Chapter 2

Review of Literature
Chapter 2

Literature Survey

This chapter is divided into two sections - Section 1 and 2. Section 1 deals with the various concepts and tools relating to quality assurance practices normally followed in various organizations in general and software organizations in particular. Section 2 describes various studies conducted by different authors relating to quality assurance practices.

Section 1

Quality Assurance Concepts and Practices

2.1 Introduction

Software organizations follow several best practices in order to make sure that the quality of the deliverables is as expected by the customer. There are many such practices defined based on the software industry’s orientation towards quality. There are also practices that the organizations follow from the manufacturing and service industries. These adaptations intend to improve various practices followed in software development.

This section of chapter 2 describes the various quality assurance practices followed in software organizations in India. This section is further divided into two parts: the first part deals with the various industry accredited best practices followed in the software organizations namely practices like ISO QMS (ISO Quality Management System- ISO 9001), ISO ISMS (ISO Information Security Management System- ISO 27001) and SEI-CMMI (Software Engineering Institute – Capability Maturity Model Integrated). The second part of the section deals with various quality assurance tools used in software organizations with the guidelines for their implementation. The various quality models like ISO 9001, ISO 27001 and CMMI models are described in detail in ISO web site, delegate notes QMS Lead Auditor Course (Zandig), delegate notes ISMS Lead Auditor Course (Zandig), Training Material of ISO 9001 Internal Quality Auditors (QSR Technologies), Guide to The CSQA Common Body Of Knowledge Hand Book V 6.1, SEI Website, John Oakland (1998), Dennis Ahern et al (2004) Daniel Galin, (2004), Roger Pressman ,Nina Godbole (2009) and CMMI development v 1.3 (2010).
2.2 The PDCA Cycle

The major quality management premise is the environment that emphasis on the continuous improvement. PDCA cycle, developed in the 1930's by Dr. Shewhart of the Bell System, best illustrates the organizations approach in continuous improvement in quality environment. This concept forms the basis of all quality models developed later like ISO systems, CMMI, six sigma etc. The four steps of PDCA, Plan, Do, Check and Act as shown in the figure 2.1. The cycle, also called as the Deming Wheel, is termed as a key concept in quality.

![PDCA Cycle Diagram](image)

**Figure 2.1: PDCA Cycle**

2.2.1 PDCA Concept

Each of the steps in the PDCA cycle is elaborated below:

**Plan (P):** Devise a plan - Defines the objective and express it numerically, if possible. This step clearly describes the goals and policies needed to attain the objective. It also determines the procedures and the means and methods to achieve the designated objective.

**Do (D):** Execute the Plan - Teaching employees the procedures and skills required to execute the plan and make them understand the responsibilities, so that the employees will be able to perform the work by following the defined procedure.

**Check (C):** Check the Results - As often as possible checking the results to determine whether work is in progress as per the plan and the results are as per the expectation.
Checking required for performance of the stages of the process and procedures, changes in conditions, or non-conformities or abnormalities that may appear.

**Act (A):** Take the necessary action- If the check reveals that the work done by the employees are not as per the plan or the result obtained is not as per the expectation, and then appropriate measures are devised. This needs a close look at the cause of the nonconformance or abnormality and prevent its recurrence. There could be times, where the employees need to be retrained and procedures to be revised. The next plan should reflect these changes and should define them in detail.

PDCA ensures the quality of the services and software products and meets customer's expectations. It also helps to work within the anticipated budget and helps in delivering the project on time.

Majority of the quality improvement cycles are based on the PDCA cycle.

### 2.3 The ISO Organization

ISO is a network of the national standards institutes of over 148 countries, with a central secretariat in Geneva, Switzerland, that coordinates the system.

It is a NGO or non-governmental organization. It does not have delegations from the national governments as its members. ISO is an important standard followed by public and private sectors. This is facilitated by the presence of member institutes that are part of governmental structure of their countries or are mandated by their government. The others members represent the large population of the private sector, having been setup by the national partnership of industry associations.

ISO acts as a bridging organization that brings a consensus on solutions that meet both the needs of business and the broader needs of the society, including needs such as that of the consumers and users.
2.3.1 Meaning of ISO

The abbreviation for the International Organization for Standardization would be different in different languages, for E.g. IOS in English, OIN in French of Organization internationale de normalisation. It was decided to use the Greek word 'isos', meaning equal for the abbreviation. Therefore, irrespective of the language or the country, the abbreviated form of the organization's name is always ISO.

2.3.2 Origin of ISO

The International Organization for Standardization in short known as ISO is a Nongovernmental organization that consists of the more than 150 countries' national standards. Its headquarters or the Central Secretariat is located in the Swiss capital city, Geneva. The most popular Quality Management System adopted by many organizations is ISO 9001 [www.iso.ch].

International standardization began with the establishing of International Electro technical Commission (IEC) in 1906, in the electro technical field. The International Federation of the National Standardizing Associations (ISA), which was set up in 1926, carried out commendable work in other fields. ISA emphasized heavily on mechanical engineering. Its activities ended in 1942.

The year 1946 marked the beginning of a new international organization, when delegates from 25 counties met and decided to create an organization with the objective "to facilitate the international coordination and unification of industrial standards". This new organization, ISO, officially started operations on 23, Feb 1947.

2.3.3 International Standardization

When majority of the services or products in a business or industry conform to International Standards, a state of industry-wide standardization can be said to exist. This can be achieved through consensus agreements between national delegations representing all the economic stakeholders concerned. The stakeholders include suppliers, users, government and consumers. They consent on specifications and criteria to be used consistently in the classification of materials, in the manufacturing and supply of products and raw materials, testing and analysis, in terminology and in the provision of services. In this way, international standards provide the reference framework to follow or a common
technological language, between suppliers and customers that facilitates trade and the transfer of technology.

2.3.4 Benefit to Society

The widespread adoption of International Standards means that the suppliers can base their product and services development based on these specifications that have wide acceptance in their sectors. This adoption of international standards by the business means that these businesses are free to compete on many more markets around the world.

The worldwide adoption of International standards also helps the customers as they get a wide variety of products, which adopt the international standards. It also gives the customers increase choice of offers, and they benefit from the effects of competition among suppliers.

This also helps the governments as the International Standards provide the technological and scientific bases underpinning health, safety and environmental legislation.

The international standards create a level playing field for all the competitors in the market, thereby helping the officials negotiating the emergence of regional and global markets. The emergence of many standards like the regional and national may create technical barriers to trade, even when there are political agreements to do away with restrictive import quotas.

For developing countries, International Standards that represent an international consensus on the state of the art constitute an important source of technological know-how. By defining the characteristics that products and services will be expected to meet on export markets, International Standards give developing countries a basis for making the right decisions when investing their scarce resources and thus avoid squandering them.

For consumers, products that conform to the international standards provide assurance about quality, reliability and safety.

For everyone, safety and reliability of the products is ensured by the International Standards.

Taking this on a different level, the International Standards on air, water and Soil quality, on emissions of gases and radiation contribute to the efforts to preserve the environment.
Around the world in more than 60 countries, more than half a million organizations are implementing ISO 9000 which provides quality management framework in the different stages in the production and delivery of products and services to the customer.

2.3.5 Specialty of ISO 9001

Nowadays organizations use ISO 9000 as an international reference for quality requirements in their business-to-business dealings.

ISO 9000 is concerned with the quality management, which is what organizations do to enhance client satisfaction by meeting customer and regulatory requirements and involve in continuous improvement in the performance in this regard.

2.3.6 ISO 9001 – ISO Quality Management System

ISO 9001:2008, the ISO 9001 standard that got revised in the year 2008, is the part of the ISO 9000 series that deals with the standards and requirements that organizations have to address, if they wish to be certified against the standard. Figure 2.2 shows the continuous improvement cycle model followed in the ISO 9001 standard.

![Continual improvement of the quality management system](image-url)

Figure 2.2 – ISO 9001- The continuous improvement cycle
2.3.7 The Management Principles

ISO 9001:2008 is developed based on 8 principles of management. They are as follows.

**Customer focus** - Organizations should be customer focused and therefore should understand the customer's current and future needs. Organization should meet the customer requirements and strive to exceed them.

**Leadership** - leaders provide unity and direction to the organization. They must create and maintain the internal environment in which the employees can become fully involved in reaching the organizations targets and objectives.

**Involvements of people** - people at various levels of an organization are the essence of it and their full involvement enables them to understand their abilities to be used for the organization’s benefit.

**Process approach** - a desired result is achieved efficiently when there is a proper process to manage related activities.

**System approach to management** - identifying, understanding and managing interrelated processes as a system helps to increase the organization’s effectiveness and efficiency in achieving its objectives.

**Continual improvement** - should be the objective of the organization.

**Factual approach to decision making** - effective decisions should be analysis based on data and information.

**Mutually beneficial supplier relationships** - Suppliers and organizations are interdependent and a mutual relationship could improve the performance and increases value.

All organizations follow procedures of processes that are equipped to provide services and produce products that satisfy the customer expectations.

ISO 9001:2008 requires any organization to identify and control the processes and procedures that provide products and services to satisfy customer satisfaction. It also deals with the interrelationships between the processes to meet the customer needs.
2.3.8 Different Sections in ISO 9001

ISO standard is classified into 8 different sections and each section addresses one of the important aspect of the quality management system that could impact the organizations performance and how it is applied.

Section 1 discusses the scope of application of the standard.

Section 2 discusses the references of these standards to other standards.

Section 3 describes the definitions and terminologies used in the standards.

Section 4 discusses the need of a well documented and controlled quality management system that will help organizations to identify, define and control its processes, documents and the various records.

Section 5 is aimed to place the responsibility for quality based activities on 'top management' and defines few basic systems required to support the quality management of the organization.

Section 6 defines the resources that an organization requires such as equipment and human resources. It also deals with the training and competency requirements.

Section 7 addresses all of the processes and activities that makes the product or provides the service. This section identifies all the customer requirements till the delivery of the product or service.

Section 8 includes the need to monitor and measure the product and the processes used to create them. It also describes the need to continually improve the quality management system.

As the ISO 9001 is a generic standard, it is the responsibility of the organization to interpret the requirements of the standard and implement it in their respective businesses. The organization has to make sure that the applications of these standards will not impose control on the business that is not beneficial.

An organization is certified as ISO 9001 compliant by accredited certifying bodies after an adequacy audit (verification of the documentation) and compliance audit (verification of the implementation). Periodic surveillance and recertification audits are also done.
2.3.9 Accredited Certifying Agencies

An estimated 30 numbers of certifying bodies are operating in India. Of these the following are the better known:

- BVQI
- LRQA
- BSI-QA
- NQA
- DNV
- TUV
- SA-QAS
- BIS
- IRQS
- SGS
- KPMG
- AQA
- UL
- Germanisher Lloyd’s
- KEMA (Netherlands)
- RINA (Italy)
- Q-Cert

2.4 ISO 27001 (Information Security Management System)

Information is very important in business; it needs to flow through the organization in an orderly way, without blocks and without contamination and leakage.

Every business should have enough confidence over the information to achieve the common objectives. Information exists in many forms. It can be in written form or in printed form, can be stored electronically, transmitted through mail or by electronic means, can also be shown in films or passed in conversation.

Information storage and passing are important to any organization. In the competitive business scenario, this sensitive information is constantly under threat from many sources. These can be external, internal, accidental or malicious. The increased use of new technology to store, transmit, and retrieve information has provided many ways for the information to be lost or stolen and has put the information under different types of threat.
In order to safeguard the information, organizations have implemented the Information Security management to ensure confidentiality, integrity and availability of both vital corporate information and customer information.

2.4.1 Information

Information is what an organization’s employees know or what has been compiled by the organization. It can be passed on or communicated. This information might include customer information, proprietary information, and or protected (e.g., by copyright, trademark, or patent) and unprotected (e.g., business intelligence) or could be the Intellectual Property of the organization.

The confidentiality, integrity, and availability of these important information is essential for any organization to maintain, cash flow, profitability, legal compliance and commercial image and competitive edge with other competitors. ISO 27001 is intended to assist the organizations with this tough task. If you imagine the consequences for an organization if these important information are lost, destroyed, corrupted, burnt, flooded, sabotaged or misused. In many cases may even lead to total collapse of the organization.

Security, in general, relates to the safeguarding of valuable assets against loss, disclosure, or damage. Securing these valuable assets from threats, sabotage, or natural disasters with physical safeguards such as locks, fences and by insuring these assets are a common phenomena employed by many organizations. However, security should also include logical and other technical safeguards such as user IDs, passwords, internet usage, firewalls, etc. In organizations where a security breach has been experienced, the effectiveness and efficiency of security policies and procedures has had to be analyzed and reassessed.

