and trademark of Motorola, Inc. Motorola has reported over US$17 billion in savings from Six Sigma as of 2006.

Six Sigma methodology can also be used to create a brand new business process from ground up using ***DFSS** (Design For Six Sigma)* principles. Six Sigma Strives for perfection. It allows for only **3.4** defects per million opportunities for each product or service transaction. Six Sigma relies heavily on statistical techniques to reduce defects and measure quality.

Historical Overview

Six Sigma was originally developed as a set of practices designed to improve manufacturing processes and eliminate defects, but its application was subsequently extended to other types of business processes as well. In Six Sigma, a defect is defined as anything that could lead to customer dissatisfaction.

The particulars of the methodology were first formulated by Bill Smith at Motorola in 1986. Six Sigma was heavily inspired by six preceding decades of quality improvement methodologies such as quality control, TQM, and Zero Defects, based on the work of pioneers such as Shewhart, Deming, Juran, Ishikawa, Taguchi and others.

Like its predecessors, Six Sigma asserts that:

1. Continuous efforts to achieve stable and predictable process results (i.e. reduce process variation) are of vital importance to business success.
2. Manufacturing and business processes have characteristics that can be measured, analyzed, improved and controlled.
3. Achieving sustained quality improvement requires commitment from the entire organization, particularly from top-level management.

Features that set Six Sigma apart from previous quality improvement initiatives include

1. A clear focus on achieving measurable and quantifiable financial returns from any Six Sigma project.
2. An increased emphasis on strong and passionate management leadership and support.
3. A special infrastructure of "Champions," "Master Black Belts," "Black Belts," etc. to lead and implement the Six Sigma approach.
4. A clear commitment to making decisions on the basis of verifiable data, rather than assumptions and guesswork.

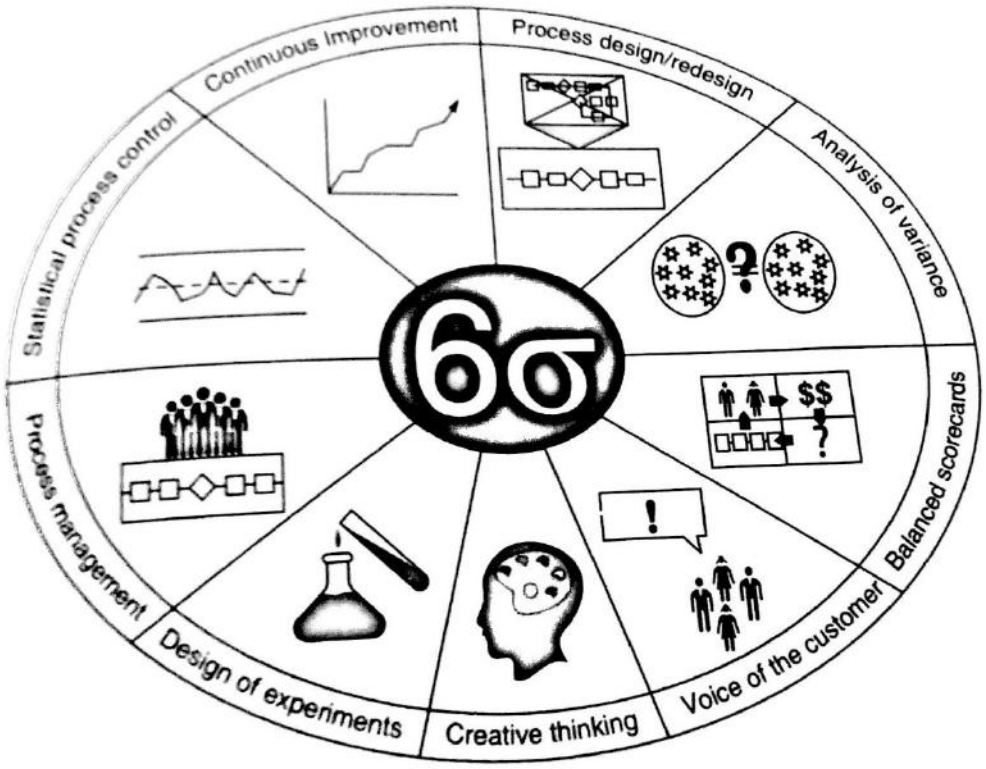


Fig. 9.7 Six Sigma

Software Requirements

Six Sigma software tools augment the implementation of Six Sigma methodology by complimenting and sometimes substituting human efforts. Six Sigma software tools fill in the vacuum of additional needs by companies that are implementing the Six Sigma methodology.