Information security is applicable to all sorts of information. In this context, the valuable assets are the information in the form of data or information recorded, processed, stored, shared, transmitted, or retrieved from an electronic medium. The data or information is secured against threats that will lead to its loss, inaccessibility, alteration, or unlawful disclosure. This information can be protected through a series of technological and non-technological safeguards.
Today's competitive environment makes this information to be under threat from many sources. These sources are varied and at many times unknown. These threats are everyday with the technological advancements in storage, transmission and retrieval of information.

The three accepted Information Security elements are:

- Confidentiality
- Integrity
- Availability

These can better be remembered by the mnemonic “CIA”, and is often referred to as the CIA triad. A common and simple way to express this is the right information at the right time to the right people.

**Confidentiality** - protecting access to Information.

Proper grading of the confidential data and set up of protection levels according to the level or grade of confidentiality.

Confidentiality to information is about preventing unauthorized users from reading that information to which they are not entitled to. Traditionally, security and confidentiality are often identified by the organizations. Many organizations provide confidentiality by implementing suitable **encryption** techniques.

**Integrity** - preventing alteration of information

Information assets are classified according to the level of its importance and protected appropriately to ensure the information assets integrity.

In the software field or computing, integrity is to prevent unauthorised users from writing information to which they are not entitled. Whereas in general system, it is about ensuring that the system's state has not been altered by any unauthorised users. In the data communications context, integrity is more or less restricted to detecting modifications or knowing where information comes from.

**Availability** - To make sure that all the required information assets are given accurately and instantly to the user in order to meet the needs.
Availability as its name would suggest is about the accessibility of the system for the authorized user. This also covers some areas beyond the normal scope of security, such as fault-tolerance. Security is ensured by preventing denial of service attacks by unauthorized entities.

**Information security management** includes the control activities used to safeguard information and is accomplished by implementing a suitable set of control activities. This could be policies, practices, procedures, organizational structures, and software functions.

### 2.4.2 Information Security Management Systems (ISMS)

ISO 27001 is more about an organization's effective security management. It is every organization's need to benchmark with ISO 27001 standard with the guidance in the 10 sections and then certifies them through an external vendor. ISO/IEC 17799:2005, the standard code of practice, is best regarded as a comprehensive catalog of 'The best things to do in Information Security' [www.iso.ch].

Security plays an important role for the businesses quest to acquire global markets in search of new businesses. The increasing trend of online usage to submit bids and complete a business could also help the employees of potential hackers to easily steal information built for many years.

The need of the businesses to allow only the 'Right One' in has become one of the most underlying factors for business success and justifies the money invested in IT.

ISMS is an cyclic approach to implement, maintain and improve the related set of controls, policies and procedures that ensure the organization's information asset's security in a way that could be appropriate for its strategic objectives.

The most important step is to understand that securing critical information falls under a broad umbrella of Information Security Management Systems' (ISMS) and not restricted just in safeguarding solutions like firewalls, anti-viruses and intrusion detection systems. An organization with a well informed Information Security Management System will have a structured process involving identification of business critical information and assets, periodic risk analysis to identify vulnerabilities and threats and finally control measures
such as ID's, user training, firewalls, physical security measures to protect these information assets. This process is reviewed periodically repeated to ensure that the safeguarding process is continuous and updated.

2.4.3 Relation of ISO 27001 with other Standards

ISO/IEC 27001 is aligned with both the ISO 9001 (quality management systems) and ISO 14001 (environmental management systems) standards. These three standards share the system elements and principles, including the adoption of PLAN, DO, CHECK ACT (PDCA) cyclic process. This sharing of PDCA makes it possible to integrate the three systems.

2.4.4 General requirements

An organization in order to provide quality services or products has to establish, implement, operate, monitor, review, maintain and improve documented ISMS within the context of overall business objectives and business risk. It is ideal for these organizations to use the Plan, Do, Check, and Act for that.

2.4.5 Establishing and Managing the ISMS

Improving information security is about business risk management through the execution of appropriate controls, which are implemented to protect information assets in line with business objectives and service requirements.

The integration of the four PDCA steps in ISMS is shown in Fig 2.3.
2.4.6 Risk Assessment

Risk assessments provide decision makers information required to understand the factors that could negatively influence operations and outcomes and make informed judgments needed to reduce the risk. These assessments can pertain to information security or other types of risks. Information security which includes electronic data has also joined this list, which requires several risk assessments to manager potential risks.

Risk assessment identifies the internal and external threats that could cause a business interruption and assesses the probability and impact of a variety of specific threats that an organization can face. The risk assessment study includes all aspects of threats that include physical, environmental, administrative, and technical measures. It provides a complete various factors of risk analysis such as identification, sourcing, and evaluation of the risk at which an organization operates and brings forward the vulnerabilities that the organization can be under.

The risk assessment practices help organizations in implementing measures to reduce the likelihood or mitigate the impact of these threats by prioritizing the most urgent business functions identified during the business impact analysis.
2.4.7 Type of Risk Assessments

It is essential to understand the two different types of risk assessments.

- Information security risk assessment.
- Business risk assessment.

Information security risk assessment focuses exclusively on the risk to an organization's information or information assets. Information security professionals should only perform information security risk assessments.

Business risk assessment focuses the risks to business operations. This is in contrast to business risk assessments that should be performed by organizations such as accounting firms who have a strong understanding of business risks. Information security risks are a subset of business risk.

2.4.8 Establish the ISMS

- Define the scope - this requirement ensures that the scope statement defines not only the scope but also the boundaries of the ISMS in terms of characteristics of the business, organization, its location, assets and technology. The boundaries must also include details and justification for any exclusion.
- An ISMS policy has to be defined that includes framework for setting objectives, legal or regulatory requirements, contractual obligations, and aligns with strategic organizational and risk management context and risk assessment criteria. This ISMS policy has to be formally approved and reviewed by the management.
- Organization has to define the risk assessment approach that it has chosen, and why this approach is appropriate to the security requirements, the business environment and the risks the organization faces. The approach adopted should aim to focus security effort and resources in a cost effective and efficient way. The approach chosen should be able to apply for risk assessment of new assets in the event of change in technology/business environment. Criteria for accepting risks and to identify the acceptable levels of risk also should be developed.
- Organization should identify the risk based on the following risk assessment details
  - Identify the assets within the ISMS scope, including information about the owner of the asset
• Valuation scale used to evaluate the asset;
• Identification of threats and vulnerabilities;
• Assessment of threats exploiting vulnerabilities, and of the impacts (loss of confidentiality, integrity or availability of the assets) caused by such incidents.
• After establishing the risk assessment criteria, the organization should conduct a risk assessment on business impacts upon the organization (loss of confidentiality, integrity or availability of the assets), the realistic likelihood of security failure and arrive at a level of risk for each information asset. Organizations should show for each identified risk - what controls are in place and what additional controls are proposed. Determine whether the risk is acceptable or require treatment.
• An acceptable level of risk needs to be identified. For each of the risks, appropriate action should be chosen from the following:
  • Decide to accept the risk, e.g. because other actions are not possible or too expensive;
  • Transfer the risks to other parties; or
  • Reduce the risk to an acceptable level.
• The risk treatment plan is a coordination document defining the actions to reduce unacceptable levels of risk and implement the controls required to protect information.

Additional controls may need to be designed and implemented where the identified risks exceed the level that can be managed with those controls. If any control is excluded justification for their exclusion should be given.

Controls designed to avoid, detect, limit, prevent and recover from, security violations (in accordance with the ISMS) are very important in the implementation of the PDCA model and should be put in place early enough to be effective, along with those governing controls providing prevention, deterrence (avoidance), limitation and recovery.

2.4.9 Risk

Some inherent vulnerability cannot be eliminated completely, nor would the cost and benefit warrant the risk avoidance approach. Organizations should provide a cost effective, rational and enduring framework using risk management as the basis for security decision making.
2.4.10 Threats

Threats are posed by organizations or individuals who intended to harm and also have the capability to accomplish their wrong intentions. These individuals pose threat to an organizations computer and communications services. In real situations, threats do not occur one at a time or don’t even occur independently.

2.4.11 Vulnerabilities

Vulnerabilities as the name suggests are weak areas that could comprise characteristics of our situations, systems or facilities that can be exploited by a threat to do harm. Vulnerabilities with no credible threat don’t require a response from the security process. Vulnerabilities can be eliminated by carefully designing the facilities and systems. Risk assessment prepares the base on which one would build the ISMS (Information Security Management System).

2.4.12 Asset Identification

Identification and classification of assets are an important step in achieving ISO 27001 certification. ISO 27001 defines risk assessment as assessment of threats to data, impacts on and vulnerabilities of information and information processing facilities and the likelihood of their occurrence.

Every organization possesses sensitive assets and information, without which one cannot continue work and achieve results. These assets can be higher or lesser value. The level of protection should be the most valuable asset would need more protection and the least value less protection.

2.4.13 Asset Classification:

Once the list of assets is identified, the level in which the asset is critical should be assessed and every asset will be classified.

After this stage, risk and vulnerability assessment will be conducted. A gap analysis document is created once this exercise is completed.
2.4.14 Risk Management
Once the testing reveals the gaps in the system, one has to manage these risks and make sure that the possibility of these risks creating an impact on the company is very low or in some cases totally eliminated.
The standard defines risk management as a process of eliminating risks as identifying, controlling and decreasing or eliminating security risks that can affect information systems, for an acceptable cost.

2.4.15 Creating of Security Policies and Procedures to Manage Risks Effectively
Implementation of an effective risk management provides the organizations with benefits such as enhanced understanding of business aspects, decrease in security breaches and or claims, decrease in adverse publicity, increased insurance liability rating, identification of critical assets through business risk assessment. It can also provide a structure for continuous improvement is a confidence factor and enhances the knowledge and importance of security level issues at the management level.

2.5 Capability Maturity Model Integrated (CMMI)

Capability Maturity Model Integration (CMMI) was jointly sponsored by the U.S Department of Defense and National Defense Industrial Association (NDIA). The first integrated CMMI models, the CMMI version 1.1 were released by the Software Engineering Institute (SEI) at Carnegie Mellon University. The subsequent version 1.2 was released in 2008. The existing or the current version is 1.3 released in 2010.

Humphrey (1989) states that The Capability Maturity model by the Software Engineering Institute (SEI) is an assessment process, which assesses the key process areas until you reach level 5. Level 5 represents a continuous process improvement. The improvement is based on the Organizations maturity model and quality maturity models developed by Rensis Likert (1967) and Crosby (1979) respectively.

Doras (doras.dcu.ie) says that the goal of this assessment-based approach is to achieve continuous process improvement through change management, defect prevention and innovation in technology. This model has a five level process maturity model, which is
defined based on many assessments on the organizations capability in key areas. Action plans are framed for the poor process areas. The very base of this approach is addressing the key process areas and improving them to improve the software development.

2.5.1 Process Areas

The fundamental organizational feature of all the CMMI models is the 'process area'. CMMI only chooses the most important topics for process improvement and then groups those topics into 'areas'. Each process areas has an ex-purpse and in addition to this purpose, this purpose area should have goals that should describe the results of a successful process implementation and practices and can help achieve these goals. There is also a great deal of explanatory and "how to" material went to provide help.

The only required component of the CMMI models is the 'Goal'. Goal represents an end state; the achievement of goal indicates that a certain degree of project and process control has been achieved. A specific goal or SG is a goal which is unique to a single process area. A generic goal applies across all of the areas.

A generic goal has a scope that crosses many of the process areas, unlike the specific goal. The application of the generic goal is broad. The wording of the generic goal, due its broad areas, is abstract than the wording of a specific goal. For example, GG 2: “The process is institutionalized as a managed process”.

2.5.2 CMMI Representations

2.5.2.1 Staged Models

The staged model is a well defined road map for organizational growth based fundamentally on proven ordering and grouping of processes and associated organizational relationships. The term "staged" also describes this road map as different series of 'stages" that are called "maturity levels." Each maturity level consists of a set of process areas on which the organization to focus has to improve its organization process. Each process area explained in terms of activities that contribute to satisfying its goals. The activities describe the infrastructure and activities that contribute to the effective implementation and
institutionalization of the process areas. Progress happens when the goals are satisfied for all process areas in a particular maturity level.

When an organization is appraised against the staged model, the appraisal evaluates the organization by determining how many process areas have been achieved or how many of the goals are satisfactorily met. Based on the key areas satisfied, the organization is assigned a key maturity level. For example, an organization is at level 4 when it has conducted an appraisal and has satisfied all goals associated with the process areas or have satisfied all the goals included in levels 3 and 4 of a staged model.

2.5.2.2 Continuous Models

Continuous models provide less specific guidance in the order in which improvement should be accomplished. They are called continuous because no specific stages are associated with the organizations maturity.

Continuous models do have process areas similar to the staged model. Unlike the staged model, the practices of a process area in continuous model are organized in a manner that concentrates on individual growth and improvement. Process area improvement and practices are mostly generic, and are external to process areas and common to all process areas. These generic practices are grouped or assembled into capability levels (CLs). Each of the CLs definition is roughly equivalent to the definition of maturity levels of the staged model. These generic practices improve and institutionalize the process areas.

The collective capability levels of all the process areas define the organizational improvement, and an organization can choose a continuous model and aim at only a few process areas for improvement. In a nutshell the organizations can create their own 'staging' of process areas.

In the continuous appraisal, each of the process areas defined in the continuous model is rated on its own capability level. Most likely the organizations will have different process areas rated at different capability levels.
2.5.2.3 Capability Dimension

CMMI consists of six levels of process area capability, called as capability levels or CLs. They are numbered as 0 to 5. These capability levels indicate an organizations performance in the individual process areas. As shown in Figure 3.4, capability level 0 (CL 0) indicates that the processes are ‘Not Performed’, which means that one or more of the specific goals of the process area are not satisfied. The capability levels increase up to capability level 5 (CL 5), where the process is performed well and is being continuously improved. Figure 2.4 represents the capability dimension as identified by the CMMI model.

![Capability Dimension Diagram]

**Figure: 2.4. Capability dimension**

2.5.2.4 Maturity Dimension

Five levels of maturing exits in the CMMI model. Each of these indicates the process maturity of the organization in assessment. These capability levels and maturity have the same name but are fundamentally different. Capability levels are applied independently to any individual process area, whereas maturity level specifies a set of process areas whose combined set of goals needs to be achieved.
2.5.2.5 CMMI Process Areas

Process areas can be grouped into four categories:

- Process Management
- Project Management
- Engineering
- Support

Process Management process areas comprise of the cross-project activities related to defining, planning, deploying, implementing, monitoring, controlling, appraising, measuring, and improving processes.

The Process Management process areas of CMMI are as follows:

- Organizational Process Focus
- Organizational Process Definition
- Organizational Training
- Organizational Process Performance
- Organizational Performance Management

Project Management process areas cover the project management activities related to planning, monitoring, and controlling the project.

The Project Management process areas of CMMI are as follows:

- Planning the project
- Monitoring and controlling of the project
- Vendor and supplier Agreement Management
- Integrated Project Management
- Risk Assessment and Management
- Quantitative Project Management

Engineering process areas emphasize concurrent development and focuses on all phases of the product's lifecycle.
The Engineering process areas of CMMI are as follows:

- Requirements Development
- Requirements Management
- Technical Solution
- Product Integration
- Verification
- Validation

The Support process areas of CMMI are as follows:

- Configuration Management
- Process and Product Quality Assurance
- Measurement and Analysis
- Decision Analysis and Resolution
- Causal Analysis and Resolution

2.6 Tools Used in Software Quality Assurance

The following section discuss on the various types of tools used in software quality assurance domain. The various tools used in quality assurance are described in detail in the books written by John Marsh (1993), John Oakland (1995), Nevin Mcmillen (1991), Greg Brue (2002), Stephen Kan (2006), Roderick Munaro et al, Peter Pande et al. This also includes a brief description of the tools and steps to implement the tools for usage:

2.6.1 Brain Storming

2.6.1.1 Aim

Brainstorming is an effective way to generate and collect wisdom to solve a problem or to generate new ideas for improvement or to solve a problem. This process requires an unthreatening environment and the team has to be supported by an unbiased and neutral moderator.
2.6.1.2 Method

1. Define the subject of brainstorming clearly
2. Allow the duration to be 15 minutes
3. Start with one person and work clockwise or anticlockwise
4. The facilitator asks each person in turn for a succinct statement of their contribution
5. Only the speaker and the contributor should speak at a time.
6. There should be absolutely no comment or criticism from the others
7. The facilitator encourages all the participants to contribute to generate as many ideas as possible.
9. Go back to the brain stormed idea. Get common understanding and classify as one or more of the following:
   - T, Total: Issue and its resolution are totally within the control of the team
   - P, Partial: Issue and its resolution are partially within the control of the team
   - N, Not: Issue and its resolution is not within the control of the team

2.6.1.3 Guidelines

It is advisable for the team to resolve the issues in a sequence as to start with ‘T’ for total, then ‘P’ for partial. The team needs to bring representations from other areas to broaden their influence. Finally, those issues termed as ‘N’ which are not under the team’s control should be passed on to the others who can resolve them.

Experiments clearly show that an efficient brainstorming session will typically generate three times the quantity of ideas generated by individuals. In a good brainstorm team members feed each other ideas and the results are often hybrids of many contributions.

Brainstorming has different variations on the theme in which it is conducted. Facilitator, as always, must put the group at ease and should ask people to jot ideas down as they come to mind.

The ideal size for a brainstorm group is between 8 and 12.
2.6.2 Mind Map

2.6.2.1 Aim

Mind map is a tool that can make associations of ideals related to a particular theme. This association helps to capture, classify and structure related thoughts and concepts. Mind maps are particularly useful for writing reports and to create presentations. They ensure that the structure and logic is inherent.

2.6.2.2 Method

1. Define the theme, subject, issue, concept, etc and agree on them.
2. Create a rectangle in the middle of the page and write the theme in it.
3. Brainstorm related issues and subjects.
4. Spread these on the page making links and interrelated lines.
5. Connect the lines with items.
6. Use the mind map for quality improvement, writing a report, preparing a presentation or setting an agenda.
Figure 2.5: Sample Mind Map of Vacation Planning
2.6.2.3 Guidelines

It is easier to write the brainstormed ideas in to cards. Their positions on the mind map and their association can be discussed with the team anytime.

Mind Maps can be used as elementary planning tools. Sequencing can be shown by working on the mind map in clockwise direction.

Numbering can be used to give the mind map a good structure.

2.6.3 Tree Diagram

2.6.3.1 Aim

A tree diagram helps to break down a complex issue micro components or elements. Also it is used to show simple cause and effect chains through simple diagrams called ‘Why Why’ diagram. The ‘How How’ variant is used to show the simple derivatives of a very complex process.

2.6.3.2 Method

1. Identify the issue, problem or project and define it precisely. Place in rectangle on left hand side of page.
2. Ask a few questions on how the project or problem is caused. Place each ‘how’ in boxes and link them.
3. Continue step 2 with each sub-issue until an achievable action is arrived at (‘How How’ diagram), or root causes are highlighted (‘Why, Why’ diagram).
2.6.3.3 Guidelines

Pieces of card or Post-Its can be used for this process. It enables a Team to use this technique and discuss and modify the Tree structure.

2.6.4 Force Field Analysis

2.6.4.1 Aim

This is a useful decision making technique. This also helps to prevent conflicts and helps to identify the key forces that are for and against change so that the positives can be nurtured and developed and the negatives reduced or removed.

2.6.4.2 Method

1. Identify the stakeholders - Who are the stakeholders? Who are those with an interest and / or involvement in the process being improved?
2. Who all support the improvement - Involve representatives from all groups of stakeholders in two brainstorm: one to identify the positive forces for change. The other to identify the negative forces for change.

3. Represent these forces acting on a line drawn in the centre of the page.

4. Discuss the relative magnitudes of these forces and draw the arrows to correspond in length or thickness.

![Figure 2.7: Representation of Force Field Analysis](image)

1. Review the diagram marking internal forces with an ‘I’ and external forces with an ‘E’. A force is internal or external to the organization experiencing it.

2. Discuss with the team and agree to reduce the negative forces and increase the positive forces.

### 2.6.4.3 Guidelines

To ensure a reliable outcome all stakeholders must be reliability represented.

Identify all the forces, no matter how much their significance is. The tool is not used to identify scientifically proven things, rather than to find feelings and fears. Each and every stakeholders feeling is considered important. The basis of this is to put one on someone else's position. This is a 'feel touch' technique but it is absolutely essential because people make successful quality improvement and not just tools. Often Newton’s Law applies: ‘for every force there is an equal and opposite force’: A positive force often has corresponding negative ones.

Numbering of items can be used to give structure.
2.6.5 Pareto Analysis

2.6.5.1 Aim

This is used to prioritize the most beneficial areas to change the focus with the limited quality improvement resources.

2.6.5.2 Method

2. Use one of the following visual aids to find the Pareto effect:
   - Graph
   - Bar Chart
   - Pie Chart
3. Agree upon the areas for further investigation considering the fact that an area of great potential improvement will usually have complex root causes within a complex process. Therefore consider the time to realize the benefits of action.
4. The following points should also be considered in the light of the Pareto effect:
   - Time to realize benefit.
   - Impact on customer satisfaction
   - Impact on employee morale
   - Impact on quality costs
   - Impact on organizations achievement of strategy.
5. Decide further actions.

2.6.5.3 Guidelines

The Pareto analysis is a powerful tool that appears throughout nature and man-made environments. In says that 20% of issues cause 80% of the effect. Identifying these critical 20% saves enormous effort but must be considered in the light of the wider issues listed in the method.
2.6.6 Fish Bone Diagram

2.6.6.1 Aim

This is problem solving tool designed to assist in the brainstorming of possible problems or solutions. It provides a framework for further analysis of a problem by categorizing a large number of issues into more manageable groupings.

2.6.6.2 Method

1. Define and agree the problem or subject for analysis. Place this in a rectangle at the right hand side of the paper or wipe board.
2. Draw a fishbone structure with 6 bones to start with:
3. Consider each brainstormed issue in turn. Once again Post-Its or cards are useful for grouping issues.
4. Place the issues one by one on each of the bones.
5. As the team precedes natural, sensible groupings (i.e. names for each main bone) will emerge, although they may need improvement.
6. The procedure is complete when all issues have been placed on the fishbone diagram.
7. Add new issues that may emerge as a result of this technique.

2.6.6.3 Guidelines

The fishbone also known as the cause and effect diagram. The fishbone is mainly useful to identify the different issues that cause a problem and it also prompts brain-storming.

Selecting the labels for the bones is a key factor in the fish bone analysis. The manufacturing environment uses a generic set – Men, Machines, methods and Materials. In time a non-manufacturing organization may find its own generic set. In the meantime the labels for the bones often drop out during or as a result of the grouping. This is further explained in Chapter 4.
2.6.7 Weighted Selection

2.6.7.1 Aim

This is used to assist in making decisions between different options.

2.6.7.2 Method

1. List all the available options and identify the options uniquely.
2. Brainstorm to select the important factors in the decision.
3. Assign a numerical value for weight age on each factor. Paired comparison of the factors would automatically generate numerical weights from the totals. These can be factored down to numbers lying between zero and ten.
5. For each option consider the impact created on each factor and rate it in a scale of zero to ten. This is the options score. Now multiply this by the factor’s weight and put the answer in the column for that option.
6. Add the scores for each of the option and group them into high, medium and low.
7. Reject the low scoring options.
8. Evaluate the high options carefully and arrive at a decision.
9. Individuals of the team can do the technique and their respective scoring can be totaled to give the team result.

2.6.8 Failure Mode Effect Analysis (FMEA)

2.6.8.1 Aim

As the name suggests, this is used to identify the most critical and likely failures in an unproven process. This is in order to prevent the failures in the initial stage itself and assure that failure would never occur.

2.6.8.2 Method

1. Brainstorm all the possible failures or nonconformance of the unproven or new process.
2. Discuss the identified failure and consider the following:
• At first, identify whether the failure is critical. That is, if the failure happens, what will be the frequency and magnitude of the impact? This is then ranked in as scale of 10 to 0 in which 10 is very critical and 0 not critical at all. This ranking by nature is subjective in non-engineering fields.

3. Enter the weights for criticality and likelihood into the Failure Mode Effect analysis matrix (combination of criticality and impact). Arrive at the FMEA factor by multiplying the weights together.

4. Use this factor to prioritize the potential failures for careful prevention design. For example if a failure is both highly critical and likely this can be handled in one of two ways. The process should be designed so that the failure doesn’t occur in the process. If this is not practical, safety systems can be designed to minimize the impact of failure.