Software developers, in accordance with the needs and demands of different businesses, have developed various Six Sigma software tool modules. Some examples of Six Sigma software tools are as follows:

1. DMAIC Six Sigma - a process management tool
2. Design for Six Sigma or DFSS - a design tool
3. Quality improvement package - a quality control tool
4. Production management package - a process simulation tool
5. Project optimization and simulation - An analytical tool
6. Testing and measurement - a testing and control tool

The all-encompassing comprehensive Six Sigma software tools packages pack a lot of powerful features into them which help speed up the decision making process and data mining, while dramatically simplifying predictive modeling activities.

List of Six Sigma Software Packages

There are generally three classes of software used to support **Six Sigma:**

1. Analysis tools, which are used to perform statistical or process analysis
2. Program management tools, used to manage and track a corporation's entire Six Sigma program
3. DMAIC and Lean online project collaboration tools for local and global teams

ANALYSIS TOOLS

1. iGrafx Process for Six Sigma
2. EngineRoom by MoreSteam
3. IBM WebSphere Business Modeler
4. JMP
5. Microsoft Visio
6. Minitab
7. QPR ProcessGuide by QPR Software
8. Quality Companion by Minitab
9. SigmaXL
10. SigmaFlow(BPA)
11. Software AG webMethods BPM Suite
12. Statgraphics
13. STATISTICA
14. Telelogic System Architect
15. Actuate
16. The Unscrambler
17. Oracle Crystal Ball
18. Select Architect Business Process Modeling

DMAIC/LEAN ONLINE COLLABORATION TOOLS

1. SigmaFlow Integrated, Project Management Tools (PPM), (BPA) and (ECM)
2. Grouputer SigmaSense

HARDWARE REQUIREMENTS

Most of the Six Sigma software tools are available for both Mac and IBM compatible PCs. The minimum system requirements are:

- At least Pentium 386; but for most products - 1.0 GHz Pentium processor
- 256MB RAM
- 1.0GB of free disk space
- Graphics card (at least VGA or a better is recommended)
- Windows, several versions; depending on which product you buy

With Six Sigma software tools at your disposal, you can process a lot of data, more than you ever could by hand. Artificial intelligence is used for faster, more dependable project selection and analysis. Six Sigma software tools also assist you in predicting future behaviors & tendencies. Six Sigma software tools have finally come of age and are here to stay.

SIX SIGMA METHODOLOGIES

Six sigma methodologies are very easy to implement and integrate into any organization if all the processes are properly followed. The six sigma methodology operates on the following main steps:

1. **Define:** In this step, the team responsible for six sigma methodology implementation in the organization collectively defines various goals and sub-goals. Define step emphasizes on customer satisfaction, identification of root causes of any identified defect, improvement and establishment of infrastructure in order to help achieve the defined goals and sub-goals.
2. **Measure:** This step involves activities such as preparing various metrics based on the data available in hand, more data collection activities, basic data packets creation or sampling etc.
3. **Analyze:** This step involves analysis of defects using 'Cause & Effect' and other diagrams, study of possible modes of failure i.e. root cause analysis etc. in order to prepare various charts to improve process and control & monitor the process improvement activities. This step can help in establishing the facts about processes currently being utilized in terms of there effectiveness, contribution to six sigma methodology success, defect rates and at what extent these processes help in achieving the organization level success etc. and can help in achieving various goals.
4. **Improve:** This step involves utilization of data collection, metrics and analysis done during the Define, Measure and Analysis steps. Improvised techniques are brought into action and applied to process improvement model. The team working on six sigma methodology application to the organization also may experiment various techniques to help in process improvement.
5. **Control:** In this step, all the techniques being utilized for process improvement are monitored and adherence to procedural methodology is assured. Various charts based on the techniques being utilized against time frame are used to help keep a check on the successful execution of six sigma methodology.

It's very important to understand the six sigma methodology and its application for any industry/ organization. Six sigma methodology not only emphasizes on reduction of defects i.e. only 3.4 per million, it also gives a significant importance to customer satisfaction and customer voice.