2.6.8.3 Guidelines

Failure Mode Effect Analysis (FMEA) is a technique developed by engineers to prevent defects in electrical and mechanical designs. This is a unique technique in which statistics is used instead of estimates to predict the likelihood of a failure. The technique is rigorous and time consuming creating a lot of paper work.

However this approach is extremely effective in services where hard data may not exist but the principle of predicting criticality and likelihood is just as important. Combining this with paired comparison makes it more reliable and extremely simple and quick to use.

2.6.9 Statistical Process Control (SPC)

2.6.9.1 Aim

SPC reduces variability and helps to prevent defect generation by gaining predictability of a process.

2.6.9.2 Method

1. Define the Process
2. Identify the critical outputs that can satisfy the customer requirements
3. Measure a sample from the process
4. Produce a histogram
5. Calculate the statistical mean and standard deviation.
   - Mean = \((\text{Sum of Values}) / (\text{Number of Readings})\)
   - Range = \(\text{Value of the Greatest Reading} - \text{Value of the Least Reading}\)

The standard deviation is the measure of spread for the distribution.

1. Calculate the upper and lower control limits
   - LCL (Lower Control Limit) = \(\text{Mean} - 3 \times \text{Standard Deviations}\)
   - UCL (Upper Control Limit) = \(\text{Mean} + 3 \times \text{Standard Deviations}\)
2. Compare to the Upper and Lower Specification Limits to see if the current process is capable of achieving the desired output values
3. Prepare Control Chart
4. Plot continuing output values onto the Control Chart
5. Analyze the control chart and take preventive action as a result of trends.

2.6.9.3 Guidelines

The concept of Statistical Process Control must be understood clearly, since this is a complex technique. One should have a profound knowledge of the technique to implement it. The practical implementation of this technique has many pitfalls.

The first is that when applying the concepts a little knowledge can be dangerous. One should be very careful in applying the SPC and should also have expert statistician. However once the control charts are established for the correct output, maintenance of these is quite straightforward.

The main benefits of rapid preventive action occur when the charts are completed by the process owners.

2.6.10 Bench Marking

2.6.10.1 Aim

This technique enables performance to be compared to other organizations and to assist in setting targets to fill performance gaps.
2.6.10.2 Method

1. Identify the Critical Success Factors or Quality Objectives.
2. Identify the following for each of the critical success factors:
   - Competitor
   - Organizations with similar problems which are in competition. They could become prospective benchmarking collaborators
   - Regional or national completeive information
3. To identify each of the above, brainstorm possible sources of information. The sources will include Central Libraries, University Research Departments, Government Statistics, Books and Journals, Available Competitor Information etc.
4. Gather all available information
5. Report trends regularly ensuring that the information is presented in ways which are useful to the target customers
6. Check accuracy by regularly reviewing the adapted method to identify new sources.

2.6.10.3 Guidelines

Benchmarking is useful, but it should not be allowed to dominate. The key reason behind this is it is far more important to concentrate on delighting the organization’s external customers and doing just enough to keep ahead.

True competitive information is extremely hard to obtain legally and ethically. The definitions behind the information may mean that the organization is not comparing like with like and this may lull the organization into a false sense of security.

Another problem is who to benchmark competitively against. Too much reliance on benchmarking could mean loss of customers, when they find new competitors who can delight them in other ways.

A useful form of benchmarking is gaining in popularity and overcomes some of the traditional problems. This is collaborative benchmarking. Organizations that are not directly in competition, but share common goals, issues and problems set up networks to share ideas on a regular basis.
2.6.11 Critical Path Analysis

2.6.11.1 Aim

To plan a project to identify and highlight the steps which on possible slippage will result in delay of software delivery.

2.6.11.2 Method

1. Brainstorm all possible activities
2. Rationalize and group activities
3. Write each activity of the project into a card mentioning the details like ‘start’, ‘duration’, ‘finish’
4. Decide which activities precede and constrain others

![Critical Path Diagram]

**Figure 2.8: Critical Path- Sample**

1. Add extra activities missed in the brainstorm but that occur for the team
2. Identify or estimate the durations of all activities
3. Put the earliest state date using a calendar (‘start’ of the activity)
4. Work forward, excluding holidays, the number of day’s duration to find the finish date. (This is the ‘finish’ of the activity)
5. Identify all other activities that could start when the first one is complete. Put the finish date from the first activity into the start date for all the following ones.
6. Use the calendar to find the finish dates for all the secondary activities.
7. Continue until the end of the continuity map.
8. Identify the earliest finish date for the whole project
9. If this is unacceptable review whether some activities could be sub-contracted, or more manpower can be brought in, or a more productive approach to be used

10. From the analysis identify those activities which, if they are completed late, affect the final completion date

11. Link these activities to identify the critical path

2.6.11.3 Guideline

Thorough Critical Path Analysis can be a complicated task requiring the use of computer tools to help schedule and resource work.
Section 2

Studies Conducted on Quality Assurance Practices

Rajiv Banker et al (1997) define Quality in many different forms in the operations management literature. Chase and Aquilano (1992) states that quality of a product can be identified in the quality of design and the quality of conformance to design. The reason behind quality improvements is to make the product attractive to the customers.

Crosby’s (1979) poses a question, ‘How should a firm, decide on its investment in quality improvement?’ He identifies the advantages of quality improvement as stronger customer loyalty; more repeat purchases; less vulnerability to price wars; ability to command higher relative price without affecting share; lower marketing costs; and sharing of improvements.

Anindya Ghose and Arun Sundararajan (2005) identifies that many manufacturers create product lines by first developing a flagship product with optimized features and functionality, and then create one or more inferior versions by purposefully reducing the quality of this flag-ship product. They call this as quality degradation, and many instances of this can be seen in practice. They also find that quality degradation is common practice in the software industry and cite example: different versions of popular desktop software packages that differ only in their quality or number of features and sold at different prices.

Ashish Arora et al (2003) and Baskerville et al (2001) state that when software becomes part of the daily business activities, its failure become critical.

Bessen James (2002) observes that media reports of disastrous effects of software failure are plenty. He also gives examples of buffer overflow bug that caused the Ariane 5 rocket to blow up 40 seconds after liftoff in 1996 (estimated loss of over $500 million) and a software failure that interrupted the New York Mercantile Exchange.

Brooks (1995) points that software quality has become important in recent days due to increased security concerns arising from software vulnerabilities and observes that the business community also watches closely on software malfunctions. He also reports a
survey where 97% of the 800 managers surveyed reported software flaws in their systems in the past year. More than 90% blamed faulty software for lost revenue or higher costs.

Banker and Slaughter (1997) reports a survey where 62% of the respondents said they believed the software industry was doing a bad job in producing bug-free software. Krishnan et al (2000) and Banker et al (1997) observe that better process leads to higher quality and lower costs of maintenance.

Ashish Arora and Jai Asundi (1999) observe that significant amount of software development is outsourced to countries like India. They also points that many Indian software firms went for certifications like the ISO 9001, and the number of certified software firms has steadily increased.

They further observe that despite its growing popularity among Indian software developers, there is very little systematic evidence on the relationship of ISO certification to the organizational performance. Using data on 95 Indian software firms and their US clients, the authors developed a model of a firm that develops software for others to articulate the different ways in which ISO certification can affect firm profits and concluded that ISO certification enhances a firm’s growth. They also talks about a survey that states that firms having certification received a higher price per unit of output and firms see ISO certification as a marketing ploy and some of them proceed to implement systematic and defined processes for software development. They further state that in software, defining quality standards is difficult, as software development projects involve design activity by humans and concludes that the difficulty of measuring output quality for complex software systems triggered strong emphasis on process.

As identified by Cole (1999) ISO certification requires the firm to have well defined and documented processes that it follows and an external auditor can verify the company adherence to the processes. He also observes that the ISO methodology has been described as document what you do, do what you document, and verify that you are doing it. Cole further articulates that ISO standards have become widely adapted as a quality standard. He again observes a gap stating that ISO standards do not prescribe processes that must be followed and the intent of ISO standards is to minimize variations in quality.
Cole further says that in a fixed-fee software contract, the deliverables as well as the
deadline for the project is decided and the contract may include penalty clauses for late
delivery and for poor quality delivery. He identifies that in many developing countries,
multinationals tend to put pressure on their suppliers; as well as the local governments
have provided a variety of incentives to firms to acquire certification. He also points that
the Indian government has granted special subsidies and licenses to firms that obtain ISO
or similar quality certifications and concludes that for some firms, ISO certification is the
first step in an ongoing commitment to quality which increases the quality of the software
developed.

Abdulrahman Alshamlan (2005) suggests that the development of the new applications and
systems with intangibility and complexity will increase the importance of measuring the
quality of software. He articulates that quality measurement will examine the correctness,
reliability, efficiency, integrity, usability, maintainability, testability, flexibility, portability,
reusability and interoperability of the software and concludes that standards like ISO 9000
series concern with the certification of development process and governing quality systems.

Cohen, Lindvall, Costa (2003) state that in a global economy, customers spanning across
the world can be more sophisticated and demanding and identifies that this requires
organizations to examine new goals and redesigning of work and business process. 
Hammer and Champy (Answers.com) called it reengineering which is determined by open
markets and competition.

Trilochan Sastri (2001) states that few Indian companies use systematic processes while
executing projects. He argues that putting the right processes in place helps to reduce re-
work, improve quality and reduce project execution time. He points that India's share in the
world software market continued to be low, while identifying some advantages Indian
firms have like the world's second largest pool of scientific labor, who are highly skilled,
English speaking workforce. He also points that the cost of this high quality labor was
relatively low, and ranged from 15% to 20% of international norms. He further state that
this was rising fast, and wonders how long the cost advantage would continue, especially
for value added activities.
He also identifies that as the level of outsourcing increased, allowing IT service providers to target on advising clients on IT needs, and finally, managing all the IT needs, for which the fees that could be charged increased considerably. He recommends that moving up this value chain means changing from doing specific programming tasks under supervision to providing IT management, consulting and maintenance services and points that a broader set of skills and capabilities are required which is beyond technical hardware and software skills.

According to Jorgensen (1999) software quality is identified by a set of quality factors like the user satisfaction as well as errors or unexpected behavior of the software and concludes that the quality factors will be required to ensure standardization.

Cotterell M and Hughes B (1998) say that quality management systems (QMS) are a set of quality factors that are created to ensure standardizations. They points that QMS can help to set organizations using services of an external contractor in setting best quality practices to be followed by contractor. They also states that QMS standards can be tailored to assure that the product will be made to the client's requirements.

The paper published by Mercury (2004) suggests that it is very important for organizations to understand market requirements and their business abilities and based on which they have to develop goals and set objectives. They further state that for positive planning, organizations need standards to measure and control business processes to guarantee achieving the desired goals and objectives in the lowest cost, best quality and optimal performance. They also observe that consistency can be developed by standardization which can ensure consistent, cost-effective and rapid implementation of organized processes. Efficiency and quality production will be attained by starting on small scale to gain experience and build for best quality practices and conclude that after this stage, leverage existing resources and expand its capabilities as the value is proven.

argues that software quality needs to be managed top-down, which means that developers need to be trained and educated about the importance of quality.

Weinberg (1971) and Brooks (1975) say software development is considered as a complex process that require expert knowledge and experience about design, coding and the application domain of software. Engelhardt (2010) identify that in many markets, software sold is bundled with complementary products like service (maintenance, individualizing) or hardware.

Easwar Nyshadham and Janaki Krishnamurthy (2012) say that it is common that software development projects fail to meet project objectives such as schedule, quality and budget with alarming regularity and observes that out of these three objectives, software quality is difficult to define in tangible terms. Stavrinoudis et al (2005) points that addressing quality issues later in the software development cycle is lot more expensive than addressing them early.

Bevan (1999) says that the first issue is to deal with the inherent difficulty in defining and measuring quality and argues that traditional approaches to quality emphasized on meeting the specified functional requirements. He also points that the definition of quality has been expanded to include non-functional attributes such as usability, maintainability, reliability and portability in addition to the functional requirements. John Marsh, in his book explains the various tools that are used for quality improvement in organizations. Roderick et al, Peter et al also explains on the various quality tools from the six sigma back ground in their books.

Moses (2009) suggests that standards such as ISO 9001 emphasize that user opinions has to be integrated into quality measurements and the subjective nature of quality measures need attention and further argues that software quality is viewed as component with many attributes; some of which are subjective and reflect the opinions of end users, in addition to traditional stakeholders.

The author further states that the second issue is to with the methods and processes used in developing software in organizations. When software is developed in organizations, the
development task is broken into large number of modular tasks (e.g., requirement elicitation, project planning, development, testing and quality assurance (QA) etc.) with different teams work on more specific tasks.

2.7 Challenges faced by Indian Companies

Trilochan Sastry (2001) identifies some unique challenges faced by Indian firms which he classified into the following categories.

- Challenge arising from sustained high growth
- Challenge of operating as a low cost service provider
- Challenge of overseas development
- Challenge of managing multiple agencies in a single project
- Cultural challenges of operating in overseas markets
- Entry barriers to higher end value added work.

He also states that other challenges common to all firms include the fast pace of change in markets, customer demands, and technology and observes that customers were changing the way they did business, wanted projects completed much faster and to add to the complexity, projects were distributed across several customer locations. He also says that companies were faced with fresh challenges in project management while managing 55% revenue growth rates. He also points that the software services industry in India sustained annual growth rates of over 50% for over 5 years and states that due to the complexity of the operations, Indian companies had to satisfy two parties: the IT consultant, and the eventual client. He also points a gap by stating that sometimes there were differing perceptions between them, adding to the complexity of operations.

Kaujalgi (1993) says that India has the third largest pool of technical persons and that Indian graduates have been appreciated as good programmers and systems analysts by many advanced countries. He further points that software development is one of the high growth sectors of economy and that the government has been encouraging this sector by giving incentives and declaring liberalized policies as they identified software export as a major thrust area.
Cooper (2004) and Ebert (2005) state that one of the most important challenges for producers are to provide quality in all products. They also identify that achieving quality software product depends on having highly experienced and capable managers.

The book ‘The Guide to The CSQA Common Body of Knowledge V 6.1 Hand Book’ from QAI says meeting requirements is a producer's view of quality and clarify that this is the view of the supplier organization responsible for the project and processes, and the products and services acquired, developed and maintained by those processes. The book further say that meeting requirements means that person developing the product does so in accordance with the requirements and points that requirements can be complete or simple, but must be defined in a measurable format, so as to determine whether they have been met.

The book further talks about two quality gap: the producer gap and the customer gap. The producer gap is the difference between what is specified versus what is delivered. The book also points that the customer gap is the difference between what the producers actually delivered versus what the customer wanted. They identify that closing these two gaps is the responsibility of the quality function. They also put across a point by stating that the quality function has to improve the processes to the point where the producer can develop the products according to requirements received and meeting its own internal standards so that this will provide customers consistency in its produce.


William Florac, Robert Park and Anita Carleton (1997) say while there are many unique characteristics to software, they require more management discipline. They also point that managers should thus create detailed plans, tracking systems which are more than traditional for effective software project management. They state that software process management is about successfully managing the work processes involved with developing, maintaining, and supporting software products and software-intensive systems. Successful management means that the products and services produced by the processes conform fully
to internal and external customer requirements as well as meeting the business objectives of the organization that produce the products.

The authors further state that at the individual level objective of software process management is to ensure that the processes that one operates or supervises should be predictable, meet customer needs, and are continually being improved and points that from the organizational perspective, the objective of process management is to ensure that the same holds true for every process within the organization.

Thomas Pyzdek (1996) emphasizes the Kano model of choosing the goal. Noritaki Kano developed a model depicting the relationship between customer satisfaction and quality, which is shown in the following figure.

![Figure 2.9: The Kano Model](image)

The Kano model shows that there is a basic level of quality which customers assumes those products will possess. If this quality level isn't met the customer will be dissatisfied. But providing basic quality isn't enough to create a satisfied customer. The model further shows that customers will be dissatisfied if their quality expectations are not met and satisfaction increases as more and more expectations are met. The exciting quality curve, which is the effect of innovation, lies entirely in the satisfaction region. The model further
say that competitive pressure will constantly raise customer expectations, which means that today’s exciting quality will be tomorrow’s basic quality.

The author further states that quality is a comparison between the product offered by the organization and those offered by others, done by people outside of the firm. This means that quality customer complaints, customer lifetime value, and a number of other issues become the concern of senior management and the quality professional.

2.8 Risk Management

Bakker (2011) and Claudiu Brandas, Otniel Didraga, Nicolae Aurelian Bibu (2012) state that with the increasing level of complexity of IT projects, the associated risks also have increased. They further say that this has generated more interest in the risk approach both in terms of research, and that of professional standards for IT project management and software development. They also points that recent researches identified the relationship between risk and IT project performance, and the relationship between risk and performance of software project management.

Jun, Qiuzhen and Qingguo and Batagan (2011) suggest that focusing on risk is more than formal act and further points that this is required to ensure the performance of software development projects. They conclude that there is a positive relationship between risk and performance of software development projects.

Na, Simpson, Li, Singh, Kim, (2007), Han and Huang (2007), Bannerman (2008), Wallace, Keil and Arun (2004), Chen et al (2009) and Didraga (2012) states that in risk management, focusing on project performance requires mandatory use of risk management methods and further say that risk factors are represented by any element or condition that can negatively or positively affect the project throughout its life cycle, and specially the final outcome of the project.

Didraga (2012) says that IT projects risks have many shapes, and hence is difficult to measure, and are divided into several dimensions: users, requirements, complexity of project, planning and control, project team as well as organizational environment. He
further say that risk management is an iterative process of risk identification, analysis and risk assessment, risk response planning, monitoring and control of risk response and is done throughout the project life cycle. They further points that from practical experience it is learned that the use of a formal and structured process for handling expected or unexpected risk events minimizes unpredictable events, costs, delays, stress or misunderstandings.

PMBOK (Project Management Body of Knowledge) is a standard methodology in project management developed by PMI and clarifies that in this methodology, the risk approach occurs in "Risk management" domain in the planning and control of the project.

SEI discuss the risk approach in the CMMI framework (Capability Maturity Model Integration) focuses on improving processes that provide basis of effective processes for the organizations. CMMI addresses risks in the level 3 of maturity ("Defined").

Lisa Meulbroek (2002) says that the integrated risk management approach identifies that a firm has several ways to manage its risk, and only optimal amount of risk retained, and the tools used to achieve this level of risk will differ among firms. The author further points that integrated risk management provides a systematic way of thinking on the risk and identifying its multi-dimensional effects on the firm, along with a framework to decide upon the best strategy for implementation. It is also stated that some risks cannot be managed effectively by the operations of the firm, either because no feasible operational approach exists, or because the solution is very expensive to implement or it is too disruptive on the organization's strategic goals.

Rene Stulz (2008) noted that in a typical firm, the primary role of risk management is to assess the risks faced by the firm and further suggests that the risk then has to be communicated to those who are in the decision making roles with respect to the risk management in the firm, and finally manage and monitor those risks to make sure that the firm only bears the risks which the management want to take up. He further points that a firm will specify a risk measure that it focuses on together with additional risk metrics.
Rene further identifies the two types of mistakes occur while measuring risks: Known risks can be mis-measured and some risks can be ignored, either because they are unknown or viewed as not material. He further says that upon measuring the risk, they have to be communicated to the firm’s top management. He also points that any failure in communicating risk to management is a risk management failure as well and further observe that after management decides what kind of risks to be accepted, risk management strategy has to make sure that the firm takes these risks.

With this perspective, Rene identifies six types of risk management failures:

- Mis-measurement of known risks.
- Failure to take risks into account.
- Failure in communicating the risks to top management.
- Failure in monitoring risks.
- Failure in managing risks.
- Failure to use appropriate risk metrics.

Brandas et al (2012) suggests that due to the increasing level of complexity of software development projects, the risks associated with them have considerably increased and that lead to lot of research and led to development of professional standards for software development and project management. They also points that software projects face risks from different sources and magnitudes based on the very own nature of the project life cycle. Jiang and Klein (2000) and Jun et al (2011) says that there is a positive relationship existing between risk and the performance of software projects and due to this reason, any focus on the project performance requires a mandatory use of risk management methods.

Wallace, Keil and Rai (2004) and Wallace, Keil and Arun (2004) state that risk factors are those which affect the project throughout their life cycle—either in a positive way or a negative way. These factors influence on the project outcome. They further points that software project risks have many dimensions, are not easy to monitor and measure, and had influencing factors like the end users, the requirements themselves, complexity of the software project, approaches of planning as well as monitoring and control, the project team structure as well as the environment of the organization.
It is further identified from these papers that the risks originate due to the customer specific reasons, organization specific reasons as well as resource and technical reasons. A key challenge faced by a software project manager is the uncertainties due to the risks posed in the projects and developing and maintaining a strategy to keep the risks in control by developing containment actions or contingency action and strategic actions or the mitigation actions. They further points that the key factors that support the success of an effective risk management includes the adoption of standards and frameworks like ISO 9001 and CMMI, an effective usage of the available organizational wisdom as well as the collective experience based wisdom of the project manager and the team and concludes that this again is influenced by the availability or non availability of the organization’s specific risk management practices.

KLCI (2001) conducted a study across the globe in 268 organizations shows that 3% of the respondents did not use a specific risk management approach, 18% of the respondents have an ad-hoc way to identify the of risks, 37% have no formal methods available for risk management, 28% of the respondents have procedures that can be repeated and only 14% of the respondents have a formal and defined way of risk management available. Jose Estevas et al (2004) states that the reasons for having an informal risk management approach are the ones like lack of clear and defined procedure in line with the project needs, the organization being young or nascent and the focus of the project team. They further identifies that the most common reasons for using an informal approach include: lack of formal procedure meeting project needs, young/immature organization, and lack of focus of the team.

Kontio et al (1997) states the reasons for lower penetration of risk management technology as lack of knowledge of formal risk management methods and available tools, limitations of the risk management approaches that prevents their usability as well as lack of systematic and sound evaluations providing details on the feasibility of usage and benefits they offer. Jiang et al (2001), Doherty and King (2001) states that risks faced by a typical software project have technical and behavioral aspects. They future quotes studies that show that most of the projects fail due to managerial reasons, and not due to technical reasons. They further add that issues related to the organization is the most dominant type of risk faced by software projects.
Schmidt et al. (2001) identifies successful project managers as those who rank the risks in which they have no control as low. This includes the following factors:

- Interdepartmental conflicts in the user group
- Change of project ownership or a change in the senior management team,
- Risks related to changes in project team as well that due to the number of organizations working in a multi vendor project.

José Esteves et al (2004) says that risk management is a dynamic and iterative activity that includes identification of the risk, analysis of the risk thus identified leading to the risk assessment, response planning for the risk as well as risk monitoring and control of the identified responses throughout the project life cycle. Claudiu Brandas et al (2012) found that the use of a formal and structured risk management approach minimizes the unpredictable events, costs, delays, stress or misunderstandings.

Ropponen and Lyytinen (2000) say that Software Risk Management research is a task that attempts to formalize risk-oriented relationship of development success into readily applicable set of principles and practices. Several risk management approaches have been proposed and used since Boehm (1988) brought risk management to the attention of the software engineering community.

Kontio (1997) believe that there are three primary reasons for the low penetration rate of risk management technology:

- Lack of knowledge about possible risk management methods and tools,
- Practical and theoretical limitations of risk management approaches that hinder the usability of these methods,

José Esteves et al (2004) identify the main responsibilities for various risk roles:

**Team members**: identify new risks, estimate probability and impact, classify risks, recommend actions, track risks and mitigation plans, and assist in risk prioritizing.

**Technical managers**: integrate risk information from various individuals within their department, ensure accuracy of probability and impact estimates and the classification,
reprioritize all risks to determine high importance risks, review recommendations on mitigation actions, assign or change responsibility for risks and mitigation plans, report to the project manager, implement control decisions for risks, build action plans, collect and report general risk measures, and coordinate communications with the project manager.

**Project manager:** authorize resources for mitigation, integrate risk information from all managers, and reprioritize all risks to determine high importance risks, make decisions to control these risks, assign or change responsibility for risks and mitigation plans within the project, and review measures with quality department periodically to evaluate effectiveness.

**Risk management Team (Quality team):** coordinate activities to identify and analyze risks, maintain the project risks list, notify new risks and report periodically risks status to the project manager.

**Team to support the risk management team:** detect risk elements and estimate potential negative impact, review and evaluate critic processes and dept within the project, review and import relevant results from other similar internal or external projects, build policies and contingency plans, and assess and assist the project manager in high critic activities. The risk identification phase consists in activities and methods used to discover risk factors before they become problems.