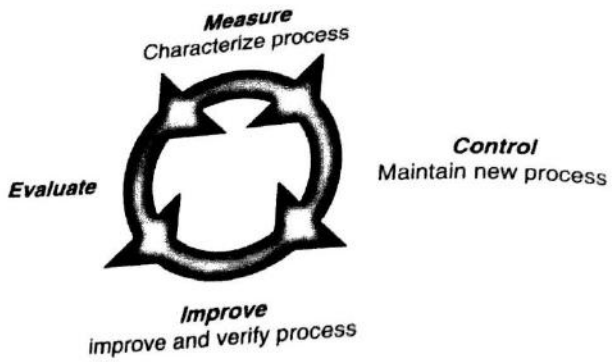


Fig. 9.8 6σ

Six Sigma projects follow two project methodologies inspired by Deming's Plan-Do-Check-Act Cycle. These methodologies comprise five phases each and are known by the acronyms DMAIC and DMADV.

- **DMAIC** is used for projects aimed at improving an existing business process.
- **DMADV** is used for projects aimed at creating new product or process designs

DMAIC

The five phases in the DMAIC project methodology are:

1. Define high-level project goals and the current process.
2. Measure key aspects of the current process and collect relevant data.
3. Analyze the data to verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered.
4. Improve or optimize the process based upon data analysis using techniques like Design of experiments.
5. Control to ensure that any deviations from target are corrected before they result in defects. Set up pilot runs to establish process capability, move on to production, set up control mechanisms and continuously monitor the process.

DMADV

The five phases in the DMADV project methodology are:

1. Define design goals that are consistent with customer demands and the enterprise strategy.
2. Measure and identify CTQs (characteristics that are Critical To Quality), product capabilities, production process capability, and risks.
3. Analyze to develop and design alternatives, create a high-level design and evaluate design capability to select the best design.
4. Design details, optimize the design, and plan for design verification. This phase may require simulations.
5. Verify the design, set up pilot runs, implement the production process and hand it over to the process owners.

DMADV is also known as DFSS, an abbreviation of "Design For Six Sigma".

The Similarities of DMAIC and DMADV

Let's first look at the DMAIC and DMADV methodologies and talk about how they're alike. DMAIC and DMADV are both:

- Six Sigma methodologies used to drive defects to less than 3.4 per million opportunities.
- Data intensive solution approaches. Intuition has no place in Six Sigma — only cold, hard facts.
- Implemented by Green Belts, Black Belts and Master Black Belts.
- Ways to help meet the business/financial bottom-line numbers.

The Differences of DMAIC and DMADV

DMAIC and DMADV sound very similar, don't they? The acronyms even share the first three letters. But that's about where the similarities stop.

When To Use DMAIC

The DMAIC methodology, instead of the DMADV methodology, should be used when a product or process is in existence at your company but is not meeting customer specification or is not performing adequately.

Table 9.1

DMAIC	Define	• Define the project goals and customer (internal and external) deliverables
	Measure	• Measure the process to determine current performance
	Analyze	• Analyze and determine the root cause(s) of the defects
	Improve	• Improve the process by eliminating defects
	Control	• Control future process performance

When To Use DMADV

The DMADV methodology, instead of the DMAIC methodology, should be used when:

- A product or process is not in existence at your company and one needs to be developed
- The existing product or process exists and has been optimized (using either DMAIC or not) and still doesn't meet the level of customer specification or six sigma level

Table 9.2

DMADV	Define	• Define the project goals and customer (internal and external) deliverables
	Measure	• Measure and determine customer needs and specifications
	Analyze	• Analyze the process options to meet the customer needs
	Design	• Design (detailed) the process to meet the customer needs
	Verify	• Verify the design performance and ability to meet customer needs

QUALITY MANAGEMENT TOOLS

Within the individual phases of a DMAIC or DMADV project, Six Sigma utilizes many establishe quality management tools that are also used outside of Six Sigma. The following table shows a overview of the main methods used.

1. 5 Whys
2. Analysis of variance
3. ANOVA Gauge R&R

4. Axiomatic design
5. Business Process Mapping
6. Catapult exercise on variability
7. Cause & effects diagram (also known as fishbone or Ishikawa diagram)
8. Chi-square test of independence and fits
9. Control chart
10. Correlation
11. Cost-benefit analysis
12. CTQtree
13. Quantitative marketing research through use of Enterprise Feedback Management (EFM) systems
14. Design of experiments
15. Failure mode and effects analysis
16. General linear model

IMPLEMENTATION ROLES

One of the key innovations of Six Sigma is the professionalizing of quality management functions. Prior to Six Sigma, quality management in practice was largely relegated to the production floor and to statisticians in a separate quality department. Six Sigma borrows martial arts ranking terminology to define a hierarchy (and career path) that cuts across all business functions and a promotion path straight into the executive suite.

Six Sigma identifies several key roles for its successful implementation.

1. Executive Leadership includes the CEO and other members of top management. They are responsible for setting up a vision for Six Sigma implementation. They also empower the other role holders with the freedom and resources to explore new ideas for breakthrough improvements.
2. Champions are responsible for Six Sigma implementation across the organization in an integrated manner. The Executive Leadership draws them from upper management. Champions also act as mentors to Black Belts.
3. Master Black Belts, identified by champions, act as in-house coaches on Six Sigma. They devote 100% of their time to Six Sigma. They assist champions and guide Black Belts and Green Belts. Apart from statistical tasks, their time is spent on ensuring consistent application of Six Sigma across various functions and departments.
4. Black Belts operate under Master Black Belts to apply Six Sigma methodology to specific projects. They devote 100% of their time to Six Sigma. They primarily focus on Six Sigma project execution, whereas Champions and Master Black Belts focus on identifying projects/ functions for Six Sigma.
5. Green Belts are the employees who take up Six Sigma implementation along with their other job responsibilities. They operate under the guidance of Black Belts.

ORIGIN AND MEANING OF THE TERM "SIX SIGMA PROCESS"

raph of the normal distribution, which underlies the statistical assumptions of the Six Sigma model. ne Greek letter a (sigma) marks the distance on the horizontal axis between the mean, μ, and the rve's inflection point. The greater this distance is, the greater is the spread of values encountered. r the curve shown above, $\mu = 0$ and $\sigma = 1$. The upper and lower specification limits (USL, LSL) are

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at a distance of 6σ from the mean. Due to the properties of the normal distribution, values lying that far away from the mean are extremely unlikely. Even if the mean were to move right or left by 1.5σ at some point in the future (1.5 sigma shift), there is still a good safety cushion. This is why Six Sigma aims to have processes where the mean is at least 6a away from the nearest specification limit.

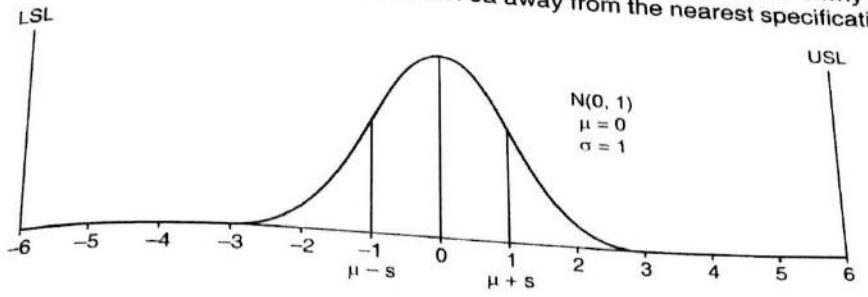

Fig. 9.9

The term "six sigma process" comes from the notion that if one has six standard deviations between the process mean and the nearest specification limit, as shown in the graphic, there will be practically no items that fail to meet specifications. This is based on the calculation method employed in process capability studies.

In a capability study, the number of standard deviations between the process mean and the nearest specification limit is given in sigma units. As process standard deviation goes up, or the mean of the process moves away from the center of the tolerance, fewer standard deviations will fit between the mean and the nearest specification limit, decreasing the sigma number and increasing the likelihood of items outside specification.

Role of the 1.5 sigma shift

Experience has shown that in the long term, processes usually do not perform as well as they do in the short. As a result, the number of sigma that will fit between the process mean and the nearest specification limit is likely to drop over time, compared to an initial short-term study. To account for this real-life increase in process variation over time, an empirically-based 1.5 sigma shift is introduced into the calculation.

According to this idea, a process that fits six sigma between the process mean and the nearest specification limit in a short-term study will in the long term only fit 4.5 sigmas - either because the process mean will move over time, or because the long-term standard deviation of the process will be greater than that observed in the short term, or both.