They further discuss on the risk analysis phase, where the risk data is converted into decision-making information and states that this involves establishing values for impact and probability of occurrence. The risk plan phase follows this where decision on what to do and when to do is identified, for each identified risks and adds that in this phase decisions and mitigation strategies are developed based on current knowledge about project risks. They also note that the risk strategy for a specific risk can take many forms: Transfer, mitigate, avoid and accept the risk. And that the risk-plan process having the following steps follows this: assignment of risk responsibility to any project stakeholder; creation of an action plan for each risk, if the action opted is mitigation, then a mitigation plan should be created; and revision of all action plans.
The authors further states that risk tracking state follows this, where risk data are acquired, compiled and reported by the person(s) responsible for tracking watched and mitigated risks. Key performance indicators are gathered and presented to decision-makers in tracking documents and/or presentations. They describe that this phase involves steps like monitor risk indication and mitigation plans, new risks identification, prioritized risks list. The next sequence as per the authors is the risk tracking phase, where deviations from the risk mitigation plans are corrected. This includes identification of a new project risk, submission of risk proposal, risk confirmation, assignment of someone responsible for the new risk, and periodical revision of new project risks. They also highlight the communication phase, where information and feedback to and from the project on the risk activities, current risks, and emerging risks etc are provided to the stakeholders. Communication is essential and critical to the success of managing risks.

Poloucek and Stavarek (2005) say that operational risk is the risk of direct or indirect loss due to inadequate or failed internal processes, people and systems or from external events. They further states that risks can be mitigated by adopting a comprehensive risk management programme that incorporates a sound strategic plan.

Kenneth Bamberger (2010) says that risk arises from the influence of different factors, and its variations diverge by context. Automating compliance and risk-management processes will increase the efficiency of the system while reducing the cost associated with it.

Mac Crimmon and Wehrung (1986), Ansel and Wharton (1992) and Foster and Kaplan (2001) says that balancing risks and potential rewards is continuous activity applying engineering and program management. Darian Unger and Steven Eppinger (2006) identify that risks in Product Development can lead to development failure as shown below.

- A slow or late product may miss a market opportunity and incur too many development costs.
- A technically challenging product might be impossible to design, may lack the expected features, or be of poor quality
- A product with misguided specifications may not fulfill customer needs and therefore completely miss a market niche.
The authors also state that metrics are easy to communicate and access by everyone: this helps managers to describe major iterations and engineers are generally familiar with the character of design and development reviews. Thus, the ease of communication and general applicability of the metrics made them useful for risk management.

Lionel Galway (2004) says the objective and purpose of Risk Management is to identify potential problems before they occur so that risk-handling activities can be planned and invoked as needed across the life of the product or project, so as to mitigate adverse impacts on achieving the target objectives.

Stephen (2002) suggests that Risk management is a continuous and forward-looking process that is an important part of management. According to him, risk management should address issues that could adversely affect the achievement of critical objectives. A continuous risk management approach is executed to effectively forecast and mitigate the risks that may have a critical impact on the project. He further clarifies by stating that effective risk management includes early and aggressive risk identification through the collaboration and involvement of relevant stakeholders, as identified in the stakeholder involvement plan addressed in the Project Planning process area. They identify that strong and able leadership across stakeholders is needed to establish an environment for the free and open disclosure and discussion of risk and that risk management must consider both internal and external sources for identifying applicable cost, schedule, and performance risk as well as other risks. He further points that early and aggressive detection of risk is vital, as it is easier, less costly, and less disruptive to make changes and correct work efforts during the earlier phases of the project life cycle. He further states that the Project Planning and Project Monitoring and Control process areas represent the fact that, organizations may initially focus simply on risk identification for awareness, and react to the realization of these risks as they occur.

Zardari (2009), Zhang and Zhen-chao (2010) suggest that risk management can be divided into three parts: defining a risk management strategy; identifying and analyzing risks; and handling identified risks, which includes the implementation of risk mitigation plans based on need.
In the guideline book CMMI for Development v 1.3, SEI describes the purpose of Risk Management as identifying potential problems before they occur so that risk-handling activities can be planned and invoked based on need across the life of the product or project so as to mitigate adverse impacts they create in achieving objectives. It is further stated that the Risk Management process area describes an evolution of practices to systematically plan, anticipate, and mitigate risks proactively so as to minimize their impact on the project. As per the book, although the primary emphasis of the Risk Management process area is with respect to the software project, the concepts can be applied to manage organizational level risks as well.

The guideline book further identifies risk management as continuous, forward-looking process that is an essential part of the project management. Risk management should address issues that could endanger achievement of critical objectives. It also points that a continuous risk management approach is applied to effectively anticipate and mitigate the risks that may have a critical impact on the project.

The guideline book also talks about the effective risk management which includes early and aggressive risk identification through the collaboration and involvement of relevant stakeholders, which will be described in the stakeholder involvement plan addressed in the Project Planning process area. Strong leadership across all relevant stakeholders is needed to establish an environment for the free and open disclosure and discussion of risk. It also rightly suggests that risk management must consider both internal and external sources for cost, schedule, and performance risk as well as other risks. Early and aggressive detection of risk is important because it is typically easier, less costly, and less disruptive to make changes and correct work efforts during the earlier, rather than the later, phases of the project.

The guideline book divides risk management into three parts: defining a risk management strategy; identifying and analyzing risks; and handling identified risks, including the implementation of risk mitigation plans when needed. It suggests that organizations may initially focus on risk identification for awareness, and then react to the realization of these risks based on the occurrence. CMMI Risk Management process describes an evolution of these practices to systematically plan, anticipate, and mitigate risks proactively so as to
minimize their impact on the project and points that the concepts can also be applied to manage organizational risks.

PMI (2008) puts a different dimension by stating that risk that can have positive and negative impacts on the project. They further highlight that the projects has to be prepared for such events in order to reduce their negative impact on the project thereby making the project move in positive direction. They also say that the project has to document the responses of the risks and say that project has to develop a clear approach and methodology of handling these risks.

They further puts across the concept of performing quality risk analysis, which is the process of approaching identified risks in details and state that this deals with analyzing risks, evaluating the probability of their occurrence and updating and confirming the reliability of the proposed responses to tackle these risks. They further state that quality risk analysis need quantitative risk analysis approach using statistical tools, as it enables identification of the costs and time impact associated with the risks. They also points that risk response plan can be developed based on the results derived from risk analysis, based on which the planned responses are implemented for handling these risks and the implementation of response is continuously monitored and controlled for its effectiveness.

2.9 Requirements Management

Davis (1993) suggests that the purpose of Requirements Management is to manage the requirements of the project’s products and product components and to identify inconsistencies between those requirements and the project’s plans and work products. Hofmann, Hubert and Franz (2001) suggest requirements management processes generates and manages all requirements of the process, including technical and nontechnical requirements as well as those requirements expected by the organization. They also points that if the requirements development process is properly implemented, it will help to generate product and product component requirements, which will be managed by the requirements management processes.
Guide to Business Analysis body of knowledge says that Requirements Planning and Management activities extends over the entire duration of a project with inputs provided for planning to each areas and output provided back that allows for the requirements management activities and re-planning work to be done.

The guide identifies some examples of common requirements risks are:

- Insufficient level of user involvement in identifying, detailed, and analyzing requirements
- Ambiguous requirements. Not enough detail in the specification of the requirements
- Missing, incorrect, and conflicting requirements
- Lack of requirements management and planning, such as requirements change

The guide further says that to convert the requirements from the user’s language into a more refined system and technical requirements, it is also necessary to consider the applicable business rules. This includes policy and legal implications to impose a specific state and transition. It also emphasis on traceability from the element to the requirement, as well as to other related requirements (business rules) to ensure completeness of the requirements and the requirements management process.

Pressman, Thayer and Dorfman (1997) says that requirements engineering provides the appropriate platform for understanding what the customer wants, analyzing need, assessing feasibility, negotiating for a reasonable solution, specifying the solution clearly, validating the specifications and managing the requirements while they are transformed into an operational system. Somerville and Sawyer (1997) describe the requirements engineering process in five distinct steps:

- Requirements elicitation
- Requirements analysis and negotiation
- Requirements specification
- System modeling
- Requirements validation
- Requirements management
Pressman also says that though it seems simple enough to ask the customer, the users, and others the objective of the system, what needs to be accomplished, how the system or product will fit into the needs of the business, as well as how the system or product is to be used on a day-to-day basis. He articulates that this process is not simple, but very hard.

Christel and Kang (1992) identify a number of problems that help us understand why requirements elicitation is difficult:

**Problems of scope:** The boundary of the system is not properly defined or the customers/users specify unwanted technical detail that may create confusion, rather than clarifying the overall system objectives.

**Problems of understanding:** The customers/users are not sure of what is needed and have a poor understanding on the capabilities and limitations of their computing environment, and many times, will not have a full understanding of the problem in the domain, would have faced trouble in communicating needs to the system engineer, would have omitted information that is believed to be “obvious,” specify requirements that conflict with the needs of other customers/users, or specify requirements that are ambiguous or cannot be validated.

**Problems of volatility:** Pressman says that the requirements changes over time. Requirements management is a set of specialized activities that help the project team to identify, control, and track requirements and the changes to requirements at any point of time as the project proceeds. Requirements management begins with identification of requirements - each requirement is assigned a unique identifier. Once requirements are identified, traceability tables are developed. He further articulates that these traceability tables are maintained as part of a requirements database so that they may be quickly searched to understand how a change in one requirement will affect different aspects of the system to be built. Pressman further states that the level of detail of the requirements list and the amount of effort put into creating it should match the overall scope of the project.

Francoise Tourniaire (2003) suggest that more ambitious projects must have detailed lists of requirements that will require several weeks of work from the project team to gather,
evaluate, and rank them and concludes that this shows the need of the process required to build the requirements list.

As projects become more elaborate, requirements definitions also become complicated. Regan and O’Conner (1994) and Sandhu (2008) and suggests several techniques for developing and reinforcing the user’s conceptual model for the system development. These include metaphors, avoiding modes, ensuring consistency, making the interface user driven, and making the interface transparent.

Asma Mobarek (2007) after examining the E-banking practices, states that as customers become more sophisticated, it becomes essential for the organization to consider the use of technology to respond to their continuously changing requirements.

In the book CMMI for Development v 1.3, it is identified that the purpose of Requirements Management is to manage the requirements of the project’s products and product components and to identify inconsistencies between those requirements and the project's plans and work products.

The book further states that the project takes appropriate steps to ensure that the agreed-on set of requirements is managed to support the planning and execution needs of the project. When a project receives requirements, the requirements are reviewed with the provider to resolve issues and prevent misunderstanding before the requirements are incorporated into the project's plans. It further states that once an agreement in this regard is attained, commitment to the requirements is obtained from the project’s stakeholders. The project manages changes to the requirements, when it occurs and identifies any inconsistencies that occur among the plans, work products, and requirements. It also adds clarity by stating that requirement management expects to document requirements changes with rationale for changes and to maintain bidirectional traceability between source requirements and all product and product component requirements.
2.10 Quantitative Project Management (Metrics Based Management)

Will Haynes and William Golaz (2002) state that the purpose of Quantitative Project Management is to manage the project with quantitatively defined process to achieve the project’s established quality and process-performance objectives.

Rajiv Banker, Robert Kauffman et al (1990) identifies that measurement of software development productivity is needed in order to control software costs. Software is increasingly being written as pre-fabricated pieces that can be reused in different combinations, much as plumbing systems built using standard pipes, valves and joints can be tailored for each house says Pollack (1990) in his paper. Norman et al (1989), Bouldin and Barbara (1989) believes that currently software industrial revolution is in the making, while cost of participating in this revolution may be substantial, while the benefits are hard to verify.

Grammas and Klein (1985), Davis (1988), Nunamaker and Chen (1989) and Senn and Wynekoop (1990) say that the opportunity of a firm lies in automating the collection of productivity data. Any firm with high software expenditures for achieving important strategic and operational goals has to measure its productivity.

The author’s further state that function point analysis is one of the most popular means of measuring the output of software development activities and identifies that code reuse is the extent to which software is developed by recycling previously written code rather than rewriting it from scratch.

Rajender Singh Chhillar and Poonam (2011) state that measurements help designers to access the software early in process, making required changes that will reduce the complexity and improve the continuing capabilities of the design.

Chung and Yang (1988,1990), Conte, Dunsmore, and Shen (1986), McCabe (1976) Halstead (1977) state that Software industry uses software metrics to measure the complexity of software systems for software cost estimation, software development control, software assurance, software testing, and software maintenance. They also state
that most of the software metrics measure the software complexity using software attributes.

Curtis, Sheppard et al (1979) identifies that more time and money are spent on maintaining existing software systems than on developing new systems. Ramamoorthy, and Tsai (1996), observes that more and more modern companies use a maintenance-based software development approach, in which software is developed using the source code of existing software systems. The maintainability of software systems becomes an important issue in software industry.