Hence the widely accepted definition of a six sigma process is one that produces 3.4 defective parts per million opportunities (DPMO). This is based on the fact that a process that is normally distributed will have 3.4 parts per million beyond a point that is 4.5 standard deviations above or below the mean (one-sided capability study). So the 3.4 DPMO of a "Six Sigma" process in fact corresponds to 4.5 sigma, namely 6 sigma minus the 1.5 sigma shift introduced to account for long-term variation. This is designed to prevent underestimation of the defect levels likely to be encountered in real-life operation.

SIGMA LEVELS

The table below gives long-term DPMO values corresponding to various short-term Sigma levels.

Note that these figures assume that the process mean will shift by 1.5 sigma towards the side with the critical specification limit. In other words, they assume that after the initial study determining

the short-term sigma level, the long-term C_{pk} value will turn out to be 0.5 less than the short-term C_{pk} value. So, for example, the DPMO figure given for 1 sigma assumes that the long-term process mean will be 0.5 sigma beyond the specification limit ($C_{pk} = -0.17$), rather than 1 sigma within it, as it was in the short-term study ($C_{pk} = 0.33$). Note that the defect percentages only indicate defects exceeding the specification limit that the process mean is nearest to. Defects beyond the far specification limit are not included in the percentages.

Table 9.3

Sigma level	DPMO	Percent defective	Percentage yield	Short-term Cp_k	Long-term C_{pk}
1	691,462	69%	31%	0.33	1-0.17
2	308,538	31%	69%	0.67	0.17
3	166,807	6.7%	93.3%	1.00	0.5
4	6,210	0.62%	99.38%	1.33	0.83
5	233	0.023%	99.977%	1.67	1.17
6	**3.4**	**0.00034%**	**99.99966%**	**2.00**	**1.5**
7	0.019	0.0000019%	99.9999981%	2.33	1.83

FLOW CHART

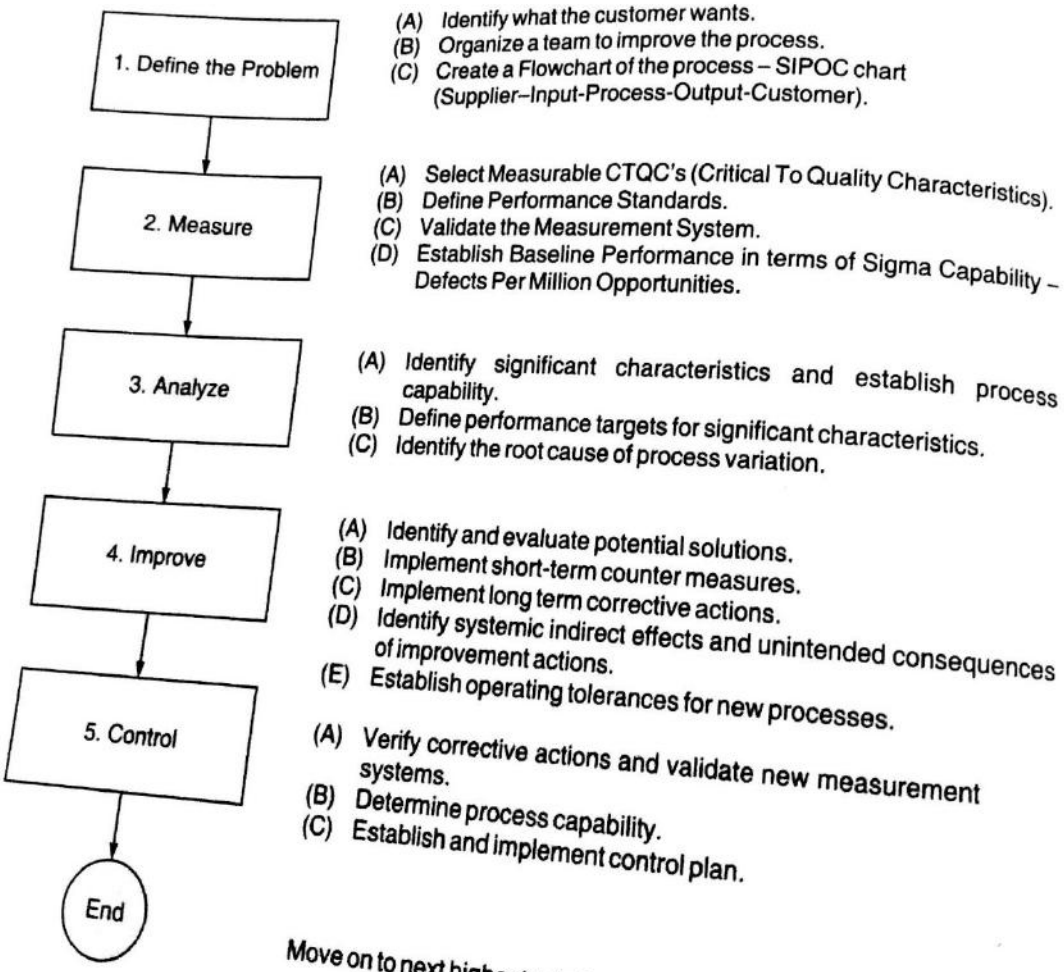

Fig. 9.10

BENEFITS OF SIX SIGMA

Obviously, in almost all cases, the reasons for Six Sigma failure have been external factors such as wrong or misguided selection of the tools, lack of application and lack of support from upper management. It is important to keep in mind that the successful implementation of Six Sigma requires a top down approach and perseverance throughout. Also important to the process is proper and thorough Six Sigma training.

1. Problem solving involves rational thinking. Somehow, companies always found themselves compromising quality with problem solving, which is the main reason why companies decide to implement Six Sigma and support Six Sigma training.
2. The top-down approach of Six Sigma requires dedication and application at all levels of the organization and on a continuous basis. The statistical methodology of Six Sigma sheds light on existing flaws and their causes after thorough analysis. Emphasis is placed on experimentation following analysis and redefining the processes and their goals. This is unlike other quality assurance methodologies. The benefits of supporting Six Sigma training for company professionals are apparent.
3. Financial Benefits: Cash flow increases due to creation of additional revenue. Through this process although cost decreases and increased profitability can be seen. It is important that all professionals involved in Six Sigma implementation have proper Six Sigma training. Although Six Sigma training is relatively expensive, the financial benefits of supporting it greatly outweigh the upfront costs.
4. Operational Benefits of Six Sigma Training: employee satisfaction due to improvement in work flow, reduction in process times and steps, better usage of work space, etc. result from implementation of Six Sigma. One major operational reason for hoosing Six Sigma is its success in waste reduction and redundancy. Waste reduction is measured in terms of improving time, product movement and decreasing material consumption.
5. Conceptually, the benefits of implementation of Six Sigma emerge from breaking the mindset that product processes are invariable. Benefits also emerge as a result of interconnected activities. The result of this methodical approach to quality management is evidenced by reduced fluctuations in processes. Stability of this kind triggers a series of positive chain reactions within rganizations.

Success stories of Six Sigma training are evident in all fields of business. Since Six Sigma methodology encompasses the entire process of doing business, it is likely to show a flaw here or there, such as companies that embraced Six Sigma have found out. Howsoever small in number the failures may be, they are all due to differing reasons. However, any negative results can probably be traced back to either improper implementation or incomplete Six Sigma training.

CRITICISM OF SIX SIGMA

Six Sigma has made a huge impact on industry and is widely employed as a business strategy for achieving and sustaining operational and service excellence. However, there have also been various criticisms of Six Sigma.

Lack of Originality

Noted quality expert Joseph M. Juran has described Six Sigma as "a basic version of quality improvement," stating that "[t]here is nothing new there. It includes what we used to call facilitators. They've adopted more flamboyant terms, like belts with different colors. I think that concept has merit to set apart, to create specialists who can be very helpful. Again, that's not a new idea. Th American Society for Quality long ago established certificates, such as for reliability engineers."

Role of Consultants

The use of "Black Belts" as itinerant change agents is controversial as it has created a cottage industry of training and certification. Critics argue there is overselling of Six Sigma by too great a number of consulting firms, many of which claim expertise in Six Sigma when they only have a rudimentary understanding of the tools and techniques involved.

The expansion of the various "Belts" to include "Green Belts," "Master Black Belts" and "Grade Belts" is commonly seen as a parallel to the various "belt factories" that exist in martial arts.

Potential Negative Effects

A Fortune article stated that "of 58 large companies that have announced Six Sigma programs, 91 percent have trailed the S&P 500 since." The statement is attributed to "an analysis by Charles Holland of consulting firm Qualpro (which espouses a competing quality-improvement process)." The gist of the article is that Six Sigma is effective at what it is intended to do, but that it is "narrowly designed to fix an existing process" and does not help in "coming up with new products or disruptive technologies." Many of these claims have been argued as being in error or ill-informed.