Halstead (1977), Conte et al (1986), Chung, and Yang (1990) state that lot of researches investigate in the techniques of improving software maintainability, software quality, and software reliability, and propose new methodologies of software metrics, which are applied to measure software complexity and for monitoring the process of software development. Verner and Tate (1992) say that size is one of the most important attributes of software systems and observes that it dominates the cost for the systems over man-power and in budget, and both for development and for maintenance projects. They also points that size based software metrics indicate the complexity of a software system by its size attributes. These size base metrics help in predicting the cost for maintaining the system.

Conte Dunsmore and Shen (1986) identify control flow and data flows as two of the most important attributes, other than size for software systems. They further explain that control flow metrics capture the relation between the logic structures in a program with its complexity, while data flow metrics indicate the complexity of software system by their data dependency.

McCabe (1976) identify readability as important attributes of software systems which affect software maintainability, He further states that software systems with less readable source code are more difficult to maintain than those with more readable source code. He identifies that software readability attribute is more about psychological activities rather than physical ones and proposes readability metrics as a set of software metrics that measure software complexity considering the readability.
Benson Davis and Parker (1986) and Rajiv Banker, Robert Kauffman and Rachna Kumar (1992), state that the sheer size of corporate investments in software indicates the business value expected by senior management. They identify static, single-point software development metrics as snapshots of the results of software development production performance.

Demski (1985) identifies the value of information describing the software development life cycle to the project manager as a function of the actions that can be taken based on the information, and the consequences of those actions.

Johnson and Kaplan (1987) say that the identification of measurements is influenced by the cost of implementation. Considerations regarding the decision value of the information produced will affect the nature and design of suitable metrics. They further state that the cost of measuring should not exceed its decision value, and say that if this is not the case, this will reduce management’s motivation to measure. Johnson and Kaplan also suggest that the reduction in the costs of information collection and processing do not justifies highly aggregated, low-detail process information which will have lesser value.

Albrecht et al (1983) says that function points are proposed as a metric to capture the size of an application, which enables the software development activities to be evaluated based on the outputs they create (irrespective of the development language), and thus help software development managers to estimate the resources required to build systems of various sizes. Rajiv Banker and Robert Kauffman (1991) say that this also serves as an output metric in for evaluation of software development productivity. Productivity is normally measured in function points per person month of development labor. They also suggest that automated software metrics will be more useful as a project moves into the construction and testing phases.

Rajiv Banker, Hsihiu Chang and Surya Janakiraman (2004) state that to survive and to face competition in the age of information, companies must use measurement systems derived based on their strategies and capabilities. They further state that as managers get excessively pressured to deliver on short-term financial performance metrics, they will
have a tendency to trade off actions that bring in long-term benefits for current profitability, and limit the search for investments in future growth opportunities.

Amir and Lev (1996) suggest that while performance metrics that balance potentially conflicting short-term and long-term objectives are required, a good performance measurement system should contain only the metrics that are traded off against each other including the short term financial metrics. They further say that nonfinancial information plays a key role in industries such as telecommunications, biotechnology, and software development.

Rajiv Banker, Robert Kauffman et al. (1990) identifies the prerequisite for any industrial revolution as the ability to measure basic factors as output and productivity. They also says that despite annual software costs of big organizations rising into the hundreds of billions of dollars, such measurement has generally proven too difficult and expensive to undertake.

Symons (1988) says that the magnitude of a software development effort depends upon several factors like the amount of information processing accomplished by the system, the quality and the extent of the input and output interfaces provided to meet the user’s needs. He further says that environmental factors ranging from the quality of the hardware used by the programmers to the sophistication of the users requesting the software also affect the magnitude.

Davenport (1990) suggests processes can be created as a structured and measured set of activities that is designed to produce a specified output. Alessandro Margherita, Gianluca Elia and Mark Klein (2007) tried analyzing how the measurement of processes can support their redesign and how IT, on its turn, can leverage a metrics-based redesign. Hammer (1990) says that many contributions exist in literature that describes the key enabling role of the proper technology in a wide-scope reengineering initiative where measurement is important.

Alessandro Margherita et al (2007) also created a specific taxonomy of metrics to be used for measuring processes. They started with classifying process-oriented performance
indexes into time-oriented, value-oriented, quality-oriented and quantity-oriented attributes. They further classified time-oriented indexes (referring to various throughput time, service time, idle time, etc.) and quantity-oriented indexes (mostly referring to number of performed tasks) into a unique group of metrics which they called as Dimension-oriented Metrics which expressed “how much” the process is great either in terms of time required for its execution and in terms of its structural complexity. They also defined a specific group of Cost-oriented Metrics (expressing the cost and the risk that the process involves for the organization) and a group of Value-oriented Metrics (expressing the capacity of the process to create customer value). Kaplan and Norton (1996) observe that to survive and prosper competing in the information age, companies must use measurement systems derived from their strategies and capabilities.

Stephen Kan (2006) in his book says that for projects with an iterative development process, the product development cycle contain phases such as analysis, design, code, test and customer validation although at the micro level, while selected components may still be going through the iterative cycles near the back end of the project schedule. He identifies that in each of the phase of the macro cycle in the development process and project schedule, there are qualitative and quantitative data that measures the development progress, helps to surface problems and provides a predictable indication of the final product quality. He also notes that positive indicators from the requirements and design phases shows that the stability and predictability of the back end of the development process will be better. He further states about the importance of planning ahead the metrics and the information required to asses at various check points. He also say that for quantitative analysis, the key point is to collect useful information from the data and say that proper usage of effort spend vs. outcome analysis is useful in assessing in-process metrics. He also stresses on the importance of cross validation of findings and observations of both quantitative data and qualitative evaluation collected as part of measurement process.

William Florac, Robert Park and Anita (1997) in their book states the organization has selected and defined the measures and planned the implementation actions, it is ready to begin collecting data. They identify that collecting data is more than making measurements and consists of implementing the plans, ensuring that plans work, and sustaining the
measurement activities. These actions have to be documented in detail as procedures for collecting, recording, and reporting data, so as to sustain the implementation. They establish the need for a data collection guide that has data definitions and collection processes and will shorten the amount of time required to stabilize the measurement results. They further say for reliable results, the data collecting process must be stable and under control.

They further state that the complexity of the data collection processes will increase as additional organizations or software processes become involved. Having a data collection guide that fully describes the data definitions and collection processes will shorten the amount of time required to stabilize your measurement results. They further highlight that it will also improve the quality of the data collected for which the data collection process need to be timely, complete, authentic, accurate, and otherwise of good quality. They also say that the results of measurement must be examined in the context of other information about the product or process to determine whether action is required and what action to take. Clearly understood factual data facilitate correct analysis helps to understand the correlation between what is happening and what has to happen as part of the process. They conclude that software measurements can form the basis of clear, objective communication with the customers.

The Airlie Council’s (1999) sixteen point plan has developed a list of “critical software practices for performance-based management.” They identify these practices as “consistently used by, and considered critical by, highly successful software projects and organizations whose ‘bottom line’ performance is consistently much better than industry averages”. One of the parameters considered for this was the availability of the metrics program to give an early indication of evolving problems.

Pressman states that software metrics refers to a broad range of measurements. Measurement can be applied to the software process with the objective of improving it on a continuous basis. This can be also be used throughout a Software project to assist in estimation, quality control, productivity assessment, and project control. He also identifies the importance of measurement by stating that measurement can be used by software
engineers to help assess the quality of technical work products and to assist in tactical decision making as a project proceeds.

He further says that software process and product metrics are quantitative measures that enable to gain insight into the efficacy of the software process and the projects that use the process as a framework. Basic quality and productivity data are collected, analyzed, compared against past averages and assessed to determine whether quality and productivity improvements have occurred. He also identifies that metrics are used to pinpoint problem areas so as to identify remedies as well as to improve the software process. He also articulates that metrics should be collected so that process and product indicators can be ascertained. He also talks about the process metrics that are collected across all projects and very long periods of time, with the objective of providing indicators that lead to long-term software process improvement. He further says that the efficacy of a software process is measured indirectly and can be derived by measuring the characteristics of specific software engineering tasks. He further highlights its importance by stating that software process metrics are used for strategic purposes. The first application of project metrics on software projects occurs during estimation. As a project proceeds, measures of effort and calendar time expended are compared to original estimates (and the project schedule) and project manager uses these data to monitor and control progress.

Ragland (1995) states that software engineers collect measures and develops metrics so as to obtain indicators, which is a metric or combination of metrics that provide insight into the software process, a software project, or the product itself. He also says that an indicator provides insight that enables the project manager or software engineers to adjust the process, the project, or the process to make things better.

The book CMMI for Development v 1.3 says that the purpose of Quantitative Project Management is to quantitatively manage the project's defined process to achieve the project's established quality and process-performance objectives and further say that quantitative management uses data from statistical sampling to help the project predict whether it will be able to achieve its quality and process-performance objectives and identify what corrective action should be taken.
2.11 Configuration Management

Mohammad Ali Kashefil (2012) suggests that industries and businesses follow differentiation strategies to attract potential customers and overcome rivals. This requires access to private information about the actual demand of a specific market. Because of this, controlling the channels of information leakage has become an important part of information management and business intelligence. He again states that this is also highlighted by the fact that several competitors work with common players in their supply chain which creates a potential threat of sharing their economic information with their rivals. He thus highlights of the importance of access control to information, which is a part of the configuration management.

Zhang and Li (2006) highlight the concern of managers on leakage of crucial information from suppliers to their rivals. They state that information imperatives should be considered in the profit function and has to be treated strategically. They thus highlight that configuration management is one key aspect to ensure and maintain the access control on key information as well as to make available the right information at the right time.

Mantask Pakamore, Virtuali Erdve et al (2011) say that garbage in garbage out issue holds while developing configuration model and say that setting the goals correctly is critical for getting valid guidance.

Mordechai Ben-Menachem (2007) highlights the importance of information transferability by stating it has become increasingly clear that methods used to manage software are inadequate, especially in massive quantities in large installations. They say that management needs must include information on the requirements for all expensive assets, which highlight the importance of tool selection for configuration management.

Reingold (1999) and Giera et al (2000) effectively highlights the importance of configuration management by identifying that “a young software engineer knows more about his product than his manager...” He further say that for software, this is much more complicated, as the manager may not be party to the technologies or even really
comprehend them, while the software professionals thinks that information about software means “documentation”.

Jemison, David and Sim Sitkin (1986) and Julie and Marc Cecere (2000) highlights the importance of configuration management by stating that in the case of corporate acquisition, proper evaluation of the acquired company’s Information Technology and the subsequent ability to integrate the two portfolios, may be critical to for the success of the merger.

Ben-Menachem (1996) identifies that competitiveness of the organization is largely dependent on their abilities to use software as a competitive weapon. What is making the competitive landscape more complex is the kind of pressures organizations are facing in terms of time to market, new features, cost and, of course, quality and reliability. Keller Eric (2004) highlights the importance of configuration management by stating that software development is a very complex set of interdisciplinary processes, rather than one demonstrable action process.

Ben-Menachem (1994) says that developers of an individual application have Software Configuration Management tools to help them with their tasks, but criticize that they do not provide management capabilities to the lowest level and aids to versioning, revising and part of change management, but do not serve to aid in the innovation processes.

Bersoff Edward, Vilas Henderson, Stanley Siegal (1980) and Ben-Menachem (1994) state that most software professionals think about version control when they think of software management, which is very narrow in scope. They highlight the importance of configuration management by stating that it is challenging to address massive issues of tens or hundreds of thousands of geographically dispersed code files, maintained by hundreds to thousands of programmers; with no centralized information of what or where the files are; no one knowing who “owns” them; no generally available information on creation dates or when, how, why or by whom they were updated, or their rates of growth or decay.
Berschoff et al (1980) also highlights the importance of configuration management by stating that if the primary dimension of the issue being dealt is management of “objects,” then the direction to look for literature is in Software Configuration Management (SCM). They further say that SCM is a discipline for physical management of objects, though from a different perspective and with a different objective. He further observes that when discussing Software assets ideas with software professionals, the first reaction is that this is “covered” by SCM.

Bersoff, Edward, Vilas and Stanely (1980) criticize that Software Configuration Management; in actuality only discuss Software Configuration Control, and not management.

Ben-Menachem et al (1996) says that managing configurations of software is multidimensional and is very difficult. Controlling its revisions and version’s history is straightforward. They further say that an attempt to address this broader issue done when the concept of a “Code Warehouse” and “Code Warehousing” were first proposed. Leon (2000) and Bendix states that Software Configuration Management is the discipline of controlling the evolution of complex software system.

Dart (1991) distinguishes that Configuration Management is the discipline of controlling the evolution of complex systems; software Configuration Management is its specialization. He further say that the purpose of Configuration Management is to establish and maintain the integrity of work products using configuration identification, configuration control, configuration status accounting, and configuration audits and also say that Configuration management is focused on the rigorous control of the managerial and technical aspects of work products, including the delivered system.

In the book CMMI for Development v 1.3, Configuration Management is identified as supports all process areas by establishing and maintaining the integrity of work products using configuration identification, configuration control, configuration status accounting, and configuration audits. It further says that the work products placed under configuration management include the products that are delivered to the customer, designated internal
work products, acquired products, tools, and other items that are used in creating and
describing these work products.

Press Man identifies the software configuration management as an umbrella activity that is
applied throughout the software process. He says that as change can occur at any time,
SCM activities are developed to (1) identify change, (2) control change (3) ensure that
change is being properly implemented, and (4) report changes to others who may have an
interest. He also identifies that the items that comprise all information produced as part of
the software process are collectively called a software configuration.

He further says that as the software process progresses, the number of software
configuration items grows rapidly and discuss on the baseline as a software configuration
management concept that helps us to control change without seriously impeding justifiable
change. The IEEE in its software engineering standards (1994) defines a baseline as: A
specification or product that has been formally reviewed and agreed upon, that thereafter
serves as the basis for further development, and that can be changed only through formal
change control procedures.

Version control combines procedures and tools to manage different versions of
configuration objects that are created during the software process. Clemm (1989) describes
version control in the context of SCM: Configuration management allows a user to specify
alternative configuration of the software system through the selection of appropriate
versions.

Bach James (1998) sums up the importance of change control by stating that change
control is vital. But the forces that make it necessary also make it annoying. He further
argues that a tiny perturbation in the code can create a big failure in the product. He further
criticize the configuration management systems by saying that a single rogue developer
could sink the project; yet brilliant ideas originate in the minds of those rogues, and a
burdensome change control process could effectively discourage them from doing creative
work.
Harter (1989) identifies that the "check-in" and "check-out" process implements two important elements of change control—access control and synchronization control and say that access control governs which software engineers have the authority to access and modify a particular configuration object. Synchronization control helps to ensure that parallel changes, performed by two different people, don't overwrite one another.

2.12 Project Monitoring and Control

SEI Web site states that the purpose of Project Monitoring and Control is to provide an understanding of the progress of the project so that appropriate corrective actions can be taken when the project's performance deviates significantly from the plan. It further highlight the importance of the plan by stating that it is the basis for monitoring activities, communicating status and taking corrective action. Progress of the project is determined by comparing actual work product and task attributes effort, cost and schedule to the plan at prescribed milestones or control levels within the project schedule or work breakdown structure (WBS). It says that this understanding enables timely corrective action to be taken when performance deviates from the plan, which can prevent the project from meeting its objectives. They further say that corrective actions taken during the time of deviations lead to re-planning, which may include revising the original plan, establishing new agreements, or including additional mitigation activities within the current plan.

Mehari Mekonnen Akalu, John Rodney (2003) highlight one important measure of project performance. Abba (1997) identifies Earned Value (EV) as a performance measurement model used to establish base line cost, schedule and goal for capital projects. Mehari Mekonnen Akalu, John Rodney states that researchers use various names for this technique. This is also called as Value Management by Thiry (1997) and Integrated Value Management Value Engineering by Green (1994) and Earned Value Management by Mayfield (1997). Locker and Gordon (1991) say that the model helps to compare physical work completed against the consumed hour or cost of a project and states that this is designed to evaluate and analyze projects through their life cycle.

Paul (1998), Akalu and Turner (2001) state that since the majority of Software Company's work is based on projects; the issue of project performance monitoring becomes an
important task in project management. They further say that questions related to completion time, total cost of completion and rate of performance vis-à-vis the target are raised during project monitoring, and in order to get accurate answer for such issues, measurement of project performance is required.

Mehari Mekonnen Akalu et al (2003) identifies that project performance measurement involves progress monitoring, which has two related processes and outcomes. They further drill down on this by stating that the first part of the process is a backward looking beginning from the date of project kickoff, whose outcome of measurement is historical data. The second part is a forward-looking measurement, which may trigger changes on the partial or total structure of the project. They further caution that since the planning is done based on historical data, the actual value may differ from the planned estimates and say that the real challenge for the project manager is to narrow the gap between estimated and actual value of a project.

Thamhain (1996) says that until 1980s, the focus of project management was on the administration of resources, while schedules and control was limited only to certain areas. He observes that in the later period of time, managers realized the effect of project control in all activities and due to which different theories and models were developed to assist the control effort of management. He further concludes that many project control systems are becoming more complex in order to meet the complex nature of project environment and data analysis.

Mehari Mekonnen Akalu et al (2003) say that there are different views about the nature and methods of project control. Turner and Payne (1999) have found that tailor made control techniques are relevant at operational levels. Dey et al (1994) proposed a multivariate project monitoring technique. Hartman and Jergeas (1997) support different methods of control for different stages of project. They propose that at the stage of project definition and approval cost, schedule and time are measures of control. Mehari Mekonnen Akalu et al (2003) says that this approach requires the use of various methods in each stage and deprives the benefits of uniform control method over the project life span and identifies that continuous assessment provides early warning, detection and correction of material errors in the operation. Purvis and McCray (1999) classified the phases of project
assessment as three: initial (during project initiation project planning), in progress (project execution) and completion (closure), but the fixed time frame based control is not capable of providing continuous data for continuous control of operation.

Mehari Mekonnen Akalu et al (2003) also put a caution that installation of a given control system has to be studied carefully in relation to its short and long run effects. They point that too tight control may frustrate project team and may lead to delay the project completion time, while too loosen control system may increase cost of operation and, hence, resulting budget overrun projects. Boynton and Zmud (1984) identify the presence of diverse critical factors as another problem to perform objective project evaluation.

The works of Pinto and Slevin (1987), Freeman and Beale (1992), Riggs, et al, (1992), Paek (1995), Slesinger (1997) and Baker (1997) focused on the identification of factors affecting project success or failure. They identify the critical factors for project monitoring as clearly defined goals, competent project manager, top management support, competent project team, sufficient resource, adequate communication, control, feedback capability, client related issues, technical tasks, and trouble shootings. They further state after that identification of factors and development of criteria, managers can apply the measurement scales and further caution that it is extremely essential to determine the range of values within which a particular project will be marked as success or failure. They further suggest that application of uniform metrics (from project inception to completion) which is consistent with the objectives of the organization as well as capable of handling both risk and time value of the money and points that this will help to evaluate the validity and degree of precision of a metric.

Mohammad Ahmed (2011) describes proposes a different dimension by stating that project’s quality is managed by evaluating the accuracy of the results in line with the quality policy and objectives and adds that quality is managed by implementing quality at every level of the project, which is supported employing tools for evaluating the quality and managing it through every process.

He further states that quality is planned by identifying the requirements of quality and developing clear and written procedures as well as tools and techniques to achieve them.
He identifies that quality assurance is performed by managing quality tools and techniques to ensure effective implementation of quality plans with the aim of continuous improvement. He also says that quality is monitored and controlled by evaluating the results against quality plans and appropriate actions are taken to ensure compliance with the plans.

Westervield (2003) says that success criteria of projects differ on several factors such as size, nature of project, industry, complexity. Hence they state that a single set of factors cannot characterize success of all types of projects. However, there are elements that influence the outcomes of a project and are identified as success directors. Bakkar, Razak, Abdullah and Wang (2009) state critical success factors are the dimensions of project management whose influence contributes successful outcomes of a project.

Cooke-Davies (2002) identifies success factors for projects as inputs to the management system that lead directly or indirectly to the success of project or business. He also observes that the existence of an effective delivery and management process that involves the mutual co-operation of project management and line management functions is required for the success of the project.

Pinto and Slevin (1988) defines success parameter of projects and state that projects are considered successful if they are carried out on schedule (time), within the budget (cost), deliver the desired output (scope) and are acknowledged by client (customer satisfaction). Atkinson (1999) calls cost, time and quality is as “Iron Triangle”. Pinto and Slevin (1988) further explain that each of these factors is part of project management knowledge areas and has influence in directing the success of projects. They also highlight the importance of the customer focus by stating that “customer satisfaction and acceptance” has become an important factor in governing the success of a project as it advances. Dimitrios (2009) adds qualitative objective to iron triangle by means of the benefits that will be derived from a completed project.

Egeland (2011) lists the success factors in terms of primary and secondary factors and lists primary factors as cost, time, quality and customer satisfaction. However, he believed that
factors such as undisturbed work, maintaining statutory regulations, cultures, conducts etc also play an important role in project.

Shenhar, Levy and Dvir (1997) categorized success factors into four dimensions. First parameter identified is the "Project Efficiency" which determines the ability of implementing processes in the project. Second is the "Impact on Customer" which maps the relevance of project outcome against customer's actual needs. Third dimension is "Business success" describes the commercial success if the project after its completion and fourth dimension is the "Future potential" i.e. the prospects of future growth and returns on the project. It is important to understand and visualize the future of a project after completion in order to assess the success criteria during the execution phase as said by Dimitrios (2009). Dimitrios also believes that any changes in the project be it cost, schedule, scope or any other component, to be made only if it is really necessary, so as to avoid resistance from all stakeholders.

Dimitrios (2009) states that the project manager, project team, projects, the organization and external environments are the important factors for success of a project, but also highlight that top management support plays the most important role in succeeding a project.

PMI (2008) identifies as the methodology of practices that are used for managing and directing the projects successfully. They further broke down these practices into specific processes to ensure that the success can be attained by following them. They also define the project scope as the boundaries of a project including the detailing of the desired results for which a project is executed. Since the stakeholder decisions are based on end results, assessment and management of the scope of a project influences its success.

Lang (2007) rightly states that stakeholders including the organization will benefit from the projects only if it satisfies them. He points out that the execution of projects has to be done keeping in mind on who are the end users and how they will they benefit upon the successful completion of the project. Hence, project management team is responsible to ensure that all parties associated with the project either directly or indirectly is satisfied with its outcome.
He further states that projects have either defined or indefinite period for their execution. He quotes the example of a manufacturing facility and says that it is a project but with an indefinite period. He further points that for projects with definite schedule, the success is hugely governed by their compliance to the schedule.

Valecha, Xiao Hang and Ma (2010) state that cost is an important aspect of a project. They argue that every project has an estimated budget which comes along with the feasibility report. They points that the clients or end users have invested their capital in the project with the expectation that benefits will come out on time and without further investment. Some time, projects can be part of a larger project train and therefore, outcomes of one project serve the input of its successor. They argue that it is very important that the projects are executed on their schedule and concludes that on-time and on-cost are considered as important success factors of a project.

Pinto and Slevin (1988) categorized success factors in terms of strategic and tactical factors. Strategy aims to assess the objectives and plans to achieve those objectives while tactics deals with allocation and usage of available resources, information etc. They conceptualized scope, scheduling and cost as strategic in nature while rests of the factors as tactical.

Sequeira and Sibashree Moharana (2012) say that one of the crucial aspects in project management is the development of an elaborate system for monitoring project implementation, project operation, maintenance and project assessment. Project assessment consists of information on the actual and intended benefits from the project over its intended lifetime.

Press Man states that in order to avoid project failure, a software project manager and the software engineers who work on the project has to take care to avoid a set of common warning signs, understand the critical success factors that lead to good project management, and develop a commonsense approach for planning, monitoring and controlling the project.
Pressman further articulates the importance of tracking the progress. For a software project, progress is tracked as work products (e.g., specifications, source code, sets of test cases) are produced and approved (using formal technical reviews) as part of a quality assurance activity. He further say that in addition to this, software process and project measures can be collected and used to assess progress against the averages developed by the software development organization.

Boehm (1996) highlight the importance of project planning by stating that one need an organizing principle that can scale down to provide simple project level plans for simple projects. Boehm suggests an approach that addresses project objectives, milestones and schedules, responsibilities, management and technical approaches, and required resources. He calls it the WWWWWHHH principle, after a series of questions that lead to a definition of key project characteristics and the resultant project plan:

- Why is the system being developed?
- What will be done, by when?
- Who is responsible for a function?
- Why is the system developed?
- What will be done, by when?
- Who is responsible for a function?
- Where they are organizationally located?
- How can the job be done technically and managerially?
- How much of each resource is needed?