Based on Arbitrary Standards

While 3.4 defects per million opportunities might work well for certain products/processes, it might not be ideal or cost-effective for others. A pacemaker process might need higher standards, for example, whereas a direct mail advertising campaign might need lower ones. The basis and justification for choosing 6 as the number of standard deviations is not clearly explained. In addition, the Six Sigma model assumes that the process data always conform to the normal distribution. The calculation of defect rates for situations where the normal distribution model does not apply is not properly addressed in the current Six Sigma literature.

Criticism of the 1.5 Sigma Shift

Because of its arbitrary nature, the 1.5 sigma shift has been dismissed as "goofy" by the statistician Donald J. Wheeler. Its universal applicability is seen as doubtful.

The 1.5 sigma shift has also been contentious because it results in stated "sigma levels" that reflect short-term rather than long-term performance: a process that has long-term defect levels corresponding to 4.5 sigma performance is, by Six Sigma convention, described as a "6 sigma process." The accepted Six Sigma scoring system thus cannot be equated to actual normal distribution probabilities for the stated number of standard deviations, and this has been a key bone of contention about how Six Sigma measures are defined. The fact that it is rarely explained that a "6 sigma" process will have long-term defect rates corresponding to 4.5 sigma performance rather than actual 6 sigma performance has led several commentators to express the opinion that Six Sigma is a confidence trick.

APPLICATION OF SIX SIGMA

India, as a fast growing economy, cannot afford to compromise on the quality of the products and services delivered. The demand for enhanced quality and reduced cost of the goods and services has coaxed many companies to introduce the Six Sigma system irrespective of the industry to which they belonged to.

In India, **Wipro** was one of the first companies to introduce Six Sigma into it's applications in 1997. Wipro's every business from software development to hardware, FMCG, BPO; all adopted Six Sigma into its processes. It is said that after the initiation of Six Sigma into its projects, the company has been able to complete 91% of its projects on time, when compared to the industrial aver

The metrics are used throughout the life cycle of the product, in production as well as in the software development. The need and importance of reducing defects have through the adoption of the Six Sigma has helped companies like Wipro to sustain SEI CMM Level 5.

In pharmaceutical industry, adoption of the Six Sigma technique helped the industry reduce wastage and rework involved in the production. It was said that 5–10% of medicines produced during a period were to be discarded or modified due to the defects. The adoption of Six Sigma helped the pharmaceutical companies to reduce the errors in the production. The success story on the adoption of Six Sigma prompted Pfizer to achieve the Pfizer Global Manufacturing mission of aiming at zero defects through Right First Time. Right First Time or RFT is a technique adapted by Pfizer to its core processes to assure quality to its products and customer services the first time.

Airline industry had to adopt the Six Sigma metrics for its survival. The increased cost of fuel, the competition driven by low budget airlines, etc has made the need for lower cost without a hit to quality the need of the hour. The number of errors in handling the calls from customers, and ticketing is to be minimized drastically. It was with this intention that the airline industry adopted Six Sigma into the organization. Indian companies like Kingfisher, Jet Airways, all have adopted Six Sigma techniques

Hospitality services are another industry which benefited by the adoption of Six Sigma techniques. Providing personalised service to each and every customer by bending to their demands within a limited time without comprising the quality was aided by the Six Sigma matrics. The Six Sigma technique is adopted in every field from maintaining full occupancy to efficient housekeeping, ensuring a balanced inventory supply, and to minimise wastage in the inventory. Starwood hotels and resorts Inc was the first company to adopt Six Sigma in the hospitality sector.

Steel industries like TISCO use this technique to minimise the inadequacies in the design, imperfect products, etc. In 1998, Forbes Magazine applauded the Mumbai Tiffin Suppliers Association of the Mumbai Dabbawallahs for their way of functioning with just one error in every 8 million. Logistics, insurance, call centres, all embrace the Six Sigma techniques for improving the quality of service provided by them.

Irrespective of the type of industry, all companies have to adopt Six Sigma techniques as quality and timely delivery are crucial for their survival.

THE FUTURE OF SIX SIGMA

Since its introduction in the 1990's, Six Sigma has become the buzzword in both the manufacturing and service industries. The various methodologies used in Six Sigma are based on a disciplined and data driven approach that help in eliminating defects and achieving near perfection by restricting the number of possible defects to less than 3.4 defects per million. The methodologies are effective in managing business processes of both the manufacturing and service industries. In manufacturing industries, the concepts and methodologies are used for reducing the number of defects whereas in service industries, they are used mainly for reducing transactional errors.

Six Sigma may appear similar to other quality management tools such as TQM or Kaizen Events, but in reality, it is quite different. Other quality management programs often reach a stage after which no further quality improvements can be made. Six Sigma, on the other hand, is different as it focuses on taking quality improvement processes to the next level. This means that Six Sigma has the potential to outlast other quality management programs in the future.

The scope of Six Sigma is also much broader than other quality management programs as it can be applied to every business process of an organization. The future is bright for Six Sigma programs with the growing awareness in small and medium enterprises about the potential benefits that can be derived from implementing such programs.

9.6 Quality Challenge

As we know that software quality is conformance to explicitly stated and agreed functional and non-functional requirements. Some challenges of quality are as follows:

1. Software cannot be seen, touched or heard. So, it is virtual in nature. Our correctional measuring methods cannot measure them.
2. Big communication gap between users and developers/testers of software is another quality challenge.
3. Customer requirements as stated in SRS are many a times incompletely, not clear and inconsistent.
4. The need is to shift focus form quality control till quality management.
5. Any level of exhaustive testing is not capable of testing each and every branch, condition and algorithm. Quality testing is now needed.
6. Project-level objectives must be in synchronization with organizational-level objectives.
7. Certain SDLC phases do not include quality as an important parameter. So, complete quality engineering is to be followed.
8. Total Quality Management (TQM) costs more.
9. Expert personnel are not available

9.7 National Quality Awards

- **Deming Awards** were the first national quality awards (in Japan). These are presented every year to individuals, groups and companies which achieve notable quality levels or improvements.
- Then, **Baldrige awards** were introduced (in USA). US companies submit themselves to the assessment process to final not whether they achieve the highest scores in a wide range of companies today.
- In Europe, the European Foundation of Quality Management (EFQM) has produced a self-assessment guide which companies can use to conduct their own evaluations. A comparison of TQ with Deming principles and with Baldrige is given below:

Table 9.4 A Comparison for the House of Total Quality with the Baidrige Categories and Deming Principles

House of Total Quality[a]	Baldring Categories[b]	Deming Principles[c]
The Roof		
Management System		
1. Systems, process 2. Leadership 3. Strategy 4. Mission, vision, values	SYSTEM 1.0 Leadership 3.0 Strategic quality planning * Long-range planning	1. Publish the aims and purpose of the organization 2. Learn the new philosophy 7. Teach and institute leadership
Social System		
1. Structure 2. Social norms Teams	4.0 Human resources development and management • Employee development	14. Take action to acco the transformation • Hierar

...ganizational personality	• Partnership development • Cross-functional teams	• management must change • Transformation can only be accomplished by people not hardware
...ctical System		
...work processes ...job descriptions ...problem-solving tools ...decision making ...measurement tools	5.0 Processes Management • Reduced cycle time • Design quality and QFD	9. Optimize efforts of teams groups, staff toward aims arid purposes * Statistical measurement
...ucational System		
...Lifelong learning ...Retraining	4.0 Human resource development and management * Employee participation and development	• Continual learning 6. Institute training
The Pillars		
...Customer satisfaction	7.0 Customer focus and satisfaction	4. End the practice of awarding business on price tag alone • Aim quality at the needs of the customer, present and future
...Continuous improvement	2.0 Information and analysis 5.0 Process management 6.0 Business results	3. Understand the purpose of inspection-improve process, reduce costs 11a-b. Eliminate quotas & MBO. Concentrate on improvement
...Speak with facts	2.0 Information and analysis * Management by fact	3. Understand the purpose of inspection—improve processes, reduce costs • In God we trust; all others bring facts • Statistical measurement
...Respect for people	4.0 Human resource development and management • Job design • Compensation and management • Employee well-being and satisfaction	14. Take action to accomplish the transformation 11a. Eliminate numerical quotas 11. Eliminate MBO 12. Remove barriers that rob people of pride in workmanship
Ethical Work Culture		
Ethical work culture	1.0 Leadership 4.0 Human resource development and management • Manage for organizational integrity	8. Drive out fear 7. Tech. and institute leadership * Create and maintain system integrity